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Fishers' tales—Impact of artisanal fisheries on threatened sharks and rays in the Bay of Bengal, Bangladesh

Alifa Bintha Haque[1,2] 🄳 | **Rachel D. Cavanagh**[2] | **Julia L. Y. Spaet**[3] 🄳

[1]Nature-Based Solutions Initiative, Department of Zoology, University of Oxford, Oxford, UK

[2]British Antarctic Survey, Cambridge, UK

[3]Evolutionary Ecology Group, Department of Zoology, University of Cambridge, Cambridge, UK

Correspondence
Alifa Bintha Haque, Department of Zoology, University of Oxford, Oxford OX1 3SZ, UK.
Email: alifa.haque@zoo.ox.ac.uk and alifa.haque@du.ac.bd

Abstract

Increasing fishing pressure has negatively impacted elasmobranch populations globally. Despite high levels of historical and current fishing pressure, the Bay of Bengal region remains data-poor. Focusing on Bangladesh, we conducted a socio-ecological study to characterize elasmobranch fisheries and evaluate their impact on threatened species. The results demonstrate that several globally threatened elasmobranch species are frequently captured, and some of them have experienced substantial population declines (e.g., wedgefishes, sawfishes, large carcharhinid sharks) over the past decade. A decrease in elasmobranch diversity, abundance, and size of caught specimens was also reported, which was attributed to increased fishing intensity, destructive practices (e.g., bottom trawling), and an accessible elasmobranch market. While catch and trade of more than 90 elasmobranchs are regulated under Bangladesh's law, non-compliance is widespread. Likely causes include a dearth of awareness, practical alternative livelihoods, and technical facilities, and the complex nature of the fisheries. Encouraging and facilitating the engagement of fishers in science (data collection), local governance (policy-making), and field implementation (bycatch mitigation) is vital. These interventions must be rooted in sustainable approaches and co-designed with fishers, with appropriate training available. Development of this work through enhanced engagement with fishers has the potential to transform the elasmobranch fishery situation in Bangladesh and could be used as a model for data-poor regions.

KEYWORDS

Bangladesh, co-design, elasmobranch, fisheries management, local governance, local/traditional knowledge, marine conservation

1 | INTRODUCTION

Elasmobranch (sharks and rays) populations have declined by 80% or more in many regions across the globe, predominantly due to unsustainable fisheries driven by high demand for fins and meat (Clarke et al., 2007; Dulvy et al., 2008; Graham et al., 2010; Kyne et al., 2020; Morgan & Carlson, 2010; Schindler et al., 2002), together with high levels of bycatch especially in the tropics (Dulvy et al., 2021). Most elasmobranchs have slow growth rates,

late age-at-maturity, and low fecundity meaning they are vulnerable to fishing pressure and have a longer recovery time to overfishing compared to most bony fish (Bräutigam et al., 2015; Schindler et al., 2002). Nearly 37% of all elasmobranch species globally are now listed as threatened with extinction, according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Bräutigam et al., 2015; Dulvy et al., 2014; Dulvy et al., 2021; IUCN, 2021). Sustainable elasmobranch fisheries are possible, and a number of developed countries manage some elasmobranch fisheries sustainably (e.g., School Shark, *Galeorhinus galeus*; Gummy Shark, *Mustelus antarcticus*; Alaskan Skate, *Bathyraja parmifera* in the USA and Australia) (Prince, 2005; Dulvy et al., 2017; Simpfendorfer & Dulvy, 2017). However, the sustainable management of these fisheries is underpinned by data, enabling effective monitoring and assessment, and a good understanding of the fishery, together with high levels of compliance to regulations (Prince, 2005; Dulvy et al., 2017; Simpfendorfer & Dulvy, 2017; Dulvy et al., 2021; Haque, Cavanagh, & Seddon, 2021). Despite initiatives such as the UN Food and Agricultural Organization (FAO) to develop sustainable management plans for elasmobranchs (https://www.fao.org/ipoa-sharks), many developing countries face challenges resulting from limited research and resources (e.g., Bornatowski et al., 2014; de Mitcheson et al., 2018; Haque et al., 2020; Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021; Haque, White, et al., 2021).

The Northern Indian Ocean region includes some of the world's largest shark fishing nations (Davidson et al., 2016). In countries bordering the Bay of Bengal (BoB), an expansion of fisheries have led to overfishing of many species and populations in recent decades and is likely the cause for observed steep declines in elasmobranch catch and landings together with population shifts from larger long-lived species to smaller short-lived species (Haque, Washim, et al., 2021; Krajangdara & Vibunpant, 2019; Krakstad et al., 2014; Lam & Sadovy de Mitcheson, 2011; Pauly et al., 2020).

This study focuses on Bangladesh, a developing country situated at the northern tip of the BoB, where elasmobranchs have been exploited for decades. Fisheries expansion has increased catch levels to some extent; however, recent declines have been observed (Haque et al., 2020; Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021; Haque, Washim, et al., 2021; Haque, White, et al., 2021; Hoq et al., 2011). All BoB coastal and marine fisheries catch elasmobranchs, in either targeted or bycatch fisheries (Haque et al., 2020; Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021;Haque, Washim, et al., 2021; Haque, White,

et al., 2021). Yet, Bangladesh is one of the most data-poor countries in the BoB regarding elasmobranch fisheries (Haque, Washim, et al., 2021; Haque, White, et al., 2021). Vital knowledge including information on fishery characteristics, catch trends, baseline data, and stakeholder information is lacking (Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021; Haque, Washim, et al., 2021; Haque, White, et al., 2021; Zafaria et al., 2018), and currently hampers informed conservation decision making. This combination of high fishing pressure, data paucity, and limited resources (Fischer et al., 2012) makes it challenging to devise and implement sustainable fishery management.

In the absence of historical data, the knowledge of fishers can be used to understand spatio-temporal abundance, for example, to reconstruct long-term population trends and species distributions (Colloca et al., 2020; Daw, 2008; Dulvy & Polunin, 2004; Foster & Vincent, 2010; Frezza & Clem, 2015; Irigoyen & Trobbiani, 2016; Lavides et al., 2016; Macdonald et al., 2014). Moreover, fishers can also offer important socio-ecological insights on conservation, legislation, and aspects related to improved compliance (Booth et al., 2020; Collins et al., 2021; Gupta et al., 2020; Jabado, 2014; Liao et al., 2019; Mason et al., 2020; Patankar, 2019; Spaet, 2019; Ward-Paige et al., 2020). However, fishers' meaningful participation in research and fisheries decision-making processes is absent in Bangladesh.

Here, we present the results of our socio-ecological study in Bangladesh to characterize elasmobranch fisheries and evaluate their impact on threatened elasmobranch species based on the knowledge of local fishers. This adds to data being collected through concurrent scientific fieldwork and helps to validate the results (Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021), especially where knowledge gaps exist such as historical accounts and population trends in the face of increasing fishing pressure. We utilize fishers' knowledge, observations, and perceptions to: (1) characterize elasmobranch target and bycatch fisheries; (2) assess population trends of selected elasmobranchs and identify the reasons behind these trends; (3) explore regulations, that is, the legal framework governing fishers' activities, and levels of compliance within this; and (4) characterize the attitude of fishers toward potential conservation measures. We evaluate these data and demonstrate the valuable role of local stakeholders in conservation decision making and conservation practice. The information presented in this study substantially improves our understanding of the complex dynamics of elasmobranch fisheries in Bangladesh and will inform conservation and management in the region and beyond.
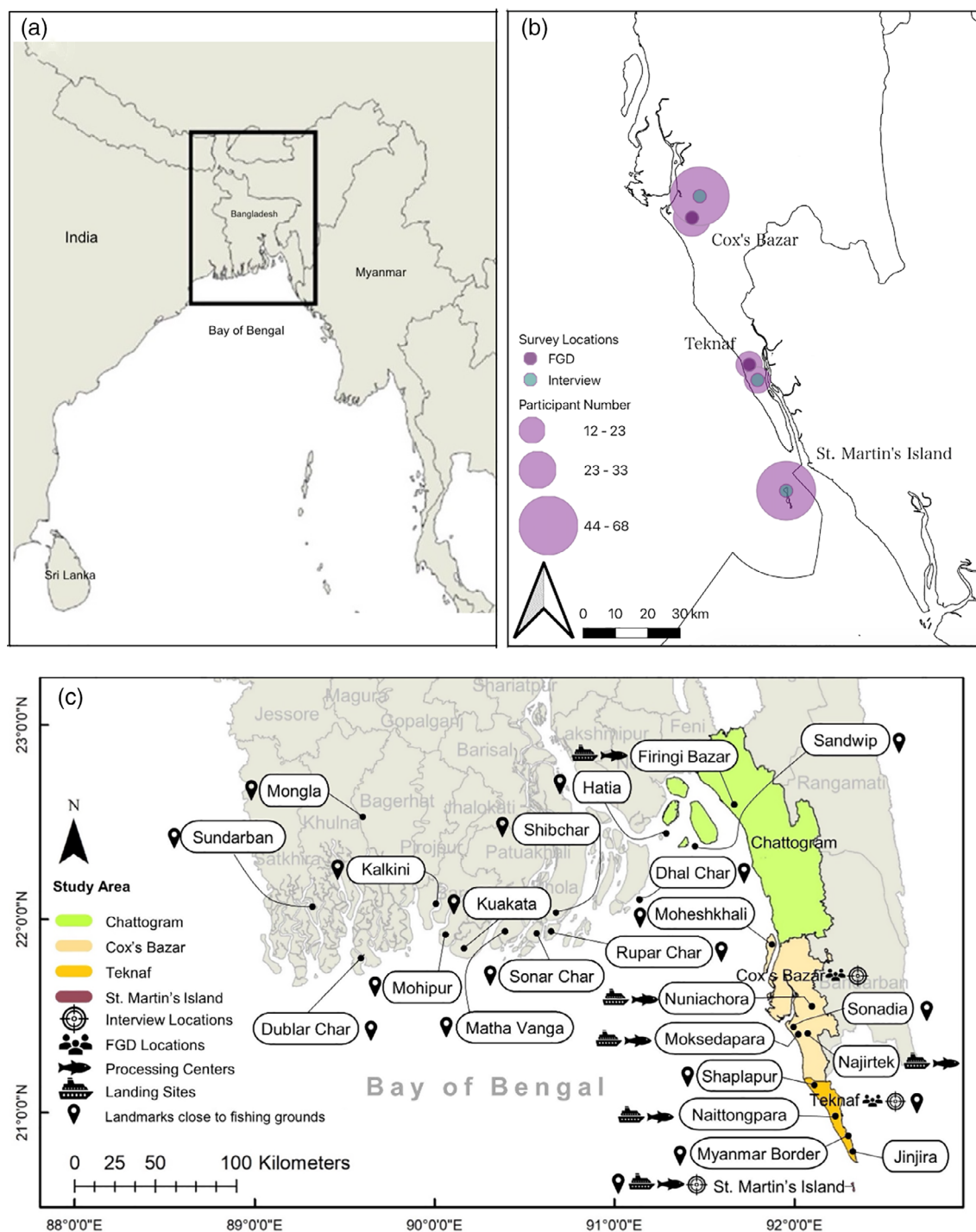
FIGURE 1 (a) Map of the study region—Bangladesh within the Bay of Bengal region (inset). (b) Survey locations of focus group discussions (FGD) and interviews with number of participants. (c) Study area indicating survey sites, processing centers, landing sites, and landmarks close to the fishing grounds along the coast of Bangladesh as identified by fishers. The map was created using QGIS version 3.22.

2 | METHODS

2.1 | Interview surveys

Between May 3, 2017 and January 28, 2019, 66 semi-structured (Table S1) and 80 structured (Table S2)

interviews with Bangladeshi nationals involved in elasmobranch fisheries were conducted. Interviews were conducted in 21 fishing villages (66 semi-structured, 39 structured), at two fish landing sites (Cox's Bazar and Teknaf; 21 structured) and two shark processing centers (Cox's Bazar and Teknaf; 20 structured) (Figure 1a,b) in

south-eastern Bangladesh (Cox's Bazar, Teknaf and St. Martin's Island). More details on study sites are described in Haque and Spaet (2021).

The semi-structured questionnaire comprised predetermined questions to enable comparison of responses, with allowance for questions that were not planned in advance. The latter provided flexibility to explore subjects important to individual respondents on an informal level, helping to characterize the system qualitatively. Stakeholder-specific semi-structured questionnaires to evaluate: (1) fishing practices; (2) target and by-caught species and their value; (3) legal frameworks governing fishing activities and compliance to these; and (4) the attitude of fishers toward conservation measures were designed partially based on Jabado et al. (2015), Jaiteh, Loneragan, and Warren (2017)., and Haque, Cavanagh, and Seddon (2021); Haque, D'Costa, et al. (2021). In some instances, related questions were grouped together (e.g., questions regarding the value or species) to aid both the information gathering and analysis. The knowledge shared by fishers was obtained either through their own experiences or shared legacies from fishing families. Additionally, to supplement this information, four focus group discussions (FGD) comprising a total of 43 participants (8–13 participants in each) were conducted in four fishing communities with targeted ray fisheries (Table S3).

Within the structured interviews, interviewees were asked a set of predefined standardized questions in the same order (Table S2). Questionnaires for structured interviews (Table S2) were designed to evaluate the perception of fishers on elasmobranch population trends (e.g., historical exploitation and observed changes in catch numbers over time). To evaluate these trends as accurately as possible, a species-identification exercise was conducted with a group of 25 experienced fishers of the Cox's Bazar District Fishing Boat Labourer Union prior to the interviews. In an FGD format, fishers were shown photographs of 65 shark and ray species reported from Bangladesh (Hoq et al., 2011) and asked questions related to species identification, species-specific fisheries, and local species names. Fishers were encouraged to discuss their knowledge of each species within the group. Nine unanimously identified species/species groups (i.e., *Galeocerdo cuvier* tiger shark, hammerhead sharks (*Sphyrna lewini* scalloped hammerhead shark, *Sphyrna mokarran* great hammerhead shark, *Sphyrna zygaena* smooth hammerhead shark, *Eusphyra blochii* winghead shark), *Rhincodon typus* whale shark, sawfishes (Pristidae), wedgefishes (Rhinidae) guitarfishes (Glaucostegidae and Rhinobatidae), *Carcharhinus sorrah* spottail shark, *Carcharhinus falciformis* silky shark, and other large Carchariniform sharks) were selected for further taxa-specific questions regarding population trends. Additionally, most of the

information on shark species provided by the fishers was corroborated by observations at landing sites (Haque, Washim, et al., 2021; Haque, unpublished data). Limitations of the study methods are detailed in Supporting Information Material S1, for example, accuracy of identification, map-reading ability (see Supporting Information Material S1). Deep-water (>60 m) fishers were not included in this study due to small sample sizes, therefore the deep-sea fishery is not characterized here.

In addition, interviewees were engaged in conversations beyond the questionnaires' capacity as a means of capturing additional information (e.g., detailed perceptions and personal experiences about the reasons for population decline, personal stories encountering specific species, information on potentially extinct species, and information on species not included in the species photo compilation). Further details on the interview process and interviewee selection processes are provided in Haque and Spaet (2021).

2.2 | Data analysis

All interviews were translated into English (Tables S1 and S2). Descriptive (e.g., age, fishing experience) and inferential (e.g., monthly and annual average number of elasmobranchs caught) statistic routines were performed in R (R Core team, 2020, version 3.6.1). For open-ended questions where multiple responses were recorded, each response was categorized and counted under a designated broad category. For example, in response to the question, "What are the main reasons for shark population decline in Bangladesh?"; fishers generally provided multiple answers such as overexploitation, increased number of boats, increased number of ports, new gear usage, greater distances covered. Each of these answers was placed within the broad category of overexploitation. Responses were categorized for several variables (e.g., reasons for elasmobranch population declines, list of target species, list of retained by-caught species, fishing grounds) (Tables S3–S5 and 1, Figures 1c and S1).

The average number of elasmobranchs caught monthly can also be associated with different variables such as gear used, fishing homeport, seasonality of fishing (monsoon [June to September], winter [October to January], summer [February to May], and all seasons), the mesh size (cm) of nets used, fishing depth (m), monthly fishing days, and distance covered from homeport (km). To determine if the number of elasmobranchs caught was associated with these independent variables, we fitted generalized linear models (GLM, Poisson regression) (R Core team, 2020). Poisson regression is a form of regression analysis in statistics used to model count data

TABLE 1 Characteristics of fishing trips, vessel types, primary and secondary gear, catch locations, seasonality, target, and valuable species of fishing vessels operating in Cox's Bazar, Teknaf, and St. Martin's Island

Bycatch elasmobranch fishery (%) indicates the percentage of respondents

Fishing trips per month	1–3 (19.7%)	4–10 (24.24%)	11–20 (31.86%)	20–25 (24.24%)	
Days at sea per trip	1–5 (34.8%)	5–10 (31.8%)	10–15 (22.7%)	>15 (10.6%)	
Distance covered from homeport (km)	1–10 (18%)	10–50 (13.6%)	50–100 (28.8%)	100–200 (19.7%)	200–250 (16.7%) >250 (3%)
Vessel size (m)	Small 5–10 (16.7%)	Medium 10–15 (36%)	Large 15–20 (25.8%)	>20 (21%)	
Engine power (HP)	7–25 (32%)	25–45 (56%)	45–65 (6%)	>65 (6%)	

Primary Gear type	Respondents (%)	Length (m)	Mesh size (cm)	Deployment depth (m)	Target species (respondent number)
Submerged and floating gill nets (hilsa gill nets)	34 (51.4)	4.5–6100	7.62–22.86	10–116	Demersal (19), Pelagic (23), both (22), do not know (2)
Set bag nets	18 (27.3)	4.5–3600	7.62–15.24	4–20	
Others (seine nets, trammel nets, modified gill nets for specific species, bottom-set nets, rock nets)	14 (21.3)	3–3900	7.62–17.78	4–24	

Secondary gear type	Respondents (%)	Length (m)	Number of hooks	Depth (m)	Target species
Baited hooks	55 (83.3)	-	3–5	No selected depth	Multi-species fishery
Unbaited long line	2 (3)	4569–6092	100–15,000	<40 m	Smaller fish and ray species

Seasonality	
	• 72% fishers did not fish in the monsoon season (June–July) due to adverse weather conditions and fishing restrictions on *Tenualosa ilisha hilsa* (except those from St. Martin's Island)
	• 17% fishers fished all year-round (Table 2)
	• 91% fishers reported winter (November to January) as a primary season for catching sharks, followed by summer to pre-monsoon (February to May)
	• Fishers identified the late summer (March) to pre-monsoon (May) as the potential breeding season for most of the shark species due to frequently caught gravid individuals

Catch location	
	• Fishers exploited extensive shallow coastal waters from southeast to southwest region (Table S4)
	• 56% identified nearshore char areas (shallow water dynamic islands in south-central Bangladesh) as prime locations for targeting guitarfishes and ray species
	• 32% mentioned these as preferred areas of pregnant rays
	• 32% mentioned bigger sharks and rays (>2 m) to be found in deeper waters (>100 m), whereas pups and sometimes pregnant individuals are found near shore
	• Most elasmobranchs were caught in shallow (1–35 m) to medium depth (36–60 m) nearshore waters

(Continues)

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TABLE 1 (Continued)

Bycatch elasmobranch fishery (%) indicates the percentage of respondents	
Target species	• *Tenualosa ilisha* hilsa
	• *Pampus* sp. pomfret
	• *Harpadon nehereus* Bombay-duck
	• Sardine (Clupeidae)
	• Jewfish (Sciaenidae)
	• Catfish (Ariidae)
	• *Penaeus monodon* tiger shrimps
	• Groupers (Serranidae) and
	• Snappers (Lutjanidae)
Most valuable species	• *Carcharhinus amboinensis* pigeye shark
	• *Galeocerdo cuvier* tiger shark
	• *Carcharhinus leucas* bull shark (mostly bigger carcharhinids)
	• *Sphyrna* spp. hammerhead sharks (due to of their large size and quality of fins)
	• Rhinopristiformes rays (giant guitarfish, guitarfish, wedgefish, including sawfish)
	• *Mobula* spp. devil rays (due to of their large size and gill rakers) and
	• Bigger dasyatid rays
Least valuable species	• *Scoliodon laticaudus* spadenose shark
	• *Carcharhinus amblyrhynchos* gray reef shark (if small in size)
	• *Rhizoprionodon acutus* milk shark
	• pups of *Carcharhinus limbatus* blacktip shark and *Carcharhinus sorrah* spottail shark
	• *Chiloscyllium* spp. bamboo sharks (<70 cm)
	• Small-sized species
	• Despite their low value, small-sized species were traded, with *Chylloscilium* spp, for example, sold at a nominal price (0.6 USD per kg)

Note: Primary gear type indicates gear used to catch the main target species; secondary gear type indicates additional gear used to catch non-target species.

TABLE 2 Percentage of respondents (*n* = 66) and their answers to selected questions pertaining to Bangladeshi shark fisheries

Question related to	Answers (in %)			
Average no. of big sharks caught per trip	1–50 (26)	50–100 (39)	100–150 (23)	>200 (12)
Monthly average catch	Tiger sharks	Hammerhead sharks	Whale sharks[a]	Sawfish
	15–20	40-60	1–3	0
	Guitarfishes	Spadenose sharks	Wedgefishes	Other large Carcharhiniformes
	1–50	500–600	0	1–65
Discards and sales	Auction (14)	Sale to middlemen/ traders (83)	Discard (3)	
Shark parts offered for sale	Whole body (94)	Fins (6)		
Main shark product destinations	Chittagong Hill Tracts and other domestic destinations (55)	Local tribal and Burmese buyers (13)	Myanmar (17)	China (15)
Estimated daily amount (kg) of landed sharks	0.5–300 (38)	300–600 (39)	600–1000 (9)	>1000 (6)
Sale to specific buyers	Yes (6)	No (94)		
Is it desirable to catch sharks as bycatch?	Yes (74)	No (17)	Sometimes (9)	
Monthly income from shark bycatch (US$)	12–120 (44)	120–235 (20)	235–353 (6)	Negligible to no income (30)
Willingness to use methods to mitigate bycatch	Yes (41)	No (23)	Only if alternatives are available (27)	Inconceivable (unsure) (9)
Reasons for shark population decline	Overfishing (36)	Bottom trawling (13)	Destructive net use (12)	Anthropogenic development, pollution, biological reasons (5)
Awareness on national laws	No (94)	Yes (6)		
Awareness on public outreach campaigns	No (100)			
Reason for population decline	Risks from specific and detrimental net use (17)	Irregular seasonal variation and extreme weather (12)	Industrial bottom trawling and increase in fishing ports (27)	Overfishing (43.94)
Desired next generational occupation	Further study (47)	Going abroad (5)	Islamic priest, Navy, or independent business (24)	Fishing (11)

[a]Whale sharks were more commonly sighted at sea than caught.

(Cameron & Trivedi, 2013). A GLM (Poisson regression) was selected as the dependent variable (number of elasmobranchs caught) was count data and had a Poisson distribution. The mean and variance of the dependent variable were checked. Overdispersion of the data observed (variance > mean). As a result, the quasi-Poisson family was used to deal with the overdispersion of data. Quasi-Poisson regression keeps the coefficients

the same as the Poisson regression; however, it adjusts the standard errors to avoid Type I errors in p values. The model fit was checked by comparing the model with a null model (without any predictors) using the summ() function in the jtools package (Long, 2020).

To test for the presence of a progressive shift in accepted standards for the state of the natural environment (Pauly, 1995; Soga & Gaston, 2018), that is "shifting environmental baseline syndrome" (Jabado, 2014), and evaluate whether observed elasmobranch population changes were associated with age and experience of interviewed fishers, a GLM (Poisson regression) was performed using the same methods described above.

A linear regression model was performed to establish whether mesh size was related to fishing depth (see Section 3.2).

3 | RESULTS

3.1 | Elasmobranch fisheries

Fishers used a multi-species and multi-gear approach (e.g., submerged or floating gill nets, set bag nets, seine nets, and long lines) in all areas and on all vessel types (Tables 1 and S5). Gear selection was primarily driven by the seasonality of the target species and sea condition. The majority of fishing boats (83%) carried three to five additional big hooks in addition to their primary gear to opportunistically catch large fish including sharks (Tables 1 and 2). According to fishers, an estimate of >8000 boats operated from three sites (St. Martin's Island, Teknaf and Cox's Bazar) on a daily basis. Targeted species generally included demersal and/or pelagic fish species (Figure S1A, Table 1). Elasmobranchs were caught as bycatch in other teleost fisheries, such as the hilsa fishery, and were targeted in ray fisheries (Figure S1B; see Section 3.2). According to fishers, a range of 0.5 to >1000 kg of whole bodied sharks was landed by each vessel per day (94% stated that between 300 and 600 kg of sharks were landed by each vessel per day in the winter months). With the exception of one exclusive shark trader in Cox's Bazar, who operated a fleet of 7–8 medium to large sized fishing vessels with modified gillnets, none of the interviewees were involved in targeted shark fisheries. Based on interviewers with three fishers who targeted rays, guitarfishes, and wedgefishes, it was inferred that at least 480 motorized fishing vessels targeted rays (e.g., *Glaucostegus* spp. giant guitarfishes, *Gymnura* spp. butterfly rays; Table S6), mostly from ports of the south-central region and 60 in the south-east region. FGD participants indicated that bottom-dwelling rays were targeted in bottom long line fisheries, using

10,000 to 30,000 unbaited 3.8–5 cm hooks per km of line, at a depth between 4.8 and 36.5 m (Table S6, Figure S2). Ray fisheries target multiple species, although guitarfishes and large-sized rays were the most desirable (Table S6).

3.2 | Catch composition

Almost all gear types used caught elasmobranchs. While smaller specimens (<70 cm) were relatively common in the catch throughout the year, large specimens (>150 cm) were generally only caught in the winter, spring, and summer months. The catch size was dependent on the season, fishing gear used, and geographic location of homeports and fishing grounds.

The most commonly by-caught elasmobranchs were *Scoliodon laticaudus/macrorhynchus* spadenose shark, small-sized whiprays and stingrays (*Pateobatis* spp. whiprays, and *Brevitrygon* spp. stingrays), followed by *Gymnura* spp. and other small-sized sharks. Fishers also commonly caught *Sphyrna* spp. hammerhead sharks, and several species of requiem sharks. Between 100 and 1000 small (<70 cm) and 1 and 200 medium (71–150 cm) and large sharks (>150 cm), respectively, were reportedly caught per fishing trip, although 12 fishers stated catches of more than 200 sharks per trip. Monthly average sightings in coastal waters were highest for spadenose shark (500–600 individuals) and lowest for sawfish (0) (Table 1). With the exception of sharks >2.5 m, all sharks were reportedly landed whole, although cases of finning and carcass discarding of larger catches around 15–20 years ago were reported by three fishers. The most commonly caught species in longline fisheries were *Glaucostegus* spp., *Gymnura* spp., *Himantura* spp. stingrays, and other dasyatid rays (*Urogymnus* spp. mangrove rays, *Maculabatis* spp. whiprays, *Neotrygon* spp. maskrays) (Table 3).

The number of elasmobranchs caught per month was dependent on area, fishing homeport, and season ($p < .001$) (details in Table S7). For example, fishers in St. Martin's Island caught significantly lower numbers of elasmobranchs than fishers from Cox's Bazar (beta $= -1.7043$, $p = .00123**$). Fishers, who fished during all seasons caught a higher number of elasmobranchs than fishers fished during the winter (beta $= -2.9219$, $p = .02886*$), summer (beta $= -1.9137$, $p = .10585$), and monsoon (beta $= -1.2293$, $p = .27906$) seasons; however, the relationship of the number of elasmobranch caught in all seasons with summer and monsoon was not significant. Quasi-Poisson regression model results showed that Set-bag nets using fishers (beta $= 2.2301$, $p = .00424**$) caught a higher number of elasmobranchs than fishers

TABLE 3 Challenges regarding elasmobranch fisheries management in Bangladesh with recommendations to address those challenges using fishers' knowledge

	Challenges	Recommendations
1	This study found that populations have already declined, and presumably to critical limits for several species of high demand	Using fishers' knowledge to inform • Prioritizing conservation of most threatened species (Haque, Washim, et al., 2021) • Engaging fishers (Islam et al., 2017) to help enforce the setting of sustainable fishing limits and quotas • Ensuring fishers'' participation in using modified destructive gears and managing bottom and mid-water trawl fisheries is essential for mitigating wasteful fisheries practices.
2	Heavy fishing pressure occurs in critical habitats in shallow water coastal areas	Using fishers' knowledge to inform spatial management, including protection of critical habitats (Moore, 2018) to provide refuge for threatened species, for example, shallow water south-central regions are crucial for Rhinopristiformes rays; the Sundarbans are important for giant freshwater rays and sawfishes.
3	Given that thousands of fishers in Bangladesh utilize unlicensed vessels and do not use logbooks and or record catches (Haque, unpublished data), monitoring of catch is challenging.	Promoting and facilitating incentive-based monitoring and bycatch mitigation (Booth et al., 2020) • This could be achieved in collaboration with Bangladesh Fisheries Development Corporation (BFDC) • Initiate research into bycatch mitigation techniques to inform this work.
4	Fishers coming from impoverished social strata	Increasing market efficiency of other sustainable catch (e.g., Hilsa) and creating alternative livelihood opportunities, thereby decreasing pressure on elasmobranchs (Haque, unpublished data)
5	Management approaches are a challenge in itself due to the limited capacity of institutions in Bangladesh; and an absence of inclusive management regimes, resulting in apparent non-compliance (Bladon et al., 2016)	Institutional capacity building and approaches for co-designing actions to manage such complex fisheries and enabling transboundary approaches to conservation
6	Lack of awareness (e.g., of legislation)	Ensuring fishers can access relevant information and practical facilitation/support for following regulations with the help of local governance, Department of Forest and Department of Fisheries.
7	Lack of relatable examples of conservation measures reflecting the benefits of both fish and fishers	Sustainable approaches to fisheries management based on fishers' participation, rather than top-down umbrella bans on catch and trade Creating and sharing relatable examples of positive conservation outcome for fishers and their livelihoods.
8	Lack of research—effective fisheries management requires reliable and regionally accurate population assessments and socio-ecological understanding (Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al. 2021; Haque, Washim, et al. 2021; Haque, White et al. 2021).	Further biological research will be critical to determine the size and seasonal catch reflecting species long-term sustainability Further research to address critical questions raised by this study, such as— • how to incorporate fishers in local governance meaningfully? • how to generate experimental and/or qualitative evidence to identify the most cost-effective and efficient pathways to support local governance at a larger scale? • how complex elasmobranch management regimes can be structured in a way that enables long-term adaptive and species/group specific solutions?

who used floating gill nets. Fishers using hilsa gill nets (beta = −0.9191, p = .04002*) on the other hand caught lower number of elasmobranchs than fishers who used floating gill nets (detail in Table S7 for quasi-Poisson regression results for all gear types). The quasi-Poisson regression model was a good fit (Nagelkerke's R^2 = 1.00; pseudo-R^2 [Cragg–Uhler] = 1.00; pseudo-R^2 [McFadden] = 0.39). Another quasi-Poisson regression model results showed, the number of elasmobranchs caught per month was also negatively related to mesh size of gear used (beta = −0.151837,

$p = .0172*$) (Table S7). This quasi-Poisson regression model was also a good fit (Nagelkerke's $R^2 = 1.00$; pseudo-R^2 [Cragg–Uhler] $= 1.00$; pseudo-R^2 [McFadden] $= 0.16$). Linear regression results showed that with increasing depth, larger mesh sizes were used (beta $= 0.05$, $p < .01$). Here, the beta coefficient is the degree of change in elasmobranch catch numbers for every 1-unit of change in the predictor. As the effect sizes in the models are small, these results need to be interpreted with caution.

3.3 | Fishers' species identification skills

Elasmobranch identification skills varied amongst fishers. Identification capacities were particularly low when obvious traits, such as body markings or a distinctive body shape were absent. Elasmobranch identification was particularly poor for morphologically similar species, and overall fishers grouped most large Carcharhiniformes without any distinctive marks (e.g., black tips on fins) into one category. Additionally, all rhinopristiformes rays (guitarfishes, giant guitarfishes, wedgefishes, except for *Rhynchobatus laevis/australiae* smoothnose wedgefish/ bottlenose wedgefish and *Rhina ancylostoma* bowmouth guitarfish), all sawfishes (*Pristis pristis* largetooth sawfish, *Anoxypristis cuspidate* narrow sawfish, *Pristis zijsron* green sawfish) and all hammerhead sharks, respectively were grouped together. Although several fishers were able to identify at least four to five different Rhinopristiformes and at least two to three hammerhead sharks, this identification capacity was not consistent, for example, smaller guitarfishes (Rhinobatodae) and giant guitarfishes (Glaucostegidae) were mostly identified as the same species, as were *Carcharhinus amboinensis* pigeye shark, *Carcharhinus leucas* bull shark, and *Glyphis* spp. ganges shark (Table S8).

3.4 | Population trends

Fishers observed a steep decline in diversity, individual size, and catch size of elasmobranchs during their fishing careers. One fisher stated, "*there was a time a few decades ago when we could not keep all the sharks caught due to limited storage capacities; now the size of catch has declined tremendously*" (Table S9). Reports of the disappearance of several species from the catch were also reported unanimously. The majority of fishers associated the decline primarily with overfishing and bottom trawling.

The vast majority of interviewees (98%) reported a change in elasmobranch catch and abundance over time, with a decrease in catch size (total catch) of all valuable species (large and high priced; see Haque & Spaet, 2021).

A reduction in the size of individual species within the past 20 years (mean $= 14.21 \pm 5.6$ SD) was also mentioned by fishers (80%; mean $= 14.21 \pm 5.6$ SD) (Figure 2a,b). Sixty-eight percent of fishers suggested changes occurred over the last two decades and 95% indicated accelerated declines over the past 5–10 years. In contrast, 25% of fishers were unaware of any changes in population size over the past 10–20 years, whereas 3.75% had not observed any change in population size over the past 5–10 years. Changes were reported for both, species diversity (34% of fishers) and total catch (41% of fishers). Seventy percent reported a reduction in valuable species
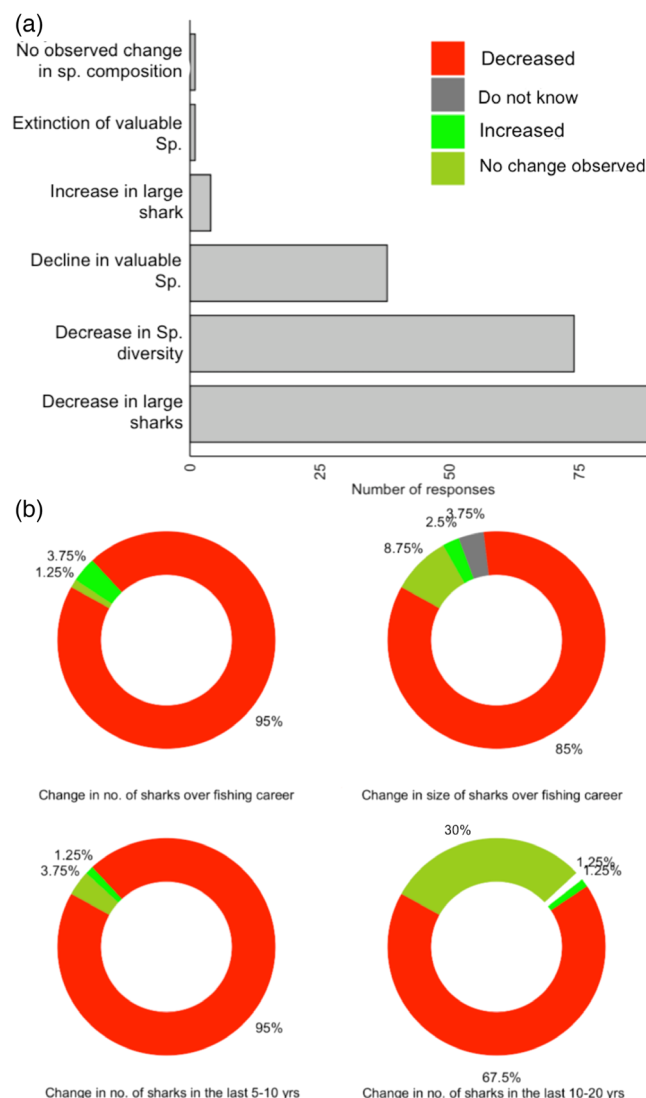

FIGURE 2 Observed changes in the catch composition of sharks. (a) Observed change in catch composition over individuals' fishing careers ($n = 66$). (b) Observed changes in the number and size of caught sharks over the entire fishing career of interviewed fishers [2–55 years (mean $= 26.5 \pm 13$ SD)]. Observed changes in the number of caught sharks over the past 5–10 and 11–20 years, respectively

only (e.g., sawfishes, wedgefishes). Fishers identified at least 12 species or species groups which had become less common over their career (Figure 3a) with the disappearance of some species such as sawfishes (75% fishers) and wedgefishes (especially smoothnose wedgefish/bottlenose wedgefish) (15%) from their catches (Figure 3b). Fishers also reported lower catches of large sharks (e.g., whale sharks, large hammerhead sharks, and large carcharhinid sharks), now, compared to 10–20 years ago (Figure 2a). Twenty-four percent of fishers reported an increase of smaller hammerhead sharks (likely juveniles, corroborated by unpublished landing data) over the past 10 years. All fishers reported a steep decline in ray

populations, especially after the late 1990s (Table S9). Fishers targeting rays also reported an overall decline in larger ray species. Reported catch sizes varied, with fishers reporting 1–20 individuals (per 7-day trip in recent times). A steep decline in catch rates between 2000 and 2010 was reported (e.g., recent one individual caught in 2018, compared to >1000 large dasyatid rays in one trip in 2000s). For instance, fishers mentioned that fishing trips were cut short due to a lack of storage capacity caused by catching large numbers of rays 10–20 years ago.

The reported main drivers of change in elasmobranch abundance were overfishing by artisanal fisheries (cited by 55% fishers; e.g., introduction of modified gears and

FIGURE 3 (a) International Union for Conservation of Nature (IUCN) Red List of Threatened Species status of species that have shifted from common to uncommon. Fishers were asked to list the species which were common at the beginning of their fishing careers, but became uncommon in recent years (total no. of respondents = 80). Twelve species/taxa that fitted this description were identified by the fishers; these are presented in the graph. The colors represent the IUCN Red List categories for the status of these species/taxa, whereby CR = critically endangered; EN = endangered; VU = vulnerable, NT = near threatened, NE = not evaluated. Species that could not be determined based on local names are labeled as unidentified and colored gray. Number of fishers who did not respond were also colored gray. (b) Observed population trends of selected elasmobranch species, over the past 10 years. (a) Whale shark, (b) tiger shark, (c) silky shark, (d) sawfishes, (e) wedgefishes (Rhynchobatus spp.), (f) hammerhead sharks, (g) guitarfishes and wedgefishes, (h) small carcharhinid sharks (e.g., spottail shark), (i) large carcharhinid sharks
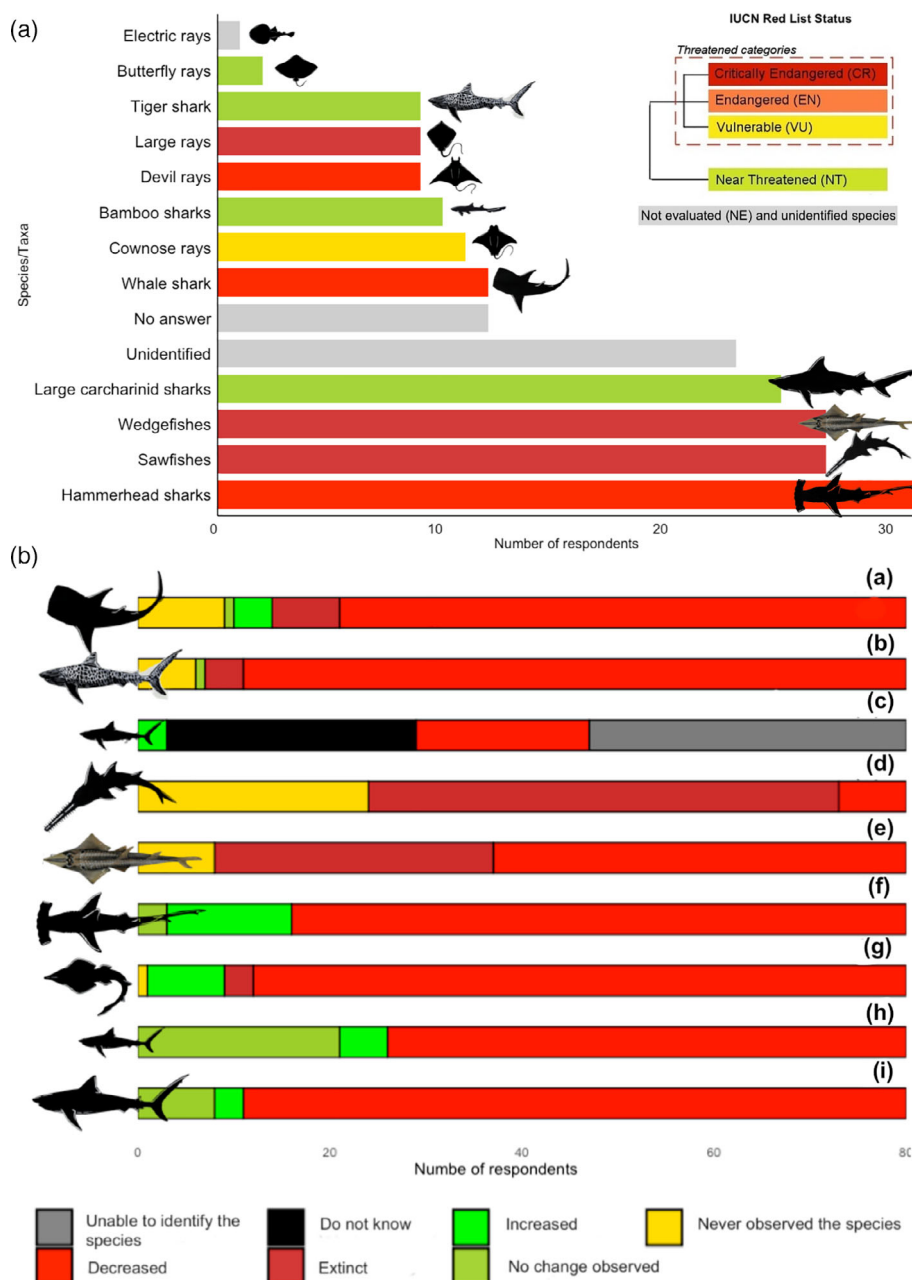
methods targeted to increase catch sizes (e.g., smaller mesh size, bottom longlines), commercial mid-water and bottom trawling, unselective fishing gear, as well as an expansion of fishing areas, an increase in numbers and size of vessels, as well as the introduction of negative subsidies to industrial fisheries. Coastal habitat degradation by other anthropogenic drives (e.g., coal-based power plant, industries) and the K-selected life history of elasmobranchs were also considered important (62%).

3.5 | Cross-generational differences in perception

Fisher age was positively and significantly related to the perception of the timeline since a change in elasmobranch population size was observed (beta = 0.02, 95% CI [8.45e−03, 0.02], $p = 7.56e−05***$). Correlations of fishing experience and perception of the timeline since a change in elasmobranch population size was observed were positive but non-significant (beta = 7.45e−03, 95% CI [−1.04e−03, 0.02], $p = .0817$). This suggests that older fishers observed a change in population earlier than the younger fishers (Figure S3) allowing no time for a "shifting environmental baseline syndrome" to develop. The quasi-Poisson regression model was a good fit ($\chi^2(2) = 114.08$, $p = .00$, see Table S10) and 84% of the variation in the outcome was explained by covariates (Nagelkerke's $R^2 = .84$) (Nagelkerke, 1991).

3.6 | Fishers' attitudes toward fisheries management and conservation

Ninety percent of interviewed fishers were unaware of Bangladesh's national Wildlife (Conservation and Security) Act, 2012 (WCSA). Those who were aware of the Act were unable to elaborate on existing laws (Table 2). While several fishers stated that some sharks might be protected, they were unable to provide details on their protection status. None of the fishers were familiar with CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). Fishers stated that permits to trade shark products were not required. Ray fishers in the FGD group were unaware of any national and international laws or treaties protecting ray species. Reportedly awareness campaigns on declining ray populations and conservation had not been conducted. Additionally, fishers claimed that they were compelled to pay bribes to avoid punishment for trading certain undefined species.

Fishers showed a genuine interest in national laws. During interviews and FGD, they were eager and compassionate about the recovery of elasmobranch populations in Bangladesh. Several participants ($n = 15$) asked about ways to concurrently conserve elasmobranchs and their livelihoods. Over 75% of fishers acknowledged the importance of sharks to ocean health and 41% were willing to employ new methods to stop shark and ray catch or mitigate bycatch with alternative livelihoods provided. A fifth (22%) were unwilling to change fishing practices mainly because of the unavailability of required support. The remaining fishers either did not answer the question (33%), or were not sure of the actions needed for shark conservation, but showed interest by inquiring about appropriate conservation approaches. Fishers mentioned the potential unsustainability or failure of conservation measures due to insufficient income of affected fishers leading to non-compliance. Fishers noted that trading had become minimally profitable due to declining elasmobranch populations. As a result, they showed willingness to change to more sustainable fishing methods if facilitated (e.g., through financial support, social security, training, ownership of vessels and nets) and incentivized. Many fishers ($n = 35$) also stated that a better and equitable share of profit or salaries from fish catches in coastal waters may improve their decision making regarding best practices and conservation of threatened species. Fishers also mentioned the possibilities of including existing cooperatives in managing resources. For instance, one fisher in Cox's Bazar stated, "*We have a cooperative with 500 registered fishers but we never participated in any conservation actions regarding elasmobranchs.*" Mechanical (e.g., diverse net use, variation in season, and fishing practices) and social complexities (e.g., poverty, unequal profit sharing, oppression by fishing companies, limited access to fundamental rights) were mentioned as hurdles to conservation planning (e.g., live release, possible temporal or spatial closure or trade ban). Additionally, interviewees requested specific information regarding bycatch mitigation, the release of by-caught species. Fishers also wanted to understand governance issues regarding potential regulations impacting their livelihoods. For instance, they requested information on authorities responsible for potential compensations or alternative livelihood facilitation if targeted ray fisheries were to be banned. Interviewed fishers also showed interest in understanding the possible monitoring mechanisms for ensuring adherence to regulations at sea (e.g., "what if, in fear of being fined or jailed, fishers discarded dead sharks at sea?"; "Who will monitor what is happening at sea and how?"). Finally, several fishers were eager to learn about the ecological benefits of healthy shark and ray populations.

4 | DISCUSSION

Our study highlights that in data-poor regions such as Bangladesh, fishers' knowledge provides an invaluable

information source for an increased understanding of exploited species, current and historical trends, and to inform the development of conservation and management measures. The insights gathered by this study highlight the benefits of fishers' participation in conservation and the importance of co-designing management regimes for better sustainability and success.

4.1 | Elasmobranch: fisheries and population trends

Elasmobranch catch is prevalent in every gear used in Bangladesh, either as targeted or desirable bycatch. Monthly catch and daily landings reported during the interviews indicate higher catch numbers than those reported in national statistics (DoF, 2018; Haque & Spaet, 2021). Catches have perpetually declined over the past decade, indicating size distribution change, stock depletion due to overexploitation (see Section 3.4), and increasing fishing effort potentially leading to stock collapse.

Most fishers reported changes in elasmobranch species composition and/or catch rates over time. Several fishers identified species that were commonly present in the past but had not been caught over the past 5–10 years or more, for example, bottlenose wedgefish/smoothnose wedgefish, and sawfish potentially indicating extreme rarity. According to IUCN Red List criteria (IUCN, 2021) at least 21 of the elasmobranch species that were frequently caught and traded by interviewed fishers are currently threatened with extinction (12 critically endangered, seven endangered, and two vulnerable) (Tables 1 and S9) and several were listed in different CITES appendices (Haque & Spaet, 2021). None of these species are currently managed in Bangladesh. Fisher's responses were corroborated by recent studies that recorded the disappearance or reduced landings of several elasmobranch species at these sites (Haque, Washim, et al., 2021; Haque, unpublished data, 2022). Changes in abundance were emphasized for largetooth sawfish, narrow sawfish, bottlenose wedgefish/smoothnose wedgefish, great hammerhead shark, and smooth hammerhead shark, amongst several others. This corroborates declines of these species globally (IUCN, 2021). For instance, largetooth sawfish populations have been depleted by more than 80% throughout their range across the Indo-West Pacific (Kyne et al., 2013; Yan et al., 2021). At least 30 nations within this region have declared largetooth sawfish as locally extinct owing to an array of threats, particularly fisheries (Harrison & Dulvy, 2014; Yan et al., 2021). The case is similar for wedgefishes and giant guitarfishes (Rhinidae and Glaucostegidae). Exploited by targeted and incidental catch, these species have gone through severe population depletion and even localized disappearances (Dulvy

et al., 2016; Jabado et al., 2018; Moore, 2017). For instance, in neighboring Pakistan, a 99% population decline was reported for all rhinids and glaucostegids (Kyne et al., 2020). These species are particularly vulnerable to extinction due to their limited biological productivity (Kyne et al., 2020), intense coastal fisheries overlapping their habitats, and ensuing food security for vulnerable communities (Moore, 2017). Similarly, in Bangladesh, fishers stated that declines in elasmobranchs were primarily associated with destructive bottom trawling practices and unselective net use.

The decreases in catch rates over the past two decades reported in this study coincide with an estimated 34% decrease in reconstructed Bangladesh elasmobranch landings over 15 years starting in 2000 (Pauly et al., 2020), and a four-fold increase in overall fishing effort between 2000 and 2014 (Pauly et al., 2020; Ullah et al., 2014). Although there is evidence that gear modification for increased capture rates can lead to overfishing, the direct quantitative relationship between gear modification and elasmobranch population change could not be determined. However, it is commonly accepted that fisheries expansion (e.g., overfishing) is the primary cause of worldwide elasmobranch population reduction (Dulvy et al., 2021).

Reported decreases in size and number of caught elasmobranchs in this study, corroborate findings across Southeast Asia, where large sharks have declined and landings of small-bodied sharks (e.g., bamboo sharks) have increased over the past few decades (Arunrugstichai et al., 2018; Khine, 2010; Krakstad et al., 2014; Lack & Sant, 2012; Lam & Sadovy de Mitcheson, 2011). At the same time, many resilient and small-bodied shark populations have either declined or collapsed, for example, in India, spadenose shark, *Rhizoprionodon acutus* milk shark, *Carcharhinus limbatus* blacktip sharks (Mohamed & Veena, 2016), highlighting the problem of fishing for elasmobranchs in the absence of practical regulations. Fishers also cited overexploitation of juvenile and pregnant individuals as reasons for the observed population declines. It is of critical importance to connect the conservation of early life-stage individuals, in nursery areas, with management strategies safeguarding all life-stages (Kinney & Simpfendorfer, 2009). Interventions such as large-scale net/mesh-size modification, fishers' involvement in live release programs, and designating species-specific quotas are crucial for limiting catch. For habitat level, interventions spatial co-management of critical habitats are key. This study found that the size of catch is associated with gear, mesh size of net used, total fishing days, depth at the catch, fishing homeports, seasonality, and distance covered from homeports. These results can be applied to help co-design appropriate quotas to curb unsustainable catches by introducing location, depth, and gear selectivity within these fisheries.

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4.2 | Fishers' attitude: conservation and challenges

Changes in elasmobranch populations were observed by all age classes of fishers, signifying that overexploitation has been occurring for decades. This also suggests that the perceived changes are occurring at such a rapid pace that all age groups are experiencing it without adequate time for a "shifting environmental baseline syndrome" (Jabado, 2014) to develop. It is likely that the fishers may have attuned to the increasing scarcity of the elasmobranchs and perceived this as "natural" when they started their careers. This can impact their behavior toward the corrective policies (Bunce et al., 2008; Haque & Spaet, 2021; Jabado, 2014). For instance, without adequate time for a "shifting environmental baseline syndrome" to develop, in the current study, several fishers were certain that some species (e.g., wedgefish, sawfish) have been uncommon/rare throughout their fishing career, and that there is no way to prevent bycatch. As a result, some fishers had the view that regulations may not help to conserve such species. Such mindsets can be challenging when attempting to convince fishers to adhere to specific regulations to limit catch. This emphasizes the need for education, including evidence and relatable examples of the positive effects of conservation actions on species survival, and on fishers' livelihoods; which can help change these views and mindsets. Inclusion of fishers' perceptions and understanding of conservation measures can be used to develop more effective conservation regimes for fisheries management (Fauconnet et al., 2019; Liao et al., 2019; Maynou et al., 2018).

The capacity and willingness of fishers to abide by laws and regulations are cardinal for management regimes to be effective. Nevertheless, this study reveals that legal frameworks governing fishing activities and protected species were, in many cases, unknown or not well-accepted by fishers, resulting in non-compliance. This dearth of knowledge is likely caused by limited interactions with fisheries officers, a lack of implementation of existing laws, undemocratic law development processes, increasing corruption, and the fear of livelihood loss. Local managers from BFDC and employees of the local government were also either unaware of the fisheries or disinterested due to lack of resources/incentives in promoting elasmobranch protection beyond setting up signboards at some sites (Haque, pers. comm. January 2019). Another important aspect is the oversimplification of the national law, which does not consider the complexities of fisheries. For example, several species are prohibited from being caught and traded, with little provision for awareness generation or facilitating fishers' adherence to the regulations, either logistically or technically (e.g., bycatch mitigation strategies). A more detailed and holistic approach is needed for effective conservation and compliance. Additionally, incentives for fishers would help secure compliance and effectiveness of the law in protecting threatened species. For such interventions, it is essential to understand the fishers' situations, perceptions, and capacity to comply.

Fishers showed mixed reactions toward participating in elasmobranch conservation actions, depending on several socio-ecological aspects (e.g., financial capacity for good practice at sea, poverty, access to information, effective livelihoods). Although education programs organized by several local and international NGOs exist, they were unable to reach the fishers at the scale required due to a lack of resources, the sheer number of fishers in all coastal regions, and the short-term nature of such projects.

A substantial number of fishers were willing to participate in bycatch mitigation methods and were aware of the reasons behind population depletion. However, as fishers face lost incomes, unpaid debts (Haque et al., 2020), and corruption, it is also likely that these factors will cause illegal activities and enhanced levels of non-compliance (Jaiteh, Hordyk, et al., 2017). Prosocial attitude is critical for the long-term management of common property resources like fisheries. Socioeconomic characteristics influence fishers' prosocial actions, as a result, management regimes need to understand fishers' socio-economic backgrounds (Rojas et al., 2021). For example, providing ineffective alternative livelihoods/compensations for hilsa seasonal catch ban to mitigate fishing mortality generated conflicts in Bangladesh (Islam et al., 2017). Similarly, recent sporadic implementation of the umbrella bans on shark catch has instigated alternative ways of landing and selling the catch in coastal Bangladesh and conflicts amongst fishers and government fishery officials, but failed in mitigating capture of elasmobranch species (Haque, unpublished data, 2022). For both cases, this was because these actions were largely devoid of in-depth understanding of fishers' socio-economic conditions. Similar bans on shark catch remained futile in Myanmar and non-compliance was an issue in the absence of acceptance by the fishers (Begum et al., 2020; Collins et al., 2021). Ensuring fishers' participation in data collection has been effective in the Bay of Bengal as it builds trusted relationships and active participation (e.g., reporting Critically Endangered sawfish catch in Haque et al., 2020), which can lead to ownership of the actions and marine resources (Haque et al., 2020). Monitoring measures are also essential in this regard (Price et al., 2016) to ensure mitigating any further illegal activates. There are several other factors which enhance fishers' compliance with laws.

For instance, fishers follow laws when they understand them, feel that the laws serve their interests, and have relationships with management authorities that are based on trust (Hauck, 2008; Hønneland, 1999). Nonetheless, participating meaningfully and representing the fisher communities in the fisheries decision-making process has hardly been considered to date in Bangladesh.

The decline in elasmobranch populations and the difficult financial and economic situation of most fishers is succinctly captured in the following quote of a bycatch fisher from Alipur interviewed in January 2018: "*In the early days (the 1970s - 90s), we caught sharks and rays abundantly. Now they have declined due to heavy fishing pressures. We have no other alternatives for our livelihoods than fishing. Although we do not target them, an extra income from sharks and rays is always helpful. We do not own boats or nets. We have debts from the boat owners, and more catches are better for us. But the recent attempts from the government officials to stop the catch at the landing sites will not help anyone... not the sharks or fishers. They have to understand our problems and help us if they are expecting real change. Otherwise, there will be some corruption from both ends*"—translated from Bangla. This reflects the multifaceted problems that need to be addressed in order to improve fisheries management in Bangladesh and other/similar developing countries. Building on the evidences from this study, openness of fishers for inclusive, future management scenarios, a democratic conservation strategy could be an effective way forward.

4.3 | Future directions: preserving fish and fishers

Political interest in, and conservation initiatives for, elasmobranchs are new for Bangladesh and need to be supported with geographically appropriate scientific and socio-economic evidence (White et al., 2017), which will take time. A precautionary approach, whereby management regimes are planned before a species is depleted would be ideal but currently lacking (Haque, D'Costa, et al., 2021). This study highlights the value of local fishers' knowledge, observations, perceptions, and participation to support conservation through corroborating results from concurrent scientific fieldwork; identifying and addressing knowledge gaps and priority areas; and supporting and guiding the development of management measures. We recommend a three-pronged approach to enhance fishers' engagement in this work and potentially transform the elasmobranch fishery situation in Bangladesh.

4.3.1 | Input from fishers to ensure management interventions for exploited elasmobranchs in Bangladesh are species/taxa specific

In response to target and by-caught practices, management interventions for exploited elasmobranchs in Bangladesh need to be species/taxa specific. For example, for guitarfishes (CR, CITES II), low catch allocations or total bans (depending on the species' biological resilience against existing fishing pressures) on target catch and retention may be appropriate. Given that post-release mortality is low for some giant guitarfishes (Ellis et al., 2017; Fennessy, 1994), these can be successful endeavors. On the other hand, for sawfish (CR, CITES I), a complete ban on catch and trade with live release protocols (Haque et al., 2020) can be a suitable intervention. For hammerhead sharks and other big carcharhinids, controlling the catch of several age classes toward protecting reproductive adults may be appropriate. Managing all life stages with interventions embedded in evidence is also crucial in this regard (Haque, Washim, et al., 2021). However, these will all depend on the availability of technical and social means to control such fishing mortalities. Moreover, due to the extensive spatial extent of many species caught in Bangladeshi fisheries (e.g., hammerhead sharks, whale sharks, devil rays), regional management interventions are necessary to achieve biologically meaningful outcomes. Keeping species-specific realities in mind, we recommend a holistic approach for effective conservation (Booth et al., 2020) to start with, comprising traceable short- and long-term management goals (Table 3).

4.3.2 | Meaningful participation of fishers in co-designing, and engaging in, management actions for governing fishery resources

Fishers' meaningful participation in co-designing and engaging in management actions for governing fishery resources is cardinal. It will improve governance by decentralizing decision making and endorsing local governance (Dawson et al., 2021), creating trust and improving sustainability. The current study found growing distance and distrust between fishers and fishery policymakers/managers where state governance supersedes customary institutions (e.g., cooperatives) in policymaking (see Section 3.6, Figure 4). It has been profusely reported that local communities play a prominent role, such as when they have significant influence over decision-making or when local institutions control part of governance, producing excellent outcomes for
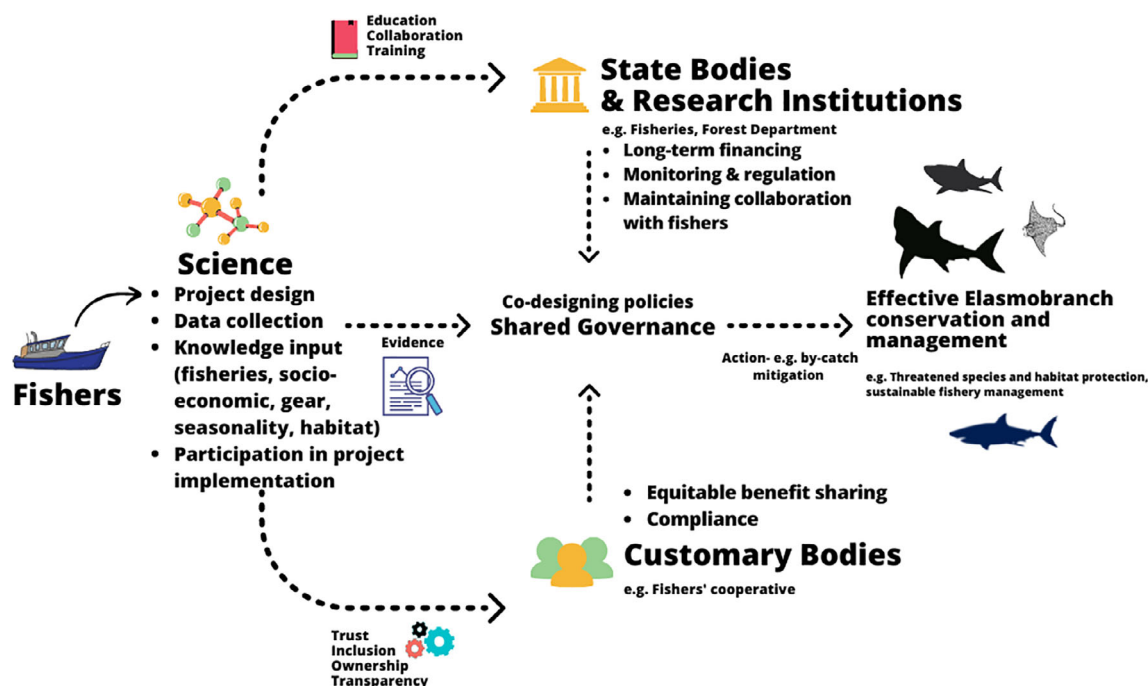
FIGURE 4 Model for fisher's meaningful inclusion and collaboration for science/research, local governance, and filed implementation of conservation actions toward species protection

well-being and conservation. Externally managed initiatives, on the other hand, that involve strategies to influence local habits and override traditional institutions tend to produce relatively ineffective conservation while also causing adverse social effects (Dawson et al., 2021). Equitable conservation, which empowers and supports local communities' environmental responsibility, is the key avenue to sustainable long-term biodiversity conservation, mainly when backed by law and policy. Conservation can become more effective through an increased focus on governance type and quality and fostering solutions that reinforce the role, capacity, and rights of communities (inclusion of fishers in this process is graphically represented in Figure 4).

4.3.3 | Provision of education, training, facilitation, and incentives

Endorsing local governance, providing adequate and long-term education, training, technical facilities, and incentives are crucial for fishers to adhere to management actions and regulations. The current study found low to medium identification capacity amongst fishers for morphologically similar species, difficult for untrained personnel (Haque, White, et al., 2021). Education and training in species identification linked with existing knowledge (ability to identify specific groups and taxa, see Section 3.3) will contribute toward species/taxa-specific regulation compliance. An assessment of true improvement in identification ability following trainings can aid in determining the efficacy of such trainings. A substantial number of fishers were willing to adapt to bycatch mitigation if they could be adequately supported in this. Training on safety and live release for by-caught species and best practices at sea are essential. For target elasmobranch fishers, facilitating smooth progress toward an alternative sustainable fishery (e.g., hilsa) and engaging in mainstream financial mechanisms can reduce pressure on elasmobranchs. Ensuring adequate long-term finances supporting gear modification, loss of income concerning live release programs and catch limits, rewards/incentives, and punitive measures for positive and negative behavior, respectively, are all important factors to facilitate progress.

We have highlighted the importance of local knowledge in filling crucial data gaps and conservation decision-making in a data-poor region. This study has wider application, especially for other fishery data-poor regions where elasmobranch populations lack the past understanding. In the absence of baseline studies, fisher's knowledge provides an unconventional yet highly valuable basis for assessing fishery status, population trends, and for conducting further quantitative assessments. While it is clear from this and other recent studies (Haque et al., 2020; Haque, Cavanagh, & Seddon, 2021; Haque, D'Costa, et al., 2021; Haque & Spaet, 2021; Haque, Washim, et al., 2021; Haque, White, et al., 2021) that

Bangladesh needs to prioritize elasmobranch conservation and sustainable fisheries management, the approach needs to be holistic and inclusive. Fishers need to be included in co-designing management actions and participating in governance. Such actions may include identifying the most threatened species, critical fishing areas, incentives, and facilitation required by the fishers to adhere to good fishing practices at sea and devising strategies for reducing elasmobranch mortality by both legal and social interventions. It is crucial to acknowledge that Bangladeshi fishers belong to the most impoverished communities and reside in the country's least developed areas. As a result, while they face real struggles to provide food and education to their families, they do not have the economic freedom to reduce their impact on the ecosystem to safeguard the future generations of elasmobranchs. We emphasize that approaches to managing elasmobranch fisheries must account for these real-life problems and incorporate appropriate and economically viable incentives and livelihood alternatives to both enable and ensure compliance. This model can potentially be used to change the top-down management of elasmobranch fisheries globally.

We call for further research on specific issues (e.g., taxa specific understanding of threats, mortalities, the biological potential to withstand fisheries pressure, bycatch mitigation strategies, culturally appropriate and accepted alternative livelihoods, incremental approach of management) for geographically appropriate and bespoke actions that also contribute to improving the conservation and management of elasmobranchs in a global context.

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CONFLICTS OF INTEREST
The authors declare that there are no conflicts of interest.

AUTHOR CONTRIBUTIONS
Alifa Bintha Haque: conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; visualization; roles/writing - original draft. Rachel D. Cavanagh: validation; writing - review & editing. Julia L. Y. Spaet: methodology; validation; writing - review & editing.

DATA AVAILABILITY STATEMENT
The data are fully presented in the supporting information material and available upon a reasonable request from the corresponding author.

ETHICS STATEMENT
The ethical approval to conduct a survey with human participants was reviewed and approved by the Ethical review committee of the Faculty of Biological Sciences, University of Dhaka (reference number- 59/Biol.scs.).

ORCID
Alifa Bintha Haque https://orcid.org/0000-0001-8250-0030
Julia L. Y. Spaet https://orcid.org/0000-0001-8703-1472

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