

Full length article

Utilization and trade of sharks and rays in the Andaman Islands, India



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ABSTRACT

Overfishing is recognized as the most pervasive threat to sharks and rays globally. While there is increasing emphasis on ecological aspects of shark and ray fisheries, socio-economic considerations are often poorly incorporated into management policies. Here, we assess the utilization and trade of sharks and rays across the Andaman Islands by conducting semi-structured interviews with 87 fishers and eight traders. Sharks and rays were exported to supply the meat market in peninsular India and contribute to the international trade in products such as fins, gill plates, and liver oil. A large proportion of fishers ($n = 38$, 43.67%) consumed sharks and rays due to declines in reef fish, as an accessible and cheap protein source. Small-sized sharks (<1 m total length), juvenile hammerheads, and uniformly coloured rays were preferred for local consumption. Fishers ($n = 43$, 49.42%) noted the difficulty of relying on profits from shark fishing due to declines in shark populations. However, it was easier to fish and trade rays due to their perceived abundance, few regulations, and increased demand for their products. Traders ($n = 7$, 87.5%) mentioned a rising demand for ray meat from peninsular India, leading to the development of a targeted ray fishery. Expanding and targeted shark and ray fisheries benefit the stakeholders who have the resources to invest, while affecting the livelihoods of others due to declining local fisheries resources. Our results highlight the need to revise and improve legal frameworks to consider the conservation needs of threatened species and likely impacts on local communities.

1. Introduction

Overfishing is recognized as a major threat to sharks and rays globally, leading to rapid population declines and an elevated extinction risk for 36% of ray species and 31.2% of shark species assessed on the IUCN Red List of Threatened Species [1]. Recent studies suggest that the global abundance of oceanic sharks and rays has declined by 71% since 1970, owing to an 18-fold increase in relative fishing pressure [2]. Moreover, in surveys using Baited Remote Underwater Videos, no sharks were observed in almost 20% of reefs surveyed around the world [3]. At regional levels, declining trends in populations have also been documented for stingray (family Dasyatidae) stocks in the Arabian Sea with declines of 55% from their historical maximum catch [4,5]. This overwhelming trend in shark and ray population declines is alarming considering these animals serve diverse functions in aquatic ecosystems [6–8]. At the other end of the spectrum, sharks and rays are often a

source of livelihood, food security, and cultural identity for many coastal communities, and contribute to national economies through fisheries and trade [9–11].

The utilization of sharks, rays, and their products has been reported for centuries in many communities and regions of the world [12]. This utilization has seen an increasing trend over the years with shark and ray trade valued at over USD 4.1 billion between 2012 and 2019 [13]. In India, fresh, salted, and dried shark meat was traditionally consumed in several coastal communities, especially along the west coast of India in Kerala, Lakshadweep and Maharashtra, where it constituted a staple diet for the poor [14,15]. Shark meat was considered nourishing food for mothers after childbirth [14,15], while ray meat was consumed during festivities in Kerala [16]. Harpoon fisheries also existed for mobulids (family Mobulidae) in Andhra Pradesh and Lakshadweep for domestic consumption of meat [17].

Between 1950 and 1980, in response to the increasing global demand

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for shark products, targeted shark fisheries developed in Tamil Nadu, Andhra Pradesh, and the Andaman Islands [18,19]. This demand also indirectly opened local and export markets for other products such as dried, fresh, salted or frozen meat for consumption, liver oil, skins as leather, jaws as ornaments, as well as cartilage and gill plates for medicinal purposes [12,16,18]. Indeed, a meat market developed in Tamil Nadu in the 1960 s [15], with targeted fishing for whale sharks (*Rhincodon typus*) (currently protected under the Indian Wildlife Protection Act, 1972) and gulper sharks (*Centrophorus* spp.). With time, other markets developed across the country based on local, regional, or international demand. For example, mobulids were not commercially utilized in India until late 2007 when a market for gill plates emerged and targeted fisheries developed in the states of Gujarat, Maharashtra, Kerala, and Tamil Nadu [20]. The increase in mechanization of fisheries further led to increasing fishing effort in these targeted fisheries. Overall, by the late 2000 s, this exploitation had led to a steep decline in reported shark and ray landings in both coastal and offshore fisheries [4, 21,22].

While much of this information on exploitation and utilization of sharks and rays is available from several states across India, the Andaman Islands remain an understudied region with poorly reported catch. The fisheries of the Andaman Islands are diverse and include a targeted shark fishery (pelagic and deep-sea longline) as well as high levels of documented incidental captures of sharks and rays across various types of vessels and gears in industrial and artisanal fisheries [23,24]. Furthermore, this sector is heterogenous in terms of human characteristics and constitute a mix of settler groups from several parts of the Indian subcontinent and Myanmar (the Karen community) [25,26] as well as migrant fishers brought from peninsular India by traders and boat owners to work in the fishing sector. These stakeholders encompass diverse fishing behaviours, attitudes, perceptions, knowledge, and traditions [27]. Further, available infrastructure, accessibility to markets and export facilities, shape the Islands fisheries [28]. Despite these expanding shark and ray fisheries [29], and considering the socio-economic complexities related to the interactions of communities with this sector and its diverse, unmonitored and unregulated characteristics, there is limited understanding of its drivers and trade on the islands. This limited understanding currently precludes governing agencies from effectively implementing existing conservation policies or taking timely conservation management actions to also ensure the sustainability of shark and ray fisheries.

Understanding the interactions between the various actors in the fisheries sector and trade provides insights into marine resource use, the external influences on markets, supply chain dynamics, drivers of the fishery, and can inform inclusive decision making processes. Using social science as an interdisciplinary approach for data collection allows us to gain a wealth of knowledge from local stakeholders on these socio-ecological factors [30,31]. Indeed, using Local Ecological Knowledge (LEK) provides insights into local status and threats to sharks and rays [32], supply chain dynamics [33,34], and drivers of fishers [35], factors which feed into designing effective management plans.

Within this context, we aimed to characterise shark and ray fishing patterns and utilization in the Andaman Islands. Specifically, we aimed to understand the 1) demographics of fishers and traders engaged in shark and ray fisheries, 2) fishing practices and interactions with sharks and rays, 3) utilization and trade of species and products, and 4) stakeholder awareness and perceptions regarding the conservation status of sharks and rays. Based on our findings, we provide recommendations and discuss implications of shark and ray management on the Andaman Islands.

2. Materials and methods

2.1. Study area

The Andaman and Nicobar Islands, situated between 6–14°N and

92–94°E (Fig. 1) are part of the Indo-Burma biodiversity hotspot [36]. The Andaman Islands constitute a diverse fishery with 2784 fishing vessels, including mechanized, motorized and non-mechanized boats, supporting 7034 licensed fishers who fish across the Andaman and Nicobar Islands [29]. Fishing gears include trawl nets, gillnets (drift and bottom-set), longline (pelagic, demersal, deep-sea), hook and line, trolling, and cast nets. On the other hand, due to their seclusion, communities on the Nicobar Islands are only engaged in traditional fishing for subsistence (using spears, hook and line, and troll line) or for the sale of reef fish in local markets [28,37,38].

The Andaman Islands are subdivided into two districts – North and Middle Andaman, and South Andaman. We conducted our study at landing sites and markets across seven villages in North and Middle Andaman, and six villages in South Andaman (Fig. 1). These sites were selected to represent important landing sites based on volumes of fish landed and fishing gears used across the Islands [23,24]. Port Blair in South Andaman supports landings from large-scale commercial fishing vessels that operate across the Islands and export fish out of the islands. On the other hand, the rest of the Islands support landings at a relatively smaller scale from commercial and small-scale or artisanal fisheries.

2.2. Interviews surveys

Semi-structured questionnaires were adapted from Jabado et al. [39] to the local context to include sharks and rays. Interviews with fishers included questions on (1) demographics and experience, (2) fishing practices and interactions with sharks and rays, (3) utilization and trade of products, and (4) awareness and perceptions of existing regulations and future management. Those with traders (including middlemen and processing unit managers) were modified to only include questions on (1) demographics and experience, (2) utilization and trade of products, and (3) awareness and perceptions of existing regulations and future management.

Pilot surveys were conducted with fishers in June 2018 in Junglighat, with final interviews conducted with fishers and traders across the islands in June–July 2018 and February 2019. Fishers and traders were approached at fish landing sites through purposive sampling, where an appointment was set up to interview them at a time convenient for them [40]. Surveys were carried out one-on-one to avoid influence from other respondents and maintain independence of responses. Each interview took between 30 and 60 min to complete. This is because the questionnaire consisted of open-ended questions where respondents were allowed a certain degree of freedom to initiate new topics and provide additional information regarding shark and ray fisheries. Respondents were asked to clarify species identification by using published guides [41–44] and images taken at local landing sites.

To obtain a representative picture of the shark and ray fishery, we aimed to sample 10% of fishers at each site or until data saturation was reached. Data saturation refers to the point where interviewees provide similar responses and where no novel data are found that can further understanding [45]. On the other hand, interviews were conducted with all known traders involved in processing and trade of sharks and rays at our chosen sites. All interviews were conducted in Hindi at tea stalls, fishing villages, or processing units by the lead author.

2.3. Data analysis

All responses were translated into English, and open-ended responses were coded for exploratory analysis, with the data analysed for percentages using Microsoft Excel 2017. All conversions from INR to USD were calculated on 16th July 2021, where 1 USD = 74.58 INR, as per www.xe.com, a currency converter website.

A map of sampling sites was produced using QGIS Development Team 2019. QGIS Geographic Information System. Open Source Geospatial Foundation Project (<http://qgis.osgeo.org>).

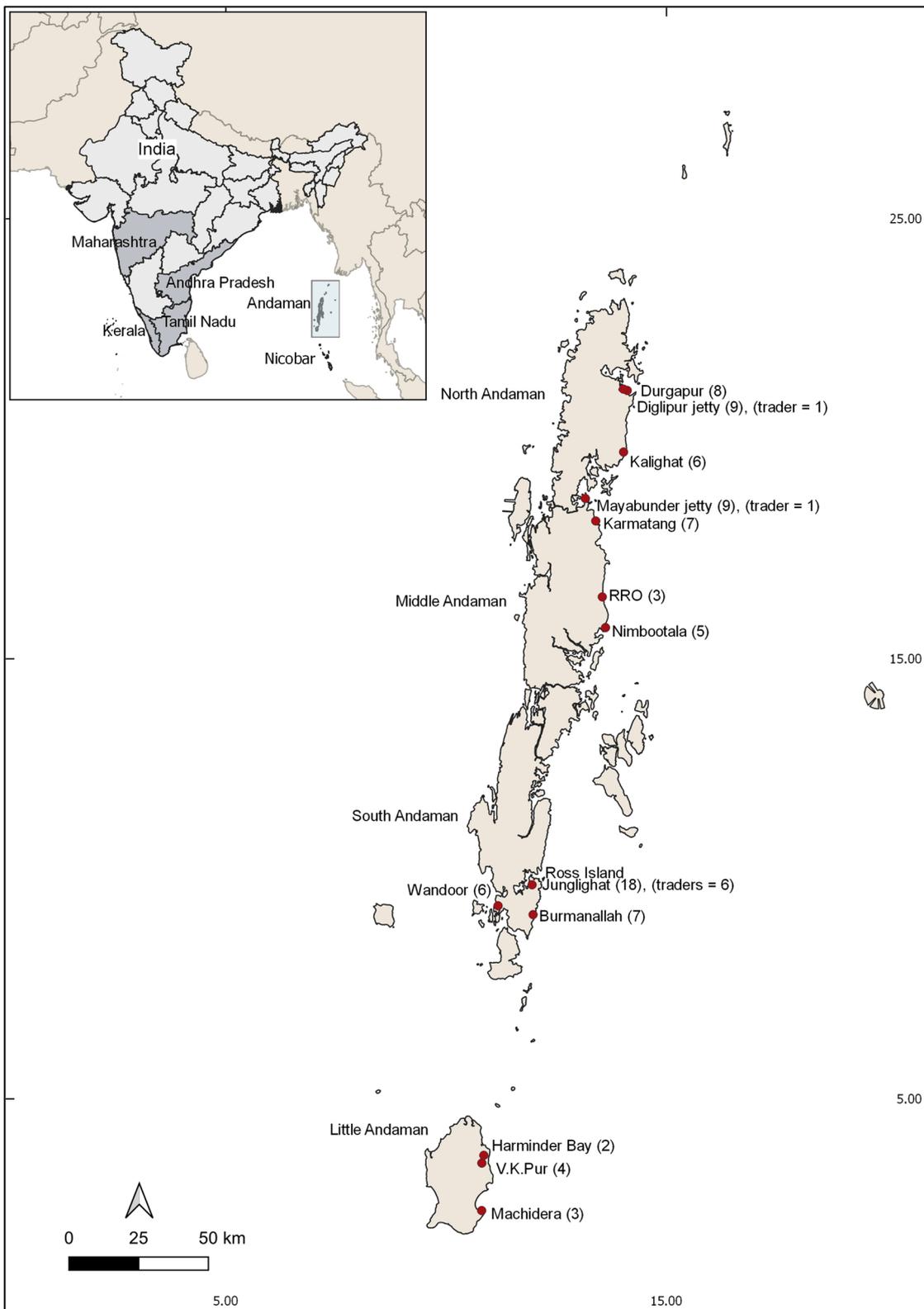


Fig. 1. Map of India (inset) and the Andaman Islands with red dots indicating villages where interviews were carried out with fishers and traders (number of respondents are provided in brackets).

2.4. Ethics statement

Verbal consent was obtained from all respondents after they were informed of the objectives of the study, the voluntary nature of the information provided, and the strict confidentiality of responses. All

standard ethical norms for socio-economic research as per the guidelines set by the EU code of ethics were adhered to (<http://www.respectproject.org/ethics/412ethics.pdf>).

3. Results

Of 110 participants approached, 95 participants (86.36%), consisting of 87 fishers and eight traders agreed to participate (Fig. 1). Twelve fishers from Wandoor and three traders from Junglighat refused to participate due to concern regarding increasing regulations and bans on shark fisheries and trade in India.

3.1. Demographics of fishers and traders

The majority of fishers interviewed were settlers who arrived on the islands through settlement schemes in the late 19th century ($n = 69$, 89.61%), while 10.38% ($n = 8$) were migrant labourers from peninsular India. Fishers were from Andhra Pradesh ($n = 32$, 36.8%), Tamil Nadu ($n = 27$, 31%), West Bengal ($n = 18$, 20.7%), Karen community ($n = 8$, 9.2%) and Nicobar community ($n = 2$, 2.3%). The age of fishers ranged from 19 to 82 years (mean = 42.13 years \pm 13.45 SD), with fishing experience ranging from 4 to 60 years (mean = 24.8 years \pm 12.50 SD). Fishing was the primary occupation for 91.95% ($n = 80$) of respondents, with some complementing their fishing income with farming ($n = 10$, 11.49%) (Fig. 2).

All traders interviewed were born in the Andaman Islands but belonged to the coastal states of Tamil Nadu ($n = 5$, 62.5%), Andhra Pradesh ($n = 2$, 25%), and Kerala ($n = 1$, 12.5%), from peninsular India (Fig. 1). The age of traders ranged from 31 to 53 years (average = 41.75 years \pm 6.49 SD), with experience ranging from seven to 32 years (average = 13.62 years \pm 8.07 SD). Three traders were fishers-turned-traders, whereas five came from a family of traders, who traded *bêche-de-mer* (sea cucumber, class: Holothuroidea) and trochus (order: Trochida) in the past, in addition to shark fins. Three traders worked exclusively with sharks and rays, had visited markets in Singapore, and had established networks with international markets.

3.2. Fishing gear and techniques

All fishers reported targeting multiple species throughout the year including groupers (family Serranidae), snappers (family Lutjanidae), sardines (*Sardinella* spp.), tuna (family Scombridae), and deepwater sharks (*Centrophorus* spp.). They used multiple fishing gears ($n = 72$, 82.75%), dependent on the weather and seasonal fluctuations of the target species. However, 17.24% of fishers ($n = 15$) operated only one fishing gear.

Sharks were dominantly caught in drift gillnets ('badmash jaal' = shark net with a mesh size of up to 400 mm) ($n = 54$, 62.06%) (fishers mentioned these nets were used in the 1990 s, but are no longer used),

and pelagic longlines ($n = 42$, 48.27%), whereas rays were mainly caught in trawl nets ($n = 80$, 91.95%), bottom set gill nets ($n = 78$, 89.65%) and demersal longlines ($n = 52$, 59.77%). Further, fishers stated that sharks were mostly caught at night, while rays were caught throughout the day ($n = 62$, 71.26%).

3.3. Knowledge of sharks and rays

3.3.1. Identification of sharks and rays

Fishers and traders could not differentiate between morphologically similar species from the family Carcharhinidae (e.g., blacktip shark (*Carcharhinus limbatus*) and spinner shark (*C. brevipinna*)), and the *Himantura uarnak* species complex (leopard whipray (*H. leoparda*), fine-spotted leopard whipray (*H. tutul*) and coach whipray (*H. uarnak*)). However, they could identify species based on unique morphological characteristics, such as the head shape of hammerhead sharks (family Sphyrnidae), snout shape of the clubnose guitarfish (*Glaucostegus thouin*), broad rounded snout and spotted colouration of bowmouth guitarfish (*Rhina ancylostoma*) and colouration and/or patterns and the large size of the whale shark and the tiger shark (*Galeocerdo cuvier*) and had local names for them (Table 1).

3.3.2. Population trends and perceived causes of declines of sharks and rays

Respondents (fishers = 77, 88.5%; traders = 6, 75%) reported shark declines due to overfishing. Fishers from North and Middle Andaman ($n = 14$, 16.09%) believed Junglighat fishers are provided with special shark fishing licences which led to overfishing. On the other hand, fishers in Diglipur (fishers = 16, 18.39%) blamed the 2004 Indian Ocean tsunami for shark declines. Respondents further commented on local extinction of species such as a 'shark, blue in colour, with long pectoral fins in proportion to the body' due to fishing in the 1990 s (traders = 2) and localised population declines due to fishing of aggregating grounds in South Andamans since the past five years. These aggregating grounds included those for juvenile scalloped hammerhead sharks (*Sphyrna lewini*) (fishers = 17, 19.54%) near Wandoor and deepwater sharks (gulper sharks) (fishers = 7, 8.04%; traders = 2) at Burmanallah.

Contradictorily, two traders from South Andaman remarked on the increased abundance of large (pelagic) sharks due to the tsunami, which they stated formed new habitats from the South Andamans inundation. They also mentioned that while catching large sharks is now rare on peninsular India, they are still caught in abundance around the islands. Some fishers ($n = 3$, 3.44%) stated that fish 'swam away' due to an increase in fishing boats, and that the false perception of fish declining was due to shared fish populations amongst increasing fishers, but that shark populations remain the same ($n = 7$, 8.04%).

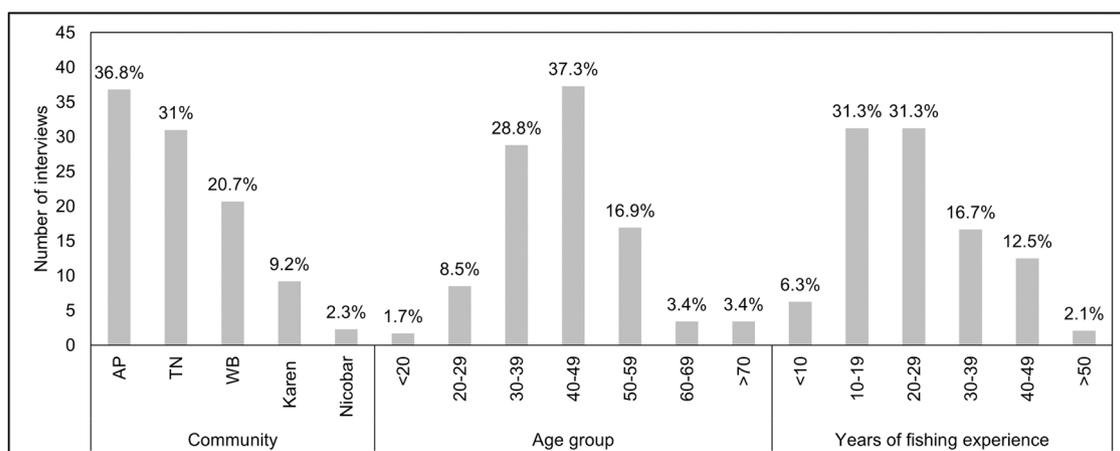


Fig. 2. Characteristics of fishers interviewed ($n = 87$) including community, age group (number of years), and fishing experience. Communities settled from states of mainland India are indicated as AP: Andhra Pradesh, TN: Tamil Nadu, and WB: West Bengal.

Table 1

Etymology of local species names and remarks on the utilisation and perceptions of shark and ray species according to respondents across the Andaman Islands (NA = Not Applicable). *This species does not occur in India [24].

Scientific name	Common name	Local names (influenced by Telegu, Tamil and Hindi etymology) and their meaning		Remarks
Superorder: Selachimorpha SQUALIFORMES: Squalidae and Centrophoridae	Shark	Badmash	Rascal	Overall term used to refer to 'sharks'
<i>Centrophorus</i> spp. and <i>Squalus</i> spp.	Deepwater sharks: gulper sharks	Oil macchi or bandar badmash	Macchi – fish (Hindi); Bandar – monkey (Hindi) – named because of its behaviour where once the shark is removed from the hook, it 'jumps' or thrashes around like a monkey	NA
ORECTOLOBIFORMES: Stegostomatidae <i>Stegostoma tigrinum</i>	Zebra shark	Tiger shark or buddhu badmash	Buddhu – fool (Hindi)	Fishers sometimes mistake it for a tiger shark and thus perceive it as a banned species
ORECTOLOBIFORMES: Ginglymostomatidae <i>Nebrius ferrugineus</i>	Tawny nurse shark	Buddhu or baloo badmash	Buddhu – fool (Hindi); Baloo – sand (Urdu) – named because of its sandy/coarse skin	Has a low market value due to its tough skin and meat
ORECTOLOBIFORMES: Rhinodontidae <i>Rhincodon typus</i>	Whale shark	Whale shark or tiger shark	NA	Fishers and traders mistook this species for tiger sharks or whales and perceived it as a banned species; few respondents were aware of it being a whale shark; protected under the WLPA
CARCHARHINIFORMES: Carcharhinidae <i>Rhizoprionodon acutus</i> , <i>Carcharhinus macloiti</i> , <i>Paragaleus randalli</i> , juvenile of some larger shark species such as juvenile <i>Carcharhinus brevipinna</i>	Milk shark, hardnose shark, slender weasel shark, spinner shark	Paal sura or dudh badmash	Paal sura – milk (Tamil); dudh – milk (Hindi)	All are perceived to be milk sharks and believed to be good for pregnant and lactating women
<i>Galeocerdo cuvier</i> CARCHARHINIFORMES: Sphyrnidae <i>Sphyrna lewini</i>	Tiger shark Scalloped hammerhead shark	Tiger shark Ravan badmash or achani badmash	NA Ravan – Indian mythological character with several heads; achani (Tamil) – iron rod which helps to balance the bullock cartwheel	Perceived as a banned species Juveniles of this species are in high demand as their consumption is believed to give exceptional strength
Superorder: Batoidea	Stingray	Shankar	Person in Indian mythology which resembles the ear of an elephant	Overall term used to refer to 'rays'
RHINOPRISTIFORMES: Glaucostegidae, Family Pristidae	Pristidae, Rhinidae, Rhinobatidae Sawfishes	Ari macchi	Ari (Tamil) – something that cuts; macchi – fish (Hindi)	Perceived as a banned species. Protected under WLPA
Family Rhinobatidae, Glaucostegidae and Rhinidae <i>Rhina ancylostoma</i>	Guitarfishes, Giant guitarfishes and wedgefishes Bowmouth guitarfish	Balua macchi Paper balua	Balua – shoal and sand (Hindi); macchi – fish (Hindi) Named due to the lightness of its flesh and fins; balua – shoal and sand (Hindi)	Perceived to be banned. Only <i>Rhynchobatus djiddensis</i> * is protected under WLPA Perceived to be banned
MYLIOBATIFORMES: Dasyatidae <i>Himantura leoparda</i> , <i>Himantura tutul</i> , <i>Himantura uarnak</i> , <i>Himantura undulata</i>	Leopard whiplay, fine spotted whiplay, coach whiplay, honeycomb whiplay	Tiger shankar	Named due to the spots and patterns on their body	NA
<i>Taeniurops meyeri</i>	Blotched fantail ray	Paani shankar	Paani – water – named because it has very high-water content and no meat, rendering it inedible	Discarded as it is not consumed
MYLIOBATIFORMES: Mobulidae, Myliobatidae Family Myliobatidae	Eagle rays	Chidiya shankar or bahadur macchi	Chidiya – bird (Hindi) – because it flies above water; bahadur – brave (Hindi); macchi – fish (Hindi)	Known to have grey meat, so are less favourable to consume
Family Mobulidae	Manta and devil rays	Hathi shankar or chidiya shankar or bahadur macchi	Hathi – elephant (Hindi) – because they are caught when found in aggregations which is why they will weight tonnes and be very heavy for the boat; chidiya – bird (Hindi) – because it flies above water; bahadur – brave (Hindi); macchi – fish (Hindi); Mobulid gill plates are called 'phool' (flower in Hindi).	Known to have black meat, so are less favourable to consume

Respondents reported declines in sawfish (family Pristidae) (n = 36, 41.37%; traders = 6) due to overfishing in the 1990 s. All fishers and traders reported that stingrays (pink whiplay (*Pateobatis fai*), maskrays (*Neotrygon* spp.), and whiplays (*Himantura* spp.) are still abundant both in coastal and offshore areas. Fishers also observed offshore aggregations of cownose rays (family Rhinopteridae) (n = 3, 3.44%) and mobulids (family Mobulidae) (n = 12, 13.79%) and frequently sighted

individuals of juvenile giant guitarfishes (*Glaucostegus* spp.) in shallow nearshore areas (n = 73, 83.90%). However, they commented on mobulid declines at Ross Island (fishers = 11, 12.64%; traders = 3) due to overfishing of aggregations within three years. Fishers remarked on the rarity of encountering wedgefish (*Rhynchobatus* spp.), clubnose guitarfish, bowmouth guitarfish, and eagle rays (family Myliobatidae) (n = 8, 9.19%), but did not know whether it was due to overfishing or if

their populations were small, and that they were rare species.

3.4. Awareness and perceptions regarding regulations

All fishers were aware of prohibited areas for fishing but did not have clarity on the demarcations of protected areas. Traders and fishers in South Andamans (fishers = 31, 35.63%; traders = 8) were aware of the yearly 45-day seasonal shark fishing ban from 15th April to 30th May. However, they were not aware of the fishing gears it was applicable to (pelagic longlines and trawl nets).

Fishers in North and Middle Andaman incorrectly believed that both targeted fishing and retaining bycatch of all sharks was banned ($n = 29$, 33.33%), whereas fishers in South Andaman incorrectly believed that fishing for mobulids was banned ($n = 11$, 12.64%). All fishers and traders were aware that sawfishes and whale sharks were protected and incorrectly believed that tiger sharks, and all species of rhino rays (giant guitarfishes (family Glaucoptegidae), guitarfishes (family Rhinobatidae) and wedgefishes (family Rhinidae)), were also protected (Table 1) due to the posters displayed in South Andamans of protected species under the WLPAs, along with being informed by other stakeholders across the Island.

Four traders commented about the export ban for jaws, cartilage, and fins, stating that fins are currently sold in black markets, but mentioned there were no bans on ray products (other than rhino rays), liver oil or gill plates. One trader remarked on the non-selective nature of fishing gears and that the WLPAs regulation was therefore ineffective.

When asked who informs them about regulations, the combination of answers varied from posters of species protected under the WLPAs (fishers = 18, 20.68%; traders = 4), the Forest Department (fishers = 41, 47.12%; traders = 1), Fisheries Department (fishers = 36, 1.37%), coastguard at sea (fishers = 32, 36.78%), or when other fishers were apprehended (fishers = 8, 9.19%), or from other traders on peninsular India (traders = 2).

3.5. Trade and product utilization

3.5.1. Profitability of fishing sharks and rays

Almost half of fishers ($n = 43$, 49.42%) noted the difficulty of relying on profits from shark fishing due to the declines in shark populations, expensive fishing gear, onboard storage and transport facilities, along with the fishing technique and effort required. Fishers ($n = 51$, 58.62%) mentioned that they did not prefer to fish for rays since their slime made them slippery and spoiled other fish in storage, and their relatively fast decomposition rate. A few fishers ($n = 11$, 12.64%) in Diglipur mentioned cutting the barb and releasing large live rays as they spoil other fish. However, respondents (fishers = 10, 11.49%; traders = 6) from South Andaman, specifically Junglighat, who targeted and profited from the large-scale shark and ray fishery, answered that they had the equipment, labour, accessibility to cold storage and processing units, transport and export facilities, and prominent linkages to markets outside the Andamans, to profit from the shark and ray fishery. They also had facilities to fish in pelagic offshore areas, including Nicobar Islands which are not accessible to other fishing vessels, as sharks have declined around waters of the Andaman Islands. Further, two traders mentioned that large quantities of sharks and rays could be sold for a higher price on peninsular India and international markets. However, trading sharks is relatively difficult due to the influence of regulations focused on sharks on peninsular India, permits required for their trade, coupled with their declining populations in nearshore areas (traders = 2). According to respondents, it was relatively easier to trade rays, due to their abundance, relatively few regulations, and the increased demand for their products (fresh and dried meat as well as mobulid gill plates). However, two traders also mentioned unreliable access to electricity, transportation costs to peninsular India, and trade permits reduce their profits for both sharks and rays.

3.5.2. Shark and ray meat

All fishers preferred consuming 'white' fish (demersal and reef fish) over sharks and stingrays (family Dasyatidae) due to their taste and texture. Non-preference for sharks and rays stemmed from the smell, tough skin, and difficulty of cooking. However, with the nearshore decline in 'white' fish, they consumed sharks and stingrays if incidentally caught as an accessible and cheap source of protein ($n = 38$, 43.67%). Twelve fishers (13.79%) also mentioned that the Bengali and Tamil communities on the islands consume and buy sharks and stingrays relatively more than other communities.

In North and Middle Andaman, 11 fishers (12.64%) stated that sharks and rays caught as bycatch were either consumed, sold as fresh or dried meat pieces per kg, or as fresh whole individuals at local markets. This was based on the species, quantity, and quality of catch, need for protein, and the distance needed to travel to the market to sell their catch. Whole fresh shark prices ranged from 30 INR/individual of < 1 m total length (TL) to 100 INR/individual of > 1 m TL (0.40–1.34 USD) ($n = 11$, 12.64%). Whole fresh rays were sold for 100–150 INR/individual (1.34–2.01 USD) of < 1 m disc width (DW), and 150 INR/individual (2.01 USD) for larger individuals of > 1 m DW. Fresh shark and ray meat pieces were sold for 30–40 INR/kg (0.40–0.54 USD). Fishers ($n = 8$, 9.19%) mentioned that traders sometimes collect dried shark and ray meat for 50–80 INR/kg (0.67–1.07) from North and Middle Andaman while transporting reef fish to sell in the local markets of Junglighat.

Uniformly coloured rays were preferred for consumption over rays with patterns on their bodies (*Himantura* spp.) ($n = 28$, 32.18%) as they were considered 'clean'. Mobulid and eagle ray meat were noted to be black or grey and were not consumed as they were considered to be 'spoil' meat and of poor quality. On the other hand, all fishers discarded the blotched fantail ray (*Taeniurops meyeri*) due to its high-water content and little meat. Fishers ($n = 43$, 49.42%) from Little Andaman, North and Middle Andaman did not prefer to consume or catch rhino rays and would release them live if incidentally caught due to the tough skin, and meat which was hard to cook and consume. However, 12.64% of fishers ($n = 11$) reported keeping the fins and discarding the body, waiting for traders to collect and transport fins to Port Blair.

In South Andaman, fishers sold whole fresh sharks for 40–100 INR/kg (0.54–1.34 USD) and whole fresh rays to traders for 30–80 INR/kg (0.40–1.07 USD) based on size, weight, and species. Small sized sharks were immediately packed in ice and transported to Chennai in the state of Tamil Nadu, where they were sold, or further transported to Kerala (fishers = 11, 12.64%; traders = 4). Large sharks and rays were frozen and stored at a processing unit in South Andaman. The internal organs of stingrays were often discarded at the fish-landing site to reduce decomposition and the smell before transportation to the processing unit. Depending on the demand, two traders mentioned selling whole frozen large sharks for 100–200 INR/kg (1.34–2.68 USD) and whole frozen rays for 100–150 INR/kg (1.34–2.01 USD) if sold in bulk at a minimum order of 10 tonnes. Large sharks were transported to Chennai by flight, after which they were exported internationally (fishers = 9, 10.34%; traders = 3) (Fig. 3).

Respondents (fishers = 21, 24.13%; traders = 5) stated that juvenile scalloped hammerhead sharks were perceived to give exceptional strength when consumed and were more expensive (200 INR/kg (2.68 USD) for 1 m TL), whereas 'milk sharks' (*Rhizoprionodon acutus* and sharks < 1 m TL, Table 1), were believed to be good for pregnant and lactating women and were cheaper (40 INR/kg upwards (0.53 USD)) (fishers = 24, 27.58%; trader = 2). Both these shark groups were noted to be in high demand on peninsular India. Contrastingly, fishers believed that the meat of larger species was tough (especially bull shark (*Carcharhinus leucas*) and pigeye shark (*C. amboinensis*)) and therefore these were exported internationally from Chennai. Further, demersal sharks (bamboo shark (*Chiloscyllium* spp.) and tawny nurse shark (*Nebrius ferugineus*)) were in low demand and often discarded throughout the islands due to their tough skin and meat (fishers = 61, 70.11%; trader =

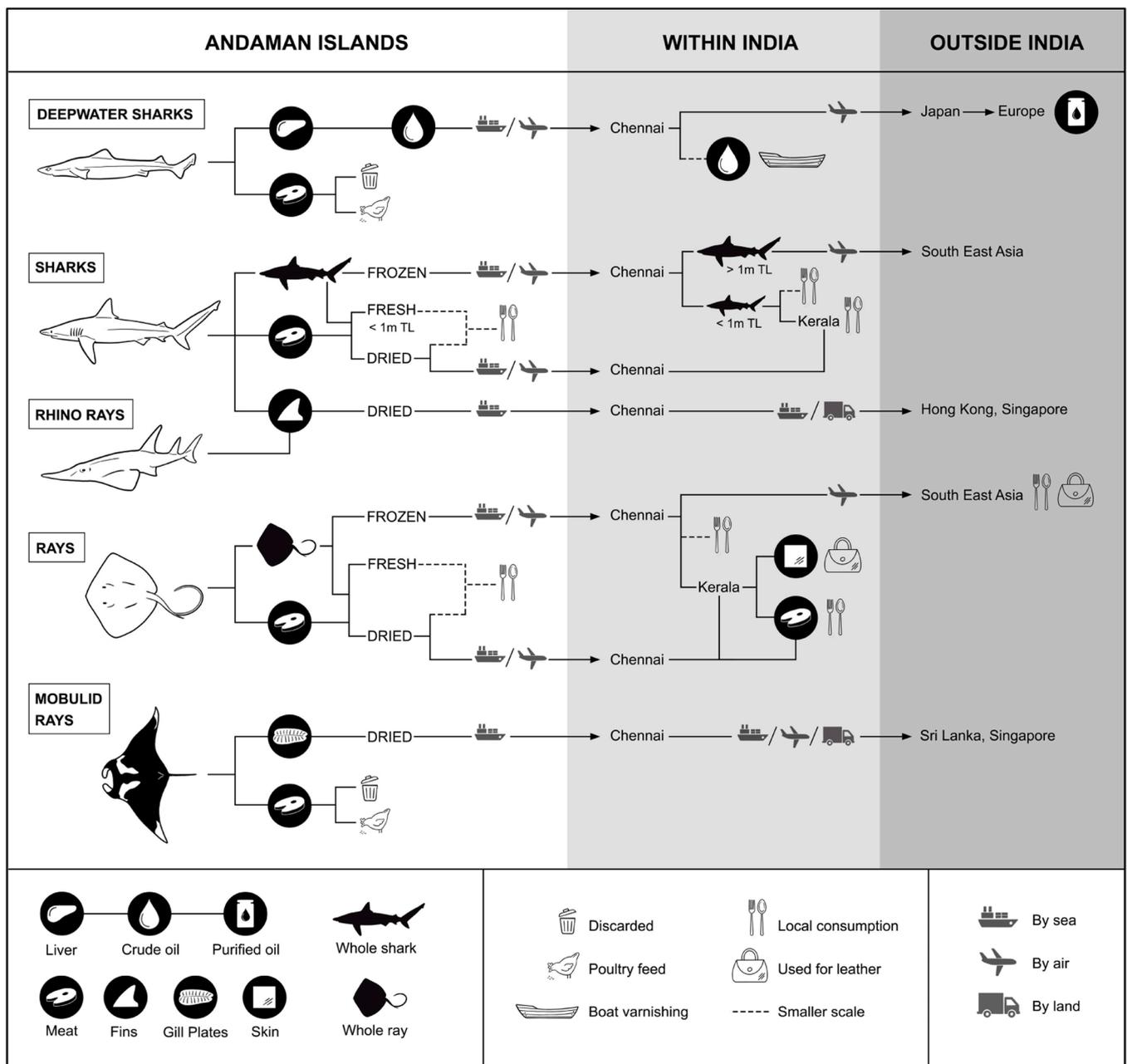


Fig. 3. Overall shark and ray utilization and trade routes according to fishers and traders.

1) making them difficult to cook and eat. However, two fishers in Middle Andaman stated that their village had started consuming tawny nurse sharks in the past five years and called them ‘shark biscuits’ due to the texture while consuming the shark.

Seven traders also mentioned a rising demand for ray meat from peninsular India during the past ten years. One trader commented on investing in four fibreglass boats using bottom gill nets to target rays to supply this demand. Another trader mentioned starting a company in 2015 near Burmanallah where sharks and rays are salted, dried and exported to Kerala, due to the increasing demand for dry meat of rays. Three fishers (3.44%) mentioned that stingray skin (family Dasyatidae) is processed both domestically and internationally for leather.

3.5.2. Shark and ray fins

Prior to the tsunami and until 2012, a trader from Port Blair would collect all shark fins from fishers (n = 78, 89.65%) across the islands. Today, shark fins are priced according to the size of the fins with rhino

ray fins being the most expensive (Table 2). According to four traders, dried fins are exported from Chennai to Singapore, Hong Kong or China (Fig. 3). However, since around 2012, demand has reduced with traders

Table 2

Shark fin prices provided by three traders. Conversion rates 1 USD = 74.58 INR (16 July 2021).

Grade	Fin size from the base to the apex	Price (INR/kg)	Price (USD/kg)	Rhino ray fins (Price/kg)
A	> 40 cm	6000	80.45	8000 INR – 107.26 USD
B	30–39 cm	5000	67.04	7000 INR – 93.85 USD
C	20–29 cm	3000	40.22	5000 INR – 67.04 USD
D	10–19 cm	1800–2000	24.13–26.82	2200 INR – 29.49 USD

stockpiling dried fins as they are non-perishable commodities, waiting for demand from international markets (traders = 2). All fishers and traders were aware of fins being used for shark fin soup. Three traders also mentioned surgical threads made from the 'yield' (fin needles or ceratotrachia from processed shark fins).

3.5.3. *Mobulid gill plates*

While mobulids were discarded in the past in the Andaman Islands, fishers stated that since 2009, they were retained bycatch from gillnets and trawl nets (Junglhat fishers = 12, 13.79%). They also provided additional income to fishers during the monsoon as they could catch aggregations of mobulids in addition to catching baitfish (n = 8, 9.19%). Fishers operating gillnets (n = 5, 5.74%) sold fresh whole mobulids to traders for 60–80 INR/kg (0.80–1.07 USD). The meat was discarded or used for poultry feed while gill plates were dried. The price of dried gill plates varied based on their colour and size, seasons and the catch, ranging between 6000 and 12,000 INR/kg (80.45–160.90 USD) (traders = 2). Dried gill plates were transported to Chennai via ship with shark fins and exported to Sri Lanka and Singapore (Fig. 3). Fishers were not aware of how gill plates were used, with four fishers (4.59%) assuming it was used as a delicacy. Two traders were aware of it being used as a tonic or medicinal purposes.

3.5.4. *Liver oil from deepwater sharks*

Deepwater sharks (*Centrophorus* spp. or *Squalus* spp.) are sold to a processing unit in South Andaman, where the liver is macerated to produce oil. All fishers commented that 20 years ago, they used to sell whole fresh sharks starting from 20 to 30 INR/kg (0.26–0.40 USD) which was profitable for them as they fished at an aggregating site in Ross Island, South Andaman. Currently, deepwater sharks are sold for 150 INR/kg (2.01 USD) (n = 5, 5.74%) as they have to fish further away. Although with the costs of bait, ice, fuel and transport, they profit only if the selling price is 170–200 INR/kg (2.27–2.68 USD). All fishers from Burmanallah (n = 7, 8.04%) stated that their main income comes from fishing for tuna and deepwater sharks depending on the seasons, where deepwater sharks are fished whenever the weather permits as they travel to offshore fishing grounds. Two traders mentioned that the final product is exported to Europe, where it is used in pharmaceuticals, but since India does not meet the European Union standards, it is first exported to Japan, where it is further purified to be colourless and odourless. They also mentioned it is used for cosmetics. Fishers (n = 7, 8.04%) and one trader mentioned the use of crude oil to varnish furniture and boats.

3.6. *Other products*

Two traders mentioned selling cartilage and jaws in 2000 to international markets, with the tiger shark having the most profitable jaw due to its size, costing up to 10,000 INR/kg (134.08 USD).

4. Discussion

This study furthers our understanding of the utilization and trade characteristics of sharks, rays, and their products in India with new insights from the Andaman Islands. Our results provide essential information regarding the drivers of the fisheries and highlight that population declines of several shark and ray species have been reported by fishers, particularly at fished aggregation sites. Yet, a targeted shark fishery persists while a targeted ray fishery is quickly expanding for local consumption as well as international trade in products. Considering the status of many shark and ray populations, this raises concerns about the sustainability of these practices. These results further reveal the complexities and nuances that constitute the drivers of shark and ray fisheries, highlighting the underpinning challenges for conservation. Considering the increasing dependency of coastal communities on the Islands on shark and ray products as a source of protein as well as

economic well-being, the development of strategic domestic legislative measures to manage fisheries and trade are urgently needed along with community-driven initiatives to ensure their effective implementation.

4.1. *Local consumption of sharks and rays*

According to past literature from the Islands, there was historically no local demand for shark and ray meat [46], with consumption of teleost fish preferred over these species. However, over the last two decades, the rise in large-scale export-oriented fisheries led to local shortages of seafood as well as increased prices at local markets [47]. With these fluctuations in markets as well as seasonal abundance of species, small-scale fishers adapted by utilising different fishing gears and altering their target catch. Similar adaptive fisher behaviors have been observed in Zanzibar, Tanzania, where engaging in multiple fisheries has provided social and economic resilience to islanders affected by temporal changes in climate and available catch [48]. Indeed, according to fishers, shortages in the availability of protein sources such as reef fish led to the consumption of sharks and rays on the Islands when caught as bycatch. This rise in meat consumption and its marketability in the Andaman Islands was compounded by the influx of communities from peninsular India who traditionally consumed sharks and rays (especially those from West Bengal and Tamil Nadu). This demand from peninsular India for various shark and ray products also contributes to additional income for small-scale fishers across the Islands who sell sharks and rays in various forms to traders. However, while there is a clear emerging trend in local consumption and demand, it appears that the trade and export of shark and ray products is the key driver behind their exploitation with local consumption still at a much smaller scale on the Andaman Islands. National conservation policies do not currently apply to domestic trade in shark and ray products. This hinders our ability to monitor the species, quantities, and products being traded between Indian states. Such data are crucial to determine how trade might potentially be impacting species and additional research on the domestic shark and ray fishing and trade is warranted.

4.1.1. *Trade and supply chain*

Whole sharks and rays were exported to supply the rising demand for meat on peninsular India, mostly in Kerala and Tamil Nadu, and international markets. Small-sized sharks were preferred along with juvenile hammerhead sharks on peninsular India due to softness of the meat and various cultural beliefs. This preference has been observed in several coastal communities worldwide including in many countries across the Indian Ocean [12] including Madagascar [49], the United Arab Emirates (UAE) [39], and the northwest region of India [35]. It is often attributed to the lower urea concentrations and mercury content of the flesh and it being easier to process than larger sharks [12]. However, in the UAE, demand and consumption has also been influenced with the increasing migrant population from India [39]. It is clear that to inform interventions aimed at changing consumer behaviour on the Andaman Islands, a comprehensive assessment of the culture and traditions behind the local consumer and its market characteristics is required. Yet, addressing consumption alone will not mitigate overfishing. Indeed, similarly to what was reported from the UAE [39], traders here also indicated that the trade in shark and ray meat is increasingly profitable since large quantities of meat could be sold with higher profit margins. In a country like India, where many coastal communities depend on fisheries and trade [50], alternative livelihood options will need to be evaluated and proposed to determine how best to reduce the dependence on shark and ray fisheries and trade.

In addition to providing meat as a source of protein, shark and ray fisheries on the Islands feed the international demand of products such as fins, gill plates, and liver oil. In fact, the high demand for shark fins brought fishers and traders from different parts of India to the Andaman Islands. Between 1970 and the mid-2000 s, fins represented the most profitable shark and ray product, exclusively destined for international

markets. Traders noted that rhino ray fins were considered to be high quality and thus most expensive. However, in the past 5–6 years, the demand decreased with diminishing profits to the traders. Traders attributed this fall in demand to regulations placed on shark fisheries and trade in India [24], including the short lived 2001 blanket ban on shark and ray fishing and trade, 2013 ‘fins naturally attached’ policy, and 2015 ‘Prohibition on export of shark fins of all species of shark’ [24], along with an overall reduction in international demand. This fall in demand has also been attributed to the economic crisis and a reduction in demand from Hong Kong [39,51]. Yet, several traders also mentioned that attempting to prohibit the trade in fins in 2015 led to the creation of an underground business, a black market which is now will be even more difficult to monitor [51]. Other traders highlighted that they continue to stockpile non-perishable dried shark fins, including those from rhino rays, as they will eventually provide an additional income when the export ban is lifted or if they are traded through black markets. It is clear that the blanket bans on the export of shark fins in India have not been efficient at curbing the trade of shark fins. They may even have limited the potential positive impacts of shark and ray listings on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (e.g., hammerhead sharks and mobulid rays) whereby parties should issue permits for the trade in Appendix II listed species and develop Non-Detrimental Findings to ensure trade is not detrimental to species in the wild [52]. Such listings on international treaties have the potential to regulate trade of threatened species while allowing data to be collated on the volumes traded and destinations. Instead, an illegal trade network is now operating across India which hinders the management and conservation of these species. Within the current legislative framework, it is likely that measures such as harvest limits or spatial closures (e.g., in critical habitats) would be more efficient at curbing overfishing of threatened shark and ray species.

4.1.2. Trends in populations and markets

Respondents described declines in shark populations across the Andaman Islands and attributed these to various factors, including the export-driven shark fishery during the mid-1990 s coinciding with the high market for shark fins. Similar notable breakpoints of declines in shark catches and landings have been observed worldwide in the 1990 s and are hypothesised to coincide with the increased retention of sharks to meet an emerging market demand for fins [2]. Communities from West Bengal, who were the major shark players in the Andaman Islands, also exited the shark fishery in the late-1990 s due to dwindling catches and low economic returns [53]. Over time, fishers adapted to these changes in stocks by fishing in deeper and offshore areas, including that of the Nicobar Islands. In fact, the Nicobar Islands are governed by traditional marine management systems [54], and therefore are likely to harbour populations of at least coastal shark and ray species that remain relatively healthy. Several studies globally have shown that expanding fisheries to offshore areas signal overexploitation [39,55–57], with fishers intensifying their effort to capture the same quantities of sharks.

Moreover, respondents operating longlines noted the depletions of pelagic and deepwater shark populations. Declines of oceanic shark populations have been documented globally due to the twofold increase in fishing with longlines, along with lack of regulatory measures and significant fishing effort expansion [2,58]. Similarly, deepwater sharks (*Centrophorus* spp.) are known to be extremely susceptible to fisheries [59] and yet continue to be exploited for the production of liver oil. Steep population declines of deepwater sharks have been observed on the southwest coast of India where population reductions greater than 99% have been reported [16,60] and in the Maldives after 20 years of targeted fisheries [61]. Our results highlight potentially similar declines in oceanic and deepwater shark populations and are a cause of concern. This is particularly worrisome since the Government of India perceives fisheries around the Andaman Islands as a resource to be exploited, is encouraging the opening of existing marine protected areas, and the development of the fishing sector in the Islands [29,62]. This

development push is likely due to the increasing demand for marine resources on peninsular India, where many fisheries stocks have been overexploited [63, 64]. Several studies [65,66] have reported declining shark landings in India over the past two decades despite increasing fishing effort. The development of the fisheries in the Andaman Islands will exert more pressure on the declining stocks due to habitat loss of vulnerable species and overfishing. It will also threaten the livelihoods of the local communities who depend on the Islands coastal and marine resources. Therefore, these developments will not be sustainable in the long term, unless regulations, especially for fishing and export are established. As a first step, identifying critical habitats such as nursery and breeding grounds of threatened species would support decision making by providing key information on sites that require protection for the long-term survival of species. For example, several coastal areas in the Andaman Islands are likely nursery areas for the Critically Endangered giant guitarfish (*Glaucostegus typus*) [67]. Recognizing such habitats and proposing temporal or spatial protection through policy change or through the involvement of coastal communities is key to ensuring the conservation of species and reducing long term impacts on coastal communities.

Our results also highlight that overfishing of sharks and other valuable teleost fish species across India has led to an increase in fishing for rays to supply a rising meat market. This has also been observed in The Gambia, West Africa, where a ray fishery developed in response to declining shark populations [68]. Indeed, a targeted stingray fishery is now developing on the Islands to supply the high demand for meat on peninsular India. This trade remains profitable due to the perceived local abundance and limited management measures in place for fishing and trade of rays across the Andaman Islands. This fishery has also led to a rise in regional and international trade of the skin of rays (*Dasyatidae* family) as a byproduct. This trend is alarming as there is growing recognition globally that rays have a higher extinction risk than sharks with 36% of assessed species considered threatened with extinction according to the IUCN Red List [1]. Drastic declines in stingray (*Dasyatidae*) populations have been recorded from the west [4,5,69] and east coast of India [66]. If these ray fisheries in the Andaman Islands continue to grow while remaining unmonitored and unregulated, there is a risk of similar steep population declines within a short timeframe. Much of the policies currently in place in India and around the world have largely focused on sharks. However, there is a clear need to shift the conservation narrative to ensure rays are also receiving the attention needed before population declines become irreversible.

Of immediate concern on the Andaman Islands are mobulid rays which were reportedly retained in tuna fisheries, with multiple species or aggregations landed in a single haul. Their schooling behaviour [70], and the fishing at aggregation sites, has resulted in steep population declines, corroborated by fishers, who increase their catch to gain profits, and traders who profit from the sale of gill plates. Mobulids are unable to withstand high rates of fishing due to their conservative life history characteristics [71,72]. This emphasises the need for the urgent development of fisheries management measures as well as the implementation of trade regulations such as CITES listings. Domestic regulations should incorporate scientifically based catch and trade limits, spatial fishing bans at aggregation sites, and live release incentives. Live release programs have been successful in Pakistan, where fishers have been trained to safely release megafauna, including mobulids from gillnet fisheries [73]. Lastly, establishing monitoring schemes for catches, landings, and trade will provide a more accurate representation of the fisheries allowing robust stock assessments to assess the regional population status and trends.

4.1.3. Perceptions and policy implications

Fishers and traders were able to distinguish between and recognize several species of sharks and rays, with species validated through pictures, allowing us to gather some species-specific information. Fishers believed that fishing for all species of rhino rays was banned, due to

species misidentification with the whitespotted wedgefish (*Rhynchobatus djiddensis*). This was due to posters listing the 10 shark and ray species, including *R. djiddensis*, protected under the WLPA in South Andaman. While fishers noted this rhino ray protection, some landings of giant guitarfishes and wedgefishes were observed at Junglighat (<15 individuals) [24]. However, fins of many more rhino rays individuals (>50) were visually confirmed [44] and regularly recorded drying between the months of December and February coinciding with operational shark and ray fisheries (pelagic longline and trawl nets) (Tyabji, unpub. data). On the other hand, *G. cuvier* was perceived to be banned due to confusions with *R. typus*. The belief that this species was banned could explain why it has not been encountered in landings for over 20 years [23,74]. This false perception leads to an underestimation of the actual magnitude of catches and landings. Further, existing policies which include the total fishing and trading ban of the ten shark and ray species protected under the WLPA is not effective [24]. Amending the WLPA to include science-based policies that are well framed and that consider the socio-economic dimensions of a multi-gear and multi-stakeholder fishery is key. The lack of clarity of existing regulations also leads to conflict between fishers and enforcing agencies, causing negative perceptions towards regulations by stakeholders. These aspects could be addressed by sensitizing communities to the threats faced by sharks and rays. Additionally, engaging stakeholder groups, especially fisher communities, in decision making through interactive sessions would help provide effective solutions to curbing overfishing and regulating trade of sharks and rays. Finally, communicating policy changes through awareness and training programs to create transparency, ensure clear messages are clearly communicated, and improve policy decisions would help reduce conflict between different stakeholders.

4.1.4. Stakeholder dynamics and market influence

Market actors are seen to play a prominent role in connecting fishing communities to seafood export markets, as well as driving local fisheries and livelihoods [53]. These actors often influence not only the development of fisheries but also perceptions. Traders and migrant fishers from peninsular India often lack population baselines for the Islands and compare fisheries to peninsular India. One such example is respondents stating that large (pelagic) sharks are still fished in the Andaman and Nicobar Islands, unlike peninsular India where large sharks are no longer caught. Further, the large-scale export-driven shark and ray fishery could create conflicts between stakeholders for shared resources and reduce revenues for the locals and small-scale fishers, making fisheries economically unsustainable for the islands in the long term. For example, traders and migrant fishers who have the support, network, and resources to fish in offshore areas benefit and profit more than the small-scale fishers, who are at a loss or do not make high profit margins due to limitations in resources. The pressure on shark and ray stocks for short-term economic gains would put the local fishers livelihoods and the ecosystems health at risk. It may be much easier for traders, who take a substantial share of the profits from the trade, to move on to other goods than it would be for the fishers whose livelihoods partially or completely depend on fishing [12]. Existing local fisheries management institutions thus need to be mobilised to enhance engagement and coordination among fishers and traders and facilitate collective action, such as agreed limits on the total number of sharks and rays that can be landed or traded per site within a specific time period. This would help regulate the flow of revenue and profits into the islands, along with conserving fishers livelihoods and managing shark and ray populations for the Islands.

5. Conclusion

The current study provides a crucial and in-depth understanding of the drivers and supply chain of the shark and ray fisheries from the Andaman Islands where shark fisheries began after the international

demand for shark products was at its peak. Currently, despite declining shark and ray populations, there is an expanding and targeted shark and ray fishery which benefits the stakeholders who have the resources to invest in it, while this overfishing negatively impacts the catch of local stakeholders. Further, high quality fins, meat, gill plates, and liver oil are traded internationally and nationally without traceability mechanisms in place. For the export markets, this is often in violation of CITES permitting requirements. There is an urgent need to improve legal frameworks, not only at the export level, but specifically at the local scale to address the domestic situation of declining stocks. This also highlights the need to consider local socio-economic contexts in the development of the fisheries sector. Given the socio-economic importance of these species, it is imperative to understand fisheries characteristics, product utilization and trade, as well as evaluate trade-offs of elasmobranch conservation with safeguarding of livelihoods to ensure effective management of these resources.

Considering that fishing communities on the islands are heterogeneous and require different needs, such legal frameworks should be carefully developed and aimed at inclusivity. These needs could differ due to social governance structures and traditional practices of the different stakeholders. We suggest implementing a sustainable harvest and export limit, while involving local communities in the management of shark and ray resources. This will allow fishers to regulate the fisheries themselves with enforcement agencies within the sustainable harvest limits provided. Better participation in management from individuals at each level of a fishery would help identify and address the variety of issues that may result from sustainably managing these fisheries. While stakeholders are informed about change in regulations, vagueness and misinformation about the laws exists. Better communication regarding these existing regulations is needed, which can be achieved through focus groups and interactive sessions. Finally, we reinforce the need for long-term and fine-scale monitoring of the shark and ray fisheries and trade that can feed into management strategies and can enhance ecological and economical sustainability in the Andaman Islands.

CRediT authorship contribution statement

Zoya Tyabji: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualisation, Project administration, Funding acquisition. **Rima W. Jabado:** Methodology, Validation, Writing – review & editing, Supervision. **Dipani Sutaria:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data is shared within the manuscript.

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