RESEARCH ARTICLE

Local drivers of declining shark fisheries in India

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Abstract This study evaluates local-scale drivers of shark harvests in India, one of the world's largest shark fishing nations. Focusing on key harbours in the states of Gujarat and Maharashtra, which together contribute 54% of India's shark harvest, this study uses a semi-structured survey to examine the practices of shark fishers and traders, their knowledge of shark trade and policy, and perceptions of shark declines. Findings indicate that a domestic market for shark meat is presently the main local driver for harvests rather than the global trade in shark fins. Sharks are mostly non-target catch, landed whole, contributing to the protein needs of coastal communities. Consumer demand is the greatest for small-bodied and juvenile sharks. Perceived steep declines in shark numbers and sizes have had economic impacts on fishers and traders. The unregulated domestic market for shark meat is a key challenge requiring nuanced local approaches that diverge from global shark conservation priorities.

Keywords Conservation policy · Fishing community · Interviews · Management · Trade

INTRODUCTION

Over a quarter of chondrichthyan species (sharks, rays and chimaeras) have an elevated risk of extinction due to threats from overfishing and habitat loss and degradation (Dulvy et al. 2014). Shark and ray populations are

particularly imperilled by poorly regulated fisheries in countries like India (John and Varghese 2009; Davidson et al. 2015). India has ranked amongst the top five global shark- and ray-harvesting nations for several decades, and reported shark harvests and fin export quantities have been steadily declining over the last decade (Dent and Clarke 2015; Kizhakudan et al. 2015). Indeed, an average of 52 640 tonnes of sharks and rays were harvested yearly between 1961 and 2013, with landings peaking at around 75 000 tonnes in 1998 and 2000 and declining to 23 595 tonnes in 2015 (Kizhakudan et al. 2015; CMFRI 2016). Furthermore, from 2000 to 2011, Indian global shark fin exports peaked at 415 tonnes in 2000 and have declined to a yearly average of 185 tonnes since (Dent and Clarke 2015).

Prior to the 1950s, sharks were discarded as bycatch, and shark meat was not considered an important protein source in India except in some poor communities in the state of Kerala (Hanfee 1997; Vannuccini 1999). India's shark fisheries peaked in the 1980s, when a targeted shark fishery developed in Thootur (Tamil Nadu), to supply an increasing demand for fins from southeast Asia (Hanfee 1997). This demand and the resulting trade in shark products became an important source of income for fisher communities belonging to the country's lowest economic classes (Hanfee 1997; De Young 2006). However, even with the mechanization of fisheries leading to increasing fishing effort, teleost and chondrichthyan landings declined steeply by the late 2000s in both onshore and offshore fisheries (Devaraj and Vivekanandan 1999; DeYoung 2006; Raje et al. 2007; Mohamed and Veena 2016). Despite the introduction of certain fisheries management measures at the state level, including seasonal trawl bans, fishing gear restrictions, mesh size specifications, and areas of operation, the organization of Indian

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fisheries remains complicated with limited regulations specific to shark fisheries and overall poorly enforced and unregulated fishing (Bavinck 2001; Kizhakudan et al. 2015; Karnad 2017). In fact, there are no restrictions on landings, except for a few species listed on Schedule I of the Indian Wildlife Act (1972), and these state regulations have repeatedly proved inadequate to protect sharks (Kizhakudan et al. 2015) other than the whale shark (*Rhincodon typus*).

Continuing declines in stocks of teleost fish and sharks could have serious consequences for both shark populations and fishers on the west coast of India, where two-thirds of fishers and 70% of marine fish production originate (De Young 2006). This is especially true since India's marine fisheries support the livelihoods of over 14 million people, with over two million individuals directly engaged in fishing operations (Flewwelling 2000; DAHD 2014). In response to shifts in the species composition and volumes of landings, it is likely that trends in shark fisheries have also been changing so that supply can meet the change in demand of various products such as meat and fins. While several studies have linked the international shark fin trade to increased shark harvests (e.g. Bonfil 1994; Lack and Sant 2011; Dent and Clarke 2015), it remains unclear how this global trade articulates with local drivers of shark overexploitation and whether fins are the primary drivers in Indian shark fisheries.

The sustainability of shark fisheries increasingly relies on creating appropriate, context-specific, and adaptive management approaches that consider the wider implications for the health of marine ecosystems and that target the socio-economic drivers influencing shark fishing at the local scale (Dulvy et al. 2017). With changing characteristics of the shark trade and harvest, it is important to examine what drives shark harvests under current conditions in India as they contribute significantly to the global market. Therefore, this study sought to use fisher and trader knowledge to understand what drives shark fishing at local scale, in large- and small-scale fisheries, within two major shark harvesting sites in India. To gain insight into the domestic trade in shark products, we investigated the behaviour, motivation and perceptions of fishers and shark product traders. Specifically we (1) examined fishing practices and interactions with sharks; (2) identified fisher and trader knowledge of the legal, economic, and trade values of sharks and their byproducts; (3) analysed fisher and trader perceptions about shark catches, while investigating perceived changes in abundance; and (4) recommended conservation actions that are most suited to the current situation along the west coast of India.

MATERIALS AND METHODS

Study area

The study was carried out at two key landing sites, namely Porbandar and Malvan, in the states of Gujarat and Maharashtra, from September 2014 to September 2015 (Fig. 1). These states contributed over 54% of India's shark landings in 2015, and together have some of the most extensive multigear, multispecies fishing operations in the country (CMFRI 2016).

Porbandar is a major centre for trawl, gillnet, longline, and dol net (bag net) fisheries, supporting ~ 3500 full-time fishers, mainly from the *Kharwa* community (GSIDS 2016). It is one of the most important shark and ray landing centres in terms of volumes landed (FSI 2017). These landings may not be sustainable, in that changes in targeted species and use of bycatch have led to fishing down the food chain (Johnson 2001). Historically, the fishing villages along the Porbandar coast had a targeted fishery for whale sharks (*Rhincodon typus*), which is now banned. These fisheries are characterized by large operations with up to 30 people in a boat and several boats working together and operated by the same company. While there are 1584 boat owners registered with the Gujarat Department of Fisheries (2014), in practice, due to a high level of fleet consolidation (Bavinck and Johnson 2008), these effectively constitute a consolidated fishing fleet of nearly one-tenth the strength (D. Johnson pers. comm.).

Malvan is the third largest port in the state of Maharashtra. Fisheries, using gillnets, cast nets, purse seine nets, shore-seines, and small trawlers, provide livelihoods for ~ 4500 full-time fishers, mainly from the *Gabhiti* community (GOI 2012). Malvan's historically significant targeted shark fishery used handlines, with about 100 hooks to a line, with eels, *Loligo* spp., *Arius* spp. and *Sardinella* spp. as bait (Kaikini 1960). Currently, vessels operate with up to 15 persons per boat, fishing mainly along the Ratnagiri and Sindhudurg districts (Karnad et al. 2014).

Survey with fisherfolk

This study uses a mixed methods approach, attempting to sample 25% of independent boat owners in Malvan and 10% in Porbandar. Fishers were stratified based on their affiliation with boat owners. While every attempt was made to achieve an evenly represented sample size, in the absence of clear data regarding ownership and consolidation, the actual representation of the sample is unknown. A semi-structured questionnaire, including pictures of species and modified from Jabado et al. (2015) to suit the local

Fig. 1 Map of the study area indicating the location of the study sites, as well as important domestic hubs of trade in shark fins and meat

context, was administered to boat captains and crew (one from a sample of each of the companies) in Porbandar and Malvan in the local language (i.e. Gujarati and Marathi, respectively) (Appendix S1). Fishers were purposively approached at landing sites or local markets. All surveys were carried out one-on-one to avoid influence from other respondents and maintain independence of responses. Each survey took an average of 20–30 min to complete.

The questionnaire had four sections: (a) background information with questions about age, fishing experience, sources of income, and position held on the boat; (b) vessel and fishing gear characteristics including questions about vessel characteristics, seasonality of trips, and target species, (c) shark catch characteristics to ascertain composition of catches with local species names, changes over time, and shark utilization, (d) perceptions and trade knowledge to understand interactions with sharks, opinion on shark conservation, and recommendations for future management.

Interviews with traders and local retailers

Qualitative interviews, with domestic retailers selling at local markets and domestic traders linked to export houses, but not directly involved in exports, were conducted with all known traders involved in the local shark trade at each site. Markets, fish landing sites, and fish trading units, were observed during the first 3 months of the study, to identify key informants in the shark trade and understand the movement of catch from the landing vessel to the different local markets and companies. The final interview protocol

was tailored to the different roles played by individual key informants in the supply chain of shark products. Respondents were interviewed for over an hour and interviews were conducted at each study site until data saturation was reached. Questions focused on the following broad themes: (1) history in the business, experience, and connections with other middlemen in the supply chain, (2) knowledge of shark fisheries, shark species, and perceptions of change in landings, (3) utilization of sharks and their parts, and (4) economics, profitability, and markets. Knowledge of the source (fishing), market, and final destination (consumer location) points for shark products was also assessed.

Ethics

Informed consent was obtained from all respondents for all methods described above. Participants were informed of the objectives of the study, the absence of financial incentives or benefits from participation, the voluntary nature of the information provided, and the strict confidentiality of responses. The identity of respondents, including details such as their names and contact information were not recorded, unless permission was provided.

Data analysis

Data saturation was defined as at least 90% of interviewees providing similar responses. All responses were translated into English, and open ended responses were coded. Open codes were created based on the content of the responses

and in some cases axial coding was used to group responses with similar open codes. The data were analysed for percentages using Rstudio v. 1.0.44 (RStudio Team 2016).

RESULTS

Survey with fisherfolk

A total of 61 fishers ($n = 20$ in Porbandar, $n = 41$ in Malvan) were surveyed. All respondents were male as women are not involved in active fishing but rather in the marketing and trade of fish products. A response rate of 100% was achieved in Porbandar and 80% in Malvan. Details of fishers' characteristics and gear used to capture sharks are provided in Table 1.

Sharks were mainly caught in trawl nets (65% in Porbandar) and gillnets (90% in Malvan) (Table 1). Fishers reported catching sharks both at night and during the day, including occasionally large-bodied sharks (> 1 m total length), as unintentional catch or bycatch. In hook and line fisheries, shark bait used in Porbandar included horse mackerel (*Megalaspis cordyla*) and cuttlefish (*Sepia* sp.), while in Malvan, cuttlefish (Sepiidae; 66%, $n = 27$), catfish

(Ariidae; 51%), eels (Ophichthidae; 49%), mackerels (*Rastrelliger* spp.; 37%) and sea snakes (Hydrophiinae; 10%) were used.

At both sites, whole sharks were auctioned at local markets. In Malvan, sharks were still caught near-shore with 27% of respondents ($n = 11$) reporting < 24 h trips. One respondent from Malvan reported multiday targeted shark fishing as having occurred in the past.

Knowledge and interactions with sharks

All respondents from Porbandar, and 44% of respondents in Malvan, reported that small-bodied sharks (< 1 m total length) were the most commonly caught with only occasional catches of large-bodied sharks (> 1 m total length) (details in Table 2). Across both sites, all fishers identified small-bodied sharks as having a high economic value for local markets. However, three fishers mentioned selling whole large-bodied sharks for Rs 30 000–Rs 50 000 (USD 440–USD 750).

Some species of sharks could not be identified from the drawings made by fishers (Malvani names: *phendas*, *badadi* and *chukaro*). However, all respondents had encountered and were able to identify the whale shark, tiger shark (*Galeocerdo cuvier*), hammerhead sharks

Table 1 Characteristics of fishers interviewed in Malvan and Porbandar during 2014–2015

Respondent characteristics	Malvan (n = 41)	Porbandar (n = 20)
Traditional occupation		
Fishing	100%	45%
Age		
< 30 years	0% of respondents	5% of respondents
30–39 years	18% of respondents	70% of respondents
40–49 years	37% of respondents	25% of respondents
50–59 years	39% of respondents	0% of respondents
60–69 years	4% of respondents	0% of respondents
Average	46.8 years	35.9 years
Range	31–62 years	25–42 years
Experience		
Average	30.9 years	16.5 years
Range	15–55 years	5–28 years
Occupation		
Main	Fishing	Fishing
Alternate	Tourism (10% of respondents)	Involved in farming or daily wage labour during seasonal ban (65% of respondents)
Type of gear (multiple gear may be used by the same individual)		
Gillnet and modified purse seine	90%	35%
Hand line	90%	0.05%
Beach seine	7%	0%
Trawl net	0%	65%

Table 2 Comparison of survey results from respondents at the two study sites, Malvan and Porbandar

Category	Questions	Maharashtra—Malvan	Gujarat—Porbandar
Shark landings	Commonly caught shark groups	Hammerhead (<i>Sphyrnidae</i>) and Spadenose shark (<i>Scoliodon laticaudus</i>) (39%)	Grey sharpnose shark (<i>R. oligolinx</i>), Spadenose shark (<i>S. laticaudus</i>), Bigeye houndshark (<i>Iago omanensis</i>) and Milk shark (<i>R. acutus</i>) (50%)
Fishing patterns	Season of highest catch	Aug–Dec (65%)	May–September (75%)
	Season of lowest catch	Feb–June (65%)	Nov–Feb (75%)
	Time of day to catch sharks	Before 6 am (65%)	Between 6 pm and 6 am (80%)
	Gear that caught sharks	Hook and line (90%)	Gillnet, Hook and line and Trawl
	Bait used for shark fishing	Cuttlefish (31%)	Squid/Cuttlefish (15%)
	Shark product marketing	Shark landed as	Whole animal (100%)
Trade patterns	Sale of fins	Yes—export (98%)	Yes—but did not know details (20%)
	Fins of highest value	Fins with black tips (46%)	Do not know (100%)
	Fins not sold	Small sharks (98%)	Small sharks (20%)
	Sale of meat	Yes—locally (100%)	Yes (100%)
Shark conservation	Perception of shark catch	Decline (98%)	Decline (100%)
	Reason for decline	Overfishing (66%)	Increase in trawling and foreign fishing vessels (100%)
	Conservation plan	Conserve all fish not just sharks (80%)	Don't know (100%)
	Shark conservation measures	Ban targeted shark fishing (17%)	Don't know (100%)

(*Sphyrnidae*) (98% of respondents) and sharks with black markings on their fins as a single category (95%; see Table 3). Of these, 72% identified bull (*C. leucas*) and pigeye (*C. amboinensis*) sharks as the same species. All respondents in Porbandar and 90% of respondents in Malvan were able to identify sawfishes (*Pristidae*) and discussed their steep decline and their rarity in catches over the last 15–20 years. Large-bodied sharks were not commonly encountered by gillnetters in Porbandar ($n = 7$ respondents), since fishers in Porbandar generally used gillnets with small mesh sizes targeting reef fishes or pomfrets, and only 66% of Malvan fishers ($n = 27$) regularly encountered them. Porbandar fishers were aware of a seasonal rise in the catches of sharks, fins with black markings during the summer and monsoon (May to July).

Only respondents from Porbandar reported economic associations with sharks, particularly the lucrative whale shark industry (prior to the 2001 ban on fishing this species). Only the oldest respondent from Malvan reported a cultural association with sharks. He remembered that catching a large shark used to be a rite of manhood for young boys from his village until the introduction of nylon nets and fishing lines which made catching large sharks easier.

Fishers' awareness about shark trade and legislation

Only 20% of respondents in Porbandar knew shark fins were exported compared to 98% ($n = 40$) of respondents in Malvan. No respondent knew the export value of fins. Malvan respondents distinguished large fins (70% of respondents), and fins with black markings (46% of respondents), as fetching higher prices with export agents. While Malvan fishers were unwilling to reveal the exact prices they received for fins, a few mentioned they were aware that shark fin traders “got five to ten times the price they paid fishers for their fins in the export market”. Also, 75% of respondents from Malvan ($n = 31$) stated that prices for shark fins had declined and believed this was caused by a decrease in demand from export markets.

All respondents in Porbandar and 95% of respondents in Malvan knew that catching whale sharks was illegal according to Indian law. In Malvan, 90% ($n = 37$) also incorrectly believed that catching tiger sharks was illegal, and 73% of respondents stated that there were laws against catching all large-bodied sharks (Table 3). Catching small sharks, including the young of any shark, except whale sharks, was not considered illegal. In Porbandar, all respondents were concerned about harsher protection

Table 3 Comparison of the conservation statuses of different species of sharks and rays identified by fishermen in Malvan and Porbandar and their listing on the Indian Wildlife Act, the Convention on International Trade in Endangered Species of Flora and Fauna (CITES), and status according to the IUCN Red List of Threatened Species (CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient. Fishers grouping of taxonomically separate species is apparent in the local names used that also vary between sites surveyed (**P** – in Porbandar; **M** – in Malvan)

Species	Common name	Local names in Gujarati (P) and Marathi (M)	Fisher perceived status	Indian Wildlife Act	CITES	IUCN Red List
Sharks						
<i>Carcharhinus amblyrhynchoides</i>	Graceful shark	NA	Protected as adult	Not listed	–	NT
<i>Carcharhinus amboinensis</i>	Pigeye shark	(P) Patari, (M) Pitori	Protected as adult	Not listed	–	DD
<i>Carcharhinus brevipinna</i>	Spinner shark	NA	Protected as adult	Not listed	–	NT
<i>Carcharhinus leucas</i>	Bull shark	(P) Patari, (M) Pitori	Protected as adult	Not listed	–	NT
<i>Carcharhinus limbatus</i>	Blacktip shark	(M)Kalya Pakatchi Mori	Protected as adult	Not listed	–	NT
<i>Carcharhinus longimanus</i>	Oceanic whitetip shark	(M) Pitori	Protected as adult	Not listed	Appendix II	VU
<i>Carcharhinus sorrah</i>	Spottail shark	(M)Kalya Pakatchi Mori	Protected as adult	Not listed	–	NT
<i>Galeocerdo cuvier</i>	Tiger shark	(M) Waghbeer	Protected as adult	Not listed	–	NT
<i>Glyphis gangeticus</i>	Ganges shark	(M) Pitori	Protected as adult	Protected	–	CR
<i>Rhizoprionodon acutus</i>	Milk shark	(P) kalo magra, (M) Mushi	Not Protected	Not listed	–	LC
<i>Rhizoprionodon oligolinx</i>	Grey sharpnose shark	(P) son magra; (M) son mori	Not Protected	Not listed	–	LC
<i>Scoliodon laticaudus</i>	Spadenose shark	(P) Pani-sandha; (M) Khivad	Not Protected	Not listed	–	NT
<i>Sphyrna lewini</i>	Scalloped hammerhead shark	(P) Jhuliyo; (M) Phiski	Protected as adult	Not listed	Appendix II	EN
<i>Rhincodon typus</i>	Whale shark	(P) Barrel, (M) Bahiri, Devmaasa	Protected	Protected	Appendix II	EN
Rays						
<i>Anoxypristis cuspidata</i>	Narrow sawfish	(P) Karvatwala magra (M) Karvaat Maasa	Protected	Not listed (possibly misidentified as <i>Pristis zijsron</i> in the Act)	Appendix I	EN
<i>Pristis microdon</i> (= <i>Pristis pristis</i>)	Large-tooth sawfish	(P) Karvatwala magra (M) Karvaat Maasa	Protected	Protected	Appendix I	CR

measures if sharks were to be protected but did not know how to avoid the incidental catch of sharks.

Fishers' perceptions about shark conservation

All respondents mentioned declines in shark catches across all gear types, particularly large-bodied species, within the context of fish catch decline since the late 1990s (Table 2). They were particularly concerned about the decrease in numbers and sizes of hammerhead sharks.

Interviews with traders

A total of eight interviews were conducted with all identified local traders in the shark trade ($n = 6$ in Porbandar and $n = 2$ in Malvan). In Porbandar, two female traders, who sold shark meat at the local market, and four male traders, who supplied the local, national and international market, were interviewed. In Malvan, the two traders interviewed bought sharks directly from the fishers and sold to shark fin traders, who in turn exported the fins.

Trader perceptions and awareness about legislation

Shark traders were unaware of national shark protection measures for any species other than the whale shark. All traders and retailers used indicators, such as sudden price drops or a halt in international exports to identify species-specific regulations. A Malvan trader identified only four species banned for trade—the whale shark, two pristids (likely the largetooth sawfish, *Pristis pristis*, and the narrow sawfish, *Anoxypristis cuspidata*), and the tiger shark (Table 3).

Shark products followed different distribution chains at each site. Traders reported buying whole sharks but selling the fins separately. In Malvan, fins of large sharks were sold to traders at the landing site, while the meat was sold fresh at local markets. Fins went to exporters in Madgao and Mangalore, two large fish trading centres, but thereafter they guessed that final consumers were in China and Japan. None of the traders in Malvan were willing to reveal the sale price of shark fins, although they stated that prices depended on species and size. In Porbandar, large-bodied sharks, particularly with black fin markings and hammerheads, were either frozen whole or with their fins removed for export. The meat was sold fresh locally or salt-dried for consumption mainly on the southwest coast of India and in Assam while remains such as heads were used as fertilizer. Female traders in Porbandar reported that prices for small-bodied shark meat (e.g. *Scoliodon laticaudus*, the spade-nose shark) were increasing in the local market, from Rs 25–30/kg (USD 0.46) 10 years ago to > Rs 80/kg (USD 1.25) today. Large-bodied shark meat sold at > Rs 150/kg

(USD 2.33) and those with black fin markings sold at Rs 170/kg (USD 2.66). Juvenile hammerheads sold at Rs 200/kg (USD 3) and juvenile bull or tiger shark meat fetched Rs 220/kg (USD 3.4). Small sharks were preferred because the meat was considered more tender and edible.

Traders in Porbandar also sourced fins or whole sharks from surrounding fishing harbours, such as Okha and Veraval. They sold the fins to exporters in Veraval, Mumbai, Calicut, and Kochi at a 7–8% commission rate. Thereafter, they believed that fins were exported either to Singapore and Hong Kong, or to Dubai and Abu Dhabi, via Ahmedabad.

Trader perceptions about shark catches and conservation

All traders perceived declines in shark catches. This was exemplified by a statement made by one of the traders from Malvan: “our sharks used to be taken by traders to Kerala. Now the catch has reduced so those traders do not even come anymore”. They reported declines in the sizes of sharks being caught, and noted that consequently fins from small-bodied sharks or juveniles of large-bodied sharks had also become important on the export market. All traders in Porbandar reported difficulties in sourcing large-bodied sharks with large fins and white markings on their fins (likely oceanic whitetip (*C. longimanus*), or silvertip sharks (*C. albimarginatus*) and drastic reductions in the size of hammerhead sharks from > 300 kg animals 15 years ago to 2–3 kg animals today. One claimed that shark catches have declined over 35 years and another that the profitability of the shark trade had declined by 95% over the same period.

All traders also reported declines in the prices of shark fins, which they attributed to a fall in demand. In Porbandar, fins were 90% of the value of the whole shark 10 years ago, 60% of the value 5 years ago, and 20% of the value today. One trader attributed the fall in prices to the loss of high-value species, such as those sharks with white markings on their fins. A decade ago, fins with white markings sold for Rs 8000–Rs 10,000/kg (USD 123–154), and the said trader sold ~ 150 kg of fins per day. He now made only 5% of those profits. With the reduction in demand from the international market, some species, like bull sharks were sold domestically as dried meat. The reported timeline for this decline in price varied between one and two decades.

DISCUSSION

This study reveals that while fins from large-bodied sharks are still being traded, albeit in reduced quantities,

the current shark trade in northwestern India is considerably driven by shark meat consumption. Although the majority of fishers in Porbandar and all of the respondents in Malvan stated that fishing was their primary occupation, they did not depend on income generated from sharks. Instead, sharks were generally bycaught in various fisheries, landed whole, with the domestic market for meat being the most common reason for retaining them. Profits gained from the international market for shark fins were only an additional temporary incentive for fishers to trade in these products, and this market was perceived to have drastically declined in the past 10 years. While it is recognized that the sample size in this study is limited, and that additional interviews with fishers across India would provide a more accurate overview of the fishing and trade situation, data saturation was quickly reached at both sites, and these results provide insight into the considerable declines of shark populations in India. What was clear from all respondents is that legislation has not been effective in protecting India's shark species (except whale sharks) because it does not treat sharks as non-targeted fishery catch, has not kept pace with international efforts, and because fishers and traders remain unaware of conservation policies.

Shark meat as a driver for fisheries

Although the global fin trade has received considerable attention as the main driver of shark harvests (e.g. Clarke et al. 2006), recent studies suggest that anti-finning regulations encouraging the full utilization of carcasses, coupled with demand growth and the decline of valuable fisheries, has led to an expansion in the global shark meat market (Davidson et al. 2015; Dent and Clarke 2015). Indeed, although prices remain low, worldwide shark meat exports appear to have increased by 150% since 2000 (Clarke et al. 2013). Additionally, the traditional consumption of shark meat (especially from small-bodied sharks) amongst coastal communities has been reported from several locations (e.g. Indian Ocean islands: Vannuccini 1999; UK: Friedrich et al. 2014; Madagascar: Cripps et al. 2015; United Arab Emirates (UAE): Jabado et al. 2015; Peru: De la Puente Jeri 2017; Indonesia: Jaiteh et al. 2017) including India where sharks are landed whole and fully utilized (Hanfee 1997; Hausfather 2004; Kizhakudan et al. 2015). Our findings provide evidence for the unregulated and unmonitored domestic market for shark meat as a key challenge for shark conservation. To further understand shark utilization as well as consumption and trade patterns, household and value chain surveys of shark meat and fin trade are warranted.

Declining catches and sizes

Across the study area, respondents indicated that the number and size of sharks captured had declined compared to previous decades. Species like sawfishes, which were easily identified, had practically disappeared from their catches, even though they were commonly caught two decades ago. Direct comparison of abundance is difficult because only anecdotal information on the high abundance of sawfishes in this area exists (e.g. Campbell 1883). However, declines in sawfish populations are widespread and corroborated by surveys elsewhere in the Arabian Sea and its adjacent waters (Dulvy et al. 2014; Moazzam and Osmany 2014; Moore 2015; Jabado et al. 2017). Similarly, shark species with white tipped fins, which likely refers to the oceanic whitetip and silvertip sharks (Raje et al. 2007; Akhilesh et al. 2014), were now rarely encountered. Several fishery dependent surveys in waters of the Arabian Sea have indicated that the abundance of both species has drastically declined (e.g. Varghese et al. 2017). Furthermore, a regional Arabian Sea and adjacent waters IUCN Red List of Threatened Species assessment has evaluated them as Critically Endangered and Endangered, respectively, suggesting population declines between 50 and 80% over the past 50–60 years (Jabado et al. 2017).

Fishers also reported an overall decrease in the number of adult large-bodied sharks concurrent with an increase in the landings of small-bodied sharks and juveniles of large-bodied species. Many shark species have relatively low productivity when compared to teleost fish and are therefore at higher risk from growth overfishing than teleost fish in mixed-species fisheries (Stevens et al. 2000; Lam and Sadovy de Mitcheson 2011). Signs of growth overfishing were evident from responses at both landing sites and this perceived decline is confirmed by previous reports of declining shark landings in India over the past two decades despite increasing fishing effort (Hausfather 2004; Kizhakudan et al. 2015; Jabado et al. 2017) with stocks of blacktip sharks (*Carcharhinus* sp.) having collapsed (Mohamed and Veena 2016) and suggesting that many large-bodied sharks have been fished out (Karnad et al. 2014). The stated timeframe of these declines corresponded to that documented by Hanfee (1997), as having become apparent in the 1990s. It is critical to note that these reported declines of large-bodied sharks are from fisheries where, other than the Gujarat fishery for whale sharks during the 1980s–1990s (Vivekanandan and Zala 1994), no significant targeted shark fishery has existed. This is consistent with trends reported from the northwest Indian Ocean, China, and Madagascar, where landings of large sharks have been reduced with a simultaneous increase in landings of small-bodied animals (McVean et al. 2006; Henderson et al.

2007; Lam and Sadovy de Mitcheson 2011; Jabado et al. 2015). Simultaneously, it is interesting to note that while fishers noted declines in the overall abundance of sharks irrespective of body size, declines in catches of small-bodied sharks was relatively less discussed by respondents, despite scientific evidence that some small-bodied sharks are also currently being overexploited (e.g. *R. oligolinx*: Purushottama et al. 2017) which could be due to their limited ability to distinguish between similar looking small-bodied species. The multiple strands of evidence, in combination with limited shark fishing regulations in India, suggest that the perceptions of shark fishers and traders mirror real trends of declines in shark abundance.

Shifting market forces

According to the traders interviewed, the profitability of the export trade in shark fins has fallen by up to 95% and was attributed to a fall in demand. Fishers from Malvan, who used to receive regular visits from exporters when the fin trade was economically profitable, no longer received these visits. Indeed, falling prices for fins have also been reported in Chinese markets (Eriksson and Clarke 2015) and this has in turn depressed the shark fin trade in important shark fishing nations, like Indonesia (Jaiteh et al. 2017) and possibly India where exports of dried fins have also dropped (Dent and Clarke 2015). Nevertheless, even with the reduced profit margins, fishers still sold fins to traders who then exported them across the country and internationally to generate income.

Yet, fishers remained disconnected from the high profits that characterize the international trade in fins, both in terms of knowledge and capital accumulation, but were well acquainted with local markets for shark meat. The domestic demand for shark meat has increased in the past two decades, at the same time that many teleost fisheries have declined (Mohamed and Veena 2016). Vannuccini (1999) also identified an international market for shark meat harvested from India with 10% of the 580 tonnes of exported shark meat being sent to the United Kingdom in 1996. However, Clarke et al. (2013) do not report India as a key trading partner for any of the top shark meat importers. Indeed, fishers and traders in Porbandar and Malvan were only aware of the domestic demand for shark meat with fresh meat usually marketed and sold at local or within-state markets, while salted meat could be moved across the country. This domestic demand was linked to the preference for small-bodied sharks, known to be mostly used for meat as they generally have lower urea concentrations and are easier to process (Vannuccini 1999). Also, small-bodied sharks were also perceived as increasingly an important source of income for fishers as they could fetch relatively high prices at local markets, compared to the fins of large-

bodied sharks, which benefit fin traders. These shifts in drivers provide crucial evidence that conservation campaigns ought to focus on the social and economic realities of fishers and the increasingly important role of shark meat as a driver of shark exploitation in India.

Shark conservation

A large knowledge gap was identified amongst Indian fishers and shark product traders with regards to species identification, current shark conservation policies, and the implications of trade on shark conservation. Fishers and traders were only able to identify and name the most common shark species landed but were unable to separate between morphologically similar species like in many parts of the world (e.g. Jabado et al. 2015). Except for the whale shark and sawfishes listed in 2001, respondents were unaware of other national protections under the Indian Wildlife Act 1972 (Table 3). Fishers and traders were mostly unaware of existing regulations and operated using rules of thumb, whereby catching large-bodied sharks was likely illegal but the capture of small-bodied sharks was likely legal. Traders also reported using trends, such as a sharp fall in demand or prices of fins as an indicator of regulations on the trade of a species, rather than being made aware of laws themselves. It is clear that the whale shark has benefited from its distinct appearance along with large-scale awareness campaigns that led to a significant reduction in landings (Hanfee 2007). But the misidentification of protected species, such as the Critically Endangered Ganges shark (*Glyphis gangeticus*), renders its legal protection of limited effect. Indeed, the precipitous decline in its abundance and a recent record of the Ganges shark suggests that existing protection mechanisms are not achieving their expected results (e.g. Jabado et al. 2018). For long-term conservation strategies to be effective, campaigns aimed at species identification and directed towards fishers and traders in various locations will be critical to help maintain shark populations and prevent extinctions. This will require a large-scale dedicated campaign to educate fisheries-dependent communities across India.

An overarching policy related to sharks in India is the 'Fins Naturally Attached' (MoEF 2013) to prevent shark finning. But the need for a finning prohibition policy in India is questionable since all interviewed fishers reported landing sharks whole, and anecdotally in most other coastal regions of India (Hanfee 1997; Kizhakudan et al. 2015). Instead, a nuanced policy focused on regulating actual shark bycatch, managing the domestic demand for sharks, and countering incentives to continue overfishing juvenile and small-bodied sharks is likely to be more effective. For instance, fishery-wide regulations on gear usage, seasonal

and temporal restrictions, such as regulating night fishing at times when most sharks are caught, would prove most effective and enforceable (e.g. Schiffman and Hammer-schlag 2016). This is largely because a technological approach to conserving sharks would require greater government oversight in the fisheries, something that has proven difficult so far considering the scale of Indian fisheries (see: Pandav and Choudhury 1999). Indeed, Indigenous bycatch reduction devices have been developed by Indian government agencies, but they are not utilized by fishers and their use is not well enforced (Boopendranath 2012). Instead, seasonal fishery closures based on localized differences in capture patterns, such as the reported seasonal peaks in shark catches from May to August in Porbandar, and August to December in Malvan, could improve shark conservation in these areas. Malvan already has the social capital to institute such regulations through its existing customary fishing management which enforces seasonal and temporal closures and restricts gear use at the scale of groups of villages (Karnad 2017). Providing education and awareness about the conservation of threatened shark species could improve these customary management institutions for shark conservation. Porbandar, where social capital is lower (Johnson 2010), may require a co-management approach, where the government and fishing communities work together to create, monitor, and enforce regulations. In fact, such targeted conservation action might provide the way forward to conserve sharks in mixed-species fisheries. Regular enforcement at local fish markets to prevent the sale of protected species could also be achieved with the cooperation of local government departments, and through the education of local traders. However, this approach would be most effective if the Indian Wildlife Act was revised to include all Endangered and Critically Endangered shark species in Indian waters.

CONCLUSION

This initial evaluation of shark fisheries in northwest India highlights that socio-economic drivers of shark declines may be scale dependent. While there is a need for further studies to compare potential spatial and temporal differences in perceptions and behaviours, our results emphasize that the existing conservation measures are failing to address the drivers of shark fisheries in India. Indeed, the landing of sharks whole, as bycatch to supply an unregulated meat market, with little species-specific or conservation knowledge amongst the key stakeholders in shark fisheries, highlights the complex nature of the drivers affecting shark fisheries in the region. To ensure that fisheries management strategies have a positive impact on shark stocks and their sustainability, we recommend

improving education and awareness about sharks amongst fishers and traders, instituting locally relevant, temporal closures of fisheries, bringing local fish markets under the ambit of species protection enforcement, and focusing scientific and policy attention on key threatened species populations. With multiple lines of evidence pointing to serious reductions in shark species abundance, we stress the importance of immediate actions to regulate fisheries and enhance the efficacy of shark conservation measures in India.

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