

Fins and (Mis)fortunes: Managing shark populations for sustainability and food sovereignty

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ABSTRACT

Sharks are simultaneously a subsistence food and a luxury item. Shark fins are consumed during special occasions among primarily the East Asian elite, whereas shark meat is consumed by many globally, including by fishers and their families. Policies guiding the management of shark fisheries vary globally, with inconsistent protections for sharks across their ranges and insufficient consideration of the multifaceted demands for shark products. Banning shark fishing is a popular management strategy; however, a full ban on shark fishing has the potential to threaten both food security and food sovereignty of small-scale fishing communities. In this paper, we investigate the tension between the subsistence and commercial value of sharks, examining the history and current status of shark fishing practices in Madagascar. From this case study, we analyze how current management strategies contribute to shark conservation and food sovereignty. Ultimately, we argue in favor of a rights-based approach to shark fisheries policy in Madagascar, and in other food insecure nations in the process of evaluating and expanding their shark conservation efforts, that considers (a) the end use of the sharks (e.g. implement policies favoring fishers who land sharks for subsistence), (b) the mode of access fishers use to harvest sharks (e.g. imposing greater restrictions on industrial vessels), and (c) direct and ongoing participation of local fishers in decision-making occurring at all scales of governance. While these suggestions pertain to shark fisheries globally, they are especially pertinent to fisheries-dependent countries with high rates of food insecurity in the Global South.

1. Introduction

In the past few decades, the global shark trade has heightened pressures on shark populations, with estimates of annual mortality from fishing, finning, and discards ranging from 63 to 273 million individuals [1]. Sharks are simultaneously a subsistence food and a luxury item; whereas the meat is consumed by many, including by fishers and their families, nearly globally, the fins fetch a high price and are consumed during special occasions among primarily the East Asian elite [2]. Luxury resources are defined as objects of social performance that tend not to transition to become ‘necessities’ and can maintain their status over a long period of time without falling out of fashion [3]. Luxury food items, often culturally reserved for consumption by particular social groups [4], are associated with big cash incentives for producers, which in the case of sharks are the fishers. For some resources, like sharks, for which luxury and subsistence products come from the same animal, these two mechanisms work in tandem to drive patterns of harvest. Given the multi-faceted drivers of shark fishing, managing shark populations in a way that both addresses human subsistence and overall shark population needs is challenging.

In coastal regions globally, fisheries have the potential to contribute both directly and indirectly to food security and food sovereignty. An

estimated 40% of reported global shark catch comes from shark fishing nations with the lowest Human Development Indices, and nearly one-third of fishing nations categorized as “least developed” are major shark fin exporters [5]. While food security focuses on one’s “access to sufficient, safe and nutritious food to meet [one’s] dietary needs and food preferences for an active and healthy life” [6], food sovereignty underscores how food insecurity and hunger more broadly do not simply stem from scarcity, but instead stem from an inequity in the distribution, control, and access of food-producing and distributing resources [7]. Food sovereignty uses a rights-based framework emphasizing the right of people, especially fishers, small-holding farmers, and pastoralists, not to only control processes of food production and distribution, but also the regulation of these processes [7,8].

A growing literature focused on the nexus of food sovereignty and fisheries argues that fisheries management strategies need to move away from a narrow focus on commercial fisheries yield, towards a strategy that privileges the health and nutrition needs of fishing communities [9–11], the ecological context in which these health needs are met [12, 13], the rights of fishers to help define processes of production, trade and consumption [14], and the representation of fishers in all levels of decision-making [8,12]. Additionally, at its core, a food sovereignty approach to fisheries management helps reconcile the tension between

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small-scale producers and large-scale agri-food companies through centering the needs, values and voices of small-scale producers [11,14,15].

Although there is significant debate concerning the best way to conserve sharks [16], in the past decade there has been an increase in the use of complete or partial bans to manage shark fishing [17] (Fig. 1). A complete ban on shark fishing has the potential to intensify fishing efforts in the exclusive economic zones (EEZ) of poor countries, which may not have adequate resources to patrol their waters, which in turn could threaten both food security and food sovereignty among small-scale domestic fishing communities. The displacement of shark fishing effort relates to Ewers and Rodrigues' [18] concept of reserve "leakages," where destructive resource use practices that would take place inside a restricted area are displaced to unrestricted or unenforced areas. Leakages should be considered at the spatial scale at which resource users operate. While artisanal shark fishers tend to operate within a small perimeter of their home, many industrial shark fishing operations target sharks in large numbers across a wide area. According to one study, a single vessel seized in the Galápagos Marine Reserve, a vast protected area over 130 000 km² in area, had illegally harvested

379 sharks in and around the reserve [19]. Long-ranging industrial fisheries that either target sharks or obtain sharks as bycatch are able to adapt their efforts spatially according to relative strength of monitoring and enforcement effort in each area. These operations have the potential to sequentially exploit and eventually deplete fisheries, often before the relevant national authorities are aware of the problem [20,21]. Illegal, unreported, and unregulated (IUU) fishing is particularly challenging to address and not only contributes to inaccurate estimates of shark populations, but also to inaccurate designation of catch origin [2], thus compounding the difficulty of addressing food sovereignty within shark fisheries management.

In this paper, we investigate the tension between subsistence and commercial values of sharks by examining the history and current status of shark fishing practices in Madagascar and the broader management policies in which these practices are situated. Through a case-study approach, this research investigates the role of shark fishing as a source of household income as well as food. In doing so, we place shark fishing in a historical context both globally and in Madagascar, and explore how conservation policies might be restructured to best serve the rights and needs of fishing communities in Madagascar. We maintain

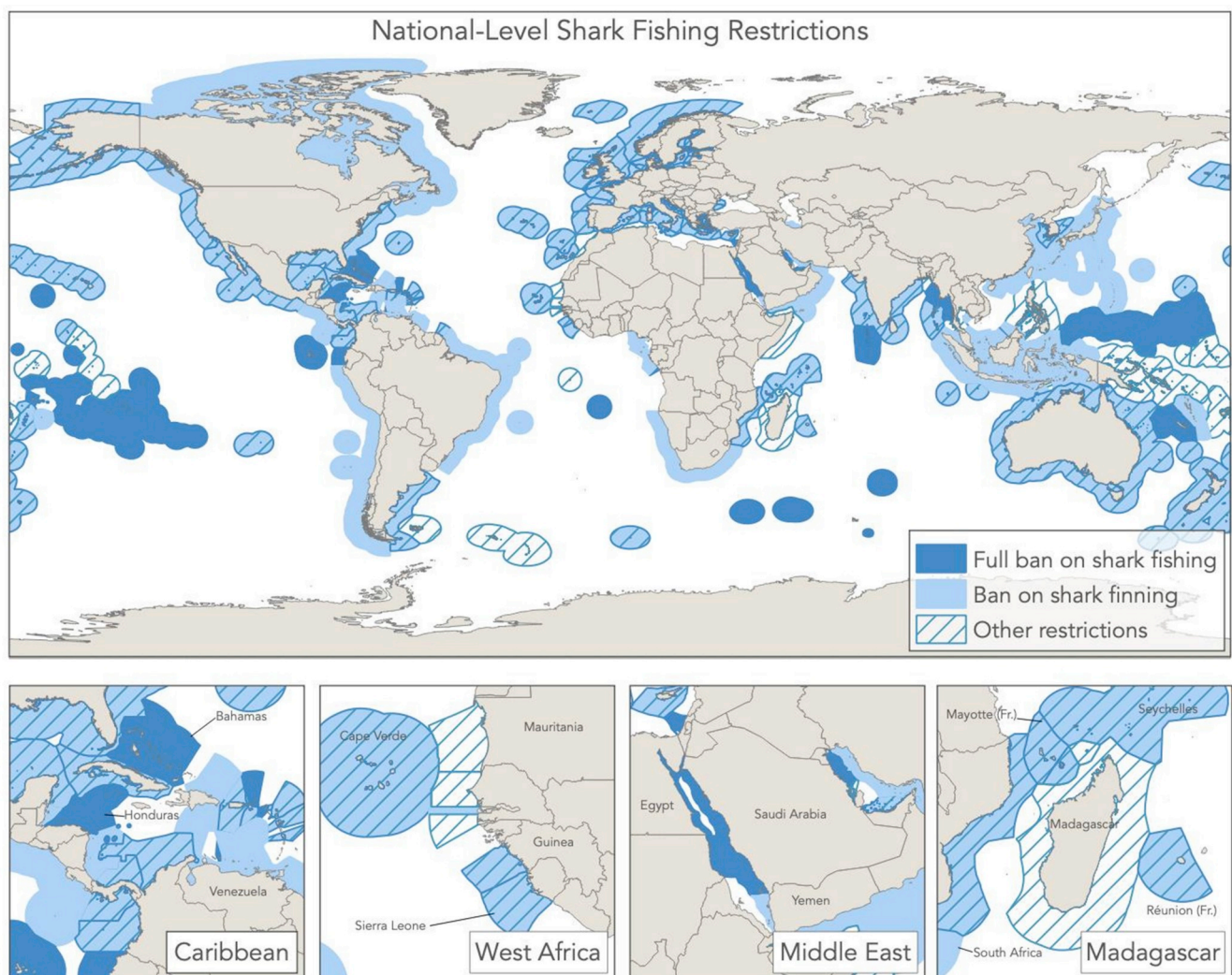


Fig. 1. National-level shark fishing restrictions. Categories indicate each nation's implementation of restrictions on shark fishing in its exclusive economic zone (EEZ). Bans on shark finning reflect restrictions on the practice of harvesting shark fins while discarding the body at sea. Nations that prohibit shark fishing within territorial waters with no or few exceptions are considered to have full bans on shark fishing. Other restrictions indicate a variety of policies that establish limits including seasonal fishery closures, bans on commercial fishing, or gear restrictions, which may exist in addition to or separately from bans on shark finning. Maritime boundaries provided by Flanders Marine Institute (2019). Geodatabase, version 11: <https://doi.org/10.14284/382>. See supplementary material for country-level shark fishing policy data.

that as global funding for marine conservation grows, thus bolstering enforcement efforts in recipient nations [22], fisheries policies should work to balance the needs and values of small-scale fishing communities with broader fisheries development and biodiversity conservation goals. Ultimately, we argue that shark management should engage a nuanced rights-based approach that considers (a) the end use of the sharks (e.g. implement policies favoring fishers who land sharks for subsistence), (b) the mode of access fishers uses to harvest sharks (e.g. imposing greater restrictions on industrial vessels), and (c) direct and ongoing participation of local fishers in decision-making occurring at all scales of governance. While these suggestions pertain to shark fisheries globally, they are especially pertinent to fisheries-dependent countries with high rates of food insecurity in the Global South.

2. Shark trade in context

By weight, shark fins comprise only 2.5%–5.3% of an animal's body weight depending on the species [23], and international markets for meat and fins diverge in their geographic and economic trends. Demand for shark meat products, which rose by 42% by volume between 2000 and 2011, is geographically dispersed, with consumption particularly prevalent in Brazil and Italy [2]. Chinese consumers, on the other hand, are the primary market for fin sales. Between 30 and 50% of the global fin trade is centered in Hong Kong [24], which acts largely as a port of entry for fins destined for various East Asian markets, with 81% of fin exports by volume destined for mainland China [2]. The demand for shark fins in China has increased significantly since the 1980s given socio-economic changes in the country [24] and the spread of southern Chinese cuisine, where shark fin soup is most prevalent, to urban centers throughout the country [25]. The highest quality shark fins are sold in complete sets of all the fins from a single shark. Fins sold in mismatched sets, or fins that have blemishes, rough cuts, or too much meat at the base obtain lower prices. Many of the fins exported from African countries, including Madagascar, sell for low prices due to improper cutting and excessive meat at the base [26].

The FAO Fisheries Department recorded in a 2006 report that global shark catch peaked in 2003 at 880 000 tons, an increase of 17% over the level recorded just a decade earlier [27]. Since then, the trend in shark landings declined by almost 20% in the following decade, however models have demonstrated that the likely cause for this decline is more likely due to population declines than to the implementation of improved management strategies [28]. While fins account for only 7% of globally traded shark products by weight, conservative estimates show that fins account for more than 40% of the market value of shark products [29,30]. Shark fins remain one of the most expensive fish products in the world, and illegal and unreported trade makes an accurate estimate of both their quantity and total value elusive.

The high value of shark products in this lucrative global trade exerts harvest pressure on animals that, because of several key biological features, are easily susceptible to overharvest and subsequent population decline. Sharks invest strongly in juvenile and adult survival rather than fecundity and are particularly prone to the effects of adult and juvenile harvest on population growth rate [31]. Therefore, sharks have a slow replacement rate that is easily exceeded by growing fishing pressure [1]. Sharks also occupy the highest trophic levels in most marine ecosystems, filling generalist niches that exert ecological pressures on many other marine species and maintain community structures [32]. As a result of global shark population decline caused by overexploitation, additional ecosystem-scale effects are predicted, such as trophic cascades resulting in increases in mesopredators and decreased bony fish populations, with potential consequences for both subsistence and commercial fisheries [31]. These cascading effects are particularly problematic for fishing communities that depend mostly or entirely upon marine products for their subsistence and livelihood.

3. Methods

This work is based on research conducted primarily in Madagascar, an island in the Western Indian Ocean and a known hotspot for shark and ray species endemism, species diversity, and functional richness [33,34]. This research draws on a mixture of interviews, survey data, archival research, and participant observation. We conducted a total of 22 semistructured interviews, where pre-determined open-ended questions oriented an otherwise free-flowing conversation about an individual's perspective on shark fishing, finning and management. We interviewed shark fishers, regional and national level government officials in Madagascar, shark fin collectors and exporters, and non-governmental conservation organization personnel. We used snowball sampling to identify these key informants. Seven semistructured interviews took place in 2010, prior to the administration of our survey, and 15 semistructured interviews took place after. In 2011, with the help of a team of 8 Malagasy researchers, we conducted 889 randomized surveys, stratified by gender (431 men, 458 women) across 19 fishing villages. The survey, a standardized questionnaire, focused primarily on fisher demographics, marine harvest practices, uses of marine products, prices fishers obtain for their catch, and the destination of the catch. Shark fishers were a small subset of this larger dataset (see Table 1). Surveys were randomized by estimating the number of houses from Google Earth maps or recent village census data available at district government offices, assigning a number to each house, and then generating a random number table online at stattrek.com (30 numbers/houses for villages over 200 houses, 15 for villages under 200 houses) to select a house. Each survey team, stratified by gender with separate number tables, surveyed the first willing female or male respondent over the age of 18 in each randomly selected house. For the historical portion of our research we conducted archival research at the French National Overseas Archives (Archives Nationale d'Outres Mers) in Aix-en-Provence.

In addition to the interviews, surveys, and archival research, we draw on more than 13 months of participant observation in primarily four fishing villages in three regions of Madagascar including southwestern, northeastern and northwestern Madagascar from 2010 to 2018. Participant observation helped us contextualize the broader cultural and financial importance of shark fishing, and observe numerous fluctuations in shark fin prices (our survey reports 2011 prices) by year and season. Additionally, we were able to observe the slow build of momentum to protect sharks within Madagascar's EEZ, with the establishment of new shark sanctuaries in 2015 and meetings oriented towards revising old and adding new shark conservation legislation.

We obtained data concerning national-level legislation on shark fishing and finning in each country or territory's EEZ (Fig. 1) from a suite of previously existing databases [17,35–38], bolstered by country-specific reports, legal documents and peer-reviewed literature. To highlight key shark management trends globally, we distilled complex and varied national-level shark management policies into several categories: bans on the practice of shark finning; full bans on all shark fishing; and other restrictions on shark fishing, which may exist in addition to or independent of bans on the practice of shark finning.

Table 1

Proportion of fishers who harvest sharks, and the destination of their catch. Results of randomized surveys in 2011, n = total number of respondents as a fraction of total surveyed (431 men, 458 women). Categories are not mutually exclusive.

Region	Number of shark fishers (n)	% Bring catch home	% Give catch to neighbors or friends	% Trade catch for other goods	% Sell catch to exporter
Southwest	21% (95)	86.3	83.2	12.6	100
Northwest	18% (11)	90.9	27.3	0	90.9
Northeast	3% (13)	84.6	7.7	7.7	100

Within these broad categories, the types of bans that countries enact on shark fishing vary substantially. While full bans indicated in Fig. 1 generally have complete moratoria on shark fishing, there are a few exceptions (e.g. Kuwait bans all shark fishing except for two species) [17]. “Other restrictions” in our analysis indicate the presence of one or several kinds of shark fishing restrictions. These include cases such: Mauritania, which has restrictions on gear use for shark fishing and special protections for several additional species [39]; bans on commercial but not subsistence fishing, as in Kiribati and St. Maarten [40]; and seasonal fishery closures, as in Mexico [17]. Some nations, such as Senegal and Curaçao, have taken significant steps towards national-level restrictions on shark fishing and finning, however to date policies have not been ratified and implemented at the national level [35,39]. Similarly, Fig. 1 excludes signatories of international agreements such as CITES unless the country has taken additional steps domestically to restrict shark fishing. For example, Cape Verde not only restricted fishing of certain shark species as per CITES, but additionally implemented a nationwide finning ban [41].

We generally excluded MPAs from our review, as protected areas do not typically constitute nationwide protections on shark populations, as is the case for countries such as Guinea-Bissau [42] and Madagascar [43]. However, a few examples exist where non shark-specific MPAs constitute over 90% of a country's EEZ such as the Dutch Caribbean islands of Bonaire and Saba [44], and we considered these cases to be equivalent to full bans on shark fishing. Similarly, we aimed to nuance the geographic area in which particular shark legislation exists. For example, in American Samoa and Egypt, nationally mandated full shark fishing bans are limited to smaller subsets of each nation's territorial waters (3 and 12 nautical miles from shore respectively), which we mapped accordingly. The European Commission's guidelines indicate that European Union waters include the Canary Islands, the Azores, French Guiana, Mayotte, Reunion, and Guadeloupe and Martinique [45] and thus these territories are subject to the European Union's shark finning ban as well as shark fishery quotas and species restrictions [17]. In instances where disputes between nations exist in defining EEZ boundaries, we selected the least-restrictive policy among the nations claiming overlapping territory or joint regimes to represent in the map. Given the rapidly shifting terrain of shark fishing policy globally, conflicting information found in different sources, and a general dearth of information concerning shark fishing legislation in some countries, some of our designations are incorrect or outdated. Fig. 1, and the database (in supplementary material) were created to show general trends globally.

4. Brief history of shark fishing in Madagascar

Malagasy fishers have responded to a variety of shark product markets across the years. While shark exports from Madagascar started well over 100 years ago [46], there has been a significant narrowing of shark product exports to primarily fins [47]. By the early 20th Century, Madagascar acquired a reputation as a region with an abundance of sharks and other marine organisms, which were of particular interest to the French colonial government [46,48]. In the early 1900s marine products from Madagascar often passed through Zanzibar, a long-established port for all goods leaving southeastern Africa for Asia and beyond [48,49]. Dry shark meat, fins and shark liver oil from Madagascar brought to Zanzibar were eventually exported to Canton and Shanghai, China [49,50]. In addition to Zanzibar, shark fins, oil and meat were also exported to the Mascarene Islands, French territories to the east of Madagascar and a hub for trade between Europe and the East African coast [46,48]. Direct export from Madagascar to East Asia started in the 1920s as more Chinese merchants settled in Madagascar and started purchasing directly from fishers [46]. In the early 1900s, the shark fin trade fluctuated at around 2000–5000 fins/year exported to Zanzibar, China, and Reunion Island [46].

Literature on shark fishing during the colonial period in Madagascar emphasizes the variety of marketable products associated with the shark

including its fins, skin, and liver oil [49,51]. Shark skin leather was used to cover furniture and trunks and was also used in hat-making in the early 20th century [46]. According to interviews conducted in southwestern Madagascar, a small hub of shark liver oil production existed near the village of Tsiandamba in the early 1920s. From this hub, French colonists hired Malagasy fishers from the area to fish shark, harvest the shark livers, and boil the livers to make oil to export to France (pers. comm. village elder Tsiandamba September 13, 2010). In Europe, shark liver oil was used in cosmetics, perfume, skin lighteners, lamps, leather tanning, metallurgy, and as a dietary supplement [26,46,51].

An article circulated in Madagascar in 1961 touted the versatility of shark products and suggested that “all parts of sharks are able to be used ... everything is good except their bite,” encouraging fishermen to make more targeted use of the variety of products potentially derived from sharks [51]. However, by the middle of the 20th Century, the demand for shark liver oil began to decline due to the growing prevalence of replacements including petroleum products, and the export market for fins in the Western Indian Ocean region began to steadily grow [50]. Shark fishing quickly became one of the more lucrative fisheries in the region, reaching a peak in the early 1990s [34,52].

5. Madagascar's shark fishery today

An estimated 123 species of sharks and rays exist in Madagascar's EEZ [47]. The Global Sharks and Rays Initiative (GSRI), a consortium of numerous international governmental and non-governmental conservation organizations, have identified Madagascar as a hotspot for shark conservation and a priority country for more stringent monitoring and enforcement of international laws that protect sharks and rays [53].

Currently in Madagascar, contributions from fisheries to overall food security in coastal regions are threatened by fishery depletion [52,54,55]. Shark harvests in Madagascar's waters occur both due to targeted catch and bycatch from primarily foreign-based industrial fishing companies targeting shrimp, tuna, and other pelagic species [47,56,57]. A 2015 report estimates that sharks account for 10% of total catch from industrial longline tuna and similar fisheries working offshore [47]. In Madagascar “traditional fishing” is legally defined by the Ministry of Fisheries Resources and Conservation as fishers using either non-motorized boats or motorized boats with engines under 25 horsepower. The “artisanal fishing” category includes fishers who use boats with 25–50 horsepower engines, and the “industrial fishing” category is for fishers using boats powered by engines over 50 horsepower.¹

Traditional fishers, whose operations account for 72% of total fish catch in the country [55], harvest sharks in every region of the island, although significant regional variation exists (Table 1). More than 20% of surveyed fishers in the southwest, 18% of fishers in the northwest, and less than 5% in the northeast reported harvesting sharks. While likely indicative of general trends, the smaller survey sample size in the northwest may mean the estimate is conservative. Across all three regions shark catch is both brought home for the family to eat and sold to local or regional collectors. In all three regions surveyed, shark meat is not highly sought after in terms of its taste or consistency, but is nonetheless frequently consumed and serves as an important protein source for many middle and low-income families, a finding that has been reported elsewhere [58]. While the practice of finning and discarding the shark body at sea exists within the traditional fishing sector [47,59], over 90% of traditional shark fishers bring shark meat home to their family or friends. In southwestern Madagascar, 20 fishers with the

¹ These categories have not changed in several decades and should be reevaluated to more meaningfully match changes in engine technology and overall use in Madagascar. See A.J. Cooke. 1997. Survey of elasmobranch fisheries and trade in Madagascar, in: Marshall & Barnes (Eds.), The trade in sharks shark products in the western Indian and southeastern Atlantic oceans, TRAFFIC Eastern/Southern Africa, Nairobi, Kenya.

fewest reported assets (proxy for wealth) brought catch home 100% of the time. The vast majority of shark meat is consumed domestically while shark fins are typically exported. Of those that sell their shark catch, 70% sell both the meat and fins, whereas 30% sell only the fins and either keep the meat for their family, give it to neighbors and friends, or trade it for other local goods. There is also a clear division of labor in the shark fishery. Men account for 99% of the capture effort and 32% of the processing effort (fin drying, meat extraction, salting and/or smoking), whereas women account for 1% of the capture effort and 68% of the processing effort across the three regions surveyed in this study.

Fishers derive a variety of benefits from shark fishing including income, subsistence, and social status. Other fishers sometimes thank local shark fishers for making the seas “safer” (fisher focus group Nosy Be region, July 15, 2011; fisher focus group Manombo-Sud region, June 22, 2015). This sentiment is especially prevalent among skin divers who harvest sea cucumbers. Another less-studied perceived benefit of shark fishing, specific to southwestern Madagascar (specifically St. Augustin and Anakao), is the potential for shark fishers to pull in a very lucrative bycatch: coelacanth (*Latimeria chalumnae*). Shark fishers obtain anywhere from 150 to 400,000 Ariary (~40–110 USD) for a single coelacanth (pers. comm. fishers Anakao April 6, 2011; Saint Augustin June 10, 2011; Toliara June 6, 2015). This critically endangered species on the IUCN red list [60] has been illegal to extract since 1975 (law 75-014) [61], however, most fishers are not aware of the law and instead bring coelacanths to Toliara to sell to museums, hotels and tourist sites. Interviews with shark fishers in this region indicate that in the past decade approximately two coelacanths per year have been pulled up with deep set nets targeting sharks (pers. comm. fishers Anakao April 6, 2011; Saint Augustin June 10, 2011; Toliara June 6, 2015). The museum director at the Institut Halieutique et des Sciences Marines (IHSM) in Toliara has purchased several of these coelacanths for the museum, and noted that this bycatch estimate may be low, for some shark fishers discard dead coelacanths at sea because the fish is generally too oily for consumption (pers. comm. C. Ravelo, January 19, 2019).

Examining the price differential between meat and fins in southwestern Madagascar shows a large disparity between the two most common shark products consumed and traded on the island. Shark fins bring an average of \$76 USD per dry kilogram, whereas meat brings an average of \$0.26 USD per dry kilogram² (Fig. 2). Anecdotal evidence gathered through participant observation and key informant interviews indicate that the price of shark meat stayed fairly stable over the eight years of the study (fluctuated both up and down ~ \$0.10 from 2011 levels), whereas shark fin prices were more volatile (fluctuated up ~\$2 and down ~ \$33 from 2011 levels). Shark fishers from the southwest and northeast interviewed in 2015 and 2018 note that late 2011 had peak prices for shark fins. Via Chinese buyers based in Madagascar, 90% of Malagasy shark fins are exported to Hong Kong, however Malaysia (accounting for 6%), Thailand (accounting for 1.8%) and other countries such as Canada, the United States, and Japan also import Malagasy fins [47].

IUU fishing on both licensed and unlicensed vessels continues to be a major challenge in Madagascar and a substantial contributor to overall shark takes [47,62–64]. Estimates of targeted shark catch by Malagasy fishers peaked in the mid 1990s at a rate of approximately 7000 tons per year, but has since decreased to an estimated 3800 tons per year [57]. One estimate indicated that up to 1 million sharks were harvested in 1995 alone [65]. Some foreign vessels appear to be specifically targeting sharks while still labeling and referring to them as “bycatch.” In 2011, for example, Spanish longline fishing vessels reported landing 152 metric tons of sharks with only 14 metric tons of tuna [66]. The majority of shark products caught from both illegal industrial fishing targeting shark and authorized bycatch of shark in Madagascar’s EEZ are not

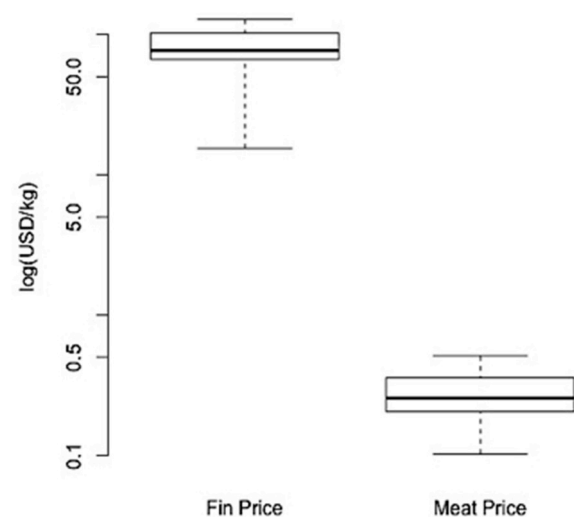


Fig. 2. Prices for shark fins versus meat in Madagascar, 2011. Averages reflect values reported by shark fishers across all regions as they apply to dry weight of both fins and meat. All prices have been converted to USD from Ariary at the May 2011 conversion rate. A Mann-Whitney *U* test indicated that mean reported fin prices ($n = 58$, median = 76.65 USD/kg dry) are significantly higher than mean reported meat prices ($n = 51$, median = 0.26 USD/kg dry); $p < 0.001$.

landed on the island, contributing to the decline of shark populations in Malagasy waters, and providing no nutritional benefit to Malagasy people [47].

With a GDP per capita estimated at \$450 USD in 2017 [67], Madagascar is categorized amongst the poorest countries in the world, with over 90% of its population falling below the \$2.00/day poverty rate and more than half the nation’s children under 5 malnourished [55,68]. Growth of the country’s coastal populations, especially dependent on small-scale fisheries, is also currently increasing at rates higher than the rest of the country [69]. In this context, the consequences of declining fisheries in Madagascar are especially grave beyond the conservation implications.

Not unlike many other countries in the Global South where declining fisheries production per capita is accompanied by growing food insecurity and related human rights issues [70,71], Madagascar is at a crossroads where fisheries management decisions can either help address or undermine the interconnected relationship between poverty alleviation, food security, food sovereignty, and marine conservation. As increased attention, financial commitment, and personnel are dedicated to marine conservation [22], thus bolstering monitoring and enforcement efforts globally, revisiting existing as well as devising new shark conservation policies with an eye to these interconnected relationships will help create more just and sustainable shark management solutions.

6. Managing the shark fishery in Madagascar

To date there is not yet comprehensive national-level legislation regulating shark fishing in Madagascar [47,72]. There are, however, several ways in which local, regional, and international policies and agreements influence Madagascar’s shark fisheries. A study by the World Bank in 2015 called attention to the “incoherent and ambiguous” legal framework regarding Madagascar’s fisheries sector [66]. Shark bycatch is not addressed anywhere in national legislation in spite of Decree 94–112, which specifies that the state can manage and limit bycatch. It is therefore expected that unless legislative changes regarding enforcement are made, further exploitation of pelagic species by foreign vessels will likely continue and lead to greater declines in shark abundance in Malagasy waters. The lack of national-level

² Shark meat once dry has the potential to quadruple in price, therefore averaging 1.04 USD per dry kilogram.

legislation is not unique to Madagascar; many under-resourced nations in the Global South lack management plans despite the large role they play as exporters of shark products [28].

Regulatory authorities in Madagascar also do not currently possess the resources needed to adequately patrol inshore waters, let alone Madagascar's EEZ. The fisheries enforcement system was reported in 2012 to be composed of only 3 monitoring vessels, 8 speedboats, 18 inspectors and 22 observers [55]. A new \$83 million (USD) World Bank project called SWIOFish2,³ which launched in 2017, aims to help bolster the monitoring and enforcement capacity of this fleet, however one year into this project, according to the Director of Fisheries at the Ministry of Fisheries Resources and Conservation, only 4 observers had been added to the team, and 1 monitoring vessel was out of commission (pers. comm. July 13, 2018).

To date, one of the most significant influences on Madagascar's fisheries and the wildlife trade more broadly has been the country's role as a contracting party of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 1975, ratifying the agreement domestically in 2005 [66,73]. Currently sawfish (*Pristidae* family) are the only Appendix I⁴ elasmobranchs listed in CITES, however there are currently six shark species listed in Appendix II⁵ of CITES that are found in Malagasy waters (*Carcharhinus falciformis*, *C. longimanus*, *Sphyrna lewini*, *S. mokarran*, *Carcharodon carcharias*, *Rhincodon typus*) and four species listed in Appendix I⁶ (*Pristis microdon*, *Pristis zijsron*, *Anoxypristis cuspidata*, and *Pristis pectinata*) [73].⁷ CITES listing for these species means that there is pressure on the Malagasy government to ensure adequate monitoring of fishing vessels that have the capacity to take these threatened or endangered species (such as longliners and purse seining operations), and enforcement of bans on their trade [66]. Several of the shark species listed in CITES are also protected by the Convention on the Conservation of Migratory Species of Wild Animals (CMS), to which Madagascar became a party in 1979, and ratified domestically in 2007 [74]. With *Carcharodon carcharias* (Appendix I, CMS), and *Rhincodon typus*, (Appendix II, CMS) two additional shark species are listed in Appendix II of the CMS: *Isurus oxyrinchus* and *Isurus paucus*. Similar to CITES, taking species listed in Appendix I is prohibited, and conservation measures are strongly encouraged for Appendix II listed species [74].

In addition to CITES and CMS, Madagascar is part of the Indian Ocean Tuna Commission (IOTC), an intergovernmental organization that coordinates the regional management of tuna, tuna-like fisheries (e. g. mackerels, bonitos), and sharks [75]. As a member of the IOTC, Madagascar is mandated to report all shark captures, including bycatch. Madagascar's fisheries, whether targeting sharks or not, are required to: a) "fully utilize" sharks captured, which means all parts must be retained except for the head, guts and skin, and b) abide by a maximum of a 5% fin-to-body weight ratio⁸ for all sharks captured up to the first point of

landing [77]. A 2019 report from the IOTC indicates that Madagascar historically failed to monitor and report catch statistics to the IOTC, however in the past six years Madagascar significantly improved their efforts, and as of 2018 complied with 74% of IOTCs monitoring and reporting requirements [78].

CITES and CMS regulations represent a top-down approach that provides framework for controlling shark fishing. However, species-specific protection, like the CITES regulations, are a source of great tension between commercial and conservation interests [79]. For these regulations to be effective, strong enforcement capacities and quantitative information on shark species populations are needed to monitor progress. Madagascar is severely lacking in both these areas [80]. Consistent and comprehensive data on shark catches, both by large-scale foreign fisheries in Madagascar as well as by local traditional and artisanal fisheries are essentially non-existent. Currently, there are no national-level monitoring and reporting mechanisms for the catch of small-scale fisheries, and foreign industrial vessels do not consistently declare their shark catches (pers. comm. CMS National Representative January 22, 2019). Fisheries statistics in Madagascar are frequently inconsistent, with contradictions between regional and national data and confounding declarations of volumes from exporters and different agencies.

More decentralized efforts to conserve sharks exist, specifically through locally managed marine areas (LMMAs) [81]. These conservation efforts often ascribe territorial use rights of the fishery (TURF) within local communities. TURFs are location-specific instead of resource-specific, and can include the surface, the seabed, or all levels of the water column in a chosen area [82]. LMMAs have the potential to move shark management closer to the goals of establishing food sovereignty given their emphasis on community decision-making. In addition, pairing TURFs with an adjacent Marine Reserve (TURF-Reserves) has been shown to be a successful method in equally serving conservation and economic goals [83].

In 2015 the Malagasy government in collaboration with the Wildlife Conservation Society (WCS) and Madagascar National Parks (MNP) announced the establishment of Madagascar's first shark-oriented MPA, thus titled a "shark sanctuary" [43]. All shark fishing is banned in the sanctuary, encompassing approximately 1446 square kilometers in Antongil Bay, located in northeastern Madagascar adjacent to the Masoala Peninsula. Three other shark sanctuaries have been selected by the Ministry of Fisheries Resources and Conservation in collaboration with the Wildlife Conservation Society [108], however to date, none has been implemented (pers. comm. Ministry of Fisheries Resource and Conservation agent July 20, 2018). These new shark sanctuaries grant priority access rights to local communities for non-shark related fishing, and all industrial fishing is prohibited. In return, the local communities are responsible for monitoring and reporting any illegal fishing [108]. In Antongil Bay, eight historically operating and locally owned artisanal shark fishing boats are permitted to harvest a limited number of sharks [108]. In theory, by limiting shark catch to eight artisanal vessels, shark conservation can occur alongside the consideration of the socio-economic needs of local communities. Based on interviews with several fishers in the area, and two conservation agents, the regional ban has increased awareness about the protection of sharks, however it has had mixed success at changing shark fisher behavior. For example, one fisher who used to target sharks now focuses almost exclusively on fishing sea cucumbers, which he partially ascribes to the ban and partially to the higher prices he can now get for sea cucumbers compared to shark fin (pers. comm. February 6, 2018). Another fisher reported that he continues to see fishers harvest sharks, however he also added that some fishers are more hesitant to do so since the establishment of the sanctuary (pers. comm. February 8, 2018). One conservation agent reported that while the permitted artisanal shark fishers are helping monitor illegal industrial shark fishing, more education campaigns are needed to ensure that everyone follows the new rules (pers. comm. January 19, 2018). Another conservation agent said that to date,

³ The Second West Indian Ocean Fisheries Governance and Shared Growth Project.

⁴ Appendix I species are threatened with extinction and international trade in their products is banned, and only authorized in exceptional circumstances.

⁵ Appendix II species are not necessarily threatened with extinction, but may become extinct unless trade is strictly regulated in order to avoid utilization incompatible with the survival of the species in the wild.

⁶ Appendix I species are considered "most endangered" and threatened with extinction. CITES prohibits international trade in specimens, except for scientific research.

⁷ While *Pristis pectinata* is listed within CITES as extant in Madagascar, its presence has not been well documented (A. Cooke pers. comm. August 24, 2019).

⁸ While similar to a finning ban, a 5% fin-to-body-weight ratio does not prevent finning, as "mix-and-match" or so-called "high-grading" can occur between fins and carcasses [76] D.S. Shiffman, N. Hammerschlag, Shark conservation and management policy: a review and primer for non-specialists, Animal Conservation 19(5) (2016) 401–412.

the large sanctuary exists more on paper than on the ground, and has not had a real impact on shark conservation yet (pers. comm. July 30, 2018).

Given that the Antongil shark sanctuary is very large, there is a direct trade-off in terms of reserve size and the ability of managers to effectively involve local communities in decision-making, as well as effectively monitor and enforce the restricted zone [84]. A recent review of the impact of MPAs globally on human well-being indicates that primarily older, well-enforced MPAs with no-take zones contribute the most to the well-being of local communities [85]. Without participatory governance, or adequate funding for monitoring and enforcing fishing in the large area, high levels of illegal extraction within the MPA will likely occur [83,85,86]. Despite some efforts to involve fishers, key management decisions regarding the boundaries and shark fishing rules applied to Madagascar's first shark sanctuary were made primarily by non-governmental and governmental organizations, with little local participation (pers. comm. conservation agents July 30, 2018; January 19, 2018). Although these organizations are aware that local participation in management is an important strategy to help reduce illegal extraction inside MPAs [11], the long history of top-down conservation decision-making, rooted in the colonial period in Madagascar, makes implementing a truly participatory MPA governance scheme more challenging. Based on preliminary observations of the Antongil shark sanctuary and interviews with conservation organization personnel helping implement the shark sanctuary, it is precisely inadequate funding, the lack of local involvement, and overcoming the perceived and institutionalized legacy of top-down conservation intervention that has hindered the sanctuary's success (pers. comm. MPA manager January 20, 2019).

6.1. Policy recommendations

Currently, the existing shark management strategies in Madagascar do not adequately consider coastal communities' need for food sovereignty alongside shark conservation. First, fishing communities are not the primary decision-makers concerning shark management across the island, despite being expected in some cases to help monitor and enforce management rules. Second, existing policies do not adequately account for differences in the end use of sharks caught for subsistence vs. sale on the luxury market. Third, current policies do not adequately consider the value chains through which shark products move. To date there has been little consideration of regulating the broader value chain through which Malagasy shark products flow [47]. Focusing regulation too narrowly on harvest practices means that strategies such as MPAs are easily undermined by illegal harvest, which can easily find its way to willing exporters who may remain unaware of the problematic origin of their commodity [19]. The collection and export of shark products (primarily fins) is concentrated in the hands of a few predominantly foreign-based regional collectors and exporters (pers. comm. Director of Fisheries at the Ministry of Fisheries Resources and Conservation, July 13, 2018) [47].

One approach that might help address some of these deficits is a strategy that provides preferential and secure rights-based access to shark fishers who serve local food markets. This could be done by matching shark fishing restrictions to boat size and engine power. While vessel and engine size are imperfect proxies for both catch capacity and end use of shark products, they may be a useful starting point; ultimately, policies using vessel length and engine power should also be paired with gear restrictions or other fisheries management tools [87]. Graduated rights could map onto boat categories established by the Malagasy government. Under this scheme, traditional fishers would be granted the greatest number of rights, followed by artisanal fishers, and then industrial fishers. This differentiated rights approach is used in places like Antigua and Barbuda as well as Kiribati (see supplemental material). The exact nature of the fishing rights and restrictions would have to be negotiated by the fishers themselves, with careful consideration of the voices and needs of traditional fishers. Implementing this

graduated rights-based strategy would necessitate formalizing a robust democratic process to enable widespread participation of shark fishers in decision-making at multiple scales of organization (village, commune, region and nation). This process will help avoid the pitfalls experienced in other countries such as Bangladesh and Saudi Arabia, where finning and other shark fishing legislation exists but few fishers either know or respect the policies [88,89]. Scholars underscore how the democratization of resource management decision-making is the foundation upon which communities establish food sovereignty [8,11,12,14]; this is a critical step in shifting existing power-dynamics among industrial fishers, artisanal and traditional fishers, and among state authorities, non-governmental organizations, fishing associations, and processing and/or exporting companies.

This strategy might be met with resistance from industrial fishers, and to some extent artisanal fishers (who use 25–50 horsepower engines). However, if there is nominal and effective representation of traditional fishers in the decision-making process, the sheer number of traditional fishers would help outweigh opposition from industrial and artisanal fishers. Over the long-term, this kind of graduated rights-based strategy may impel artisanal fishers to switch to traditional fishing methods (using a sail instead of motor, for example), which would likely decrease their individual productivity [87,90,91]. In terms of industrial fishing, to date there are few registered industrial boats that directly target sharks, instead the majority of sharks taken by industrial fleets are by-catch [47]. Several exceptions to this exist, including Refrigipeche registered and operating out of Toamasina on the east coast of the island (pers. comm. A. Cooke August 24, 2019).⁹ A reduction of rights for the industrial sector would mean restricting all targeted industrial catch, and further restricting bycatch laws by improving surveillance and enforcement of longlining and purse seining operations in Madagascar's EEZ. Although numerous conservation organizations and shark researchers working in Madagascar advocate for stricter surveillance and enforcement of shark bycatch from foreign-owned industrial fishing [34, 47,55,65,92,93], there has not been enough financial support and personnel time have been dedicated to the task. As financial commitments to marine conservation, and an interest in shark conservation in particular, increase [22,76], incentives for the Malagasy government to decrease the number of permits allocated to foreign vessels and to better monitor bycatch of all industrial vessels needs to outweigh incentives (both legal and extra-legal) from the industrial sector to the Malagasy government [56].

A corollary to the graduated rights-based approach to shark fisheries management are strategies such as establishing place-based fishing rights to small-scale fishing communities [94], sharing management authority with small-scale fishers in these places [95], and creating ways for shark fishers to capture a greater proportion of the market price for shark products [47]. These three strategies could work in tandem by coupling export permits with area-based cooperative harvest rights. For example, a cooperative harvest rights system could build on established locally managed TURFs where shark management efforts are already underway [94,96]. Currently, export permits are not paired with harvest permits, and permit-associated regulation aiming to relieve pressure on shark populations exist only in terms of Madagascar's compliance with regional agreements such as IOTC guidelines. Introducing cooperative harvest rights would be an expensive and labor-intensive undertaking, but there are precedents for this approach in other developing countries [97,98]. Presently, non-cooperative patron-client relations dominate Madagascar's shark fishery [47]. However, fishing cooperatives have been shown to lead to better coordinated harvest activities, improved adoption and enforcement of restrictions on fishing methods and effort, and improved conservation actions [97,98]. If coupled with processing

⁹ Due to the decline in shrimp fisheries in Madagascar, some shrimp trawlers have re-gearred to catch fish along the shelf breaks, and they also catch sharks (A. Cooke pers. comm. August 24, 2019).

training and other capacity-building measures, securing harvest rights for small-scale shark fishing cooperatives would likely enable fishers to have greater control over multiple nodes of the value chain, ensuring that shark products continue to serve local food needs, and allowing fishers to obtain a better price for their fins [47].

7. Conclusion

It is evident that existing policies and institutions in Madagascar insufficiently address the joint needs of sustainability and food sovereignty in the country's shark fisheries, and further development of policies as nuanced as the complex and varied drivers of, values associated with, and benefits from shark fishing is needed to adequately address these concerns within the country. While Madagascar's shark fishery exists in a particular socio-political, economic, and ecological context, the challenges in managing shark fisheries for the future are not unique to the country. Many other under-resourced nations in the Global South, which have some of the lowest human development scores, share some of the highest rates of food insecurity, yet also rank among the top producers of shark fins and other shark products globally [5]. In these countries especially, management decisions should consider the nuanced dynamics at play in these fisheries. For example, a complete ban on shark fishing, as used in countries like Sri Lanka [99], can be too blunt a management tool that ignores the rights of fishing communities in accessing adequate, healthy, and culturally appropriate food and livelihoods [11,100]. Similarly, large MPAs that ban all fishing over a wide area have the potential to exacerbate the loss of food sovereignty [101,102]. Alternatively, banning just the practice of finning for all vessels (traditional, artisanal and industrial) as is the case in Brazil [103], or all shark fishing for just commercial vessels, as in Kiribati [40], would allow the lucrative fin market to exist alongside a subsistence-driven shark fishery. Additionally, given the stark contrast in extraction capacity of an individual vessel depending on its engine and size, and thus ecological impact between shark fishing by an industrial operation versus small-scale fisher, it makes sense to have vessel- and engine-specific restrictions. Restricting or banning larger operations from shark fishing would likely help increase the value of fins for smaller-scale fishers, and allow the broader values and benefits, notably food, associated with shark fishing for these coastal communities to persist¹⁰.

Creating mechanisms for greater participation of shark fishers in all levels of decision-making concerning the production, distribution and consumption policies regarding shark products is the foundation upon which developing countries like Madagascar can help establish food sovereignty for small-scale coastal fishers. Allocating special spatial or harvest rights to traditional fishers would enable those who contribute the most to local food security to have an advantage over large-scale mobile operations. Encouraging establishment of shark-fishing cooperatives could improve harvest reporting transparency and the implementation of conservation measures, help fishers become co-owners of boats and gear, and allow shark fishers to bypass the first link of the supply chain, increasing the revenue they obtain by selling fins to middlemen further up the chain or directly to exporters [47,98,105,106].

It is clear that better monitoring and control of industrial fishing operations, both of vessels that land their catch or not, should be implemented globally, but especially in under-resourced countries in the Global South like Madagascar. While financially and logistically

difficult, the current lack of transparency around the origin of shark products contributes to the decline of threatened shark species and is a detriment to establishing food sovereignty for coastal shark-fishing communities [2,47].

What may be considered a luxury food for some is a vital source of subsistence food for others. Shark fishing and the shark product industry are highly complex; their impacts on small-scale fishing communities as well as shark populations globally do not lend themselves to simple solutions. Indeed, these complex systems may be classified as “wicked problems,” defined by Ludwig and others as problems that “cannot be separated from issues of values, equity and social justice” [107]. Addressing these problems requires a fundamentally different, interdisciplinary approach, with high degrees of transparency and accountability. It requires an understanding of the complexity of interactions between nature and society, and a shift away from broadly top-down controls to active inclusion of communities in the management process.

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Appendix A. Supplementary data

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¹⁰ While some sharks are likely caught by both industrial and subsistence fishers, an overall decrease in supply could help stabilize or increase prices for shark products, see: [104] A. Chin, M. Heupel, C. Simpfendorfer, A. Tobin, Ontogenetic movements of juvenile blacktip reef sharks: evidence of dispersal and connectivity between coastal habitats and coral reefs, *Aquatic Conservation: Marine and Freshwater Ecosystems* 23(3) (2013) 468–474.

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