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Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar?

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ABSTRACT

Madagascar, the world's fourth largest island, is one of the world's poorest developing countries, and its people depend heavily on marine resources for subsistence and income. Exports of these resources and foreign fishing access agreements are also important, at least from a large-scale economic perspective. In recent years, concerns have been voiced amongst local fishers and industry groups regarding the growth of the country's fishing effort. Despite these concerns, existing knowledge of the scale, composition and trends of Malagasy fisheries remains poor, and there is negligible information regarding unreported catches and illegal fishing in Madagascar's waters. Small-scale fisheries, which are often substantial in developing countries such as Madagascar, are often unreported or underestimated. Unfortunately, fisheries legislations, management plans and foreign fishing access agreements are often influenced by these incomplete data, leading to serious over-estimations of resource availability. This also appears to be the situation in Madagascar, where the reconstruction of total catches by all Malagasy fisheries sectors conducted here showed that total catches between 1950 and 2008 were twice the volume reported by national fisheries agencies. Most importantly, much of the subsistence sector is missing from official statistics, and signs of decline have already been observed in several stocks, suggesting that current levels of catches are likely to be exceeding sustainable yields. This has profound implications for the economic and ecological sustainability of fisheries, as well as food security in a country where people rely heavily on the ocean for their daily protein needs and livelihoods.

1. Introduction

Madagascar, the world's fourth largest island, is located in the Western Indian Ocean and is separated from Africa by the Mozambique Channel (Fig. 1). Oceanic and geological features have shaped Malagasy ecosystems, and the wide, western continental shelf encompasses extensive mangrove and coral reef ecosystems [1–3]. These geographical features have influenced the distribution of the human population on the island. The west coast is home to most of the country's fishers, and therefore experiences the highest fishing pressure [4–7], while the eastern part of the island has the highest overall human population density.

Madagascar's fisheries focus mainly on coastal species: shrimps have been exploited industrially since the mid-1960s, while other invertebrates (notably octopus, lobster, crab and sea cucumber) and sharks are exploited for subsistence or on a semi-industrial scale. Finally, sea turtles and small fish species are caught by small-scale fishers for local consumption. Much of Madagascar's pelagic environment remains unexploited by domestic fisheries, but several species of tuna (e.g., yellowfin *Thunnus albacares*, big-eye *Thunnus obesus*) are heavily targeted by illegal Asian and legal European fleets.

Economically, Madagascar is one of the poorest countries in the world. Per capita GDP has declined steadily since independence in 1960, having never exceeded $410. It is currently at less than $300 (year 2000 USD). Approximately 70% of the population lives under the poverty threshold, and over half of the country's population depends on the exploitation of natural resources for their livelihood [8,9]. Small-scale fisheries are therefore of

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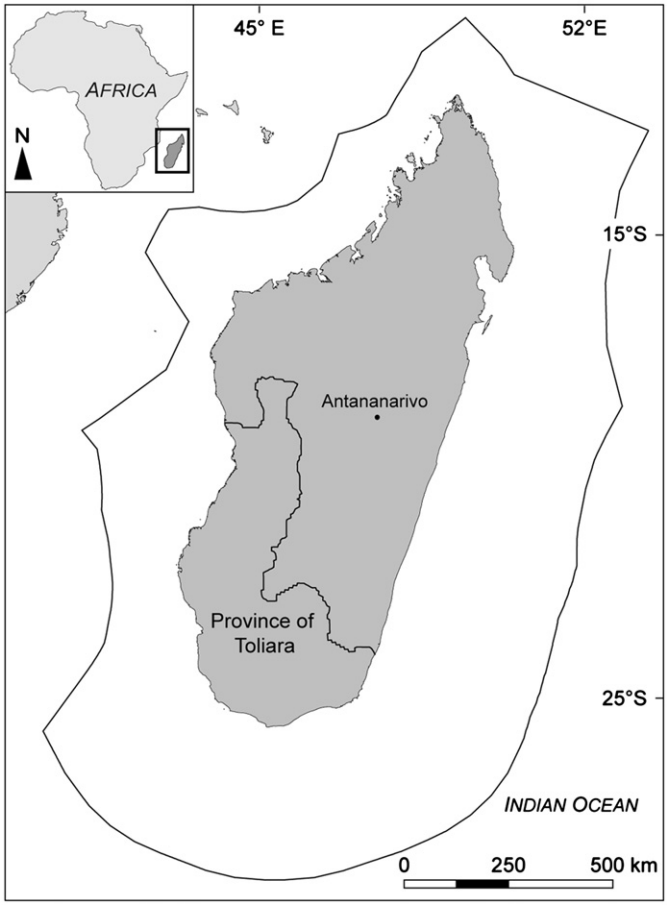

Fig. 1. Map of Madagascar and its Exclusive Economic Zone (solid line).

fundamental importance to coastal communities, especially in the arid south-western region of the country where agriculture is largely unviable, and where many communities rely on food assistance. Furthermore, populations of east African and western Indian Ocean island states are concentrated in coastal areas, which show higher rates of population growth than inland areas, a trend that is exacerbated by urbanization and migration towards coastal zones from inland areas. Existing infrastructure and amenities are often unable to support the region's extremely rapidly growing coastal populations [10]. In Madagascar, growth of coastal populations is taking place more rapidly than across the country as a whole, with population doubling times of approximately 10–15 years, and women giving birth to an average of over 6 children in some coastal provinces [11].

Madagascar has experienced political turmoil in recent decades [12]. From 1896 to 1960, the island was under French colonial rule, which was followed by three successive republics. The third republic has been in place since 1992, but the country continues to be unstable, with the last democratically elected government overthrown in a military backed coup in 2009. Resulting unrest, political sanctions and the withdrawal of many bilateral aid and development programs have resulted in an economic downturn [13]. These events have also influenced national fisheries with more fishing licenses being made available, although local authorities are likely not to have enough power or the resources to effectively control these fisheries. Throughout this turbulent political history, Madagascar's extensive EEZ has remained largely unexploited relative to other countries of the western Indian Ocean, and monitoring of the contribution of seafood to national food security, or of trends and

Table 1
Summary of data, assumptions and sources used to reconstruct total catches by shrimp fishing fleets in Madagascar.

Time period	Shrimp catches (t yr^{-1})	Associated bycatch and discards		Sources	Comments
		Bycatch ratio	Discards (%)		
1967–2008	300–13,300[a]			[15,20–23]	
1967–1989		1:4.1	90	[18]	
1990–2000		1:4.1	72	[20]	
2001–2004		1:2.5[b]	62	[55]	Decree 1999/2000
2005–2008		1:1.7[b]	62		BRD introduction

[a] Values reported to FAO were kept for the years 1966, 1994, 2000–2003, as they were deemed more representative than those reconstructed.
[b] Based on a 32% reduction of bycatch due to BRDs [19].

composition of fisheries catches, has not been rigorously pursued by the various political regimes. Furthermore, tensions between commercial shrimp fleets and small-scale, local fishers seem to have increased in recent times [14], suggesting increasing resource competition. This article aims to serve as a baseline framework for future integrated fisheries management by presenting the case of fisheries in Madagascar. A synthesis of the different fisheries sectors in Madagascar is provided along with their total catches back to 1950. Historical trends and recent events, which may be leading to a national fisheries and food security crisis, are also highlighted.

2. Methods

Official data, as reported by Madagascar to the Food and Agriculture Organization of the United Nations (FAO), were extracted from the FAO FishStat database and served as the foundation for the study [15]. A bibliographic review of the different fisheries activities in Madagascar allowed us to determine which sectors were being underreported. Data sources included peer-reviewed publications, reports by non-governmental organizations (NGOs), other gray literature and technical reports and local expert knowledge. For each fisheries sector, anchor points of total catches (in contrast to reported statistics) were derived from the literature and from informed local expert knowledge, in order to reconstruct total fisheries catches from 1950 to 2008.

The method used here followed the general catch reconstruction method described by [16]. The total catch reconstruction, including minor sectors not described here in detail (such as the relatively recent deep-sea fishery), are fully documented in the technical report underlying the present study [17].[1] Here, we focus on the country's total catches, and on four major components: shrimp, shark and small-scale fisheries, as well as foreign fisheries.

For the domestic industrial shrimp fisheries, bycatch and associated discards are not accounted for in official data. Therefore, these fisheries components were estimated based on existing studies and local knowledge [18–20] (Table 1). Anchor points for the industrial shrimp catches were extracted from [21], except when FAO values were higher. In those instances, it was assumed that FAO had additional information not available, and therefore

[1] This technical research report is freely available through the University of British Columbia Fisheries Centre website at http://www.fisheries.ubc.ca/publications/reports/fcrr.php. A copy of this report has been submitted as Supplementary material.

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Table 2
Summary of data, parameters, assumptions and sources used for the reconstruction of shark fisheries catches in Madagascar.

Sector	Time period	Hong Kong and Singapore imports (tonnes of shark fin)	Sources	Total catch (t)	Comments
Targeted	1950–1979		[25]	160–570[a]	Exports at least since 1930s Backward extension of 1980 per fisher catch rate
	1980–1985			600–3050	Backward extension of 1986–1988 trend in derived catch
	1986–1995	34.5–64.7	[26]	3430–6440	
	1996–2008			5400–3760[b]	Decrease of 3% yr^{-1}
Shrimp bycatch	1967–2008			Up to 385 t (1998)[c]	

[a] 1950 value of 60 t derived by keeping the 1980 catch per fisher fixed.
[b] Values for this period were based on interpolations from the 1994 fin trade data, and an assumed 3% per year decrease in catches ([26,28]; Y. Sadovy, personal communication, University of Hong Kong).
[c] Values were based on reconstructed industrial shrimp catches and an assumed 1% of total shrimp bycatch composed of sharks (C. Chaboud, personal communication, Institut de Recherche pour le Développement).

considered their values to be more accurate. The small-scale shrimp catch component was also revised, as data submitted to FAO by Madagascar underestimated this sector, especially for the period preceding the industrial exploitation of shrimp ([22–24], C. Chaboud, personal communication, Institut de Recherche pour le Développement).

Catches of sharks also seemed to be missing from the official data [15,25]. Three approaches were used to reconstruct total shark catches by Malagasy fishers (Table 2). Data on the trade of shark fins were used to conservatively estimate the likely minimum catches of sharks that occurred in Madagascar's waters during the period 1970–1994: dried fins imported between 1986 and 1995 by Honk-Kong and Singapore from Madagascar were converted to whole body, wet weight using a conversion factor of 98.5% ([26–28], Y. Sadovy, personal communication, University of Hong Kong). It was assumed that the market started to greatly expand in 1980, and therefore linearly extended the 1986–1988 trend backwards to 1980. For the 1950–1979 period, it was assumed that the 1980 per fisher catch rate remained constant back to 1950, and expanded it to total catches using fisher population data. For the 1996–2008 period, it was conservatively assumed that the 1994 per fisher catch rate decreased by 3% yr^{-1}, based on literature and local knowledge ([29], Y. Sadovy, personal communication, University of Hong Kong). Sharks are also caught as bycatch in Madagascar's commercial shrimp fishery, in which they have been suggested as representing 1% of the unreported bycatch (C. Chaboud, personal communication, Institut de Recherche pour le Développement). This bycatch was also added to the reconstructed shark catches.

The small-scale, artisanal (commercial) and subsistence (non-commercial) fisheries for small coastal fishes and invertebrates (but excluding artisanal shrimp and shark catches, which were incorporated above) were reconstructed to address discrepancies in reported data. For finfish, total catches by the small-scale sector were estimated, based on reported numbers of fishers and their catch per unit of effort (CPUE). A census of small-scale fishers conducted by FAO [5] was used to derive a time-series of the number of artisanal fishers in Madagascar for the 1950–2008 time-period (Fig. 2). The population of fishers was divided into two areas: (1) the southwest coast, comprising the district of Toliara (Fig. 1) where fishing pressure is known to be the highest [4–7] and (2) the remaining coastal districts, where fishing pressure is thought to be lower. Each area was assigned a unique CPUE value and trend (Table 3), based on local knowledge and existing studies [7,30]. In order to re-estimate the total catches of invertebrates, product weight as it appears in the trade data was converted to whole body, wet weight, using FAO conversion

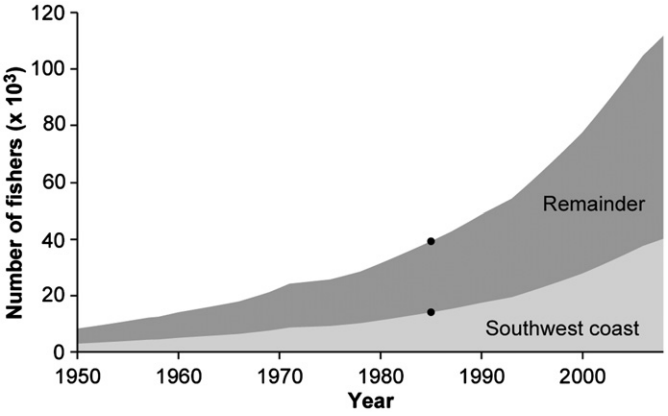

Fig. 2. Estimated numbers of artisanal fishers, with the 1987–88 census data anchor point [5] indicated by solid circles.

factors [31]. A highly conservative export rate of 80% (for sea cucumber, cephalopods, crabs and lobsters) or 20% (for the other products) was then applied for the entire time period for which exports were thought to have occurred (1970–2008) in order to calculate the domestic subsistence component. Finally, the average subsistence catch rates for the first three years of exports were applied to the number of inhabitants prior to the first year of export, in order to estimate the domestic subsistence component of invertebrate catches back to 1950.

Foreign fleets have been extensively present in Madagascar's waters since at least the 1980s. These fleets target mainly tuna-like species and sharks. Catches quickly growing to exactly 10,000 tonnes have been declared each year since 1986[2] by the European Union based on access agreements (www.seaaroundus.org). However, actual catches are thought to be substantially underreported, and are more likely to have been around 18,000 t yr^{-1} [32]. An Asian long-line fleet also operates in Malagasy waters, with unreported catches of up to 50,000 t yr^{-1} [33]. Except for the 1991–1994 period with legal catches varying around 6,000–8,000 t yr^{-1} [34], no official access agreements exist between Madagascar and the Asian flag countries; therefore, these catches are considered illegal under international law. Five to ten percent of the bycatch of these long-line fleets is composed of sharks [33,35], of which only the fins are retained. Sharks are

[2] Madagascar formally declared its Exclusive Economic Zone in 1985 (www.un.org/Depts/los/LEGISLATIONANDTREATIES/STATEFILES/MDG.htm).

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Table 3
Summary of parameters used for the estimation of small-scale catches in Madagascar.

Taxa	Time period	Southwest coast		Source	Rest of the coast		Source
		CPUE (kg fisher^{-1} day^{-1})	Total catches (t)		CPUE (kg fisher^{-1} day^{-1})	Total catches (t)	
Finfish[a]	1950–1990	5.0[b]	5150–24,250				
	1991	5.0	24,000	[7]			
	1992–2008	2.1[c]	23,600–22,215				
	1950–2001					8200–59,500	
	2002					61,500	[30]
	2003–2008					63,400–70,500	
					4.3[b]		
					4.3		
					3.8[d]		
Invertebrates[e]	1950–1962		400–550[f]				
	1962–2008		550–14,000[f]				

[a] Total catches = CPUE × number of fishers (Fig. 2) × 260 [assumed average number of fishing days in Madagascar ([29]; Gough and Humber, unpublished data; G. Hosch, personal communication. Fisheries Planning and Management)].
[b] CPUE assumed to have remained stable for this period.
[c] CPUE assumed to have decreased by 5% yr^{-1}.
[d] CPUE assumed to have decreased by 3% yr^{-1}.
[e] Catches for the 1962–2008 period have a commercial component (calculations based on export data and [31]) and a subsistence component (based on either 80% or 20% of exports—see Section 2; Methods). Catches for the 1950–1962 are only for subsistence.
[f] Values are for the whole country.

also purposely targeted by Asian fleets in the Western Indian Ocean, as evidenced by recent incidents and vessel seizures [36,37]. However, the extent of such targeted shark fisheries in Madagascar's waters is currently unknown. Finally, a pole-and-line fleet targeting tuna and other large pelagic species (e.g., swordfish, marlin) operates in Madagascar's water from La Réunion (France; [38]), but catches are unknown [33]. For our purposes, it was assumed that these catches have increased from 0 t yr^{-1} in 1980 to 5000 t yr^{-1} in 2008.

3. Results

3.1. Total catches

Total catches by Madagascar's domestic fisheries in its EEZ were reconstructed to be 4.7 million tonnes for the 1950–2008 period. Thus, total reconstructed catches are twice as high as the data submitted by the government of Madagascar to the FAO would suggest (Fig. 3A). However, the unreported component appears to have decreased over time, as it decreased from over 500% in the 1950 s to around 40% by the 2000s (Fig. 3A). Overall, total catches increased steadily, from approximately 15,000 t yr^{-1} in 1950 (compared to 2400 t yr^{-1} as reported) to around 140,000 t yr^{-1} in the mid-1990s (compared to 85,000 t yr^{-1} as reported). Since then, total catches seem to have decreased to around 130,000 t yr^{-1} in 2008 (Fig. 3A).

Foreign catches of mainly tuna and sharks in Madagascar's EEZ, both legal and illegal, are thought to have increased markedly since the mid-1980s (Fig. 3B). Catches increased rapidly from around 45,000 t yr^{-1} in 1990 to approximately 80,000 t yr^{-1} by 2008 (Fig. 3B). The majority of these catches are taken illegally, mainly by the Asian long-line fleet. Total catches of sharks taken by foreign vessels based on bycatch rates from the tuna fisheries suggested that total catches increased steeply since 1950, and are currently estimated at 4,300 t yr^{-1}. These shark catches do not include targeted shark catches, the amount of which is currently unknown.

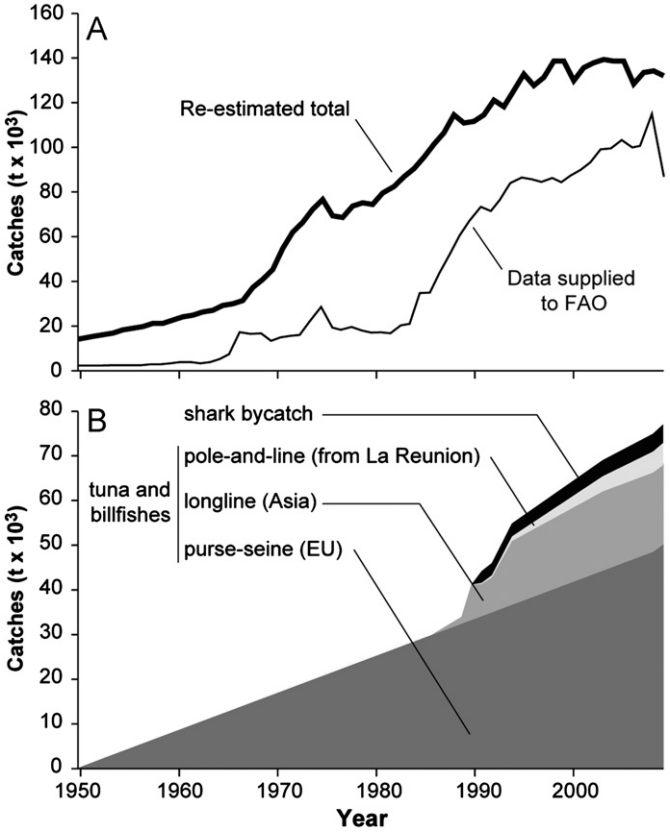

Fig. 3. (A) Reconstructed total catches versus reported landings as supplied to FAO by Madagascar and (B) reconstructed total catch estimates by foreign vessels in Madagascar's waters, showing legal but underreported catches by EU vessels, and illegal catches by Asian long-line fleets and pole-and-line fleets based out of La Reunion.

3.2. Domestic catches by fisheries sectors

Total reconstructed catches of shrimp remained low between 1950 and the mid-1960s, at around 300–700 t yr^{-1} (Fig. 4A). With the introduction of commercial operations, shrimp catches increased steadily to a peak of 13,000 t yr^{-1} in 2003, but have declined by almost 40% since then to around 7900 t yr^{-1} in 2008 (Fig. 4A). Reconstructed total catches and reported landings

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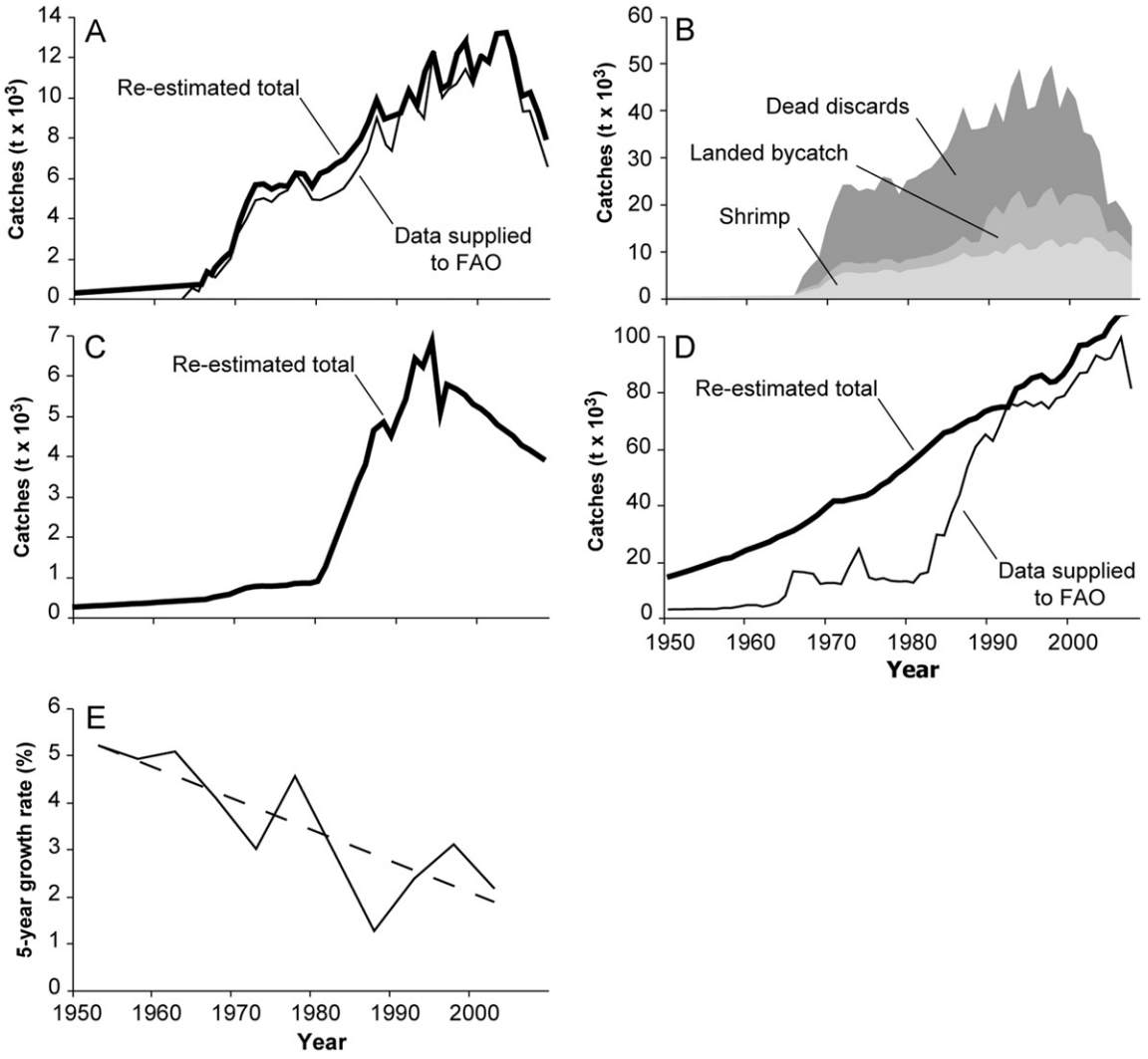

Fig. 4. Total reconstructed data for (A) shrimp catches, (B) bycatch and discards from the shrimp fisheries, (C) shark catches, (D) small-scale fisheries catches (excluding shrimp and shark) and (E) the smoothed 5-year growth rate (%) of small-scale fisheries catches.

differed only slightly, as the reconstruction added on only 9% over the 50+ year time period considered here.

The bycatch taken during shrimp trawling operations also followed a similar trend, reaching a maximum of 38,800 t yr^{-1} in 1998, of which 25,500 t were discarded (72%). Since then, bycatch has decreased to around 8,000 t yr^{-1} in 2008, of which 4400 tonnes were discarded (62%; Fig. 4B).

Total catches of sharks remained low until the early 1980s, after which they rapidly increased to almost 7000 t yr^{-1} in 1992 (Fig. 4C). Thereafter, shark catches by Malagasy fishers are thought to have declined to an estimated 3800 t yr^{-1} tonnes by 2008. Thus, total catches of sharks taken by both domestic (3800 t yr^{-1}) and foreign fishers (4300 t yr^{-1}) in Madagascar's waters at present are likely well over 8000 t yr^{-1}.

In contrast to the predominantly large-scale and declining shrimp and shark fisheries, the small-scale, artisanal and subsistence fisheries, which target a wide variety of small coastal species of fish and invertebrates, appear to have continuously increasing catches (Fig. 4D). Total catches were estimated at around 13,800 t yr^{-1} in 1950, and have increased to over 107,300 t yr^{-1} by 2008. Importantly, small-scale catches appear to be increasing at a declining rate, as illustrated by the declining 5-year growth rate for this sector (Fig. 4E). If the current trend does not change, the growth rate would become negative by the early 2030s, meaning that catches by the small-scale, artisanal and subsistence fisheries will be declining. If finfish are considered separately, catches of small-scale fisheries could be declining by the early 2020s.

4. Discussion

Overall, actual catches taken by Malagasy fisheries had been underreported by over 500% in the early time periods, but at present seem to be underreported by at least 40%. Furthermore, while commercial fisheries seem to have experienced declining catches for a few years, small-scale catches appear to continue to increase, although at a declining rate. These trends have serious ramifications for domestic food security. The largest component of total domestic fisheries catches is taken by small-scale artisanal and subsistence fishers, which account for 72% of total catches in the 2000s. This clearly illustrates the overwhelming importance of the small-scale fishery sector for domestic markets and food security in Madagascar, although it is marginalized and poorly monitored [39]. The west coast (characterized by a broad shallow continental shelf), where most of fishers live, also hosts the vast majority of the commercial shrimp fishing fleet [40]. As a consequence of the habitat destroying nature [41] and the high

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associated bycatch and discard rates of shrimp trawl operations, the availability of fish to small-scale fishers in these areas would appear to be declining (see Fig. 4E), and tensions are amplifying between these stakeholders. Based on a simple interpolation of trends drawn from this study, it is suggested that catches of small-scale fishers could start to decline within 10–20 years. It is worth noting that serious concerns about declining catches and stocks of invertebrates, mainly collected through reef-gleaning [42,43], have already been noted in several cases [44–46]. Thus, these trends are likely to be already occurring at a local level. The potential trend reversal portended here does not yet consider the rapidly growing coastal populations, and therefore the number of fishers, or the increasing tourism interest in this region [47], both of which will result in further growth in fishing effort. Recent studies suggest that traditional fishers are now migrating in unprecedented numbers to increasingly remote and isolated regions of the west coast as a coping mechanism in direct response to declining catches [48]. Therefore given these factors, tensions are likely to increase in the future, and food insecurity may become a growing concern for coastal populations in the near future. Indeed, the small-scale coastal fisheries supply the majority of local seafood demand, as most of the catches are sold and consumed locally. Furthermore, given that the declining per capita GDP would suggest that the population of Madagascar is getting poorer, it is unlikely that fishers will be able to upgrade their gear for re-targeting to pelagic stocks, which currently receive little domestic fishing pressure (but are already heavily targeted by largely illegal foreign fleets). In fact, fishing access license fees paid by foreign countries are so attractive to the governments in poor countries [49,50] that it is likely that most of the large pelagic species will continue to be exploited almost exclusively by foreign countries. This situation raises the very serious issue of inappropriate low fishing access fees paid by developed countries, associated corruption [49,50] and poor to non-existent monitoring and enforcement of such agreements [47]. The monitoring and enforcement system in Madagascar is indeed only composed of 3 monitoring vessels, 8 speedboats, 18 inspectors and 22 observers (R. Fanazava, personal communication, Centre de Surveillance des Pêches), which has led to increasing illegal fishing in the waters of Madagascar. These illegal fisheries are therefore unlikely to be addressed by Madagascar, which may have serious socio-economic consequences for the livelihoods of local coastal populations, and likely contribute significantly to unsustainable fishing practice in the Western Indian Ocean.

Catches of shrimp, which have been significantly higher (by up to 5000 t yr^{-1}) than the estimated maximum sustainable yield of 8700 t yr^{-1} in the past [51], are now declining. Furthermore, the overall CPUE of the shrimp fisheries is decreasing [52]. This decline in the ecological sustainability and economic viability of this fishery is now causing owners to reduce their fleets [14,53], and has resulted in increasing conflict between artisanal and industrial fishers amongst the west coast fishing communities [42]. On the one hand, artisanal fishers, sometimes using fine-meshed mosquito nets, are accused by the industrial sector being responsible for this decline in CPUE [14], while on the other hand, the industrial fleet is depleting resources and damaging the gear of traditional fishers within the 2-nautical mile zone, where most of the artisanal fishers operate [51].

Bycatch and discard volumes of the industrial shrimp fishery have also been decreasing. In part, this is due to the requirement to use Turtle Exclusion Devices (TEDs) and Bycatch Reduction Devices (BRDs) since the 1990–2000s, resulting in reduced incidental bycatch [53–55]. However, only an estimated 30% of licensed shrimp boats carry enforcement personnel from the national fisheries surveillance authority, and it cannot be confirmed whether crews use TEDs and BRDs when not under surveillance. Discards have been reduced as well, as traditional fishers have taken to following shrimp boats to collect bycatch, which is often traded for cigarettes or small amounts of cash (Harris, unpublished data).

The time-series of shark catches reconstructed here presents a very different picture to the officially reported data. It is considered that an artisanal fishery for sharks has existed since at least 1950, while the reported data show little evidence of shark catches despite this being fairly well documented in the independent literature [25,35]. Our estimates of total shark catches are based on trade data for the Hong Kong and Singapore markets, and are considered conservative given that these two markets do not account for 100% of the global shark fin trade [28,56]. Currently, Madagascar's sharks are also heavily targeted by illegal foreign vessels. A number of known IUU vessels, which previously targeted Patagonian toothfish (Dissostichus eleginoides) in the Southern Ocean, have been reported to have converted to shark fishing in southern and western Madagascar by substituting bottom trawl nets with bottom-set gillnet gear to target sharks for liver oil and fins [36,37,57]. Furthermore, the high market demand for shark fin as a lucrative, yet diminishing fisheries resource is a key factor driving Madagascar's nomadic Vezo fishers further afield, with shark fishers increasingly exploiting more remote and more offshore areas of the west coast of Madagascar [48]. While the ecological importance of sharks for healthy ecosystems is clearly established [58,59], it is a major concern that regulatory authorities do not possess the resources to patrol and enforce Madagascar's EEZ to address the problem of illegal fishing.

5. Conclusions

In Madagascar, fisheries are of prime importance for domestic economy and food security. However, past and present political instabilities have resulted in poor monitoring of national fisheries that does not acknowledge the importance of these fisheries, as underlined by the small surveillance system. This study has shown that important components of Malagasy fisheries are not accounted for, their catches missing from officially reported data, and that the trends over the last decade suggest a decrease in total catches for several key taxa, including shrimp and sharks. Evidence presented here suggest that the highly important small-scale fisheries are likely reaching a plateau in terms of total catches despite growing numbers of fishers, and are projected to start declining within the next decade. Given the heavy reliance on marine resources for fundamental food security, mainly through small-scale fisheries, in a country with few if any livelihood alternatives, it is suggested that sustainable small-scale fisheries can be viewed as a human-rights issue and should be given precedence over export-oriented commercial or foreign access fisheries. This would suggest that resolving conflicts between the commercial and artisanal fleets and aggressively dealing with the predominantly illegal foreign fisheries should become a priority topic at both the national and international levels. At present, fisheries regulations in Madagascar are under review, but available information suggests that no major modifications regarding small-scale fisheries or IUU regulations will be included. We hope that the present study, now submitted to domestic policy-makers, may help address this oversight. The consequences of diminishing fisheries resources as evidenced here by the leveling off of total catches, declining commercial landings and declining small-scale fisheries catch rates would indeed be particularly severe in an island nation in which over 50% of children under five years of age are suffering from malnutrition, and where persistent food insecurity affects over 65% of the population [11,60].

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2011.05.007.

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