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Fisheries Catch Reconstructions in the Western Indian Ocean, 1950-2010

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Fisheries Centre, University of British Columbia, Canada

Edited by

Frédéric Le Manach and Daniel Pauly

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Content

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Foreword

This Fisheries Centre Research Report presents catch reconstructions for the fisheries of eleven entities of the western Indian Ocean, ranging from mighty South Africa in the South to the tiny Djibouti in the North, and from the uninhabited Îles Eparses — the scattered islands in and near the Mozambique Channel — to the densely populated Comoros Islands, and from the flourishing democracy of the Seychelles to the failed state that is Somalia. Only Madagascar and Mauritius are not included here — but their catches were reconstructed earlier.[1]

The contrasts that these wide ranges of climate, population, and governance styles represent are not necessarily related as one would expect with the state of marine fisheries resources of these various entities. Thus, Somalia and Djibouti may have, overall, the least impacted coastal fish stocks of the region, while stocks along the Indian Ocean Coast of South Africa, a country which boasts a considerable research and management capacity, are generally in dire straits.

Although the 'national' catch reconstructions presented here emphasize the coastal and thus domestic catches of Western Indian Ocean countries, the attention of their fisheries ministries is often directed elsewhere, i.e., at the tuna fisheries that have made the Western Indian Ocean a bonanza for European (mainly Spanish and French) and East Asian fishing fleets.[2]

These fisheries are very lucrative, and the Western Indian Ocean countries that permit tuna vessels to operate in their Exclusive Economic Zones (EEZs) get a share — albeit small — from access fees. But they should not forget their domestic fisheries because they are the ones that ensure — or at least contribute — to the (sea)food security of their populations. The eleven chapters in this report document that this contribution to seafood security is much higher than previously assumed, but also that it is sharply declining in several countries.

Thus, this report suggests that it is time to devote more attention to coastal fisheries and to rehabilitate them, e.g., as achieved in Southern Kenya, where strong, positive interactions between governments, scientists and fishers enabled the banning of gears not suitable for sustainable reef fisheries, and the establishment of marine reserves. Hopefully, initiatives such as these can be duplicated throughout the region.

The Editors

Paris and Vancouver

February 2015

[1] For Madagascar: Le Manach F, Gough C, Humber F, Harper S and Zeller D (2011) Reconstruction of total marine fisheries catches for Madagascar (1950–2008). Pp. 21–37 *In* Harper S and Zeller D (eds.), Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19(4). University of British Columbia, Vancouver (Canada).
For Mauritius: Boistol L, Harper S, Booth S and Zeller D (2011) Reconstruction of marine fisheries catches for Mauritius and its outer islands, 1950–2008. Pp. 39–61 *In* Harper S and Zeller D (eds.), Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19(4). University of British Columbia, Vancouver (Canada).

[2] Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Reconstructing Catches for the Union of the Comoros: Uniting Historical Sources of Catch Data for Ngazidja, Ndzuwani and Mwali from 1950–2010*

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Abstract

Comorian fisheries consist of a small-scale boat fleet of *pirogues* and motor boats operated by men as well as shore-based fishing by women, both of which have few catch statistics. We compiled historical data on catch rates and the number of boats in the fleet from both grey literature and national statistics, and used these to reconstruct a time series of boat-based catch from 1950–2010. We also estimate catch by women fishers by extrapolating per-capita catch rates from a recently published study on the island of Ngazidja. Catches increased slowly from 1,000 t in 1950 to around 5,000 t in 1980, after which catches increased rapidly due to the increasing number of motorized vessels and the use of FADs offshore. The size of the fleet has grown rapidly since the 1990s and catch estimates are highest from 2005–2010 at around 19,000 t·year^{-1}. Overall, the reconstructed catches are 1.3 times the figures reported to and by the FAO for the Indian Ocean. Total reconstructed catches consist primarily of *Thunnus albacares* (yellowfin tuna), *Katsuwonus pelamis* (skipjack tuna), *Sardinella* spp. (sardinellas) and Engraulidae (anchovies).

Introduction

The Union of the Comoros (referred throughout as 'the Comoros') is an archipelago in the northern Mozambique channel of the Western Indian Ocean that is composed of three islands: Ngazidja (or Grande Comore), Ndzuwani (or Anjouan) and Mwali (or Mohéli; Figure 1). Fisheries in the Comoros consist of a small-scale *pirogues* and fibreglass motor boat (locally known as *barques* or *vedettes*) fleet as well as shore-based subsistence fishing by women. Until the 1980s the boat fleet was almost exclusively non-motorized *pirogues* using mostly handlines (de San 1983). Catches by this fleet increased in the 1980s, due to the importation of fibreglass motorboats and the use of anchored Fish Aggregating Devices (a-FADs) for fishing further offshore (Cayré 1991; Anon. 2013). The high season fishing months have historically occurred between November and February when tunas migrate around the islands; catches in other months are generally lower (Van Nierop 1985; James 1988).

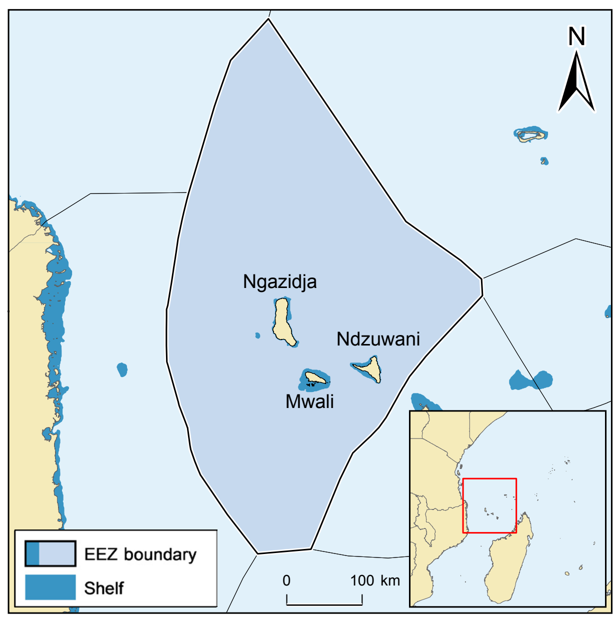

Figure 1. Map of the Comoros showing the islands of Ngazidja (Grande Comore), Ndzuwani (Anjouan) and Mwali (Mohéli), the extent of the Exclusive Economic Zone (EEZ), as well as the continental shelf (darker blue).

The fishing conditions on the three islands vary. Ngazidja is surrounded by a narrow coral reef extending about 500 m from shore (Fourmanoir 1954). The reef is generally not very deep, nor is it followed by a large shelf with productive fishing areas for reef species. Fishing here has historically targeted large pelagic species (e.g., sharks,[1] tuna, billfish and dolphinfish) in areas about 5–15 km offshore (Fourmanoir 1954). The fishing conditions off Ndzuwani are comparable to Ngazidja, except the productivity of the coral reefs is higher (Fourmanoir 1954). Fishermen from Ndzuwani and Ngazidja frequently fish the waters near Mwali, perhaps even more heavily than local residents (James 1988). Ndzuwani fishers also regularly fish in Mayotte's waters (Maggiorani *et al.* 1993; Doherty *et al.* this volume).

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[1] Historically there was a targeted fishery for sharks (Fourmanoir 1954), but fishing effort now targets more tuna and it does not appear that there is a fishery targeting sharks specifically. When caught, sharks are finned for the Chinese market and the meat is consumed locally (Kiszka *et al.* 2008).

Mwali is the least densely populated island, and its continental shelf extends about 10 km from the coast and harbours much more productive reef fisheries (Fourmanoir 1954). Thus, fisheries in Mwali have historically targeted more reef species (e.g., snappers, groupers and emperors). A marine park was established around the southern half of the island in 2001, extending from the high tide mark to 100 m depth and covering over 400 km² (Granek and Brown 2005).

Fishing in the Comoros is mostly day trips, as no vessels have refrigerating units (de San 1983; James 1988) and crews are small, usually 1–2 people per boat (WIOMSA 2011). The average crew and boat sizes are larger in Ngazidja, as these vessels often fish further offshore (WIOMSA 2011). Catches are usually landed on shore and sold on the same day (Anon. 2013). There are no restrictions on the amount of fish that may be landed, but fishers rarely catch more than they can consume or sell in one day (Hauzer *et al.* 2013a).

A survey conducted by the *Direction Nationale des Ressources Halieutiques* (National Fisheries Department) in 1994 provided the only comprehensive assessment of catch by the small-scale boat fleet, and Hauzer *et al.* (2013a) provided the only catch estimates for women fishers. Fishers reported declines in catch abundances, mean size and changes in species composition over the last two decades (Hauzer *et al.* 2013b), but there was a lack of official catch statistics to verify these trends. Other studies during the 1950–2010 period provided estimates of catch rates and the number of boats in the fleets, and were used to reconstruct a time-series of boat-based catch. The size of the fleet has grown rapidly since the 1990s, but data collection and catch statistics has remained limited.

The purpose of this report was to estimate the total marine fisheries catches for the Comoros from 1950 to 2010, using FAO data as the baseline. Reconstructed estimates were compared with FAO landings in an attempt to identify unreported sources of catch and increase transparency in Comorian catch statistics.

The Comoros' Fisheries and Reconstruction Methods

Boat-based catch

We compiled catch and effort data from grey literature and unpublished datasets for select years with available data from 1950–2010. These data were treated as anchor points and linear interpolation of catch rates, and the number of fishing boats were used to estimate gaps in the data between anchor points.

Boat time-series

Table 1 summarizes the boat counts that were available for the small-scale fishing fleets since 1950. In the early 1950s, Fourmanoir (1954) estimated that there were 130 *pirogues* in the southern villages of Ngazidja. Moal (1962) counted 213 boats in these same villages, representing a ratio of 0.61:1 for boats in 1954 compared to those in 1962. We assumed that the same increase occurred proportionally on other areas of Ngazidja, Ndzuwani and Mwali and applied this ratio to boat counts by Moal (1962) to estimate boat numbers in 1954. There was a large discrepancy in the number of boats recorded in the 1993 and 1994 national survey data. Since we found no explanation to justify this, we used the average number of boats from 1993–1994.

Table 1. Anchor points for the number of boats in the Comoros for various years between 1950–2011.

Year	*Pirogues*						Motor boats[b]			Sources
	Non-motorized			Motorized[a]						
	Ngazidja	Ndzuwani	Mwali	Ngazidja	Ndzuwani	Mwali	Ngazidja	Ndzuwani	Mwali	
1954	566	123	36	-	-	-	-	-	-	Fourmanoir (1954)[c]
1962	928	201[d]	59	-	-	-	-	-	-	Moal (1962)
1979	1,455	970	194	45	30	6	-	-	-	Faharoudine (1979)
1983	-	-	-	-	-	-	15[e]	25	10[e]	Van Nierop (1985)
1987	1,500	1,200	300	-	-	-	11	18	6	James (1988)
1993	2,012	1,391	242	107	120	79	250	92	69	Unpub. data, 1994 survey, *Direction National des Ressources Halieutiques*
1994	1,748	1,505	247	87	80	54	109	77	39	
2011	1,888	1,864	227	23	25	209	802	708	18	Unpub. data, 2011 boat census, *Direction National des Ressources Halieutiques*[f]

[a] Includes Fedawa I.
[b] Includes *barques*, *vedettes*, Fedawa II, Yamaha G18, and Japawa). Classification of boat categories are based on boat size, capacity, and horse power (Lablache-Carrara and Laloë 1993; Aboulhalik 1998).
[c] Multiplied 1962 boat numbers by 0.61.
[d] Missing boat data for 3 communities (Vouani, Pomoni and Moya) was estimated using the median value from other communities in Ndzuwani.
[e] Estimated the distribution of vedettes in 1983 for Ngazidja and Mwali. There were originally 50 *vedettes* supplied (James 1988), 25 of which were originally on Ndzuwani (Van Nierop 1985).
[f] Obtained through SWIOFP database (http://41.206.61.142:8080/statbase_3).

The boat anchor points in Table 1 were converted to a boat per-capita[2] rate for each boat type and linear interpolation was used to estimate boats per-capita for years without boat data. This provided a boat per capita time-series from

[2] Population statistics for 1960–2012 were available from the World Bank database (http://databank.worldbank.org, Accessed: 06/06/2013) and for 1950 and 1955 from the United Nations database (http://data.un.org, Accessed: 06/06/2013). Missing years in the 1950s were linearly interpolated.

1950–2010 that was used to estimate a boat time-series by multiplying per capita boat rates by annual populations on each island (Figure 2).

Catch rates time series

Where available, estimates of annual catch were divided by total boats on the island to estimate an annual catch rate. Otherwise, daily catch rates were multiplied by the number of trips per year to estimate the annual catch for different boat types (Table 2).

Early observations of small-scale fisheries in the Comoros archipelago were well-documented by Fourmanoir (1954). These included catch rates of 50 kg·trip^{-1} for *pirogues* fishing twice per week on the southern offshore banks of Mwali, and an average annual catch rate of 5.2 t·*pirogue*$^{-1}$. *Pirogues* fishing every day on the interior reef had an average catch rate of 10 kg·trip^{-1} and an annual catch rate of 2.6 t·*pirogue*$^{-1}$, assuming trips occurred 5 times per week (Table 2).

During this time, a normal week of pelagic fishing by 70 *pirogues* off Ngazidja landed: 1,500 kg of sharks (*Isurus glaucus* and *Carcharinus longimanus*), ten yellowfin tuna (*Thunnus albacares*) with an average weight of 20 kg, two dolphinfish (*Coryphaena hippurus*) with an average weight of nine kilos, and four Indo-Pacific sailfish (*Istiophorus platypterus*). Average lengths of landed sailfish on Ngazidja were 2.9 m (Fourmanoir 1954), and we estimate their average weight as 50 kg per fish using length-weight relationships from FishBase (www.fishbase.org). This yielded a total of 1,918 kg of pelagic fish by 70 boats in one week, or an average weekly catch of 27.4 kg per *pirogue*. Based on the overall catch composition in the 1994 survey data (unpub. data, *Direction Nationale des Ressources Halieutiques*), we assumed an additional 20% of annual catches were composed of yellowtail barracuda (*Sphyraena flavicauda*), oilfish (*Ruvettues pretiosus*), small pelagics and other reef fish (e.g., Lethrinidae and Carangidae), also documented in catches by Fourmanoir (1954).

Linear interpolation between catch rates was used to fill in gaps. We used the same rates for all three islands where island specific rates were not available. We had no catch rates beyond 1994; however, the majority of boat fishers interviewed by Hauzer *et al.* (2013a) reported declines in catch abundance and mean fish sizes over the last 20 years. This was not surprising given the large increase in motorized vessels in the small-scale fishing fleet during this time (Figure 2). We assumed catch rates declined by 50% between 1994 and 2010 (Figure 3).

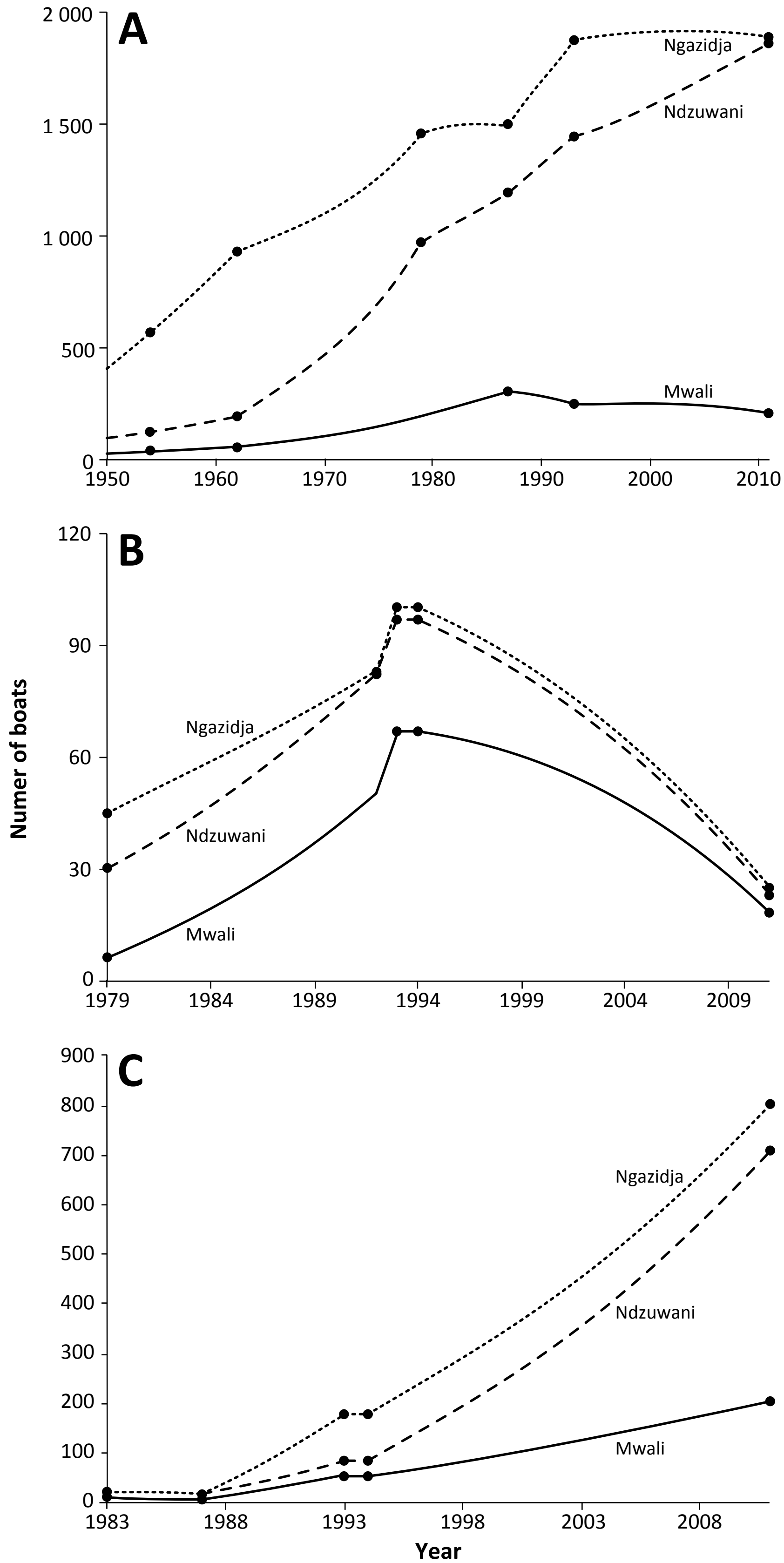

Figure 2. Estimated annual number of A) non-motorized *pirogues* from 1950–2010, B) motorized *pirogues* from 1979–2010, and C) motor boats from 1983–2010. Solid circles represent anchor points described in Table 1.

Table 2. Summary of annual catch rate estimates from 1954 to 1994.

Year	Boat type	Daily catch rate (kg·boat⁻¹)	Trips per year	Annual catch rate (t·boat⁻¹)[a]	Sources and comments
Ngazidja					
1954	Non-motorized *pirogue*	34.3[a]	-	1.8	Fourmanoir (1954)
1962		-	-	1.5	Moal (1962)
1978		-	-	1.4	de San (1983)
1994		-	-	1.7	Unpub. data, 1994 survey, *Direction Nationale des Ressource Halieutiques*
	Motorized *pirogue*	-	-	12.2	
	Motor boat	-		23.7	
Ndzuwani					
1962	Non-motorized *pirogue*	-	-	3.5	Moal (1962)
1979		-	-	1.4	de San (1983)
1983–1984		39.7 (high season), 21.8[b] (low season)	104.0	3.0	Van Nierop (1985), James (1988). Annual catch rate assumes 60% of trips occur in low season and 40% of trips occur in high season (Van Nierop 1985; James 1988)
	Motorized *pirogue*	69.0 (high season), 38.0[b] (low season)	104.0	5.2	
	Motor boat	252.4 (high season), 138.9[b] (low season)	122.0	22.6	
1986–1987	Non-motorized *pirogue*	20.0	104.0	2.1	James (1988)
	Motor boat	250.0	122.0	30.5	
1994	Non-motorized *pirogue*	-	-	1.4	Unpub. data, 1994 survey, *Direction Nationale des Ressources Halieutiques*
	Motorized *pirogue*	-	-	8.0	
	Motor boat	-	-	15.0	
Mwali					
1954	Non-motorized *pirogue*	50 (offshore) and 10 (inshore)	104 (offshore) and 260 (inshore)[c]	3.9	Fourmanoir (1954). Average of inshore and offshore rate
1962		-	-	5.1	Moal (1962)
1979		-	-	2.1	Faharoudine (1979), de San (1983)
1994		-	-	0.8	Unpub. data, 1994 survey, *Direction Nationale des Ressources Halieutiques*
	Motorized *pirogue*	-	-	4.7	
	Motor boat	-	-	9.8	

[a] Numbers reflect weekly catch rates observed in October; number of trips per week unknown.
[b] Low-season rate estimated as 55% of high season rate based on ratios from James (1988).
[c] Fourmanoir (1954) indicates these fishers fish every day; here we assume an average of 5 trips per week throughout the year (Van Nierop 1985).

Shore-based fishing by women

Hauzer *et al.* (2013a) provided the only estimates of catch by women fishers in the Comoros. Based on data collected from interviews in 2009–2010, the annual catch by women was estimated for three communities on Ngazidja (Table 3). Each community had 80 women fishers and catch estimates for each village ranged from 40–99 tonnes due to the differences in catch rates and the number of full-time fishers. There are another seven communities on the island consisting of women fishers, one of which contains only ten fishers (Hauzer *et al.* 2013a). We estimated that the other six villages also contained approximately ten women fishers, based on the second author's personal experience. Extrapolated to the entire island of Ngazidja, this yielded an estimate of 255 tonnes for 2010. We converted these 255 tonnes to a shore-based catch per-capita and assumed the same per-capita catch rate for the islands of Mwali and Ndzuwani in 2010.

Table 3. 2010 annual catch estimates for full-time and part-time women fishers on Ngazidja (derived from Hauzer *et al.* 2013a).

Community	Annual catch (t)	Average catch per year		Number of fishers		% full time
		Full time	Part time	Full time	Part time	
Chindini	40.2	0.9	0.4	10	70	0.13
Hantsindzi	59.7	0.9	0.5	50	30	0.63
Mitsamiouli	98.8	1.4	0.7	60	20	0.75
Seven other villages	8.1	1.1[a]	0.5[a]	5	5	0.50[a]

[a] Estimated as average value from the three communities above.

All women fishers interviewed by Hauzer *et al.* (2013a) reported declines in catch abundance in the last ten years. We therefore assumed a higher shore-based catch per-capita in 2000, increasing the 2010 per-capita rate by 25%. We used linear interpolation to derive per-capita catch rates from 2001–2009 and maintained the 2000 rate from 1950–1999.

Taxonomic and sectoral breakdown

We maintained the same annual taxonomic compositions for the boat-based reconstructed catch as what was reported to the FAO for the 1970–2010 period. Data reported to the FAO from 1950–1969 had poor taxonomic detail, with 20–70% of the catch reported as 'marine fishes nei' (i.e., unidentified marine fish). To improve the taxonomic breakdown prior to 1970, we reallocated catches of unidentified fish to other taxonomic groups based on the catch composition in the early 1970s, using the average 1971–1973 breakdown from FAO. The assumption here was that new taxa reported in 1971–1973 FAO landings (e.g., Carangidae, Engraulidae, Istiophoridae and Scombriae) were reflective of improved taxonomic reporting rather than new fish species targeted by fisheries. This retained 7%

of annual catches as 'unidentified marine fish' and reassigned the remainder as anchovies, bigeye tuna, Carangidae, Indian mackerel, Indo-Pacific sailfish, kawakawa, skipjack tuna, swordfish and yellowfin tuna.

The *Sea Around Us* uses the following fishing sectors in its global catch database: 'industrial' (i.e., large-scale commercial), 'artisanal' (i.e., small-scale commercial), 'subsistence' (i.e., small-scale non-commercial with primary purpose being self- or family-consumption), and 'recreational' (i.e., small-scale non-commercial with the primary purpose being pleasure). For the purposes of the *Sea Around Us* database, the small-scale shore fishing and boat-based catches were divided into artisanal and subsistence components. Species of higher value, such as tunas (*Thunnus* spp. and *Euthynnus* spp.), billfishes (Istiophoridae) and lobsters, were assumed to be primarily sold commercially and thus 80% of this catch was allocated to the 'artisanal' sector. Fish species sold at lower prices, such as small pelagics (Clupeiformes), and marine molluscs, were assumed to be primarily used for take-home consumption and 80% of these catches were allocated as 'subsistence'. For other species where the distinction was not obvious, such as jacks (Carangidae), mackerels (*Auxis* spp., *Rastrelliger* spp., *Scomberomorus* spp.), and other unidentified marine fish, we used an even split, allocating 50% to each small-scale sector. All shore-based catch was allocated as subsistence.

Flags of Convenience

FAO landing data (FishStat 2014) also included catches from the Central Eastern Atlantic (FAO Area 34) from 2007–2012. These landings were composed mostly of pelagic species (primarily Clupeidae, Engraulidae, and Carangidae) as well as a small amount (2%) of demersals. However, as there were no records of any distant water Comorian fishing fleets, these catches were not considered domestic.

Rather, we suspected that these catches were from industrial fishing vessels fishing the high seas using the Comoros as a flag of convenience. As a matter of fact, the Comoros has been previously identified as a potential flag of convenience state for high seas fishing (Gianni and Simpson 2005; Anon. 2013). The FAO fishing vessels finder database (www.fao.org/figis/vrmf/finder; Accessed: June 26, 2014) listed six foreign vessels (Table 4) that have been registered with the Comoros flag between 2004 and 2012. Given the absence of any other information we assumed that these countries were responsible for the FAO reported landings in the Atlantic. We allocated 89% of the pelagic catch to Lithuania

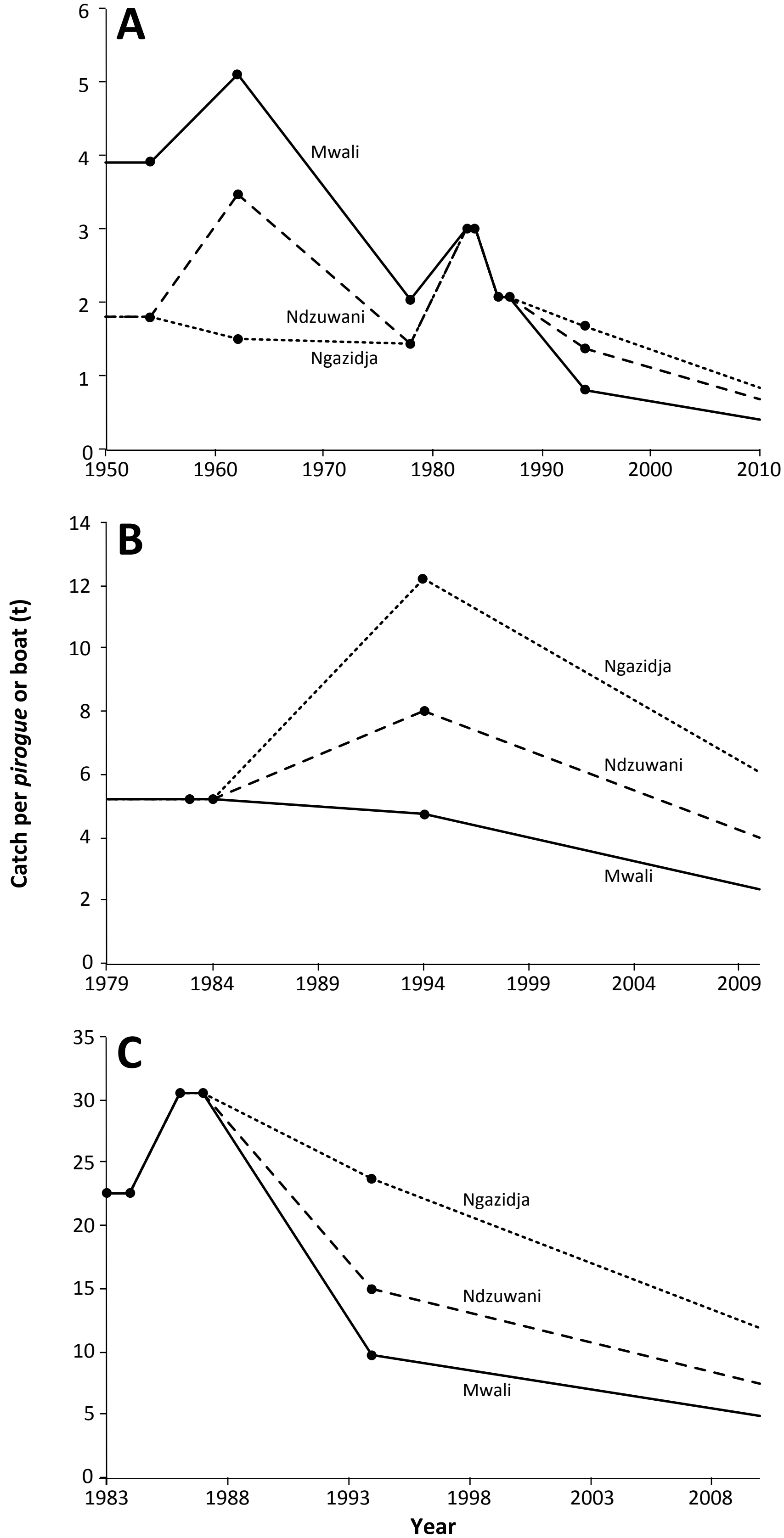

Figure 3. Estimated annual catch rates (t·boat-1) for A) non-motorized pirogues from 1950–2010, B) motorized pirogues from 1979–2010, and C) motor boats from 1983–2010. Solid circles represent anchor points described in Table 2.

Table 4. Fishing vessels registered with the Comoros flag in the FAO fishing vessel finder database.

Country	Boat name	Period	Gear	Length (m)	Gross tonnage
Lithuania	ARAS-1	2009, 2012	Midwater otter trawl	104	4,378
	IRVINGA	2011–2013		105	4,407
	BALANDIS	2011, 2012		109	5,953
	KOVAS			118	5,979
The Netherlands	OCEAAN VII	2012		90	2,624
France	LA MADONE 2	2004	Bottom trawl and dredging	11	16

and 11% to Netherlands based on the proportion of total tonnage by vessels from these countries using midwater otter trawls. Demersal catches were reallocated to France, the only country with vessels using bottom trawls.

Although we could not confirm that France, Lithuania and Netherlands were responsible for these catches, we are confident that these catches were not from the Comoros fishing fleets and our reallocation is, therefore, more informative than what is currently in the FAO database.

Foreign fisheries

Industrial longliners from Japan have fished in Comorian waters since at least the late 1950s (Moal 1962). Although there were no formal agreements at this time, Japan has contributed funds and equipment (e.g., fiberglass vessels, fishing nets) to develop the Comoros' fisheries over the years (de San 1983; James 1988; Lablache-Carrara and Laloë 1993). Formal agreements with the European Union have been signed in recent years, which allowed up to 45 tuna seiners and 25 longliners from France, Spain, Italy and Portugal to fish for tuna in the Comoros EEZ (Anon. 2013; Eckstein 2014).

Results

Overall, the total reconstructed catches from 1950–2010 were nearly 516,000 t, 96% of which were from the small-scale boat fleet, and 4% of which were from shore-based fishing by women (Figure 4A). Catches increased slowly from 1,000 t in 1950 to around 5,000 t in 1980, after which catch volumes increased rapidly due to the increasing number of motorized vessels and the use of offshore a-FADs. The size of the fleet has grown rapidly since the 1990s and despite decreasing catch rates, catch estimates were the highest from 2005–2010 at around 19,000 t·year^{-1}. Overall, the reconstructed catches were 1.3 times the landings reported to FAO in the Indian Ocean. Total reconstructed catches consisted primarily of yellowfin tuna, skipjack tuna, sardinellas, and anchovies (Figure 4B). The sectoral assignments suggested that 'artisanal' and 'subsistence' catches accounted for 61% and 39% of total reconstructed catches from 1950–2010, respectively (Figure 4A).

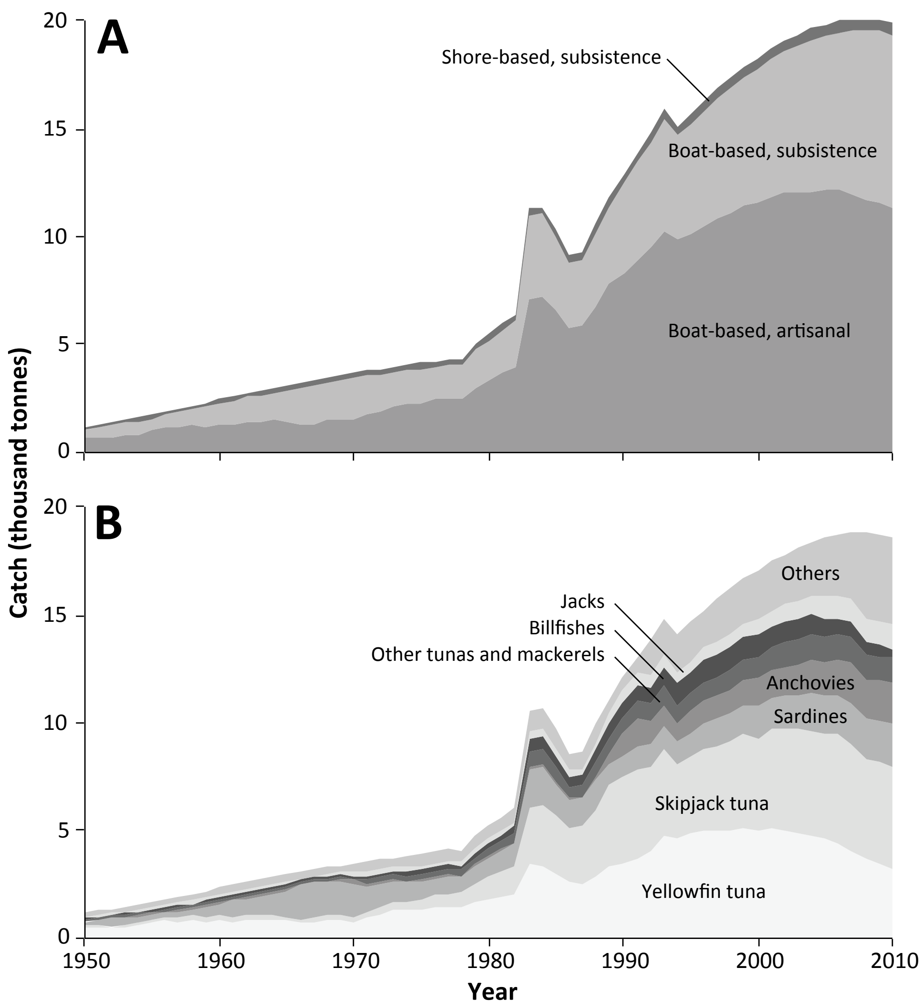

Figure 4. Reconstructed catches by A) sector and B) major taxa. 'Others' includes lobsters, molluscs, sharks, rays and other unidentified marine fish. See details in Appendix Table A1 and Appendix Table A2.

Discussion

The overall discrepancy between the reconstructed domestic catches and the data reported to FAO was mainly due to an increase in catch since 1995, which contributed 54% of the total reconstructed catch (and were 95,000 t higher than what was reported to FAO). In estimating catches for these years, we assumed a 50% decline in catch rates since the 1994 survey by the *Direction Nationale des Ressources Halieutiques*,which is the only comprehensive assessment of small-scale fisheries in the Comoros.

The 2012 dataset produced by FAO (2012; i.e., the dataset used here) showed that catches have steadily decreased from 1994 to around 11,000 t·year^{-1} from 2001–2010. This was in stark contrast to the 2010 dataset (FAO 2012), where catches increased from 1994 to 20,500 t·year^{-1} in 2008–2010. As we found no catch statistics for this period, the reasons for this change in the FAO data remains unknown. What we do know is that the number of motor boats in the Comoros increased from around 300 in 1994 to about 1,700 in 2011 (Figure 2). Catches in the 2012 FAO data declined by 23% over this same period and, if accurate, would correspond to about a 70% decline in annual catch per boat since 1994 (Figure 5).

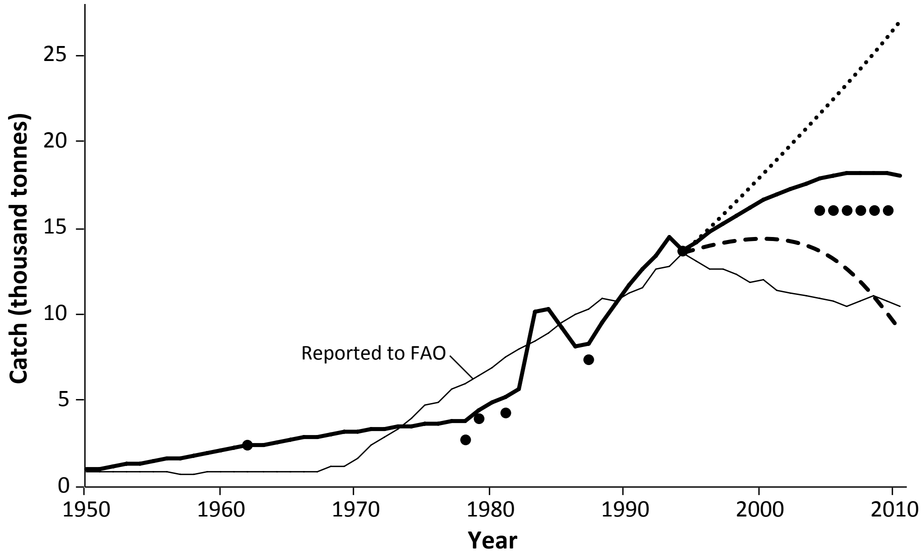

Figure 5. Reconstructed boat-based catch compared to other sources of catch data. Solid circles represent estimates observed in the grey literature (Moal 1962; de San 1983; Van Nierop 1985; James 1988; Amoriggi 2010) and the 1994 survey by the *Direction National des Ressources Halieutiques*. Dashed (75% decline) and dotted (25% decline) lines show sensitivity analysis for different assumptions about the decline in catch rates between 1994–2010.

Interviews with fishermen confirmed that there has been a decrease in mean fish sizes and perceived catch abundance over the last 20 years (Hauzer *et al.* 2013b), but by how much we do not know. In these interviews 62% of motorized boat fishers and 55% of *pirogue* fishers reported declines in fish sizes. Similarly, 50% of motorized boat fishers and 75% of *pirogue* fishers reported declines in catch abundance. Given that this perception was not consistent among fishers, Hauzer *et al.* (2013b) suspected that the declines in catch were not drastic. Furthermore, catch figures remained reasonably high in recent years, averaging 22 kg·day^{-1} for *pirogues* and 110 kg·day^{-1} for motor boats (Hauzer *et al.* 2013b). Thus, we think that our assumption of a 50% decline may well be conservative, and catches over this period may actually be higher. Not surprisingly, sensitivity analysis of this assumption shows that catches in the last 15 years would vary considerably depending on the decline in catch rates assumed; thus this is a major source of uncertainty in our estimates (Figure 5). We were not able to provide estimates of uncertainty for the reconstructed totals, as error estimates are unavailable for catch statistics used, including those reported by the FAO.

For most of the 1950–1994 period, we found the 2012 FAO dataset to be a reasonable estimate of boat-based catches. The reconstructed estimates here provide an alternative, but show a similar trend to FAO data. The reconstructed catches yielded per-capita consumption rates of 6–15 kg·person^{-1}·year^{-1} from 1950–1979. These are low for an island country with few other protein sources. However, it is known that throughout the 1950s-1970s, fishing did not satisfy local consumption requirements and large amounts of salted fish were imported from Madagascar and Zanzibar (Fourmanoir 1954; Moal 1962; Faharoudine 1979; Meyer *et al.* 2006).

Further studies are necessary to improve confidence in our results, notably with regards to the shore-based activities conducted by women fishers. In this study we extrapolated estimates by Hauzer *et al.* (2013b) for the island of Ngazidja to estimate catches for all of the Comoros and using population data estimated historical catches by this sector. This information provides a preliminary estimate of the scale of these catches, which could be improved through specific studies on the islands of Mwali and Ndzuwani. The importance of such activities for food security and livelihoods is increasingly recognized (Harper *et al.* 2013; Anon. 2014; Kleiber *et al.* 2014). Thus, further research is required to better understand the species most affected by these fisheries and well as their social and economical impact.

We found few data on the species composition of catches in the Comoros and much of the data reported to FAO from 1950–1969 was recorded as unidentified marine fish. We attempted to improve the taxonomic detail of these catches, by disaggregating them based on more detailed information in FAO data in the early 1970s. Information on major species caught by fisheries in 1950s (Fourmanoir 1954) and the 1994 national statistics could be used in future efforts to improve Comorian catch statistics and may provide valuable information of changes in species composition over time. For example, approximately 80% of catches on Ngazidja observed by Fourmanoir (1954) over a one-week period were composed of sharks, whereas they accounted for less than 1% of annual catches on Ngazidja in 1994 and fishermen reported that sharks are now rarely seen in catches (M. Hauzer, unpub. data). It is clear that tunas are now the main target species for offshore pelagic fisheries, but sharks likely accounted for a much larger proportion of catches in earlier years and this is not reflected in our estimates. Groupers (*Plectropomus pessuliferus*,[3] *Epinephelus merra*, *Variola louti*), snappers (*Lutjanus argentimaculatus*, *Aprion virescens*) and emperors (*Lethrinus nebulosus, L. olivaceus*[4]) were commonly caught in Mwali reef fisheries in the 1950s (Fourmanoir 1954), but we found no species specific catch statistics for reef fisheries in recent years to compare these with. Interviews with fishermen suggested that some species that were once common are now rarely seen,

[3] *Plectropomus maculatus* listed in Fourmanoir (1954) is a likely misidentification (Froese and Pauly 2014).

[4] *Lethrinus miniatus* listed in Fourmanoir (1954) is a likely misidentification (Froese and Pauly 2014).

while other species have completely disappeared from catches (M. Hauzer, unpub. data). The lack of detailed catch statistics for the Comoros makes it difficult to assess the magnitude of such changes, their causes and their impacts on fisheries and marine ecosystems

It is critical for fisheries management that the Comoros dedicates more resources to accurately recording fisheries statistics (Pauly *et al.* 2013). Other than the 1994 national statistics and a few recently published studies (e.g., Hauzer *et al.* 2013a,b), data that exist are mostly from grey literature and often based on brief observations of the fishery in select regions. It is unlikely that we will ever know the 'true' historic catches of small-scale fisheries in the Comoros, but we hope this work may serve as a starting point to account for unreported catch statistics, improve transparency in fisheries data, and provide a resource of historical information for Comorian fisheries. If there are additional data that were unavailable to us, we hope they may be used to improve this work and we welcome contributions from other researchers to improve this database, which will be made available *via* the *Sea Around Us* website.

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References

Aboulhalik FM (1998) Marine science country profiles — Comores. Intergovernmental Oceanographic Commission, Western Indian Ocean marine science association (WIOMSA). 35 p.

Amoriggi S (2010) Union des Comores — Appui au développement de la transformation des produits agricoles aux Comores. Fonds international de développement agricole (FIDA), Rome (Italy).

Anon. (2013) Contrat Spécifique n°4 — Évaluation rétrospective et prospective du protocole de l'accord de partenariat dans le secteur de la pêche entre l'Union européenne et l'Union des Comores. Contrat Cadre MARE/2011/01 — Évaluation et analyse d'impacts — Lot 3 — Évaluations rétrospectives et prospectives relatives à la dimension internationale de la Politique Commune des Pêches, Cofrépêche, Marine Resources Assessment Group (MRAG), Poseidon Aquatic Resource Management Ltd, and Nordenfjeldske Development Services (NFDS), Brussels (Belgium). 111 p.

Anon. (2014) Sustainable fisheries and aquaculture for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition, Rome (Italy). 118 p.

Cayré P (1991) Behaviour of yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonous pelamis*) around fish aggregating devices (FADs) in the Comoros Islands as determined by ultrasonic tagging. Aquatic Living Resources 4: 1–12.

de San M (1983) Profil de la pêche artisanale aux Comores. South West Indian Ocean Fishery Project SWIOP/RAF/79/065/WP/6/82, FAO, Moroni. 22 p.

Doherty B, Herfaut J, Le Manach F, Harper S and Zeller D (this volume) Reconstructing domestic marine fisheries in Mayotte from 1950–2010.

Eckstein A (2014) MEPs green-light three fisheries agreements. Europolitics, edition of April 23, 2014.

Faharoudine AH (1979) Country statement on the fisheries situation in the Comoros. pp. 45–47 *In* Report of the FAO/IOP workshop on the fishery resources of the Western Indian Ocean south of the Equator. Indian Ocean Fishery Commission, Indian Ocean Programme, Development Report No. 45. FAO, Mahé (Seychelles).

FAO (2012) FishstatJ Capture Production 1950–2010. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

FAO (2014) FishstatJ Capture Production 1950–2012. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Fourmanoir P (1954) Ichthyologie et pêche aux Comores. Mémoires de l'Institut Scientifique de Madagascar Série A — Tome IX. 187–239 p.

Froese R and Pauly D, editors (2014) Fishbase (www.fishbase.org).

Gianni M and Simpson W (2005) The changing nature of high seas fishing: how flags of convenience provide cover for illegal, unreported and unregulated fishing. Australian Department of Agriculture, Fisheries and Forestry, International Transport Workers' Federation, and WWF International. 83 p.

Granek EF and Brown MA (2005) Co-management to Marine Conservation in Mohéli, Comoros Islands. Conservation Biology: 1724–1732.

Harper S, Zeller D, Hauzer M, Pauly D and Sumaila UR (2013) Women and fisheries: contribution to food security and local economies. Marine Policy 39: 56–63.

Hauzer M, Dearden P and Murray G (2013a) The fisherwomen of Ngazidja island, Comoros: fisheries livelihoods, impacts, and implications for management. Fisheries Research 140: 28–35.

Hauzer M, Dearden P and Murray G (2013b) The effectiveness of community-based governance of small-scale fisheries, Ngazidja island, Comoros. Marine Policy 38: 346–354.

James JRW (1988) Summary of the fisheries and resources information for the Comores. *In* Sanders MJ, Sparre P and Venema SC (eds.), Proceedings of the workshop on the assessment of the fishery resources in the southwest Indian Ocean. RAF/79/065/WP/41/88/E. FAO/UNDP, Albion (Mauritius).

Kiszka J, Wickel J, Jamon A and Layssac K (2008) Note sur l'exploitation et la capture accidentelle des requins autour de la Grande Comore (Union des Comores), Canal de Mozambique. Document interne — Groupe de Recherche sur les Requins — MAYSHARK. 2 p.

Kleiber D, Harris LM, Vincent AC and Rochet M-J (2014) Improving fisheries estimates by including women's catch in the Central Philippines. Canadian Journal of Fisheries and Aquatic Sciences 71(5): 656–664.

Lablache-Carrara G and Laloë F (1993) Plan d'exécution d'un système d'échantillonnage des captures aux Comores. 46 p.

Maggiorani JM, Minet JP and Taquet M (1993) Situation de la pêche artisanale à Mayotte en 1992–93 — Résultats de l'enquête halieutique (mars 1992 — février 1993) et comparison avec l'enquête halieutique de 1988–89. IFREMER, Collectivité Territoriale de Mayotte — Direction de l'Agriculture et de la Forêt, Service des Pêches. 34 p.

Meyer J, Nelson D, Black D and TANGO International (2006) Comoros: comprehensive food security and vulnerability analysis (CFSVA). World Food Programme (WFP), Vulnerability Analysis and Mapping Branch (ODAV). 62 p.

Moal RA (1962) La pêche aux Comores. Ministère d'état chargé départements et territoires d'outre-mer, France. 78 p.

Pauly D (2013) Fisheries: does catch reflect abundance? Nature 494(7437): 303–306.

Van Nierop M (1985) Rapport préliminaire sur la performance des embarcations de pêche sur l'île d'Anjouan aux Comores. RAF/79/065/WP/20/85, SWIOP. Available at: http://www.fao.org/docrep/field/279543.htm#F007 [Accessed: July 16, 2012].

WIOMSA (2011) Migrant fishers and fishing in the Western Indian Ocean: socio-economic dynamics and implications for management. Final report of commissioned research project MASMA/CR/2008/02. 158 p.

Appendix Table A1. Total reconstructed catch compared to official data reported to FAO.

Year	Reconstructed				Reported to FAO
	Shore-based	Boat-based		Total	
		Artisanal	Subsistence		
1950	142	653	347	1,142	835
1951	145	659	431	1,235	935
1952	148	634	549	1,331	918
1953	152	739	542	1,433	818
1954	155	796	584	1,535	818
1955	158	975	518	1,651	835
1956	161	1,052	559	1,772	835
1957	164	1,091	643	1,898	717
1958	167	1,166	688	2,021	717
1959	170	1,143	839	2,152	817
1960	173	1,221	896	2,290	817
1961	176	1,171	1,087	2,434	817
1962	179	1,285	1,115	2,579	917
1963	182	1,344	1,165	2,691	917
1964	185	1,403	1,217	2,805	917
1965	189	1,318	1,407	2,914	917
1966	193	1,212	1,617	3,022	875
1967	197	1,258	1,678	3,133	875
1968	202	1,425	1,619	3,246	1,235
1969	206	1,470	1,671	3,347	1,235
1970	211	1,420	1,815	3,446	1,662
1971	215	1,647	1,672	3,534	2,470
1972	220	1,832	1,564	3,616	2,879
1973	225	1,985	1,486	3,696	3,287
1974	230	2,074	1,472	3,776	4,047
1975	237	2,115	1,517	3,869	4,756
1976	245	2,315	1,412	3,972	4,864
1977	255	2,357	1,470	4,082	5,621
1978	265	2,378	1,408	4,051	6,027
1979	275	2,821	1,610	4,706	6,486
1980	285	3,131	1,732	5,148	6,952
1981	295	3,428	1,863	5,586	7,460
1982	304	3,711	1,990	6,005	7,975
1983	312	6,684	3,540	10,536	8,494
1984	321	6,774	3,543	10,638	9,000
1985	330	6,136	3,175	9,641	9,516
1986	339	5,444	2,773	8,556	9,971
1987	348	5,543	2,757	8,648	10,379
1988	357	6,349	3,151	9,857	10,914
1989	366	7,345	3,282	10,993	10,752
1990	375	7,804	3,855	12,034	11,252
1991	385	8,321	4,291	12,997	11,552
1992	394	8,853	4,597	13,844	12,591
1993	403	9,624	4,807	14,834	12,758
1994	413	9,191	4,510	14,114	13,537
1995	423	9,484	4,756	14,663	13,109
1996	434	9,838	4,934	15,206	12,696
1997	445	10,110	5,170	15,725	12,576
1998	456	10,368	5,358	16,182	12,317
1999	468	10,701	5,475	16,644	11,818
2000	480	10,770	5,826	17,076	12,003
2001	482	11,077	5,895	17,454	11,425
2002	485	11,246	6,069	17,800	11,178
2003	487	11,314	6,289	18,090	11,053
2004	489	11,263	6,587	18,339	10,987
2005	491	11,383	6,661	18,535	10,738
2006	492	11,393	6,784	18,669	10,464
2007	494	11,102	7,156	18,752	10,724
2008	495	10,921	7,352	18,768	11,093
2009	496	10,803	7,414	18,713	10,825
2010	496	10,621	7,449	18,566	10,540

Appendix Table A2. Total reconstructed catch by taxa.

Year	Yellowfin tuna	Skipjack tuna	Sardines	Anchovies	Jacks	Others
1950	477	99	120	44	69	334
1951	463	98	233	43	67	332
1952	396	95	386	47	74	333
1953	479	117	313	58	90	376
1954	516	126	337	62	96	397
1955	701	159	179	66	102	445
1956	754	173	193	71	110	470
1957	735	186	242	89	138	508
1958	783	201	258	95	148	535
1959	735	189	485	89	139	515
1960	782	204	518	95	148	542
1961	714	183	829	81	126	500
1962	788	209	785	96	150	552
1963	821	221	821	101	157	572
1964	857	231	857	105	163	592
1965	759	206	1,188	87	136	538
1966	673	175	1,616	48	74	436
1967	695	185	1,677	49	77	450
1968	822	225	1,479	73	113	535
1969	845	235	1,526	75	116	550
1970	732	202	1,557	195	195	565
1971	865	249	1,209	134	269	808
1972	1,072	319	1,062	118	236	809
1973	1,235	379	950	106	211	815
1974	1,249	397	876	88	219	947
1975	1,269	432	916	76	191	984
1976	1,423	552	766	77	192	963
1977	1,386	607	817	68	170	1,033
1978	1,383	675	754	63	157	1,019
1979	1,607	870	840	68	178	1,142
1980	1,742	1,039	881	70	189	1,227
1981	1,855	1,213	936	71	199	1,312
1982	1,950	1,392	987	79	207	1,391
1983	3,404	2,643	1,733	144	361	2,250
1984	3,345	2,816	1,720	138	355	2,265
1985	2,932	2,668	1,526	117	313	2,084
1986	2,525	2,479	1,327	99	264	1,862
1987	2,498	2,638	1,288	96	256	1,873
1988	2,760	3,134	1,471	113	287	2,092
1989	3,283	3,756	988	494	494	1,978
1990	3,441	3,938	1,036	1,036	518	2,065
1991	3,626	4,149	1,092	1,310	546	2,274
1992	4,000	3,906	1,068	1,068	534	3,268
1993	4,712	3,972	1,131	984	566	3,470
1994	4,643	3,408	1,012	881	506	3,664
1995	4,799	3,615	1,086	978	543	3,642
1996	4,941	3,828	1,163	1,047	570	3,656
1997	4,954	3,951	1,215	1,093	571	3,941
1998	4,987	4,103	1,277	1,149	600	4,066
1999	5,112	4,347	1,300	1,163	616	4,105
2000	4,928	4,339	1,452	1,313	691	4,353
2001	5,040	4,605	1,486	1,263	743	4,318
2002	4,993	4,743	1,549	1,317	775	4,424
2003	4,861	4,816	1,593	1,433	796	4,591
2004	4,682	4,850	1,868	1,543	812	4,583
2005	4,554	4,954	1,680	1,596	1,008	4,742
2006	4,410	5,053	1,737	1,650	1,042	4,776
2007	4,033	4,890	1,958	1,873	1,107	4,891
2008	3,621	4,667	1,894	1,812	1,071	5,704
2009	3,413	4,705	1,935	1,851	1,094	5,714
2010	3,185	4,728	1,972	1,886	1,114	5,680

Le Développement Soutenu de Pêcheries Artisanales : Reconstruction des Captures Marines à Djibouti de 1950 à 2010*

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Extended abstract

This study is part of the *Sea Around Us* and consists of a 'reconstruction' of the likely total fisheries catch (i.e., domestic and foreign catch) made in Djibouti's waters from 1950 to 2010, as well as catches by fishers from Djibouti in foreign waters. This reconstructed time-series contrasts with official catches reported to the Food and Agriculture Organization of the United Nations (FAO) by Djibouti, which were found to be incomplete and misleading. Indeed, failed to account for several sectors such as discards, subsistence and recreational fisheries, or illegal catches by foreign fleets.

The reconstruction of Djibouti's marine fisheries catches over the 1950–2010 period overlapped with the development of Djibouti's artisanal sector and allowed us to account for the aforementioned missing sectors. A thorough bibliographic research on fisheries in Djibouti was carried out, and 'anchor points' required for estimating historical catches were then identified (Pauly 1998), similar to other reconstructions made around the world (see, e.g., Zeller and Pauly 2007; Zeller and Harper 2009; Harper and Zeller 2012; Harper *et al.* 2013). We separated our analysis into three sections: Djibouti's catch within its own Exclusive Economic Zone (EEZ), Djibouti's catch outside its EEZ, and finally, foreign catches within Djibouti's EEZ.

Our results show that FAO data contained several inconsistencies. Artisanal catches for the pre-independence period appeared to be too high given the low number of fishers and fishing practices at that time. For the post-independence period, our reconstruction was based on data provided by the *Département de la Pêche* (Department of Fisheries) — deemed to better reflect Djibouti's fisheries trends — which also substantially differed from those published by FAO. Our reconstruction also included crude estimates for previously unaccounted sectors, which enabled us to produce a more realistic picture of the overall catch within Djibouti's EEZ and in foreign waters. Most notably, we identified that 25% of the total artisanal catches were not declared. In addition, we identified and estimated a small subsistence fishery that was never accounted for in official statistics, similarly to other sectors such as an holothurian fishery, artisanal discards, and a recreational fishery by tourists and residents.

We also estimated catches made outside Djibouti's EEZ, mostly in Somalia. Illegal foreign fisheries, mostly from Yemen (but also Somalia to a lower extent), were also estimated.

Finally, we also improved the taxonomic composition of catches during the early time-period using FAO's breakdown in more recent years.

Overall, our total reconstructed catches (mostly composed of inshore species such as Serranidae, Lutjanidae, Carangidae, and Lethrinidae) are roughly similar to total catches reported to FAO, but annual catches are wildly different, especially in the earlier time-period. Before the independence in 1977, we estimated that catches increased from 130 $t \cdot year^{-1}$ to almost 300 $t \cdot year^{-1}$, due to an increase in the number of fishers. Afterward, the annual catch quickly increased to 1,000 t by the end of the 1980s, thanks to the development of a real fisheries vision by the national authorities. Catches steeply decreased in the mid-1990s due to the Civil War, but then steadily increased again to reach around 1,300 $t \cdot year^{-1}$ in the 2000s.

This report also provide some evidence of overexploitation, and we recommend to improve the data collection scheme and statistical framework in Djibouti, in order to better monitor domestic and foreign fisheries and thus ensure a sustainable use of marine resources.

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Résumé

Cette étude menée dans le cadre du *Sea Around Us* avait pour objectif de reconstruire les captures effectuées dans les eaux de Djibouti et pas les pêcheurs djiboutiens en dehors des eaux nationales, afin de les comparer aux captures déclarées à la FAO. Cette étude a recoupé le développement de la pêcherie artisanale djiboutienne, et nos résultats montrent que les captures artisanales déclarées au programme des Nations Unies pour l'alimentation et l'agriculture (FAO) avant l'indépendance sont trop élevées par rapport au nombre de pêcheurs et aux pratiques de l'époque. Pour la période post-indépendance, nous avons estimé que l'équivalent de 25% des captures artisanales déclarées ne l'étaient pas. Nous avons également mis en évidence une pêche de subsistance non-déclarée, mais relativement faible (2% du total déclaré). D'autres secteurs ont aussi été inclus, tels que la pêche non-déclarée d'holothuries, les rejets de la pêche artisanale, et la pêche récréative. Les captures totales effectuées dans la ZEE djiboutienne sont en fin de compte relativement proches de celles déclarées par Djibouti à la FAO, mais les captures annuelles sont très différentes. Nous avons également estimé les captures artisanales djiboutiennes faites en dehors de la ZEE nationale (principalement en Somalie). Enfin, nous avons estimé les pêches illégales étrangères en provenance du Yémen, mais aussi de Somalie. Ces résultats montrent qu'il est aujourd'hui nécessaire de mieux surveiller les activités de pêche à Djibouti afin d'améliorer la collecte des données et ainsi garantir une gestion durable des ressources.

Introduction

La République de Djibouti ('Djibouti' sera utilisé par la suite) est un petit pays d'Afrique de l'Est situé au nord de la Somalie, face au Yémen. Il occupe une position stratégique à la jonction de deux grands ensembles maritimes, le golfe d'Aden et la Mer Rouge, reliés par le détroit de Bab-el-Mandeb (Figure 1). Cette position stratégique entre la Mer Rouge et l'Océan Indien en a fait un point de contrôle essentiel pour les intérêts commerciaux et militaires français avant l'indépendance en 1977 (Devinat 1957). Ces intérêts n'ont pas limités à la France, et on y trouve encore aujourd'hui des bases militaires américaines, japonaises, et autres.

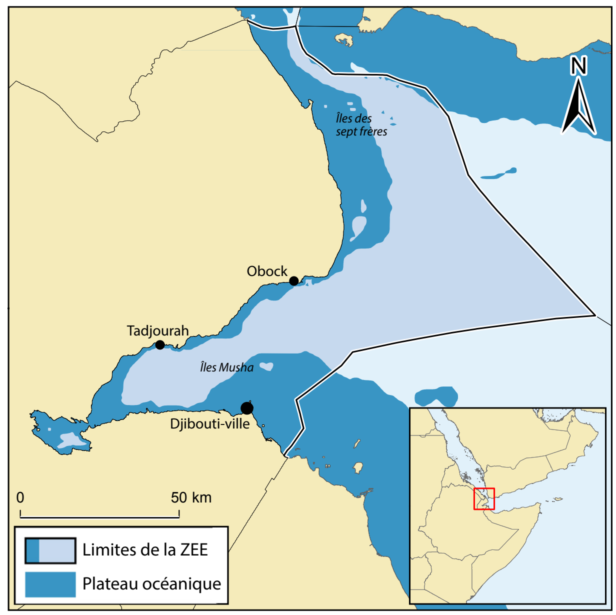

Figure 1. Carte de la ZEE de Djibouti, montrant l'étendue du plateau océanique (bleu foncé) et de la Zone Exclusive Économique (ZEE), ainsi que les principales villes côtières de Djibouti-ville (capitale), Tadjourah et Obock.

L'espace maritime sous juridiction djiboutienne s'étend environ 7 200 km² dont 2 500 km² de plateau continental (parmi les plus modestes du continent africain, avec une largeur moyenne estimée à 8 km ; El Gharbi 1987 ; Bouhlel 1988 ; Hosch 2010). Ce plateau est fortement développé au Nord et au Sud de la bande côtière, et est plus étroit à l'intérieur, atteignant tout au plus 1,5 km de largeur à certains endroits. Il recouvre en grande partie le golfe de Tadjourah, où la grande vallée du rift s'enfonce dans la mer, et la rive sud du golfe s'étire jusque dans les eaux somaliennes, alors que la rive nord se prolonge par une longue plaine (Bouhlel 1988). Des récifs coralliens son présents sur presque toute la bande côtière et le pourtour des îles attenantes, jusqu'à une profondeur de 20–30 m. Au-delà, on observe un fond en pente douce couvert de sable et/ou de vase (Bouhlel 1988 ; Hosch 2010).

La structure hydrologique est conditionnée par l'opposition de deux masses d'eau : celle du Golfe d'Aden dans la couche supérieure, et celle plus profonde originaire de la Mer Rouge. La température en surface est d'environ 31°C en été et 26°C en hiver ; en profondeur, la température la plus basse observée était de 15°C vers 600 m (Allain 1974). Le régime des vents influence fortement la situation en surface, et conditionne la profondeur de la thermocline (20–30 m en été et autour de 100 m en hiver), la quantité d'oxygène dissous, ainsi que la salinité. Ces paramètres influent sur le comportement des espèces et les saisons de pêche (Abbes 1985). La saison sèche qui s'étend de juillet à août est caractérisée par des vents (*Khamsiin*) allant jusqu'à sept sur l'échelle de Beaufort, entrecoupée de tempêtes sporadiques empêchant les sorties en mer. Entre les mois de novembre et mars apparaît souvent une houle allant jusqu'à cinq Beaufort (particulièrement dans le Nord), freinant également les activités de pêche (Künzel *et al.* 1996a). Les principales saisons de pêche sont donc comprises entre avril-début juin et août-octobre (El Gharbi 1987 ; Künzel *et al.* 1996a).

Les récifs coralliens sont les écosystèmes côtiers les plus représentatifs à Djibouti, mais il existe également un réseau important de lagunes, mangroves et herbiers sous-marins (El Gharbi 1987). Les fonds sont productifs jusqu'à une profondeur de 70 m, la faune se raréfiant au-delà (Allain 1974). L'étendue du plateau continental aux extrémités nord (notamment autour des îles des Sept Frères ; El Gharbi 1987) et sud du pays permet la présence de stocks importants de poissons démersaux. La région nord jouît également de conditions très favorables avec la présence des eaux froides de la mer d'Arabie engendrant une forte production primaire et une abondance des petits pélagiques. De même, dans le golfe de Tadjourah, la remontée de la thermocline pendant l'été est suivie d'une explosion de la production primaire stimulant ainsi la production des stocks pélagiques. La descente de la thermocline en hiver réduit l'activité planctonique et entraîne le départ vers d'autres régions de la majorité des stocks associés (Bouhlel

1988). Ainsi, une grand diversité d'espèces est pêchée (Bouhlel 1988). Les taxons les plus importants sont ceux des grands démersaux nobles (Acanthuridae, Balistidae, Epinephelinae, Haemulidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, et Sparidae) et les grands pélagiques (Carangidae, Carcharhinidae, Coryphaenidae, Istiophoridae, Scombridae, Sphyraenidae, Sphyrnidae, et Xiphiidae). Des stocks de *Sepia* spp. (seiches), *Loligo* spp. (calmars), *Holothuria* spp. et *Actinopyga palauensis* (holothuries), et crustacés (crevettes, cigales, langoustes et crabes), présentent également un intérêt (Hosch 2010). Les petits pélagiques (Carangidae, Clupeidae, et Scombridae) et les petits démersaux restent quant à eux majoritairement inexploités par la flotille djiboutienne (Künzel *et al.* 1996a ; Morgan 2006).

Traditionnellement, la pêche a toujours été faible à Djibouti, et le poisson semble peu consommé par la population (Bjoerklund et Walter-Dehnert 1983). La tradition des Afars et des Issas, les ethnies premières de Djibouti, est plutôt pastoraliste que maritime (comme en Somalie ; cf. Persson *et al.* ce volume). Le développement de cette activité a principalement été dû aux Yéménites qui fréquentaient saisonnièrement la côte africaine et qui, pour certains, se sont installés sur le territoire au moment de sa colonisation par la France. C'est à partir de ces populations yéménites fixées sur le territoire depuis deux ou trois générations que s'est constituée la première communauté de pêcheurs de Djibouti (Moal et Grateau 1967 ; Clouet 1970 ; Rouaud 1997). Par la suite, la pêche s'est développée dans la partie sud du pays majoritairement peuplée par les Issas, rattachés au groupe ethnique Somali et profondément influencés par les Arabes. Les Afars, peuplant majoritairement le Nord du pays, sont restés plus longtemps tournés vers la terre et négociaient des droits de pêche avec les Yéménites venus sur la côte (Clouet 1970). Durant la période coloniale, l'activité de pêche est restée peu développée avec un faible nombre de pêcheurs, peu de moyens, et une volonté du gouvernement français portée en premier lieu sur l'exploration du domaine maritime (Moal et Grateau 1967 ; Allain 1974). Suite au gain de l'indépendance en 1977, le gouvernement djiboutien a souhaité développer cette activité afin d'exploiter pleinement son potentiel halieutique, créer des richesses et améliorer la sécurité alimentaire du pays. Cette volonté s'est traduite par la réalisation de projets de soutien au développement des activités de pêche, financés par plusieurs instances internationales. L'objectif était le développement d'une pêcherie exclusivement artisanale et nationale (Waldstein et Lampe 1988 ; Darar 1994 ; Morgan 2006). La pêche industrielle a donc toujours été formellement interdite au sein des eaux djiboutiennes, les seuls bateaux autorisés à la pêche (inférieurs à 16 m et sans chalut de fond) devant posséder une licence accessible aux seuls citoyens djiboutiens (Künzel *et al.* 1996a ; Darar et Hosch 2010). De manière générale, la pêche est donc longtemps restée un travail à temps partiel dû aux revenus faibles et moyens de production limités, et a gardé sa nature artisanale, étant pratiquée en zone côtière avec de petites embarcations. Entre 1982 et 1986, plus de 60% de la production nationale étaient réalisés par l'Association Coopérative de Pêche Maritime (ACPM) située à Djibouti-ville. En 1986, 14 patrons pêcheurs sur 165 débarquant à l'ACPM produisaient 56% des captures avec 35% des sorties en mer. Les zones de pêche étaient principalement concentrées au Sud (seulement 2% des captures de l'ACPM dans le Nord), et l'activité à terre était concentrée à Djibouti-ville avec du matériel au potentiel limité (El Gharbi 1987). L'activité s'est par la suite développée et professionnalisée au cours des années 90 et 2000 avec des projets de soutien et l'arrivée de nouveaux opérateurs (Künzel *et al.* 1996a ; Emerton 1998 ; Hosch 2010). Les moyens de production et équipements se également sont améliorés, permettant d'exploiter les zones au Nord du pays à fort potentiel (El Gharbi 1987), et représentant 77% des captures totales en 2010 (Direction de la Pêche).

Les sorties en mer ne dépassent jamais 72 heures, et se font le plus souvent à la journée selon les marées et les vents. Elle a peu changé au cours des années bien qu'ayant connu des progrès technologiques depuis les années 50 (apparition du monofilament et des moteurs hors-bords, par exemple). Les principaux types sont la pêche à la ligne (palangrotte) visant les démersaux, la ligne de traîne visant les pélagiques, et accessoirement le filet maillant (El Gharbi 1987 ; Künzel *et al.* 1996a). Ils se pratiquent depuis des embarcations, les *houris*, pouvant contenir deux à trois hommes pour les petits bateaux (six à huit mètres) et cinq pour les plus grands (10–14 mètres). La pêche se pratique également à pied sur le plateau madréporique avec l'utilisation d'éperviers (pour la pêche à la crevette notamment), de filets, et également la pêche en apnée (en particulier pour la pêche à la langouste ; Clouet 1970 ; Moal et Grateau 1967 ; Künzel *et al.* 1996a). Cette pêche à pied est supposée de faible envergure,et ne constituerait qu'une petite activité annexe ou de subsistance (Künzel *et al.* 1996a ; Morgan 2006).

Les séries statistiques publiées par l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) sont souvent incomplètes de par leur non prise en compte de plusieurs secteurs tels que la pêche de subsistance et la pêche récréative. Ici, nous proposons de reconstruire les captures déclarées à la FAO par Djibouti depuis 1950 afin d'en améliorer la qualité et la lecture, notamment par la réestimation des secteurs manquants, ainsi que la ré-allocation des captures aux différents secteurs..

Matériels et Méthodes

Les données servant de base au travail présenté ici ont été extraites de la base de données FAO FishstatJ (FAO 2012). Elles correspondent aux données de captures déclarées par Djibouti de 1950 à 2010. Une recherche bibliographique portant sur les pêches dans les eaux djiboutiennes a ensuite été effectuée afin d'en comprendre et compléter le contenu. Des 'points d'ancrage', requis pour l'estimation des captures historiques depuis 1950 (Zeller et Pauly 2007), ont ensuite été identifiés. Nous avons séparé notre analyse en trois composantes : l'étude des captures de Djibouti à l'intérieur de sa ZEE, celle des captures de Djibouti à l'extérieur de sa ZEE, et enfin celle des captures étrangères dans la ZEE djiboutienne.

Reconstruction des captures djiboutiennes à l'intérieur de la ZEE nationale

Captures déclarées de la pêche artisanale djiboutienne

Nous avons dissocié deux périodes pour la reconstruction des captures déclarées de la pêche artisanale djiboutienne : les périodes (i) pré-indépendance de 1950 à 1977, et (ii) post-indépendance de 1978 à 2010. La période pré-indépendance est caractérisée par une très faible disponibilité d'informations. Cependant, l'ensemble des éléments trouvés dépeignent une pêche peu développée avec peu de pêcheurs (Moal et Grateau 1967 ; Moal 1969 ; Clouet 1970), contredisant clairement les données FAO présentant des captures relativement hautes entre 1950 et 1963.[1] La période post-indépendance est caractérisée par plus de données, notamment de la Direction de la Pêche (branche du gouvernement chargée du suivi et contrôle des pêches dans le pays).[2]

- Période pré-indépendance

Nous avons reconstruit les captures de cette période en utilisant le nombre de pêcheurs présents dans la ville de Djibouti, à savoir, 107 en 1951 et 150 en 1967 (Moal et Grateau 1967). Ces deux valeurs ont constitué nos points d'ancrage pour le calcul des captures de la pêche artisanale entre 1950 et 1977. Nous disposions également des captures annuelles par pêcheur, calculées entre 1982 et 1986 pour l'ACPM (El Gharbi 1987). Afin d'uniformiser nos méthodes de calcul avec celles développées par El Gharbi (1987) et utilisées pour le calcul des captures de la pêche artisanale entre 1982 et 1986 (reprises par la Direction de la Pêche ; cf point suivant), nous avons considéré que ces deux valeurs du nombre de pêcheurs correspondaient au nombre total de pêcheurs à Djibouti-ville, et divisé ces valeurs par 1,5 (i.e., le nombre moyen de pêcheurs par équipage). De cette manière, nous avons obtenu le nombre de 'patrons pêcheurs', que nous avons par la suite multiplié par une valeur constante de prise annuelle par pêcheur égale à environ 1 285 kg·année^{-1}·pêcheur^{-1} (i.e, les deux-tiers de la moyenne des captures annuelles par pêcheur sur la période 1982–85).[3] Ainsi, nous avons considéré que la prise par pêcheur dans les années 50 et 60 était inférieure de un tiers à celle effectuée au début des années 80, reflétant les progrès techniques substantiels entre les deux périodes et une dynamique plus active de la filière (cf. Introduction). D'autre part, nous avons également ajouté aux captures obtenues 5% (poids des viscères) et 7,9% (captures dans les autres localités ; i.e., la moitié de la proportion observée en 1986 pour traduire le faible développement de la pêche dans le Nord ; El Gharbi 1987). Nous avons ensuite interpolé linéairement (extrapolé pour l'année 1950) les captures entre nos deux point d'ancrages en 1951 et 1967, puis entre 1967 et la moyenne des captures en 1978–79.

Selon plusieurs auteurs, ces captures comprenaient plusieurs espèces telles que les mérous, carangues, barracudas, thons, bonites, maquereaux royaux et langoustes (que l'on retrouve dans les débarquements récents), mais également les mulets, aiguillettes, et sardinelles, très peu ciblés de nos jours (Moal et Grateau 1967 ; Clouet 1970). Il semblerait donc que les espèces débarquées aient changé au cours du temps, les captures se concentrant de plus en plus sur les poissons de grande taille grâce aux progrès technologiques et au développement de la pêche professionnelle (Darar 1994). De plus, plusieurs petits types de pêche existaient à l'époque, tels que la pêche à la nacre (*Pinna* spp. ; pratiquée principalement par les érythréens sur le récif des îles Musha et dont le marché très limité disparut à la fin des années 70), ou la pêche au corail (vendu aux touristes ; Clouet 1970). Cependant, les informations concernant la composition taxonomique et son évolution au cours du temps restant extrêmement limitées, nous avons décidé de conserver la composition taxonomique présente dans les données rapportées à la FAO de 1983 à 1987, comme pour le début de la période post-indépendance.

- Période post-indépendance

Pour cette période, la Direction de la Pêche nous a fourni la série de données des captures nationales de la pêche artisanale, que nous avons substituée aux données de la FAO (considérées comme moins représentatives/précises) pour le tonnage. La série de la Direction de la Pêche ne comportait cependant aucune résolution taxonomique. De la même manière que pour la période pré-indépendance, nous avons donc utilisé la composition des données déclarées à la FAO de 1983 à 1987.[4]

Secteurs non-déclarés

Plusieurs secteurs n'ont jamais été pris en compte dans l'estimation des captures djiboutiennes. Tout d'abord, une partie des captures réalisées par la pêche artisanale djiboutienne était et est toujours non-déclarée à la Direction de la Pêche. Cette pêche artisanale produit également des rejets non comptabilisés. Une pêche de subsistance a également existé depuis longtemps, pratiquée par quelques pêcheurs de la capitale et dans d'autres régions (Morgan 2006 ; Direction de la Pêche, données non publiées). Enfin, la pêche récréative, de plus en plus importante, prélève également nombre d'espèces marines sans suivi adéquat.

[1] A noter que l'intégralité des données FAO pour la période pré-indépendance est constituée du groupe générique 'marine fishes nei'.

[2] Les données déclarées par Djibouti ont été corrigées par la FAO pour la période 1983–91 (estimations basées sur 70% de la production officiellement déclarée ; FAO 1991). Il en est de même pour la période 1992–2004, où les données de la FAO correspondent à des estimations dont les méthodes de calcul ou sources ne sont pas précisées (FAO 2012).

[3] Nous avons exclu l'année 1986 de ces calculs car elle a connu une augmentation de la production à l'ACPM due à une nette amélioration de l'efficacité de pêche (El Gharbi 1987).

[4] Entre 1979 et 1982, les données publiées par la FAO incluent déjà *Panulirus* spp.. Ces captures rapportées ont donc été soustraites aux captures ré-estimées à partir de la composition taxonomique de 1983 à 1987.

- La pêche artisanale non-déclarée

Ce secteur équivaut à un pourcentage non négligeable des captures déclarées (Künzel *et al.* 1996a ; Emerton 1998 ; Hosch 2010). Ce phénomène est ancien, et a été causé par un développement lent de la pêche artisanale et de la filière associée (e.g., infrastructures de conservation, commercialisation), et donc de son contrôle (Clouet 1970 ; Abbes 1985 ; Darar 1994 ; Morgan 2006). Les captures non-déclarées sont en partie débarquées et vendues à Djibouti en dehors des circuits contrôlés (e.g., restaurateurs). Elles sont également données aux personnes qui aident lors du débarquement, gardées pour auto-consommation, ou jetées à cause d'une mauvaise conservation par les pêcheurs (dans le cas de l'ACPM, cette dernière cause a été estimée à 5% des captures en 1986, El Gharbi 1987 ; aussi estimée hypothétiquement à 25% des captures artisanales, Emerton 1998). El Gharbi (1987) a inclus une partie de ces pratiques (pour l'ACPM seulement, soit 3% des captures artisanales déclarées) dans ses estimations des captures artisanales nationales reprises par la Direction de la Pêche. De plus, des débarquements de pêcheurs basés à Obock et sur la côte Nord se faisaient et font toujours au Yémen (marché plus attractif, accès au carburant fortement détaxé, et proximité des points de débarquements). Enfin, une grande partie de la pêche se faisait hors contrôle, étant donné que nombre de pêcheurs artisanaux ne possédaient pas de licence. En effet, la mise en place de licences n'a eu lieu qu'en 2008 (Hosch 2010), et sont aujourd'hui délivrées aux propriétaires de bateaux (les pêcheurs non propriétaires se voyant également attribuer des cartes. Les captures de cette pêche artisanale non-déclarée correspondraient à 20–30% des déclarations officielles (e.g., Künzel *et al.* 1996a). Nous avons donc utilisé une valeur de 25% de données non-déclarées pour l'ensemble de la période 1950–2010.

Les espèces concernées par cette pêche non-déclarée semblent similaires à celles dont la capture est déclarée, même s'il semblerait qu'il existe quelques différences. Par exemple, plusieurs groupes seraient plus particulièrement visés : les requins (principalement des Carcharhinidae ; Anon. 2011) et les Mugilidae (pêche à l'épervier au Sud; Direction de la Pêche). Les petits pélagiques (e.g., Clupeidae, principalement *Sardinella longiceps*), complètement absents des débarquements déclarés, seraient également concernés. Il n'y a cependant jamais eu de marché intérieur pour ces derniers, et à part leur utilisation comme appâts, leur pêche est donc restée faible (Bouhlel 1988 ; Hosch 2010 ; Künzel *et al.* 1996a).[5] A cause du manque d'information flagrant sur ces captures non-déclarées, nous avons repris donc l'allocation taxonomique utilisée pour la pêche artisanale déclarée.

Enfin, une exploitation récente des holothuries est également présente à Djibouti (Hosch 2010). Ce phénomène est commun à de nombreux pays est-africains, en réponse à une très forte demande du marché asiatique (Hosch 2010 ; Le Manach *et al.* 2011). Les données publiées par la FAO ne contiennent pas d'holothuries ; nous avons donc utilisé les données fournies par la Direction de la Pêche (Tableau 1 ; pêche non-rapportée).

Tableau 1. Captures des différentes espèces d'holothuries en t.

Taxon	1996	1997	1998	1999	2000	2001	2002	2003	2004
Holothuria scabra	15,0	18,0	17,0	16,0	15,0	16,0	12,0	5,0	2,0
H. fuscogilva	0,0	0,0	5,0	6,0	7,0	8,5	6,0	5,0	1,0
H. nobilis	0,0	0,0	0,2	0,3	0,3	0,5	0,3	0,1	0,1
Actinopyga palauensis	2,0	5,0	10,0	12,0	14,0	12,0	13,0	11,0	7,0
H. atra	5,0	12,0	25,0	24,5	24,0	26,0	25,0	16,0	15,0
Total	**22,0**	**35,0**	**57,2**	**58,8**	**60,3**	**63,0**	**56,3**	**37,1**	**25,1**

- Rejets de la pêche artisanale

Les rejets de la pêche artisanale ne semblent pas importants à Djibouti, n'étant mentionnés dans aucune étude. Cependant, l'utilisation d'engins de pêche tels que le filet maillant entraîne souvent la capture d'espèces accessoires ou de petite taille (Kelleher 2005 ; Anon. 2010), généralement non débarquées. Il semble en effet peu probable que les pêcheurs gardent l'ensemble de ces captures comme appâts, et nous avons donc supposé que ces captures (estimée de manière tentative à 1% de la pêche artisanale totale (rapportées + non-rapportée) sur l'ensemble de la période)[6] étaient rejetées. Étant donné les faibles tonnages, nous avons simplement alloué ces rejets au groupe générique 'poissons de fond'.

- La pêche de subsistance

La pêche de subsistance a toujours été considérée comme étant faible, bien que pouvant être importante à une échelle locale (Darar 1994 ; Morgan 2006 ; Hosch 2010). Elle a historiquement été pratiquée par quelques pêcheurs de Djibouti-ville et des autres régions côtières. Ces pêcheurs opèrent sur le plateau madréporique à l'aide de lignes à main ou de harpons, et ne possèdent généralement pas de bateaux (Morgan 2006 ; Hosch 2010). Aucune estimation de l'ensemble de la pêche de subsistance n'existe, mais ses caractéristiques se rapprochent d'un pays tel que la Mauritanie. En effet, à Djibouti comme en Mauritanie, il n'y a à l'origine pas de tradition de pêche, mais une tradition pastorale tournée vers la terre. La pêche de subsistance y a été estimée à 2% de la pêche artisanale déclarée (Belhabib *et al.* 2013), et il nous a semblé réaliste d'appliquer une valeur similaire pour Djibouti sur l'ensemble de la période étudiée.[7] Ne possédant pas d'information quantitative, nous avons également alloué ces captures de subsistance au groupe générique 'poissons de fond'.

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[5] Il y aurait eu quelques tentatives d'exportation à destination de l'Ethiopie, où le marché était plus ouvert (Morgan 2006). Morgan (2006) estimait également que 10 à 15% des débarquements étaient des petits pélagiques (sources et/ou méthodes de calcul non précisées), ce qui semble grandement surestimé étant donné les informations collectées sur l'ensemble de la période.

[6] Cette proportion de rejets correspond à un taux de rejet moyen pour la petite pêche côtière des pays en voie de développement (Kelleher 2005 ; Anon. 2010).

[7] La Somalie est également un pays côtier à tradition pastoraliste, et beaucoup plus proche géographiquement que la Mauritanie. Cependant, la méthode employée par Persson *et al.* (ce volume) n'a pas pu être appliquée ici pour cause de manque de données concernant le nombre de bateaux.

- La pêche récréative

La pêche récréative semble encore peu développée et aucune étude concrète n'a encore été réalisée à ce sujet. En 2008–09, trois licences ont été octroyées à des entreprises de pêche sportive (Hosch 2010). Le système des licences fait également état de personnes possédant une licence de pêcheur non-commercial (i.e., pêchant de manière récréative principalement le week-end) au nombre de 60 en 2008 et 50 en 2009 (Hosch 2010). Enfin, il existe également des clubs de pêche au sein des bases militaires étrangères, comme l'ASAC Pêche de Djibouti pour l'armée française. Pour estimer les captures associées à ces trois types de pêches récréatives, nous avons procédé de plusieurs manières.

Concernant la pêche sportive et les entreprises touristiques associées, nous avons pris contact avec la seule entreprise proposant des séjours de pêche à Djibouti pour les touristes étrangers ('Mémoire d'un Fleuve' ; www.memoiredunfleuve.com). Cette entreprise a commencé son activité en 2001 et est active 20 semaines par an d'avril à fin juin, puis d'octobre à début novembre. La pratique de pêche est le *no kill*, c'est-à-dire qu'il y a remise à l'eau systématique des individus pêchés. Cependant, le responsable nous a indiqué que les guides sur place gardaient généralement un ou deux gros *Scomberomorus commerson (*thazards rayés) pêchés chaque semaine, soit environ 25 kg. Nous avons donc estimé que ce type de pêche récréative capturait 0,5 t de thazard par an (20 x 25 = 500 kg) depuis 2001. Il existe également des hôtels, structures de vacances qui proposent des activités pêche, mais nous ne possédions aucun renseignement précis sur ces acteurs. Nous avons donc considéré que les 500 kg de thazards pêchés annuellement représentaient la moitié des captures de 'Mémoire d'un Fleuve' (l'autre moitié étant allouée au groupe générique 'poissons pélagiques'), et que les autres sources de pêche récréative représentait deux fois ces captures (toutes attribuées au groupe 'poissons pélagiques').

Concernant les pêcheurs récréatifs locaux pratiquant la pêche le week-end, cette pêche est ancienne de par la présence française pré- et post-indépendance, et sa pratique est concentrée à Djibouti. El Gharbi (1987) mentionnait 612 pêcheurs 'amateurs' autorisés à pêcher en 1987. Cependant, ces chiffrens semblent être très sur-estimés, étant donné que la distinction entre pêcheurs récréatifs et pêcheurs artisans est difficile à faire à cause du faible coût de l'autorisation et la pratique de la pêche artisanale à mi-temps. En 2008, nous avons donc considéré qu'il y avait 55 pêcheurs récréatifs en 2010, suivant les chiffres proposés par la Direction de la Pêche (60 pêcheurs en 2008 et 50 en 2009). Nous avons ensuite estimé le nombre de pêcheurs récréatifs annuels au *pro rata* du nombre d'habitants à Djibouti-ville (Guillaume 1979 ; République de Djibouti).[8] Finalement, nous avons considéré que ces pêcheurs capturaient cinq kilos de 'poissons pélagiques' par sortie, 24 fois par an (i.e., deux week-ends par mois), soit 120 $kg{\cdot}pêcheur^{-1}{\cdot}année^{-1}$.

Enfin, concernant les clubs de pêche au sein des armées, comme le club ASAC de l'armée française enregistré auprès des Clubs Sportifs et Artistiques de la Défense (CSAD).[9] Ces pêcheurs pratiquent également majoritairement la remise à l'eau, mais les guides locaux gardent une partie des poissons lors des sorties. Ainsi, en 2010, 20% des captures d'un voyage de pêche sont allées aux guides (www.youtube.com/watch?v=TAjsjWg6070), soit 0,5 t de 'poissons pélagiques' (V. Cressy, comm. pers.). Nous avons donc inclus les clubs de pêche des armées étrangères dans notre reconstruction en estimant la capture à 0,5 t par an depuis 2000, n'ayant pas plus de détails sur les effectifs historiques de l'ensemble des clubs et les pratiques associées.

Reconstruction des captures djiboutiennes à l'extérieur de la ZEE nationale

Les captures djiboutiennes à l'extérieur de la ZEE nationale sont supposées assez rares, étant donné le bon état des stocks et la petite échelle des activités (Hosch 2010). Cependant, au début des années 80, certains pêcheurs étaient connus pour fréquenter les eaux somaliennes. El Gharbi (1987) estimait que 42% des captures débarquées à l'ACPM en 1986 provenaient de Somalie, soit 30,1% des captures totales de la pêche artisanale déclarée. En 1987, une interdiction de l'accès aux zones somaliennes a été prononcée et a possiblement stoppé le phénomène (El Gharbi 1987) pour quelques temps. Pendant le conflit des années 90, les activités de pêche se sont cependant concentrées dans le sud du pays, engendrant une nouvelle expansion des activités dans la ZEE somalienne (Künzel *et al.* 1996a). Enfin, une pêche dans les eaux somaliennes est pratiquée depuis 2008 par trois *boutres* (>16 m) possédées par l'entreprise 'Red Sea Fishing' (RSF). Ces trois *boutres* ciblent les démersaux nobles avec des nasses et parfois les crevettes au chalut. Ces techniques sont très différentes de celles pratiquées par les autres pêcheurs djiboutiens (Hosch 2010). Les informations fournies par la Direction de la Pêche et l'entreprise RSF font état de 50% des captures de RSF provenant de Somalie pour l'année 2010, avec une répartition par espèce similaire au reste des débarquements. En 2010, RSF représentait 9,12% des captures nationales déclarées. Il existe également un armateur privé, 'Pêcherie de Loyada', qui opère quelques bateaux pêchant presque uniquement dans les eaux somaliennes et débarquant à la frontière.

A partir des données présentées ci-dessus, nous avons estimé les captures faites hors de la ZEE djiboutienne en construisant une série temporelle des captures artisanales provenant des eaux somaliennes (seul pays mentionné pour ces pratiques) à partir des données de pêche artisanale déclarées dans les eaux djiboutiennes. Pour la période pré-indépendance, nous avons considéré que la pêche dans les eaux somaliennes était nulle à cause des faibles moyens techniques et du bon état des ressources halieutiques. Le pourcentage a ensuite augmenté linéairement à partir de 1980 pour atteindre 30,1% en 1986 suite au développement de la pêche artisanale et un accroissement de la fréquentation de ces zones. Nous avons ensuite estimé que cette valeur a été nulle entre 1987 et 2007 suite à

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[8] Ces deux publications nous ont permis de recréer une série temporelle du nombre d'habitants à Djibouti-ville. Une interpolation linéaire a été faite entre les différents points d'ancrage.

[9] Ce groupe existe depuis une dizaine d'année et compte entre 10 et 25 membres selon les années (Vincent Cressy, ex-trésorier ASAC, *comm. pers.*).

l'interdiction de fréquenter les eaux somaliennes, sauf entre 1992 et 1994, où elle a été égale à la moitié de la valeur de 1986 (15,05%). En effet, il nous a semblé raisonnable de considérer une valeur moitié moins importante afin de refléter l'impact du conflit sur l'étalement des zones de pêche. Enfin, pour les années 2008–10, nous avons estimé que le pourcentage des captures hors Djibouti était égal à la moitié du ratio des captures artisanales déclarées par RSF, soit 4,56%. La répartition des captures par famille/espèce pour ces captures est la même que pour la pêche artisanale déclarée dans les eaux djiboutiennes.

Reconstruction des captures étrangères dans la ZEE djiboutienne

La pêche étrangère dans les eaux djiboutiennes est une activité non prise en compte dans les captures totales. Ceci est préjudiciable, car il apparaît que ce phénomène est très important et ancien (Morgan 2006). Des bateaux étrangers (principalement originaires du Yémen, mais aussi de Somalie) y ont pêché depuis les années 50, notamment le long de la côté Nord, où les pêcheurs yéménites "hantaient la côte Nord [...] aux termes d'accords de péage mystérieux" (Pujo 1967). Ces pêcheurs sont mentionnés dans de nombreux travaux (e.g., Allain 1974 ; Künzel *et al.* 1996a ; Morgan 2006), et ont constitué une concurrence mieux organisée, débarquant parfois à Djibouti et submergeant ainsi le marché local (Clouet 1970). Après l'indépendance, ces pratiques ont continué, les capacités de contrôle en mer restant limitées (Morgan 2006). A ce jour, des centaines d'embarcations généralement bien plus importantes que celles utilisées par les djiboutiens continuent d'y prendre part, avec des captures représentant entre 30–35% (Direction de la Pêche, données non publiées) et 50% (Hosch 2010) des captures totales officielles (majoritairement yéménites). Nous avons donc estimé une pêche artisanale étrangère représentant 42,5% des captures totales de la pêche artisanale déclarée sur toute la période. Les flottilles djiboutiennes et étrangères n'ayant pas connu la même vitesse de développement, nous avons utilisé les données de débarquements de la pêche artisanale somalienne (Persson *et al.*, ce volume) et yéménite (Tesfamichael *et al.*, 2012) afin d'ajuster l'allocation des captures à ces deux pays pour l'ensemble de la période étudiée. Nous avons considéré une pêche yéménite représentant 35% sur les 42,5% cités plus haut pour l'année 2010, et estimé les autres années au *pro rata* de l'évolution des débarquements artisanaux calculés par Tesfamichael *et al.* (2012) et Persson *et al.*, (ce volume; au final, ces proportions ont varié de 28,8 à 39,3% de pêche somalienne, et le reste de pêche yéménite). Bien qu'il existe quelques informations sur les espèces ciblés,[10] nous avons gardé ici encore la composition taxonomique de la pêche artisanale.

Résultats et Discussion

Reconstruction des captures domestiques dans la ZEE nationale

Pour la période pré-indépendance, les captures reconstruites sont bien plus faibles que celles publiées par la FAO.[11] Ces données reconstruites offrent une lecture plus juste de l'évolution réelle des pêches à Djibouti, avec une augmentation d'environ 130 à près de 300 t entre 1950 et 1978, liée à l'augmentation

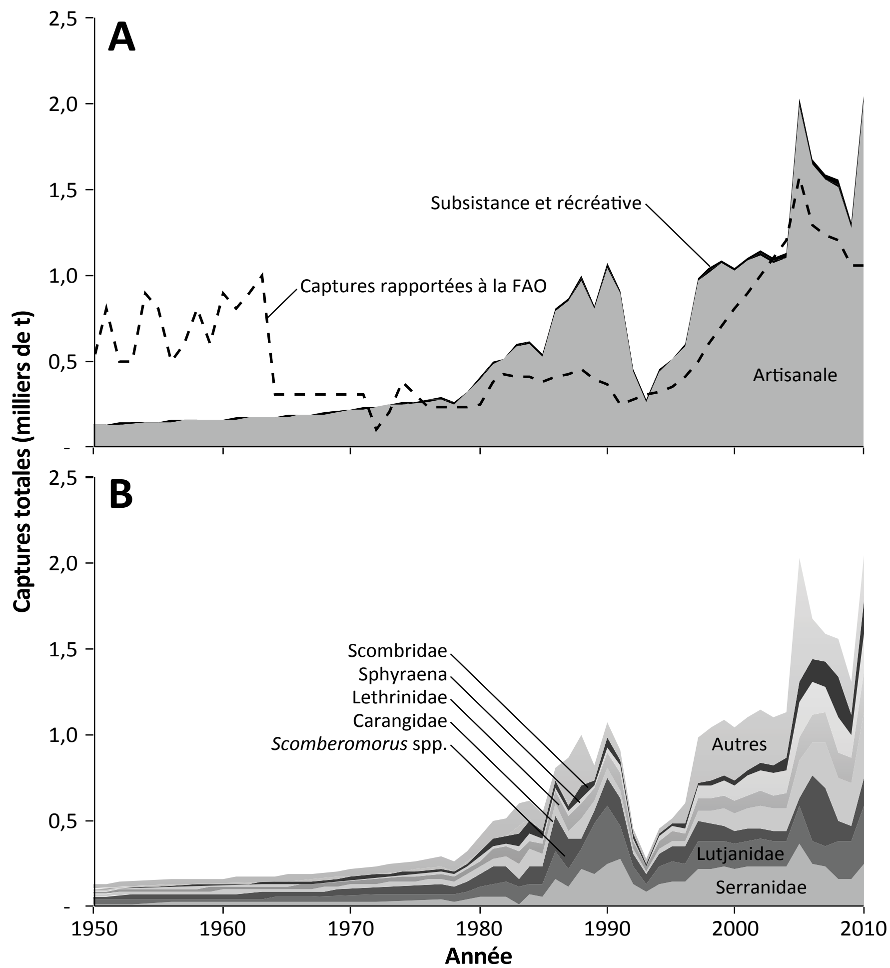

Figure 2. Captures djiboutiennes de 1950 à 2010 dans la ZEE nationale, A) par secteurs et comparées aux données déclarées à la FAO, et B) par taxons pêchés. Voir Tableau Annexe A1 et Tableau Annexe A2 pour plus de détails.

[10] Par exemple, concernant le Yémen, les sardinelles étaient historiquement ciblées dans le Nord de Djibouti par ces opérations (Clouet 1970 ; Allain 1974). Les requins ont également été historiquement ciblés, notamment par la tribu Hakimé durant des campagnes de un ou deux mois (Clouet 1970). Il semblerait que les populations de requins soient maintenant sur-exploitées à cause de cette pêche étrangère, qui s'est par ailleurs intensifiée (Künzel *et al.* 1996a). Ces opérations de pêche cibleraient également de nombreuses autres espèces démersales et pélagiques (Darar et Hosch 2010).

[11] Les données publiées par la FAO (déclarées par la France) restent inexpliquées, nous n'avons pu en trouver ni la source, ni des explications associées.

du nombre de pêcheurs (Figure 2). Pour la période 1950–1967, l'hypothèse forte d'une CPUE constante mais plus faible que pour les années suivantes est justifiée par le progrès technique substantiel entre les deux périodes (e.g., amélioration des bateaux, développement du monofilament) et une dynamique plus active de la filière (El Gharbi 1987 ; Künzel *et al.* 1996a).

La reconstruction de la période post-indépendance a également permis de mieux comprendre les données FAO et de mieux refléter l'évolution des pêches à Djibouti. Les données FAO étaient différentes de celles de la Direction de la Pêche jusqu'en 2005, année à partir de laquelle plus aucune correction n'a été appliquée. Les corrections appliquées entre 1983 et 1991 (i.e., 70% des captures déclarées ; FAO 1991) ne correspondaient pas à 70% des données que la Direction de la Pêche nous a transmises.[12] Les données reconstruites permettent de visualiser les différentes phases de l'évolution de la pêche post-indépendance (Figure 2). Les captures ont rapidement augmenté jusqu'à plus de 1 000 t à la fin des années 80, ce qui a marqué le début d'un engagement réel des pouvoirs publics en faveur du développement de la pêche artisanale avec une amélioration de la qualité de l'intervention et de l'appui des pouvoirs publics. Les captures ont ensuite diminué jusqu'en 1995, ce qui s'explique par les difficultés financières des gérants de la Pêcherie de Boulaos, mais aussi la guerre civile au Nord du pays de 1992 à 1994. Elles ont ensuite augmenté de nouveau jusqu'en 2004 pour atteindre plus de 2 000 t. Durant cette période, les activités de pêche se sont re-développées et les infrastructures de débarquement de la Pêcherie de Boulaos ont été reprises par un opérateur privé. Après une nouvelle baisse, ce niveau a de nouveau été atteint en 2010. Cette dernière période a été caractérisée par (i) l'ouverture des infrastructures de débarquement du port de pêche de Djibouti-ville, financée par la Banque Africaine de Développement (BAD), (ii) la réhabilitation des sites de débarquement d'Obock et de Tadjourah par la Coopération française, et (iii) l'arrivée de nouveaux opérateurs privés. Cette volonté de développement s'est surtout traduite par la concentration des moyens concernant le port de pêche de Djibouti-ville, plus facile à contrôler.

Au final, les captures de la pêche artisanale ont été démultipliées entre 1950 et 2010, sans aucune pêche industrielle. Le développement de la pêche à Djibouti a donc exclusivement focalisé sur les pêcheries artisanales, soutenu par une volonté gouvernementale en plusieurs phases au cours des soixante dernières années.

Nous avons également complètement amélioré la composition taxonomique de ces captures (Figure 2B). Cette nouvelle allocation repose sur les taxons déclarés à la FAO dans le courant des années 80 et met en évidence l'importance des Serranidae (17%), des Lutjanidae (15%), des *Scomberomorus* spp. (13%), des Carangidae (11%) et des Lethrinidae (9%). Étant donné le peu d'informations disponibles sur cette composition taxonomique, celle-ci nous paraît être une amélioration substantielle par rapport aux données publiées par la FAO, en ce qui concerne la période pré-indépendance. Un travail de reconstruction plus poussé pourrait cependant être envisagé afin de refléter les changements temporels qui ont eu lieu au niveau des espèces pêchées.

Notre reconstruction met également en avant une part importante non déclarée des captures djiboutiennes. Ceci est d'autant plus vrai dans le contexte de faiblesse de moyens du service de la Direction de la Pêche et l'absence d'enquête sur la consommation de poisson à mettre en regard avec les données de production. Il est ainsi difficile de faire des recoupements d'informations, et il existe toujours par exemple des circuits de vente directe aux restaurateurs par des personnes pour qui la pêche est une activité partielle. Pour la période pré-indépendance, ce phénomène était dû majoritairement à une filière encore peu développée et une commercialisation par des circuits non contrôlés. Plus récemment, ce phénomène a principalement été dû aux débarquements faits par les pêcheurs djiboutiens de la côte Nord au Yémen où les avantages économiques sont nombreux (Hosch 2010).

L'ensemble de ces hypothèses montre l'importance d'améliorer les moyens de suivi et contrôle de la Direction de la Pêche afin de mieux connaître l'importance de ces captures et leur composition spécifique. Même si les secteurs de subsistance et de pêche récréative sont marginaux en terme de tonnages, ce constat s'y applique également. Ceci met en avant la nécessité d'augmenter aujourd'hui les moyens alloués à la Direction de la Pêche afin de mieux contrôler et évaluer ces pratiques encore très peu étudiées. De plus, plusieurs indices peuvent indiquer la surexploitation de certains stocks (détaillés plus bas). Il semble donc nécessaire de mettre en place un processus de récolte de données exhaustif quant aux différents secteurs contribuant aux captures dans les eaux djiboutiennes. Ceci est nécessaire afin de pouvoir réaliser des diagnostics et avis scientifiques fiables pour une exploitation durable des ressources.

Reconstruction des captures djiboutiennes en dehors de la ZEE domestique, et pêches étrangères

Notre estimation des captures hors ZEE repose sur des hypothèses fortes qu'il conviendrait de préciser par l'inclusion de nouvelles données et une analyse détaillée de ce phénomène. Cette série temporelle représente une première approche caricaturale du phénomène décrit (Figure 3), et nous avons utilisé les seules mentions faites d'une pêche djiboutienne opérée en dehors de la ZEE sur l'ensemble de la période. A l'heure actuelle, les seules opérations recensées concernent l'entreprise privée RSF qui pratique des techniques différentes (i.e., nasses, et chalut interdit dans la ZEE djiboutienne) et ceux sans accord particulier signé avec la Somalie. Nous avons supposé que la répartition par famille/espèce était la même que la pêche artisanale déclarée effectuée dans la ZEE djiboutienne, mais ceci reste à consolider. Il conviendrait de mieux encadrer et estimer ces pratiques aujourd'hui assez faibles afin de pouvoir établir des diagnostics justes, et peut-être mettre en place des accords précis avec la Somalie qui pêche également dans les eaux djiboutiennes. Ces captures somaliennes mais surtout yéménites dans la ZEE djiboutienne équivalent à des captures considérables, puisqu'elles ont atteint plus de 1 500 t en 2010 (Figure 3). Bien que nous ayons gardé un ratio *pêche étrangère:pêche domestique* constant au cours du temps, il est cependant possible que ce ratio ait été plus important pendant la période pré-indépendance à cause du faible développement de la pêche djiboutienne en

[12] De 1983 à 1985, les données FAO correspondaient à 70% des seules captures de l'ACPM, puis à 100% en 1986 (El Gharbi 1987). Enfin, les corrections appliquées entre 1992 et 2004 n'étaient, à notre connaissance, expliquées nulle part.

comparaison de celle en provenance de la Somalie et du Yémen. Cette pêche est majoritairement pratiquée par les Yéménites dont la présence est attestée depuis longtemps (Clouet 1970 ; Hosch 2010 ; Morgan 2006). Les capacités de patrouille en mer étant limitées et les fonds riches, il est logique qu'une telle activité soit apparue de par l'importance de la flotte yéménite sur la période 1950–2010 et leur tradition de pêche. La limite entre opérations djiboutiennes et étrangères dans la ZEE est cependant parfois floue. En effet, la présence yéménite ancienne se traduit aujourd'hui par des contournements, comme celui de l'obligation d'être citoyen djiboutien pour obtenir une licence. Il existe apparemment des pêcheurs yéménites en possession d'une licence djiboutienne (et d'un bateau immatriculé à Djibouti) leur permettant de pêcher dans la ZEE, ces captures n'étant ensuite pas débarquées à Djibouti. Toutes sortes d'opérations de ce genre ont été reportées. Dans cette étude, nous nous sommes basés exclusivement sur le pavillon et la zone, mais il faut garder à l'esprit que cela occulte une série de comportements difficiles à catégoriser. Par manque d'information, nous avons utilisé la composition taxonomique des captures djiboutiennes. Il existe cependant quelques informations laissant penser que les captures yéménites laissent une plus grande part aux requins (e.g., *Carcharhinus brevipinna* et autres Carcharhinidae) qui sont préférentiellement ciblés, ainsi qu'aux petits pélagiques dont la consommation est plus répandue au Yémen (Abbes 1985 ; Clouet 1970 ; Hosch 2010). Devant l'importance de ce secteur et les captures illicites engendrées, il conviendrait de mieux contrôler ces opérations afin d'en connaître l'étendu et ainsi garantir une gestion durable de la pêche artisanale djiboutienne. Plusieurs éléments semblent en effet indiquer la surexploitation de certains stocks : les ressources en holothuries auraient déjà été exploitées jusqu'à épuisement commercial, et les pêcheurs notent que certaines strates bathymétriques sont surexploitées (les vivaneaux et les mérous se seraient apparemment raréfiés entre 30 et 50 m), ou que les migrations saisonnières des grands pélagiques se font plus irrégulièrement et moins fortement qu'avant (Hosch 2010). De plus, les pêcheurs se plaignent d'une abondance accrue de dauphins responsables d'une déprédation importante de leurs prises, phénomène pouvant être lié à l'exploitation intense des requins dans la ZEE djiboutienne (Hosch 2010). Nous avons estimé que la capture totale de requins dans la ZEE djiboutienne s'élevait à environ 116 t en 2010, ce qui est supérieur au potentiel estimé de capture de 70 t par année (Darar 1994).

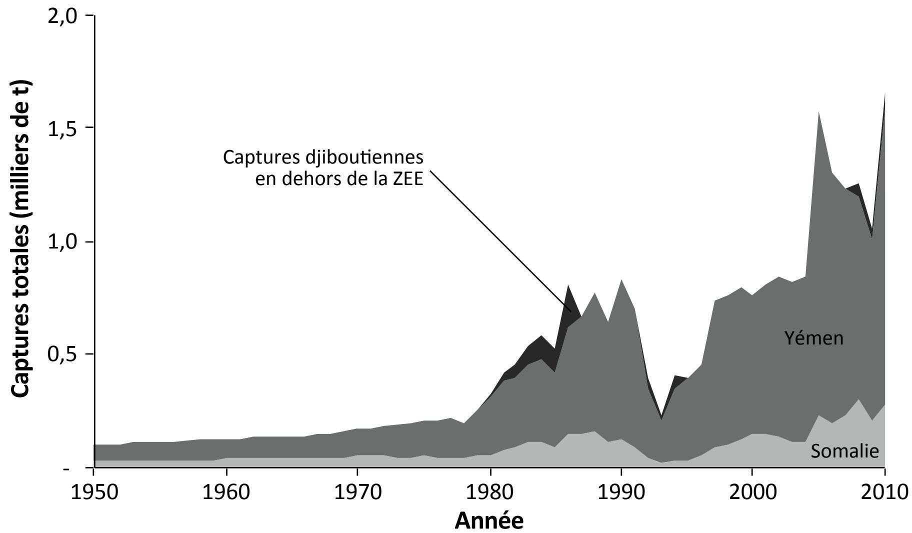

Figure 3. Captures étrangères dans la ZEE djiboutienne et captures djiboutiennes à l'extérieur de la ZEE nationale, 1950–2010.(voir Tableau Annexe A1 pour détails).

Conclusion

Cette étude nous a permis de reconstruire l'ensemble des captures par la pêche à Djibouti de 1950 à 2010. Nous avons ainsi pu mieux comprendre, réviser et compléter les données de la série FAO. Les données reconstruites comprennent notamment l'évolution de la pêche artisanale djiboutienne : la capture est restée très limitée durant la période pré-indépendance avec l'ancrage d'une tradition pastorale dans les coutumes. La période post-indépendance a ensuite vu le développement d'une flottille artisanale professionnelle de par la volonté des pouvoirs publics. De plus, la prise en compte de plusieurs secteurs tels que la pêche artisanale non-déclarée, la pêche récréative, et la pêche de subsistance affine le diagnostic sur l'évolution du secteur de la pêche. Il existe aujourd'hui peu de données et d'enquêtes précises sur ces secteurs qui, bien qu'ayant des tonnages faibles, peuvent avoir un impact substantiel sur les ressources. Il semble donc essentiel d'augmenter les moyens alloués à la Direction de la Pêche pour l'encadrement et le contrôle des différentes activités de pêche afin d'obtenir de meilleures estimations, et ainsi garantir une exploitation durable des ressources. L'ajout des captures illégales opérées par des pêcheurs étrangers illégaux (du Yémen majoritairement) renforce ce diagnostic puisqu'ils prélèvent sans contrôle et de manière importante des ressources halieutiques.

Au final, il semble aujourd'hui nécessaire d'établir des diagnostics plus précis de l'impact de la pêche sur les stocks ciblés. En effet, plusieurs éléments pourraient indiquer une surexploitation de certains stocks ciblés, ce qui pourrait avoir des répercussions néfastes sur les écosystèmes marins djiboutiens.

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Références

Abbes R (1985) Bilan des connaissances acquises sur la faune et la flore sous-marines de la région de Djibouti. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Nantes (France). 6 + xxxiv p.

Allain C (1974) Mission d'information sur le développement de la pêche dans le Territoire des Afars et des Issas — du 10 au 15 avril 1974. Office Scientifique et Technique des Pêches Maritimes (ISTPM), Nantes (France). i + 8 p.

Anon. (2010) The hidden harvests — The global contribution of capture fisheries. Agriculture and Rural Development Department, Sustainable Development Network. Prepared by The World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the WorldFish Center, Washington, DC (USA). 99 p.

Anon. (2011) Pour un plan stratégique de recherche sur les ressources et l'environnement marins à Djibouti — Compte-rendu de l'atelier sur les ressources et l'environnement marins. Université de Djibouti, Faculté des Sciences, Djibouti. 17 p.

Augustin P (1971) Quelques dénombrements de la population du Territoire français des Afars et des Issas (suite). POUNT (Bulletin de la Société d'Etudes de l'Afrique Orientale) 4ème Année(14): 15–38.

Belhabib D, Gascuel D, Kane EA, Harper S et Zeller D (2013) Preliminary estimation of realistic fisheries removals from Mauritania, 1950–2010. pp. 63–80, Dans: Belhabib D, Zeller D, Harper S and Pauly D (éds.), Marine fisheries catches in West Africa, 1950–2010, part I. Fisheries Centre Research Reports 20 (3). University of British Columbia, Vancouver (Canada).

Bjoerklund I et Walter-Dehnert G (1983) Baseline socio-economic and marketing study of artisanal fisheries in the Republic of Djibouti. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie) 80 p.

Bouhlel M (1988) Poissons de Djibouti. Dubai Printing Press. 416 p.

CITES (2002) Interprétation et application de la Convention — Commerce et conservation des espèces — Commerce des concombres de mer des familles Holothuridae et Stichopodidae. Douzième session de la Conférence des Parties (CdP 12) 45, Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction (CITES), Santiago (Chili). 29 p.

CITES (2006) Concombres de mer. Vingt-deuxième session du Comité pour les animaux (AC 22) 16, Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction (CITES), Lima (Pérou). 32 p.

Clouet A (1970) La pêche à Djibouti. La Revue Maritime 275: 476–493.

Darar A (1994) An account of fisheries development in the Republic of Djibouti with notes on the growth and mortality of three species of groupers. Naga, The ICLARM Quarterly 17(2): 30–32.

Darar A et Hosch G (2010) Analyse des implications pour la mise en opération d'embarcations de pêche industrielles à Djibouti. Direction des Pêches de Djibouti, Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie). i + 9 p.

Devinat P (1957) La mer Rouge et les intérêts français. Politique Etrangère 22ème année(3): 311–324.

El Gharbi R (1987) La pêche artisanale dans la République de Djibouti — Analyse bio-économique. Projet de développement de la pêche artisanale, Phase II, United States Agency for International Development (USAID), Resource Development Associates International (RDA), Djibouti. 59 + xxix p.

Emerton L (1998) Djibouti biodiversity: economic assessment. Djibouti national biodiversity strategy and action plan, International Union for Conservation of Nature (IUCN), Djibouti. 54 p.

FAO (1991) Fishery statistics — Catches and landings. FAO yearbook 72, Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie).

FAO (2012) FishStat Plus — Universal software for fishery statistical time series. v2.3. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie).

Guillaume A (1979) Djibouti. pp. 41–50 In L'évaluation des effectifs de la population des pays africains — Tome 1. Groupe de Démographie Africaine IDP-INED-INSEE-MINCOOP-ORSTOM, Paris (France).

Harper S and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada). 143 p.

Harper S, Zylich K, Boonzaier L, Le Manach F, Pauly D and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part III. Fisheries Centre Research Reports 20 (5). University of British Columbia, Vancouver (Canada). 134 p.

Hosch G (2010) Plan d'action national visant à prévenir, à contrecarrer et à éliminer la pêche illicite, non déclarée et non réglementée — République de Djibouti. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie). v + 54 p.

IFAD (1984) Rapport de la mission de formulation de renforcement du projet pilote de développement de la pêche artisanale. Projet de développement de la pêche artisanale, Phase I, International Fund for Agricultural Development (IFAD), Djibouti. 1 p.

Kelleher K (2005) Discards in the world's marine fisheries — An update. FAO Fisheries Technical Paper 470, Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie). 131 p.

Künzel T, Darar A et Vakily JM (1996a) Composition, biomasses et possibilités d'exploitation des ressources halieutiques djiboutiennes — Tome 1 — Analyse. Ministère de l'Agriculture et de l'Hydraulique, Direction de l'Elevage et des Pêches, République de Djibouti, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). ix + 63 p.

Künzel T, Darar A et Vakily JM (1996b) Composition, biomasses et possibilités d'exploitation des ressources halieutiques djiboutiennes — Tome 2 — Données. Ministère de l'Agriculture et de l'Hydraulique, Direction de l'Elevage et des Pêches, République de Djibouti, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Bundesrepublik Deutschland, Djibouti. 156 p.

Le Manach F, Gough C, Humber F et Harper S (2011) Reconstruction of total marine fisheries catches for Madagascar. pp. 21–37 In Harper S et Zeller D (eds.), Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada).

Lewin WC, Arlinghaus R et Mehner T (2006) Documented and potential biological impacts of recreational fishing: insights for management and conservation. Reviews in Fisheries Science 14(4): 305–367.

Moal RA (1969) Les perspectives de développement de Djibouti, port de pêche industrielle. POUNT (Bulletin de la Société d'Etudes de l'Afrique Orientale) 2ème Année(7): 39–42.

Moal RA et Grateau J (1967) Pêche en Territoire Français des Afars et des Issas. POUNT (Bulletin de la Société d'Etudes de l'Afrique Orientale) 1ère Année(3): 17–24.

Morgan G (2006) Country review: Djibouti. pp. 195–201 Dans De Young C (éd.) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries and Aquaculture Technical Papers 488. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome (Italie).

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Persson L, Lindop A, Harper S, Zylich K and Zeller D (this volume) Failed state: reconstruction of domestic fisheries catches in Somalia 1950–2010.

Pujo JM (1967) Les boutres à Djibouti : une survivance de l'âge de la voile. POUNT (Bulletin de la Société d'Etudes de l'Afrique Orientale) 1ère Année(2): 9–16.

République de Djibouti (2012) Annuaire statistique de Djibouti — Edition 2012. Ministère de l'économie et des finances chargé de l'industrie et de la planification. 121 p.

Rouaud A (1997) Pour une histoire des Arabes de Djibouti, 1896–1977. Cahiers d'Etudes Africaines 37(146): 319–348.

Tesfamichael D, Rossing P and Saeed H (2012) The marine fisheries of Yemen with emphasis on the Red Sea and cooperatives. Pp. 105–152. *In* Tesfamichael D and Pauly D (eds.) Catch reconstruction for the Red Sea large marine ecosystem by countries (1950–2010). Fisheries Centre Research Reports 20(1). Fisheries Centre, University of British Columbia [ISSN 1198–6727].

Waldstein AS et Lampe H (1988) Djibouti fisheries development project. AID evaluation working paper 110, United States Agency for International Development (USAID), Djibouti. xiv + 45 p.

Zeller D and Harper S, editors (2009) Fisheries catch reconstructions: islands, part I. Fisheries Centre Research Reports 17 (5). University of British Columbia, Vancouver (Canada). 108 p.

Zeller D et Pauly D, editors (2007) Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15 (2). University of British Columbia, Vancouver (Canada). 163 p.

Tableau Annexe A1. Captures domestiques reconstruites (par secteur) et rapportées à la FAO, et captures étrangères et en dehors de la ZEE nationale, de 1950 à 2010.

Années	Captures domestiques						Captures étrangères dans la ZEE nationale	
	Dans la ZEE nationale					Hors ZEE		
	Artisanales	Récréatives	Subsistance	Total reconstruit	Total rapporté à la FAO		Somalie	Yémen
1950	127	1	2	130	500	-	28	73
1951	131	1	2	134	800	-	29	75
1952	134	1	2	137	500	-	27	79
1953	137	1	2	140	500	-	27	82
1954	140	1	2	144	900	-	28	83
1955	144	1	2	147	800	-	26	88
1956	147	1	2	150	500	-	35	81
1957	150	1	2	154	600	-	35	84
1958	154	1	2	157	800	-	37	85
1959	157	1	2	160	600	-	35	89
1960	160	1	3	164	900	-	38	89
1961	163	1	3	167	800	-	39	90
1962	167	1	3	171	900	-	40	92
1963	170	1	3	174	1 000	-	41	93
1964	173	1	3	177	300	-	40	98
1965	177	2	3	181	300	-	41	99
1966	180	2	3	184	300	-	42	100
1967	183	2	3	188	300	-	42	103
1968	192	2	3	197	300	-	45	107
1969	202	2	3	207	300	-	48	111
1970	211	2	3	216	300	-	51	116
1971	220	2	3	226	300	-	56	118
1972	229	2	4	235	100	-	55	127
1973	239	2	4	245	200	-	49	140
1974	248	3	4	254	380	-	47	150
1975	257	3	4	264	300	-	49	154
1976	266	3	4	273	230	-	45	166
1977	275	3	4	283	230	-	47	171
1978	253	3	4	260	230	-	45	155
1979	316	3	5	325	231	-	53	197
1980	392	3	6	402	251	13	59	252
1981	486	3	8	497	385	33	76	309
1982	505	3	8	516	425	52	90	310
1983	581	4	9	594	409	79	114	346
1984	606	4	10	619	409	103	116	364
1985	529	4	8	541	380	108	95	324
1986	789	4	13	805	409	188	152	473
1987	843	4	13	861	426	-	148	520
1988	971	4	15	990	454	-	160	609
1989	807	4	13	824	399	-	119	520
1990	1 048	4	17	1 069	361	-	125	705
1991	894	4	14	912	253	-	90	618
1992	436	5	7	447	276	52	40	305
1993	260	5	4	269	301	31	21	185
1994	442	5	7	454	321	53	33	317
1995	505	5	8	518	351	-	30	370
1996	590	5	9	604	401	-	51	399
1997	962	5	15	981	501	-	87	647
1998	1 017	5	15	1 037	601	-	103	657
1999	1 066	5	16	1 088	701	-	124	674
2000	1 021	6	15	1 042	801	-	150	611
2001	1 081	8	16	1 105	901	-	149	657
2002	1 117	8	17	1 142	1 001	-	135	705
2003	1 074	8	16	1 099	1 101	-	109	712
2004	1 099	8	17	1 124	1 201	-	110	741
2005	1 983	9	31	2 023	1 571	-	229	1 342
2006	1 641	9	26	1 676	1 299	-	192	1 108
2007	1 552	9	25	1 585	1 229	-	228	1 001
2008	1 518	9	24	1 550	1 206	55	297	905
2009	1 270	9	20	1 299	1 058	46	207	799
2010	2 007	9	32	2 048	1 058	73	281	1 309

Tableau Annexe A2. Composition taxonomique des captures domestiques dans la ZEE djiboutienne de 1950 à 2010.

Années	*Epinephelus* spp.	Lutjanidae	*Scomberomorus* spp.	Carangidae	Lethrinidae	Sphyraena	Scombridae	Mugilidae	Autres
1950	15	19	25	14	14	5	10	3	26
1951	16	19	25	14	14	6	10	3	27
1952	16	20	26	15	14	6	10	3	27
1953	16	20	26	15	15	6	10	3	28
1954	17	21	27	15	15	6	11	3	29
1955	17	21	28	16	15	6	11	3	29
1956	18	22	28	16	16	6	11	3	30
1957	18	22	29	17	16	6	11	3	31
1958	18	23	30	17	16	7	12	3	31
1959	19	23	30	17	17	7	12	3	32
1960	19	24	31	18	17	7	12	3	33
1961	20	24	31	18	18	7	13	3	33
1962	20	25	32	18	18	7	13	3	34
1963	20	25	33	19	18	7	13	3	35
1964	21	26	33	19	19	7	13	4	36
1965	21	26	34	19	19	8	14	4	36
1966	22	27	35	20	19	8	14	4	37
1967	22	27	35	20	20	8	14	4	38
1968	23	29	37	21	21	8	15	4	40
1969	24	30	39	22	22	9	15	4	42
1970	25	31	41	23	23	9	16	4	44
1971	26	33	42	24	24	9	17	4	46
1972	28	34	44	25	25	10	18	5	48
1973	29	35	46	26	26	10	18	5	50
1974	30	37	48	27	27	11	19	5	52
1975	31	38	50	28	28	11	20	5	53
1976	32	40	51	29	29	11	20	5	55
1977	33	41	53	30	30	12	21	6	57
1978	30	38	49	28	27	11	19	5	53
1979	38	47	61	35	34	13	24	6	66
1980	47	58	76	43	42	17	30	8	81
1981	58	72	94	54	52	21	37	10	99
1982	61	75	97	56	54	22	39	10	103
1983	4	105	45	96	72	31	66	41	134
1984	69	54	107	103	48	48	66	12	112
1985	55	74	105	66	70	21	47	4	99
1986	157	160	210	65	78	15	44	6	71
1987	118	104	178	39	90	27	33	6	265
1988	214	125	55	112	91	32	68	15	279
1989	190	286	74	64	74	18	22	2	94
1990	239	348	164	60	83	29	58	1	87
1991	270	193	168	46	98	42	39	1	57
1992	131	94	81	22	48	20	19	0	31
1993	79	56	49	13	29	12	11	0	20
1994	134	94	83	22	49	20	19	0	32
1995	143	114	96	29	57	26	21	0	33
1996	140	112	91	28	56	28	21	0	127
1997	220	165	112	64	73	64	26	0	257
1998	221	158	95	79	71	79	24	0	309
1999	228	157	85	100	71	93	21	0	333
2000	214	148	71	107	71	95	30	0	305
2001	224	157	67	123	78	106	39	0	310
2002	236	157	63	131	84	121	47	0	302
2003	229	149	56	131	84	121	56	0	273
2004	235	150	53	137	89	128	66	0	265
2005	361	221	53	216	136	204	115	-	717
2006	244	138	374	204	158	185	134	-	240
2007	228	123	339	263	174	145	161	-	154
2008	157	214	123	257	140	212	240	-	207
2009	158	213	97	242	150	143	119	-	177
2010	250	336	154	383	237	225	188	-	275

First Estimate of Unreported Catch in the French Îles Éparses, 1950-2010*

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Abstract

In this report, we used the catch reconstruction approach developed by the *Sea Around Us* to estimate the total marine fisheries catch in the EEZs of the Îles Éparses. These islands being uninhabited, there are no records of such fisheries in the official fisheries data published by the Food and Agriculture Organization of the United Nations (FAO), and thus, our reconstruction is entirely comprised of unreported catches. Catches were estimated to around 2,800 tonnes between 1989 and 2010, essentially in the Glorieuses Archipelago. The small-scale artisanal *barques* from Mayotte represented 76.8% of the total, followed by the recreational and semi-industrial handline fisheries, with 14.0% and 6.7%, respectively. *Lutjanus bohar* represented 39.9% of the catch, followed by Serranidae, yellowfin tuna, other Scombridae and Carangidae, representing 21.5%, 7.0%, 7.3%, and 5.5% of the catch, respectively (the rest being composed of various species of groundfishes and pelagic fishes).

Introduction

The Îles Éparses (i.e., 'Scattered Islands') encompass a group of five small entities dispersed around Madagascar, in the Western Indian Ocean. Four of these islands, i.e., Europa, Bassas da India (an atoll), Juan de Nova, and the Glorieuses Archipelago (MPA since 2012; République Française 2012) are located in the Mozambique Channel, while Tromelin — which is jointly managed with Mauritius (Anon. 2010; Juppé 2012) — is located northeast of Madagascar (Figure 1). Overall, the Exclusive Economic Zone (EEZ; declared in 1978; République Française 1978) of these entities reaches over 640,000 km² (Anon. 2011), i.e., more than the surface of France's mainland. However, neighbouring countries claim all of these islands: all but Tromelin are claimed by Madagascar, and as well, by Mauritius; the Glorieuses Archipelago is claimed by Comoros and, until 2001, also by the Seychelles (République Française 2001).

Tromelin was the first of the islands to be claimed by France in 1776 (Malick 1976), and by the end of the 19th century, all of them were under French rule (Anon. 2011). In 1960, the Îles Éparses became administered by the French island of La Réunion, located east of Madagascar (République Française 1960). In 2007, the Îles Éparses eventually became a district of the *Terres Australes et Antarctiques Françaises* ('Territory of the French Southern and Antarctic Lands'; République Française 2007), along with the islands of Kerguelen, St Paul & Amsterdam, and Crozet.[1]

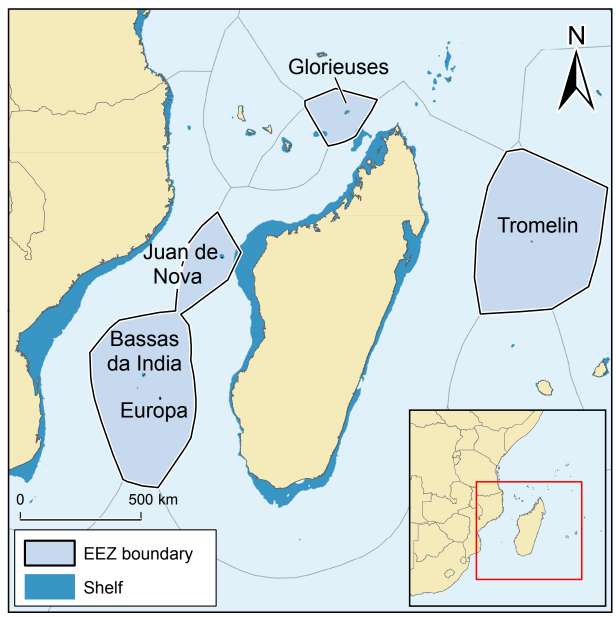

Figure 1. Map of the Îles Éparses showing the extent of their EEZs, as well as the -200 m isobaths (i.e., the 'shelf') in the region.

The Îles Éparses have virtually always been uninhabited (or occupied for very short periods of time), but they host early-warning meteorological stations since 1950 (this region is under cyclonic threats part of the year), as well as a small but continuous military (and sometimes scientific) presence since 1973 (IUCN 2003; d'Aboville 2007).[2] This presence is used to exert sovereignty on these islands, as well as to deter illegal fishing from the coast (Anon. 2011).

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[1] Adélie Land on the Antarctic continent also belongs to the same district, with Article IV of the Antarctic Treaty suspending all territorial claims in Antarctica (Guyomard 2010).

[2] Note that there was a French guano industry occurring in Juan de Nova from the late 19th century until 1972 to supply the Seychellois market (d'Aboville 2007; IUCN 2003). A coconut plantation also exists on the Glorieuses Archipelago; it was planted in the late 19th century and exploited until 1958 by Seychellois mandated by the French government (Malick 1976).

Patrols are also carried out regularly in the Mozambique Chanel by the French Navy to prevent illegal activities in the French EEZs.

Thanks to their remoteness and their uninhabited status, the waters of the Îles Éparses are in an almost pristine state and host a very rich marine diversity (Le Corre and Safford 2001; Perillo 2008), compared, e.g., to its heavily populated and exploited Malagasy neighbour. An extensive mangrove of 700 ha (similar to the one found in Mayotte) is found on Europa (Barnaud 2011; Mangion *et al.* 2012), which largely motivated its classification as a RAMSAR site in 2011 (Barnaud 2011; RAMSAR 2014). There is also a much smaller mangrove on Juan de Nova, and minor seagrass meadows on two islands. Since 1975, all islands but Juan de Nova have benefited from a status of natural reserve (République Française 1975), which aims to protect the rich flora and fauna, including turtles, cetaceans, coral reefs, and seabirds (Anon. 2011; Quod *et al.* 2007). Moreover, recent legislation prohibits fishing activities within the 12 nm zone (10 nm around Geyser Bank; 24 nm for purse-seiners; République Française 2010a, 2013a).[3]

Unlike their surrounding waters, the terrestrial parts of these islands have faced a high pressure due to the introduction of various exotic species over time — including rats, cats, goats, chicken, and many plants — which have negatively impacted the indigenous species. Some of these invasive species have been entirely extirpated, while this is still in process for some others (IUCN 2003; Anon. 2011).

Given that these islands are uninhabited, there are no fisheries data currently estimated and transmitted to the Food and Agriculture Organization of the United Nations (FAO) and made publicly available *via* the FishStat fisheries database (FAO 2013). In this report, we apply to the Îles Éparses the reconstruction methods developed around principles in Pauly (1998), described in Zeller *et al.* (2007) and applied worldwide by the *Sea Around Us* (see e.g., Zeller and Pauly 2007; Zeller and Harper 2009; Harper and Zeller 2012; Harper *et al.* 2012). Due to the severe lack of catch data, this work of reconstruction was mostly based on Fermi solutions (von Baeyer 1993; Pauly 2010). We aimed to produce a first estimate of marine fisheries catch in these waters by reviewing the existing literature on the topic and estimating the total extraction of marine fish from 1950 to 2010.

Material and Methods

Small-scale fisheries

Recreational fishery

Virtually all recreational fisheries occur in Bassas da India's EEZ. This is an example of a highly organized unreported, illegal recreational fishery, with over a dozen South African and Mozambican charter companies offering "extreme adventure holiday [to] fish this mythical fishing destination" (www.bassadaindia.com). Boats filled with tourists (mostly from South Africa) are present in the zone at least half of the year, targeting all sorts of large species ranging from tuna and sharks, to Lutjanidae (snappers) and *Coryphaena hippurus* (dolphinfish) with speargunss, lines, flies, jigs, and other gears.[4] Note that some of these entirely unregulated practices — such as walking directly on the reefs (see vimeo.com/41090694), may result in severe damages to the habitats and the local wildlife, on top of the major impact on some fish stocks. In order to avoid fines by the French authorities, a known trick is to use paired boats: when the patrol arrives, tourists are transferred onto the empty boat, while the catch and the gears are kept on the other boat.[5] This way, the authorities cannot charge the charter companies with illegal fishing, as there are no proofs that the catch comes from these waters. However, it has to be noted that the French authorities recently improved their legislation to avoid such practices, by prohibiting the possession of fisheries products onboard boats within the no-fishing zone (10 nm around Geyser Bank, 12 nm elsewhere; République Française 2013b).

In order to produce a first estimate of this fishery, we considered that there were 20 boats doing each six trips per year (based on www.bassadaindia.com) for the year 2010, and that this number had increased from zero in 1989 to half of the 2010 level by 2005 (and interpolating in between; i.e., we assumed that this activity slowly expanded in its first years, and expanded more quickly in recent years). We also considered that 500 kg of fish were caught during each trip. We believe this is a conservative estimate, as one recreational fisher reported to have caught at least half a dozen 30–40 kg *Thunnus albacares* (yellowfin tuna), many *Carcharhinus longimanus* (oceanic whitetip shark) and *C. leucas* (Zambezi shark), "a few ignobilis kingfish [*Caranx ignobilis*]", "a number of black kingfish [*C. lugubris*][6]", "some decent sized snapper", "a number of big wahoo [*Acanthocybium solandri*], [...] the biggest estimated at over 30 kg", and "some other reef dwellers" (Milford 2006).

Based on this account, we considered that 50% of the catch was comprised of tunas (80% of yellowfin tuna and 20% of other species) and 20 % of selachimorpha (sharks; 80% of oceanic whitetip sharks and 20% of other species of sharks). The remaining 30% were equally distributed among Lutjanidae, Serranidae, Carangidae, Sphyraenidae, Coryphaenidae, and Istiophoridae.

[3] However, we know that Geyser Bank has been regularly fished by *barques* since at least 1997. Thus, unless there really is strict enforcement, these measures may not 'mostly protect' these waters.

[4] Some of these fish are released, but most are kept for consumption and we assumed 100 % mortality for all species except sharks, for which we assumed 30% survival (based on Diaz and Serafy 2005, Campana *et al.* 2009, and Butcher *et al.* 2014).

[5] The lead author heard this story several times during a trip to South Africa in 2012, while inquiring about a potential fishing trip to Bassas da India.

[6] Assumed to be the South African common name. Source: www.fishbase.org.

Holothurian fishery

Since 2011, another illegal fishery started to operate in the Îles Éparses' EEZ, from a base in Madagascar (Anon. 2013, 2014a; Pruffer 2013). What started as a small-scale fishery is increasing in organization and size with large (15+ m) mother ships deploying motorized *barques* and *pirogues* around the Glorieuses Archipelago (Geyser and other lagoons) and Juan de Nova (Anon. 2014a).[7] These fishers mostly target holothurians while scuba diving, although there is an ancillary catch of sharks (fins and tails kept for the Chinese market as well) and reef fish using lines and spearguns (Anon. 2014a).

Fishers likely started fishing these grounds in the early 2000s, i.e., when signs of over-exploitation of Malagasy holothurians started to be conspicuous (Le Manach *et al.* 2011, 2012, 2013). Noteworthy, it seems that part of this fishery is using boats owned by French expatriates who live in northwest Madagascar part of the year (and get Malagasy people to look after their boats the rest of the year). It happened several times that private sailboats were arrested by the French (or the Seychellois in their own EEZ) with Malagasy fishers and hundreds of holothurians on board, without the owner of the boat knowing that it was no longer moored in Madagascar (Pruffer 2013; G. Cripps, *pers. comm.* Blue Ventures Conservation).

Given that this fishery only started in 2011, i.e., after the end of the time-period studied here, reconstructed catches are not included in the present report. However, for future references, at least ten Malagasy fishing operations (with several boats involved in each) can be assumed to have ventured in the Glorieuses Archipelago and Juan de Nova to catch holothurians in 2013 and early 2014. To get an idea of the catches, one operation that was blocked by the French authorities had collected around one tonne (wet weight) of holothurians (for three small-scale and two semi-industrial boats and over 100 fishers; Anon. 2014a).

Reef fishery

From late 1989 to mid-1992, a semi-industrial exploitation of reef fish occurred around the Geyser Bank (Glorieuses Archipelago's EEZ) with the 12 m long YVALANN (see Doherty *et al.*, this volume). It quickly stopped due to plummeting catches of the main target species, *Lutjanus bohar* (two-spot red snapper; Maggiorani *et al.* 1994; Chabanet *et al.* 2002). Maggiorani *et al.* (1994) provided catch data as well as a taxonomic breakdown. Since this vessel used handlines, we considered that all of the bycatch was released in good condition; therefore, we did not estimate any dead discards.

Since 1997, fishers from Mayotte also started to travel further offshore to satisfy the local demand for reef fish and they reached the Glorieuses Archipelago's EEZ to target reef fish and some pelagic species (Wendling and Le Calvé 1999; Herfaut 2005; Thomassin and Andrefouet 2009; Fraisse 2010; Doherty *et al.*, this volume). These French fishers operate mostly illegally: fishing activities are forbidden within 10 nm of Geyser Bank and 12 nm of the other emerged land of the Glorieuses Archipelago (République Française 2010a), except for vessels that are deemed safe-enough to travel so far and which can apply for an exemption.[8] However, only one vessel was granted this authorization since 2009 (one longliner of 12+ meters), which did not declare any catch (making it illegal with regards to the exemption). As such, all other boats from Mayotte should be considered illegal. Most of this fishery occurs around Geyser Bank, but some *barques* (which mostly use longlines at night and other types of lines during the day) also travel further and operate around the main islands of the Archipelago.

During the first couple of years, it was reported that up to one tonne of fish could be caught per boat and per trip, but this yield quickly declined to only 200–300 kg by the mid-2000s (for longer trips; Thomassin and Andréfouët 2009).[9] Therefore, after a strong increase in the number of visits around Geyser bank, a decrease in the number of boats was observed due to this decreasing catch per trip (Quod 2007). Unofficial figures for 2012 suggest that at least 35 *barques* in Mayotte were equipped for fishing at Geyser and other offshore banks (Doherty *et al.*, this volume).

To reconstruct this sector, we considered that the number of *barques* slowly increased from zero in 1996 to 20 in 2000, and then more rapidly to 60 in 2005. We then considered that this number was halved by 2010, due to the decreasing catch. Regarding the catch, we considered that one tonne was caught by boat and by trip (one trip per month for each *barque* until 2005, and only 10 per year after 2009) during the first two years, and that this figure declined to 250 kg by boat and by trip after 2005. Regarding the taxonomic composition, we used the same as that of the YVALANN catch published by Maggiorani *et al.* (1994).

Other fisheries

Other very anecdotal small-scale fisheries may occur in the Îles Éparses' EEZ, such as the ones carried by sailboats in transit, military detachments, or even civilians staying at the islands' stations. However, regarding the latter two, it has to be noted that such activities are neither authorized by the hierarchy, nor by the *Terres Australes et*

[7] Such fishing operations have also been reported once in Bassas da India in 2013.

[8] France is becoming rather worried about such fishery, as the target species (Lutjanidae) are known to be highly sensitive to fishing. The state of the resource is supposed to be assessed as part of the Regional 10th European Development Fund allocated to local French authorities (Mayotte's *Conseil Général* and *Terres Australes et Antarctiques Françaises*) in order to implement a "sustainable use of natural resources in Mayotte and the Îles Éparses" (especially in the perimeter of the two *Parc Naturel Marins* of Mayotte and the Glorieuses Archipelago).

[9] These illegal fishers will often stay at sea for several days when fishing around offshore banks and risk dangerous sea conditions as well as explosions (Anon. 2014b), in order to remain profitable (Herfaut 2005; Guézel *et al.* 2009; Fraisse 2010). Some of these illegal fishers operating within the 12 nm are sometimes caught by the French authorities (Anon. 2014c, b).

Antarctiques Françaises. Although this may occur from time to time, their catch is therefore likely very low. Due to the elusive nature of these fisheries, no estimates were made here.

Large pelagics industrial fishery

The Îles Éparses are located in the second largest tuna fishing ground in the world (FAO 2012), and as such, are attractive to large-scale industrial vessels interested in pursuing this resource. Catches of these fleets were not reconstructed as part of this report. Rather, they were considered to have been reported to the Indian Ocean Tuna Commission (IOTC), and were dealt with as part of the global reconstruction of large pelagics catches (Le Manach *et al.* in press). However, we present here a brief summary of these fisheries.

French fleet

French purse-seiners (flagged in France mainland, Mayotte, or La Réunion) and longliners (flagged in La Réunion) are active in the Îles Éparses' EEZ (Laurent-Monpetit *et al.* 2012; www.taaf.fr/Navires-autorises-293). In order to access fishing grounds of the *Terres Australes et Antarctiques Françaises*, owners of these French vessels must annually apply for a licence, pay a specific fee to contribute to the observation and surveillance program of the *Terres Australes et Antarctiques Françaises* since 2010 (République Française 2010b, 2013c), and finally, pay fishing rights since 2013 (none until then; République Française 2013d). Since 2008, these vessels must follow the *Terres Australes et Antarctiques Françaises* regulations (République Française 2008, 2010c, 2013a, 2014),[10] and take on fisheries observers (on average 10–15% of trips are monitored).

Foreign fleets

Spanish seiners are also authorized to fish in the Îles Éparses' EEZs as part of a bilateral agreement with France. These vessels are either flagged in Spain or in the Seychelles (see Le Manach *et al.*, this volume; www.taaf.fr/Navires-autorises-293).

In 1993, there were also licenses delivered to 28 Taiwanese longliners for a trial period of one year (René *et al.* 1998). It seems that very few industrial vessels have ventured into the Îles Éparses' EEZs over the past couple of decades to fish illegally,[11] as they are generally afraid of the increasing French military presence and are thus more inclined to fish in areas further north (known to be more productive and less tightly monitored; e.g., Kenya, Somalia).

Results

Overall, catches in the Îles Éparses' EEZs are estimated to have totalled over 2,800 tonnes between 1989 and 2010 (Figure 2A; mostly in the Glorieuses Archipelago with 84% of the total, Bassas da India representing only 16%). The small-scale artisanal *barques* from Mayotte represented 76.8% of the total (followed by the recreational and semi-industrial handline fisheries, with 14.0% and 6.7%, respectively; Figure 2A).

Regarding the taxonomic breakdown, *Lutjanus bohar* made up 39.9% of the catch, followed by Serranidae, yellowfin

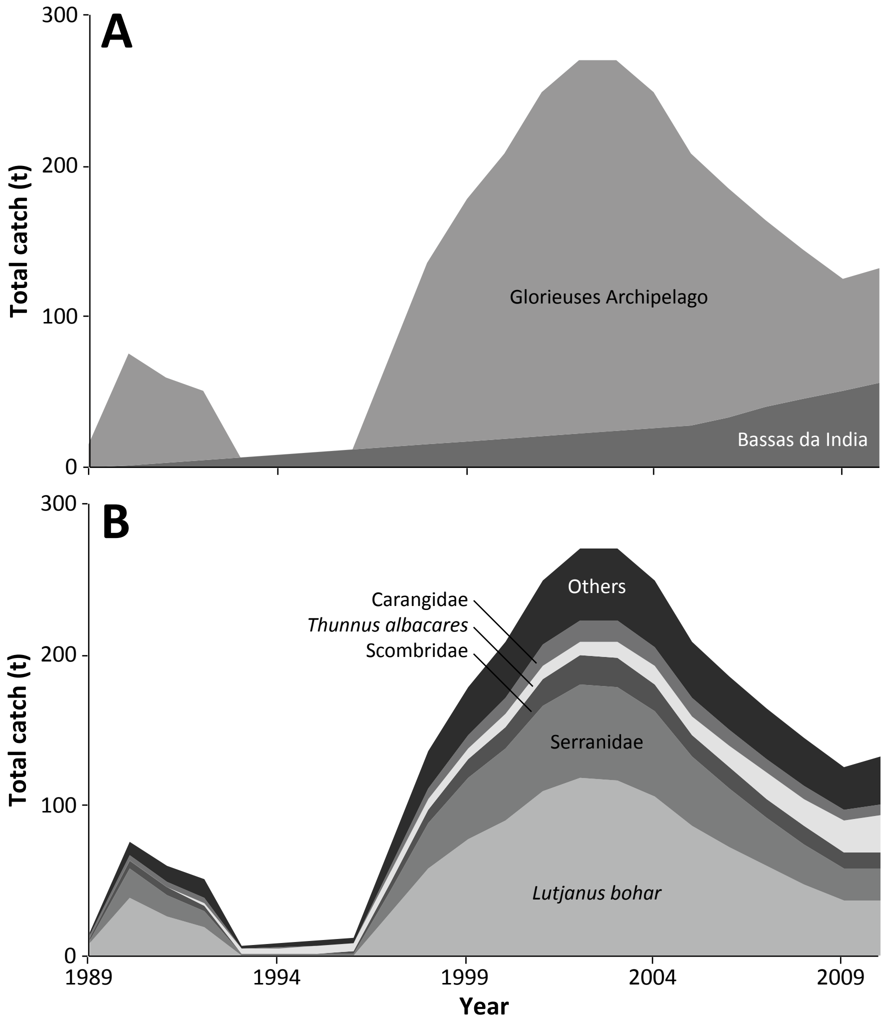

Figure 2. Annual reconstructed catch (t), by A) EEZ and B) taxa. See Appendix Table A1 and Appendix Table A2, respectively, for details.

[10] Regulations established by the *Terres Australes et Antarctiques Françaises* are updated every year in accordance with the best available scientific data and national or regional regulations (e.g., IOTC's recommendations and resolutions).

[11] Note, however, that this concept of 'illegal' fishing does not apply for the period prior to 1978, as no EEZ existed (République Française 1978).

tuna, other Scombridae and Carangidae, representing 21.5%, 7.0%, 7.3%, and 5.5% of the catch, respectively. The rest of the catch was composed of various species including sharks, other Lutjanidae, Sphyraenidae, and undetermined groundfishes and pelagic fishes (Figure 2B).

Discussion

In this report, we provide a first estimate of total marine fisheries catch in the Îles Éparses' EEZs from 1950 to 2010. While the overwhelming majority of the catch is that of the large pelagics industrial fleets (consisting of longliners active since the early 1950s and purse-seiners active since the early 1980s; not included in this report), more recent fisheries are increasingly targeting vulnerable, nearshore species such as holothurians and reef species of fish in an entirely uncontrolled and unmonitored fashion. Signs of over-exploitation are already visible for some of these stocks (e.g., the ones targeted by the *barques* fishery in the Glorieuses Archipelago and associated banks), with important decreases reported in catch per unit of effort.

While our estimates are based on assumptions and are thus perfectible, we do point out the necessity to dedicate increasing efforts towards improving the monitoring and control of these fisheries. This should include the most recent one for holothurians (not reconstructed here), in order to ensure that the exploitation of the marine resources in the biodiversity sanctuary that are the Îles Éparses remains sustainable (if legal), e.g., by restricting fishing activities to areas where stocks are assessed and monitored.

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References

Anon. (2010) Maurice-France : signature d'un accord cadre de cogestion de l'île Tromelin–14 juin.

Anon. (2011) Les Iles Eparses–Europa, Bassas da India, Juan de Nova, Glorieuses, Tromelin. Terres Australes et Antarctiques Françaises, Saint Pierre (France). 26 p.

Anon. (2013) Pêche illégale dans les TAAF : un voilier dérouté. LINFO.re, edition of November 20, 2013.

Anon. (2014a) Opération de lutte contre la pêche illégale aux îles Eparses. Préfecture de La Réunion, Saint-Denis (France).

Anon. (2014b) Pêcheurs arraisonnés aux îles Glorieuses : la polémique enfle. ImazPress Reunion, edition of January 9, 2014.

Anon. (2014c) 2 navires de pêche épinglés aux Iles Eparses. LINFO.re, edition of January 6, 2014.

Barnaud G (2011) Evaluation de trois propositions de sites Ramsar (France) — Analyse des critères d'identification de zones humides d'importance internationale. Rapport SPN 2011–5, Service du Patrimoine Naturel, Muséum National d'Histoire Naturelle, Paris (France). 39 p.

Chabanet P, Tessier E, Durville P, Mulocheau T and René F (2002) Peuplement ichtyologique des bancs de Geyser et Zélée (Océan Indien Occidental). Cybium 26(1): 11–26.

d'Aboville G (2007) La pêche et l'aquaculture en outre-mer. Avis et Rapports du Conseil Economique et Social, République Française, Conseil Economique et Social, Paris (France). 168 p.

Doherty B, Herfaut J, Le Manach F, Harper S and Zeller D (this volume) Reconstructing domestic marine fisheries in Mayotte from 1950–2010.

FAO (2012) The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 209 p.

FAO (2013) FishStatJ — Software for fishery statistical time series. V2.1.1. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Fraisse N (2010) Analyse des débarquements de poissons à Mayotte par la COPEMAY de 2007 à 2010. COPEMAY, Parc Naturel Marin de Mayotte. 17 p.

Guézel R, Quartararo A, Aboutoihi L, Saindou K, Salaün P, Ybrahim B and Arnaud JP (2009) Richesses de Mayotte — Parc naturel marin de Mayotte — Les hommes et l'océan — Mission d'étude pour la création d'un parc naturel marin à Mayotte. Agence des aires marines protégées, Mamoudzou (Mayotte). 72 p.

Guyomard A-I (2010) La protection de l'environnement en Antarctique — Droit international et droit comparé. PhD thesis, University of Université de Nantes, France. 806 + 484 p.

Harper S and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). Fisheries Centre, University of British Columbia, Vancouver. 143 p.

Harper S, Zylich K, Boonzaier L, Le Manach F, Pauly D and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part III. Fisheries Centre Research Reports 20 (5). Fisheries Centre, University of British Columbia, Vancouver. 134 p.

Herfaut J (2005) Evaluation de la rentabilité économique de l'exploitation des bancs éloignés (Geyzer, Zelée, Castor…) par la pêcherie artisanale mahoraise. Ingénierie de l'environmnement (INENV), Service des Pêches de la Direction de l'agriculture et de la Forêt, Mamoudzou, Mayotte. 22 p.

IUCN (2003) Iles Eparses. pp. 107–115 *In* Gargominy O (ed.) Biodiversité et conservation en Outre-Mer. Planète Nature — Collection du Comité français pour l'UICN — Groupe DOM-TOM. Comité français pour l'UICN, Paris (France).

Juppé A (2012) Projet de loi autorisant l'approbation de l'accord-cadre entre le Gouvernement de la République française et le Gouvernement de la République de Maurice sur la cogestion économique, scientifique et environnementale relative à l'île de Tromelin et à ses espaces maritimes environnants. Session ordinaire de 2011–2012–No 299, Sénat, Paris (France). 39 p.

Laurent-Monpetit C, Chavance P, Bourjea J and Chassot E (2012) France-Territoires — Rapport national destiné au Comité scientifique de la Commission des Thons de l'Océan Indien, pour sa réunion annuelle 2012. Indian Ocean Tuna Commission. 25 p.

Le Corre M and Safford RJ (2001) La Réunion and Îles Éparses. pp. 693–702 *In* Evans M and Fishpool L (eds.), Important bird areas in Africa and associated islands: priority sites for conservation. BirdLife International, Cambridge (UK).

Le Manach F, Andrianaivojaona C, Oleson KLL, Clausen A and Lange G-M (2013) Natural capital accounting and management of the Malagasy fisheries sector — A technical case study for the WAVES Global Partnership in Madagascar. The World Bank, New-York, NY (USA). 46 p.

Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–225.

Le Manach F, Gough C, Humber F, Harper S and Zeller D (2011) Reconstruction of total marine fisheries catches for Madagascar (1950–2008). pp. 21–37 *In* Harper S and Zeller D (eds.), Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada).

Le Manach F, Bach P, Boistol L, Robinson J and Pauly D (this volume) Artisanal Fisheries in the world's second largest tuna fishing ground — Reconstruction of the Seychelles' marine fisheries catch, 1950–2010.

Maggiorani F, Minet J-P, Roos D and Tessier E (1994) Diagnostic sur l'état de la pêcherie des bancs Geyser et Zélée (Océan Indien) — Analyse des résultats de pêche du navire YVALANN à Mayotte d'octobre 1989 à juillet 1992. Contrat-cade No. 91/1211331/F, Ifremer and Collectivité Territoriale de Mayotte, Le Port (France).

Malick M (1976) Notes sur les Iles Eparses de l'Océan Indien. pp. 75–81 *In* Guézé P (ed.) Biologie marine et exploitation des ressources de l'Océan Indien occidental. Travaux et Documents de l'ORSTOM 47, Paris (France).

Mangion P, Lambs L and Fromard F (2012) Nutrient cycling and use by the species *Rhizophora mucronata* in two contrasted mangrove settings from the French Scattered Islands, Western Indian Ocean In VLIZ Special Publication. Proceedings of the international conference: meeting on mangrove ecology, functioning and management (MMM3), July 2–6, 2012, Galle (Sri Lanka).

Milford N (2006) Bassas da India — A spot on the map in the middle of the ocean. SKI-BOAT 22(5): 61–68.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Pauly D (2010) Five easy pieces: how fishing impacts marine ecosystems. Island Press, Washington, DC. 193 p.

Perillo T (2008) Iles Eparses. Revue d'Ecologie (La Terre et la Vie) 63: 115–116.

Pruffer G (2013) Lutte contre la pêche illégale aux îles Eparses. Mayotte 1ère, edition of November 11, 2013.

Quod J-P, Barrère A, Chabanet P, Durville P, Nicet J-B and Garnier R (2007) La situation des récifs coralliens des Iles Eparses françaises de l'Océan Indien. Revue d'Ecologie (La Terre et la Vie) 62: 3–16.

Quod J-P, editor (2007) Suivi des peuplements ichtyologiques, des peuplements benthiques sessiles et des peuplements d'invertébrés du banc du Geyser. Comparaison des peuplements ichtyologiques entre 1996 et 2006. Direction de l'Agriculture et de la Forêt, PARETO écoconsult, and Agence pour la Recherche et la VAlorisation Marines (ARVAM), Mamoudzou (France). 107 p.

RAMSAR (2014) Ramsar sites in order of their addition to the Ramsar list of wetlands of international importance. 40 p.

René F, Poisson F and Tessier E (1998) Evolution de la pêcherie palangrière ciblant l'espadon (Xiphias gladius) à partir de La Réunion. pp. 287–312 *In* Cayré P and Le Gall JY (eds.), Le thon : enjeux et stratégies pour l'océan Indien. ORSTOM, Paris (France).

République Française (1960) Décret n°60–555 du 1 avril 1960 relatif à la situation administrative de certaines îles relevant de la souveraineté de la France. Journal Officiel de la République Française: 5343.

République Française (1975) Arrêté préféctoral n° 13/DG/IOI du 18 novembre 1975.

République Française (1978) Décret n° 78–146 du 3 février 1978 portant création, en application de la loi du 16 juillet 1976, d'une zone économique au large des côtes des îles Tromelin, Glorieuses, Juan-de-Nova, Europa et Bassas-da-India. Journal Officiel de la République Française: 686–686.

République Française (2001) Décret n° 2001–456 du 22 mai 2001 portant publication de la Convention entre le Gouvernement de la République française et le Gouvernement de la République des Seychelles relative à la délimitation de la frontière maritime de la zone économique exclusive et du plateau continental de la France et des Seychelles, signée à Victoria le 19 février 2001.

République Française (2007) Loi n° 2007–224 du 21 février 2007 portant dispositions statutaires et institutionnelles relatives à l'outre-mer Journal Officiel de la République Française 0045(2): 3220.

République Française (2008) Arrêté n° 2008–154 du 17 décembre 2008 prescrivant les règles encadrant l'exercice de la pêche aux thons et autres poissons pélagiques autorisée dans les zones économiques exclusives des îles Éparses (Glorieuses, Juan de Nova, Bassas da Indian, Europa, Tromelin). Journal Officiel des Terres Australes et Antarctiques Françaises 40: 18–28.

République Française (2010a) Arrêté n° 2010–151 du 9 décembre 2010 portant interdiction de la pêche dans les eaux territoriales des îles Bassas da India, Europa, Juan de Nova, Glorieuses et dans les 10 milles marins autour du banc de Geyser (district des îles Eparses). Journal Officiel des Terres Australes et Antarctiques Françaises 48: 14–15.

République Française (2010b) Arrêté n° 2010–104 du 9 octobre 2010 créant une redevance annuelle de surveillance et d'observation de la pêche dans les zones économiques exclusives des îles Glorieuses, Juan de Nova, Bassas da India et Europa. Journal Officiel des Terres Australes et Antarctiques Françaises.

République Française (2010c) Arrêté n° 2010–20 du 22 mars 2010 modifiant l'arrêté n° 2008–154 du 17 décembre 2008, prescrivant les règles encadrant l'exercice de la pêche aux thons et autres poissons pélagiques autorisée dans les zones économiques exclusives des îles Éparses (Glorieuses, Juan de Nova, Bassas da India, Europa, Tromelin). Journal Officiel des Terres Australes et Antarctiques Françaises 45: 15–16.

République Française (2012) Décret n° 2012–245 du 22 février 2012 portant création du parc naturel marin des Glorieuses Journal Officiel des Terres Australes et Antarctiques Françaises 53: 21–23.

République Française (2013a) Arrêté n°2013–14 du 8 mars 2013 prescrivant les règles encadrant l'exercice de la pêche aux thons et autres poissons pélagiques dans les zones économiques exclusives des Iles Éparses (Glorieuses, Juan de Nova, Bassas da India, Europa, Tromelin). Journal Officiel des Terres Australes et Antarctiques Françaises 57: 15–23.

République Française (2013b) Arrêté n° 2013–24 du 19 avril 2013 portant interdiction de détention d'animaux marins et de produits de la mer dans les eaux territoriales des îles Bassas da India, Europa, Juan de Nova, Glorieuses et dans les 10 milles marins autour du banc du Geyser (district des îles Éparses). Journal Officiel des Terres Australes et Antarctiques Françaises 58: 6–6.

République Française (2013c) Arrêté n° 2013–06 du 30 janvier 2013, créant une redevance annuelle de surveillance et d'observation de la pêche dans les zones économiques exclusives des îles Glorieuses, Juan de Nova, Bassas da India et Europa. Journal Officiel des Terres Australes et Antarctiques Françaises.

République Française (2013d) Arrêté n° 2013–08 du 8 février 2013 fixant le montant des droits assis sur les quantités pêchées de thons dans les zones économiques exclusives françaises de Europa, Bassas da India, Juan de Nova, Glorieuses et Tromelin pour la campagne de pêche 2013. Journal Officiel des Terres Australes et Antarctiques Françaises 57: 13–14.

République Française (2014) Arrêté n° 2014–51 du 23 avril 2014 prescrivant les règles encadrant l'exercice de la pêche aux thons et autres poissons pélagiques dans les zones économiques exclusives des îles Éparses (Glorieuses, Juan de Nova, Bassas da India, Europa, Tromelin). Journal Officiel des Terres Australes et Antarctiques Françaises 62: 13–21.

Thomassin BA and Andrefouet S (2009) Geyser et Zélée : les sommets d'un même volcan sous-marin. Univers Maoré 12: 22–37.

von Baeyer HC (1993) The Fermi solution: essays on science. Random House, New York City, NY (USA). 176 p.

Wendling B and Le Calvé S (1999) Technologie et utilisation des DCP ancrés dans les eaux de la collectivité territoriale de Mayotte (archipel des Comores, canal du Mozambique, océan Indien). pp. 261–275 *In* Le Gall J-Y, Cayré P and Taquet M (eds.), Pêche thonière et dispositifs de concentration de poissonsTrois-Ilets, Caraïbe-Martinique.

Zeller D and Harper S, editors (2009) Fisheries catch reconstructions: islands, part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia, Vancouver. 108 p.

Zeller D and Pauly D, editors (2007) Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15 (2). Fisheries Centre, University of British Columbia, Vancouver (Canada). 163 p.

Zeller D, Booth S, Davis GE and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. Total reconstructed catch (t) by EEZ, 1989–2010.

Year	Bassas da India	Glorieuses Archipelago
1989	-	15.6
1990	1.8	73.7
1991	3.5	55.4
1992	5.3	45.7
1993	7.1	-
1994	8.8	-
1995	10.6	-
1996	12.3	-
1997	14.1	60.0
1998	15.9	120.0
1999	17.6	160.7
2000	19.4	188.6
2001	21.2	228.0
2002	22.9	246.9
2003	24.7	245.1
2004	26.4	222.9
2005	28.2	180.0
2006	33.8	150.9
2007	39.5	123.8
2008	45.1	98.4
2009	50.8	75.0
2010	56.4	75.0

Appendix Table A2. Total reconstructed catch desaggregated by taxa, 1950–2010.

Year	Carangidae	*Carcharhinus longimanus*	Selachimorpha	Groundfishes	Lutjanidae	*Lutjanus bohar*	Pelagic fishes	Scombridae	Serranidae	Sphyraenidae	*Thunnus albacares*
1989	2.1	-	-	1.3	-	8.6	-	1.7	1.9	-	-
1990	3.1	0.2	0.1	8.4	0.1	38.5	0.1	5.1	19.0	0.1	0.8
1991	2.7	0.4	0.1	8.8	0.2	25.5	0.2	4.6	14.7	0.2	1.5
1992	3.0	0.6	0.2	11.7	0.3	18.2	0.3	2.4	11.6	0.3	2.3
1993	0.5	0.8	0.2	-	0.5	-	0.5	0.8	0.5	0.5	3.0
1994	0.6	1.1	0.3	-	0.6	-	0.6	0.9	0.6	0.6	3.8
1995	0.7	1.3	0.3	-	0.7	-	0.7	1.1	0.7	0.7	4.5
1996	0.8	1.5	0.4	-	0.8	-	0.8	1.3	0.8	0.8	5.3
1997	4.1	1.7	0.4	9.5	0.9	28.6	0.9	5.5	15.6	0.9	6.0
1998	7.5	1.9	0.5	19.0	1.0	57.3	1.0	9.6	30.3	1.0	6.8
1999	9.8	2.1	0.5	25.5	1.1	76.7	1.1	12.5	40.4	1.1	7.5
2000	11.4	2.3	0.6	29.9	1.2	90.0	1.2	14.5	47.3	1.2	8.3
2001	13.6	2.5	0.6	36.1	1.4	108.8	1.4	17.3	57.0	1.4	9.0
2002	14.8	2.7	0.7	39.1	1.5	117.8	1.5	18.8	61.8	1.5	9.8
2003	14.8	2.9	0.7	38.9	1.6	117.0	1.6	18.8	61.5	1.6	10.5
2004	13.7	3.2	0.8	35.3	1.7	106.3	1.7	17.6	56.1	1.7	11.3
2005	11.5	3.4	0.8	28.5	1.8	85.9	1.8	14.9	45.8	1.8	12.0
2006	10.3	4.0	1.0	23.9	2.2	72.0	2.2	13.6	39.0	2.2	14.4
2007	9.2	4.7	1.2	19.6	2.5	59.1	2.5	12.4	32.8	2.5	16.8
2008	8.2	5.4	1.3	15.6	2.9	47.0	2.9	11.3	26.9	2.9	19.2
2009	7.3	6.0	1.5	11.9	3.2	35.8	3.2	10.4	21.6	3.2	21.6
2010	7.6	6.7	1.7	11.9	3.6	35.8	3.6	11.0	21.9	3.6	24.0

Tentative Reconstruction of Kenya's Marine Fisheries Catch, 1950–2010*

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Abstract

Total marine fisheries catches were estimated for Kenya for the 1950–2010 time-period using the catch reconstruction approach developed by the *Sea Around Us* and applied to coastal countries worldwide. This included catches (including dead discards) of the industrial, artisanal, recreational, and subsistence fishing sectors. The total reconstructed catch for domestic sectors for the 1950–2010 time-period reached almost 985,000 tonnes. This figure is 2.8 times the official catch reported to the Food and Agriculture Organization of the United Nations (FAO). Major taxa caught were Lethrinidae (emperors; 9.0%), Scaridae (parrotfishes; 8.8%), *Siganus* spp. (rabbitfish; 8.6%), Elasmobranchii (sharks and rays; 5.3%), and Carangidae (jacks; 4.7%). The artisanal sector (i.e., small-scale commercial) was the most prominent, with 64% of the total catch. Unreported landings represented 63% of the total catch, whereas dead discards represented close to 2%.

Introduction

Kenya is located on the east coast of Africa between Somalia and Tanzania. Its Exclusive Economic Zone (EEZ) extends over 110,000 km² (97th in the World and declared in 1986; Figure 1). The coast is lined with coral reefs covering over 600 km² (Spalding *et al.* 2001), except in the central part, where coral growth is prevented by inputs from the Tana River (Ungwana Bay). Mangrove stands are also abundant, especially in the northern half of the coast (UNEP 1998). Despite these rich habitats, marine fisheries are limited due to a narrow shelf, resulting in a small inshore fishing area (Chuenpagdee *et al.* 2006),[1] where essentially all small-scale fisheries occur. Other factors influence small-scale fisheries, such as the northeast and southeast monsoons (from December-March and May-October, respectively), which further restrict fishing activities to inshore waters when the sea is too rough (Obura 2001a). Consequently, marine fisheries have been estimated to represent only 10% of Kenya's total fish catch (FAO 2012); the vast majority of the total fisheries catch comes from the thriving fisheries of Lake Victoria (one of the most important fishing areas on the African continent; FAO 2001; Anon. 2007).

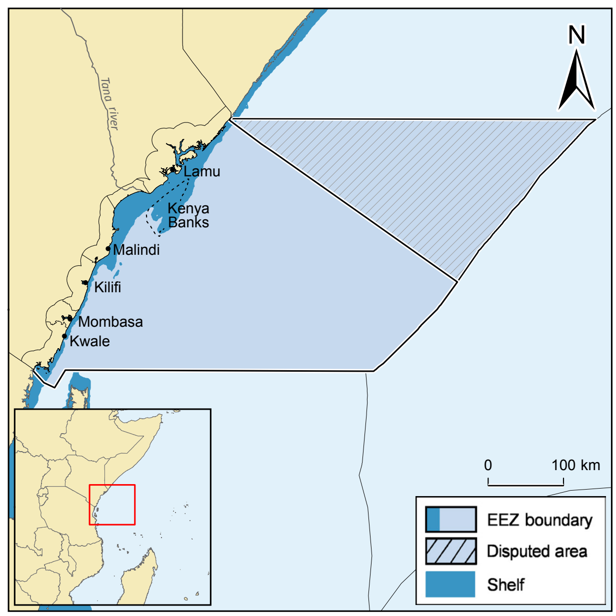

Figure 1. Map showing the extent of the Kenyan Exclusive Economic Zone (EEZ) and shelf water (to 200 m depth), as well as the location of the major coastal cities of Kwale, Mombasa, Kilifi, Malindi and Lamu (the limits of these districts are also shown), as well as the North Kenya Banks (dotted line).

Kenyan marine fisheries have always been critical to food security and livelihoods for coastal communities (Devisse 1989), similarly to many developing countries around the world (see also Zeller *et al.* 2014). For example, Malleret-King (2000) estimated that fisheries provided 80% of the total income to 70% of some coastal communities. Although the number of fishers increased at a rate of 2% per year during the 1980s (McClanahan *et al.* 2008), there is now some evidence that traditional fishing activities are declining, while other sectors are developing (e.g., sport fishing). One possible explanation is that tourism-related activities play an increasing role in coastal development (Mangi *et al.* 2007). Thus, some fishers have found alternative livelihoods: or tourists who wish to do sport fishing or visit marine protected areas for their more diverse fauna and protected habitats (Malleret-King 2000; Obura 2001a; Pitcher and Hollingworth 2007).

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[1] Defined as the area between the shoreline and either 200 m depth or 50 km distance from shore, whichever comes first.

Declining marine fisheries catches may also be related to declines in fish abundance. Reefs that sustain small-scale fisheries have been under severe pressure for decades in Kenya (see e.g., Khamala 1971; Muthiga and McClanahan 1987; Obura 2001b; Tuda *et al.* 2008). Their resources have been heavily exploited, and concerns of over-exploitation have been raised since the 1980s (Weber and Durand 1986; UNEP 1989). This has had impacts on both fish biomass and species composition, as evidenced by a long-term decrease in biomass and an increasing proportion of small, herbivorous species (Kaunda-Arara *et al.* 2003; McClanahan *et al.* 2008). A Beach Management Unit (BMU) system was introduced in 2006 to reverse these trends by involving communities in fisheries management (Oluoch and Obura 2008). Several gears such as spearguns and beach seines have also been forbidden, and the number of locally-managed marine protected areas (no-take zones, seasonal closures, or gear restrictions) has increased in the last decade. This shift in fisheries management has already had positive results in fish biomass and diversity (Kaunda-Arara and Rose 2004; Abunge 2011), and may lead to increased resilience for local marine ecosystems in light of changing global climate.

Official fisheries statistics provided each year since 1950 to the Food and Agriculture Organization of the United Nations (FAO) consist of four distinct taxonomic groups:

- Reef fishes (by far the most important group; e.g., Siganidae, Lethrinidae);
- Large pelagics (e.g., tunas, billfishes, and sharks);
- Shrimps (i.e., 'natantia');
- Other invertebrates (e.g., oysters, squids, octopuses).

Although it has been claimed in official reports that landing data were reliable (Nzungi *et al.* 2008), various researchers have criticized the quality of these data, underlining the poor monitoring of fishing activities along the coast, aggravated by low fishers' compliance (Oduor 1984; de Sousa 1987; Obura 2001a). This was clearly evidenced by a small-scale fisheries' reporting system designed in 1984, which determined that almost twice the officially reported amount was actually caught (Carrara and Coppola 1985). Although these new figures should have been processed and released as early as 1985, the absence of any increase in the official catch time-series documents that this was not done. More recently, McClanahan and Kaunda-Arara (1996) and McClanahan *et al.* (2008) showed that the actual catch per area was as high as 16 $t{\cdot}km^{-2}{\cdot}year^{-1}$ in some areas, starkly contrasting with the number based on official statistic, which oscillated between 2 and 4 $t{\cdot}km^{-2}{\cdot}year^{-1}$ (Kaunda-Arara *et al.* 2003). However, the situation is thought to have improved over the last decade (Obura 2001a; Muthiga *et al.* 2008), notably due to the implementation of frame surveys in 2004 (Republic of Kenya 2004–2012). Unfortunately, the monitoring, control and surveillance capacities are still lacking, as many fishers do not report their catch and official catch data still appear to have an unreported component (UNEP 1998; Mangi *et al.* 2007; Tuda *et al.* 2008; Maina 2012).

In this report, we apply to Kenya the reconstruction methods developed around principles in Pauly (1998), described in Zeller *et al.* (2007) and applied worldwide by the *Sea Around Us* (Zeller and Pauly 2007; Zeller and Harper 2009; Harper and Zeller 2012; Harper *et al.* 2012; Zeller *et al.* 2014). We aim to improve the overall quality of fisheries statistics by thoroughly reviewing the available literature and re-estimating the total extraction of marine fish since 1950.

Materials and methods

Preliminary re-allocation of the catch

The nominal catch provided by the Indian Ocean Tuna Commission (IOTC; www.iotc.org/data/datasets) was used to re-allocate the FAO catch of the large pelagics to various sectors. Given that the FAO dataset clearly includes the catch of the longline fleet (targeting swordfish) from 1980 to 1983, we assumed that the catch of this fleet was included in the FAO data for the entire period. When the IOTC catch for a given taxa was higher than the catch of this taxa reported by FAO, we assumed that it was because it was grouped in a more general taxon (due to low catches). We made the same assumption for the sport fishing fleet, thus we also assumed that at least some recreational (i.e., sport) fishing catches were included in the officially reported data. For both these fleets, the re-allocation of the FAO data was done according to Table 1.

The remaining catch of 'IOTC species' was re-allocated to the small-scale coastal fleets. However, we point out that except for 'Elasmobranchii', IOTC and FAO data series exhibit considerable and unexplained discrepancies when compared to each other. However, for consistency reasons and due to the rather unrealistic IOTC series (e.g., mostly flat for *K. pelamis*; plateauing and then steeply dropping for *Scomberomorus commerson*), we only used the FAO data here. The 'non-IOTC species' catch reported to FAO was also automatically allocated to the either the reef-gleaning sector ('Brachyura', '*Crassostrea* spp.', 'Crustacea', 'Holothuroidea', and 50% of 'Octopodidae') or the small-scale coastal fleet (remaining taxa).

As a result, the FAO catch was reallocated to several sectors, which were then studied and reconstructed separately (Figure 2).

Table 1. Correspondence between IOTC taxa and their FAO names, from which their catch was reallocated.

Fleet	Original IOTC taxon	Reallocated FAO taxon	Period
Longline (targeting swordfish)	*Acanthocybium solandri*	Perciformes	
	Alopias		
	Carcharhinidae		
	Carcharhinus falciformis	Elasmobranchii	All years these species were reported
	C. longimanus		
	C. obscurus		
	Istiompax indica	*Makaira indica*	1980–83
		Istiophoridae	2005 onward
	Istiophoridae		All years these species were reported
	Istiophorus platypterus	*Istiophorus platypterus*	1981–83
		Istiophoridae	2005 onward
	Isurus oxyrinchus	Elasmobranchii	
	I. paucus		
	Kajikia audax	Istiophoridae	
	Katsuwonus pelamis	*Katsuwonus pelamis*	
	Lamna nasus	Elasmobranchii	
	Makaira nigricans	Istiophoridae	
	Marine fishes not identified[a]	Perciformes	
	Prionace glauca	Osteichthyes[b]	All years these species were reported
	Pseudocarcharias kamoharai	Elasmobranchii	
	Scombridae	Scombroidei	
	Selachimorpha		
	Sphyrna lewini	Elasmobranchii	
	S. zygaena		
	Sphyrnidae		
	Tetrapturus angustirostris	Istiophoridae	
	Thunnus alalunga	*Thunnus alalunga*	1980–83
		Perciformes	2005 onward
	T. albacares	*Thunnus albacares*	1980–83
		Perciformes	2007 onward
	T. obesus	*Thunnus obesus*	1980–83
		Perciformes	2005 onward
	Xiphias gladius	*Xiphias gladius*	1980–83
		Perciformes	2005–08, 2010
		Osteichthyes	2009
Sport fishing	*Acanthocybium solandri*	Perciformes	
	Auxis thazard thazard		
	Carcharhinidae	Elasmobranchii	All years these species were reported
	Carcharhinus longimanus		
	Euthynnus affinis	Perciformes	
	Istiompax indica		1987, 1990–93, 1995, 2008
		Osteichthyes	1994
		Istiophoridae	2006–07, 2009
	Istiophoridae	Perciformes	1995
		Istiophoridae	2000 onward
	Istiophorus platypterus	Perciformes	1987, 1989–1993, 1995, 2008
		Osteichthyes	1994
		Istiophoridae	1996–2006, 2009–10
	Isurus oxyrinchus	Elasmobranchii	All years these species were reported
	Kajikia audax	Perciformes	1987, 1989–1993, 1995
		Osteichthyes	1994
		Istiophoridae	1996 onward
	Katsuwonus pelamis	*Katsuwonus pelamis*	All years these species were reported
	Makaira nigricans	Perciformes	1987, 1990–93
		Osteichthyes	1994
		Istiophoridae	1998 onward
	Marine fishes not identified[a]	Perciformes	
	Prionace glauca	Elasmobranchii	
	Scombridae	Perciformes	
	Selachimorpha		
	Sphyrna zygaena	Elasmobranchii	All years these species were reported
	Sphyrnidae		
	Thunnus albacares		
	T. obesus	Perciformes	
	Xiphias gladius		

[a] Given that the IOTC focuses on large pelagics, we changed this taxon to 'pelagic fishes' in our database.
[b] For some reasons, the catch of that species were very high compared to the other species of sharks. Given that the catch of *Prionace glauca* was even higher than the total catch of sharks reported to FAO, we decided to reallocate it from the higher taxon 'Osteichthyes'.

Domestic fisheries

Small-scale, coastal fisheries

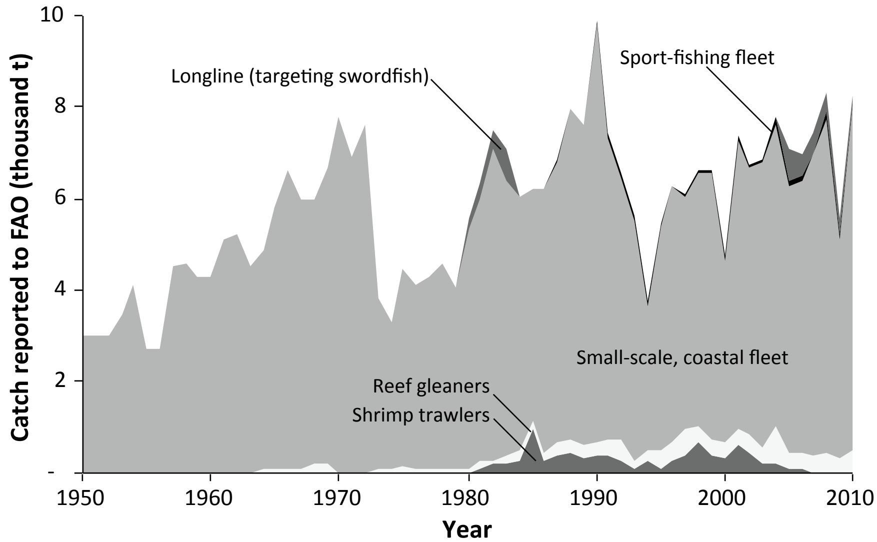

Figure 2. Catch reported to the FAO and reallocated to various fisheries sectors.

Small-scale fisheries represent the bulk of total Kenyan marine fisheries and essentially involve men.[2] Many species of fish are targeted, be they demersal reef species or small pelagic species roaming inshore waters, as well as commercially-important invertebrates such as shrimp, octopus, and lobster (Okechi and Polovina 1994; McClanahan and Mangi 2004; Anon. 2007; Maina and Samoilys 2011; Samoilys *et al.* 2011a,b). A dozen gears are used on a regular basis to target these different species, ranging from spearguns to beach seine and ring nets, and from traps to boat-operated driftnets (Samoilys *et al.* 2011a).[3] The major fishing grounds are found around Lamu, the mouth of the Tana River, Ungwana Bay/Malindi, as well as the Mombasa area and the North Kenya Banks (see Figure 1; Oduor 1984; Fondo 2004; Maina 2012; Munga *et al.* 2012). Spearguns, which were introduced in the 1970s (McClanahan *et al.* 1997), are now commonly used by the poorest fishers because they are cheap (McClanahan *et al.* 2005), similarly to other less efficient gears (Ochiewo 2002). On the other hand, beach seines (now also illegal) are mostly used because their efficiency is higher than that of any other gears (however, their catch is split into more shares as it requires more men). Beach seines capture a high diversity and size range, overlapping with other gears and, by impacting on the recruitment of a wide range of species, impair the functioning of the ecosystems that are exploited (McClanahan and Mangi 2004; McClanahan *et al.* 2005; Mangi and Roberts 2006). Due to these different uses, numerous conflicts between gear users have been reported over access to the resource (McClanahan *et al.* 2005; Mangi *et al.* 2007; Munga *et al.* 2010; Fulanda *et al.* 2011).

The pelagic component[4] of the small-scale fleet (motorized boats) seems to be increasingly important due to the decline of reef fish, although this fleet is mostly active during the north-east monsoon (when non-motorized boats cannot leave the inshore area; Maina 2012). During this season, fishers that are usually active further offshore are also known to retarget to valuable invertebrate species such as lobsters, holothurians and shells (Marshall *et al.* 1999; Maina and Samoilys 2011).

To re-estimate the total small-scale coastal fisheries, we first estimated the number of fishers from 1950 to 2010. To our knowledge, no reliable time-series of the number of fishers and fishing effort exist for this entire period, although figures have been published by the Government since the early 2000s (Republic of Kenya 2004). Officially, the Government reports that there were approximately 13,000 fishers in 2010 (Republic of Kenya 2012), but Tuda *et al.* (2008) and Maina (2012) suggested that these numbers were underestimated, and provided a higher figure of 15,000 fishers for as early as the 1990s. To remain conservative, we disregarded these non-official figures, and calculated the ratio of the geometric mean of the number of fishers provided by the Government for the years 2004 to 2010 (Republic of Kenya 2004–2012; the 2010 figure being the average of 2008 and 2012) over the total population in 2007. We then considered this fishers:total population ratio to be constant from 1950 to 2010 and applied it to the total population time-series (Figure 3).[5] We further disaggregated this fishers' time-series into five regions (roughly following the 'official districts'; see Figure 1), based on the percentage of the population living in the 15 km-band of each of them.[6]

There also exist some indications that fishers are now active fewer days per year, with an average of 220 fishing days per year (McClanahan and Mangi 2001; Caroline A. Abunge and Timothy R. McClanahan, pers. obs.).[7] We therefore assumed that fishers have been active 220 days per year since 1995, but that they used to fish 275 days per year prior to 1975 (i.e., prior to our assumed initial decline in CPUE; see Table 2).

[2] However, women and children are largely involved in collecting and marketing this fish, and in reef gleaning (see section below).

[3] Note that dynamite and poison are thought to be rarely used, except near the Tanzanian border (McClanahan *et al.* 2005).

[4] Besides medium to large pelagics such as tuna and billfishes, these offshore fishers also target sharks. They are valued as a cheap source of meat (traded up to 100 km inland) and for their dried fins exported to Asia. According to Marshall (1997), Kenya exported at least 140 t of shark fins between 1986 and 1990. Most of these exports (75%) were actually re-exports, as about 10 to 20 t (and 50 t during summer) were imported from Somalia every month. However, anecdotal evidence suggests that the domestic fishery is increasingly widespread, threatening shark populations (Spooner 2012).

[5] This resulted in an annual growth rate higher than the one published by McClanahan *et al.* (2008), i.e., +2% per year, but our estimate resulted in a more conservative number of fishers in the earlier period.

[6] These figures are based on the World Resource Institute's high-resolution GIS files (http://www.wri.org/publication/content/9291), from which we extracted the population living in the 15-km coastal band (assuming homogeneous distribution of the population within each polygon).

[7] Note that this number is an average for the entire coastline. Some sources tend to indicate that there are more fishing days in the south, e.g., 300 fishing days (Crona *et al.* 2010).

Table 2. Summary of the methods used to reconstruct the catch of the small-scale coastal fisheries in the five regions defined in Figure 1, 1950 to 2010.

Region	Period	CPUE (kg·fisher⁻¹·day⁻¹)	Note	References
Mombasa	1950	16.4	Anchor point; assumed 20% higher than anchor point in 1985	Grottanelli (1955)[a]
	1951–1974	16.4	Assumed similar to 1950	-
	1975–1984	16.2→13.9	Linear interpolation until 1985	-
	1985	13.7	Anchor point	Samoilys *et al.* (2011b,c)
	1986–1994	12.8→5.8	Linear interpolation until 1995	-
	1995–2010	4.9→2.5→3.2	Anchor points	WCS data
Lamu	1950–1985	16.4→13.7	Similar to Mombasa	-
	1986–2000	13.5→10.0	1975–1985 trend carried forward[b]	-
	2001–2010	10.1→11.3	Increase of 1.2% per year[c]	-
Kilifi/Kwale	1950–2000	16.4→2.5	Similar to Mombasa	-
	2001–2010	2.6→2.9	Increase of 1.2% per year[c]	-
Malindi	1950–2010	16.4→7.1	Average between Lamu and Kilifi/Kwale (central position)	-

[a] This author does not provide any specifics, but based on his observations, it can be assumed that catches were abundant. Since there were already signs of over-exploitation of Kenyan reefs in the 1980s (Weber and Durand 1986; UNEP 1989), we assumed that the average CPUE was 20% higher than that reported by Samoilys *et al.* (2011b,c) for the mid-1980s.
[b] We considered that the CPUE decrease in the area of Lamu was slower than in the area of Mombasa, due to a much lower population density, and thus, fishing pressure.
[c] We considered that the trend in CPUE reversed after 2000 as well, similarly to Mombasa area. However, we considered that the recovery rate was half that of Mombasa's, due to lower enforcement of management measures.

We then estimated a CPUE time-series for each of the five regions, based on data collected by the Kenyan branch of the Wildlife Conservation Society (WCS) since 1995, coupled with other anchor points found in the literature (Grottanelli 1955; Samoilys *et al.* 2011b,c), as described in Table 2.

By multiplying these regional CPUE time-series by the number of fishing days and their respective time-series of fishers (Figure 3), we obtained the total 1950–2010 small-scale, coastal fisheries catch (catches in the Tana River estuary were estimated separately; see below).

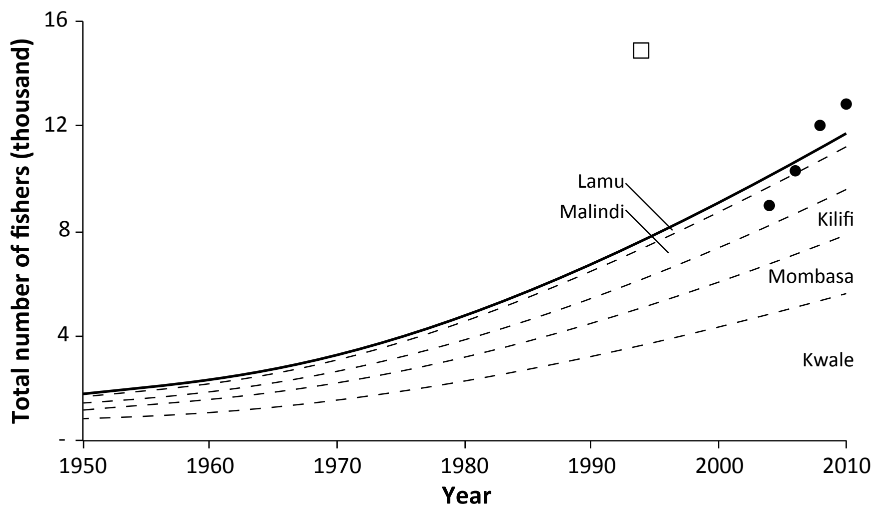

Figure 3. Suggested time-series of the total number of fishers (solid line), given the demography of Kenya. The solid dots represent the estimates of the Government (Republic of Kenya 2004–2012; the 2010 point being the average of 2008 and 2012 data). The white square represents Maina (2012)'s estimate, and is provided here as an illustration only. The dashed lines represent the estimated number of fishers in each region (see Figure 1).

With regards to the taxonomic breakdown, we first adjusted the 1950–1974 data reported to FAO by reallocating part of the meaningless 'Osteichthyes' taxon to the various taxa reported in following years:

- From 1972 to 1974, we applied the 1975–79 average taxonomic breakdown of the small-scale coastal fleet minus 'Elasmobranchii' and '*Panulirus* sp.' (already reported);
- For 1970 and 1971, we applied the updated 1972–76 average taxonomic breakdown of the small-scale coastal fleet minus '*Panulirus* sp.' (already reported);
- From 1950 to 1969, we applied the updated 1970–74 average taxonomic breakdown of the small-scale coastal fleet;
- Finally, we added a new taxon, Scaridae, which seems to represent an important part of the catch according to WCS surveys, but which is absent from FAO data. For this taxon, we simply considered that it was making up 50% of the remaining groundfishes (FAO name is 'demersal perciformes) throughout the time-series.[8]

Once these adjustments were made, we applied the same taxonomic breakdown to the unreported landings estimated above (equals 'total reconstructed' minus 'total reported').

The last step was to allocate the total catch to either the subsistence or artisanal (i.e., commercial) sectors. Based on personal observations and communications with local fishers, we considered that 80% of 'Clupeoids' and 50% of 'Carangidae' and the larger groups of 'groundfishes', 'marine fishes not identified', and 'pelagic fishes' were kept for subsistence purposes, while 90% of all other taxa were sold (commercially-valuable taxa corresponding to the 'artisanal catch'; Maina 2012) and the remaining 10% (e.g., juveniles and low-value species) were kept for subsistence.

Catches in the Tana River estuary were estimated separately, using shrimp and associated fish catches reported by Munga *et al.* (2012):

[8] The rest of the taxonomic breakdown was kept as is for the 1975–2010 period.

- From 1963 to 1979, we considered that the entire shrimp catch reported to FAO was small-scale, as the industrial fishery started in 1980. We then applied the average 1963–1979 catch (i.e., 115 t per year) back to 1950, and then from 1980 to 2000;
- From 2000 to 2006, we used Munga *et al.* (2012)'s small-scale catch data;
- From 2007 to 2010 (no industrial fishery), we took whichever data was the highest for any given year, between Munga *et al.* (2012)'s small-scale catch data and FAO data;
- Munga *et al.* (2012) further estimated that fish were making between 87.6% and 93.5% of the small-scale catch from 2001 to 2008. We therefore applied these percentages from 2001 to 2008, and their average (i.e., 90.9%) from 1950 to 2000 and from 2009 to 2010, to estimate the fish catch by small-scale fishers in the Tana River area.

We considered that the species of shrimp caught by the small-scale fishers were similar to those targeted by the industrial fleet (see below; Mutagyera 1984), i.e., *Penaeus indicus* (70.6%), *Metapenaeus monoceros* (15.6%), *P. monodon* (5.6%), *P. semisulcatus* (5.6%), and *P. japonicus* (2.6%). Similarly, we also used the taxonomic composition of the fish catch reported by Munga *et al.* (2012), which we applied throughout the time-period. We further considered that 80% of Acanthuridae, Cichlidae, Claridae, Clupeidae, and Protopteridae[9] were kept for subsistence purposes (low-value fish), and that 90% of sharks, billfishes, Lethrinidae, Lutjanidae, Mugilidae, cephalopods, Palinuridae, Scaridae, Scombridae, Serranidae, and Siganidae were sold (i.e., artisanal catch; the rest being kept for subsistence). The remaining groups (i.e., Carangidae, and mixed demersals and pelagics) were allocated to the subsistence and artisanal sectors in equal proportions.

<u>Industrial shrimp fisheries</u>

The shrimp fishery is the only sector with a management plan in Kenya (Republic of Kenya 2011; Maina 2012).[10] The single shrimp fishing ground of commercial importance is located in the Ungwana Bay (at the mouth of the Tana River; Mwatha 2002),[11] and is in fact one of the largest in east Africa (Fulanda *et al.* 2011). Due to important discharge of sediments and nutrient-rich freshwater from the river, the Ungwana Bay is also known as the most productive fishing ground along the Kenyan coast (Kitheka 2002; Mwangi 2002). A small fleet fluctuating between four and 20 industrial trawlers was active since the late 1970s (Mwatha 2002), but official statistics were only reported since the mid-1980s (Fulanda *et al.* 2011; Munga *et al.* 2012). Industrial trawling was restricted to waters beyond nine kilometers from shore, whereas small-scale fishers (who not only target shrimp) were allowed to fish within the 9 km zone.[12] However, increasing tensions between the two sectors (e.g., due to gear destruction and resource-sharing (Mwatha 2002; Ochiewo 2002)) forced the government to implement seasonal closures for the industrial fishery in 2001 (Gazette No 7565 of October 31, 2001) and completely ban industrial trawling in 2006.

The main targeted species were *Penaeus indicus* (70.6%), *Metapenaeus monoceros* (15.6%), *P. monodon* (5.6%), *P. semisulcatus* (5.6%), and *P. japonicus* (2.6%; Mutagyera 1984).

To reconstruct the full time-series of industrial shrimp catches, we used the following methodology:

- From 1981 to 2000, we subtracted the average 1963–1979 small-scale catch (i.e., 115 t; see section above) from the reported FAO data, in order to estimate the industrial component. The missing 1980 data were replaced by the average between the assumed zero in 1979 (considered to be the last year before industrial trawling for shrimp started) and the 1981 value;
- From 2001 to 2006, we took whichever data were the highest for any given year, between Munga *et al.* (2012)'s industrial data and FAO data.

Fish accounted for between 25.6% to 56.7% of the trawlers' total catch from 2001 to 2006 (Munga *et al.* 2012), and were as high as 70–80% of the total catch before the 2000s (Ochiewo 2002). Therefore, we considered that shrimp were only contributing 20% of the reconstructed total industrial trawler catch from 1980 to 2000, and then used the data provided by Munga *et al.* (2012) from 2001 to 2006. We also applied the taxonomic composition provided by Munga *et al.* (2012) from 1980 to 2006.

Furthermore, Mwatha (2002) suggested that only adults of commercially-important bycatch species were retained. We assumed 25% of the following species were juveniles and thus discarded: Carangidae, Istiophoridae, Lethrinidae, Lutjanidae, octopodiformes, Palinuridae, Scaridae, Scombridae, Serranidae, and Siganidae. We also assumed that 80% of the 'mixed demersals' were discarded. We applied these ratios from 1980 to 2006, the only exception being Claridae[13] (i.e., catfishes), for which we considered that 100% were discarded until 1999, and then only 80% from 2000 to 2006 (Mwatha 2002). The sum of these assumed discard rates applied to the taxonomic breakdown described above amounted to 79.8% of the bycatch being discarded from 1980 to 1999 and 75.1% from 2000 to 2006, in the same range as discards of 67% reported by Kelleher (2005) and the 1:7 shrimp:discard ratio reported by Mwatha (2002).

[9] This taxon was probably misidentified as it refers to lungfishes, which are strictly limnic.

[10] There have also been unsuccessful attempts of deep-water shrimp/lobsters fisheries in the Ungwana Bay, but this was not economically feasible (Mutagyera 1984).

[11] However, note that some Kenyan trawlers are known to have been fishing shrimp illegally in Somali waters (Anon. 2005a).

[12] This segregation between these two sectors is due to technology: industrial freezers are equipped with funnel-shaped otter trawls and are 25 to 40 m long (storage capacity of 30 to 350 tonnes; engines from 115 to 1,500 horsepower), while small-scale fishers use dug-out canoes and plank wood canoes, thus limiting their activity to a narrow band along the coast.

[13] This taxon is included in the 'miscellaneous marine fishes' category the *Sea Around Us* database, as at the time of writing there was no code for this taxonomic group.

Reef gleaning

Women and children have always been involved in collecting invertebrates such as crabs, holothurians and shells all along the coast at low tide (Grottanelli 1955). Overall, though, the catch of reef-gleaners is thought to be smaller than that of the reef fisheries performed by male fishers (Samoilys *et al.* 2011b).

Shellfish account for the bulk of reef-gleaning catches and are mainly collected for the tourism market (Kimani 1995; Marshall *et al.* 1999), but concerns of over-exploitation have been voiced since the 1970s (Marshall *et al.* 1999). Holothurians are exclusively targeted for the export Chinese market, and, similarly to shells, it appears that both the average size and the density of holothurians have decreased over-time. They are now mostly targeted by scuba divers in deeper waters, similar to Madagascar (Le Manach *et al.* 2012) and Tanzania (Bultel *et al.* this volume). Crabs (mainly *Scylla serrata*) are consumed locally and are mainly caught in the north, where most mangroves are located (Mutagyera 1984; Kimani 1995; UNEP 1998).

We assumed that the number of gleaners was equivalent to 30% of the intermediate number of male fishers (see Figure 3) from 1950 to 1970, and 20% from 2005 onwards (we linearly interpolated the values). This was based on the assumption that reef-gleaning is becoming less important due to the emergence of alternative livelihoods. We then assumed that each gleaner was active 200 days per year and was catching 4 $kg \cdot day^{-1}$ in 1950. This catch rate was linearly interpolated to 3 $kg \cdot day^{-1}$ in 2010, based on the aforementioned signs of over-exploitation.

Due to the lack of information on this sector, we used the FAO data corresponding to these taxa, and allocated to this sector (Figure 2) to estimate a taxonomic breakdown for our reconstructed catch. For years without data, we carried backward the average percentage of each taxon, and re-scaled the total to 100%. Finally, we created another category, i.e., 'shells', which was deemed to represent the species collected for the tourism market.

Longline (targeting swordfish) fleet

As far back as the 1950s, Kenyan waters have been considered to be productive, and Williams (1956) noted the possibility to develop a troll line fishery. As pointed out by de Sousa (1987), FAO data "include the catches from two [domestic] industrial scale tuna longliners which were operated from Mombasa during the early 1980s" (Figure 2). Although IOTC data display the same trend as the FAO data, they are slightly higher. In our database, the difference was thus included as 'unreported landing with respect to data reported by FAO on behalf of Kenya', since we deemed IOTC data to be more accurate.

Since 2005, two industrial longliners targeting swordfish have also been registered in Kenya. In 2010, only one vessel remained (then owned by a Spanish company), before it was highjacked by pirates when it ventured into Somali waters (Anon. 2010; IOTC 2012); this vessel was later transferred to the Atlantic Ocean (Nyongesa Wekesa and Ndegwa 2011). Their catch was estimated by a 'liaison officer' to have declined from 730 and 156 $t \cdot year^{-1}$. The catch of these longliners were also re-allocated from the FAO series (see above; Table 1).

In this report, we did not re-estimate any discards for this sector. This was done separately as part of the *Sea Around Us* work on harmonizing worldwide catches of large pelagics (Le Manach *et al.* in press).

Sport fishing fleet

Kenya has been a tourist destination since at least the 1950s (Williams 1970), but mass tourism started in the 1980s (Weaver 1999; Irandu 2004). This sector is now a pillar of the Kenyan economy (Mangi *et al.* 2007), as there are currently over 1.6 million tourists visiting Kenya every year (Kenya National Bureau of Statistics 2010). Most visitors spend part of their stay visiting places such as the Massai-Mara,Tsavo and Ambosseli National Parks for safaris (Weaver 1999), and about one third also visit coastal areas Williams 1970; Kimani 1995).

Kenyan sport fishing started in the 1950s (Williams 1970) and became much more prominent in the mid-1980s (Marshall 1997), due to increased tourism. According to Marshall (1997), there were about 60 sport fishing boats (5–12m long; 60 to 200 trips each per year) that were registered in the late 1990s, but we can expect this figure to have greatly increased in the 2000s. Indeed, Ndegwa (2010) reported that about 30 centers were registered along the coast in the late 2000s; thus, it is easily imaginable that each center has, on average, more than only two boats. As a matter of fact, Ndegwa (2010) also reports that there are on average nine boats per day at sea at Malindi's resort.

Sport fishing mostly occurs from April to August, the weather being too rough the rest of the year (Abuodha 1999). Boats mainly use hook and line, in contrast with shore-based recreational fishing (mostly trolling, drifting, and spinning).[14] The sport fishing charters generally operate from all major ports and fish the more distant Kenyan Banks, 35–55 km offshore (Ndegwa 2011; Figure 1). However, it seems that, although resorts occur along the entire Kenyan coast, the resorts of Watamu, Malindi (and offshore Kenya banks), Shimoni and Mombasa make up most of the sport fishing activity (Abuodha 1999; Ndegwa 2010). Ndegwa (2010) reports that 22,000 trips were recorded between 1990 and 2008 in the resort of Malindi alone. This author notes, however, a decrease from 1,600 trips per year in the early 1990s to currently 1,200 (Ndegwa 2010).

Some authors previously believed that FAO data included some recreational fisheries data at some point in the past (de Sousa 1987), but this was later questioned by Ndegwa (2010). According to the latter author, the Kenyan

[14] Although a tag and release project was introduced in 1987 (Abuodha 1999), it seems that most fish are still sold on local markets. When skippers judge the fish to be in good-enough physiological condition, though, they may release it after the photo-shoot.

Fisheries Department collected sport fisheries data since 1940, but never computerized them. In 2006, the Indian Ocean Tuna Commission and the Overseas Fishery Cooperation Foundation aimed to collect these data in order to create a historical database and analyze CPUE trends. This database is now available at 41.206.61.142:8080/statbase_3 and has been included in the IOTC catch database. Here, we assumed that these data were now included in the FAO data (Figure 2). These reported catches oscillated between 11 and 182 tonnes and averaged 91 tonnes between 1987 and 2010. However, Ndegwa (2010) reported that recreational catches in Malindi's resort alone consistently ranged around 100 $t \cdot year^{-1}$, making it therefore likely that only a subset of total recreational catches were ever included in the IOTC dataset.[15] As a matter of fact, Maina (2012) reported catches around 206 $t \cdot year^{-1}$, with 318 t in 2009. He also noted that much remains to be done to improve the quality of these statistics, reinforcing the feeling that official statistics miss a large part of the recreational sector.

To reconstruct this sector, we produced a set of assumptions based on data provided by Williams (1970) for the 1960s:

- Sailfish were weighting on average 29.5 kg;
- Sailfish were making up 30% of the total catch in weight (the author notes that both sailfish and marlin make up a majority of the catch);
- Malindi's area was accounting for half of the recreational catch in Kenya.

A catch of zero tonnes was set for 1950, and data were linearly interpolated to 1958, the first year for which Williams (1970) presented data.

From 1987 to 2006, we used the data published by the IOTC (Ndegwa 2010), filling the gaps with linear interpolations (1988–89 and 2002–04). For 2007–2010, we used the average of the period 1987–2006; excluding interpolations). Further, we considered that this author only managed to collect half of the actual catch in the area of Malindi (Ndegwa [2010] noted that data still needed to be much improved).

To scale these results to the entire Kenyan coastline, we considered that Malindi's resort made 50% of the total catch until 1980, and only 25% from 2000 onward (linearly interpolating in between). This was based on the assumption that other resorts gained a larger portion of the total share due to the tourism expansion in the 1980s.

The taxonomic breakdown for this sector was based on Abuodha (1999), although some modifications were made to accommodate the data reported to FAO: *Istiophorus* sp. (30%) and Scombridae (20%); the rest being equally distributed among *Sphyraena* spp., *Scomberomorus commerson*, *Makaira* spp., *Acanthocybium solandri*, Elasmobranchii, and other pelagic species.[16] The unreported landings were calculated by subtracting the data reported to FAO from the data estimated above (Table 3).

Table 3. Correspondence between the reported taxa and the assumed FAO taxa, from which their catch was subtracted to calculate the 'unreported landings'.

Reported taxon	Assumed FAO taxon
Acanthocybium solandri	*Acanthocybium solandri*
Carcharhinidae	Elasmobranchii
Carcharhinus longimanus	
Isurus oxyrinchus	
Prionace glauca	
Selachimorpha	
Sphyrna zygaena	
Sphyrnidae	
Auxis thazard	Scombridae
Euthynnus affinis	
Katsuwonus pelamis	
Scombridae	
Thunnus albacares	
T. obesus	
Istiophoridae	*Istiophorus* spp.
Istiophorus platypterus	
Istiompax indica	*Makaira* spp.
Kajikia audax	
Makaira nigricans	
Pelagic fishes	Pelagic fishes
Xiphias gladius	
Sphyraena spp.	No reported catch; All 'unreported landing'
Scomberomorus commerson	

Foreign fisheries

Distant-water tuna fleets

Historically, offshore stocks have remained largely unexploited by local fishers (Anon. 1996), but have long been intensively exploited by distant-water fleets (FAO 2007). Indeed, Kenyan waters are located in the productive Mozambique Channel and are therefore host to highly productive tuna fisheries (Tuda *et al.* 2008).

In recent years, dozens of purse seiners and longliners from the Seychelles, Mayotte, Spain, France and Taiwan have been reported to have fishing licenses in Kenya, with however no conclusive information.[17] For example, FAO reported licenses for 33 purse seiners and 30 longliners (FAO 2007), while National reports stated that 19 and 34 licenses were active in 2008 and 2010 respectively (Sigana 2009; Nyongesa Wekesa and Ndegwa 2011); Signa *et al.* (2008) on the other hand reported a much higher figure of 116 vessels licensed in 2008. Therefore, it seems that many countries have fishing interests in Kenyan waters, but that they may not be legally present (i.e., licensed) every

[15] Pitcher and Hemphill (1989) also collected recreational catch data from 1976 to 1987, showing that several hundred yellowfin tuna (i.e., several tonnes) were caught in the resort of Shimoni alone.

[16] Noteworthy, it seems that shark sightings decreased over the last few decades (Marshall 1997), similarly to most places in the world.

[17] Note that the EU and the Government of Kenya have been negotiating the signature of a Fisheries Partnership Agreement for several years (Anon. 2005a, 2014).

year. Indeed, the lack of monitoring and surveillance capacity is thought to be a major incentive for illegal fishing (up to 160 vessels; i.e., only 20% of tuna vessels are licensed) and underreporting (Anon. 2005a, 2007).

Catches of this sector are not presented here. Rather, they are estimated as part of the global large pelagic catch reconstruction conducted by the *Sea Around Us* (Le Manach *et al.* in press).

Small-scale migrant fishers

Kenyan waters also host migrant fishers from Tanzania. These fishers, coming from the south during the north-east monsoon season, seek calmer waters and often reach the Malindi area, about halfway up the country. These fishers mainly target highly valuable species such as sharks, Carangidae, Lethrinidae and Siganidae (Crona *et al.* 2010), mainly using lines in the north, and shark nets in the south. Because of the species they target and their usually higher CPUEs (i.e., 2.2 times higher than domestic artisanal fishers, on average), there are often tensions between the two groups. Here, we considered that migrant fishers had a CPUE 2.2 times higher than local fishers in the regions south of Lamu (Figure 1), that their number was equivalent to 10% of that of the local fishers, and that they fished 300 days per year (Crona *et al.* 2010).

Results

Domestic fisheries

The total catch by Kenyan fishers is estimated to have been almost 985,000 tonnes from 1950 to 2010, which is 2.8 times the amount reported to FAO (Figure 4). It increased from 9,600 tonnes in 1950 to a peak of nearly 27,000 tonnes in 1985. It then decreased to 12,100 tonnes in 2000 and increased again to 15,900 tonnes in 2010.

Overall, artisanal, subsistence, industrial, and recreational catches made up 64%, 27%, 5%, and 4%, respectively (Figure 4).

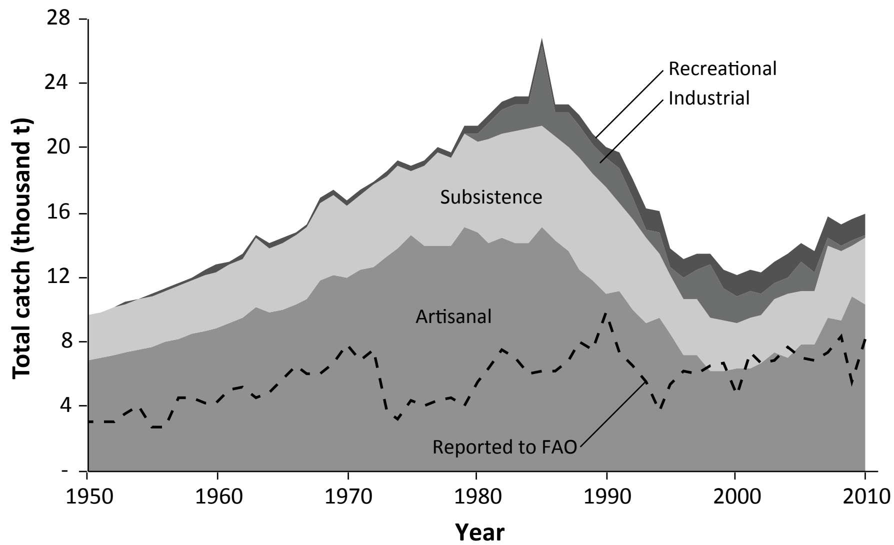

Figure 4. Total reconstructed catch (from 1950 to 2010), showing the artisanal, subsistence, industrial, and recreational sectors, as well as the data reported to FAO (dashed line; see Appendix Table A1 for details).

We estimated that the small-scale coastal fisheries (including those in the Tana River estuary) caught in excess of 845,000 t between 1950 and 2010 (86% of the total). Catches increased from around 9,200 t in 1950 to a peak of 20,500 t in 1985. Catches then decreased to 7,900 t in 2000 to increase again to around 13,000 t by the late 2000s. Lethrinidae, Scaridae, *Siganus* spp., elasmobranchii, and Carangidae were the main taxa, with 10%, 10%, 10%, 6%, and 5% of the catch, respectively, the rest being composed of other taxa of fish and various invertebrates.

More marginalized than reef fishers, reef-gleaners come as the second most important group of fishers in terms of total catch. Over 55,000 tonnes of invertebrates were caught over the 1950–2010 period (6% of the total catch). The overall catch increased from 400 tonnes in 1950 to 1,400 tonnes in 2010, out of which 25% were shells, 23% were marine crabs (mostly *Scylla serrata*), 19% other crustaceans, 15% holothurians, 12% octopuses, and 5% oysters.[18]

Recreational catches by tourists steadily increased — although fluctuating — from 34 t in 1951 to around 1,300 t by 2010. A substantial decrease occurred in 1997–98 (to around 700 t), which was caused by the collapse of coastal tourism following political riots (Obura 2001a). Overall, tourists caught 38,000 t in Kenyan waters, which still only represents around 4% of the total catch. Sailfish represented 28% of the catch and tuna 19%. The rest of the catch was composed of various species of large pelagics.

Finally, the industrial shrimp sector caught 41,000 t of targeted shrimp and associated bycatch (of which almost 18,500 t were discarded) between 1980 and 2006. Total catches (including discards) have increased from 280 t to a peak at 5,000 t in 1985. After a steep decrease, another peak occurred in 1998 at 3,300 t, before the catch decreased to around 800 t when the industry ceased in 2006.

[18] Although the meat of the shells is consumed locally, we considered that this fishery exclusively targeted the tourist market, and was thus artisanal. Furthermore, we considered that cupped oysters and marine crustaceans were caught for subsistence purposes, and that the other categories were sold on local markets (i.e., artisanal catch).

Overall, Lethrinidae, Scaridae, *Siganus* spp., Elasmobranchii, and Carangidae were the most caught taxa, with 9%, 9%, 9%, 5%, and 5% of the total catch, respectively (Figure 5).

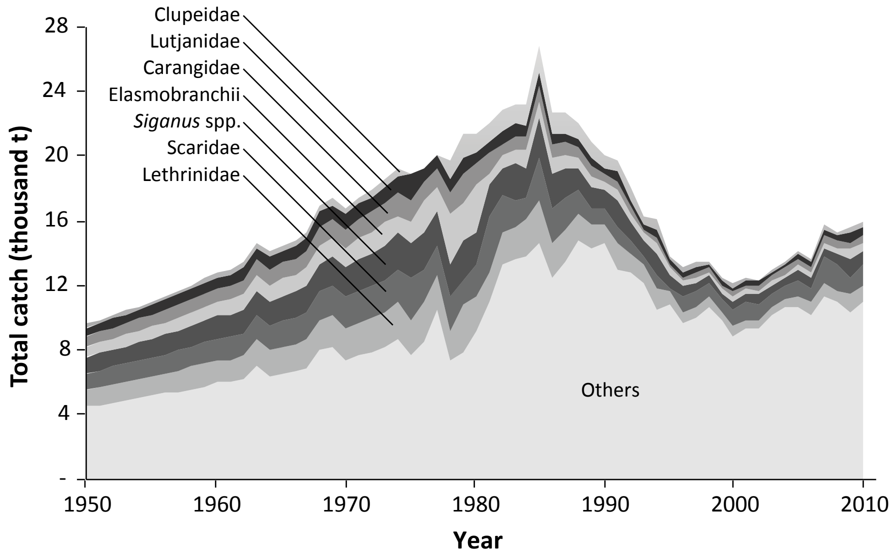

Figure 5. Total reconstructed catch (from 1950 to 2010), showing the main taxa (see Appendix Table A2 for details). 'Others' includes an additional 58 taxa.

Foreign fisheries

Migrant fishers caught almost 100,000 t between 1950 and 2010, with catches increasing from 900 t in 1950 to 2,600 t in 1985, then dropping to 700 t in 2000 and then increasing again to 1,200 t in 2010 (i.e., similar pattern as the domestic small-scale coastal fisheries, due to the series of assumptions used here).

Discussion

In this reconstruction, we showed that, similarly to most maritime countries around the world, official fisheries statistics in Kenya only account for a portion of small-scale fisheries, especially in the early time-period (see also Zeller *et al.* 2014). However, these small-scale fisheries generally constitute the pillar of coastal livelihoods (Barnes-Mauthe *et al.* 2013), and represent the bulk of fisheries activities. We also show that subsistence activities (e.g., reef gleaning), recreational fisheries, and industrial discards, are largely missing from official catch statistics, although they have an important social, economic, and ecological impact.[19] Noteworthy, the quality of the official catch statistics has improved over time, as the reported catch was representing only 32% of reconstructed total catches in the 1950s but increased to 50% in the 2000s. However, this relatively good news should not over-shadow the fact that the annual catch per fisher has steeply declined between the 1950s and the 2000s, although this decline may have been stopped due to improved management measures and an expansion of the fleet to more offshore waters.

Our results for the small-scale coastal fisheries are highly dependent on the reconstructed fishers' time-series (Figure 3). This area should be investigated further (e.g., with a sensitivity analysis), as there seems to be some Malthusian overfishing (Pauly 1990, 1994; McClanahan *et al.* 2008) in Kenya, with many people turning to fishing in order to feed their families (Mangi *et al.* 2007). Therefore, our time-series of the number of fishers shall be viewed as preliminary, and more robust estimates of the number of fishers would be welcome.

We hope that these revised statistics will be taken into account by official bodies, as is the case in Mozambique (Doherty *et al.* this volume). Effective fisheries regulations and management must be based on comprehensive and unbiased catch statistics, accounting for all sectors including non-commercial activities.

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References

Abunge CA (2011) Managing finite marine resources the Kenyan way. Swara 3: 46–47.

Abuodha P (1999) Status and trends in recreational marine fisheries in Kenya. pp. 46–50 *In* Pitcher TJ (ed.). Fisheries Centre Research Reports 7 (2). University of British Columbia, Vancouver (Canada).

Anon. (1996) Towards integrated management and sustainable development of Kenya's coast — Findings and recommendations for an action strategy in the Nyali-Bamburi-Shanzu area. Prepared by Coast Development Authority, Kenya Marine and Fisheries Research Institute, Kenya Wildlife Service, Fisheries Department, Mombasa Municipal Council, and Kenya Association of Hotelkeepers and Caterers. ix + 77 p.

Anon. (2005a) Review of impacts of Illegal, Unreported and Unregulated fishing on developing countries. Marine Resources Assessment Group Ltd (MRAG), London (UK). 176 p.

Anon. (2005b) Kenya and EU open fisheries negotiations Agritrade — News and Analysis, Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA), Wageningen (The Netherlands). 1 p.

Anon. (2007) Kenya — State of the coast report 2007 — Towards an integrated management of Kenya's coastal and marine resources. National Environment Management Authority (NEMA), Nairobi (Kanya). vi + 101 p.

[19] Pitcher and Hollingworth (2007) reported that "a U.S. big-game fisher going on holiday in Kenya may spend more money fishing for one day (say $1,000) than many local people, including the boat crew or resort staff, might earn in 5 years".

Anon. (2010) Somali pirates hijack Kenyan longliner Fish Information Services, edition of March 10.

Anon. (2014) An interview with Peter Sol Rogers, Head of Trade Policy and Business Development at Wanainchi Marine Products, (K) Ltd. Agritrade, edition of March 9, 2014.

Barnes-Mauthe M, Oleson KLL and Zafindrasilivonona B (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. Fisheries Research 147(0): 175–185.

Bultel E, Doherty B, Herman A, Le Manach F and Zeller D (this volume) An update of the reconstructed marine fisheries catches of Tanzania with taxonomic breakdown.

Carrara G and Coppola SR (1985) Results of the first year implementation of the Kenyan catch assessment survey. Regional project for the development and management of fisheries in the southwest Indian Ocean. RAF/79/065/WP/18/85/E, Food and Agriculture Organization of the United Nations (FAO), Rome. 85 p. Available at: http://www.fao.org/docrep/field/279541.htm.

Chuenpagdee R, Liguori L, Palomares MD and Pauly D (2006) Bottom-up, global estimates of small-scale marine fisheries catches. Fisheries Centre Research Reports 14(8), Fisheries Centre, University of British Columbia, Vancouver. 112 p.

Cinner JE, Huchery C, Darling ES, Humphries AT, Graham NAJ, Hicks CC, Marshall N and McClanahan TR (2013) Evaluating social and ecological vulnerability of coral reef fisheries to climate change. PLOS ONE 8(9): e74321.

Crona B, Wanyonyi I, Ochiewo J, Ndegwa S and Rosendo S (2010) Fishers' migration along the Kenyan coast Implications for management of coastal fisheries. Policy brief, Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar (Tanzania). 10 p.

de Sousa T (1987) Summary of fisheries and resources information for Kenya. pp. 21–43 *In* Sanders MJ, Sparre P and Venema SC (eds.), Proceedings of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, September 14–25 1987, Albion (Mauritius) SWIOP Document OISO RAF/79/065/WP/41/88/E. Food and Agriculture Organization of the United Nations (FAO), and United Nations Development Programme (UNDP), Rome (Italy).

Devisse J (1989) Les Africains, la mer et les historiens. Cahiers d'études africaines 29(115–116): 397–418.

Doherty B, McBride MM, Brito AJ, Le Manach F, Sousa L, Chauca I and Zeller D (this volume) Marine fisheries in Mozambique: catches updated to 2010 and taxonomic disaggregation.

FAO (2001) Fishery country profile — Kenya. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). Available at: http://www.fao.org/fi/oldsite/FCP/fr/KEN/profile.htm.

FAO (2007) Fishery country profile — Kenya. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 23 p.

FAO (2012) FishStatJ, a tool for fishery statistics analysis. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Fondo EN (2004) Assessment of the Kenyan marine fisheries from selected fishing areas. The United Nations University Fisheries Training Programme, Reykjavik (Iceland). 55 p.

Fulanda B, Ohtomi J, Mueni E and Kimani EN (2011) Fishery trends, resource-use and management system in the Ungwana Bay fishery Kenya. Ocean and Coastal Management 54: 401–414.

Grottanelli VL (1955) Pescatori dell'Oceano Indiano — Saggio etnologico preliminare sui bagiuni, bantu costieri dell'oltregiuba. Cremonese, Rome (Italy). xxii + 409 p.

Harper S and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada). 143 p.

Harper S, Zylich K, Boonzaier L, Le Manach F, Pauly D and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part III. Fisheries Centre Research Reports 20 (5). University of British Columbia, Vancouver (Canada). 134 p.

IOTC (2012) Nominal catch database. Available at: http://www.iotc.org/English/data/databases.php [Accessed: March 12, 2013].

Irandu EM (2004) The role of tourism in the conservation of cultural heritage in Kenya. Asia Pacific Journal of Tourism Research 9(2): 133–150.

Kaunda-Arara B and Rose GA (2004) Effects of marine reef National Parks on fishery CPUE in coastal Kenya. Biological Conservation 118: 1–13.

Kaunda-Arara B, Rose GA, Muchiri MS and Kaka R (2003) Long-term trends in coral reef fish yields and exploitation rates of commercial species from coastal Kenya. Western Indian Ocean Journal of Marine Science 2(2): 105–116.

Kelleher K (2005) Discards in the world's marine fisheries: an update. Fisheries Technical Paper 470, Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 152 p.

Kenya National Bureau of Statistics (2010) Tourism indicators, 2001–2010. Government of Kenya, Nairobi (Kenya). Available at: http://www.knbs.or.ke/tourism_summary.php [Accessed: April 8, 2013].

Khamala CPM (1971) Ecology of *Echinometra mathaei* (Echinoidea: Echinodermata) at Diani Beach, Kenya. Marine Biology 11(2): 167–172.

Kimani EN (1995) Coral reef resources of East Africa: Kenya, Tanzania and the Seychelles. Naga, the ICLARM Quarterly 18(4): 4–7.

Kitheka JU (2002) Freshwater and sediment discharge in Ungwana Bay: the role of the Tana and Sabaki rivers. pp. 2–16 *In* Current status of trawl fishery of Malindi-Ungwana Bay — Final report. Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa (Kenya).

Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–225.

Maina GW (2012) A baseline report for the Kenyan small and medium marine pelagic fishery. Ministry of fisheries development, South West Indian Ocean Fisheries Project (SWIOFP) and EAF-Nansen Project. 74 p.

Maina GW and Samoilys MA (2011) Lamu lobsters — a dwindling resource. Swara 3: 34–35.

Malleret-King D (2000) A food security approach to Marine Protected Area impacts on surrounding fishing communities: the case of Kisite Marine National Park in Kenya. PhD thesis, University of Warwick, Department of Biological Sciences, UK. xi + 307 p.

Mangi SC and Roberts CM (2006) Quantifying the environmental impacts of artisanal fishing gear on Kenya's coral reef ecosystems. Marine Pollution Bulletin 52(12): 1646–1660.

Mangi SC, Roberts CM and Rodwell LD (2007) Reef fisheries management in Kenya: Preliminary approach using the driver–pressure–state–impacts–response (DPSIR) scheme of indicators. Ocean and Coastal Management 50: 463–480.

Marshall NT (1997) Trade in sharks and shark products in Kenyan waters. pp. 31–38 *In* Marshall NT and Barnett R (eds.), The trade in sharks and shark products in the western Indian and southern Indian and south east Atlantic Oceans. TRAFFIC International, Nairobi (Kenya).

Marshall NT, Milledge SAH and Afonso PS, editors (1999) Stormy seas for marine invertebrates — Trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique. Trade Review. TRAFFIC East/Southern Africa. 53 p.

McClanahan TR, Glaesel H, Rubens J and Kiambo R (1997) The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. Environmental Conservation 24(2): 105–120.

McClanahan TR, Hicks CC and Darling ES (2008) Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. Ecological Applications 18(6): 1516–1529.

McClanahan TR and Kaunda-Arara B (1996) Fishery recovery in a coral-reef marine park and its effect on the adjacent fishery. Conservation Biology 10(4): 1187–1199.

McClanahan TR, Maina JM and Davies J (2005) Perceptions of resource users and managers towards fisheries management options in Kenyan coral reefs. Fisheries Management and Ecology 12(2): 105–112.

McClanahan TR and Mangi S (2001) The effect of a closed area and beach seine exclusion on coral reef fish catches. Fisheries Management and Ecology 8(2): 107–121.

McClanahan TR and Mangi SC (2004) Gear-based management of a tropical artisanal fishery based on species selectivity and capture size. Fisheries Management and Ecology 11(1): 51–60.

Munga CN, Mohamed MOS, Obura DO, Vanreusel A and Dahdouh-Guebas F (2010) Resource users' perceptions on continued existence of the Mombasa Marine Park and Reserve, Kenya. Western Indian Ocean Journal of Marine Science 9(2): 213–225.

Munga CN, Ndegwa S, Fulanda B, Manyala J, Kimani EN, Ohtomi J and Vanreusel A (2012) Bottom shrimp trawling impacts on species distribution and fishery dynamics; Ungwana Bay fishery Kenya before and after the 2006 trawl ban. Fisheries Science 78(2): 209–219.

Mutagyera WB (1984) Distribution of some deep water prawn and lobster species in Kenya's waters. *In* Iversen SA and Myklvoll S (eds.), Proceedings of the NORAD-Kenya seminar to review the marine fish stocks and fisheries in Kenya, Mombasa (Kenya). 18–20 p.

Muthiga N, Costa A, Motta H, Muhando C, Mwaipopo R and Schleyer M (2008) Status of coral reefs in East Africa: Kenya, Tanzania, Mozambique and South Africa. pp. 91–104 In Wilkinson C (ed.), Status of coral reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville (Australia).

Muthiga NA and McClanahan TR (1987) Population changes of a sea urchin (*Echinometra mathaei*) on an exploited fringing reef. African Journal of Ecology 25(1): 1–8.

Mwangi SN (2002) Water quality and productivity of the Malindi-Ungwana Bay fishing grounds. pp. 30–42 *In* Current status of trawl fishery of Malindi-Ungwana Bay — Final report. Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa (Kenya).

Mwatha GK (2002) Assessment of the prawn fishery, bycatch, resource use conflicts and performance of the turtle excluder device. pp. 43–64 *In* Current status of trawl fishery of Malindi-Ungwana Bay — Final report. Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa (Kenya).

Ndegwa S (2010) Kenyan sports fishing Tuna CPUE. IOTC-2010-WPTT-42, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 8 p.

Ndegwa S (2011) Kenyan sports fishing Kawakawa and Frigate Tuna CPUE. IOTC–2011–WPNT01–28, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 10 p.

Nyongesa Wekesa P and Ndegwa S (2011) National report of Kenya. IOTC-2011-SC14-NR13, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 9 p.

Nzungi PM, Kimani EN and Okemwa G (2008) Fisheries data management in Kenya. pp. 42–43 *In* Report of the first working party on fisheries data and statistics, Mombasa (Kenya), April 24–27 2007. FAO Fisheries Report 852. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Obura DO (2001a) Kenya. Marine Pollution Bulletin 42(12): 1264–1278.

Obura DO (2001b) Participatory monitoring of shallow tropical marine fisheries by artisanal fishers in Diani, Kenya. Bulletin of Marine Science 69(2): 777–791.

Ochiewo J (2002) Assessment of socio-economic impacts of prawn trawling on the artisanal fisheries of Malindi and Ungwana Bay. pp. 71–81 *In* Current status of trawl fishery of Malindi-Ungwana Bay — Final report. Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa (Kenya).

Oduor BW (1984) Status of fish catches and landings in Kenya. *In* Iversen SA and Myklvoll S (eds.), Proceedings of the NORAD-Kenya seminar to review the marine fish stocks and fisheries in Kenya, March 13–15, 1984, Mombasa (Kenya). 64–72 p.

Okechi JK and Polovina JJ (1994) The spiny lobster fishery of Kenya. pp. 103–107 *In* Phillips BF, Cobb JS and Kittaka J (eds.), Spiny lobster management. Fishing news books, Oxford (UK).

Oluoch SJ and Obura DO (2008) Assessment of fisherfolk organizations and beach management units (BMU) in the management of fishery resources in Diani-Chale, southern Kenya. pp. 335–343 *In* Obura DO, Tamelander J and Linden O (eds.), Ten years after bleaching — facing the consequences of climate change in the Indian Ocean — CORDIO Status Report 2008. CORDIO and SIDA/Sarec, Mombasa.

Pauly D (1990) On Malthusian overfishing. Naga, the ICLARM Quarterly 13(1): 3–4.

Pauly D (1994) From growth to Malthusian overfishing: stages of fisheries resources misuse. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 3: 7–14.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Pitcher TJ and Hemphill SC (1989) Stock assessment of indian ocean yellowfin tuna (*Thunnus albacares*) based on data from a sport fishery. Fishbyte (ICLARM) 7(3): 15–17.

Pitcher TJ and Hollingworth CE (2007) Fishing for fun: where's the catch? pp. 1–16 *In* Pitcher TJ and Hollingworth CE (eds.), Recreational Fisheries. Blackwell Publishing Ltd, Oxford (UK).

Republic of Kenya (2004) Marine waters frame survey 2004 report. Ministry of livestock and fisheries development, Fisheries department, Nairobi (Kenya). 40 p.

Republic of Kenya (2006) Marine waters frame survey 2006 report. Ministry of livestock and fisheries development, Fisheries department, Nairobi (Kenya). 47 p.

Republic of Kenya (2008) Marine waters frame survey 2008 report. Ministry of livestock and fisheries development, Fisheries department, Nairobi (Kenya). 55 p.

Republic of Kenya (2011) Prawn Fishery Management Plan 2010 (L.N. 20 of 2011). The fisheries act (cap. 378), legal notice No. 20, Ministry of livestock and fisheries development, Fisheries department, Nairobi (Kenya). 7 p.

Republic of Kenya (2012) Marine waters frame survey 2012 report. Ministry of livestock and fisheries development, Fisheries department, Nairobi (Kenya). 78 p.

Samoilys MA, Maina GW and Osuka K (2011a) Artisanal fishing gears of the Kenyan coast. CORDIO East Africa and USAID, Mombasa (Kenya). 36 p.

Samoilys MA, Osuka K and Maina GW (2011b) Artisanal fishing in Kenya: what are the effects? Swara 3: 18–25.

Samoilys MA, Osuka K, Maina GW and Obura DO (2011c) Artisanal fishing on the Kenya coast: what are the impacts? *In* 7th WIOMSA Scientific Symposium, October 24–29, 2011, Mombasa (Kenya).

Sigana D (2009) Tuna fishery in Kenya. IOTC-2009-SC-INF09, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 3 p.

Signa D, Tuda PM and Samoilys MA (2008) Social, economic and environmental impacts of beach seining in Kenya — an information review and field study. CORDIO and FAO, Mombasa (Kenya). 86 p.

Spalding MD, Ravilious C and Green EP, editors (2001) World atlas of coral reefs. University of California Press, Berkeley, CA (USA). 416 p.

Spooner S (2012) How demand for delicacy drives silent massacre of Kenya's sharks. Daily Nation (Kenya), edition of March 9.

Tuda PM, Nyaga W, Maina GW, Wanyonyi I and Obura DO (2008) Estimating total fishing effort over tidal to annual periods in the Diani-Chale-Gazi reff fishery in Kenya. pp. 321–334 *In* Obura DO, Tamelander J and Linden O (eds.), Ten years after bleaching — facing the consequences of climate change in the Indian Ocean — CORDIO Status Report 2008. CORDIO and SIDA/Sarec, Mombasa.

UNEP (1989) A coast in common: an introduction to the eastern African action plan United Nations Environment Programme, Nairobi (Kenya).

UNEP (1998) Eastern Africa atlas of coastal resources 1: Kenya. United Nations Environment Programme (UNEP), Nairobi (Kenya).

Weaver DB (1999) Magnitude of ecotourism in Costa-Rica and Kenya. Annals of Tourism Research 26(4): 792–816.

Williams F (1956) Preliminary survey of the pelagic fishes of East Africa. Colonial Office Fishery Publications 8: 1–68.

Williams F (1970) The sport fishery for sailfish at Malindi, Kenya, 1958–1968, with some biological notes. Bulletin of Marine Science 20(4): 830–852.

Zeller D, Booth S, Davis GE and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Zeller D and Harper S, editors (2009) Fisheries catch reconstructions: islands, part I. Fisheries Centre Research Reports 17 (5). University of British Columbia, Vancouver (Canada). 108 p.

Zeller D, Harper S, Zylich K and Pauly D (2014) Synthesis of under-reported small-scale fisheries catch in Pacific-island waters. Coral Reefs DOI: 10.1007/s00338–014–1219–1.

Zeller D and Pauly D, editors (2007) Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15 (2). University of British Columbia, Vancouver (Canada). 163 p.

Appendix Table A1. Reconstructed catch (t) by sector, compared to the catch reported to FAO, as presented in Figure 4.

Year	Total reconstructed				Reported
	Artisanal	Industrial	Recreational	Subsistence	
1950	6,904	-	-	2,715	3,000
1951	7,089	-	23	2,777	3,000
1952	7,273	-	46	2,838	3,000
1953	7,458	-	68	2,900	3,500
1954	7,643	-	91	2,962	4,100
1955	7,827	-	114	3,024	2,700
1956	8,057	-	137	3,101	2,700
1957	8,287	-	159	3,178	4,500
1958	8,517	-	182	3,255	4,600
1959	8,747	-	222	3,332	4,300
1960	8,976	-	266	3,409	4,300
1961	9,263	-	150	3,505	5,100
1962	9,549	-	165	3,601	5,200
1963	10,304	-	146	4,152	4,500
1964	9,838	-	219	3,910	4,900
1965	10,118	-	251	4,011	5,800
1966	10,468	-	166	4,137	6,600
1967	10,819	-	162	4,263	6,000
1968	11,867	-	168	4,781	6,000
1969	12,221	-	175	4,903	6,700
1970	11,979	-	181	4,530	7,800
1971	12,436	-	187	4,675	6,900
1972	12,867	-	194	4,844	7,600
1973	13,571	-	200	4,741	3,800
1974	13,922	-	206	4,990	3,316
1975	14,488	-	212	4,035	4,459
1976	14,082	-	219	4,834	4,100
1977	14,148	-	225	5,579	4,319
1978	14,367	-	231	4,996	4,596
1979	15,838	-	237	5,116	4,055
1980	15,610	285	244	4,988	5,552
1981	14,397	569	256	6,583	6,316
1982	14,972	994	270	6,319	7,512
1983	15,288	924	284	6,445	7,070
1984	14,655	1,449	299	6,617	6,041
1985	15,185	4,919	314	6,230	6,196
1986	14,547	1,399	331	6,254	6,212
1987	13,888	2,039	348	6,221	6,875
1988	12,793	2,119	365	6,549	7,970
1989	12,272	1,764	382	6,232	7,610
1990	11,423	1,794	400	6,174	9,905
1991	11,505	2,039	663	5,142	7,419
1992	10,473	1,364	706	5,156	6,566
1993	9,699	464	730	4,847	5,617
1994	9,766	1,319	800	3,636	3,772
1995	8,613	459	709	3,585	5,465
1996	7,108	1,314	705	3,555	6,296
1997	7,236	1,879	565	3,365	6,099
1998	6,321	3,294	421	3,225	6,600
1999	6,565	1,989	647	2,843	6,634
2000	6,321	1,714	753	2,844	4,763
2001	6,604	1,708	796	2,847	7,388
2002	7,146	1,412	821	2,476	6,720
2003	7,823	937	847	2,849	6,830
2004	7,496	1,018	872	3,493	7,774
2005	8,233	1,039	757	2,927	7,105
2006	8,161	814	763	2,947	6,955
2007	9,834	-	788	4,120	7,448
2008	9,473	-	788	4,121	8,301
2009	11,105	-	788	2,861	5,564
2010	10,671	-	788	3,764	8,264

Appendix Table A2. Taxonomic breakdown of the reconstructed catch (t), as presented in Figure 5.

Year	Lethrinidae	Scaridae	*Siganus* spp.	Elasmobranchii	Carangidae	Lutjanidae	Clupeidae	Others[a]
1950	1,078	1,000	1,030	629	658	513	210	4,514
1951	1,109	1,029	1,061	650	675	527	216	4,645
1952	1,140	1,058	1,091	672	693	542	222	4,775
1953	1,171	1,088	1,122	694	711	556	227	4,905
1954	1,202	1,117	1,152	715	728	570	233	5,036
1955	1,233	1,146	1,183	737	746	585	239	5,166
1956	1,272	1,183	1,221	763	768	603	246	5,320
1957	1,310	1,219	1,259	789	790	621	254	5,475
1958	1,349	1,256	1,297	815	812	639	261	5,630
1959	1,387	1,292	1,336	843	834	657	268	5,808
1960	1,426	1,329	1,374	872	856	675	276	5,990
1961	1,474	1,374	1,421	887	883	697	285	5,985
1962	1,522	1,420	1,469	917	910	720	294	6,159
1963	1,597	1,475	1,516	944	985	762	312	7,106
1964	1,613	1,509	1,563	982	956	761	310	6,392
1965	1,661	1,554	1,611	1,015	983	783	320	6,589
1966	1,721	1,611	1,670	1,041	1,018	811	331	6,663
1967	1,781	1,668	1,729	1,076	1,052	839	342	6,849
1968	1,872	1,736	1,789	1,113	1,142	890	364	8,017
1969	1,932	1,793	1,848	1,151	1,176	918	376	8,218
1970	1,957	1,892	1,915	1,215	1,144	966	296	7,414
1971	2,030	1,963	1,987	1,262	1,185	1,001	307	7,677
1972	2,131	1,935	2,064	1,294	1,260	954	497	7,890
1973	2,166	1,967	2,098	1,397	1,280	969	505	8,256
1974	2,279	2,070	2,208	1,120	1,344	1,019	531	8,677
1975	2,064	2,712	2,194	1,205	1,293	1,650	5	7,741
1976	2,406	2,066	2,299	1,866	1,192	868	6	8,569
1977	2,170	1,856	2,058	1,590	1,115	790	12	10,508
1978	1,758	2,180	1,954	3,141	1,321	722	1,215	7,452
1979	3,087	1,396	2,573	2,202	1,804	1,016	1,473	7,809
1980	2,134	2,010	2,061	2,840	1,390	627	1,124	9,153
1981	1,778	3,465	1,980	647	1,269	758	1,121	11,039
1982	2,071	2,221	1,711	778	737	860	1,188	13,268
1983	2,042	1,529	2,391	769	843	840	1,203	13,663
1984	2,228	1,336	1,946	1,023	841	667	1,358	13,837
1985	2,686	2,660	2,447	1,006	1,003	775	1,676	14,645
1986	2,081	2,150	2,156	1,004	927	627	1,324	12,502
1987	2,052	1,981	1,879	829	693	512	1,373	13,435
1988	1,563	1,515	1,276	679	671	442	1,081	14,867
1989	1,453	1,010	1,342	704	619	473	1,012	14,315
1990	1,135	1,032	1,114	522	438	410	763	14,667
1991	1,548	1,114	1,563	668	522	590	773	13,041
1992	1,188	825	1,170	498	445	411	866	12,789
1993	1,094	501	1,047	451	243	340	410	12,158
1994	1,338	779	1,319	698	374	464	607	10,496
1995	852	232	788	455	236	261	244	10,786
1996	707	953	602	383	233	264	345	9,687
1997	665	1,002	570	301	312	289	335	9,972
1998	639	821	466	228	291	211	237	10,684
1999	510	859	370	246	256	238	229	9,794
2000	651	1,091	520	290	272	259	231	8,844
2001	580	1,195	460	295	222	237	204	9,310
2002	581	956	608	258	266	262	146	9,342
2003	609	744	503	371	313	195	175	10,128
2004	612	721	490	298	353	220	158	10,630
2005	664	910	620	395	381	294	185	10,763
2006	738	953	600	308	307	313	216	10,217
2007	721	1,611	602	295	437	390	246	11,447
2008	733	1,640	618	331	403	381	214	11,031
2009	1,109	1,021	1,196	646	414	638	304	10,327
2010	982	1,211	949	493	516	477	223	11,083

[a] Includes an additional 58 taxa.

Reconstructing Domestic Marine Fisheries in Mayotte from 1950–2010*

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Abstract

National fisheries statistics often underestimate total catches due to a lack of available catch data from unmonitored sectors. Here, we used a catch reconstruction approach to improve the Food and Agriculture Organization of the United Nations (FAO) time-series of the domestic catches made by Mayotte (France) since 1950. Thus, we also removed FAO data corresponding to industrial tuna vessels that were deemed as non-domestic fisheries. The total reconstructed catches from 1950–2010 were just nearly 84,000 tonnes, which is 1.4 times the official domestic catches reported to FAO. The main reason for this discrepancy was the limited official data prior to 1989, corresponding to unreported catches from shore-based activities and small-scale boat fisheries. This reconstructed catch time-series provides a more comprehensive view of Mayotte's historical catches, which may serve to influence future policy and management decisions regarding the sustainability of fisheries.

Introduction

Mayotte is composed of several islands, Grande Terre making up most of Mayotte's 375 km² land mass (Figure 1). It is surrounded by a barrier reef with a productive (Biais *et al.* 1987) yet increasingly threatened lagoon,[1] which contributes the bulk of the 1,100 km² inshore fishing area in Mayotte's 63,000 km² Exclusive Economic Zone (EEZ; www.seaaroundus.org). Mayotte is the most southeastern of the four islands that make up the Comoros Archipelago (Figure 1). Unlike the three other islands (i.e., the Union of the Comoros), Mayotte voted to keep its ties to France in a 1976 referendum and was recognized as one of its Overseas Territories (Dumas 2009). In 2011, Mayotte officially became the 101st French Department and France's 5th Overseas Department (Dumas 2009; Guézel *et al.* 2009a; Hopquin 2011).[2]

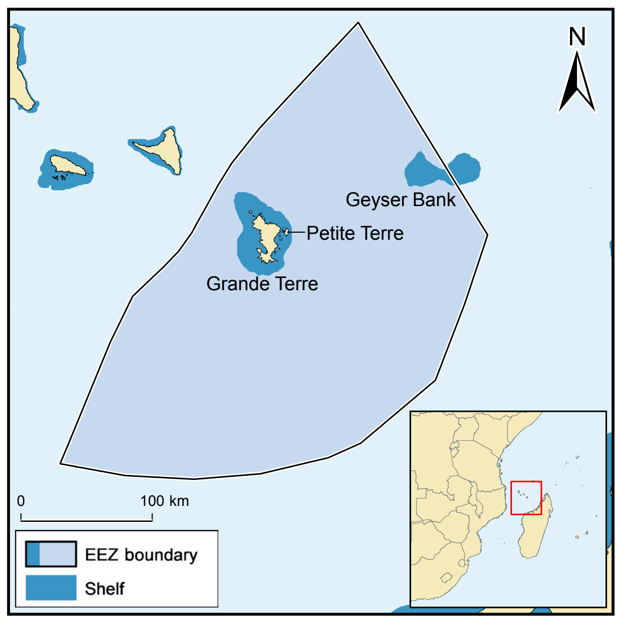

Figure 1. Map of Mayotte and its EEZ showing the two main islands of Grande Terre and Petite Terre, as well as the extent of the continental shelf (in darker blue). The Union of the Comoros is visible in the top left corner.

Since 1950, Mayotte's population has grown rapidly and is now following Mauritius as the second most densely populated island in the southwest Indian Ocean (500 inhabitants per km²; IEDOM 2011). The population has increased considerably since the 1980s, from 47,000 in 1978 to 186,000 in 2007 (INSÉE 2007), due to both a high birth rate and immigration. Mayotte's relatively high GDP for the region (INSÉE 2011) is in large part responsible for this immigration: many Comorans have immigrated to Mayotte in search of improved economic and social security, as well as the possibility of acquiring French citizenship (IEDOM 2011). In recent years, the number of Comorans living in Mayotte has more than doubled, from 26,000 in 1997 to almost 53,000 in 2002 (IEDOM 2006). A significant portion of these immigrants is illegal and occupy jobs in the agricultural and fishing sectors (Anon. 2004; Guézel *et al.* 2009a).

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[1] Insufficient wastewater treatment systems, increased sedimentation from erosion, and coastal development are polluting coastal ecosystems such as mangroves and the lagoon. In the most densely populated urban areas around Grande Terre and Petite Terre, some of the fringing coral reefs have an average of only 5% live coral cover (Guézel *et al.* 2009a; Thomassin *et al.* 2011).

[2] Mayotte, La Réunion and eight other entities in the Indian Ocean (the *Terres Autrales et Antarctiques Françaises*) are sovereign to France and collectively known as France's Indian Ocean Territories (see Le Manach and Pauly, this volume). These territories occupy an important fishing zone for France, as they add 2.7 million km² to its EEZ (Bouchard 2009), making it the world's second largest (www.seaaroundus.org).

As a result of increasing pressures affecting the marine environment (e.g., demography, pollution, exploitation, urbanization), many developments have occurred in recent years. Among the most significant, is the creation of the *Parc Naturel Marin de Mayotte* in 2010, which encompasses the entire EEZ. Rather than an integral reserve, it aims to protect the sensitive areas within the lagoon system, while developing better-monitored inshore artisanal fisheries as well as domestic and foreign offshore pelagic fisheries (www.aires-marines.fr). Increased tourist activities such as scuba diving, whale watching and recreational fishing also provide further incentives for marine protection measures and create alternative job opportunities for locals (Guézel *et al.* 2009a).

Mahorans (the island's native citizens) and immigrants have always depended on marine resources from the lagoon as their primary source of protein (Anon. 2004; Aboutoihi *et al.* 2010) and most of the population has concentrated in villages along the coast (Jacquemart 1980; Maggiorani *et al.* 1993; Guézel *et al.* 2009a). For generations, they have been fishing in *pirogues* (locally-crafted wooden canoes) with handlines in the surrounding lagoon (Fourmanoir 1954; Biais *et al.* 1987; Herfaut 2006; IEDOM 2011). However, perhaps due in part to decreasing catches in the lagoon (Anon. 1994; Guézel *et al.* 2009a), there have been major changes to Mayotte's small-scale fisheries the last few decades. Polyester motorboats, outboard motors, and anchored fish aggregating devices (a-FADs) were introduced (Table 1); consequently, offshore pelagic species have become more important in the total catch over time, as evidenced by the shift in species in the official FAO statistics (FAO 2014).

Table 1. Major developments in Mayotte's fisheries.

Period	Changes	Source
1970s	Appearance of outboard motors	Jacquemart (1980)
1977	Creation of first fishing school, *l'École de Pêche*	Anon. (1994)
1978	Creation of COPEMAY[a] fishing cooperative	Anon. (1994)
1980s	Increased fishing effort of sites further outside of the lagoon	Maggiorani *et al.* (1993)
1980s	Increased motorization of *pirogues*	Jacquemart (1980)
1980s	Introduction of Yamaha polyester motor boats[b] (*barques*), imported from Japan	Biais *et al.* (1987), Minet and Weber (1992)
1985	Increased use of trolling to target pelagics[c] in areas up to 20 nautical miles offshore	Biais *et al.* (1987)
1989	Introduction of anchored FADs	Wendling and Le Calvé (1999)
1990s	Subsidies by Mayotte's *Service des Pêches* allowed acquisition of depth sounders and radios by the COPEMAY and the distribution of iceboxes to the local fleet	Anon. (1994)
1990s	a-FADs are more commonplace with 15 sites located in and outside lagoon	Wendling and Le Calvé (1999)
1995	10 village cooperatives (COVIPEM) in operation at this time	Guézel *et al.* (2009a)
2001	Appearance of first artisanal longliner targeting swordfish and tuna	Abellard and Herfaut (2004)
2004	Importing *barques* is banned[d]	Guézel *et al.* (2009a)
2009	Industrial tuna fleets are restricted to fishing in areas that are within 24 nautical miles of Mayotte's coast	Guézel *et al.* (2009a), Busson (2011)

[a] The COPEMAY has the goal of professionalizing the artisanal fishing fleet by commercializing the catch and improving the fleet through access to better equipment, boats, motors, and fuel subsidies (Anon. 1994; IEDOM 2011).
[b] The artisanal fishery changed significantly with the introduction of *barques* which allowed fishers to operate further offshore and for longer trips, leading to an increased effort targeting pelagics. Since the introduction of these *barques*, the number of *pirogues* has declined (Maggiorani *et al.* 1993; Herfaut 2006; Guézel *et al.* 2009a).
[c] Target species were *Thunnus albacares* (yellowfin tuna), *Katsuwonus pelamis* (skipjack tuna), *Istiophorus platypterus* (Indo-Pacific sailfish), and other Istiophoridae (e.g., marlins; Biais *et al.* 1987).
[d] In order to update the fishing fleet, subsidies of up to 80% were offered for new boats built between 2008 and 2014. As a result, new boats and longliners as well as several shipyards have appeared on the island in recent years (Guézel *et al.* 2009a).

Being located in the productive Mozambique Channel, Mayotte's waters have also attracted industrial tuna purse-seiners and longliners from France, Spain and the Seychelles (but actually owned by Spanish interests; see Le Manach *et al.*, this volume). However, these foreign fleets have increasingly been perceived by the artisanal fleets as competing for local resources (Busson 2011), and industrial purse-seiners have been banned from the 24 nautical miles (nm) zone since December 2009 (République Française 2009).[3]

Other major developments have shaped Mayotte's fisheries since 1950 and are summarized in Table 1. From these developments and the obvious lack of official catch data before 1989, it was clear that the official statistics for Mayotte were incomplete. This is not unique to Mayotte, as small-scale fisheries are frequently underreported or missing from official statistics (see e.g., Van der Elst *et al.* 2005; Jacquet *et al.* 2010; Le Manach *et al.* 2012). Rather than accepting these missing catches as 'zero catch', a re-estimation of the missing components was completed using a catch reconstruction method, following the rationale highlighted in previous studies (Pauly 1998; Pauly and Zeller 2003; Zeller *et al.* 2007). These catch reconstructions have proven useful for assessing the extent of marine fisheries catches in various places (Pauly 2007), and increasingly serve as a more realistic baseline of historic catches for policy and management decisions (Pauly 1998; Zeller *et al.* 2007). In some cases, such new baselines were even used by official institutions to improve their records, as has been observed in Mozambique (Doherty *et al.* this volume). As part of the effort of the *Sea Around Us* to reconstruct global fisheries statistics, a reconstruction of Mayotte's catch was completed by determining the missing and underreported sectors and by adding them to official statistics to improve their overall quality.

Mayotte's Fisheries and Reconstruction Methods

The FAO data for the years 1950–2010 were extracted from FAO's FishstatJ software (FAO 2014). These data contained reported landings from 11 different taxon groups, 10 of which were pelagic. The remaining category

[3] However, since it became a French overseas department, Mayotte can request foreign fleets to be excluded from its 100 nm zone (i.e., the vast majority of its EEZ), according to the European common fisheries policy.

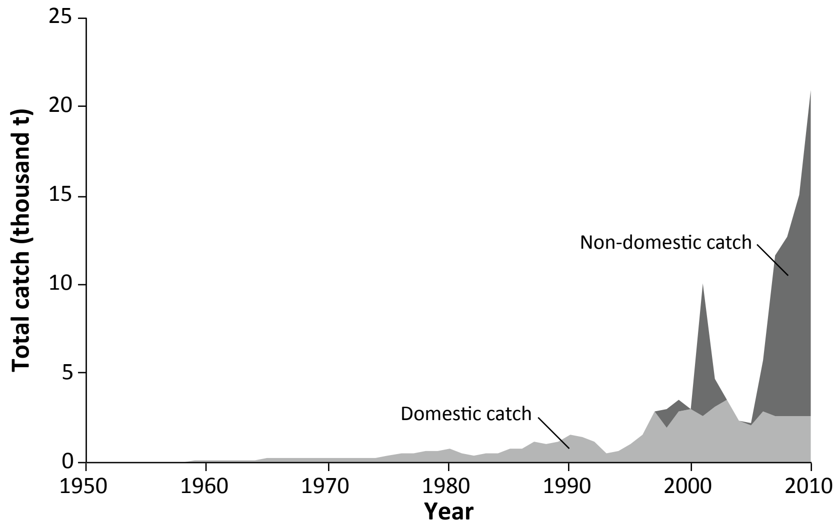

Figure 2. FAO reported catch data and the adjusted domestic FAO catch data for Mayotte, 1950–2010 (See Appendix Table A1 for annual catch data).

was 'marine fishes nei' and was the only category reported prior to 1994. For the purposes of this reconstruction, Mayotte's catch was considered to be all catches from fishing sectors which were owned and operated by Mayotte and fish in Mayotte's EEZ. Therefore, catches from foreign fleets registered[4] and/or fishing in Mayotte's EEZ[5] were excluded from the catch reconstruction outlined herein; rather, they were dealt with separately as part of the *Sea Around Us*' atlas of large pelagics fisheries (Le Manach *et al.* press). To do so, we used the "France Overseas Territories (France OT)" data published by the Indian Ocean Tuna Commission (IOTC), which matched total catches of pelagic taxa reported by Mayotte to FAO for years 1995–2010,[6] but which also included a breakdown by gear (IOTC 2012b). Based on our knowledge of the structure of the fishing sectors in Mayotte, we determined that the data corresponding to all purse-seiners (all years) and longliners (in 1998–99 and 2005; see below) were non-domestic, and were thus removed from the catch baseline used here.[7] The adjusted FAO landings data with the non-domestic industrial pelagic catches removed are referred to throughout as the 'domestic FAO landings' (Figure 2).

An extensive literature search and consultation with local experts provided additional sources of information, which allowed us to compare and improve the domestic FAO landings data, notably by developing anchor points for specific years to estimate the underreported (small-scale boat fishery) and unreported (shore-based and recreational) sectors.

Small-scale boat fisheries

The bulk of the small-scale fishing fleets and effort is carried out by *pirogues* (78% in 2005; Biais *et al.* 1987; Minet and Weber 1992; Herfaut 2006) and polyester motor boats (locally known as *barques*, generally ranging from 5 to 7 m; Herfaut 2006; Busson 2011):

- Typically non-motorized, small (3–5 m) and medium *pirogues* (5–7 m) are generally operated by one or two fishers in the lagoon and along the barrier reef (Biais *et al.* 1987; Minet and Weber 1992; Busson 2011). They are primarily used for subsistence purposes with only a small portion of their catch being sold (Minet and Weber 1992);
- Historically, large motorized *pirogues* (7–10 m) have been used for both artisanal and subsistence purposes (Biais *et al.* 1987; Service des Pêches 1990 in Minet and Weber 1992; Guézel *et al.* 2009a), usually with two to three fishers onboard (Service des Pêches, 1990 in Minet and Weber 1992). They are used both inside the lagoon and up to five nautical miles offshore of the barrier reef.
- Motorized *barques* are mostly operated by two to three artisanal fishers (Service des Pêches 1990 in Minet and Weber 1992; Herfaut 2006), up to five nautical miles outside the barrier. Since their introduction in the 1980s (Biais *et al.* 1987), they have increasingly occupied a larger percentage of the artisanal effort and catch.

Handlines remain the most common gear, accounting for 71% of effort and 57% of the catch in 2005 (Herfaut 2006). Nets and trolling occupy the bulk of the remaining effort (Biais *et al.* 1987; Maggiorani *et al.* 1993; Herfaut 2006) and have been commonly used since at least the 1980s (Jacquemart 1980; Biais *et al.* 1987). The proportion of the catch derived from trolling has increased dramatically over the years from 6% in 1992 (Maggiorani *et al.* 1993) to 32% in 2005 (Herfaut 2006), and is likely the result of increased motorization of vessels and effort targeting pelagic species.

[4] Some French operators flagged their vessels in Mayotte. This may be motivated by several factors such as benefiting from tax breaks, or being able to build new vessels without scrapping older ones (the EU's Common Fisheries Policy applies to Mayotte only since it became a French Department in 2011). There were between two and five such vessels from 2000 to 2010 (Anon. 2007a; IOTC 2006, 2011, 2012a). La Réunion had one Mayotte-registered vessel in 2009, and three in 2010; the other ones were operated by companies from France mainland (IOTC 2012a).

[5] A number of Spanish and Seychellois seiners (both requiring licenses) and French seiners (requiring a license since 2010; République Française 2010; see Le Manach and Pauly, this volume) have also been regularly fishing in Mayotte's EEZ between 2000 and 2010 (Anon. 2007b; Busson 2011). Their catches were not included in the Mayotte's FAO landings data, nor the reconstructed catches presented here. Prior to 2009, Mayotte received no compensation from the French purse-seiners fishing in their waters as profits from their annual fishing licenses went to the *Terres Australes et Antarctiques Françaises* (Busson 2011).

[6] This is not surprising, given that none of the French Îles Éparses (Tromelin, Glorieuses Archipelago, Juan de Nova, Bassas da India and Europa) have any permanent population or their own administrative units (they are administered by the *Terres Australes et Antarctiques Françaises* since 2007; see Le Manach and Pauly, this volume), and since La Réunion's catch is recorded in a separate category by the FAO/IOTC. Therefore, Mayotte is the only 'legitimate France OT' that can be included under this name.

[7] In the *Sea Around Us* database, catches by purse-seiners were re-allocated to either La Réunion or the French mainland, based on the origin of the operator in any given year and assuming equal catches for each vessel. Catches by longliners were entirely re-allocated to the French mainland.

The first extensive survey of the *pirogue* and *barque* fisheries was completed in 1989 by Mayotte's *Service des Pêches*. Since 1989, additional surveys have taken place and catch data were also available for 1992 (Maggiorani and Maggiorani 1990) and 1997–2005 (Herfaut 2004, 2005b, 2006). We used the national survey data to reconstruct catch from 1989 and 1997–2006, and the domestic FAO landings for 2006–2010.

We disregarded the 1992 survey (Maggiorani *et al.* 1993), because many demonstrations against Anjouan fishers working illegally in the fishing sector occurred that year. This forced many Anjouan fishers to land their catches at non-traditional landing sites in a clandestine manner (Maggiorani *et al.* 1993), which was likely not captured by the national surveys (Anon. 1994). Prior to 1989, FAO data were likely based on independent estimates from research for various years between 1962 and 1981 studies (Jacquemart 1980; Maggiorani and Maggiorani 1990) and catch data from the cooperatives from 1981 to 1983 (Maggiorani *et al.* 1993).[8]

To reconstruct catches for data-limited years, we compiled boat effort data from national surveys, grey literature and unpublished datasets (Table 2). These data were converted to a boat per-capita rate[9] for each boat type and linear interpolation was used to estimate boats per capita for years without data. A boat time-series from 1950 to 2010 was created by multiplying the boat per-capita time-series by annual population data (Figure 3).

Table 2. Anchor points for the number of boats in Mayotte, used to reconstruct fishing effort from 1950–2010.

Year	Small *pirogues*	Medium *pirogues*	Large *pirogues*	*Barques*	Source
1962	147	91	56	0	Moal (1962)[a]
1982	486	303	272	-	Le Gall (1986)
1985	419	297	289	-	
1987	-	-	-	30	Biais (1987)
1989	536	144	197	114	Maggiorani and Maggiorani (1990); Minet and Weber (1992)
1990	-	-	-	140	Minet and Weber (1992)
1992	580	221	185	175	Maggiorani *et al.* (1993)
1995	365	437	108	250	(unpub. data, J Herfaut)[b]
1997	481	575	142	240	Herfaut (2004)
1998	446	770	124	235	
1999	411	965	107	230	
2000	411	817	126	248	
2001	411	668	145	267	
2002	410	520	163	285	
2003	410	371	182	303	
2005	361	326	149	303	Herfaut (2006)
2006	334	301	138	319	(J. Herfaut; unpub. data)[c]
2010	325	293	134	297	(J. Herfaut; unpub. data)[d]

[a] 238 small/medium *pirogues*; proportions estimated based on 1982 data.
[b] 910 *pirogues*; proportion of small, medium and large estimated based on 1997 data.
[c] 773 *pirogues*; proportion of small, medium and large estimated based on 2005 data.
[d] 752 *pirogues*; proportion of small, medium and large estimated based on 2005 data.

To reconstruct catches from 1950–1988 and 1990–1997, the boat time-series was then multiplied by annual catch per unit of effort (CPUE) estimated from the 1989 and 1997 surveys: 0.3, 0.6, 3.6, and 5.9 t·boat^{-1}·year^{-1} in 1989 (Minet and Weber 1992) and 1.6, 0.5, 4.3, and 5.0 t·boat^{-1}·year^{-1} in 1997 (Herfaut 2004), for small, medium and large *pirogues*, and *barques*, respectively. We used linear interpolations to estimate catch rates in between 1989 and 1997, and maintained a constant catch rate from 1950–1989, given that there was no annual survey CPUE data prior to 1989. Thus, we did not account for annual variations in CPUE prior to 1989, but the 1989 CPUE estimates seemed reasonable for earlier years given the occasional observations of catch rates in the 1950s (Fourmanoir 1954) and 1970s (Barbaroux 1977; Jacquemart 1980). However, this is difficult to confirm

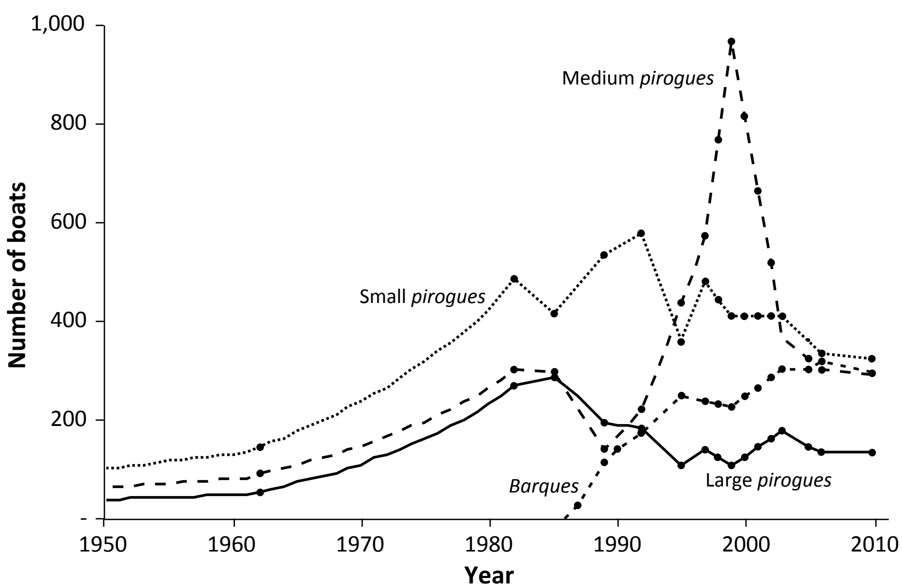

Figure 3. Evolution of the number of *barques* and *pirogues* in Mayotte since 1950. Solid dots represent anchor points from the literature.

[8] Population data from 1961–2012 were extracted from the Food and Agriculture Organization statistics (faostat.fao.org) and for 1958 from France's *Institut national de la statistique et des études économiques* (www.insee.fr). Missing years in the 1950s were linearly interpolated.

[9] Unofficial figures suggest that around 35 *barques* (J. Herfaut; unpub. data) fish year-round around Zélée (Mayotte) and Geyser (Glorieuses Archipelago) banks. France is rather worried about this fishery and about a possible steep decline in demersal biomass, which will be assessed thanks to a European Development Fund unlocked for the implementation of the Mayotte's Parc Naturel Marin.

since catch rates vary widely depending on the area fished (e.g., interior, barrier or exterior reef) and fishing gear (e.g., hand line or troll).

Most FAO landings are reported as 'unidentified marine fish' (100% of landings prior to 1995) and taxonomic breakdowns by family [1989: Maggiorani and Maggiorani (1990); 2003 and 2005: Herfaut (2004, 2006) and by species (1989: Maggiorani and Maggiorani (1990); 2003–2005: *Service des Pêches*, unpub. data)] were developed to disaggregate catch into more specific taxonomic groups (Table 3).). These breakdowns were used to estimate the historical taxonomic composition of catches. The 1989 breakdown was used for years 1950-1989, and the 2003-2005 averaged composition for years 2003-2010. Catch compositions between 1990-2002 were linearly interpolated.

Since 1999, the taxonomic detail in the FAO landings has improved, reporting catches for 8 taxonomic groupings of large pelagics. These FAO landings of large pelagics were left unadjusted, with one exception: Elasmobranchii were unreported until 2006, at which time they were still considered underreported. As an alternative to the FAO data, catches of Elasmobranchii were estimated based on the 1989 and 2003-2010 taxonomic breakdowns (Table 3). Catches of 6 other taxa (Acanthocybium solandri [wahoo], Istiophorus platypterus [Indo-Pacific sailfish], Istiophoridae [billfishes], skipjack tuna, Scombridae [other tuna-like species], and yellowfin tuna) were estimated by linear interpolation between the 1989 estimate (Table 3) and the first year reported in FAO landings (1995 for Scombridae and 1999 for all others). Catches of Xiphias gladius (swordfish) are only reported in the 2005 FAO domestic catch and no further additions were made.

Table 3. Taxonomic breakdowns for the *pirogue* and *barque* fisheries.

Family	Taxon	1989	2003-2010[a]
Carangidae	*Caranx sexfasciatus*	-	3.3
	Elagatis bipinnulata	-	2.1
	Other Carangidae	7.5	7.8
Hemiramphidae	*Hemiramphus far*	1.8	-
Holocentridae	*Myripristis* spp.	5.9	-
Lethrinidae	*Gnathodentex aurolineatus*	1.8	-
	Lethrinus obsoletus	8.9	-
	L. rubrioperculatus	-	4.0
	Lethrinus. spp.	-	3.4
Lutjanidae	*Aphareus furca*	2.4	-
	Aprion virescens	4.7	2.1
	Lutjanus bohar	4.4	2.3
	L. gibbus	-	2.5
	L. kasmira	1.7	-
Scaridae	Scaridae	-	1.9
Scombridae	*Acanthocybium solandri*	-	2.7
	Katsuwonus pelamis	-	15.3
	Other Scombridae[b]	15.1	9.1
	Thunnus albacares	-	9.7
Serranidae	*Epinephelus* spp.	-	2.4
	Plectropomus pessuliferus	4.1	-
	Serranidae	4.3	-
	Variola louti	3.3	-
Sparidae	Sparidae	5.9	-
Sphyraenidae	*Sphyraena* spp.	4.3	6.9
Others[c]		23.9	24.5

[a] The 2003- 2010 taxonomic breakdown was estimated based on the average between the 2003 and 2005 catch compositions.
[b] It should be noted that a significant portion of Scombridae catches are likely composed of Indian mackerel (*Rastrelliger kanagurta*), which represented 9% of the total catches in both 1989 (Maggiorani and Maggiorani 1990) and 2005 (Herfaut 2006).
[c] Contains species belonging to 41 taxa, including Lethrinidae, Lutjanidae, Acanthuridae, Carangidae, Clupeidae, Mugillidae, Sphyraenidae, and Priacanthidae.

The *Sea Around Us* defines small-scale fishing as either 'artisanal' (i.e., small-scale commercial) or 'subsistence' (i.e., small-scale non-commercial with primary purpose being self- or family-consumption), within its global catch database to facilitate international comparisons. A subsequent split of 'small-scale' *pirogue* and *barque* catches was required to assign these catches to one of the two small-scale sectors in the database (Table 4). National estimates for total catch by boat type were available for 1989 (Minet and Weber 1992), 1997 to 2003 (Abellard and Herfaut 2004), and 2005 (Herfaut 2006). Based on this sectoral allocation, the average artisanal and subsistence components of the *pirogue* and *barque* catch were 60% and 40% (considered as our 2010 'anchor point'). Moal's 1962 catch estimate in Maggiorani *et al.* (1993) was approximately 47% as subsistence and 53% as artisanal; based on this estimate and the observed trend of increased artisanal caches in more recent years, it was assumed that 50% of the catch was artisanal and 50% was subsistence in 1950 (the 1951–2009 proportions were linearly interpolated between our anchor points).

Table 4. Sectoral allocation of artisanal and subsistence components of the *pirogue* and *barque* fleets between 1989 and 2005.[a]

Boat type	Catch Breakdown (%)	
	Subsistence	Artisanal
Small/Medium *pirogues*	90	10
Large *pirogues*	50	50
Barques	10	90

[a] These assumptions were based on the total effort and average catch rates from national surveys (Minet and Weber 1992; Herfaut 2004, 2006) and the 2004 survey of fishing households (Anon. 2004).

In addition to the lagoon and relatively nearshore fisheries, more *barques* have been fishing around offshore banks since the late 1990s (Wendling and Le Calvé 1999; Herfaut 2005a). In 2003, there were an estimated 405 trips by *barques* to offshore banks in search of demersal species to satisfy local demand. An estimated 244 of these trips were to banks outside of Mayotte's EEZ, such as Geyser Bank in the Glorieuses Archipelago and Castor banks in Madagascar's EEZ, accounting for an estimated 86 tonnes (3% of the annual *pirogue* and *barque* catch; Herfaut 2004; an estimate was done as part of the reconstruction of the Îles Éparses, though; see Le Manach and Pauly, this volume).

The YVALANN (a 12 nm fishing vessel) also fished the offshore banks of Zélée and Geyser between 1989 to 1992 and sold their catches to the COPEMAY (Maggiorani *et al.* 1994; see Le Manach and Pauly, this volume). Total catches over this period were 190 t (Maggiorani *et al.* 1994) and were included in the reconstructed artisanal estimates. Their main catches were *Lutjanus bohar* [two-spot red snapper], *Epinephelus fuscoguttatus* [brown-marbled grouper], *Gymosarda unicolor* [dogtooth tuna], and *Lutjanus rivuletus* [Blubberlip snapper; Maggiorani *et al.* 1994).

Longline fishery

A small-scale artisanal longline fishery started in Mayotte in 2001, and as of 2010, there were three active vessels (all less than 10 m; Kiszka *et al.* 2010; Bein *et al.* 2011). The longline fishery represents a small component of Mayotte's annual catches at present, but is rapidly growing (Anon. 2007b; Kiszka *et al*. 2010) and as of 2012 there were two new vessels and plans to add larger vessels to fish further offshore (IOTC 2011). This fleet targets swordfish, *T. alalunga* (albacore tuna), *T. obesus* (bigeye tuna), and yellowfin tuna, but most of the bycatch species (Indo-Pacific sailfish, *Sphyraena* spp. [barracudas], *Coryphaena hippurus* [dolphinfish] and *Caranx* spp. [jacks]) are retained and sold (Abellard and Herfaut 2004; Kiszka *et al*. 2010; Bein *et al*. 2011).[10]

As previously mentioned, the IOTC longline catch reported for 'France OT' was not considered indicative of Mayotte's longline fishery in some years. The IOTC nominal catch database contains catch data for 'France OT' from 1998, 1999 and 2001–2005 for 'longliners (targeting swordfish)', which match the FAO landings data for Mayotte. Since the review of literature indicated that there were no longliners based in Mayotte prior to 2001 (Abellard and Herfaut 2004; Kiszka *et al*. 2010; Busson 2011), it was assumed that domestic longline catches prior to 2001 for Mayotte were zero. The IOTC also reported catches of 143 tonnes for 'France OT' in 2005, much higher than what was typically landed by the domestic fleet from 2001–2010 (Table 5). These catches could be attributed to the industrial longline vessel ALALUNGA, which was reported to have fished in the EEZs of France's Indian Ocean Territories during 2005 (Anon. 2007b). It is possible that the 1998 and 1999 catches reported by the IOTC may also be representative of similar vessels, however, no information was found to verify this.

Several sources of data, including national data, IOTC nominal catch data, and data from the national fishing cooperative (COPEMAY) were used to estimate the catches of Mayotte's domestic longline fleet (Table 5). For the taxonomic breakdown, most of the artisanal longline catch data were already separated to the species or family level and were accepted. However, note that:

- Catch recorded as 'non-target, associated and dependent species (NTAD)' or 'others' was assigned to the 'miscellaneous marine fishes' category;
- Adjustments were made to account for shark discards and assumed unreported elasmobranch catches in instances where the reported figures were low. For example, the COPEMAY catch data contained zero shark or ray catches from 2006–2009, but it is known that shark and ray catches were still occurring (Bein *et al*. 2011). The Bein *et al*. (2011) study of the Mayotte longliner MTWARO I recorded the number of shark and ray species captured, their average lengths and, if discarded, whether they were alive or dead. Using this information and length-weight conversions (www.fishbase.org; Forselledo *et al*. 2008; Ribeiro-Prado and Amorim 2008), it was possible to estimate the proportions of landed and discarded elasmobranch catch for years where they were underreported (Table 3). We did not estimate discard mortality of sharks released alive.

Table 5. Summary of longline catch data with assumptions and sources used.

Period	Reconstructed catch (t)	Shark and ray catch (%)		Sources	Comments
		Unreported	Discards		
Prior to 2000	0	0	0	Abellard and Herfaut (2004), Kiszka *et al.* (2010)	No domestic longline fleet
2001–2003	12–17	0[a]	6	Abellard and Herfaut (2004), IOTC (2012b)	Both sets of data were identical, suggesting that the artisanal longline fishery was properly reported to FAO
2004	17	4	6	IOTC (2012b)	-
2005	16[b]	4	6	Assumption[c]	-
2006–2010	16–46	4	6	Fraisse (2010)	The increase from 2008 to 2010 could be attributed to increased effort, from one to three vessels circa 2006 (Anon. 2007b)

[a] No adjustments were made for the landed sharks and rays for these years and the existing data were accepted.
[b] No data were available for 2005; catch was estimated as an average between 2004 and 2006 values.

Shore-based subsistence fisheries

Many shore-based fishing activities are conducted primarily for subsistence purposes. The primary shore-based fishing methods used throughout Mayotte include reef gleaning (hand collection of octopus, shellfish and fish on reef margins), *djarifa* fishing (using nets made from cotton sheets or mosquito nets), nets, traps and the use of toxic plants (locally known as *uruva*; Guézel *et al*. 2009b). *Djarifa* fishing is practiced exclusively by women (Dahalani 1997), and takes place predominantly in mangroves and shallow bays throughout the island (Aboutoihi *et al*. 2010). Aerial surveys of the island observed the frequency of these activities and show reef gleaning (89.5% of observations) and *djarifa* fishing (9.1% of observations) accounted for the majority of shore-based fishing effort (Guézel *et al*. 2009b).[11]

Catches by this sector are unreported in FAO landings and only a few recent studies have estimated fishing effort and catch (Dahalani 1997; Guézel *et al*. 2009b; Aboutoihi *et al*. 2010; Jamon *et al*. 2010, Anon. 2014). *Djarifa* catches were estimated at 121 t in 1997 (Dahalani 1997) and 26 t in 2009 (Jamon *et al*. 2010). Reef gleaning catches in 2012 were 38 t, 15 t and 5.5 for octopus, shellfish and fish, respectively (Anon. 2014). We convert these estimates to shore-based per capita rates and used Mayotte's population data to generate a preliminary estimate of these catches from 1950 to 2010 (Table 6). Given that there has not been a decrease in *djarifa* catch rates between 1997 and 2008 (Jamon *et al*. 2010), the difference in per-capita catch rates likely reflects a change in the proportion of the population practising this traditional activity (Anon. 2014).

[10] Elasmobranchii are mostly discarded, although *Isurus oxyrinchus* (mako shark) and *Pteroplatytrygon violacea* (pelagic stingray) have commercial value and are generally sold on the local markets. Sharks are reportedly not targeted for the Asian shark-fin trade (Kiszka *et al*. 2010).

[11] Although nets and *uruva* do not currently occupy a significant portion of fishing effort, this may not have always been the case. *Uruva* fishing has been banned since 1997 and net fishing has been regulated and banned in certain areas since 2004 (Guézel *et al*. 2009b). These activities may have been more prevalent in the past (Fourmanoir 1954; Maggiorani and Maggiorani 1992), providing further justification for increased shore-based catch rates in earlier years.

Recreational fishing

Increased tourism and immigration of French expatriates in recent years has led to an increase of recreational fishing activities (Guézel *et al.* 2009a; Busson 2011). Recreational fishing can be broken down into two sectors: sport fishing and spearfishing.

There are currently only two commercial boats offering sport fishing trips and their annual catch for 2008 was estimated at 4.8 tonnes (Guézel *et al.* 2009a). This estimate was considered conservative as it did not take into account the catch from individuals who fished recreationally on their own boats, nor tourists who may have rented a boat from locals.

Table 6. Methods and sources used to derive per-capita catch rates for Mayotte shore-based fisheries, 1950–2010.

Year or period	reef gleaning	djarifa[b]
2010	Anon. (2014)	Jamon *et al.* (2010)
2009	Linear interpolation	
2008–1998		Linear interpolation
1997		Dahalani (1997)
1996		Maintained 1997 rate
1995	Increased shellfish catch rate by 200%, maintained 2010 rate for other taxa[a]	
1950–1994	1995 rate maintained	

[a] Shellfish collectors said catch rates were 4 times higher circa 1995 (Aboutoihi *et al.* 2010; K. Saindou, pers. comm., Agence des aires marines protégées)
[b] *Djarifa* catches were assigned to taxonomic families based on surveyed catch composition from Jamon *et al.* (2010).

Spearfishing has been regulated since 1991, when it was banned in the interior of the lagoon (Guézel *et al.* 2009a). It has been practiced for at least 20 years and now mostly takes place on the exterior slope of the barrier reef and in the open ocean. Based on information from Guézel *et al.* (2009a), a conservative estimate of 50 spearfishers and an average catch rate of 8.5 $kg \cdot fisher^{-1} \cdot trip^{-1}$ were used for 2008. An assumption was made that recreational spearfishers were active once every two weeks (i.e., 26 trips per year).

Little recreational fishing took place prior to 1985, as there were few outboard motors at this time (Biais *et al.* 1987) and few French expatriates living on the island (IEDOM 2006). Due to no other available data, we made a simplifying assumption that recreational catches for 1985 and earlier years were zero, and that catches increased linearly between 1985 and 2010.

Catches were allocated evenly among the target taxa, as no other information is available regarding catch composition. These boats generally target pelagic and demersal species such as barracuda, billfishes, dolphinfish, *Gymnosarda unicolor* (dogtooth tuna), jacks, Lutjanidae (snappers), Lethrinidae (emperors), Selachimorpha (sharks), Serranidae (groupers), Sparidae (sea breams) skipjack tuna, tuna-like species, and wahoo (Guézel *et al.* 2009a). Spearfishers target dogtooth tuna, groupers, jacks, Scaridae (parrotfish), sharks, snappers, swordfish, tuna-like species, and wahoo (Guézel *et al.* 2009a).

Holothurian fishery

Despite the lack of any holothurians in the FAO data, historic evidence indicates the presence of such catches in Mayotte for export to Asian markets since as early as 1916 (Anon. 1916, in Eriksson *et al.* 2010). There is little information on the extent of harvesting after this, other than that harvesting of holothurians occurred from the mid-1990s until 2004 when it was declared illegal (Eriksson *et al.* 2010). Pouget (2004) documented exports of 5.4 tonnes of processed dried holothurians (*trepang*) in 2002. The species most often targeted when Mayotte's fishery was active was *Holothuria nobilis* (black teatfish; Pouget 2004; Eriksson *et al.* 2010). There were only documented exports of 422 kg of processed holothurians in 2003, which suggested unrecorded exports (Pouget 2004). Other than that, there was no data available on this fishery, and it was therefore not included in the reconstructed catches.

Results

The total reconstructed catch for Mayotte was nearly 84,000 t from 1950 to 2010, a figure that is 1.4 times the domestic portion of the FAO landings of 58,000 t (Figure 4A). The total reconstructed catches ranged from 240 t in 1950 to 2,700 tonnes in 2010 and reached peaks of 3,000 t in 1997 and 1999. The reconstructed catches were allocated to 110 taxonomic groups for the 1950–2010 time period of which the families Sombridae (25%), Lethrinidae (12%), Lutjanidae (12%), Carangidae (11%) and Serranidae (8%) accounted for the bulk of catch (Figure 4B). An increase in the percentage of large pelagic fish (Coryphaenidae, Scombridae, and Istiophoridae) within the total catch has occurred since 1989.These large pelagic families occupied 15-16% of annual catch prior to 1990 and between 28–48% of annual catch between 1995 and 2010, most of which are Scombridae (Figure 4B).

The small-scale boat fleet accounted for 78,000 t over the 1950–2010 period (Figure 4A). Catches were mostly from the *pirogue* and *barque* fleet (77,600 t), followed by longliners (238 t) and the YVALANN (190 t). *Pirogue* and *barque* catches increased from 200 $t \cdot year^{-1}$ in 1950 to 2,600 $t \cdot year^{-1}$ in 2010 and peaked at 2,900 t in the late 1990s. Shore-based subsistence fisheries accounted for 5,000 t from 1950–2010, (Figure 4A). The total shore-based catches varied from 30 t in 1950 to 80 t in 2010 and peaked at 180 t in 1997.

The total recreational catches were an estimated 220 t, estimated for the 1985–2010 period (Figure 4A).

Discussion

The total reconstructed catches from 1950–2010 were 1.4 times the total domestic FAO reported landings. The main reason for this discrepancy was the missing catch data prior to 1989 and the assumed unreported portion of catches during the early 1990s. No system was in place prior to 1989 to record catches of the small-scale *pirogue* and *barque* fisheries, and these catches were considered underestimated. The *pirogue* and *barque* fleets were responsible for the bulk of the total landings (93%) between 1950 and 2010, most of which are locally consumed. As this fishery represents such a large component of total landings, it is important that it continues to be monitored. Although only available until 2005, national surveys of the *pirogue* and *barque* fleets are known to have continued until 2010. The *Service des Pêches* then ceased operations as part of Mayotte's transition to an Overseas Department of France, and future surveys are now being organized by Ifremer's *Système d'Information Halieutique* (d'Aboville 2007). It should be noted that the 'marine fishes nei' and pelagic catches recorded by the FAO are identical for 2007–2010 and 2006–2010, respectively, and thus have not been updated since 2005. These catches should be retroactively adjusted once the analyses of 2006–2010 national surveys are available. The reporting of catch statistics resumed in 2013 thanks to the implementation of Ifremer's *Système d'information halieutique* (d'Aboville 2007) and should be visible in the version of FishStat due to be released in 2015.

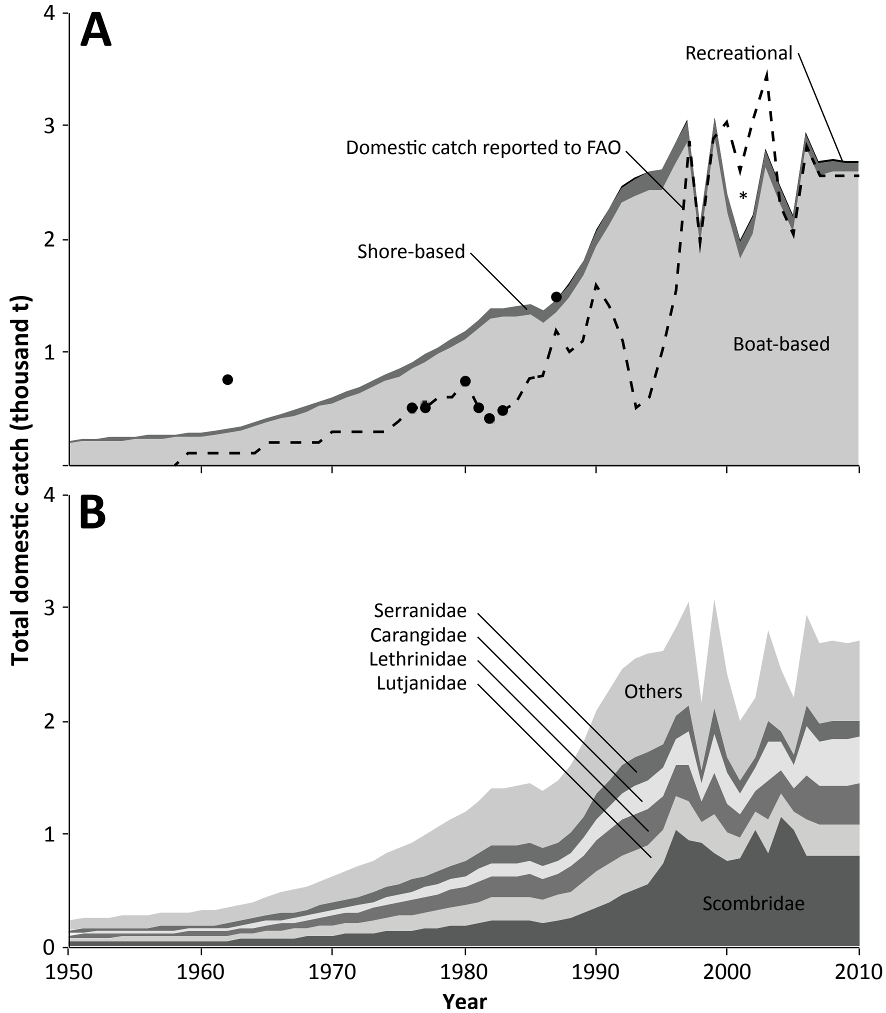

Figure 4. A) Total reconstructed catches for Mayotte by different marine fishing sectors. The 'boat-based' component includes catches by the pirogue and barque fleet, artisanal longliners, and the YVALANN. (see Appendix Table A1 for annual catches by sector). Solid dots represent historical estimates for small-scale *pirogue* and *barque* fleets (i.e., excluding shore-based fishing; Moal 1962; Jacquemart 1980; Biais 1987; Maggiorani *et al.* 1993). B) Taxonomic composition of major families in total reconstructed catches for Mayotte (See Appendix Table A2 for annual catches).
*FAO data are higher than reconstructed catches due to double-counting of pelagics.

The reconstructed catches were allocated to 110 taxonomic groups in the reconstructed time series, whereas there are only 11 taxa in the reported FAO data. It should be noted that the taxonomic disaggregation of unidentified and unreported catches is approximate and based on data from limited years (1989, 2003–2005). Several assumptions were necessary to estimate the catch composition data for the 1950–2010 period, and thus catch composition estimates will be less reliable for some years. For example, species documented in the 1989 survey may be overrepresented in earlier years. Despite the uncertainties in the allocation, this exercise is still valuable given the shifts in catch composition that have occurred as the fleet is 'professionalizing' and fishing further offshore. Our taxonomic disaggregation may prove more useful than the alternative of allocating the majority of catch as 'unidentified marine fish'. More specific information from annual surveys (Maggiorani and Maggiorani 1990, Maggiorani *et al.* 1993, Herfaut 2003, 2004, 2005) and historical observations (Fourmanoir 1954, Moal 1962, Maggiorani *et al.* 1994) may be used to improve the species disaggregation for specific years, and retroactively update landings data in the future.

Historically, Mahorans depended on the reef fisheries and shore-based fishing for much of their dietary needs (Aboutoihi *et al.* 2010). The reef resources within the lagoon had increased fishing pressure as Mayotte's population has grown, and interviews with fishers suggested that the resource may be overfished (d'Aboville 2007; Guézel *et al.* 2009a). Fishers now have to increase their effort and travel further offshore, regularly visiting neighbouring EEZs (Madagascar and Glorieuses Archipelago), to satisfy local demand for reef fish (Herfaut 2005a; Fraisse 2010). These fishers will often stay at sea for several days when fishing at offshore banks and risk dangerous sea conditions as well as being detained by foreign patrols, in order to remain profitable (Herfaut 2005a; Guézel *et al.* 2009a; Fraisse 2010). The plans to expand the artisanal longline fleet, operating within 20 nm of the coast (Busson 2011), and increase the effort targeting pelagics outside the lagoon may provide a safer and more economical alternative to the dangerous fishing conditions at offshore banks.

Fishing effort and catches by the *pirogue* and *barque* fleets have also increasingly moved outside the lagoon. This is reflected in shifts in species composition of catches, as Scombridae were not commonly targeted in the 1950s (Fourmanoir 1954), but now account for up to 50% of the *pirogue* and *barque* annual catch (Herfaut 2006). The 2009 decision to restrict industrial tuna fleets from fishing within 24 nm of Mayotte (Busson 2011) may help conserve the fishing resource and provide more fishing opportunities for the local population. However, it requires enforcing, and local enforcement capacity has historically been limited (Maggiorani *et al.* 1993; Guézel *et al.* 2009a; Busson 2011).

Due to the limited availability of data for the early part of the time series and for unreported sectors, there is some uncertainty associated with the estimated catches in this study. This is particularly the case for years prior to 1989 and for the shore-based and recreational fishing sectors, which have limited data. Recently completed studies by the *Parc Naturel Marin* (Guézel *et al.* 2009b; Aboutoihi *et al.* 2010; Jamon *et al.* 2010, Anon. 2014) suggest that *djarifa* fishing and reef gleaning are important subsistence fishing activities. The recreational fishery has increased rapidly in recent years (Busson 2011), and recording fisheries statistics from sport fishing operators may provide valuable information as it continues to grow.

This study attempts to provide an improved historical time-series of Mayotte's domestic fisheries catches for the 1950–2010 period, by including estimates of unreported (shore-based subsistence fisheries, recreational fisheries and discards) and underreported sectors (small-scale boat fisheries), and by disaggregating catches by foreign industrial fleets (e.g. longliners and purse seiners). This report may also serve as a resource to identify the existing sources of catch statistics for Mayotte's domestic fisheries and provides a comprehensive view of Mayotte's different fishing sectors.

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References

Abellard O and Herfaut J (2004) France, Mayotte et Îles Êparses — Rapport national 2003. Septième Session du Comité Scientifique, November 8–12, 2004, Victoria (Seychelles). 4 p.

Aboutoihi L, Saindou K and Salaün P (2010) La pêche à pied à Mayotte: la pratique des pêches traditionelles. Mission d'étude pour la création d'un parc naturel marin à Mayotte, Agence des Aires Marines Protégées (AAMP), Mamoudzou (Mayotte). 32 p.

Anon. (1916) Administrative report written by the governor of Mayotte. MAD 2D73, Madagascar et Dependances (MAD), Archives Nationales d'Outre-Mer, Antananarivo (Madagascar).

Anon. (1994) Livre blanc de la pêche artisanale Mahoraise — Assises de la pêche les 6,7 et 8 décembre 1994. Collectivité Territoriale de Mayotte — Service des Pêches, Copemay, Mayotte. 105 p.

Anon. (2004) Agreste Mayotte — Enquête statistique sur l'agriculture et la pêche (ESAP). Ministère de L'Agriculture et de l'Agroalimentaire (Agreste), Direction de l'Agriculture et de la Forêt, INSÉE. 19 p.

Anon. (2007a) Contrat cadre pour la réalisation d'évaluations, d'études d'impact et de suivi concernant les accords de partenariat dans le domaine de la pêche (FPA) conclus entre la Communauté européene et les pays tiers, et plus généralement sur le volet externe de la Politique Commune de la Pêche: étude de la filière thonière européene. Internal document, Oceanic Développement, MegaPesca Ltda, Brussels (Belgium). iv+156 p.

Anon. (2007b) Rapport national de la France (territoires) — Réunion du comité scientifique 2006. Ministère de l'Agriculture et de la Pêche, Paris (France). 6 p.

Anon. (2014). La pratique des pêches traditionnelles dans le Parc naturel marin de Mayotte: la pêche à pied des poulpes et coquillages. Mission d'étude pour la création d'un Parc naturel marin à Mayotte, Agence des aires marines protégées, 58 p.

Barbaroux O (1977) Compte rendu de mission à Mayotte (7 au 17 septembre 1977). Institut Scientifique et Technique des Pêches Maritimes. 33 p.

Bein A, Kiszka J, Layssac K, Jamon A, Wickel J and Labart S (2011) Caractéristiques de la pêcherie palangrière pélagique de Mayotte (2009–2010). Mayshark, Mayotte. 24 p.

Bell JD, Kronen M, Vunisea A, Nash WJ, Keeble G, Demmke A, Pontifex S and Andréfouët A (2009) Planning the use of fish for food security in the Pacific. Marine Policy 33(1): 64–76.

Biais G, Maggiorani JM and Taquet M (1987) Enquête cadre sur la pêche artisanale Mahoraise. Collectivité Territoriale de Mayotte, Direction de l'Agriculture, Service des Pêches. 70 p.

Bouchard C (2009) Fisheries in the French Indian Ocean Territories. pp. 177–193 *In* Rumley D, Sanjay C and Sakhuja V (eds.), Fisheries exploitation in the Indian Ocean — Threats and opportunities. Institute of Southeast Asian Studies, Singapore.

Busson O (2011) La pêche à Mayotte: entre archaïsme et postmodernité. L'Harmattan, Paris (France). 183 p.

d'Aboville MG (2007) La pêche et l'aquaculture en Outre-Mer. Avis et rapports du conseil économique et social, République Française. vi+48+111 p.

Dahalani Y (1997) L'impact de la pêche djarifa sure le recrutement des populations des poissons et des crustacés en face des mangroves du littoral côtier de Mayotte (baie de Chiconi). Msc thesis, Université de Poitiers (France). 26 p.

Doherty B, McBride MM, Brito AJ, Le Manach F, Sousa L, Chauca I and Zeller D (this volume) Marine fisheries in Mozambique: catches updated to 2010 and taxonomic disaggregation.

Dumas V (2009) Mayotte, île de France. Historia 750: 6–9.

Eriksson BH, Wickel J and Jamon A (2010) Mayotte commercial sea cucumber inventory and assessment 2010. Prepared for the Direction de l'Agriculture et de la Forêt de Mayotte and Conseil General, Mamoudzou (Mayotte), Stockholm University, Sweden. 26 p.

FAO (2014) FishstatJ Capture Production 1950–2012. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Forselledo R, Pons M, Miller P and Domingo A (2008) Distribution and population structure of the pelagic stingray, *Pteroplatytrygon violacea* (Dasyatidae), in the south-western Atlantic. Aquatic Living Resources 21: 357–362.

Fourmanoir P (1954) Ichthyologie et pêche aux Comores. pp. 187–239 *In* Mémoires de l'Institut Scientifique de Madagascar Série A — Tome IX.

Fraisse N (2010) Analyse des débarquements de poissons à Mayotte par la COPEMAY de 2007 à 2010. COPEMAY, Parc Naturel Marin de Mayotte. 17 p.

Guézel R, Quartararo A, Aboutoihi L, Saindou K, Salaün P, Ybrahim B and Arnaud JP (2009a) Richesses de Mayotte — Parc naturel marin de Mayotte — Les hommes et l'océan — Mission d'étude pour la création d'un parc naturel marin à Mayotte. Agence des Aires Marines Protégées (AAMP), Mamoudzou (Mayotte). 72 p.

Guézel R, Salaün P, Arnaud JP, Aboutoihi L, Gigou A, Saindou K and Ybrahim B (2009b) La pêche à pied à Mayotte : localisation des principaux sites de pêche et estimation de l'effort de pêche par comptages aériens. Mission pour la création d'un parc naturel marin à Mayotte, Agence des Aires Marines Protégées (AAMP), Mamoudzou (Mayotte). 30 p.

Herfaut J (2004) Suivi statistique de la pêcherie artisanale Mahoraise: évaluation de l'effort de pêche, des captures et des CPUE de 1997 à 2003. Service des Pêches de la Direction de l'Agriculture et de la Forêt. 31 p.

Herfaut J (2005a) Evaluation de la rentabilité économique de l'exploitation des bancs éloignés (Geyzer, Zelée, Castor…) par la pêcherie artisanale mahoraise. Ingénierie de l'environnement (INENV), Service des Pêches de la Direction de l'agriculture et de la Forêt, Mamoudzou (Mayotte). 22 p.

Herfaut J (2005b). Suivie statistique de la pêcherie artisanale mahoraise: Effort de pêche, captures et CPUE en 2004, Direction de l'Agriculture et de la Forêt de Mayotte, Service des pêches, 23 p.

Herfaut J (2006) Suivi statistique de la pêcherie artisanale Mahoraise: effort de pêche, capture et CPUE en 2005. Service des Pêches de la Direction de l'Agriculture et de la Forêt. 23 p.

Hopquin B (2011) Mayotte devient le 101^{e} département de France. Le Monde, edition of March 30, 2011.

IEDOM (2006) Mayotte en 2005. Institut d'Émission des Départements d'Outre-Mer (IEDOM). 176 p.

IEDOM (2011) Mayotte rapport annuel 2010. Institut d'Émission des Départements d'Outre Mer (IEDOM), Paris (France). 206 p.

INSÉE (2007) Recensement Général de la Population de Mayotte — 186 452 habitants au 31 juillet 2007. INSÉE Infos No. 32, Insitut National de la Statistique et des Études Économiques (INSÉE). 4 p.

INSÉE (2011) Produit intérieur brut à Mayotte en 2009: Une croissance dynamique mais un retard à rattraper. INSEE Mayotte Infos No. 55, Institut National de la Statistique et des Études Économiques (INSÉE). 4 p.

IOTC (2006) Indian Ocean tuna fisheries data summary, 1994–2003. IOTC Data Summary No. 25, Indian Ocean Tuna Commission (IOTC). 112 p.

IOTC (2012) IOTC record of authorised vessels. Indian Ocean Tuna Commission. Available at: http://www.iotc.org/English/record/search3.php [Accessed: April 25, 2012].

IOTC (2011) France-Territoires rapport national destiné au Comité scientifique de la Commission des Thons de l'Océan Indien, pour sa réunion annuelle 2011. Indian Ocean Tuna Commission (IOTC), Food and Agriculture Organization of the United Nations (FAO). 19 p.

IOTC (2012a) IOTC record of authorised vessels. Indian Ocean Tuna Commission. Available at: www.iotc.org/English/record/search3.php [Accessed: April 25, 2012].

IOTC (2012b) IOTC nominal catch database. Indian Ocean Tuna Commission. Available at: www.iotc.org/English/data/databases.php [Accessed: April 4, 2012].

Jacquemart PGF (1980) Les problèmes de la pêche à Mayotte. Doctorat Vétérinaire, École Nationale Vétérinaire d'Alfort, Faculté de Médecine de Créteil. 56 p.

Jacquet J, Fox H, Motta H, Ngusaru A and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science 32(2): 197–206.

Jamon A, Wickel J, Nicet JB, Durville P, Bissery C, Fontcuberta A and Quod JP (2010) Evaluation de l'impact de la pêche *Djarifa* sur la ressource halieutiques. Mission pour la Création d'un Parc Naturel Marin à Mayotte, Parc Naturel Marin de Mayotte, Agence des Aires Marines Protégées (AAMP), Mamoudzou (Mayotte). 59 p.

Kiszka J, Bein A, Bach P, Jamon A, Layssac K, Labart S and Wickel J (2010) Catch and bycatch in the pelagic longline fishery around Mayotte (NE Mozambique Channel), July 2009-September 2010. Shark Research Group — Mayshark, Institut de Recherce pour le Dévelopment (IRD), Mayotte. 6 p.

Le Gall J Y (1986). Élements sur l'évolution de la pêche à Mayotte (Archipel des Comores — Ocean Indien) 1960–1985. Pêche Maritime, 1301, 546–555.

Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–255.

Le Manach F and Pauly D (this volume) First estimate of unreported catch in the French Îles Éparses, 1950–2010.

Le Manach F, Bach P, Boistol L, Robinson J and Pauly D (this volume) Artisanal Fisheries in the world's second largest tuna fishing ground — Reconstruction of the Seychelles' marine fisheries catch, 1950–2010.

Maggiorani F and Maggiorani JM (1990) Enquête sur la pêche artisanale Mahoraise. Tome 2: effort de pêche et captures. Collectivité Territoriale de Mayotte, Direction de l'Agriculture et de la Forêt, Service des Pêches. 75 p.

Maggiorani F, Minet J-P, Roos D and Tessier E (1994) Diagnostic sur l'état de la pêcherie des bancs Geyser et Zélée (Océan Indien) — Analyse des résultats de pêche du navire YVALANN à Mayotte d'octobre 1989 à juillet 1992. Contrat-cade No. 91/1211331/F, Ifremer and Collectivité Territoriale de Mayotte, Le Port (France).

Maggiorani JM and Maggiorani F (1992) Les techniques de pêche utilisées à Mayotte. Enquête halieutique Tome 4, Collectivité Territoriale de Mayotte, Direction de l'Agriculture et de la Forêt, Service des Pêches. 47 p.

Maggiorani JM, Minet J-P and Taquet M (1993) Situation de la pêche artisanale à Mayotte en 1992–93 — Résultats de l'enquête halieutique (mars 1992–février 1993) et comparison avec l'enquête halieutique de 1988–89. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and Collectivité Territoriale de Mayotte, Direction de l'Agriculture et de la Forêt, Service des Pêches. 34 p.

Maggiorani JM and Planchot D (1995) Propositions pour le développement de la pêche mahoraise. Assises de la pêche du 6 au 8 décembre 1994. Collectivité Territoriale de Mayotte, Représentation du Gouvernement, Direction de l'Agriculture et de la Forêt. 98 p.

Minet JP and Weber J (1992) Perspectives de developpement du secteur des pêches à Mayotte. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and Collectivité Territoriale de Mayotte, Direction de l'Agriculture. 44 p.

Moal RA (1962) La pêche aux Comores. République Française — Ministère d'état chargé des départements et territoires d'outre-mer, Territoire des Comores — Société centrale pour l'équipement du territoire (SCET), France. 78 p.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–7.

Pauly D (2007) The *Sea Around Us* project: documenting and communicating global fisheries impacts on marine ecosystems. Ambio 36(4): 290–295.

Pauly D and Zeller D (2003) The global fisheries crisis as a rationale for improving the FAO's database of fisheries statistics. Fisheries Centre Research Reports 11 (6), University of British Columbia, Vancouver. 9 p.

Pouget A (2004) Sea cucumber fisheries in the Mayotte reef system, Indian Ocean. pp. 35–38 *In* SPC Bêche-de-mer Information Bulletin #19, Secretariat of the Pacific Community (SPC).

République Française (2009) Arrêté du 2 décembre 2009 portant interdiction de l'usage des filets de type senne à moins de vingt-quatre milles marins des lignes de base à partir desquelles est mesurée la largeur des eaux territoriales françaises adjacentes à Mayotte. Journal Officiel de la République Française 0291.

République Française (2010) Arrêté n° 2010–104 du 9 octobre 2010 créant une redevance annuelle de surveillance et d'observation de la pêche dans les zones économiques exclusives des îles Glorieuses, Juan de Nova, Bassas da India et Europa. Journal Officiel des Terres Australes et Antarctiques Françaises.

Ribeiro-Prado CC and Amorim AF (2008) Fishery biology on Pelagic stingray *Pteroplatytrygon violacea* caught off southern Brazil by longliners settled in Sao Paulo State (2006–2007). ICCAT Collective Volume of Scientific Papers 62(6): 1883–1891.

Thomassin BA, Garcia F, Sarrazin L, Schembri T, Wafo E, Lagadec V, Risoul V and Wickel J (2011) Coastal seawater pollutants in the coral reef lagoon of a small tropical island in development: the Mayotte example (N Mozambique Channel, SW Indian Ocean). pp. 401–407 *In* H-J Ceccaldi, Dekeyser I, Girault M and Stora G (eds.), Global change: mankind-marine environment interactions. Proceedings of the 13th French-Japanese Oceanography Symposium. Springer, Dordrecht (The Netherlands).

Van der Elst R, Everett B, Jiddawi N, Mwatha G, Afonso PS and Boulle D (2005) Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 363(1826): 263–284.

Wendling B and Le Calvé S (1999) Technologie et utilisation des DCP ancrés dans les eaux de la collectivité territoriale de Mayotte (archipel des Comores, canal du Mozambique, océan Indien). pp. 261–275 *In* Le Gall J-Y, Cayré P and Taquet M (eds.), Pêche thonière et dispositifs de concentration de poissons, Trois-Îlets, Caraïbe-Martinique.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. Annual reconstructed catches (t) of domestic fleet by sector and FAO reported catches

Year	Boat-based	Recreational	Shore-based	Total reconstructed catch	Domestic FAO reported catch	Total FAO reported catch
1950	211	-	26	237	0.25	0.25
1951	220	-	27	247	0.25	0.25
1952	226	-	28	254	0.25	0.25
1953	231	-	29	260	0.25	0.25
1954	237	-	29	266	0.25	0.25
1955	242	-	30	273	0.25	0.25
1956	248	-	31	279	0.25	0.25
1957	254	-	32	285	0.25	0.25
1958	260	-	32	292	0.25	0.25
1959	269	-	33	302	100	100
1960	274	-	34	308	100	100
1961	280	-	35	314	100	100
1962	302	-	38	339	100	100
1963	326	-	39	365	100	100
1964	353	-	40	394	100	100
1965	393	-	43	436	200	200
1966	424	-	44	469	200	200
1967	453	-	46	499	200	200
1968	485	-	47	533	200	200
1969	533	-	50	583	200	200
1970	565	-	51	617	300	300
1971	617	-	54	671	300	300
1972	654	-	56	709	300	300
1973	706	-	58	764	300	300
1974	762	-	61	823	300	300
1975	803	-	63	865	400	400
1976	863	-	65	929	500	500
1977	924	-	68	992	500	500
1978	989	-	71	1,060	600	600
1979	1,054	-	74	1,128	600	600
1980	1,122	-	76	1,199	742	742
1981	1,215	-	81	1,296	516	516
1982	1,308	-	85	1,393	420	420
1983	1,318	-	89	1,407	480	480
1984	1,323	-	93	1,416	550	550
1985	1,344	-	99	1,442	780	780
1986	1,270	1	104	1,375	800	800
1987	1,360	1	110	1,472	1,200	1,200
1988	1,493	2	115	1,610	1,000	1,000
1989	1,698	3	121	1,821	1,100	1,100
1990	1,954	3	128	2,085	1,600	1,600
1991	2,136	4	136	2,276	1,400	1,400
1992	2,323	5	144	2,472	1,100	1,100
1993	2,386	5	153	2,545	500	500
1994	2,444	6	161	2,612	600	600
1995	2,450	7	169	2,626	1,033	1,033
1996	2,659	8	176	2,842	1,553	1,553
1997	2,867	8	181	3,056	2,867	2,867
1998	1,971	9	177	2,157	1,971	3,003
1999	2,892	10	173	3,075	2,892	3,452
2000	2,234	10	168	2,412	3,047	3,048
2001	1,831	11	161	2,003	2,621	10,052
2002	2,052	12	154	2,218	3,076	4,754
2003	2,641	12	146	2,799	3,464	3,464
2004	2,319	13	138	2,470	2,306	2,306
2005	2,072	14	128	2,214	2,051	2,194
2006	2,826	14	118	2,958	2,810	5,772
2007	2,573	15	107	2,695	2,560	11,661
2008	2,608	16	95	2,719	2,560	12,677
2009	2,603	16	82	2,701	2,560	15,006
2010	2,606	17	82	2,705	2,560	20,842

Appendix Table A2. Reconstructed catches (t) grouped by 5 most important taxa.

Year	Scombridae	Lethrinidae	Lutjanidae	Carangidae	Serranidae	Others
1950	35	30	34	19	25	94
1951	37	31	35	20	26	98
1952	38	32	36	20	27	100
1953	39	33	37	21	28	103
1954	40	33	38	21	28	105
1955	41	34	39	22	29	108
1956	42	35	40	22	30	111
1957	43	36	41	23	30	113
1958	44	37	42	23	31	116
1959	45	38	43	24	32	120
1960	46	39	44	24	33	122
1961	47	39	45	25	34	125
1962	51	42	48	27	36	134
1963	55	46	52	29	39	144
1964	60	50	57	32	42	154
1965	66	55	63	35	47	169
1966	72	60	68	38	51	181
1967	76	64	73	40	54	191
1968	82	68	78	43	58	203
1969	90	75	85	47	64	221
1970	95	80	91	50	68	233
1971	104	87	99	55	74	252
1972	110	92	105	58	78	266
1973	119	99	113	63	85	285
1974	128	107	122	68	91	306
1975	135	113	129	72	96	321
1976	145	122	138	77	104	343
1977	156	130	148	82	111	365
1978	167	139	159	88	119	389
1979	178	148	169	94	126	412
1980	189	158	180	100	135	437
1981	205	171	195	108	146	471
1982	220	184	210	116	157	505
1983	222	186	211	117	158	513
1984	223	186	212	118	159	518
1985	226	189	216	120	161	531
1986	214	179	204	113	152	513
1987	230	192	218	121	163	547
1988	252	210	240	133	179	596
1989	286	237	279	152	204	664
1990	342	265	331	184	233	730
1991	399	293	338	217	239	789
1992	458	320	350	253	244	848
1993	503	334	336	277	231	864
1994	541	342	332	299	223	875
1995	739	311	292	285	191	808
1996	1,040	296	270	285	171	780
1997	949	354	312	355	192	893
1998	921	194	166	204	99	573
1999	829	389	322	422	186	928
2000	763	282	226	317	126	697
2001	790	207	160	241	86	518
2002	1,023	207	155	248	80	504
2003	820	367	274	438	141	759
2004	1,154	236	177	283	91	529
2005	1,023	210	158	252	81	489
2006	794	410	307	490	157	799
2007	794	359	269	429	138	705
2008	806	359	269	429	138	717
2009	802	359	269	429	138	704
2010	810	359	269	430	138	699

Marine Fisheries in Mozambique: Catches Updated to 2010 and Taxonomic Disaggregation*

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Abstract

Reconstructed catch and discard estimates for Mozambique's marine fisheries sectors (small-scale and industrial) were updated from a 2007 contribution by J. Jacquet and D. Zeller to encompass the entire 1950–2010 period. The species composition of the reconstructed catches was also estimated for each year. The total reconstructed catch for 1950–2010 was approximately 8.2 million tonnes (t), which is 4.6 times the official data reported to the Food and Agriculture Organization of the United Nations (FAO), i.e., landings of 1.8 million t over this 61-year period. However, significant improvements have occurred in the data reported to FAO for recent years (2003–2010), specifically in 2009 and 2010, when small-scale catches were comprehensively reported. FAO data prior to 2003 remain incomplete, with large unreported catches and poor taxonomic resolution for small-scale fisheries. Mozambique's total marine fisheries catch for the 1950–2010 period were composed largely of the families Clupeidae (11%), Engraulidae (9%), and Penaeidae (8%). However, historical data from the 1970s suggest significant changes in overall species composition of small-scale fisheries that are unaccounted for in official catch statistics.

Introduction

Mozambique stretches along the coast of East Africa, between South Africa and Tanzania (Figure 1), where its mangroves, coral reefs, and seagrass beds support a variety of marine life (Bandeira *et al.* 2002). Of the 1,425 marine finfish species known to occur within Mozambique's Exclusive Economic Zone (EEZ), nearly 300 are of commercial importance (www.fishbase.org). At least 14 species of shrimps are of commercial importance (Appendix Table A1), while other valuable fisheries are conducted for *Metanephrops mozambicus* (African lobster), *Palinurus delagoae* (Natal spiny lobsters), *Chaceon macphersoni* (pink geryons), holothurians, and sharks (contributions in Pauly 1992; Groeneveld and Melville-Smith 1995; Fennessy and Groeneveld 1997; Abdula 1998; Kroese and Sauer 1998; de Sousa 2001; Pierce *et al.* 2008). A listing of valuable species across Mozambique's different fishing sectors is presented in Appendix Table A1.

Officially, marine capture fisheries account for more than 90% of Mozambique's total fish catch (FAO 2007) and coastal communities depend on the sea and its resources for survival, with fish accounting for 50% of the population's protein intake (Hara *et al.* 2001; van der Elst *et al.* 2005). National catch data show that small-scale fisheries account for over 80% of landed marine captures and thus play a significant role in the national economy (e.g., providing direct employment in fishing, fish processing and marketing). Industrial/semi-

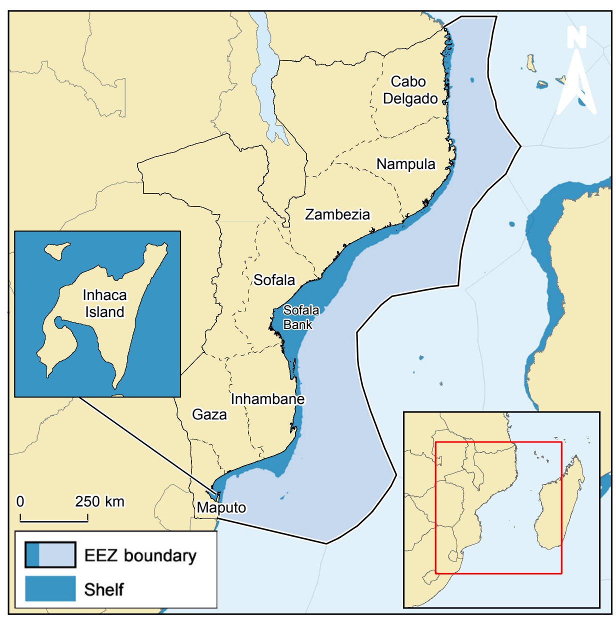

Figure 1. Map of Mozambique and its Exclusive Economic Zone (EEZ), as well as the extent of the continental shelf (in darker blue). The various districts are also delimited by dotted lines.

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industrial fisheries are mostly export-oriented, targeting mainly penaeid shrimp, and represent an important source of export income (Pinto 2001; FAO 2007).

Despite the importance of marine fisheries for food security and the national economy, fisheries statistics for Mozambique and much of the region remain underreported, mainly due to underestimates of landings by the small-scale fisheries (van der Elst *et al.* 2005; Blythe *et al.* 2013). FAO catch statistics for Mozambique's industrial fisheries are also underreported (Jacquet *et al.* 2010) and do not include discards, which are substantial for the industrial crustacean fisheries (Fennessy 1994; Fennessy and Groeneveld 1997; Pinto 2001). A shallow-water shrimp fishery has been present since the 1950s (FAO 2013), mostly operating at depths below 50m off Sofala Bank (Fennessy and Isaksen 2007). On average about 15% of the landings are shrimp, while about 85% is bycatch (Brito and Abdula 2008). Most shrimp catch is composed of *Fenneropenaeus indicus* (Indian white prawns) and *Metapenaeus monoceros* (speckled shrimp), but *Marsupenaeus japonicus* (Kuruma shrimp), *Melicertus latisulcatus* (western king prawns), *Penaeus monodon* (giant tiger prawns), and *P. semisulcatus* (green tiger prawns) are also landed (Fennessy and Groeneveld 1997; IIP 2003; Pinto 2001). Since *circa* 1986 (FAO 2013), Mozambique has also had a deep-water crustacean fishery that fishes at depths around 300–500 m (Groeneveld and Melville-Smith 1995), landing predominantly *Haliporoides triarthrus* (knife shrimp), African lobster, and pink geryons (Tortensen and Pacule 1992; de Sousa 1992; IIP 2008, 2009). A bottom trawl fishery targeting *Decapterus russeli*, *D. macrosoma*, and *Selar crumenophthalmus* (three species of scads), and *Rastrelliger kanagurta* (Indian mackerel) also operated in Sofala Bank and Boa Paz from 1977 to 1992 as part of the Mozambique-USSR joint venture, MOSOPESCA (Silva and Sousa 1988; Sousa 1992).

Mozambique began its sampling program for multi-national industrial and semi-industrial fisheries with the founding of the *Instituto Nacional de Investigação Pesqueira* (Fisheries Research Institute) in 1977 (Bandeira *et al.* 2002). Since the early 1980s, the program has included the collection of fishery-dependent data *via* logbooks of commercial catch categorized taxonomically (by order, family, or species), and publications of the *Revista de Investigação Pesqueira* (Fisheries Research Journal; Bandeira *et al.* 2002). This program was broadened during the 1980s to include an onboard observer-sampling component. Fishery-independent data have also been collected through a series of scientific surveys that were conducted occasionally between 1976 and 1991 depending on the availability of vessels, but have been conducted systematically after 1991. Collection of data (catch, effort, and species composition) from Mozambique's small-scale fisheries began in 1997 in two provinces (Inhambane and Nampula), but has now been expanded to cover all coastal provinces (Dias and Afonso 2011). The composition of species discarded from industrial shallow-water shrimp fisheries was first reported in 2008 and 2009 (IIP 2008, 2009). Additional studies for South African shrimp fisheries also provided valuable information for Mozambique fisheries (Fennessy 1994; Fennessy *et al.* 1994; Groeneveld and Melville-Smith 1995; Fennessy and Groeneveld 1997; Fennessy and Isaksen 2007; Olbers and Fennessy 2007), as they have historically fished in Mozambique, and have similar target species and bycatch compositions (Groeneveld and Melville-Smith 1995; Fennessy *et al.* 2004).

The sustainable management of fisheries is imperative for food and job security in Mozambique. In many countries, catch data are often the only data available for such management (Kleisner *et al.* 2012; Pauly 2013) and may be underreported by 100% or more (see, e.g., Zeller *et al.* 2007; Wielgus *et al.* 2010; Le Manach *et al.* 2012). Historical baselines and improved catch statistics, such as those presented in this study, are needed to better understand the impacts of Mozambican fisheries on its diverse marine ecosystems and inform fisheries policies (Pauly 1998, 2007; Pandolfi *et al.* 2003; McClenachan *et al.* 2012). The previous catch reconstruction for Mozambique (Jacquet and Zeller 2007; Jacquet *et al.* 2010) included reconstructed catches from domestic small-scale fisheries, industrial fisheries and discards from 1950–2004. Jacquet *et al.* (2010) total reconstructed catches over this period were 6.2 times those supplied to FAO by Mozambique, largely due to a lack of resources for collecting catch statistics for small-scale fisheries and their consequent under-reporting. This research updates the original work, extending catch estimates up to 2010 and providing an improved taxonomic disaggregation by sector. This work focuses on Mozambique's domestic fisheries and does not include estimates of industrial fishing by foreign-owned vessels operating in Mozambique's EEZ, although these are substantial (see, e.g., Silva and Sousa 1988; van der Elst *et al.* 2005).[1]

Methods

Update of marine catches

Catch data for marine fisheries for 1950–2010 were extracted from FishStatJ (FAO 2012), the fisheries database of the Food and Agriculture Organization of the United Nations (FAO). The most recent FAO dataset shows significant increases in the reported catches for 2003 and 2004, compared to the FAO landings data used in the original catch reconstruction (Jacquet *et al.* 2010). FAO landings for 2005–2010, which were not reviewed in Jacquet and Zeller (2007) and Jacquet *et al.* (2010), have also significantly increased compared to previous levels and are further discussed herein.

[1] There are significant catches by industrial purse seiners (mostly European) and longliners (mostly Central and Eastern Asian) targeting tuna, billfish and sharks in Mozambique (www.transparentsea.co). The Mozambique government issues licenses to many of these vessels, however, it is also thought that there is up to 100 unlicensed longline vessels fishing illegally in the Mozambique channel (Anon. 2008; www.transparentsea.co).

Sectoral catch as defined by the Sea Around Us

The *Sea Around Us* uses the following fishing sectors in its global catch database: 'industrial' (i.e., large-scale commercial), 'artisanal' (i.e., small-scale commercial), and 'subsistence' (i.e., small-scale non-commercial activities whose primary purpose is self- or family-consumption). For this study, small-scale fisheries are defined as fisheries that use small (or no) vessels, have a low capital investment, and generally fish inshore waters of Mozambique. Industrial fisheries are defined as fisheries that use larger vessels with more advanced equipment and have a higher capital investment (www.fao.org). This study classified both semi-industrial and industrial fisheries as industrial.[2]

National fisheries catch statistics from 2000–2010 (obtained from the *Instituto Nacional de Desenvolvimento de Aquacultura;* National Institute of Aquaculture Development) form the basis of the FAO landings data and are separated into 3 sectors, i.e., 'commercial', 'artisanal', and 'aquaculture'. The national commercial catches include Mozambique fisheries classified as both industrial and semi-industrial, while the artisanal catch data were considered representative of small-scale fisheries. With the freshwater taxa and aquaculture production removed, both sector's catches were segregated into 10 separate taxa and the total catches matched exactly with FAO landings data from 2000–2010. Landings data from the *Direcção Nacional das Pescas* (Fisheries Department; DNP 1976), Krantz *et al.* (1986), and Charlier (1994) also provided an indication of the catch by industrial and semi-industrial sectors. Based on these data we allocated reported FAO landings for different taxa to small-scale (clams, holothurians, miscellaneous marine crabs, and elasmobranchs) or industrial sectors (penaeid shrimp, knife shrimp, lobsters, pink geryons, and cephalopods) for the 1950–1999 period. Unidentified marine fish in FAO landings were allocated to both small-scale and industrial sectors, based on the portion of industrial catch reported in DNP (1976), Krantz *et al.* (1986), and Charlier (1994).

Small-scale fisheries

Jacquet *et al.* (2010) estimated that the nationally reported catches from the *Instituto Nacional de Investigação Pesqueira* (National Institute of Fisheries Research; IIP) for 2003 and 2004 accounted for approximately 62% of small-scale fishers. Therefore, they assumed that 38% of catches within the small-scale sector had been unreported and adjusted the catch accordingly. We applied the same approach as Jacquet *et al.* (2010) to small-scale catches from 2003–2007 as the methods of national data collection did not change over this period and small-scale catches were in the same range (58,000–65,000 t·year-1).

In 2008, a new methodology was introduced to extrapolate surveyed catches to a larger geographical area in the Sofala bank region and, since 2009, this method has been used for all areas. Small-scale catches in 2009 and 2010 showed substantial increases and were in the same range (93,000–112,000 t) as reconstructed catches for years 2002–2007. As such, the 2009 and 2010 small-scale catches were considered fully-reported and no adjustment was made for these years. As the new extrapolation methodology in 2008 was not applied to all areas, 2008 catches were considered underreported. To estimate 2008 catches we applied an average catch rate of 0.69 $t \cdot fisher^{-1} \cdot year^{-1}$ in conjunction with estimates of small-scale fishers (see Table 1).

Table 1. Mozambique inhabitants, fishers and associated catch rates for 2007–2009

Year	Population[a]	Number of fishers	Catch rate ($t \cdot fisher^{-1} \cdot year^{-1}$)	Method for calculating catch rates
2007	21,811,326	135,529[b]	0.69	Reconstructed catches/# fishers
2008	22,332,900	138,687[c]	0.69	Average of 2007 and 2009 catch rates
2009	22,858,607	141,952[c]	0.69	Reconstructed catches/# fishers

[a] Source: http://data.worldbank.org.
[b] Source: IDPPE (2009).
[c] Estimate based on 2007 ratio of 6.21 fishers for every 1,000 inhabitants.

Industrial fisheries

We assumed industrial landings form the basis for most taxa in the FAO landings (other than those reported as 'unidentified marine fish') prior to 2000, and comparison with other data sets confirms this (DNP 1976; de Freitas 1989; Charlier 1994; de Sousa 2001). The FAO landings data did not contain MOSOPESCA catches of small pelagics (unless they are allocated as 'unidentified marine fish') from 1977–1987 (Sousa 1992) and 1988–1992 (unpub data, provided by L. Sousa),[3] nor did they contain a small amount of catches for select taxa (demersals, sharks and large pelagics) reported in Charlier (1994). Thus we supplemented the FAO data in the 1970s-1990s with unreported industrial catches from the MOSOPESCA shad fishery from Sousa (1992) and Charlier (1994) to create an industrial time-series (Table 2).

Table 2. Source of reported industrial catches from 1950–2010

Period	Catch (t)	Source
1950–1954	3,300	Jacquet *et al.* (2010)
1955–1960	3,300–3,900	Krantz *et al.* (1986)
1961–1975	3,285–15,655	DNP (1976)
1976–1999	13,893–31,207	FAO (2012); Sousa (1992); Charlier (1994); unpub. data, provided by L. Sousa)
2000–2010	7,724–13,723	FAO (2012); National Statistics from INAQUA[a]

[a] *Instituto Nacional de Desenvolvimento de Aquacultura*.

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[2] Depending on the fidelity of coverage and sampling procedures, the lines of distinction between catch removals from industrial/semi-industrial and small-scale fisheries may become blurred. Since the 1970s, there are accounts of small-scale fishers in Nampula, Zambézia, and Sofala provinces collecting bycatch from industrial/semi-industrial shrimp trawlers. These collections are realized through an exchange program: artisanal fishers or collectors exchange their agricultural produce or money for the fish bycatch of industrial/semi-industrial vessels. The fish is either sold fresh for local consumption or dried for more distant markets (Menezes 2008).

[3] Catches from the scad fishery for the 1988–1992 period were obtained from unpublished data presented at the 1993 Master Fisheries Plan seminar.

Discards

Estimates of bycatch to landings ratios from South African and Mozambique shallow-water shrimp fisheries range from 2.3:1 to 5:1 (Fennessy and Groeneveld 1997; Pinto 2001). Most bycatch is comprised of small non-marketable fish and juvenile shrimp that are discarded (Schultz 1992). We used these studies to develop estimates of discard to landings ratios for the 1950–2010 period (Table 3).

The FAO landings data included catches for three different shrimp groupings: 'Penaeus shrimps', 'knife shrimp', and 'Tsivakihini paste shrimp' (*Acetes erythraeus*). Discards associated with shallow-water shrimp fisheries were calculated by multiplying the discard to shrimp landings ratios from Table 3 by FAO 'penaied shrimp' landings, present in FAO data since 1958.

Table 3. Discards to shrimp landings (D/L) rates used to estimate discards in Mozambique shallow water shrimp trawl fisheries

Period	D/L	Source
1958–1979	2.9	Carried back 1980 rate
1980	2.9[a]	Pelgröm and Sulemane (1982)
1981–1982	2.9–3.0	linear interpolation
1983–1984	3.1[a]	Gislason (1985), in Pinto (2001)
1985	3.5	linear interpolation
1986–1990	3.8[b]	Pacule and Baltazar (1995), in Pinto (2001)
1991	3.8	Fennessy and Groeneveld (1997)
1992	2.9	Fennessy and Groeneveld (1997)
1993	4.5[b]	Anon. (1994), in Pinto (2001)
1994–1999	4.3–3.0	linear interpolation
2000–2010	2.8	Jacquet *et al.* (2010)

[a] Assuming 5% of bycatch is retained (Pelgröm and Sulemane 1982).
[b] Assuming 11% of bycatch is retained (Anon. 1994).

Discard and catch data from Fennessy and Groeneveld (1997) indicated a ratio of target landings (knife shrimp, African lobster, deep-sea crab) to discards of 1:2.7 in 1992. Discards associated with deep-water crustacean fisheries were calculated by multiplying this ratio by FAO landings of knife shrimp, African lobster and pink geryons, present in the FAO data since 1986. We ignored any discards from Tsivakihini paste shrimp fisheries, as these are generally caught in coastal areas using push nets, bag nets and seines by small-scale fisheries with lower bycatch rates (Chen 1994; Chan 1998; Gillett 2008).

Bycatch data for MOSOPESCA were available from 1980–1985 (Krantz *et al.* 1986), and we applied the median discard to landings ratio of 0.4 to estimate bycatch for years without data (1977–1979, 1987–1996).

Taxonomic disaggregation

The FAO landings data extracted from FishStatJ (FAO 2012) were allocated to 30 different taxa. The taxonomic allocation of the FAO landings were accepted without further disaggregation, with the exception of the 'marine fishes nei' category, which accounted for 34–99 % of reported landings per year.

The IPP began regular publication of industrial/semi-industrial and small-scale fisheries statistics in 2001. These reports (IIP 2001–2010) were used to estimate the catch composition for Mozambique's marine fishing sectors during the 2000s (Table 4). They included bycatch composition of shallow-water industrial shrimp fisheries and catch composition of small-scale fisheries from select provinces from 2001–2010. Additional available information included: a Portuguese Research Report to the International Commission for the South-East Atlantic Fisheries (ICSEAF) that provided estimates of percent catch composition by family for 1972–1973 (Monteiro 1973), and additional bycatch studies from shallow-water shrimp fisheries in the region (Fennessy *et al.* 1994; Pinto 2001).

Reported estimates of species catch composition were therefore unavailable for periods extending from 1950–1971 and 1974–1999. Accordingly, assumption-based estimations, interpolations, extrapolations and averaging have been used to derive estimates for these periods, with input and expert advice from experienced senior scientists at the IIP (Table 4).

Small-scale sector

Small-scale FAO landings of specific taxa were left unadjusted, while unreported landings and FAO catches allocated as 'unidentified fish' were assigned to specific taxa (Table 4). We assigned 500 t and 700 t of unreported catch in 1990 and 1993, respectively, as holothurian catch based on estimates reported in Abdula (1998) which are missing from the FAO database.

Table 4. Reconstructed catch compositions for small-scale fisheries and industrial crustacean fisheries discards in Mozambique from 1950–2010.

Taxa	Catch Composition (in %)			
	Small-scale			Discards
	1950–1973	2003[a]	2004–2010[a]	1950–2010
Invertebrates				
Brachyura	-	-	-	1.7
Cephalopoda	0.8	0.6	0.4–1.3	1.5
Nephropodidae	0.1	-	0.0–0.2	-
Penaidae	5.3	8.7	1.5–8.7	3.8
Portunidae	0.4	0.5	0.2–0.8	4.4
Chondrichthyes				
Elasmobranchii	1.1	0.6	0.2–2.8	1.0
Teleosts				
Ariidae	0.9	1.3	1.3	5.3
Caesionidae	1.4	1.9	2.0	-
Carangidae	7.8	10.9	11.1–11.6	0.6
Clupeidae	12.3	17.2	17.4–18.2	2.3
Cynoglossidae	-	-		1.5
Drepaneidae	-	-		2.2
Engraulidae	9.8	13.7	13.9–14.5	2.8
Haemulidae	10.7	2.9	3.0–3.1	3.7
Leiognathidae	0.1	0.2	0.2	0.5
Lethrinidae	8.5	3.1	3.2–3.3	-
Lutjanidae	6.4	0.3	0.3–0.4	-
Mugilidae	1.2	1.6	1.6–1.7	-
Mullidae	1.1	1.5	1.5–1.6	1.7
Polynemidae	-	-	-	2.0
Scaridae	3.0	1.1	1.1	-
Sciaenidae	2.2	3.1	3.1–3.2	25.9
Scombridae	3.4	4.7	4.8–5.0	-
Serranidae	<0.1	<0.1	<0.1	-
Siganidae	6.3	2.0	2.0–2.1	-
Synodontidae	-	-	-	2.2
Trichiuridae	1.5	2.1	2.1–2.2	4.7
Tetraodontidae	-	-	-	2.7
Others[b]	15.6	21.9	22.1–23.1	29.6

[a] A separate breakdown for 7 major groups was available for the small-scale sector for each year from 2003–2010. The values for 5 major groups and the disaggregated teleost component are shown for 2003 as well as the range of maximum and minimum values for 2004–2010.
[b] Small-scale includes 10 taxa, each occupying <1%, and marine fishes not identified. Discards includes 6 families and unidentified species.

The *IIP Relatório Anual* report series contained annual estimates of catch composition by family for small-scale fisheries for select coastal provinces between 2001 and 2010. These reports provided national catch compositions for the small-scale sector from 2003–2010 that separated catches into seven groups; shrimps, cephalopods, crabs, lobster, sharks, fish and others. The latter two groups were combined as teleosts (encompassing both the 'fish' and 'others' categories) as shown in Table 4, and these annual catch compositions were used to further disaggregate unidentified taxa in the reconstructed small-scale catches from 2003–2010. The average catch composition from 2003–2010 was applied to disaggregate the 1950–1973 small-scale reconstructed catches and catch compositions from 1974 to 2002 were interpolated between the assumed 1950–1973 and 2003 breakdowns. The catches were composed mostly of teleost families (90–95% of total catches) and a further disaggregation of the teleost component was attempted.

Mozambique's national data have only provided complete estimates covering all coastal areas for 2009 and 2010, and as a result, these years were considered the best representation of catch composition for Mozambique's small-scale fishing sector. Mozambique's national fisheries surveys (IIP 2009, 2010) provide small-scale catch compositions for all coastal provinces (Cabo Delgado, Nampula, Zambezia, Sofala, Inhambane, and Maputo) except Gaza. We converted these provincial catch compositions into a national catch composition,[4] which was weighted proportionally to the reported 2010 small-scale catches by province (IIP 2010). This 2010 small-scale catch composition was used to disaggregate the teleost component from 2003–2010 (Table 3).

There was little information regarding the catch composition of Mozambique's fisheries prior to 2000; however, a survey by Monteiro (1973) provided some indication of the major taxa present in catches during the earlier period. Monteiro (1973) recorded the catch composition of 39 beach seines, hauled by tractor winches, in the province of Inhambane between September 1972 and September 1973. Their catch composition was compared with the 2010 small-scale catch compositions for Inhambane in an attempt to estimate a 1973 national catch composition. Based on this comparison, the 5 major taxa (Haemulidae, Lethrinidae, Lutjanidae, Scaridae and Siganidae) observed by Monteiro (1973) were adjusted to levels which were assumed more representative for the entire coastline (Table 5). This left approximately 62% of catches as 'others', which were allocated proportionally to other families in the 2010 small-scale teleost catch composition. This 1973 catch composition was used to disaggregate the teleost component from 1950–1973 (Table 4), and catch compositions from 1974 to 2002 were interpolated between the assumed 1950–1973 and 2003 breakdowns.

Table 5. Development of the 1973 teleost breakdown (%) for Mozambique's small-scale fishery

Taxa	1972/1973 catch composition for Inhambane[a]	2010 teleost catch composition for Inhambane[b]	1972/1973–2010 ratio	2010 national teleost catch composition[b,c]	Estimated 1973 national teleost catch composition[d]
Haemulidae	11.3	3.2	3.5	3.3	11.6
Lethrinidae	28.7	10.8	2.7	3.5	9.3
Lutjanidae	4.5	0.25	18.3	0.38	6.9
Scaridae	12.3	4.6	2.7	1.2	3.2
Siganidae	24.2	7.8	3.1	2.2	6.9
Other taxa	19	73	-	90	62

[a] Source: Monteiro (1973).
[b] Source: IIP (2010).
[c] See Table 3.
[d] 1973 national catch composition was estimated based on the ratio of the 2010 Inhambane catch composition to the 1973 Inhambane catch composition. These are the percentages used to disaggregate the teleost component and thus are not equivalent to the percentages of total catch shown in Table 4.

For the purposes of the *Sea Around Us* database, small-scale catches were further subdivided into artisanal and subsistence components. It is often difficult to distinguish between these two sectors as most small-scale fishers fish for both subsistence and artisanal purposes, selling the more valuable species landed and taking the rest home for consumption. The collection of landings data did not record this information and we found no other studies that distinguished between these sectors in Mozambique. We thus employed the same approach as Le Manach *et al.* (this volume), assigning 90% of catch from taxa associated with higher commercial values (Decapoda, Elasmobranchii, Haemulidae, Istiophoridae, Lethrinidae, Lutjanidae, Scaridae, Sciaenidae, Scombridae, Serranidae, Siganidae and Sparidae) as 'artisanal' and the remaining 10% as 'subsistence' to account for spoilt and undersized catches. The remaining taxa were considered less commercially important and we allocated 80% of these catches as 'subsistence' and 20% as 'artisanal'. For species where the distinction was less obvious, i.e., Carangidae and unidentified marine fish, we used an even split, allocating 50% to each small-scale sector. All holothurian catches were considered 'artisanal' (Abdula 1998).

Industrial sector

Catches from the MOSOPESCA shad and mackerel trawl fishery were disaggregated based on the 1986 and 1987 species compositions reported in Sousa (1992). These two years were then averaged to estimate species composition for all other years.

[4] The 2010 catch composition (IIP 2010) was used for all provinces except Maputo, which used the 2009 catch composition (IIP 2009) since it was not available in the 2010 report.

Discards

The *IIP Relatório Anual* reports contained bycatch data from 2000–2010, and discard data for 2008–2009 from select industrial shrimp fishing companies sampled. The 2004 bycatch data and the 2008 discard data were disregarded as they contained high penaeid shrimp discards, which were not considered representative of the entire fleet.

The annual 2000–2003, 2005–2008, 2010 bycatch and 2009 discard compositions were averaged to estimate an average composition of discards (Table 4). The average was composed of 11% invertebrates and 89% teleosts, 1/3 of which were unidentified species listed as 'others'. A small amount of the unidentified component (5%) was redistributed to 'missing' teleost families (Ariommatidae, Congridae, Platycephalidea, Pristigasteridae, Soleidae and Tetraodontidate) based on the proportions observed in commercial prawn trawls in Tugela Bank in the early 1990s (Fennessy *et al.* 1994). Another 1% was allocated to elasmobranchs[5] based on estimates by Schultz (1989) and Sousa (1990; see also Le Manach *et al.* 2012).

Results

Total marine fisheries catches, 1950–2010

The total catch for Mozambique during the 1950–2010 period, as reconstructed here, was nearly 8.2 million t, i.e., 4.6 times the 1.8 million t reported by FAO on behalf of Mozambique for the same period (Figure 2). The total reconstructed catch (including discards) ranged from 55,000 t·year^{-1} in 1950 to 138,000 t·year^{-1} in 2010, and reached a peak of nearly 208,000 t·year^{-1} in 1986.

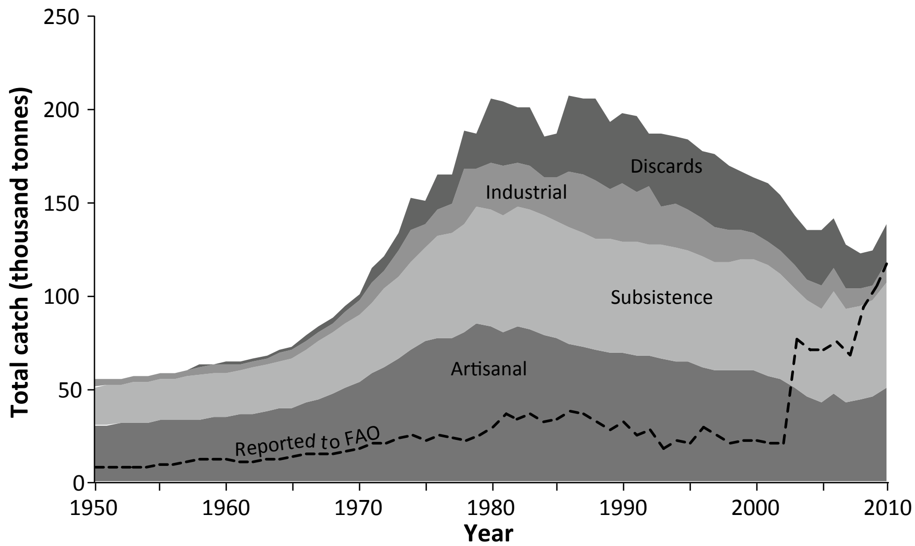

Figure 2. Total reconstructed catches by sector (subsistence, artisanal, industrial catches, and discards) for Mozambique compared to the landings reported by FAO (dashed line). Total small-scale catches are the sum of 'artisanal' and 'subsistence'.

Total small-scale catch for the 61-year period from 1950 to 2010 was over 6.2 million t, of which 55% was deemed artisanal (i.e., mainly for commercial purposes) and 45% was subsistence (Figure 2). Small-scale catches (i.e., artisanal and subsistence combined) increased from nearly 52,000 t·year^{-1} in 1950 to 108,000 t·year^{-1} in 2010. Catches from this sector peaked in 1982 at 148,500 t·year^{-1}, and accounted for 76% of the total reconstructed catches for the 1950–2010 period (annual reconstructed catches by sector are available in Appendix Table A2).

Discards and landings from industrial fisheries contributed 14% and 10% to total reconstructed catches, respectively (Figure 2). Industrial catches peaked at around 32,000 t·year^{-1} in 1988, ranging from around 3,300 t·year^{-1} in 1950 to 10,000 t·year^{-1} in 2010. Discards from industrial fisheries were also highest in 1988 at 44,000 t·year^{-1}, and ranged from around 1,500 t·year^{-1} in 1958 to 20,000 t·year^{-1} in 2010 (Figure 2).

Noteworthy is the significant improvement in the data provided to the FAO for the 2003–2010 period since the previous reconstruction (see Jacquet and Zeller 2007 and Jacquet *et al.* 2010). Annual reconstructed catches for years 2003–2010 were on average 1.6 times the reported FAO landings for the same period, while they were on average 6.4 times the reported landings for the 1950–2002 period (Figure 2).

Taxonomic disaggregation

Reconstructed catches were allocated to one of 83 taxa or higher order groupings. Results for the total catches from 1950–2010 for all of Mozambique's marine fishing sectors indicate Clupeidae (11%), Engraulidae (9%), Penaeidae (8%), Carangidae (7%), Haemulidae (6%), Sciaenidae (5%) and Lethrinidae (5%) families have historically composed large portions of the catch (Figure 3). Annual reconstructed catches grouped by important taxa are shown in Appendix Table A3.

[5] See Fennessy (1994) for common elasmobranch species in shrimp bycatch.

The catches of the small-scale sector were dominated by 28 groups of teleosts (92%), followed by shrimps (6%). The five most important taxa in small-scale catches were Clupeidae (14%), Engraulidae (12%), Carangidae (9%), Haemulidae (7%) and Lethrinidae (6%). The reconstructed catch composition, based on Monteiro (1973) study, suggests that the familes Haemulidae, Lethrinidae, Lutjanidae, Scaridae, and Siganidae were more prominent in the catches in early years, accounting for 35% of small-scale catches from 1950–1973 compared to 10% of catches for 2000–2010.

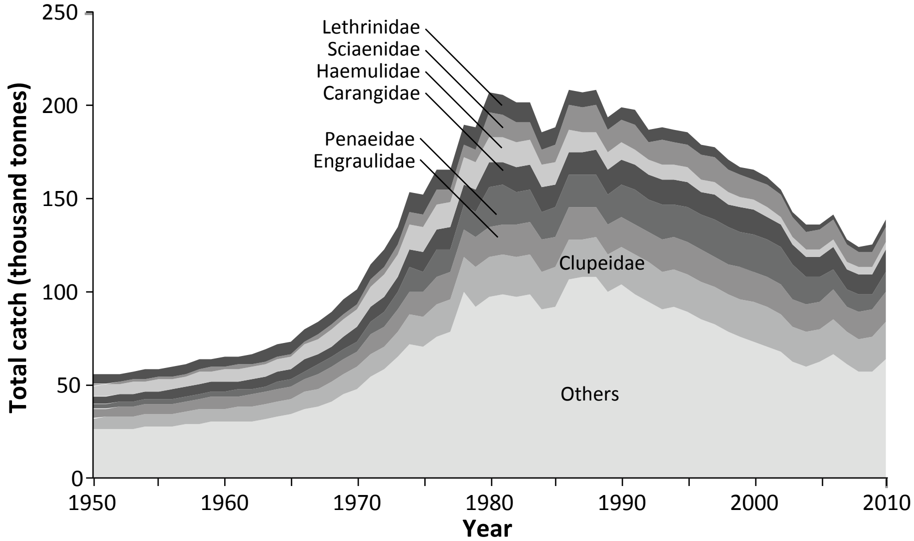

Figure 3. Taxonomic breakdown of total marine fisheries catches by major taxa for Mozambique (includes small-scale fisheries, industrial fisheries and discards). 'Others' includes 58 taxonomic groupings.

The taxonomic breakdown of Mozambique's industrial sector indicated that total catches during the 1950–2010 period were dominated by penaeid shrimp (34%), scads (*Decapterus* spp.; 7%) and knife shrimp (6%), with other teleost species composing most of the remaining catches (49%). Discards from shrimp fisheries consisted primarily of teleosts (88%), with Sciaenidae (26% of discards) being the most common family discarded.

Discussion

The 2003 and 2004 FAO reported landings have increased since the previous reconstruction by Jacquet *et al.* (2010), as have the reported catches for the 2005–2010 period in comparison with earlier years. It is evident that Mozambique's IPP has substantially improved their system of national data collection for small-scale fisheries and has retroactively adjusted the 2003 and 2004 data reported to FAO. The small-scale catch component within the FAO data for 2009 and 2010 were in the same range as the reconstructed small-scale catches (90,000–120,000) for the last decade and were considered fully reported. This is a significant improvement and Mozambique is one of the few countries in the world where this change has been observed by the *Sea Around Us*.

The FAO landings data, however, still do not account for many sources of fisheries removals, particularly from the small-scale sector prior to 2003 and discards from industrial fleets. Discards from industrial shrimp fisheries — which have one of the largest discard rates of any fishing gear (Kelleher 2005) — have historically been responsible for significant removals from Mozambique's marine ecosystems and are not included in FAO landings data. This is the case for *Otolithes ruber* (tigertooth croaker) from the highly discarded Sciaenidae family (Olbers and Fennessy 2007). The decline of this species and potentially other bycatch species that are targeted by small-scale fishers, such as *Thryssa vitrirostris* (Mualeque and Santos 2011), may have important implications for food security in the region (Olbers and Fennessy 2007). Practices such as the collecting of bycatch from industrial shrimp trawlers by small-scale fishers, may serve as a means of reducing overall waste and improving food security for coastal fishers (Olbers and Fennessy 2007; Le Manach *et al.* 2012). In fact, Mozambique regulations require that a 2:1 bycatch to shrimp ratio is landed for this purpose, however the measure is not enforced (Banks and Macfayden 2011). It is clear that monitoring of discards is still inadequate among industrial fisheries in Mozambique, and this component requires further study.

Although there has been an improvement in the total small-scale catches reported to FAO, much of the catch is still reported only as unidentified marine fishes. Despite the lack of a full time-series data for Mozambique's coastal provinces, this study attempted to disaggregate historical catch into more specific taxonomic groups (e.g., families, genus, species). Catch estimates for Inhambane, home to 15% of the country's artisanal fishers (IDPPE 2004, in Jacquet and Zeller 2007), indicate that there have been shifts in the dominant species removed by capture fisheries during the 1950–2010 time period. Reports from this province indicate that catches from the small-scale beach seine fishery during 1972–1973 were dominated by demersal species from the families Haemulidae, Lethrinidae, Lutjanidae, Scaridae, and Siganidae (Monteiro 1973). The proportions of each of these families in Inhambane beach seine catches are now less than half of what they were in the 1970s (IIP 2010). Surveys of fisherman on Inhaca island (de Boer *et al.* 2001) confirmed this trend as fishers noted that *Carangoides* spp. and *Scomberoides* spp. (both from the Carangidae family), *Pomadasys* spp. (Haemulidae), *Lutjanus* spp. (Lutjanidae), *Rhabdosargus* spp. (Sparidae), Dasyatidae and Myliobatidae (rays), squid and cuttlefish were more abundant in historical catches. De Boer *et al.* (2001) found that large predatory fish from higher trophic levels were absent from catches and suggested these trends may be indicative of overfishing (see also Pauly *et al.* 1998).

Whereas information on family-level catch composition was available for all sectors between 2000–2010 (IIP 2001–2010), the only detailed catch composition data for the small-scale sector were from the study of Monteiro (1973). A variety of assumptions were necessary to extrapolate the available catch composition data to the 1950–2010 period, and as there was little catch sampling and reporting from any sectors occurring prior to 2000 these estimates are approximate. It is possible that the catch composition of demersal families from the Monteiro (1973) report, as well as some pelagic families from the 2010 catch composition (IIP 2010) may have been given too much weight in the earlier time series and this will have significantly impacted estimated catch compositions for the small-scale sector from 1950–2002. Groupers (Serranidae) were not listed in the Monteiro (1973) catch composition and made up a small portion of national catches in recent years (IIP 2010). It is quite possible that groupers were more abundant in earlier catches in Mozambique (Kaunda-Arara *et al.* 2003; Sadovy de Mitcheson *et al.* 2013) than what is reflected in the catch compositions used in this study.

Similarly, we used bycatch data from 2000–2010 to estimate taxonomic composition of discards for the 1950–2010 period, which will not reflect changes in bycatch composition over time (Groeneveld and Melville-Smith 1995; Olbers and Fennessy 2007) and should be taken as approximate. For example, the proportion of *Trichiurus lepturus* (largehead hairtail) and *Pellona ditchela* (Indian pellona) were highly variable in bycatch from different surveys between 1995 and 2010 (Fennessy and Groeneveld 1997; IIP 2001–2010; Pinto 2001; Fennessy and Isaksen 2007). Given the limited bycatch data prior to 2000 for Mozambique shrimp fisheries, it is difficult to assess if this variation is due to sampling or indicative of larger spatial and temporal changes in bycatch species composition. Due to lack of data for deep-water crustacean fisheries, we assumed a similar composition of families in the discards of shallow-water shrimp fisheries, and thus differences in their bycatch are not reflected in our estimates.

It is well established that catch data reported by Mozambique to the FAO has historically been underreported (DNP 1976; van der Elst *et al.* 2005; Jacquet *et al.* 2010; Blythe *et al.* 2013). Van der Elst *et al.* (2005) reports that national estimates under Mozambique's National Fisheries Master Plan were actually 200,600 t and 87,700 t for 1988 and 1995, despite catches reported to the FAO of less than 32,200 t and 22,500 t for the same years. In comparison, our reconstructed catches, excluding discards, are 152,000 t and 147,000 t for years 1988 and 1995. It is clear that considerable uncertainty remains regarding the catch totals for Mozambique fisheries, and although we will never know the 'true' catches for most of this period, this study provides estimates that are much closer to the Mozambican reality than those present in FAO data. FAO data suggests that catches in the Western Indian Ocean peaked *circa* 1999 (van der Elst 2005), however, this may be the result of improved reporting and underreporting in earlier years. For example, FAO landings data for Mozambique show that catches peaked in 2010 and 2011, the last two years reported. However, reconstructed estimates peaked in the mid-1980s. Similarly, trends observed for increased numbers of species in catch data in later years (van der Elst *et al.* 2005) are also likely the result of improved reporting of more detailed taxa in the FAO catch data.

There was high variability in the discard rates observed since the 1980s for industrial shrimp fisheries, some of which were based on small sample sizes that may not have been representative of the average discard rate for the entire commercial fleet. Our discard estimates were based on landings reported to the FAO and were likely a minimum estimate for most years given historical under-reporting of industrial fisheries (see Jacquet *et al.* 2010) and that 40% of vessels do not submit their logbooks (Banks and Macfayden 2011). These estimates provide a good starting point for understanding the scale of discards and the major taxonomic groups affected. Future work that considers temporal and spatial variation in discard rates and taxonomic composition (Fennessy *et al.* 1994) could provide more accurate accounting for discards.

Taxonomic compositions in the reconstructed data remain coarse, and was often left at the family level or higher. Despite the uncertainties in historical taxonomic catch compositions for the last six decades, this exercise was valuable given changes in the catch composition that have likely occurred i) in species composition due to fishing pressure, or other changes in the ecosystem (see de Boer *et al.* 2001); and/or ii) in the species targeted by fishers/fishing sectors. For example, the bottom trawl fleet targeting pelagic fishes such as mackerel (*Rastrelliger kanagurta*) and scad (*Decapterus* spp.) during the 1980s (Silva and Sousa 1988) was closed in 1993 (L. Sousa, unpub. data). Similarly, some artisanal fishers may have transitioned from shallow waters to areas with deeper water, in which case species catch composition could have undergone corresponding changes. Increased market demand for new seafood products (e.g., holothurians, sea urchins, shark fins, paste shrimps and other non-traditional species) are rapidly gaining economic importance and changing the focus of fisheries in Mozambique (Abdula 1998; Pierce *et al.* 2008). Since *circa* 2000, there has been a large increase in the number of small-scale fishers targeting sharks for the Asian shark fin trade (Pierce *et al.* 2008; Gekoski 2011; Smith 2013). There is little data specific to the small-scale shark fishery in Mozambique (Pierce *et al.* 2008) and thus elasmobranch catches from this sector may well be underestimated in this study (Kroese and Sauer 1998; Pierce *et al.* 2008). Catch data from bather-protection gillnets off the coast of KwaZulu-Natal showed declines of some shark species that may be attributed to shark bycatch in Mozambique's small-scale and shrimp fisheries (Dudley and Simpfendorfer 2006).

Other forces, such as changing environmental conditions may also impact species composition (Cheung *et al.* 2009; Meyer and Weerts 2009; Cheung *et al.* 2010; P□rtner and Peck 2010; Perry 2011; Blythe *et al.* 2013). However, without accurate catch time series, it is very difficult to assess the magnitude of these changes and what may have caused them (see also de Boer *et al.* 2001 and Blythe *et al.* 2013). Our findings highlight the importance of recording fisheries statistics for all sources of removals (e.g. small-scale fisheries, industrial fisheries and discards), and also retroactively improving catch statistics for earlier years.

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References

Abdula R (1998) A summary about holothurians in Mozambique. SPC Bêche-de-mer Information Bulletion #10, Secretariat of Pacific Community. 34–35 p.

Anon. (1994) Projecto de recolha da fauna acompanhante em Quelimane: análise da informação recolhida pelos fiscais. IDPPE, Maputo. 6–15 p.

Anon. (2008) Stop illegal fishing in Southern Africa. Stop Illegal Fishing, Gaborone (Botswana). vi+85 p.

Bandeira SO, Paula e Silva R, Paula J, Macia A, Hernroth L, Guissamulo AT and Gove DZ (2002) Marine biological research in Mozambique: past, present and future. AMBIO: a Journal of the Human Environment 31(7): 606–609.

Banks R and Macfayden G (2011) A blueprint for sustainable tropical shrimp trawl fisheries. Prepared for WWF by Poseidon Aquatic Resource Management Ltd. 125 p.

Blythe JL, Murray G and Flaherty MS (2013) Historical perspectives and recent trends in the coastal Mozambican fishery. Ecology and Society 18(4): 65.

Brito AJ and Abdula S (2008) Relatório de Cruzeiro de investigação de camarão no Banco de Sofala realizado de 29 de Janeiro a 17 de Fevereiro de 2007. Relatorio de Cruzeiro n.46, IIP, Maputo (Mozambique). 62 p.

Chan TY (1998) Shrimps and prawns. pp. 851–864 *In* Carpenter KE and Nierm VH (eds.), FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol 2. Cephalopods, crustaceans, holothurians and sharks. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Chen A (1994) The stow net fishing situation and management in the Zhejiang coastal area. Journal Zhejiang College of Fisheries 13(3): 218–221.

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R and Pauly D (2009) Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10: 235–251.

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Zeller D and Pauly D (2010) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology 16: 24–35.

de Boer WF, van Schie AM, Jocene DF, Mabote AB and Guissamulo A (2001) The impact of artisanal fishery on a tropical intertidal benthic fish community. Environmental Biology of Fishes 61(2): 213–229.

de Freitas AJ (1989) Shrimps and prawns. pp.81–90 *In* Payne AIL and Crawford JM (eds.) Oceans of Life Off Southern Africa. VlaeBurg Publishers, Cape Town (South Africa).

de Sousa P (1992) Stock assessment of the deep-water spiny lobster Palinurus delagoae of Mozambique. Population dynamics of exploited fishes and crustaceans in Mozambique. Revista de Investigação Pesqueira 21.

de Sousa BP (2001) Fishery for the deep-water spiny lobster *Palinurus delagoae* in Mozambique, 1980 to 1999. Marine and Freshwater Research 52(8): 1535–1540.

Dias N and Afonso P (2011) Overview of fisheries and data information. IndiSeas — SWIOFP Meeting/Workshop, January 18–19, 2011, Cape Town (South Africa).

DNP (1976) Estadisticas basicas de pescas de Mocambique 1961–1975. Direcçãao Nacional de Pescas, Maputo (Mozambique).

Dudley SF and Simpfendorfer CA (2006) Population status of 14 shark species caught in the protective gillnets off KwaZulu–Natal beaches, South Africa, 1978–2003. Marine and freshwater research 57(2): 225–240.

FAO (2007) National fishery sector overview — The Republic of Mozambique. 17 p.

FAO (2013) FishStatJ — Software for fishery statistical time series. V2.1.1. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Fennessy S (1994) Incidental capture of elasmobranchs by commercial prawn trawlers on the Tugela Bank, Natal, South Africa. South African Journal of Marine Science 14(1): 287–296.

Fennessy S and Groeneveld J (1997) A review of the offshore trawl fishery for crustaceans on the east coast of South Africa. Fisheries Management and Ecology 4(2): 135–147.

Fennessy S and Isaksen B (2007) Can bycatch reduction devices be implemented successfully on prawn trawlers in the Western Indian Ocean? African Journal of Marine Science 29(3): 453–463.

Fennessy S, Mwatha G and Thiele W, editors (2004) Report of the regional workshop on approaches to reducing shrimp trawl bycatch in the Western Indian Ocean. Mombassa (Kenya), April 13–15 2003. FAO Fisheries Report 734. 49 p.

Fennessy S, Villacastin C and Field J (1994) Distribution and seasonality of ichthyofauna associated with commercial prawn trawl catches on the Tugela Bank of Natal, South Africa. Fisheries Research 20(2): 263–282.

Gekoski A (2011) Shark Hunters. The Dive Site.

Gillett R (2008) Global study of shrimp fisheries. FAO Fisheries Technical Paper No. 475, Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). xxiii+331 p.

Gislason H (1985) A short note on available information about demersal fish on shallow water part of Sofala Bank. RIP No. 13, Instituto Nacional de Investigação Pesqueira, Maputo (Mozambique). 83–95 p.

Groeneveld J and Melville-Smith R (1995) Spatial and temporal availability in the multispecies crustacean trawl fishery along the east coast of South Africa and southern Mozambique, 1988–1993. South African Journal of Marine Science 15(1): 123–136.

Hara MW, Deru J and Pitamber S (2001) Artisanal fisheries development project — Republic of Mozambique. African Development Fund. 31 p.

IDPPE (2004) Censo Nacional da Pesca Artesanal Aguas Maritimas (2002). Instituto de Desenvolviment de Pesca de Pequena Escala (IDPPE), Maputo (Mozambique). 76 p.

IDPPE (2009) Recenseamento da Pesca Artesanal 2007. Principais Resultados Instituto de Desenvolviment de Pesca de Pequena Escala (IDPPE), Maputo (Mozambique). 83 p.

IIP (2001) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 56 p.

IIP (2002) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 60 p.

IIP (2003) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 60 p.

IIP (2004) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 56 p.

IIP (2005) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 55 p.

IIP (2006) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 60 p.

IIP (2007) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 64 p.

IIP (2008) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 64 p.

IIP (2009) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 70 p.

IIP (2010) Relatório Annual. Instituto Nacional de Investigação Pesqueira (IIP), Maputo (Mozambique). 70 p.

Jacquet J, Fox H, Motta H, Ngusaru A and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science 32(2): 197–206.

Jacquet JL and Zeller D (2007) National conflict and fisheries: reconstructing marine fisheries catches for Mozambique. pp. 35–47 *In* Zeller D and Pauly D (eds.), Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15(2). University of British Columbia, Vancouver (Canada).

Kaunda-Arara B, Rose GA, Muchiri MS and Kaka R (2003) Long-term trends in coral reef fish yields and exploitation rates of commercial species from coastal Kenya.

Kelleher MK (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper No. 470, Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). xix+131 p.

Kleisner K, Zeller D, Froese R and Pauly D (2012) Using global catch data for inferences on the world's marine fisheries. Fish and Fisheries [doi: 10.1111/j.1467–2979.2012.00469.x].

Krantz L, Sorensen NK, Olesen J, Kotalova J, editors (1986) Nordic support to the fisheries in Mozambique: a sector study. Gothenburg: National Swedish Board of Fisheries.

Kroese M and Sauer W (1998) Elasmobranch exploitation in Africa. Marine and Freshwater Research 49(7): 573–577.

Le Manach F, Abunge CA, McClanahan TR and Pauly D (this volume) Tentative reconstruction of Kenya's marine fisheries catch, 1950–2010.

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–255.

McClenachan L, Ferretti F and Baum JK (2012) From archives to conservation: why historical data are needed to set baselines for marine animals and ecosystems. Conservation Letters 5(5): 349–359.

Menezes A (2008) Mozambique: fishery country review — Big number. Unpublished BNP working document.

Meyer AA and Weerts S (2009) Trends in the Indian Ocean climatology due to anthropogenic induced global warming. South West Indian Ocean Fisheries Commission, Fourth Session, Stellenbosch (South Africa). 8 p.

Monteiro CC (1973) Report B — The beach-seine fishery of Inhassoro — Mozambique. pp. 51–59 *In* de Freitas AJ (ed.) Portuguese research report 1972 — 1973: sub area 2 (Mozambique Channel).

Mualeque D and Santos J (2011) Biology, fisheries and distribution of *Thryssa vitrirostris* (Gilchrist & Thompson 1908) and other Engraulidae along the coast of the Sofala Bank, western Indian Ocean. African Journal of Marine Science 33(1): 127–137.

Olbers J and Fennessy S (2007) A retrospective assessment of the stock status of *Otolithes ruber* (Pisces: Sciaenidae) as bycatch on prawn trawlers from KwaZulu-Natal, South Africa. African Journal of Marine Science 29(2): 247–252.

Pacule H and Baltazar L (1995) A fauna acompanhante de camarão no Banco de Sofala. Análise preliminar. RIP No. 20 (1), Instituto Nacional de Investigação Pesqueira, Maputo (Mozambique). 79–95 p.

Pandolfi JM, Bradbury RH, Sala E, Hughes TP, Bjorndal KA, Cooke RG, McArdle D, McClenachan L, Newman MJH, Paredes G, Warner RR and Jackson JBC (2003) Global trajectories of the long-term decline of coral reef ecosystems. Science 301(5635): 955–958.

Pauly D (1992) Population dynamis of exploited fishes and crustaceans in Mozambique. In Use of Computers for Fisheries Research, 23 February to 15 March 1988, Instituto de Investigação Pesqueira, Maputo, Mozambique.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Pauly D (2007) The *Sea Around Us* project: documenting and communicating global fisheries impacts on marine ecosytems. Ambio 36(4): 290–295.

Pauly D (2013) Does catch reflect abundance? Yes, it is a crucial signal. Nature 494: 303–306.

Pauly D, Christensen V, Dalsgaard J, Froese R and Torres Jr. F (1998) Fishing down marine food webs. Science 279: 860–863.

Pelgröm H and Sulemane M (1982) Regional and country developments — Mozambique. pp. 139–140 *In* Fish by-catch — Bonus from the sea: report of a technical consultation on shrimp by-catch utilization held in Georgetown (Guyana), October 27–30 1981. FAO/IDRC, Ottawa (Canada).

Perry RI (2011) Potential impacts of climate change on marine wild capture fisheries: an update. The Journal of Agricultural Science 149: 63–75.

Pierce SJ, Trerup M, Williams C, Tilley A, Marshall AD and Raba N (2008) Shark fishing in Mozambique: a preliminary assessment of artisanal fisheries. Eyes on the Horizon, Maputo (Mozambique). iv+23 p.

Pinto M (2001) Gear selectivity for three by-catch species in the shallow-water shrimp trawl fishery at the Sofala Bank, Mozambique. WIOMSA Book Series 1: 489–506.

Pörtner HO and Peck MA (2010) Climate change effects on fishes and fisheries: towards cause-and-effect understanding. Journal of Fish Biology 77(8): 1745–1779.

Sadovy de Mitcheson Y, Craig MT, Bertoncini AA, Carpenter KE, Cheung WW, Choat JH, Cornish AS, Fennessy ST, Ferreira BP and Heemstra PC (2013) Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. Fish and Fisheries 14(2): 119–136.

Schultz N (1989) Programa dos recursos costeiros de peixe do Banco Sofala. Relatório 9, Instituto Nacional de Investigação Pesqueira, Maputo (Mozambique).

Schultz N (1992) Preliminary investigations on the population dynamics of *Otolithes ruber* (Sciaenidae) on Sofala Bank, Mozambique. pp. 41–49 *In* Pauly D (ed.) Population dynamics of exploited fishes and crustaceans in Mozambique: contributions from a course on the "Use of Computers for Fisheries Research", held at the Instituto de Investigação Pesqueira, 23 February to 15 March 1988 in Maputo (Mozambique). Revista de Investigação Pesqueira (21).

Silva C and Sousa MI (1988) Summary description of the marine fisheries and resources for Mozambique. *In* Sanders MJ, Sparre P and Venema SC (eds.), Proceedings of the workshop on the assessment of fishery resources in the southwest Indian Ocean. RAF/79/065/WP/41/88/E. Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), Albion (Mauritius).

Smith D (2013) Chinese appetite for shark fin soup devastating Mozambique coastline. The Guardian, edition of February 14, 2013.

Sousa MI (1990) Informação sobre a fauna acompanhante de camarão da Baia de Maputo, de Janeiro/80 a Agosto/81. Relatório 14, Instituto Nacional de Investigação Pesqueira, Maputo (Mozambique).

Sousa MI (1992) Seasonal growth of five commercially important fishes at Sofala Bank, Mozambique. p. 79- 97. *In* Pauly D (ed.) Population dynamics of exploited fishes and crustaceans in Mozambique: Revista de Investigação Pesqueira Maputo No. 21.

Torstensen E and Pacule H (1992) Stock assessment of Haliporoides triarthurus (Fam. Solesoceridae) off Mozambique: a preliminary analysis. Population dynamics of exploited fishes and crustaceans in Mozambique. Revista de Investigação Pesqueira 21. 14- 28 p.

van der Elst R, Everett B, Jiddawi N, Mwatha G, Afonso PS and Boulle D (2005) Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 363(1826): 263–284.

Wielgus J, Zeller D, Caicedo-Herrera D and Sumaila UR (2010) Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Colombia. Marine Policy 34: 506–513.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. Mozambique common species in capture fisheries by sector.

Family	Scientific name	Common name		Small-scale	Indust.	Discard
		English	Local (Portuguese)			
Crustaceans						
Aristeidae	*Aristeus antennatus*	Blue and red shrimp	alistado/gamba rosada		✓	✓
	A. virilis	Stout red shrimp	gamba vermelho forte		✓	✓
	Aristaeopsis edwardsianus	Scarlet shrimp	gamba carabineira		✓	✓
	Aristaeomorpha foliacea	Giant gamba prawn	gamba vermelha		✓	✓
Geryonidae	*Chaceon macphersoni*	Pink geryon	caranguejo de profundidade		✓	✓
Nephropidae	*Nephropsis stewarti*	Indian ocean lobsterette	lagostim indiano		✓	✓
	Metanephrops andamanicus	Andaman lobster	lagostim comum		✓	✓
	M. mozambicus	African lobster	lagostim		✓	✓
Palinuridae	*Panulirus versicolor*	Painted rock lobster	lagosta pintada	✓		✓
	P. ornatus	Coral crayfish	lagosta costeira	✓	✓	✓
	P. homarus	Scalloped spiny lobster	lagosta escamosa	✓	✓	✓
	P. delagoae	Natal spiny lobster	lagosta de profundidae	✓	✓	✓
Penaeidae	*Fenneropenaeus indicus*	Indian white prawn	camarão branco	✓	✓	✓
	Metapenaeus monoceros	Speckled shrimp	camarão castanho	✓	✓	✓
	M. stebbingi	Peregrine shrimp				
	Penaeopsis balssi	Scythe shrimp	camarão foice		✓	✓
	Penaeus monodon	Giant tiger prawn	camarão tigre gigante	✓	✓	✓
	P. japonicus	Kuruma shrimp	camarão flor	✓	✓	✓
	P. latisulcatus	Western king prawn	camarão real		✓	✓
	P. semisulcatus	Green tiger prawn	camarão tigre	✓	✓	✓
Portunidae	*Scylla serrata*	Green mangrove crab	caranguejo do mangal	✓		✓
	Portunus sanguinolentus	Three-spot swimming crab	caranguejo sangrador	✓	✓	✓
Sergestidae	*Acetes erythraeus*	Tsivakihini paste shrimp	camarão mundehe	✓		✓
Solenoceridae	*Haliporoides triarthrus*	Knife shrimp	gamba rosa		✓	
Bivalves						
Veneridae	*Eumarcia paupercula*	Beaked clam	amêijoa fina	✓		✓
	Meretrix meretrix	Asiatic hard clam	amêijoa dura	✓		✓
Cephalopods						
Octopodidae	*Octopus macropus*	White spotted octopus	polvo manchado	✓		✓
Sepiidae	*Sepia pharaonis*	Pharaoh cuttlefish	choco tigre	✓		✓
Finfish						
Acanthuridae	*Acanthurus leucosternon*	surgeonfish	cirurgião poeirento	✓		✓
Acropomatidae	*Neoscombrops cynodon*	Silver splitfin	maconde sombreado	✓		✓
Anguillidae	*Anguilla mossambica*	African longfin eel	enguia moçambicana	✓		✓
	A. bengalensis labiata	African mottled eel	enguia africana	✓		✓
	A. marmorata	Giant mottled eel	enguia gigante	✓		✓
Ariidae	*Plicofollis dussumieri*	Blacktip sea catfish	bagre	✓		✓
Atherinidae	*Hypoatherina temminckii*	Samoan silversides	rei samoano	✓		✓
Balistidae	*Rhinecanthus rectangulus*	Wedge-tail triggerfish	porco rectangular	✓		✓
Belonidae	*Ablennes hians*	Flat needlefish	agulha lisa	✓		✓
Carangidae	*Alepes djedaba*	Shrimp scad	xaréu camaroneiro	✓		✓
	Decapterus russelli	Indian scad	carapau	✓		✓
	D. macrosoma	Shortfin scad	carapau barbatana	✓		✓
	Selar crumenophthalmus	Big-eye scad	carapau preto	✓		✓
	Carangoides malabaricus	Horse mackerel	malabar cavalla	✓		✓
Centrophoridae	*Centrophorus moluccensis*	Smallfin gulper shark	lixa barbatana curta	✓	✓	✓
Chirocentridae	*Chirocentrus nudus*	Whitefin wolf herring	machope espinhoso	✓		✓
Clupeidae	*Hilsa kelee*	Kelee shad	magumba	✓		✓
Clupeidae	*Herklotsichthys quadrimaculatus*	bluestripe herring	sardinha banda azul	✓		✓
	Sardinella albella	White sardinella	sardinha branca	✓		✓
	S. gibbosa	Gold stripe sardinella	sardinha dourada	✓		✓
	Pellona ditchela	Indian pellon	sardinia de indico	✓		✓
Drepaneidae	*Drepane longimana*	Concertina fish	enxada concertina	✓		✓
Engraulidae	*Thryssa vitrirostris*	Orangemouth anchovy	ocares	✓		✓
	T. setirostris	Longjaw thryssa	ocar cornudo	✓		✓
	Encrasicholina heteroloba	Shorthead anchovy	anchoveta aduaneira	✓		✓
Gerreidae	*Gerres filamentosus*	Whipfin silver-biddy	melanúria filamentosa	✓		✓
Haemulidae	*Pomadasys kaakan*	Javelin grunter	peixe pedra	✓		✓
	P. maculatus	Saddle grunt	gonguri	✓		✓
	P. olivaceus	Olive grunt	roncador oliva	✓	✓	✓
	Plectorhinchus flavomaculatus	Lemonfish	owa-owa		✓	✓
Istiophoridae	*Kajika audax*	Striped marlin	espadim raiado		✓	✓
	Istiompax indica	Black marlin	espadim negro		✓	✓
	Istiophorus platypterus	Indo-pacific sailfish	veleiro		✓	✓
Leiognathidae	*Leiognathus equulus*	Common ponyfish	patana comum	✓		✓
	Gazza minuta	Toothpony	sabonete dentuço	✓		✓
	Secutor insidiator	Pugnose ponyfish	chita boxeira	✓		✓
Lethrinidae	*Lethrinus lentjan*	Redspot emperor	ladrão de lentejoulas	✓	✓	✓

Appendix Table 1. Mozambique common species in capture fisheries by sector (continued).

Family	Scientific name	Common name		Small-scale	Indust.	Discard
		English	Local (Portuguese)			
	L. borbonicus	Snubnose emperor	xegugo		✓	
Lutjanidae	*Lutjanus sanguineus*	Humphead snapper	pargo vermelhão	✓	✓	✓
	L. fulviflamma	Dory snapper	thana		✓	
Mullidae	*Upeneus vittatus*	Yellowstriped goatfish	salmonete	✓	✓	✓
	U. japonicus	Bensasi goatfish	salmonete bensasi		✓	✓
Mugilidae	*Chelon macrolepis*	Largescale mullet	tainha godé	✓		✓
Muraenesocidae	*Muraenesox bagio*	Common pike conger	enguia/safio comum	✓		✓
Nemipteridae	*Nemipterus bipunctatus*	Delagoa threadfin bream	baga delagoa		✓	✓
Paralichthyidae	*Pseudorhombus natalensis*	Natal flounder	areeiro		✓	✓
Polynemidae	*Polydactylus sextarius*	Blackspot threadfin	barbudo de mancha	✓	✓	✓
Scaridae	*Scarus ghobban*	Yellowscale parrotfish	papagaio de escamas amarelas	✓	✓	✓
	Leptoscarus vaigiensis	Marbled parrotfish	lundu		✓	✓
Sciaenidae	*Otolithes ruber*	Tigertooth croaker	corvina	✓	✓	✓
	Johnius amblycephalus	Bearded croaker	corvina	✓	✓	✓
	J. dussumieri	Sin croaker	macujana de barba	✓	✓	✓
	Argyrosomus hololepidotus	Southern meagre	corvina real	✓	✓	✓
Scombridae	*Rastrelliger kanagurta*	Indian mackerel	cavala	✓	✓	✓
	Scomberomorus commerson	Narrow-barred spanish mackerel	serra	✓	✓	✓
	Thunnus albacares	Yellowfin tuna	albacora	✓	✓	✓
	T.alalunga	Albacore	voador	✓	✓	✓
	T. obesus	Bigeye tuna	patudo	✓	✓	✓
	Katsuwonus pelamis	Skipjack tuna	gaiado	✓	✓	✓
Serranidae	*Gracila albomarginata*	White-edged grouper	garoupa bordo branco	✓	✓	✓
	Epinephelus andersoni	Catface grouper	garoupa gato	✓	✓	✓
	E. tukula	Potato bass	garoupa batata	✓	✓	✓
Siganidae	*Siganus canaliculatus*	White-spotted spinefoot	babi		✓	✓
Sillaginidae	*Sillago sihama*	Silver sillago	pescadinha comum	✓		✓
Sparidae	*Chrysoblephus puniceus*	Slinger seabream	marreco	✓		✓
	C. gibbiceps	Red stumpnose seabream	marreco		✓	✓
	Crenidens crenidens	Karanteen seabream	esparo	✓		
	Dentex macrophthalmus	Large-eye dentex	cachucho		✓	✓
Sphyraenidae	*Sphyraena* spp.	Barracuda	bicuda	✓	✓	✓
Synodontidae	*Saurida undosquamis*	Brushtooth lizardfish	mbolopfuma	✓	✓	✓
Trichiuridae	*Trichiurus lepturus*	Largehead hairtail	peixe fita	✓	✓	✓
Xiphiidae	*Xiphias gladius*	Swordfish	espadarte		✓	✓
Sharks, rays and skates						
Carcharhinidae	*Carcharhinus amblyrhynchos*	Grey reef shark	Marracho enlutado	✓		
	C. leucas	Bull shark	Marracho touro	✓		✓
	C. limbatus	Blacktip shark	Marracho macuira	✓		
	C. plumbeus	Sandbar shark	Marracho de Milberto	✓		
	Galeocerdo cuvier	Tiger shark	Marracho tigre	✓		
	Negaprion acutidens	Sicklefin lemon shark	Limão foiçador	✓		
	Triaenodon obesus	Whitetip reef shark	Marracho de covas	✓		
Dasyatidae	*Dasyatis kuhlii*	Bluespotted stingray	Uge ponteado	✓		
	D. microps	Smalleye stingray		✓		
	Himantura cf. *uarnak*	Honeycomb stingray	Burá alveolado	✓		
Hemigaleidae	*Hemipristis elongata*	Snaggletooth shark	Tubarão doninha	✓		
Mobulidae	*Manta birostris*	Manta	Jamanta gigante	✓		
Myliobatidae	*Aetobatus narinari*	Spotted eagle ray	Ratau ponteado	✓		
Rhinidae	*Rhina ancylostoma*	Bowmouth guitarfish		✓		
Rhynchobatidae	*Rhynchobatus djiddensis*	Giant guitarfish		✓		
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	Tubarão martelo comum	✓		
	S. zygaena	Smooth hammerhead shark	tubarão martelo liso	✓		✓
Stegostomatidae	*Stegostoma fasciatum*	Zebra shark		✓		

'√' indicates that capture of this species contributes significantly to the total catch.
Sources: Silva and Sousa (1988); Pauly (1992); Sousa (1992); Abdula (1998); Lee *et al.* (1999); de Boer *et al.* (2001); IIP (2001–2010); Motta *et al.* (2002); Kelleher (2005); Béné *et al.* (2007); FAO and WorldFish Center (2008); Jacquet *et al.* (2010); www.fishbase.org; www.sealifebase.org; www.marinespecies.org, http://species-identification.org.

Appendix Table A2. Annual reconstructed catches by sector, and FAO reported landings (t).

Year	Industrial	Discards	Small-scale	Total reconstructed catches	FAO reported landings
1950	3,300	-	51,627	54,927	7,800
1951	3,300	-	52,005	55,305	8,200
1952	3,300	-	52,760	56,060	8,000
1953	3,300	-	53,516	56,816	7,800
1954	3,300	-	54,272	57,572	7,700
1955	3,300	-	55,027	58,327	9,300
1956	3,300	-	55,783	59,083	9,300
1957	4,100	-	56,538	60,638	11,500
1958	4,100	1,450	57,294	62,844	12,100
1959	4,700	1,160	58,050	63,910	12,700
1960	3,900	1,160	59,309	64,369	11,900
1961	3,285	1,380	60,785	65,450	11,300
1962	3,256	1,186	62,262	66,704	11,300
1963	3,425	1,122	63,738	68,285	12,000
1964	4,428	1,282	65,214	70,924	12,400
1965	4,181	1,621	66,690	72,492	14,200
1966	5,347	2,955	71,007	79,309	15,300
1967	5,047	3,007	75,447	83,501	15,000
1968	5,907	3,103	80,010	89,020	15,700
1969	7,328	3,263	84,696	95,287	17,000
1970	7,934	3,271	89,505	100,710	17,600
1971	10,523	7,407	96,459	114,389	20,400
1972	10,513	7,798	103,671	121,982	20,400
1973	13,538	9,982	111,141	134,661	23,300
1974	15,895	17,609	118,869	152,373	25,660
1975	11,636	12,583	126,854	151,073	22,490
1976	13,893	18,850	132,182	164,925	24,900
1977	15,396	15,620	133,584	164,601	23,950
1978	29,146	20,684	138,643	188,473	22,940
1979	21,505	18,070	147,445	187,021	25,130
1980	24,900	34,887	145,907	205,694	30,350
1981	26,699	35,470	142,553	204,722	37,130
1982	23,384	28,969	148,465	200,818	34,680
1983	24,371	30,469	145,720	200,560	37,516
1984	20,734	21,491	142,871	185,096	31,836
1985	23,002	23,842	139,921	186,765	33,306
1986	29,566	41,233	136,875	207,674	38,671
1987	31,207	41,538	133,738	206,482	36,321
1988	32,075	44,117	130,512	206,705	32,185
1989	27,841	35,064	130,221	193,126	27,560
1990	31,473	37,364	129,754	198,591	32,919
1991	26,856	40,145	129,108	196,109	25,536
1992	30,899	27,329	128,277	186,505	27,808
1993	20,066	40,046	127,256	187,368	18,506
1994	23,673	35,959	126,042	185,674	22,531
1995	22,568	37,012	124,630	184,210	21,741
1996	20,993	35,845	121,182	178,020	29,341
1997	18,840	40,072	117,622	176,534	25,658
1998	16,701	34,112	118,847	169,660	21,010
1999	15,295	31,766	119,508	166,569	21,852
2000	13,723	30,849	119,613	164,185	22,198
2001	13,425	30,659	116,042	160,126	21,340
2002	12,685	29,574	112,224	154,483	20,545
2003	12,134	25,933	104,503	142,570	76,926
2004	11,450	26,231	97,384	135,065	71,828
2005	13,257	29,475	93,142	135,874	71,006
2006	11,909	26,111	103,182	141,202	75,882
2007	10,494	24,165	93,056	127,715	68,188
2008	8,382	19,485	95,490	123,357	93,415
2009	7,724	18,419	98,009	124,152	105,734
2010	9,974	20,051	107,876	137,901	117,850

Appendix Table A3. Reconstructed catches (t) grouped by the seven most important taxa.

Year	Clupeidae	Engraulidae	Penaeidae	Carangidae	Haemulidae	Sciaenidae	Lethrinidae	Others
1950	6,389	5,115	2,510	4,071	5,543	1,140	4,445	25,716
1951	6,439	5,155	2,508	4,103	5,586	1,149	4,480	25,884
1952	6,530	5,228	2,559	4,161	5,665	1,165	4,543	26,209
1953	6,621	5,300	2,610	4,219	5,744	1,181	4,607	26,534
1954	6,713	5,374	2,656	4,277	5,824	1,197	4,671	26,861
1955	6,822	5,461	2,611	4,347	5,918	1,217	4,746	27,204
1956	6,915	5,536	2,651	4,406	5,999	1,233	4,811	27,532
1957	7,022	5,622	2,617	4,474	6,092	1,253	4,886	28,673
1958	7,154	5,742	3,179	4,546	6,231	1,645	4,955	29,392
1959	7,240	5,808	3,109	4,604	6,301	1,587	5,019	30,242
1960	7,395	5,932	3,176	4,702	6,435	1,615	5,127	29,988
1961	7,580	6,082	3,352	4,818	6,600	1,704	5,252	30,062
1962	7,761	6,225	3,329	4,935	6,753	1,687	5,381	30,633
1963	7,908	6,342	3,480	5,029	6,880	1,696	5,484	31,466
1964	8,121	6,514	3,536	5,164	7,067	1,775	5,630	33,116
1965	8,327	6,683	3,678	5,293	7,252	1,898	5,768	33,592
1966	8,893	7,149	4,379	5,642	7,766	2,339	6,141	37,000
1967	9,440	7,588	4,633	5,990	8,241	2,450	6,521	38,638
1968	10,002	8,039	4,915	6,347	8,731	2,575	6,911	41,500
1969	10,581	8,503	5,225	6,715	9,236	2,718	7,311	44,997
1970	11,173	8,977	5,484	7,092	9,749	2,826	7,722	47,686
1971	12,106	9,766	7,434	7,651	10,630	4,046	8,306	54,449
1972	13,012	10,495	7,971	8,226	11,423	4,307	8,931	57,618
1973	13,979	11,290	9,202	8,823	12,298	5,036	9,569	64,463
1974	15,303	12,426	12,653	9,602	13,099	7,215	10,016	72,060
1975	16,380	13,239	11,351	10,331	13,406	6,127	10,445	69,793
1976	17,436	14,146	14,070	10,951	13,854	7,912	10,656	75,900
1977	17,742	14,348	12,604	11,183	13,489	6,858	10,527	77,849
1978	18,605	15,033	12,857	11,738	13,591	6,864	10,667	99,118
1979	20,038	16,186	13,640	12,645	14,070	7,268	11,083	92,091
1980	20,493	16,743	21,240	12,771	14,253	12,298	10,691	97,204
1981	20,344	16,615	20,440	12,683	13,605	12,050	10,229	98,757
1982	21,249	17,276	18,224	13,314	13,493	10,591	10,377	96,293
1983	21,146	17,190	17,544	13,252	12,892	10,458	9,940	98,138
1984	20,756	16,797	14,805	13,072	11,967	8,319	9,467	89,913
1985	20,656	16,747	15,102	12,983	11,491	9,081	9,023	91,683
1986	20,837	17,051	17,149	12,963	11,504	13,186	8,588	106,397
1987	20,566	16,830	17,113	12,793	10,899	13,046	8,136	107,097
1988	20,294	16,640	17,288	12,596	10,402	13,717	7,674	108,095
1989	20,236	16,516	15,810	12,626	9,735	11,700	7,402	99,100
1990	20,328	16,620	16,965	12,658	9,431	12,496	7,096	102,997
1991	20,558	16,831	18,221	12,782	9,182	13,230	6,848	98,459
1992	20,318	16,519	17,173	12,732	8,340	10,105	6,557	94,762
1993	20,565	16,861	18,435	12,765	8,444	13,869	6,232	90,197
1994	20,609	16,856	17,689	12,828	7,945	12,835	5,982	90,929
1995	20,569	16,834	18,793	12,793	7,575	13,096	5,677	88,873
1996	20,300	16,607	18,286	12,632	7,076	12,751	5,327	85,041
1997	19,933	16,356	20,229	12,362	6,738	13,762	4,937	82,217
1998	20,158	16,477	19,173	12,556	6,261	12,284	4,767	77,983
1999	20,453	16,689	19,362	12,764	5,906	11,739	4,588	75,067
2000	20,459	16,685	19,880	12,775	5,528	11,507	4,335	73,016
2001	20,121	16,413	19,801	12,562	5,109	11,398	4,012	70,710
2002	19,556	15,950	19,380	12,211	4,637	11,021	3,663	68,064
2003	18,483	15,055	17,956	11,558	4,017	9,902	3,250	62,348
2004	17,852	14,552	14,834	11,153	3,919	9,866	3,134	59,755
2005	17,305	14,147	13,860	10,777	3,932	10,594	3,021	62,237
2006	18,943	15,425	11,739	11,850	4,102	10,030	3,333	65,783
2007	17,200	14,010	9,321	10,756	3,739	9,223	3,024	60,442
2008	17,508	14,210	8,778	10,991	3,638	8,086	3,099	57,048
2009	17,866	14,486	8,538	11,228	3,664	7,878	3,169	57,324
2010	19,354	15,694	10,726	12,163	3,972	8,560	3,432	64,001

Reconstruction of the Domestic and Distant-Water Fisheries Catch of La Réunion (France), 1950–2010*

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Abstract

Total marine fisheries catches were estimated for the island of La Réunion (France) for the 1950–2010 time-period using the catch reconstruction approach developed by the *Sea Around Us*. This included total catches (i.e., with estimates of dead discards) of the industrial, artisanal, and recreational sectors. The reconstructed catch for domestic sectors (i.e., excluding the distant-water fleets registered elsewhere, but belonging to firms in La Réunion) for the 1950–2010 time-period reached over 199,000 t (of which 60.8% were caught in La Réunion's EEZ). This figure is 1.6 times higher than the 127,800 t officially reported to the Food and Agriculture Organization of the United Nations. The major taxa in the catches were *Thunnus albacares* (yellowfin tuna; 15.5%), *Lethrinus mahsena* (sky emperor; 14.4%), *Xiphias gladius* (swordfish; 14.2%), *Prionace glauca* (blue shark; 6.0%), *T. alalunga* (albacore tuna; 5.7%), and Carangidae (jacks and pompanos; 5.2%). The industrial and artisanal sectors were the most prominent, with 60.7% and 31.2% of the total catch, respectively. Unreported landings represented 39.9% of the total catch, including 14.2% of dead discards. Total catch of non-domestic fleets totalled over 300,000 t from 1950 to 2010, including 121,700 t of *Dissostichus eleginoides* (Patagonian toothfish), 31,500 t of *Jasus palensis* (Saint Paul rock lobster), and 32,200 t of other demersal species caught in the French Southern and Antarctic Lands, as well as 117,000 t of large pelagics caught throughout the Western Indian Ocean.

Introduction

La Réunion is a 3 million year old volcanic island of 30 km of diameter, located in the Mascarene Archipelago between the east coast of Madagascar and Mauritius (Figure 1). It is characterized by a very steep slope and two volcanoes at its center: the *Piton des Neiges* (inactive and culminating at 3,070 m), and the *Piton de la Fournaise* (active). The continental shelf is limited mostly to the west coast, where there is a narrow fringing coral reef, which is small in comparison to that of the neighbouring island of Mauritius (David and Mirault 2006). The growth of a fringing reef elsewhere is inhibited by meteorological conditions, as well as volcanic eruptions and regular hurricanes during the warm season (November to May).

Thanks to its location and history, La Réunion has always been at an important social and cultural crossroad. It was discovered by the Arabs in the 10th century, and re-discovered in 1512 by Pedro de Mascarenhas (hence the name of the archipelago to which it belongs). Since the 17th century, the French have been interested in this island and have gradually colonized it. In the 18th century, the *Compagnie Française des Indes Orientales* started to develop the national economy *via* the production and export of spices, coffee and sugar cane. In 1946, La Réunion became a French Overseas Department, and integrated the European Community in 1997. The economy of La Réunion still relies on agriculture, but also increasingly on construction, services and tourism (INSEE 2006). Despite delays in infrastructure development (Fleurant 1989), tourists (mostly from France mainland) currently account for approximately one-third of the resident population, and the trend is going upward. All major cities are located along the coast, concentrating most infrastructure and population in a narrow band, while the interior is subject to lower human exploitation. The coastal band is thus under a high anthropogenic pressure (e.g., runoff, industrial wastes, erosion, urbanization; Faure 1982; Letourneur and Chabanet 1994; Conand 2002).

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Numerous studies since the 1970s have allowed to monitor these changes (Bouchon 1978; Faure 1982; Conand 2002; Anon. 2012), and it is clear that coral reefs of La Réunion — once home to over 200 species of madreporan corals and 320 species of fish (Faure 1982; Chabanet 1994) — have been visibly degraded since the mid-1980s (Conand 2002). It is thought that 30% of local reefs are currently degraded, and 50% are still threatened (Anon. 2012). However, conservation measures are being taken,[1] and the fringing reef on the west coast — by far the largest of the island — is currently almost entirely protected (80%; not its southernmost section) by a 35 km² marine protected area created in 2007.[2]

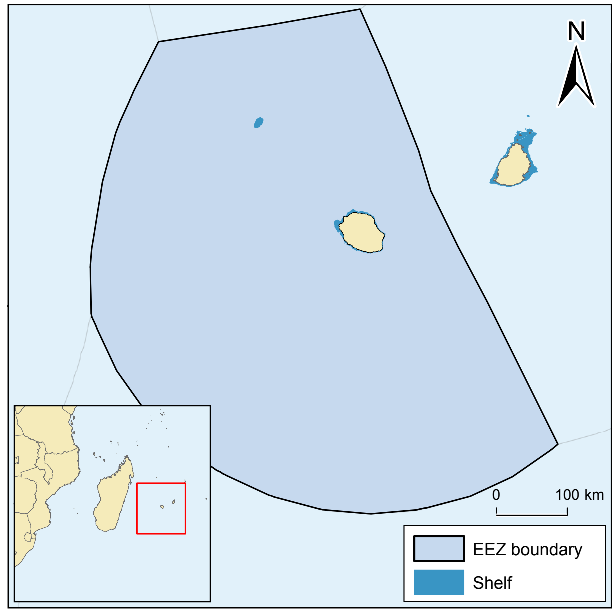

Figure 1. Map showing the location of La Réunion as well as the extent of its EEZ (light blue) and continental shelf (dark blue).

Although surrounded by the ocean, inhabitants from La Réunion have never really relied on it to provide food. This is largely explained by the limited shelf and by the often rough conditions at sea. This also has historical roots, as slaves were not allowed to fish from a boat, in order to limit risks of escape (David and Mirault 2006; Mérالli-Ballou 2008). The Exclusive Economic Zone (EEZ) of La Réunion extends well over 300,000 km², and several categories of fishers are now active within and around it. Until the early 1980s, the fisheries contribution to the island's economy was low (limited to inshore fisheries and some distant fisheries), despite motorization of the entire fleet by the mid-1960s (Bertrand 1985). However, it soon became more important, particularly in the 1990s with the expansion of the tuna and billfish (mostly swordfish) fisheries, as well as the development of the *Dissostichus eleginoides* (Patagonian toothfish) and *Jasus palensis* (Saint Paul rock lobster) fisheries in the French Southern and Antarctic Lands (Bertrand 1985; Roos *et al.* 1998; Guyomard *et al.* 2006; Mérالli-Ballou 2008; Palomares and Pauly 2011; Pruvost *et al.* 2015). These distant fisheries have gradually become of prime importance to the economy of the island, and largely contribute to the fact that the fishing industry is the second largest exporting sector, just behind sugar cane (Mérالli-Ballou 2008).

According to several authors, official statistics are solely based on declarations of commercial fishers (both artisanal and industrial), and therefore only account for the 'legal portion' of all fisheries (Biais 1987; Roos *et al.* 1998; David and Mirault 2006). However, it is acknowledged that unreported commercial activities, as well as subsistence and recreational fisheries widely occur (Bertrand 1985; Biais and Taquet 1992; Roos *et al.* 1998; David and Mirault 2006), and the lack of enforcement and observers makes this difficult to monitor despite important catches (David and Mirault 2006). Adding to the problem, the accuracy of official fisheries statistics pertaining to the commercial sector has long been criticized, notably by Biais and Tacquet (1992) and Tessier and Poisson (1997). Indeed, artisanal fishers are known to under-report their catches to pay less revenue taxes, while over-reporting the number of trips to benefit more from fuel tax breaks (Roos *et al.* 1998). Also, landing surveys do not cover fishing activities occurring at night, thus missing substantial catches. Lastly, the statistics reported to FAO are confusing with regards to some distant sectors whose ownership is from La Réunion. The rock lobster fishery in Saint Paul and Amsterdam (partly reported by La Réunion in the early time-period; see below) is also reported as 'French Southern Territories' catches; (Pruvost *et al.* in press), similarly to the finfish (mostly Patagonian toothfish) fishery in Kerguelen and Crozet (Palomares and Pauly 2011); and vessels from the tropical purse-seine fishery are reported as 'Mayotte' catches (Doherty *et al.* this volume).[3]

Official fisheries statistics are therefore of poor quality and mis-represent the true extent of fisheries activities by La Réunion's fishers. In this report, we apply to La Réunion the reconstruction methods developed around principles in Pauly (1998), described in Zeller *et al.* (2007) and applied worldwide by the *Sea Around Us* (see, e.g., Zeller and Pauly 2007; Zeller and Harper 2009; Harper and Zeller 2012; Harper *et al.* 2012). We aim to improve the overall quality of fisheries statistics of La Réunion by thoroughly reviewing the available literature, re-allocating the FAO catch to the various fisheries sectors, and re-estimating the missing catches since 1950.

Fishing Sectors and Methods

Pelagic fisheries

A substantial part of the FAO data for La Réunion is composed of large pelagic taxa (FAO 2012): major tunas (*Katsuwonus pelamis* [skipjack tuna], *Thunnus alalunga* [albacore tuna], *T. albacares* [yellowfin tuna], *T. obesus* [bigeye tuna]), other Scombridae (*Acanthocybium solandri* [wahoo], *Euthynnus affinis* [kawakawa], and

[1] The first coral reef conservation measures occurred in 1969, when it was forbidden to use live coral for construction (Faure 1982). In 1976, spearfishing was forbidden, and the lagoon was also protected (David and Mirault 2006).

[2] Critics have been raised about this MPA, as it is in a heavily populated area, highly impacted by coastal activities such as tourism. For example, over 20,000 persons meet along its beach for New Year's Eve, pouring various liquids in the lagoon, walking on the reef, and leaving tonnes of detritus behind. A recent surge in shark attacks also pointed at the MPA as a potential reason for it (Anon. 2012).

[3] Mayotte became a French Department in 2011, and these purse-seine vessels have started to reflag elsewhere, e.g., in Mauritius.

'Scombroidei nei'), billfishes (*Istiophorus platypterus* [Indo-Pacific sailfish], *Tetrapturus angustirostris* [shortbill spearfish], *Xiphias gladius* [swordfish], and 'Istiophoridae nei'), and Elasmobranchii (sharks, rays, skates, etc.). These pelagic species comprise 12 out of the overall 31 taxa reported for La Réunion and compose 52.1% of the total catch reported by FishStat over the 1950–2010 period, and 80.6% over the 1990–2010 period.

The FAO data for these 12 taxa are nearly identical to the data available in the nominal catch database of the Indian Ocean Tuna Commission (www.iotc.org/English/data/databases.php).[4] Therefore, we re-allocated the FAO catch of large pelagics to various gears using the annual IOTC gear breakdown by taxon. Taxon names appearing in both datasets were consistent for the most part with the exception of Indo-Pacific sailfish, which was reported at the family level ('Istiophoridae nei') in FAO data. We used the annual IOTC data to reallocate a portion of the 'Istiophoridae nei' FAO catches to Indo-Pacific sailfish from 1993 to 2010, and used the average 1993–1995 IOTC breakdown to reallocate catches from 1991 to 1992, as there were no IOTC data for Indo-Pacific sailfish during these two years. Also, we used the previous years' breakdown to reallocate the FAO catch of skipjack tuna in 2009–10, and 'Scombroidei nei' (IOTC name was 'Scombridae') in 2003 and 2006–07.

This re-allocation allowed us to treat the different sectors more accurately, as the artisanal fleet (using handlines and troll lines) and the industrial fleet of longliners targeting swordfish were separated. The remaining catches of 'non-IOTC species' were re-allocated to other sectors: (i) the artisanal demersal fishery in coastal waters, (ii) the industrial demersal fishery on distant banks, and (iii) the shrimp trawl fishery in Madagascar (see below).

Longline fleet targeting swordfish

Following up on the success of the Asian fleet that started to target large pelagics in the Indian Ocean in the early 1950s (Allain 1974; Marsac and Stequert 1984; Poisson and Taquet 2001), a domestic fleet of longliners targeting swordfish was created in 1991 (Poisson *et al.* 1994; Poisson and Taquet 2001), and quickly became one of the major fishing sectors in La Réunion (René *et al.* 1998). These vessels are active at night, using drifting longlines of 20–100 km equipped with baited hooks. Each vessel can deploy hundreds to several thousands of hooks per set (Poisson and Taquet 2000; Evano and Bourjea 2012).

Only two fishing boats were active the first year, but thanks to an agreement signed between La Réunion and Mauritius as well as a tax-exemption regime, the number of longliners quickly rose to 31 in 2000 (INSEE 1991, 1996, 2000, 2002; René *et al.* 1998; Poisson *et al.* 1999; Poisson and Taquet 2001).[5] Due to the resulting high fishing pressure, the biomass of some stocks of targeted species was reduced, which resulted in longliners exiting the fishery in 2002–2003 (INSEE 2003, 2005; Evano and Bourjea 2012). However, the number of longliners was soon back to the 2000 level, with 34 vessels active in 2005 (INSEE 2008; Evano and Bourjea 2012). In 2010, around 20% of all registered vessels in La Réunion (i.e., 45) were longliners targeting swordfish (Leblond *et al.* 2011; Evano and Bourjea 2012).

Longliners were first active in La Réunion's EEZ beyond 12 nautical miles (nm) to minimize competition with the artisanal fleet, as well as in Mauritian waters, Tromelin (now jointly managed by France and Mauritius),[6] and around a bank situated 90 nm northwest of La Réunion (INSEE 1997, 1998, 2000). Since then, the fleet has expanded towards the Mozambique Channel and now operates in the entire western Indian Ocean (René *et al.* 1998; Poisson and Taquet 2001; Guyomard *et al.* 2006; Evano and Bourjea 2012), although most catches occur in the waters east of Madagascar and southwest of La Réunion (Poisson and Taquet 2001; Guyomard *et al.* 2006). The fleet has also somewhat changed its target species, targeting more bigeye tuna for the sashimi market (René *et al.* 1998; Poisson and Taquet 2001), as well as other species of tuna (Evano and Bourjea 2012). Since 2010, the largest longliners operate in the Mozambique Channel from Madagascar (i.e., they only go to La Réunion to land their catch), which effectively resulted in an increase in total fishing effort (Chavance *et al.* 2012).

Although INSEE (1998, 1999) reporeted that catches of this sector were likely underestimated, it seems that the current version of reported data includes everything but discards of target species (undersized and depredated individuals) and bycatch species (Bach *et al.* 2008, 2013). Most of the bycatch consists of unwanted sharks (mostly *Prionace glauca* [blue shark]; Poisson and Taquet 2001; Poisson 2010; Sabarros *et al.* 2013), pelagic stingrays, epipelagic billfishes, dolphinfish, wahoo, oilfish, as well as various species of fish referred to as 'snoek' (Bach *et al.* 2013; Sabarros *et al.* 2013). The economic interest on sharks has changed over time: at the beginning of the pelagic longline fishery in the 1990s, most *Carcharhinus longimanus* (oceanic whitetip shark) and mako shark were regularly kept onboard, whereas blue sharks where only kept from time to time (Poisson 2010). Currently, blue sharks are always discarded, while oceanic whitetip sharks and *Isurus* sp. (mako sharks) may be commercialized in some instances (Sabarros *et al.* 2013). 'Snoek' and other minor species of fish are mostly discarded, similarly to rays (Chavance *et al.* 2012). Discards may also consist of target species (swordfish) and other bycatch of economic importance (e.g., tuna and other billfishes) made unmarketable due to the depredation by sharks (all year round) and toothed whales (seasonal). Depredated catches are estimated to make up 10–15% of the landings of target species (e.g. swordfish, tuna and other billfishes; Poisson and Taquet 2001; Romanov *et al.* 2013). However, they are

[4] The IOTC data is thought to be the source of FAO data for pelagic catches, however, this is often not the case (see, e.g., Kenya; Le Manach et al. this volume). There are a couple of discrepancies, though: in 1970 (higher IOTC data) and 2009–2010 (higher FAO data).

[5] The *Compagnie des Long Liners* operated some of these tax-exempted vessels, and exported most of the catch to Europe (Poisson and Tacquet 2001). Noteworthy, most of the tax-exempted longliners are currently abandoned at port. The size of the largest vessels have decreased from 24m to 20 m and can no longer take on observers (Bach *et al.* 2010). Consequently, the French Research Institute for Development (IRD) has initiated a self-reporting program in 2011 to collect bycatch and depredation data (Bach *et al.* 2013).

[6] It was forbidden to fish within the 30 nm zone until 1995 (René *et al.* 1998).

sometimes kept for self-consumption (Sabarros *et al.* 2013), but not declared. This undeclared portion is difficult to estimate, and to distinguish from discards. Here, we considered that the non-reported component of the catch exclusively consisted of discards. To estimate them, we assumed that 15%, 25%, 95%, and 50% of the landings of major tunas, swordfish, sharks, and other species, respectively, were unreported (Bach *et al.* 2011; P. Bach, pers. obs.).[7] Due to the lack of data, we considered that these proportions remained constant from 1991 to 2010. The only exception was for sharks, where we assumed the total mortality rate linearly decreased from 80% during the 1991–2006 period (e.g., when finning was prevalent) to 30% by 2010 when finning was no longer occurring and the use of 'circle hooks' reduced mortality (estimate of mortality based on Diaz and Serafy 2005; Campana *et al.* 2009; Butcher *et al.* 2014).

The final step of the reconstruction of this sector was to split the total catch (landings and discards) among the various EEZs within which the fleet is active. We used the IOTC data spatialized by 1°x1° cells (www.iotc.org/sites/default/files/documents/2014/05/IOTC-2014-DATASETS-CELongline.zip).[8] This allowed us to estimate the proportion of the total catch in the EEZs of La Réunion, Madagascar, Mauritius, and the Îles Éparses, as well as the High Seas from 2009 to 2012. Based on the history of the fishery (see above), we set the 1991 proportions at 80% in La Réunion and 10% in Madagascar, and interpolated to the 2009 value. We allocated 5% to Mauritius in 1991 and linearly interpolated to a 2008 value corresponding to the 2009–2012 level. For the High Seas and the Îles Éparses, we distributed the remaining percentages proportionately to their 2009–2012 contribution. For all areas, we used the 2009–10 IOTC proportions 'as is'.

Artisanal fleet

This sector represents the majority of the commercial fishing effort within La Réunion's EEZ. In 2008, over 70% of the artisanal vessels' activity occurred between 3 and 12 nm (5.5 to 22.2 km), which represented almost half of the registered fishers (Leblond *et al.* 2007). The fleet of artisanal fishers is largely composed of small boats (generally smaller than 12 m), trips are short (at most four days; generally less than 24 h), and landings are usually rapidly sold on local markets or to restaurants (Leblond *et al.* 2007). However, due to a large and rising seafood demand, these landings are not sufficient, and substantial quantities of fish must be imported to satisfy the local market demand (Biais and Taquet 1992).

Three types of boats are used by artisanal fishers:

- Traditional wooden boats, of which the range of action is limited to 5 nm (trips of less than 12 h);
- Fibreglass boats (locally known as '*vedettes*'), which can go further offshore (up to 20 nm) and are mostly used for trips longer than 12 h;
- Mini-longliners smaller than 10 m, which are also active within 20 nm from the coast.

A wide array of gears is used, including longline, handline, trap, beach seine, troll line, electric reel, and gillnet. This results in a large variety of species targeted by artisanal fishers (INSEE 2006), including large pelagics (e.g., Istiophoridae, Scombridae, Xiphiidae), small pelagics (e.g., Carangidae) and demersal species (e.g., Serranidae, Lethrinidae).[9]

Historically, the artisanal fleet focused very little on the pelagic resources. However, the first anchored fishing aggregating device (a-FAD) was tried out in 1987 under the supervision of the French Research Institute for the Exploration of the Sea's (IFREMER), and starting in 1988, many other a-FADs (managed by the regional fisheries committee [CRPMEM]) were put in place around the island to increase the artisanal fleets' efficiency and to limit the fishing pressure on reefs (Biais and Taquet 1992; Leblond *et al.* 2007, 2010, 2011). After a production peak in 1994–95 and the consequent price collapse (Roos *et al.* 1998), the fishery became less viable, and several a-FADs were abandoned. The management (funding and maintenance) of the a-FAD network was handed over to the CRPMEM, and the total number of a-FADs reached 30 by the late 1990s (Rey-Valette *et al.* 2000). Nowadays, there are 34 active a-FADs around the island,[10] and it is estimated that almost 50% of the time spent fishing by artisanal fishers is around a-FADs (Tessier *et al.* 2000). Over 90 *barques* (6 m and 20 kW) and 75 *vedettes* (6–12m; 50–200 kW) are active around La Réunion's a-FADs, mostly using handlines (Guyomard *et al.* 2012). Since the appearance of the fleet of mini-longliners in the mid-2000s, conflicts with the other fleets in the artisanal sector have emerged (Chavance *et al.* 2012).

The implementation of this network of a-FADs resulted in higher catches of pelagic species, more registered professional fishers, as well as in an increased duration of the trips (Biais and Taquet 1990; INSEE 1991; Rey 1998; Rey-Valette *et al.* 2000). The development of the pelagic fishery benefited the nearshore resource by reduced the fishing effort targeting shallow-water demersal species (INSEE 1991, 1996; Rey 1998; Rey-Valette *et al.* 2000).

[7] Data compiled by Bach and Sabarros (unpub. data) originating from the regional observer program (Bach *et al.* 2008) and the self-reporting data collection program (Bach *et al.* 2013) for 2011, 2012, and 2013 show different numbers. Here, we relied on historical knowledge based on empirical evidence rather than the self-reported data (longer 'times-series').

[8] Data by 5°x5° cells are also available but less precise, so we disregarded them for the purpose of this spatial allocation.

[9] As an aside, there is a small but extremely valuable fishery controlled by a few families for *bichiques*, which are larvaes of *Sicyopterus* spp. and *Gobius* spp. (gobies). There is also a fishery for bait (mostly *Selar crumenophtalmus*, but also *Decapterus macarellus* and small tunas; Roos *et al.* 1998).

[10] Mostly active in the western part of the island (Tessier and Poisson 1997). In particular, it seems that the quality of the FADs has degraded since 2009, since maintenance subsidies were considered illegal by the European Union after 2007 (Guyomard *et al.* 2012). The new reform of the EU common fisheries policy has re-introduced these subsidies in 2014.

These reef resources are now mostly targeted when the sea is too rough to venture offshore (Biais and Taquet 1992; Conand and Tessier 1996).

We considered two distinct groups of reported catch data for this sector: i) catch of species recorded in both IOTC and FAO database (the 'IOTC species'), but not allocated to the longline fleet targeting swordfish (see above), and ii) catch of species reported only in FAO database (the 'non-IOTC species', i.e., reef species).

IOTC species

The FAO data follow a similar pattern and are very close to those provided by Biais (1991), Biais and Taquet (1992), and DMSOI/SIH since 1980 (FAO data slightly higher in the 1970s, and slightly lower in the 1990s-early 2000s; $r^2 = 0.89$). Here, we kept the FAO data for reasons of consistency, but applied two corrections:

- From 1950 to 1966, the total FAO catch data were replaced with the data from Tessier and Poisson (1997), to which the FAO species breakdown was applied (the catch in excess, when any, was re-allocated to the generic 'groundfishes' grouping and allocated to the distant-bank fishery; see below);
- Catches data in 1970 steeply dropped, and as we found no evidence to support such a large decline in catch, we assumed that this was an issue of underreporting and disregarded the 1970 FAO data. We estimated the 1970 catch as the average of 1969 and 1971 catches.

Several authors have also reported that 'informal fishers' (i.e., non-registered commercial fishers; labeled as 'artisanal' for the purpose of the *Sea Around Us* database) and recreational fishers using the same gears and targeting the same species frequently used the a-FAD network (Biais and Taquet 1992). Non-professional and tourism boats were estimated to represent 57% and 16%, respectively, of the total fleet in the late 1990s (CRPMEM 2006; Bouchard 2009). Although these non-registered artisanal and recreational fishers are allowed to fish on a-FADs during weekends (Roos *et al.* 1998), it seems that this regulation is not really enforced (Tessier and Poisson 1997; Rey 1998), and that their total catch is of the same magnitude of the registered fishers (Guyomard *et al.* 2012). Thus, they form an entirely cryptic component of the artisanal sector, for which no data are reported (Biais and Taquet 1992; Tessier and Poisson 1997; Chavance *et al.* 2012).

These fishers are also known to target deep-water demersal species (mostly snappers; between 200 and 600 m) with electric reels, and sell most of their catches. Large commercial stocks of such species were identified at the end of the 1990s, and numerous fishers (mostly non-registered) started employing electric reels to exploit them (around 100 tonnes were caught in 2006 by the only registered professional fisher). However, as deep demersal stocks are fragile, their biomass rapidly decreased. A study conducted in 2011 confirmed their overexploited status in the western and northern part of La Réunion (Fleury *et al.* 2012a).[11]

We assumed that non-registered artisanal and recreational fishers occupied half of the total fishing effort (e.g.. number of total boat fishing days) as that of registered artisanal fishers, and half of the annual CPUE of registered fishers (D. Guyomard, pers. obs.). We reconstructed these two missing sectors by multiplying the FAO catch of the registered artisanal fishers by 0.5 (to account for reduced fishing effort) and another 0.5 (to account for reduced CPUE), maintaining the same taxonomic breakdown. For the 2007–2010 period, though, we considered that the effort of both non-registered and recreational fishers doubled compared to the previous period, since the end of fuel subsidies resulted in an important exit from the registered fleet towards the informal one. Finally, we also considered that the unreported catch of the registered artisanal fishers was representing 10% of their reported catch (D. Guyomard, pers. obs.).

Non-IOTC species[12]

For this sector, we used demersal and small pelagic total catch data extracted from previous studies (Biais and Taquet 1992), which we believe are the one that were transmitted to FAO.[13]

The taxonomic breakdown provided in several studies was used to disaggregate these totals from 1950 to 1969 (Biais 1991; Biais and Taquet 1992; Tessier and Poisson 1997; DMSOI/SIH, unpub. data). From 1970 to 1998, crabs and Clupeidae were excluded from this breakdown, as they were already included in FAO data. Two adjustments were also made to correct unexplained drops in FAO catches:

- From 1950 to 1953, the average catch and breakdown of the next five years was carried backward;
- For 1965, an interpolation was done between 1964 and 1966.

For the 1999–2010 period, the total catch of demersal species that was extracted from the various studies cited above were proportionately re-allocated from the remaining FAO data. For small pelagics (Carangidae and Clupeoids), we kept the FAO data for consistency, since trends and values of the two datasets were very similar.

We used the same set of assumptions used for the IOTC species (see above) to estimate the unreported catch of non-registered and recreational fishers. For the registered fleet, we assumed 25% of the declared catch was unreported (D. Guyomard, pers. obs.).

[11] Stocks are smaller along the eastern and southern coasts, but their catch rates are higher.

[12] The 'natatian decapods' category was dealt with separately, as it corresponds to rock lobsters targeted in Saint Paul and Amsterdam, as well as shrimp targeted in Madagascar (see below).

[13] We disregarded a seemingly official third dataset (available at: http://41.206.61.142:8080/statbase_3), because we could not determine its origin. We also made an adjustment in 1977, because the remaining FAO data (total minus the catch already re-allocated to the longliners targeting swordfish, and the artisanal fishers targeting IOTC species) was 65 t lower than the data extracted from these various studies. Therefore, were reallocated 65/2 t from both demersal and small pelagic reported components to 'unreported landing'.

Sport fishing by tourists

The tourist population is currently a third of that of the residents and given the nature of the island, an overwhelming part of these tourists stay on the coast during their trip. From the plethora of internet fora describing and praising La Réunion's sport fishing activities, there is no doubt that this sector is important in terms of its economic contribution, as well as in terms of its catch. However, skippers working for sport fishing centers are required to own a professional license; therefore, catches of this sector are thought to be included in the artisanal sector, although usually sold to restaurants and fishmongers (where tourists can therefore enjoy a small piece of their trophies). Here, we conservatively assumed that the sport (i.e., recreational) catch by tourists was included in the reported artisanal statistics (since professional licenses are required to operate sport fishing boats), and as such, we did not reconstruct any catches.

Distant banks fishery

The *Société Franco-Mauricienne de Pêche et d'Industrie* (SFMPI; Armement des Mascareignes from 1965 onward) carried out an exploratory demersal fishery in 1961 on distant banks north of Mauritius Biais and Taquet (1992). Several gears were tried out, but only handlines operated from dories yielded economically-viable catches (Lebeau and Cueff 1975; Biais and Taquet 1992; Roos *et al.* 1998), which consisted of 80–90% of *Lethrinus mahsena* alone (sky emperor), as well as *L. variegatus* (slender emperor) and other demersal species (Roos *et al.* 1998). Biais (1987) reported that gutted weight increased from 370 t in 1967 to 640 t in 1972 for the Saya de Malha bank alone. These values (for a single bank) are about half of the remaining FAO data to be allocated (minus 'natatian decapods nei', which are dealt with separately; see below), and show a similar trend. Lebeau and Cueff (1975) reported gutted weight oscillating between 600 t and 900 t per year between 1975 and 1985, and then a decrease to 400–500 t. Again, these values are in the same range as the remaining FAO data. More recently, another fleet of a smaller scale has been active around the distant banks, increasing from two vessels in 1990 to six/seven vessels by the mid-1990s (Biais 1987). These vessels also targeted groupers and snappers with bottom longlines, around the Mauritian banks and along the coast of Madagascar, thanks to access agreements negotiated by the European Commission (Roos *et al.* 1998), and troll for large pelagics when moving between fishing areas. This sector was nearly phased out by the early 2000s (European Economic Community 1989a,b; European Community 1996–2007; Roos *et al.* 1998), which is also consistent with the remaining unallocated FAO catch. Since 2010, two boats (BABOUK and BIGOUDEN) have regularly fished on these distant banks.

Based on this information, we considered that the remaining FAO catch to be allocated (except 'natatian decapods nei'; see below) were representing the distant bank sector. Four adjustments were made:

- The 'zero catch' in 1977 was replaced by interpolated values between 1976 and 1978;
- The 'marine fishes nei' catches (excluding the part reallocated from the artisanal fleet) were multiplied by 1.2 to account for the conversion factor from gutted weight to live weight (FAO 2000);
- The 'marine fishes nei' taxon was split between sky emperor (70%), slender emperor (10%), and other demersal species (20%);
- The final catch was allocated to Mauritius (80%) and Madagascar (20%) waters.

Shrimp fishery in Madagascar

In the late 1960s, the only vessel operating on distant banks also started to target shrimp in the northwest of Madagascar (94 and 48.6 tonnes in 1969 and 1971, respectively), and this second fishery soon became important with the construction of 8 trawlers (Anon. 2011a, b). However, this activity collapsed in 1974 due to the political instability in Madagascar (213.5 and 422.8 in 1971 and 1972, respectively; Bertrand 1985; Roos *et al.* 1998; Méralli-Ballou 2008).

FAO data include significant 'Natatian decapods nei' (i.e., shrimp and lobsters) catches from 1950 to 1974. However, catches prior to the mid-1960s, as well as catches of up to 1,000 tonnes per year in the second half of the 1960s indicated that this taxon also included catches from elsewhere, probably rock lobsters from Saint Paul and Amsterdam. Therefore, we allocated the entirety of the FAO catch to the shrimp sector in Madagascar from 1971 to 1974 (year of the collapse), and linearly interpolated from 0 in 1966 (the sector started around 1967–68) to the 1971 FAO catch (i.e., 300 t). We also applied the weighted discard rate of tropical shrimp fisheries published by Kelleher (2005; amounts similar to those published by Bertrand 1985), i.e., 67.8%, in order to estimate the discards of the sector.

The remaining 'Natatian decapods nei' catches from 1950–1971 were reallocated to the rock lobster fishery in Saint Paul and Amsterdam (see below). Small catches of this taxon after 1974 were allocated to the artisanal fleet.

With that last sector (i.e., shrimp fishery in Madagascar), the total FAO catch was entirely re-allocated to the sectors mentioned above (Figure 2). The following sectors thus entirely constitute add-ons to the data reported to FAO.

Shorefishing and spearfishing by residents

La Réunion only has slightly over 1,000 hectares of coral reef, exclusively along the southern coast (80% of this reef is protected since 2007 *via* the Réserve Naturelle Marine; www.reservemarinereunion.fr). The recreational reef fishing and gleaning sectors have therefore always been limited. However, reef gleaners are active on these reefs and target most edible fish (over 200 species of commercial interest; Deschamps 2005), but also invertebrates such as crabs, clams and octopuses, locally called '*zourites*' (David and Mirault 2006). Fleury *et al.* (2012b) described the recent activity of this sector in the MPA, which can provide us with a general idea of fishing practices and impact on shore resources. Four fishing techniques are authorized within the protected area (Fleury *et al.* 2012b):

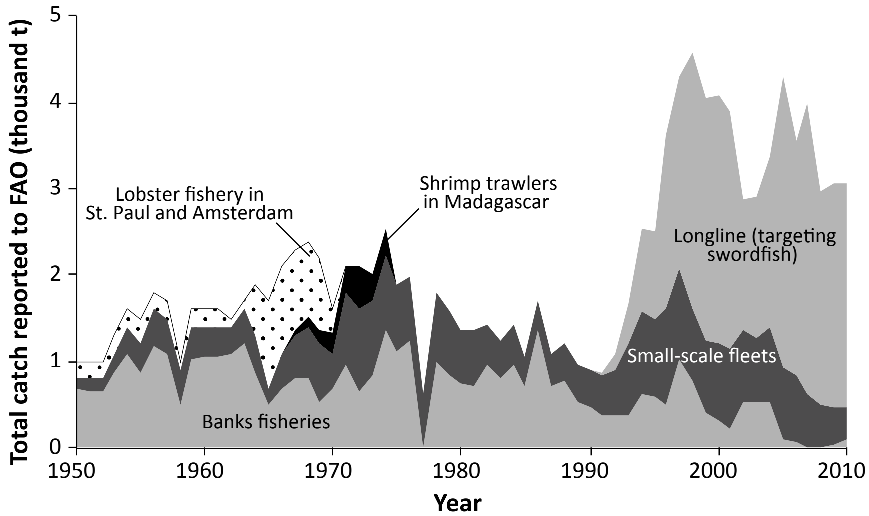

Figure 2. Breakdown of the data reported to FAO by fisheries sectors.

- Beach-seines to catch *Mulloidichthys flavolineatus* (yellowstripe goatfish);[14]
- Sticks to catch octopuses ('*zourites*');
- Handlines (from the shore) and spearguns (external slope) to catch various reef species.

These techniques (especially handlines) are also used elsewhere along the coast. There is very little information regarding historical catches of this recreational sector, but Bertrand (1985) reported that this sector was substantial, although not included in reported data (authorities only report commercial activities). Here, we applied a simple Fermi solution as a first approximation of this sector (von Baeyer 1993; Pauly 2010). Population data were extracted from Sandron (2007) and INSEE (2014), and we conservatively assumed that 1% of the population was catching 20 kg of fish per person and per year. Due to the rather low total resulting from this set of assumptions, we did not apply any taxonomic breakdown.

French Southern and Antarctic Lands

Rock lobster and patagonian toothfish fisheries

Saint Paul rock lobsters have been exploited around the French islands of Saint Paul and Amsterdam since the late 18th century (Angot 1951), in waters up to 700 meters deep (www.sapmer.com/Fishing_technique_St_Paul_Rock_Lobster.html). Most catches are exported to Japan and this sector has represented a major sector of La Réunion's fishing industry in terms of value throughout its existence (INSEE 1988, 1991, 1993). However, its importance has decreased since the expansion of the Patagonian toothfish and tropical tuna fisheries in the late 1980s.

Reconstructions for these two sectors were published separately (Palomares and Pauly 2011; Pruvost *et al.* 2015). These catches represented 121,700 t of Patagonian toothfish, 31,500 t of Saint Paul rock lobster, and 32,200 t of other demersal species.

Mozambique Channel tuna fishery

During the 2000s, some French purse-seiners (including from La Réunion) were flagged in Mayotte (IOTC 2012; Doherty *et al.* 2015).[15] These vessels were active in both Mayotte's EEZ as well as neighboring EEZs in the area, and their catches have been wrongly attributed to Mayotte in the FAO landings data (i.e., vessels were owned by firms outside Mayotte and landed in ports outside of Mayotte).

Catches from purse seiners owned by companies based in La Réunion (i.e., 117,000 t of large pelagics) were reassigned in the *Sea Around Us* database as catches from La Réunion and spatialized in Le Manach *et al.* (in press).

[14] This technique may result in some discards of bycatch. However, given the overall low catches and lack of information, no discards were estimated.

[15] Tuna seiners registered in Mayotte because it offered them certain tax advantages over being registered in the European Union. Notably, these included the ability to benefit from certain tax exemptions while avoid being constrained by limitations to engine power or tonnage (Busson 2011). Vessels rarely stopped in Mayotte other than for technical purposes or repairs, though, as being registered in Mayotte only required one stopover in Mayotte port per year (Busson 2011).

Results and Discussion

Sectors reported to FAO by La Réunion

Overall, the total reconstructed catch of La Réunion's domestic sectors totalled over 199,000 t over the 1950–2010 period. These catches show a bimodal trend, increasing from just over 1,500 t per year in the early 1950s, to almost 4,300 t per year in the early 1970s. Catches then decreased to around 1,400 t per year in 1990. The second peak occurred in the late 1990s at 8,000 t per year due to the expansion of the longline fleet, after which it declined again to reach around 5,000 t per year in the late 2000s (Figure 3).

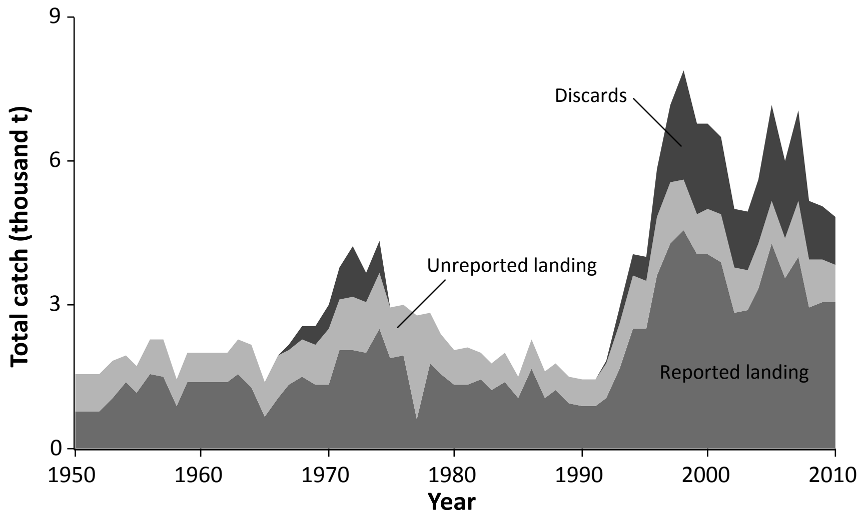

Figure 3. Total reconstructed catch disaggregated by catch type (reported vs. unreported landings, and discarded catches), from 1950 to 2010. See Appendix Table A1 for details.

The current decrease in total catch is consistent with the reported perception by many fishers that there are now less fish under the a-FADs scattered around the islands (Guyomard *et al.* 2012). Also, the longline fleet has experienced a normal initial decrease in catches, which substantially contributed to that decline. Finally, it also appears that the number of fishers has been decreasing, which also may be contributing to reduced catch.

Of the total catches over the 1950–2010 period, 39.9% were unreported (either landed, 25.7%; or discarded, 14.2%), whereas 60.1% were reported to FAO (Figure 3). The amount of unreported catches was estimated to have remained rather constant over time (Figure 3). It is thought that a redesign of the data collection scheme of IFREMER, the *Système d'Information Halieutique* in 2007 will result in improved quality of the domestic catch data in future years. However, our report suggests that three sectors remain entirely unreported in official data source: (i) the non-registered artisanal fishers targeting large pelagics, (ii) the recreational sector by locals targeting demersal species or reef gleaning/fishing from the shore, and (iii) the registered artisanal fishers active at night. Non-registered artisanal fisheries contribute substantial catches and have led to increasing tensions with registered fishers. Unreported catches by night-fishers are likely less important in terms of the magnitude of catch but probably equally important for their of impact on some species. It must be noted that the distinction between the registered and non-registered sector should be seen as a first attempt, as many fishers move from one sector to the other, depending on available subsidies and bureaucratic constraints. Therefore, further studies are necessary to better quantify them and include them in domestic policies.

The majority of this total catch was taken in the EEZ of La Réunion (60.8%). Mauritius and Madagascar were the following most fished EEZs, with 20.7% and 16.4%, respectively, whereas the remaining was caught in the Îles Éparses and in the High Seas (Figure 4).

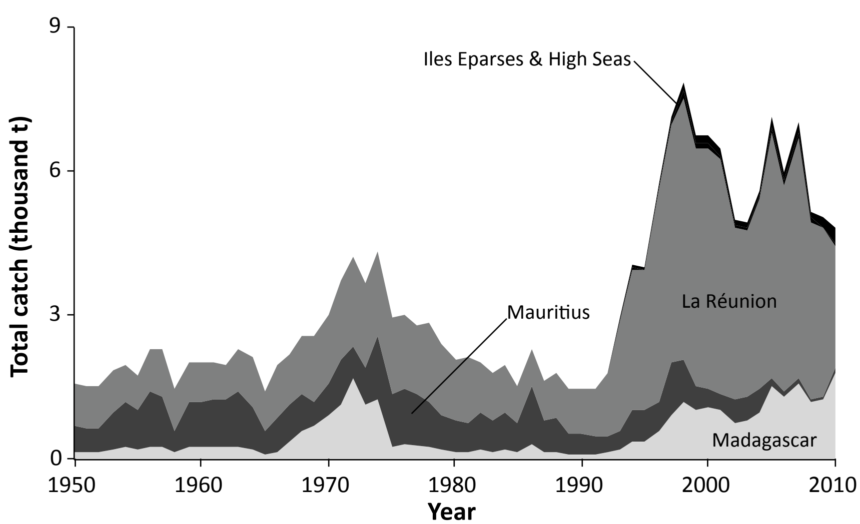

Figure 4. Total reconstructed catch disaggregated by fishing zone (EEZs of neighboring countries or High Seas), from 1950 to 2010.

The most prominent sector is by far the industrial one, with almost 60.7% of the total catch from 1950 to 2010. The artisanal sector comes second with 31.2%, whereas the recreational sector makes up the remaining 8.1%. The share of the industrial sector steadily decreased through the 1950s to early 1990s, after which it bounced back and reached its highest level ever (over 76% in 2010), mostly thanks to the development of the longline fleet (Figure 5). On the other hand, the artisanal sector has been decreasing for the last 15 years, due to the fact that it targets overfished reef species, and increasingly targeted (and already fully exploited) large pelagics. This decrease is also the result of the decreasing number of registered artisanal fishers (which is partially counter-balanced by their re-entry into the non-registered sector).

The most important taxa with regards to the taxonomic composition of the total catch (i.e., including discards) were yellowfin tuna (15.5%), sky emperor (14.4%), swordfish (14.2%), blue shark (6.0%), albacore tuna (5.7%), and jacks and pompanos (5.2%; Figure 6). Since the inception of the pelagic longline fleet, however, large pelagics occupy the majority of the catch. On the other hand, sky emperor, which represented the bulk of the catch in the earlier time period, are now virtually absent from La Réunion's catch, since the banks fishery has mostly been phased out (Figure 6).

Conclusion

La Réunion is a great example of how fisheries have expanded over-time, in oder to target new species in ever farther and deeper waters. During the first half of the 20th century, local fishing companies started to explore offshore banks between Mauritius and Madagascar, but also some fishing grounds in the Southern Ocean. Later, during the second half of the 20th century, they also started to expand towards the eastern coast of Africa to target large pelagics such as tuna and swordfish.

Paradoxically, the coastal artisanal fleet lagged behind in terms of diversification, as it is only in the 1990s that La Réunion's fishers truly started to explore waters closer to home, with the implementation of a network of a-AFDs (at least partly due to decreasing coastal resources), and in more recent years, with the development of deep-sea fisheries. Historically, local fishers were indeed satisfied with abundant inshore reef resources, but the increasing competition with recreational fishers may have been one of the main drivers for this late development.

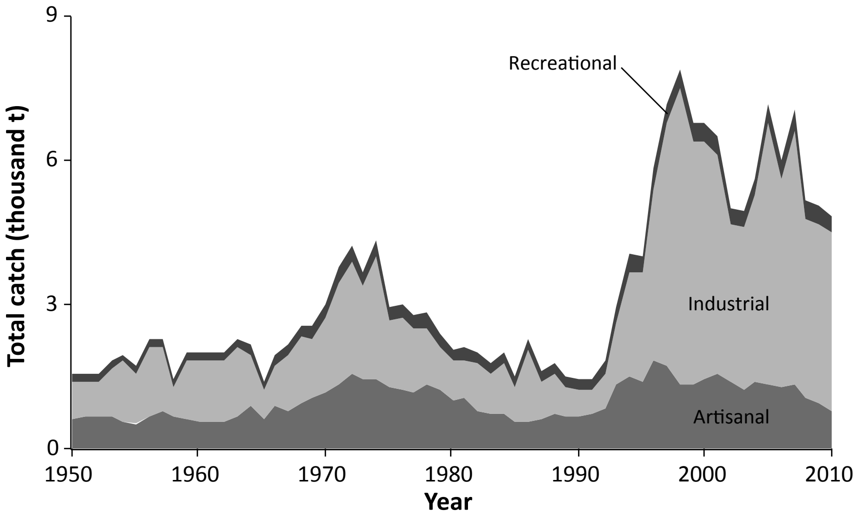

Figure 5. Total reconstructed catch disaggregated by sector, 1950–2010. See Appendix Table A1 for details.

Although we acknowledge that the reconstruction presented here is sometimes based on strong assumptions (notably with regards to these unreported catches), we feel confident regarding the reallocation of the reported catch to the different sectors, which helps clarify the situation. The sectorial allocation of the data now allows us to easily follow the successive steps in the development of La Réunion's fisheries briefly summarized in the previous paragraph. One can now easily identify the industrial fleets expanding from banks in Mauritius and Madagascar to the French Southern and Antarctic Lands and tropical waters throughout the Western Indian Ocean on the one side; and on the other side, the artisanal fleets diversifying their fisheries slightly later, by expanding further offshore notably *via* the implementation of the network of a-FADs.

These developments resulted in a shift in the composition of the landed catch, from mostly demersal and reef species, to mostly large pelagics.

Positively, this reconstruction also shows that the mortality of sensitive species, notably sharks, is decreasing. This is the result of a shift in gear (from regular 'J hooks' to 'circle hooks'), the end of 'finning' practices after 2006, and the phasing out of coastal fisheries targeting sharks (the marketing of coastal species is now banned).

We hope that this reconstruction will trigger further research, notably to fill the gaps in the data-collection system. It shows that the extent of unreported catches is still important with around 40% of the total catch from 2000 to 2010, notably due to the fleets of non-registered artisanal fishers, and recreational fishers.

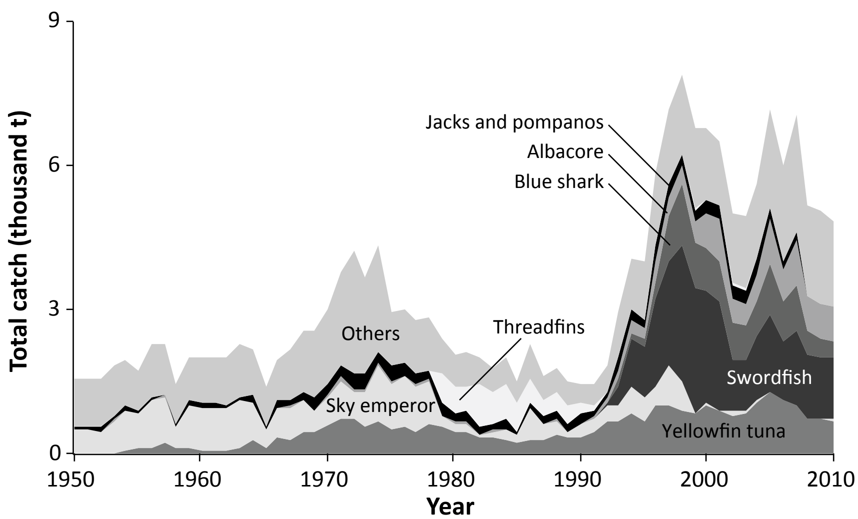

Figure 6. Total reconstructed catch disaggregated by species and higher taxa (top-seven taxa shown; the rest being aggregated as 'others'), from 1950 to 2010. See Appendix Table A2 for details.

Although part of these catches do not enter the market, such activities will have to become better monitored in future years, and we recommend that this sector should be accounted for during decision processes related to domestic fisheries management. The official accounting of these unreported catches is of prime importance for the sound management of fisheries.

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References

Allain C (1974) La pêche maritime et la recherche scientifique à La Réunion — Rapport de mission du 2 au 10 avril 1974. Office Scientifique et Technique des Pêches Maritimes (ISTPM), Nantes (France). 24 p.

Angot M (1951) Observations sur la faune marine et la pêche aux îles Saint-Paul et Amsterdam. Mémoires de l'Institut Scientifique de Madagascar Série A — Tome VI(fascicule 1): 51.

Anon. (2011a) Convention Spécifique n°33 : Ex-post evaluation of the current protocol to the Fisheries Partnership Agreement (FPA) between the European Union and Madagascar, and analysis of the impact of the future protocol on sustainability, including ex-ante evaluation. Contrat-cadre pour la réalisation d'évaluations, d'études d'impact et de suivi concernant les Accords de Partenariat dans le domaine de la Pêche conclus entre la Communauté et les Pays Tiers et plus généralement sur le volet externe de la Politique Commune de la Pêche — Projet FISH/2006/20, Oceanic Développement and MegaPesca Lda, Brussels (Belgium). xx + 109 p.

Anon. (2011b) Convention Spécifique n°34 : ex-ante evaluation of existing conditions in the fisheries sector in Mauritius with a view to concluding a new Fisheries Partnership Agreement and Protocol. Framework Contract for performing evaluations, impact analyses and monitoring services in the context of Fisheries Partnership Agreements concluded between the Community and non-member coastal states and more generally of the external strand of the Common Fisheries Policy — Project FISH/2006/20, Oceanic Développement and MegaPesca Lda, Brussels (Belgium). xii + 94 p.

Anon. (2012) Rapport d'activité 2012. GIP Réserve nationale marine de La Réunion, La Saline-les-Bains (France). 63 p.

Bach P, Rabearisoa N, Filippi T and Hubas S (2008) The first year of SEALOR : database of SEA-going observer surveys monitoring the local pelagic LOngline fishery based in La Réunion. IOTC — 2008 — WPEB — 13, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 19 p.

Bach P, Romanov E, Rabearisoa N and Sharp A (2011) Note on swordfish catches collected during commercial operations and research cruises onboard pelagic longliners of the La Reunion fleet from 2006 to 2010. IOTC–2011–WPB09–INFO11, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles).

Bach P, Romanov EV, Rabearisoa N, Filippi T and Sharp A (2010) Note on yellowfin and bigeye catches collected during fishing and research cruises onboard pelagic longliners of the La Réunion fleet in 2008 and 2009. IOTC Working Party on Tropical Tuna (WPTT), Victoria (Seychelles), October 18–25, 2010. IOTC-2010-WPTT-11, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 13 p.

Bach P, Sabarros S, Le Foulgoc L, Richard E, Lamoureux J-P and Romanov EV (2013) Self-reporting data collection project for the pelagic longline fishery based in La Reunion. IOTC–2013–WPEB09–42, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 10 p.

Bertrand J (1985) La pêche maritime à La Réunion : trente années d'effort de développement de la production. L'économie de La Réunion 15, Institut National de la Statistique et des Etudes Economiques (INSEE), Service Régional de La Réunion, Sainte Clotilde (France). 3–8 p.

Biais G (1987) Summary of fisheries and resources information for La Réunion. Pp. 108–115 *In* Sanders MJ, Sparre P and Venema SC (eds.), Proceedings of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, September 14–25, 1987, Albion (Mauritius). SWIOP Document OISO RAF/79/065/WP/41/88/E. Food and Agriculture Organization of the United Nations (FAO) and United Nations Development Programme (UNDP), Rome (Italy).

Biais G (1991) Etudes descriptives de la pêche artisanale à La Réunion et à Mayotte. Pp. 319–324 *In* Durand J-R, Lemoalle J and Weber J (eds.), La recherche face à la pêche artisanale, symposium international ORSTOM-IFREMER, Montpellier (France), July 3–9, 1989. Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris (France).

Biais G and Taquet M (1990) Technologie des dispositifs de concentration de poissons et techniques de pêche aux gros pélagiques. Compte rendu d'essais effectués pendant l'été austral 1989–90. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Paris (France). 49 p.

Biais G and Taquet M (1992) La pêche locale aux abords de La Réunion. Repères Océans 2, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Plouzané (France). 77 p.

Bouchard C (2009) Fisheries in the French Indian Ocean Territories. Pp. 177–193 *In* Rumley D, Sanjay C and Sakhuja V (eds.), Fisheries exploitation in the Indian Ocean — Threats and opportunities. Institute of Southeast Asian Studies, Singapore.

Bouchon C (1978) Etude quantitative des peuplements à base de Scléractiniaires d'un récif frangeant de IIe de La Réunion. PhD thesis, University of Aix-Marseille 2 (France). 144 p.

Busson O (2011) La pêche à Mayotte: entre archaïsme et postmodernité. L'Harmattan, Paris (France). 183 p.

Butcher PA, McGrath SP and Peddemors VM (2014) Why do they die? Mortality indices of elasmobranchs caught on demersal long lines in a south-east Australian commercial shark fishery. Sharks International, June 2–6, 2014, Durban (South Africa).

Campana SM, Joyce W and Manning MJ (2009) Bycatch and discard mortality in commercially caught blue sharks Prionace glauca assessed using archival satellite pop-up tags. Marine Ecology Progress Series 387: 241–253.

Chabanet P (1994) Etude des relations entre les peuplements benthiques et les peuplements ictyologiques sur le complexe récifal de Saint-Gilles/La Saline (Ile de la Réunion). PhD thesis, University of Aix-Marseille 2, Marseille (France). 235 p.

Chavance P, Chassot E, Bourjea J, Evano H, Nadeau A, Bach P, Marsac F and Dagorn L (2012) UE-France — Rapport national destiné au Comité scientifique de la Commission des Thons de l'Océan Indien, 2011–2012. Indian Ocean Tuna Commission. 36 p.

Conand C (2002) Marine ecology of La Réunion: an overview of recent research. AMBIO: A Journal of the Human Environment 31(7): 602–605.

Conand F and Tessier E (1996) FAD deployments around Reunion Island: background, development and influence on catches and activity in the coastal fishery. SPC Fish Aggregating Device Bulletin 1: 3–6.

CRPMEM (2006) Etude d'intégration et de professionnalisation des pêcheurs informels — Rapport final. Comité Régional des Pêches Maritimes et Elevages Marins (CRPMEM) and Armeris, Le Port (France). 40 p.

David G and Mirault E (2006) L'épuisement de la ressource récifale de la Réunion : confrontation des perceptions et régulation de l'activité halieutique. Pp. 127–140 *In* Chaussade J and Guillaume J (eds.), Pêche et aquaculture, pour une exploitation durable des ressources vivantes de la mer et du littoral : ouvrage en l'honneur de J.P. Corlay. Presses Universitaires, Rennes (France).

Deschamps G (2005) Nomenclature des espèces commerciales — Espèces pêchées à La Réunion. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 56 p.

Diaz GA and Serafy JE (2005) Longline-caught blue shark (Prionace glauca): factors affecting the numbers available for live release Fishery Bulletin 103(4): 720–724.

Doherty B, Herfaut J, Le Manach F, Harper S and Zeller D (this volume) Reconstructing domestic marine fisheries in Mayotte from 1950–2010.

European Community (1996) Protocol defining, for the period 21 May 1995 to 20 May 1998, the fishing opportunities and the financial contribution provided for by the Agreement between the European Economic Community and the Government of the Republic of Madagascar on fishing off Madagascar. Official Journal L 75: 2–7.

European Community (1997) Protocol fixing, for the period 1 December 1996 to 30 November 1999, the fishing opportunities and the financial consideration provided for in the Agreement between the European Economic Community and the Government of Mauritius on fishing in Mauritian waters. Official Journal L 163: 29–33.

European Community (1998) Protocol setting out the fishing opportunities and financial compensation provided for in the Agreement between the European Economic Community and the Republic of Madagascar on fishing off Madagascar for the period from 21 May 1998 to 20 May 2001. Official Journal L 295: 34–39.

European Community (2000) Protocol defining, for the period 3 December 1999 to 2 December 2002, the fishing opportunities and the financial contribution provided for by the Agreement between the European Community and the Government of Mauritius on fishing in the waters of Mauritius. Official Journal L 180: 30–38.

European Community (2001) Protocol setting out the fishing opportunities and financial contribution provided for in the agreement between the European Economic Community and the Democratic Republic of Madagascar on fishing off Madagascar for the period from 21 May 2001 to 20 May 2004. Official Journal L 296: 10–18.

European Community (2004) Protocol defining, for the period 3 December 2003 to 2 December 2007, the fishing opportunities and the financial compensation provided for by the Agreement between the European Economic Community and the Government of Mauritius on fishing in Mauritian waters. Official Journal L 348: 3–13.

European Community (2005) Protocol defining for the period 1 January 2004 to 31 December 2006 the Tuna fishing opportunities and the financial contribution provided for in the agreement between the European Economic Community and the Democratic Republic of Madagascar on fishing off Madagascar. Official Journal L 94: 5–44.

European Community (2007) Protocol setting out the fishing opportunities and financial contribution provided for in the Agreement between the European Community and the Republic of Madagascar on fishing off the coast of Madagascar for the period from 1 January 2007 to 31 December 2012. Official Journal L 331: 11–30.

European Economic Community (1989a) Agreement between the European Economic Community and the Government of Mauritius on fishing in Mauritian waters. Official Journal L 159: 2–6.

European Economic Community (1989b) Protocol No 1 on the fishing opportunities accorded by Mauritius and the financial contribution accorded by the Community. Official Journal L 159: 7–7.

Evano H and Bourjea J (2012) Atlas de la pêche palangrière réunionnaise de l'océan Indien. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France).

FAO (2000) Conversion factors — landed weight to live weight. FAO Fisheries Circular C847, Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 192 p.

FAO (2012) FishStatJ, a tool for fishery statistics analysis. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Faure G (1982) Recherches sur les peuplements de Scléractiniaires des récifs coralliens de l'archipel des Mascareignes (Océan Indien occidental). PhD thesis, University of Aix-Marseille 2 (France). 246 p.

Fleurant Y-E (1989) La Réunion : un tourisme tropical différent ? Cenadom, Talence (France). 107 p.

Fleury P-G, Cadet C, Turban S and Le Bonniec S (2012b) Suivi des pêches à pied traditionnelles et de la chasse sous-marine de 2008 à 2011 dans la Réserve Naturelle Marine de La Réunion. Rapport Ifremer RST-DOI-2012–03, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 83 p.

Fleury P-G, Evano H, Le Rû L and Aureche V (2012a) Synthèse de l'étude et des campagnes à la mer 2011 sur l'exploitation aux vire-lignes des espèces démersales profondes autour de La Réunion. Rapport Ifremer RST-DOI-2012–13, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 45 p.

Guyomard D, Hohmann S, Fleury P-G and Bissery C (2012) Etude technico-économique sur les DCP ancrés de La Réunion — Rapport final. Comité Régional des Pêches Maritimes et des Elevages Marins de La Réunion, Le Port (France). 204 + annexes p.

Guyomard D, Poisson F and Stretta J-M (2006) Synopsis de la pêche palangrière réunionnaise. Pp. 79–91 *In* Petit M and Huynh F (eds.), Halieutique et environnement océanique : le cas de la pêche palangrière à l'espadon depuis l'île de la Réunion. Institut de Recherche pour le Développement, Paris (France).

Harper S and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada). 143 p.

Harper S, Zylich K, Boonzaier L, Le Manach F, Pauly D and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part III. Fisheries Centre Research Reports 20 (5). University of British Columbia, Vancouver (Canada). 134 p.

INSEE (1988) La pêche. Pp. 112–113 *In* L'économie de La Réunion — Panorama. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1991) Agriculture — Pêche. Pp. 134–135 *In* L'économie de La Réunion — Panorama. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1993) Agriculture — Pêche. Pp. 130–131 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1996) Agriculture — Pêche. Pp. 136–137 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1997) Agriculture — Pêche. Pp. 136–137 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1998) Agriculture — Pêche. Pp. 178–179 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (1999) Agriculture — Forêt — Pêche. Pp. 202–203 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2000) Agriculture — Pêche. Pp. 172–173 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2002) Agriculture — Pêche. Pp. 172–173 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2003) Agriculture — Pêche. Pp. 172–173 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2005) Pêche. Pp. 178–179 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2006) La Réunion en 2005. Rapport Annuel, Institut d'Emission des Départements d'Outre-Mer, Paris (France). 262 p.

INSEE (2008) Pêche. Pp. 184–185 *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques, Service Régional de La Réunion, Sainte Clotilde (France).

INSEE (2014) Évolution de la population. *In* Tableau économique de La Réunion. Institut National de la Statistique et des Etudes Economiques (INSEE).

IOTC (2012a) IOTC record of authorised vessels. Indian Ocean Tuna Commission. Available at: www.iotc.org/English/record/search3.php [Accessed: April 25, 2012].

Kelleher K (2005) Discards in the world's marine fisheries: an update. Fisheries Technical Paper 470, Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 152 p.

Le Manach F, Abunge CA, McClanahan TR and Pauly D (this volume) Tentative reconstruction of Kenya's marine fisheries catch, 1950–2010.

Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Lebeau A and Cueff J-C (1975) Biologie et pêche du capitaine *Lethrinus enigmatus* (Smith 1959) du banc de Saya de Malha (Ocean Indien). Revue des Travaux de l'Institut des Pêches Maritimes 39(4): 415–442.

Leblond E, Demaneche S, Le Blond S, Merrien C, Berthou P, Daurès F, Le Rû L and Laurence A (2011) Activité 2009 des navires de pêche du quartier maritime Saint-Denis de la Réunion. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 10 p.

Leblond E, Demaneche S, Le Blond S, Merrien C, Berthou P, Daurès F, Pitel-Roudaut M, Le Rû L, Lajeunesse M, Laurence A and Evano H (2010) Activité 2008 des navires de pêche du quartier maritime Saint-Denis de la Réunion. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 11 p.

Leblond E, Merrien C, Berthou P, Demaneche S and Miossec D (2007) L'activité des navires de pêche du Quartier Maritime de La Réunion en 2006. Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 9 p.

Letourneur Y and Chabanet P (1994) Variations spatio-temporelles de l'ichtyofaune des platiers récifaux à La Réunion. Cybium 18(1): 25–38.

Marsac F and Stequert B (1984) Bilan des prospections sur les ressources thonières de surface effectuées depuis 1971 dans l'Océan Indien Occidental. La Pêche Maritime 1271: 1–12.

Méralli-Ballou P (2008) Homme libre, toujours… — La pêche à l'île de La Réunion depuis le XVIIe siècle. Comité Régional des Pêches Maritimes et des Élevages Marins (CRPMEM) de La Réunion, Le Port (France). 111 p.

Palomares MLD and Pauly D (2011) A brief history of fishing in the Kerguelen Islands, France. pp. 15–20 In Harper S and Zeller D (eds.), Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada).

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Pauly D (2010) Five easy pieces: how fishing impacts marine ecosystems. Island Press, Washington, DC. 193 p.

Poisson F (2010) Catch, Bycatch of Sharks, and Incidental Catch of Sea Turtles in the Reunion-Based Longline Swordfish Fishery (Southwest Indian Ocean) Between 1997 and 2000. 163–165.

Poisson F and Taquet M (2000) French swordfish longline fishery in the south west Indian Ocean: preliminary results from the PPR program. IOTC Proceedings, WPB00–06 3, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles). 169–201 p.

Poisson F and Taquet M (2001) L'espadon : de la recherche à l'exploitation durable. Programme Palangre Réunionnais — Rapport final, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 247 p.

Poisson F, Guyomard D and René F (1999) Collection of statistical and biological information of the Réunion Islands swordfish fishery. Proceedings of the 7th Expert consultation on Indian Ocean Tunas, Victoria (Seychelles), November 9–14, 1998, Indian Ocean Tuna Commission, Victoria (Seychelles). 268–276 p.

Poisson F, Tessier E, Roos D and René F (1994) Recent development of swordfish, *Xiphias gladius*, longline fisheries near Reunion Island, southwestern Indian Ocean. Pp. 89–100 *In* Barrett I, Sosa-Nishizaki O and Bartoo N (eds.), Biology and fisheries of swordfish, *Xiphias gladius* — International Symposium on Pacific swordfish, December 11–14, 1994, Ensenada (Mexico). NOAA Technical Report NMFS 142 (National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, Washington, DC (USA).

Pruvost P, Duhamel G, Le Manach F and Palomares ML (2015) Reconstruction of the fisheries in Saint Paul and Amsterdam (France), 1950–2010. pp. 36-44. *In*: MLD Palomares and D Pauly (eds.) Marine Fisheries Catches of Sub- Antarctic Islands, 1950 to 2010. Fisheries Centre Research Reports 23(1). University of British Columbia, Vancouver (Canada).

René F, Poisson F and Tessier E (1998) Evolution de la pêcherie palangrière ciblant l'espadon (Xiphias gladius) à partir de La Réunion. Pp. 287–312 In Cayré P and Le Gall JY (eds.), Le thon : enjeux et stratégies pour l'océan Indien. Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris (France).

Rey H (1998) Dispositifs de concentration de poissons (DCP) dans les pays de la Commission de l'océan Indien (COI) : innovation ou révolution dans les pratiques de pêche. Pp. 313–334 *In* Cayré P and Le Gall J-Y (eds.), Le thon : enjeux et stratégies pour l'Océan Indien, Proceedings of the lnternational Tuna Conference, Mauritius, November 27–29, 1996. Indian Ocean Commission (IOC) and Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris (France).

Rey-Valette H, Cillaurren E and David G (2000) Evaluation pluridisciplinaire de la durabilité des pêcheries artisanales autour des DCP. Aquatic Living Resources 13: 241–252.

Romanov EV, Sabarros PS, Le Foulgoc L, Richard E, Lamoureux J-P, Rabearisoa N and Bach P (2013) Assessment of depredation level in Reunion Island pelagic longline fishery based on information from self-reporting data collection programme. Presented at the 9th IOTC Working Party on Ecosystems and Bycatch (WPEB), La Réunion, September 12–16, 2013. IOTC–2013–WPEB09–47. 20 p.

Roos D, Tessier E and Guyomard D (1998) Evolution de l'activité halieutique à La Réunion de 1990 à 1996. DRV/RH/RST/98–14, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 67 p.

Sabarros PS, Romanov EV, Le Foulgoc L, Richard E, Lamoureux J-P and Bach P (2013) Commercial catch and discards of pelagic longline fishery of Reunion Island based on the self-reporting data collection program. Presented at the 9th IOTC Working Party on Ecosystems and Bycatch (WPEB), La Réunion, September 12–16, 2013. IOTC–2013–WPEB09–37 Rev_1. 29 p.

Sandron F (2007) Dynamique de la population réunionnaise (1663–2030). pp. 27–41 In Sandron F (ed.) La population réunionnaise — Analyse démographique. IRD Editions, Paris (France).

Tessier E and Poisson F (1997) Bilan sur la mise en place d'un système de récolte de données sur la pêche artisanale sur DCP. Document scientifique no. 34 du projet thonier régional II. Action I : statistiques thonières. Rapport final, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Le Port (France). 48 p.

Tessier E, Rey-Valette H, Ah-Nième D, Bargain R-M, Venkatasamy A and Wendling B (2000) Systèmes halieutiques et DCP dans l'Océan Indien : une revue de la diversité des expériences et des résultats en termes d'intégration et de durabilité. Pp. 159–183 *In* Le Gall J-Y, Cayré P and Taquet M (eds.), Pêche thonière et dispositifs de concentration de poissons, Trois-Îlets (Martinique), October 15–19, 1999. Actes de Colloques 28). Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Plouzané (France).

von Baeyer HC (1993) The Fermi solution: essays on science. Random House, New York City, NY (USA). 176 p.

Zeller D and Harper S, editors (2009) Fisheries catch reconstructions: islands, part I. Fisheries Centre Research Reports 17 (5). University of British Columbia, Vancouver (Canada). 108 p.

Zeller D and Pauly D, editors (2007) Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15 (2). University of British Columbia, Vancouver (Canada). 163 p.

Zeller D, Booth S, Davis GE and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. Reconstructed catch by sector compared to total catch reported to FAO, 1950–2010.

Year	Reconstructed catch				Reported to FAO
	Artisanal	Industrial	Recreational	Total	
1950	649	772	143	1,564	800
1951	660	750	146	1,556	800
1952	672	728	149	1,548	800
1953	662	1,028	149	1,838	1,100
1954	554	1,,284	135	1,973	1,400
1955	548	1,052	137	1,737	1,200
1956	704	1,426	162	2,292	1,600
1957	821	1,320	183	2,324	1,500
1958	685	600	163	1,448	900
1959	650	1,224	161	2,035	1,400
1960	602	1,254	155	2,011	1,400
1961	585	1,266	155	2,005	1,400
1962	550	1,290	152	1,992	1,400
1963	688	1,436	174	2,298	1,600
1964	884	1,068	207	2,159	1,300
1965	633	592	171	1,396	700
1966	912	840	216	1,968	1,100
1967	810	1,170	203	2,183	1,360
1968	988	1,344	233	2,564	1,520
1969	1,093	1,218	249	2,560	1,380
1970	1,166	1,584	264	3,014	1,341
1971	1,378	2,095	298	3,771	2,101
1972	1,553	2,355	325	4,233	2,101
1973	1,446	1,939	309	3,693	2,001
1974	1,461	2,559	314	4,334	2,533
1975	1,308	1,352	291	2,951	1,905
1976	1,220	1,501	280	3,001	1,981
1977	1,178	1,354	274	2,806	621
1978	1,335	1,207	300	2,842	1,807
1979	1,245	896	286	2,427	1,594
1980	1,044	788	257	2,090	1,374
1981	1,091	763	265	2,118	1,371
1982	802	976	223	2,001	1,442
1983	756	836	218	1,811	1,254
1984	770	1,003	222	1,995	1,419
1985	578	738	196	1,512	1,056
1986	568	1,528	197	2,293	1,705
1987	633	788	208	1,629	1,094
1988	743	851	227	1,821	1,220
1989	713	561	225	1,499	969
1990	704	548	226	1,478	911
1991	733	511	233	1,477	887
1992	870	705	258	1,832	1,103
1993	1,375	1,236	336	2,947	1,679
1994	1,525	2,170	363	4,058	2,531
1995	1,430	2,245	350	4,026	2,500
1996	1,840	3,563	415	5,818	3,607
1997	1,723	5,072	399	7,194	4,288
1998	1,367	6,169	347	7,883	4,579
1999	1,331	5,095	345	6,771	4,043
2000	1,455	4,964	366	6,784	4,082
2001	1,553	4,587	383	6,523	3,889
2002	1,415	3,250	363	5,029	2,870
2003	1,246	3,367	340	4,953	2,902
2004	1,429	3,847	371	5,646	3,371
2005	1,376	5,417	364	7,157	4,281
2006	1,276	4,374	349	5,999	3,546
2007	1,359	5,237	472	7,069	3,988
2008	1,064	3,718	408	5,189	2,981
2009	983	3,707	389	5,079	3,051
2010	803	3,684	351	4,838	3,051

Appendix Table A2. Total reconstructed catch by taxon, 1950–2010.

Year	Yellowfin tuna	Sky emperor	Swordfish	Blue shark	Albacore	Jacks and pompanos	Threadfins	Others
1950	29	484	-	-	2	71	-	977
1951	29	469	-	-	2	89	-	967
1952	29	453	-	-	2	107	-	957
1953	44	670	-	-	3	107	-	1,014
1954	58	857	-	-	4	125	-	929
1955	117	722	-	-	9	53	-	835
1956	132	991	-	-	10	53	-	1,106
1957	270	924	-	-	21	36	-	1,073
1958	146	420	-	-	11	53	-	818
1959	146	857	-	-	11	107	-	914
1960	102	857	-	-	8	89	-	955
1961	102	865	-	-	8	107	-	923
1962	102	882	-	-	8	53	-	946
1963	117	991	-	-	9	71	-	1,110
1964	312	748	-	-	24	160	-	916
1965	132	407	-	-	10	53	-	794
1966	353	588	-	-	27	178	-	822
1967	292	689	-	-	22	125	-	1,056
1968	438	680	-	-	33	160	-	1,252
1969	438	462	-	-	33	231	-	1,395
1970	585	588	-	-	44	239	-	1,558
1971	731	815	-	-	57	257	-	1,911
1972	731	563	-	-	57	330	-	2,552
1973	585	706	-	-	46	367	-	1,990
1974	705	1,140	-	-	56	257	-	2,177
1975	525	947	-	-	41	312	-	1,127
1976	561	1,051	-	-	44	257	-	1,089
1977	472	948	-	-	37	234	-	1,116
1978	651	845	-	-	52	220	-	1,073
1979	577	197	-	-	44	257	615	737
1980	481	165	-	-	37	160	552	695
1981	451	175	-	-	35	239	513	706
1982	352	55	-	-	28	138	898	532
1983	339	144	-	-	26	145	630	527
1984	322	179	-	-	26	191	747	530
1985	266	118	-	-	20	83	569	455
1986	279	688	-	-	22	68	545	690
1987	315	310	-	-	24	127	345	509
1988	387	328	-	-	30	149	382	546
1989	366	90	-	-	28	130	433	452
1990	366	257	-	-	28	218	181	428
1991	473	247	3	-	61	152	103	439
1992	670	323	87	-	82	142	-	529
1993	701	310	398	175	159	254	-	952
1994	848	541	999	146	235	222	-	1,068
1995	664	512	1,043	175	224	196	-	1,211
1996	1,019	412	1,804	350	444	338	-	1,450
1997	1,015	854	2,138	933	402	295	-	1,558
1998	884	648	2,791	1,298	406	229	-	1,628
1999	829	30	2,590	962	456	214	57	1,633
2000	1,003	80	2,345	846	733	260	6	1,511
2001	895	38	2,248	832	892	262	13	1,343
2002	826	65	1,092	775	473	308	8	1,481
2003	843	60	1,061	714	466	286	7	1,516
2004	1,090	61	1,311	744	556	286	7	1,593
2005	1,294	11	1,616	1,056	951	196	8	2,025
2006	1,130	13	1,219	846	633	168	14	1,976
2007	1,006	-	1,545	945	988	129	8	2,447
2008	754	-	1,316	515	685	19	3	1,897
2009	720	16	1,282	408	708	19	3	1,924
2010	683	52	1,285	309	723	19	2	1,764

Artisanal Fisheries in the World's Second Largest Tuna Fishing Ground — Reconstruction of the Seychelles' Marine Fisheries Catch, 1950–2010*

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Abstract

Total marine fisheries catches were estimated for the Seychelles for the 1950–2010 time-period using the catch reconstruction approach developed by the *Sea Around Us* and applied to coastal countries worldwide. This included catches (including dead discards) of the industrial, artisanal, and recreational fishing sectors. The total reconstructed catch for domestic sectors (i.e., excluding the foreign-owned but Seychelles-flagged vessels) for the 1950–2010 time-period reached almost 290 000 t. This figure is 1.3 times the catch officially reported to the Food and Agriculture Organization of the United Nations. Major taxa in catches were jacks and pompanos (Carangidae; 26.5%), snappers (Lutjanidae; 18.7%), Indian mackerels (*Rastrelliger kanagurta*; 6.4%), emperors (Lethrinidae; 6.2%), kawakawa (*Euthynnus affinis*; 4.0%), and groupers (Serranidae; 3.5%). The artisanal sector accounted for the vast majority of the catch, with 95.2% overall.

Introduction

The Republic of the Seychelles (referred throughout as 'the Seychelles') is the least populated country in Africa, with a population of around 90,000 inhabitants. It is an archipelago located north of Madagascar that is composed of 115 islands, 42 of which are granitic mountainous islands of continental origin, and the others which are flat and of coralline origin (Figure 1). Although discovered by the Arabs in the 9th century, it is only in 1756 that France set its flag in the Seychelles and inhabited it since 1770 (Filliot 1983; Doumenge 1987).[1] Half a century later, the Seychelles were ruled by the United Kingdom, and this until their independence in 1976 (Doumenge 1987). Nowadays, most of its inhabitants live on the island of Mahé, mainly in the capital city of Victoria.

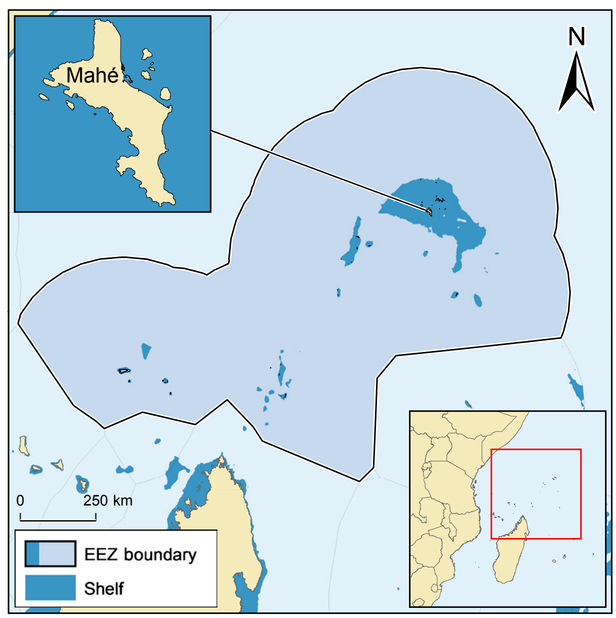

Figure 1. Extent of the Seychelles EEZ, as well as its Inshore Fishing Area (IFA; i.e., the 'shelf').

Victoria hosts the largest tuna hub in the Indian Ocean, with around 80% of the tuna caught in the region transiting every year through its infrastructures, which include the Indian Ocean Tuna (IOT) cannery (Martín 2011).[2] Canned tuna is the main good exported by the Seychelles (primarily for the European market), although there are also substantial exports of fish meal/oil, as well as dried holothurians and shark fins[3] to Asia (Marshall 1997; Robinson *et al.* 2006; SFA 2014). With between 5,000–6,000 direct and indirect jobs, i.e., 15% of the total of formal jobs in the Seychelles, the fisheries sector is the main pillar of the national economy, along with the tourism industry. Activities linked to the industrial tuna fisheries are the most important foreign exchange earners, with revenues generated by goods and expenditures (e.g., processing at the cannery, and goods and services procured by purse-seiners in Port Victoria; see Robinson *et al.* 2010), and

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[1] Several expeditions from Portugal, the United Kingdom, or France set foot on the various islands prior to 1756 (Filliot 1983; Doumenge 1987).

[2] This is one of the largest canneries in the world, with over 90,000 t of tuna processed for canning every year. It is known as a highly efficient one with regards to water use and production by employees (Michaud 2003; Martín 2011).

[3] Sharks have been caught in the Seychelles waters for centuries to such an extent that populations were already considered as over-exploited by the end of the 1950s (Marshall 1997; Nevill *et al.* 2007).

licensing fees playing the most prominent roles (Ghosh 1990; Parks 1991; Robinson *et al.* 2006). Around half of these 5,000–6,000 jobs happen to be at the national cannery, while approximately 1,500 of them consist of active fishers (Robinson *et al.* 2006; SFA 2013, 2014).[4] Historically, however, copra, cinnamon, and vanilla used to be the most important drivers of the economy, while the tourism industry took off only in 1971, after the inauguration of the international airport (Doumenge 1987; Kimani 1995; Ellis 1996). The industrial fisheries sector only started to develop in the mid-1980s with the arrival of European and Japanese funds linked to fishing access agreements. These funds were used to develop tuna-related infrastructures, such as the port and the cannery in Victoria, as well as infrastructure and fleets for semi-industrial[5] and artisanal fisheries (Michaud 1991, 2003; Robinson and Shroff 2004; Alexis and Chang-Sam 2006; Martín 2011).

Thanks to these two recent, yet thriving industries, the Seychelles have become an exception in the region (notwithstanding Mauritius), with high social and economic indexes. However, its status of middle income country limits international aid, and that issue was reinforced during the global financial crisis of 2007–08, due to a high external debt (Anon. 2004a). Also, the Seychelles are beset by strong socio-economic inequalities, with a substantial part of the population having very low incomes (Doumenge 1987; Khan 1994), although not as pronounced as comparable countries (Republic of the Seychelles 2013).

The Seychelles' EEZ (declared in 1978; Republic of the Seychelles 1978) extends over almost 1.4 million km², which is the largest in the Western Indian Ocean (www.seaaroundus.org). Coral reefs are well developed around the main group of granitic islands located on the Mahé plateau, as well as around the satellite coral islands, with a total cover of 1,700 km² (Spalding *et al.* 2001).[6] Due to the high population density and reliance on the coastal environment for development, tourism, transport and fisheries, coral reefs around the main granitic islands are under high pressure, whereas those farther from these heavily populated areas are relatively well preserved (Spalding *et al.* 2001). Consequently, remote stocks appear to be under-exploited (Anon. 2004a), while inshore fisheries around the main islands and some Mahé Plateau fisheries are fully exploited or over-exploited (Mees *et al.* 1998; Wakeford 2001; Grandcourt and Cesar 2003; Robinson and Shroff 2004). Historically, fisheries were mostly restricted to inshore areas around the main islands, but were expanded to the plateau and outer islands as motorized fleets developed in the 1960s (Wakeford 2001). Fisheries fleets in the Seychelles consist of three main types:

- A fleet of small and large (5–13 m LOA) outboard- or inboard-powered boats targeting demersal and pelagic species on or near shallow waters (typically 0–60 m) of the banks and reefs. Most catches of this artisanal fisheries sub-sector are consumed locally (Ghosh 1990; Alexis and Chang-Sam 2006);
- A semi-industrial fleet of small longliners targeting large pelagics (mostly swordfish and tuna) further offshore (Wendling *et al.* 2003; Kolody *et al.* 2011). This fleet started to develop in 1995 (Wendling *et al.* 2003);
- An industrial fleet of foreign-owned and foreign or Seychelles-flagged purse-seiners and longliners targeting large pelagics throughout the region. This fleet developed in the mid-1980s.

In an effort to preserve marine habitats and resources from degradation and overexploitation, the Government of the Seychelles adopted a number of precautionary fisheries management measures in the early stages of fisheries development. Licenses are required for all vessels longer than seven meters and for smaller vessels with engines or those that target sensitive species such as holothurians (Michaud 1995; Martín 2011).[7] Also, demersal trawling and spearfishing are forbidden in the entire EEZ, and there are limits on the total number of licenses allocated every year for the holothurian and lobster fisheries (Michaud 1995). Also, Seychelles-flagged and foreign industrial fleets are excluded from the shallow banks and reefs, and exploitation of all species except large pelagics is reserved for nationals. Last but not least, there was a network of 17 marine protected areas as of 2008 (UNEP 2008), including the Natural World Heritage Site of Aldabra Atoll (enlisted in 1982; whc.unesco.org/en/list/185).

Catch assessment surveys were first implemented in 1985 following the establishment of the Seychelles Fishing Authorities (SFA; Robinson and Shroff 2004). However, SFA noted in its 2012 report than lower catch data might result from a lack of coverage of landing sites (SFA 2014). Although there have been significant improvements in the last couple of decades (for example thanks to the implementation of logbooks on both purse-seiners and longliners), effective monitoring, control and surveillance of this large EEZ is still lacking (Michaud 1995; Wakeford 2001; Anon. 2004a; SFA 2014), with only two long-range patrol vessels (which spent between seven and 107 days at sea annually in recent years) and marginal aircraft surveillance (3.2–216 hours per year; Anon. 2004a; SFA 2014). However, the coverage by vessel monitoring system is high (SFA 2014).

In this report, we apply to the Seychelles the reconstruction methods developed around principles in Pauly (1998), described in Zeller *et al.* (2007) and applied worldwide by the *Sea Around Us* (see, e.g., Harper and Zeller 2012; Harper *et al.* 2012; Zeller and Harper 2009; Zeller and Pauly 2007). We aim to improve the overall quality of fisheries statistics by thoroughly reviewing the available literature and re-estimating the total extraction of marine fish since 1950.

[4] Noteworthy, 30% of the artisanal fleet was damaged by the December 2004 tsunami, but the sector quickly recovered (SFA 2007).

[5] In the *Sea Around Us* database, this 'semi-industrial' sector is labeled as 'industrial', in order to allow the data to be spatially allocated to the entire EEZ, rather than solely to the inshore fishing area.

[6] These coral reefs, like all those of the region, were highly impacted by the 1997–98 El Niño event, with a 50–90% mortality rate (Spalding *et al.* 2001; Spalding and Jarvis 2002). This El Niño event also resulted in decreases in fish abundance, even in protected areas (Pistorius and Taylor 2009). The Seychelles also host a marginal mangrove forest, as well as small seagrass beds (Spalding *et al.* 2001).

[7] Interestingly, fishers must also apply for a special license to fish outside the EEZ (Martín 2011).

Material and Methods

The fisheries statistics software of the Food and Agriculture Organization of the United Nations (FAO), FishStat (FAO 2013), includes catch data for up to 35 taxa (in 2009) in five FAO Areas. Based on a preliminary review of the literature, it appeared that catch data reported by FAO on behalf of the Seychelles include catches by foreign-owned vessels that are Seychelles-flagged. The first step of the reconstruction was therefore to separate the truly domestically owned catch from the foreign owned catch.

'Domestic' vs. 'Foreign' catch

Of the 46 taxa reported by FAO, eight are exclusively caught in FAO Areas other than Area 51 (Western Indian Ocean), to which the Seychelles belong (i.e., *Merluccius hubbsi* [Argentine hake], *Thunnus thynnus* [Atlantic bluefin tuna], *Macruronus magellanicus* [Patagonian grenadier], *Loligo gahi* [Patagonian squid], *Dissostichus eleginoides* [Patagonian toothfish], *Genypterus blacodes* [pink cusk-eel], Rajiformes [rays, stingrays, mantas nei], and *Salilota australis* [tadpole codling]). Since there is no distant-water fishing by Seychellois vessels, the entire catch of these eight taxa were not treated here but rather considered as if the Seychelles was acting as a flag of convenience (unknown beneficiary).

Of the remaining 38 taxa reported to be caught in the Western Indian Ocean, 19 were species of large pelagics. The catch for these 19 large pelagic taxa is virtually identical to the data published by the Indian Ocean Tuna Commission (IOTC) for the Seychelles in the Western Indian Ocean, as part of its nominal database (which contains information regarding gears; IOTC 2014). Therefore, it was possible to re-allocate the FAO catch of these taxa to various gears. To do this, we applied the gear breakdown published by IOTC to the FAO data. Once this step was performed, it was possible to determine whether a gear was used by the artisanal or semi-industrial domestic fleets, or the large-scale industrial foreign fleet. For this, we deemed both 'purse seine' and industrial 'longline' gears to belong to foreign fleets, whereas the other gears were automatically considered to be part of the domestic fleets (the rest of the FAO data — consisting of taxa not accounted for by IOTC — was automatically allocated to the domestic fleet). This re-allocation was motivated by the fact that both industrial purse-seiners and longliners, although flagged in the Seychelles, are owned by foreign interests. In 2012, there were six Spanish-owned purse-seiners and 23 Japanese- and Taiwanese-owned longliners (SFA 2012a).

This re-allocation allowed us to distinguish the different components of the reported data based on the ownership of the catch and vessel: only the catch whose ownership was from the Seychelles was treated here. The catch whose ownership was foreign (industrial purse-seine and longline fleets owned by European and Asian firms, but flagged in the Seychelles) represented 79.1% of the total FAO catch and was dealt with as part of the global tuna atlas produced by the *Sea Around Us* (Le Manach *et al.* in press).

This methodology produced data that formed the basis for the reconstruction presented in this report. This baseline is compatible with first-hand data published by the Seychelles Fishing Authority from 1985 to 2005 ($r^2 = 0.89$; de Moussac 1987a,b, 1988; SFA 1989, 1990a, 1991–2003, 2005–2008, 2012b), and 50% higher but with a similar trend from 2005 onward.

Artisanal fisheries

Composition and evolution of the fleet

The artisanal fleet is the only historical fishing sector in the Seychelles, and is of paramount importance to the population of the Seychelles, notably with regards to its daily animal protein needs.

Historically, this fleet essentially consisted of *pirogues*, which were increasingly replaced by other types of boats called whalers and schooners (the latter being introduced in 1974; Payet 1996), which are usually equipped with freezers and inboard motors. Furthermore, plastic and fiber-glass hull outboards equipped with motors were introduced in the early 1970s, and considerably changed the structure of the fleet (Bach 1992; Payet 1996). This shift in the fleet composition allowed local fishers to expand their fishing grounds by going farther offshore (Bach 1988; de Moussac and Bach 1988).

Despite precise number regarding the composition of the fleet since the mid-1980s, there is no time-series covering the entire 1950–2010 period. As a first step in the reconstruction process, we re-estimated the number of boats by type since 1950 (Figure 2), following a series of simple assumptions:

- Based on Bach (1992) and Payet (1996), we set the number of schooners at zero in 1973. To reflect an important increase in the number of boats during the first few years of a fishery, we then assumed that their number reached half of the first anchor point found in the literature (26 in 1985, but assumed similar in 1983–84; de Moussac 1987a; Payet 1996) five years later (i.e., 13 schooners in 1978). The rest of the time-series was provided in other reports (Payet 1996; SFA 1999, 2002, 2005–2008, 2012b);[8]

[8] SFA (1990a) reported somewhat different numbers for 1989, but we chose to use the updated numbers reported by SFA (2002), as they may have included corrections.

- For whalers, we set their number at zero in 1957 based on Wakeford (2001). Similarly to schooners, we then assumed that their number reached half of the first anchor point found in the literature (37 in 1985 and 53 in 1986; de Moussac 1987a; SFA 2002), i.e., 18.5 whalers in 1962. The rest of the time-series was provided in other reports (Payet 1996; SFA 1999, 2002, 2005–2008, 2012b);
- Based on Wakeford (2001), we set the number of outboards at zero in 1980. Given that the first anchor point found in the literature (222 in 1985, but assumed similar in 1983–84; Payet 1996; 171 in 1989; SFA 2002) was only 3 years later, we simply interpolated their number between 1980 and 1983. The rest of the time-series was provided in other reports (Payet 1996; SFA 1999, 2002, 2005–2008, 2012b);
- Finally, going backward from the first anchor point found in the literature (125 in 1985; de Moussac 1987a; Payet 1996), we assumed that the number of *pirogues* declined by 12.5% since the introduction of whalers (in 1983), another 12.5% between the introduction of schooners (in 1974) and whalers, and another 12.5% between the introduction of outboards (in 1971) and schooners. Between 1950 and 1970, the ratio of the number of *pirogues* to the total population in 1971 was applied throughout (i.e., one *pirogue* for 307 inhabitants).[9] The rest of the time-series was provided in other reports (Payet 1996; SFA 1999, 2002, 2005–2008, 2012b).

The resulting time-series (Figure 2) was used in the next section to re-estimate the catch of the Seychelles artisanal fleet prior to the establishment of SFA in 1984 and the implementation of a proper catch survey.

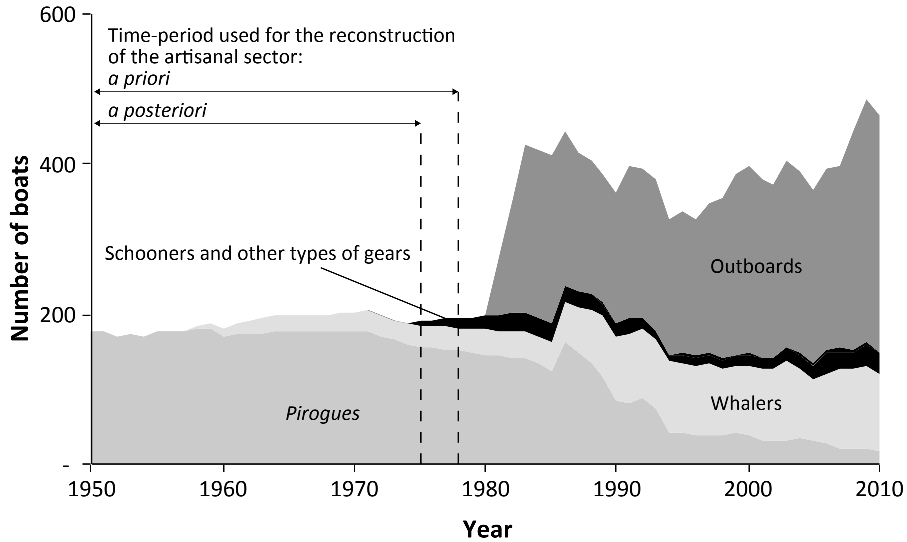

Figure 2. Reconstructed time-series of the number of artisanal boats by type, 1950–2010. This time-series was only used from 1950 to 1975 to reconstruct artisanal catches.

<u>Catches and reconstruction</u>

The artisanal fleet mostly uses handlines and traps (traps are essentially used by small boats, whereas whalers and schooners virtually use only handlines; Alexis and Chang-Sam 2006; Bach 1988, 1992; Bach and Lablache-Carrara 1991; de Moussac and Bach 1988; Martín 2011; SFA 2002; SFA 2003). The target species are snappers, jobfishes, groupers, threadfins, emperors (mainly *Lethrinus variegatus*), rabbitfishes, various species of crustaceans (such as *Ranina ranina* [Kona crab]),[10] and medium pelagics such as jacks and small tunas. Except Carangidae, which are actively targeted at times, large pelagics are mostly caught by troll when moving between fishing areas (Bach 1992). A commercial fishery for deep-water snappers started in the late 1980s (Intes and Bach 1989), with electronic reels, drop lines, sonars and GPS (dropline boats are included in the 'schooners and other types of boats' category in Figure 2; Mees and Rousseau 1997). A fishery for live reef food fish trialed in 1998 and 1999, after which it was closed and later prohibited by law (in 2005) due to concerns of over-exploitation and lack of technical means to carry out this fishery properly (Aumeeruddy and Robinson 2006).

In addition to these 'regular' reef and medium pelagics components of the artisanal fleet, there are two distinct sub-fisheries:

- A spiny lobster fishery, which is active 3–4 months per year around the months of December and January. The main targeted species are *Panulirus penicillatus*, *P. longipes*, *P. versicolor*, and *P. ornatus*, which are mostly caught at night by snorkelers and divers (Martín 2011).This fishery is very lucrative despite low catches and overfishing has probably occurred recently (SFA 2012b, 2014). For this reason, the number of licenses is controlled, sizes are regulated, and the fishery is closed most of the year (and sometimes the full year; Michaud 1995; SFA 2012b, 2014);
- A small holothurian (*bêche-de-mer*) fishery has been present since colonization, but catches increased rapidly in the 1990s due to rising demand by Asia and subsequent high prices (Aumeeruddy and Conand 2007, 2008; Pinault and Conand 2007; SFA 2013). There has been signs of over-exploitation (typical for these 'boom and bust' fisheries; Anderson *et al.* 2010), as divers now fish in deeper waters, similar to Madagascar (Le Manach *et al.* 2011, 2012). This fishery has been regulated since 1999 (i.e., poorly reported before; Pinault and Conand 2007; Aumeeruddy and Conand 2008), and there are currently around 25 licenses distributed annually (SFA 2014).

Given that the catch assessment surveys implemented in 1985 are considered to be accurate, the reconstruction of the artisanal sector only focused on the 1950–1984 period. For each type of vessels, we extracted from these surveys the information on the contribution of each gear towards the total catch (three anchor points in 1985–87 and one anchor point in 2002 for each series; de Moussac 1987a,b, 1988; SFA 2002, 2003). We then calculated an average

[9] The population time-series was extracted from the UN's demographic yearbook series from 1950 to 1959 (United Nations 1953–1959), and from the Seychelles' National Bureau of Statistics (www.nsb.gov.sc/statistics/demography) from 1960 onward.

[10] The Kona crab fishery only started in the mid-1980s, thanks to European funds (de Moussac and de San 1987).

contribution for each series and applied it back to the first year each type of vessel existed (see Figure 2). We also extracted CPUEs for each of these series from the catch assessment surveys,[11] and estimated them for missing years using different methods depending on the available data:

- For outboards, we used the 1986–87 average throughout back to 1981;
- For handlines used on whalers (traps were disregarded due to lack of data), we used the 2001–02 average CPUE throughout since their introduction in 1958. We also considered that there was an average of 6.5 crew members per boat (Bach 1988);
- For schooners, we used the 2001 CPUE throughout since their introduction in 1974. The average crew was assumed to be consisting of 6 members per boat (Bach 1988; Payet 1996).
- For *pirogues*, we considered that the CPUE of handlines in 1950 was 25% lower than in 1985. For traps and nets, we used the 1986–87 average throughout.

Finally, we assumed that all gears were active on average five days a week throughout the year, as fishers usually go out most days, except during the monsoon season. By multiplying the contribution of each gear by its CPUE, as well as the corresponding number of boats (and seamen if needed) and days at sea, the total catch of the artisanal fleet was reconstructed. This reconstructed time-series happen to almost match the FAO time-series in 1975, i.e., just a few years before the implementation of catch surveys by SFA. Therefore, we only replaced the FAO time-series by our reconstructed series from 1950 to 1974 (not 1984, as originally planned), and then used the data as provided by FAO.

However, it is fairly well accepted that poaching still occurs in most MPAs (Jennings *et al.* 1996; Wood 2004), but also that some components have been historically under-estimated (e.g., schooners and whalers until 1990; SFA 1991). Furthermore, although fisheries based on other islands are thought to be rather small (Bach 1988; de Moussac and Bach 1988), the catch survey implemented by SFA in the mid-1980s only accounts for the main three islands (SFA 1990b). Consequently, due to improving yet lacking monitoring capacities (Michaud 1995; Wakeford 2001; Anon. 2004a; SFA 2014), SFA still recently noted that a lack of coverage of landing sites and landing times likely resulted in under-estimated catches (SFA 2014). Therefore, we assumed that unreported catches decreased from 30% in 1978 (which is in line with the proportion of unreported catches in 1975–77 estimated above) to 15% in 1995 and then stabilized at that level.

With regards to the taxonomic breakdown, we applied the 1978–1982 proportions to both the unreported and reported components prior to 1978, and for 1978–2010, the annual FAO breakdown was applied to the unreported component.

Semi-industrial fleet

A fleet of semi-industrial longliners was created in 1995, with the aim to target large pelagics.[12] It is the only industrial sector in the Seychelles that is truly domestic.[13] The number of active vessels increased from two in 1995 to 10 in 2001 (Wendling *et al.* 2003; Anon. 2004b). The number of vessels then dropped to four in 2004, increased again to reach ten by 2009–10, and decreased to four in 2011 and seven in 2012 (SFA 2014). These longliners target tuna and swordfish around the Mahé plateau and in the northeastern part of the EEZ (Kolody *et al.* 2011), and usually catch between 200 and 300 tonnes annually (SFA 2014). Noteworthy, it is reported that there is a high depredation by false killer whales and sharks (Alexis and Chang-Sam 2006), similarly to La Réunion (Le Manach *et al.* this volume).

In the early 2000s, this fleet of longliners shifted to target sharks rather than tuna and swordfish, due to a European ban caused by high levels of cadmium (SFA 2005).[14] Sharks were finned for the Asian market, and carcasses were mostly discarded at sea due to the low value of the meat at local markets (SFA 2007). The EU removed the ban on tuna and swordfish imports in 2005, but longliners continued to target shark fins up until circa 2009. Blue sharks, oceanic whitetip sharks, silky sharks, mako sharks, and tiger sharks were the main target species (SFA 2012b).

For this sector, we assumed that the landings were correctly reported. However, based on information reported on depredation by cetaceans, we considered that discards were making 26%, 19%, 30%, 22%, 15%, and 11% of the total catch from 1995 to 2000, respectively (SFA 1996–1998, 2000, 2001). From 2001 to 2010, we used the average discard rate from 1999–2000 as real estimates are not available due to piracy in the area (SFA 2012b). We also assumed that half of the discarded sharks were unreported from 1995–2000. From 2001 to 2005 (i.e., during the EU ban of tuna and swordfish) we estimated shark discards using a linear regression of the decreasing discard rates between 1995 and 2000. As no longliners were engaged in shark finning in 2010 we estimated these discards as the average from the 1995–2000 period. Discards from 2006 to 2009 were linearly interpolated.

[11] Some of the CPUEs provided in de Moussac (1987a,b, 1988) and SFA (2002, 2003) seemed very different than other values in the time-series, so we did not use them. This was the case for the CPUEs of handlines and traps used on *pirogues*, in 2001 and 2002, respectively.

[12] Catches by longliners targeting swordfish were reported prior to 1994. Given the lack of information regarding this catch, we accepted as is.

[13] A bait fishery for *Decapterus* spp. was tested in the early 1980s to develop a pole-and-line fishery (Hallier 1989), but has not continued..

[14] This ban was criticized for its lack of coherence, as European vessels were still allowed to catch and land the same fish (Lahnalampi 2009).

Recreational fishery

Until 2002, annual SFA reports included estimates of catch by recreational fishers. The number of boats was low in the 1980s, ranging from 4–7 (Payet 1996).[15] During the 1990s, their number steeply increased, to reach 40 by 2000 (SFA 2005). Since 2003, logbooks are poorly transmitted, precluding catch data from being estimated and included in national data (SFA 2006–2008, 2012b). To date, there are no real estimates with regards to the number of vessels participating in this activity (SFA 2013, 2014).

For the purpose of this reconstruction, and in order to produce a time-series reflecting the aforementioned trends in this sector, we assumed that recreational fisheries started in 1971 (opening of the airport; i.e., no catch in 1970), reached 10% of the unreported artisanal fleet catches by 1990, and 25% by 2010 (proportion held constant afterward). We reallocated part of the unreported artisanal fleet catches rather than adding a whole new sector in order to avoid double-counting, as a portion of the recreational fishery's catch might have been included in official statistics, at least prior to 2003.

Results and Discussion

Overall,[16] the reconstructed domestic catch totalled nearly 320,000 t from 1950 to 2010 (of which 30% were unreported), and averaged 4,000 t annually until 1970 and then steeply increased with the introduction of outboards and schooners to reach almost 8,000 tonnes by the early 1980s. Since then, catches have been fluctuating, mostly between 4,500 and 8,000 t per year (Figure 3). The proportion of unreported catch decreased from slightly less than 80% of the total catch in 1950 to 15% by 2010. Discards have only existed since the mid-1990s and the inception of the domestic longline fleet, but they are marginal.

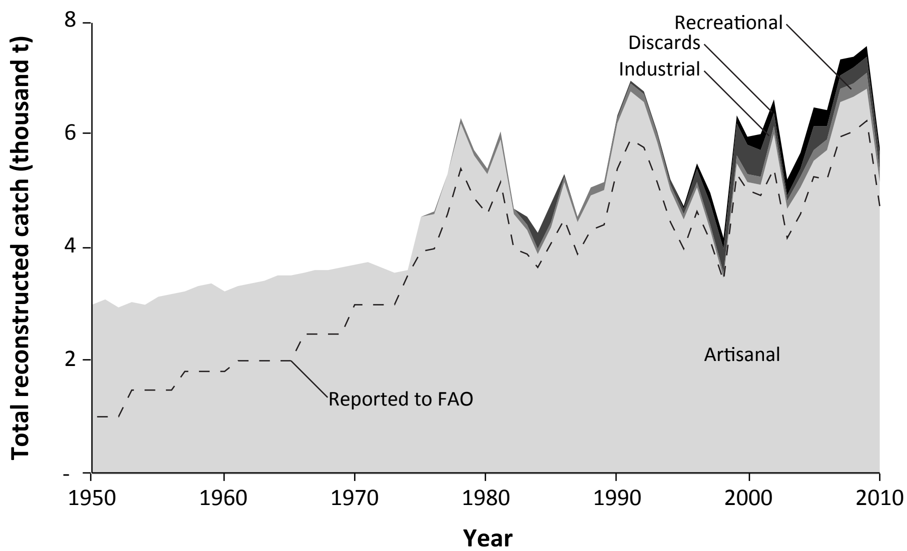

Figure 3. Total reconstructed catch by sector, compared to the data reported to FAO from 1950 to 2010 (dashed line). See Appendix Table A1 for details.

The artisanal has dominated the total catch, with an overwhelming 95.6% since 1950. The recreational sector, however, has increased its share (around 3.5% in 2010), similarly to the semi-industrial longline fleet, which made up on average 8.5% of the annual catch (Figure 3).

Jacks and pompanos (Carangidae) are the most widespread species, with 26.5% of the catch since 1950, followed by snappers (Lutjanidae), Indian mackerel (*Rastrelliger kanagurta*), emperors (Lethrinidae), kawakawa (*Euthynnus affinis*), and groupers (Serranidae), with 18.7%, 6.4%, 6.2%, 4.0%, and 3.5%, respectively (Figure 4).

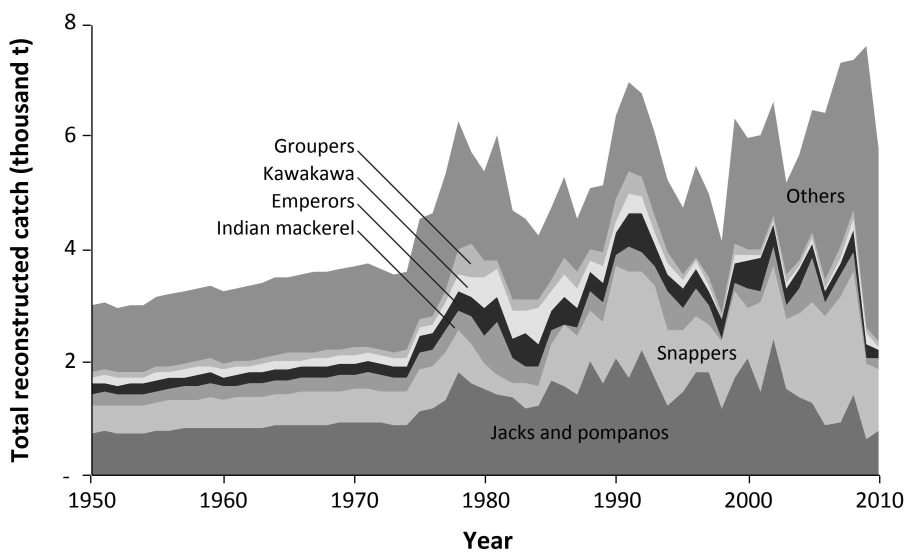

Figure 4. Total reconstructed catch by taxon, 1950–2010. See Appendix Table A2 for details.

The reconstructed time-series discussed here provides a more credible estimate of early catches, in contrast with the step-like increases in FAO data. However, the situation steeply increased in the early 1980s with the implementation of catch surveys, but also with the increasing enforcement and monitoring of

[15] This figure may, however, be an under-estimate, as the original catch assessment survey reported 17 sport fishing boats (SFA 1990b). This report also notes that the survey does not include catches on Sundays and public holidays (SFA 1990b), nor catches made by pleasure boats (which were estimated to be 50 in 1989; SFA 1990a).

[16] Only including the truly domestic catches, i.e., not including catches of the Seychelles-flagged vessels targeting tuna in the region, or other species in other oceans.

fishing activities. After the early 1980s, the increased reconstructed catches mostly account for poaching and under-reporting by artisanal and recreational sectors, but the situation is improving due to stricter enforcement.

We hope this improved time-series highlights some fundamental biases in official catch statistics, and will encourage improved data collection for fisheries operating in Seychelles' waters. For example, we believe that our recreational catch estimates are conservative, given the number of boats and economic opportunities associated with this sector. Therefore, real catches are probably higher, but difficult to record as they are likely landed outside official landing sites, or consumed by tourists without being declared. Further research would provide a better assessment of the recreational fishery, including its contribution to the national economy and implications for target species' stocks (see, e.g., reconstruction for La Réunion Island; Le Manach *et al.* this volume). Another important issue in the official statistics is the lack of accounting of shark catches by the semi-industrial fleet of longliners. Whereas official reports state that sharks have been increasingly targeted for their fins after the 2003 European ban on exports, official statistics show almost no shark catches at all. Our reconstructed time-series proposes an alternative catch for this group of vulnerable species, but better accounting would be needed.

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References

Alexis M and Chang-Sam A (2006) Fisheries industry of the Seychelles: at a crossroad. First Quarterly Review XXIV, Central Bank of Seychelles, Victoria (Seychelles). 29 p.

Anderson SC, Flemming JM, Watson RA and Lotze HK (2010) Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12(4): 317–339.

Anon. (2004a) Convention Spécifique n°8 : Seychelles. Evaluation ex-post du protocole d'accord de pêche entre les Seychelles et la Communauté européenne, et analyse de l'impact du futur protocole sur la durabilité, incluant une évaluation ex-ante — Rapport final. Contrat-cadre pour la réalisation d'évaluations, d'études d'impact et de suivi concernant les Accords de Partenariat dans le domaine de la pêche conclus entre la Communauté et les Pays Tiers — Projet Fish/2003/02, Oceanic Developpement and Megapesca, Concarneau (France). ix + 147 p.

Anon. (2004b) Convention Spécifique n°8 : Seychelles. Evaluation ex-post du protocole d'accord de pêche entre les Seychelles et la Communauté européenne, et analyse de l'impact du futur protocole sur la durabilité, incluant une évaluation ex-ante. Contrat-cadre pour la réalisation d'évaluations, d'études d'impact et de suivi concernant les Accords de Partenariat dans le domaine de la Pêche conclus entre la Communauté et les Pays Tiers — Projet FISH/2003/02, Oceanic Développement and MegaPesca Lda, Brussels (Belgium). ix + 147 p.

Aumeeruddy R and Conand C (2007) Seychelles' sea cucumber fishery: data on processed products and other parameters. SPC Beche de Mer Information Bulletin 26: 19–25.

Aumeeruddy R and Conand C (2008) Seychelles: a hotspot of sea cucumber fisheries in Africa and the Indian Ocean region. pp. 195–209 *In* Toral-Granda V, Lovatelli A and Vasconcellos M (eds.), Sea cucumbers. A global review of fisheries and trade. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Aumeeruddy R and Robinson J (2006) Closure of the live reef food fish fishery in Seychelles. SPC Live Reef Fish Information Bulletin 16: 3–9.

Bach P (1988) La pêche artisanale aux Seychelles. Rapport Scientifique 7, Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Victoria (Seychelles). 44 p.

Bach P (1992) Production et niveau d'exploitation des ressources démersales et semi-pelagiques exploitées par la pêche artisanale seychelloise sur le plateau de Mahé. Cybium 16(4): 345–360.

Bach P and Lablache-Carrara G (1991) La pêche à la ligne à main aux Seychelles. pp. 295–307 *In* Durand J-R, Lemoalle J and Weber J (eds.), La recherche scientifique face à la pêche artisanale. Symposium International ORSTOM-IFREMER, July 3–7, 1989, Montpellier (France). Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris (France).

de Moussac G (1987a) Seychelles artisanal fisheries statistics for 1985. Technical Report SFA/R&D/004, Seychelles Fishing Authority (SFA), Victoria (Seychelles). 86 p.

de Moussac G (1987b) Seychelles artisanal fisheries statistics for 1986. Technical Report SFA/R&D/003, Seychelles Fishing Authority (SFA), Victoria (Seychelles). 84 p.

de Moussac G (1988) Seychelles artisanal fisheries statistics for 1987. Technical Report SFA/R&D/005, Seychelles Fishing Authority (SFA), Victoria (Seychelles). 87 p.

de Moussac G and Bach P (1988) Coup d'oeil sur la pêche artisanale aux Seychelles. La Pêche Maritime 1317: 101–110.

de Moussac G and de San M (1987) The Kona crab fishery — The Seychelles experience. SWIO Fisheries Bulletin, RAF/79/065. 5 p.

Doumenge J-P (1987) Les îles Seychelles. Annales de Géographie 96(533): 78–102.

Ellis S (1996) Africa and international corruption: the strange case of South Africa and Seychelles. African Affairs 95: 165–196.

FAO (2013) FishStatJ—Software for fishery statistical time series. V2.1.1. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Filliot J-M (1983) Découvreurs des Seychelles. La Nouvelle Revue Maritime: 46–60.

Ghosh R (1990) The fisheries sector in the economy of the Seychelles. Pp. 111–120 *In* Appleyard R and Ghosh R (eds.), Economic planning and performance in Indian Ocean Island States. National Centre for Development Studies, Australian National University, and Centre for Migration and Development Studies, University of Western Australia, Canberra (Australia).

Grandcourt HSJ and Cesar HSJ (2003) The bio-economic impact of mass coral mortality on the coastal reef fisheries of the Seychelles. Fisheries Research 60(2–3): 539–550.

Hallier J-P (1989) Aspects of the biology of the major tuna baitfishes from the Seychelles. ACIAR Proceedings 30, Seychelles Fishing Authority, Victoria (Seychelles). 60–69 p.

Harper S and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada). 143 p.

Harper S, Zylich K, Boonzaier L, Le Manach F, Pauly D and Zeller D, editors (2012) Fisheries catch reconstructions: islands, part III. Fisheries Centre Research Reports 20 (5). University of British Columbia, Vancouver (Canada). 134 p.

Intes A and Bach P (1989) La campagne "CEPROS" du N.O. ALIS sur les accores du plateau Seychellois. Convention France/Seychelles No 87/206/01, Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM), and Seychelles Fishing Authority (SFA), Victoria (Seychelles). 119 p.

IOTC (2014) Nominal catch database (updated: May 20, 2014).

Jennings S, Marshall SS and Polunin NVC (1996) Seychelles' marine protected areas: comparative structure and status of reef fish communities. Biological Conservation 75(3): 201–209.

Khan Q (1994) Republic of Seychelles — Poverty in paradise. The World Bank, Population and Human Resources Division, Washington, DC (USA). iv + 20 p.

Kimani EN (1995) Coral reef resources of East Africa: Kenya, Tanzania and the Seychelles. Naga, the ICLARM Quarterly 18(4): 4–7.

Kolody D, Robinson J and Lucas V (2011) Swordfish catch rate standardization for the Seychelles semi-industrial and industrial longline fleets. IOTC-2010-WPB-04, Indian Ocean Tuna Commission (IOTC), Victoria (Seychelles).

Lahnalampi R (2009) Why coherence counts for development. OECD Observer 270/271.

Le Manach F, Bach P, Barret L, Guyomard D, Fleury P-G, Sabarros PS and Pauly D (this volume) Reconstruction of the domestic and distant-water fisheries catch of La Réunion (France), 1950–2010.

Le Manach F, Chavance P, Cisneros-Montemayor AM, Lindop A, Padilla A, Schiller L, Zeller D and Pauly D (in press) Global catches of large pelagic fishes, with emphasis on the high seas. *In* Pauly D and Zeller D (eds.), Global atlas of marine fisheries: ecosystem impacts and analysis. Island Press, Washington, DC (USA).

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–225.

Le Manach F, Gough C, Humber F, Harper S and Zeller D (2011) Reconstruction of total marine fisheries catches for Madagascar (1950–2008). Pp. 21–37 *In* Harper S and Zeller D (eds.), Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19(4). University of British Columbia, Vancouver (Canada).

Marshall NT (1997) The Seychelles shark fishery. Pp. 13–18 *In* Marshall NT and Barnett R (eds.), The trade in sharks and shark products in the western Indian and southern Indian and south east Atlantic Oceans. TRAFFIC International, Nairobi (Kenya).

Martín JI (2011) Fisheries in the Seychelles and fisheries agreements with the EU. Note IP/B/PECH/NT/2011_04, European Parliament, Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies—Fisheries, Brussels (Belgium). 58 p.

Mees CC and Rousseau J (1997) The potential yield of the lutjanid fish *Pristipomoides filamentosus* from the Mahé Plateau, Seychelles: managing with uncertainty. Fisheries Research 33: 73–87.

Mees CC, Shotton R and Margueritte M (1998) An inshore fisheries management strategy for Seychelles. FAO/TCP/SEY/6713(A), Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 117 p.

Michaud P (1991) Impact d'un développement thonier sur une économie insulaire : l'exemple des Seychelles. Pp. 33–38 *In* Le Gall J-Y, Reviers X and Roger C (eds.), Actes de la Conférence Thonière Régionale, May 9–12, 1990, Antananarivo (Madagascar). Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris (France).

Michaud P (1995) Coastal legislation for the sustainable development of marine resources. Seminar on coastal zone protection, January 23–27, 1995. 17 p.

Michaud P (2003) Experience from the bilateral fisheries access agreement, impact on the economy and implications for Seychelles of the outcome of the WTO mediation on the case of tuna between the EU and Thailand and the Philippines. Seminar on ACP-EU fisheries relations: towards a greater sustainability, ACP Secretariat, April, 7–9 2003 Brussels (Belgium). 12.

Nevill J, Robinson J, Giroux F and Isidore M (2007) Seychelles national plan of action for the conservation and management of sharks. Seychelles Fishing Authority, Victoria (Seychelles). 59 p.

Parks WW (1991) A Review of Indian Ocean Fisheries for Skipjack Tuna, *Katsuwonus pelamis*, and Yellowfin Tuna, *Thunnus albacares*. Marine Fisheries Review 53(1): 1–9.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4–10.

Payet RJ (1996) Artisanal fishing boats in Seychelles. Technical Report SFA/R&D/041 Seychelles Fishing Authority (SFA), Victoria (Seychelles). v + 25 p.
Pinault M and Conand C (2007) Sea cucumber fisheries in WIO: Masma project Seychelles — Field survey 20–26 May 2007. Western Indian Ocean Marine Science Association.
Pistorius PA and Taylor FE (2009) Declining catch rates of reef fish in Aldabra's marine protected area. Aquatic Conservation: Marine and Freshwater Ecosystems 19(S1): S2-S9.
Republic of the Seychelles (1978) Exclusive economic zone (No.2) Order, 1978.
Republic of the Seychelles (2013) Millennium Development Goals—Status report 2013. Ministry of Foreign Affairs, Victoria (Seychelles). v + 126 p.
Robinson J and Shroff J (2004) The fishing sector in Seychelles: an overview, with an emphasis on artisanal fisheries. Seychelles Medical and Dental Journal 7(1): 52–56.
Robinson J, Aumeeruddy R, Isidore M, Payet RJ, Marguerite MA, Laval M, Domingue G and Lucas V (2006) Southwest Indian Ocean — Seychelles. Pp. 425–435 *In* De Young C (ed.) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper 488 (Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).
Robinson J, Guillotreau P, Jiménez-Toribio R, Lantz F, Nadzon L, Dorizo J, Gerry C and Marsac F (2010) Impacts of climate variability on the tuna economy of Seychelles. Climate Research 43(3): 149–162.
SFA (1989) Annual report 1988. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 17 p.
SFA (1990a) Annual report 1989. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 21 p.
SFA (1990b) Artisanal catch assessment survey — Notes for implementation — Updated August 1990. Research section, Seychelles Fishing Authority (SFA), Victoria (Seychelles). 36 p.
SFA (1991) Annual report 1990. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 19 p.
SFA (1992) Annual report 1991. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 18 p.
SFA (1993) Annual report 1992. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 17 p.
SFA (1994) Annual report 1993. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 21 p.
SFA (1995) Annual report 1994. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 34 p.
SFA (1996) Annual report 1995. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 33 p.
SFA (1997) Annual report 1996. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 40 p.
SFA (1998) Annual report 1997. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 46 p.
SFA (1999) Annual report 1998. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 54 p.
SFA (2000) Annual report 1999. Seychelles Fishing Authority (SFA), Victoria (Seychelles). v + 52 p.
SFA (2001) Annual report 2000. Seychelles Fishing Authority (SFA), Victoria (Seychelles). 72 p.
SFA (2002) Seychelles artisanal fisheries statistics for 2001. Seychelles Fishing Authority (SFA), Victoria (Seychelles). xi + 85 p.
SFA (2003) Seychelles artisanal fisheries statistics for 2002. Seychelles Fishing Authority (SFA), Victoria (Seychelles). x + 85 p.
SFA (2005) Annual report 2003. Seychelles Fishing Authority (SFA), Victoria (Seychelles). iv + 64 p.
SFA (2006) Annual report 2004. Seychelles Fishing Authority (SFA), Victoria (Seychelles). v + 75 p.
SFA (2007) Annual report 2005. Seychelles Fishing Authority (SFA), Victoria (Seychelles). vi + 74 p.
SFA (2008) Annual report 2006. Seychelles Fishing Authority (SFA), Victoria (Seychelles). vi + 65 p.
SFA (2012a) Information on Seychelles Flag vessel for 2012. Seychelles Fishing Authority (SFA), Victoria (Seychelles).
SFA (2012b) Annual report 2007–2010. Seychelles Fishing Authority (SFA), Victoria (Seychelles). ix + 96 p.
SFA (2013) Annual report 2011. Seychelles Fishing Authority (SFA), Victoria (Seychelles). x + 93 p.
SFA (2014) Annual report 2012. Seychelles Fishing Authority (SFA), Victoria (Seychelles). xiii + 75 p.
Spalding MD and Jarvis GE (2002) The impact of the 1998 coral mortality on reef fish communities in the Seychelles. Marine Pollution Bulletin 44(4): 309–321.
Spalding MD, Ravilious C and Green EP, editors (2001) World atlas of coral reefs. University of California Press, Berkeley, CA (USA). 416 p.
UNEP (2008) National and regional networks of marine protected areas: a review of progress. World Conservation Monitoring Centre, United Nations Environment Programme, Cambridge (UK) vi + 144 p.
United Nations (1953a) Demographic yearbook — 1952. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). 518 p.
United Nations (1953b) Demographic yearbook — 1953. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). 441 p.
United Nations (1954) Demographic yearbook — 1954. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). 729 p.
United Nations (1955) Demographic yearbook — 1955. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). xii + 781 p.
United Nations (1956) Demographic yearbook — 1956. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). viii + 744 p.
United Nations (1957) Demographic yearbook — 1957. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). viii + 656 p.
United Nations (1958) Demographic yearbook — 1958. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). viii + 541 p.

United Nations (1959) Demographic yearbook — 1959. Department of Economic Affairs, Statistical Office of the United Nations, New York, NY (USA). x + 719 p.

Wakeford RC (2001) Management of the Seychelles artisanal fishery. PhD thesis, University of London, Imperial College of Science, Technology and Medicine, London (UK). 377 p.

Wendling B, Lucas V, Bargain R-M, Poisson F and Taquet M (2003) Characteristics of swordfish (Xiphias gladius) catches achieved by experimental fishing using instrumented longline in the Seychelles exclusive economic zone (EEZ): preliminary results of an experimental long line fishing program: "Programme d'Action de la Pêche Palangrière Seychelloise — PAPPS". Pp. 315–324 *In* 3rd Session of the IOTC Working Party on Billfish, November 10–12, 2003, Perth (Australia).

Wood L (2004) Motives for poaching in Marine Protected Areas in the Seychelles. Western Indian Ocean Journal of Marine Science 3(2): 199–208.

Zeller D and Harper S, editors (2009) Fisheries catch reconstructions: islands, part I. Fisheries Centre Research Reports 17(5). University of British Columbia, Vancouver (Canada). 108 p.

Zeller D and Pauly D, editors (2007) Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15(2). University of British Columbia, Vancouver (Canada). 163 p.

Zeller D, Booth S, Davis GE and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. Total reconstructed catch by sector compared to the data reported to FAO, as well as total catch by Seychelles-flagged but foreign-owned vessels as reported to FAO.

Year	Domestic catch						Foreign-owned catch		
	Reconstructed catch					Reported to FAO			
	Artisanal	Industrial	Discards	Recreational	Total		Asia	Flag of convenience	Spain
1950	3,018	-	-	-	3,018	1,000	-	-	-
1951	3,081	-	-	-	3,081	1,000	-	-	-
1952	2,977	-	-	-	2,977	1,000	-	-	-
1953	3,038	-	-	-	3,038	1,500	-	-	-
1954	3,015	-	-	-	3,015	1,500	-	-	-
1955	3,153	-	-	-	3,153	1,500	-	-	-
1956	3,207	-	-	-	3,207	1,500	-	-	-
1957	3,258	-	-	-	3,258	1,800	-	-	-
1958	3,322	-	-	-	3,322	1,800	-	-	-
1959	3,383	-	-	-	3,383	1,800	-	-	-
1960	3,260	-	-	-	3,260	1,800	-	-	-
1961	3,339	-	-	-	3,339	2,000	-	-	-
1962	3,379	-	-	-	3,379	2,000	-	-	-
1963	3,442	-	-	-	3,442	2,000	-	-	-
1964	3,511	-	-	-	3,511	2,000	-	-	-
1965	3,542	-	-	-	3,542	2,000	-	-	-
1966	3,568	-	-	-	3,568	2,500	-	-	-
1967	3,597	-	-	-	3,597	2,500	-	-	-
1968	3,632	-	-	-	3,632	2,500	-	-	-
1969	3,674	-	-	-	3,674	2,500	-	-	-
1970	3,726	-	-	-	3,726	3,001	-	-	-
1971	3,767	-	-	7	3,774	3,001	-	-	-
1972	3,662	-	-	16	3,678	3,001	-	-	-
1973	3,555	-	-	26	3,581	3,000	-	-	-
1974	3,600	-	-	28	3,628	3,500	-	-	-
1975	4,543	-	-	31	4,573	3,950	-	-	-
1976	4,612	-	-	43	4,655	4,010	-	-	-
1977	5,290	-	-	39	5,329	4,600	-	-	-
1978	6,210	-	-	93	6,303	5,400	-	-	-
1979	5,641	-	-	91	5,731	4,905	-	-	-
1980	5,318	-	-	91	5,409	4,624	-	-	-
1981	5,944	-	-	107	6,051	5,169	-	-	-
1982	4,592	-	-	86	4,678	3,993	-	-	-
1983	4,335	117	-	84	4,536	3,886	-	-	-
1984	3,912	283	-	78	4,273	3,684	-	-	-
1985	4,392	290	-	90	4,771	4,108	-	-	0
1986	5,178	30	-	107	5,315	4,532	-	-	0
1987	4,450	21	-	93	4,564	3,890	-	-	0
1988	4,956	24	-	104	5,084	4,333	-	-	0
1989	5,042	18	-	106	5,166	4,402	-	-	0
1990	6,192	43	-	130	6,364	5,427	-	-	0
1991	6,757	47	-	144	6,947	5,922	-	-	2,218
1992	6,581	66	-	141	6,788	5,788	-	-	875
1993	5,896	51	-	127	6,074	5,178	-	-	-
1994	5,028	88	-	107	5,222	4,459	-	-	-
1995	4,495	94	71	95	4,755	4,003	-	-	5
1996	5,055	245	90	112	5,502	4,641	-	-	66
1997	4,308	377	194	101	4,979	4,122	6	2,302	7,613
1998	3,483	414	190	86	4,172	3,442	103	3,886	16,455
1999	5,514	538	150	142	6,343	5,333	438	22	28,432
2000	5,155	534	155	138	5,982	5,016	1,342	320	26,100
2001	5,119	472	281	143	6,015	4,924	2,514	4,168	41,986
2002	6,006	203	244	175	6,628	5,425	5,007	3,475	49,476
2003	4,684	116	266	142	5,209	4,190	12,496	732	68,604
2004	5,086	178	283	160	5,707	4,601	13,289	623	82,158
2005	5,550	423	340	181	6,494	5,249	12,798	155	90,478
2006	5,732	235	288	194	6,448	5,219	5,710	288	81,522
2007	6,602	238	253	230	7,324	5,979	7,118	712	51,705
2008	6,690	252	185	241	7,368	6,069	5,044	1,702	56,385
2009	6,838	298	202	254	7,593	6,244	5,241	1,875	67,737
2010	5,155	277	177	198	5,806	4,760	5,623	1,502	75,224

Appendix Table A2. Total reconstructed catch by taxon, 1950–2010.

Year	Jacks and pompanos	Snappers	Indian mackerel	Emperors	Kawakawa	Sea basses and groupers	Others
1950	773	475	208	172	116	100	1,173
1951	789	485	213	176	118	102	1,198
1952	762	469	205	170	114	99	1,158
1953	778	479	210	173	117	101	1,181
1954	772	475	208	172	116	100	1,172
1955	807	497	218	180	121	105	1,226
1956	821	505	221	183	123	106	1,247
1957	834	513	225	186	125	108	1,267
1958	851	523	229	189	127	110	1,292
1959	866	533	233	193	130	112	1,315
1960	835	514	225	186	125	108	1,268
1961	855	526	230	190	128	111	1,298
1962	865	532	233	193	130	112	1,314
1963	881	542	238	196	132	114	1,338
1964	899	553	242	200	135	117	1,365
1965	907	558	244	202	136	118	1,377
1966	914	562	246	203	137	118	1,387
1967	921	567	248	205	138	119	1,399
1968	930	572	251	207	139	121	1,412
1969	941	579	254	209	141	122	1,428
1970	954	587	257	212	143	124	1,449
1971	966	595	260	215	145	125	1,467
1972	942	579	254	210	141	122	1,430
1973	917	564	247	204	137	119	1,392
1974	929	572	250	207	139	120	1,410
1975	1,171	721	316	261	175	152	1,778
1976	1,192	733	321	265	179	154	1,810
1977	1,364	839	368	304	204	177	2,072
1978	1,867	700	350	350	292	467	2,276
1979	1,637	677	526	347	347	573	1,625
1980	1,545	434	501	499	554	275	1,600
1981	1,447	369	926	446	480	172	2,211
1982	1,379	252	469	318	525	173	1,563
1983	1,204	438	283	612	368	203	1,428
1984	1,261	357	318	386	638	151	1,162
1985	1,677	657	232	345	383	156	1,321
1986	1,595	1,066	41	466	379	335	1,433
1987	1,456	1,044	129	362	322	290	962
1988	2,042	876	352	353	180	217	1,064
1989	1,649	1,073	346	363	272	275	1,188
1990	2,068	1,625	238	359	221	404	1,450
1991	1,765	1,842	476	583	344	386	1,552
1992	2,261	1,356	362	657	308	336	1,509
1993	1,753	1,595	357	417	191	292	1,468
1994	1,252	1,311	688	335	200	156	1,281
1995	1,508	1,092	378	345	147	83	1,202
1996	1,843	996	500	347	109	78	1,630
1997	1,838	831	351	259	114	146	1,440
1998	1,188	1,209	29	330	48	53	1,315
1999	1,739	1,550	119	336	186	169	2,244
2000	2,083	903	348	500	89	66	1,993
2001	1,519	1,543	215	571	57	126	1,984
2002	2,417	1,303	333	398	69	88	2,022
2003	1,532	1,245	244	277	140	109	1,661
2004	1,396	1,460	486	306	76	114	1,869
2005	1,310	1,768	772	270	84	110	2,180
2006	912	1,931	219	200	74	145	2,969
2007	935	2,224	393	225	90	176	3,280
2008	1,470	2,152	348	405	156	185	2,652
2009	645	1,344	107	260	161	98	4,977
2010	811	1,093	208	116	45	93	3,441

Failed State: Reconstruction of Domestic Fisheries Catches in Somalia 1950–2010*

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Abstract

Somalia is a country in north eastern Africa that has suffered a high degree of political and social instability since the collapse of its last national government in 1991. This study reconstructed domestic fisheries catch data between 1950 and 2010, including the industrial, artisanal, subsistence and recreational sectors. We found that the Somali reconstructed total catch was nearly two times the landings reported by the FAO on behalf of Somalia, most of which was attributed to the reconstructed small-scale sector. Although there was an initial decline in catches after the collapse of government, small-scale catches strongly increased after the mid-1990s, as a result of increased private investment in artisanal fisheries, changes in seafood consumption habits and population displacement to the coast due to the civil war. However, the absence of monitoring and enforcement in Somali waters, coupled with the lack of transparency amongst international monitoring agencies in the Indian Ocean, resulted in a lack of reliable data for the significant level of illegal and semi-illegal foreign fishing activity also taking place in Somalia's Exclusive Economic Zone. Therefore, such activities were not included in this study.

Introduction

The Federal Republic of Somalia (referred to here as 'Somalia') is located on the Horn of Africa, has an extensive Exclusive Economic Zone (EEZ; over 830,000 km^2, i.e., the 5th largest Exclusive Economic Zone (EEZ) of any country in Africa; www.seaaroundus.org), and is bordered in the north by the Gulf of Aden and in the east by the Indian Ocean (Figure 1). The marine ecosystem is characterized by seasonal monsoons driving a strong south-north current along the east African coast, resulting in a significant upwelling off the coast of northeast Somalia. This system is highly productive, but the great quantity of small pelagic fish usually found in upwelling areas (Rykaczewski and Checkley 2008) does not occur to the same extent in the upwelling area off Somalia. However, the region is known for the seasonally high abundance of large pelagic fish (tuna and billfishes) that has attracted distant-water fleets (mainly from Europe and East Asia) to fish for these high value species (Bakun *et al.* 1998). In contrast, the environmental conditions have not been quite as favorable for the domestic fisheries sector; the coast does not have many natural harbours, and climate and ocean features give rise to large variation in the available resources between seasons and years (Haakonsen 1983). The Somali people have historically had a nomadic or agro-pastoral culture (Mukhtar 1996; UNEP 2005), similarly to other countries in the region, e.g., Djibouti; see Colléter *et al.* this volume). Thus, despite their abundant fish resources, the Somalis in general have had very limited interest in fishing[1] and their seafood consumption is thought to be among the lowest in the world. However, the coastal communities have a tradition of fishing, but the fraction of fishers compared to the total population has always been small (UNEP 2005).

Figure 1. The Exclusive Economic Zone (EEZ) of Somalia, based on general UNCLOS principles, and the shelf waters to 200 m depth.

Somalia gained its independence in 1960, when the former colonial territories of Italian Somalia and British Somaliland united and became the Somali Republic. During the 1960s, two elections were held. In 1969 the sitting president was assassinated and Mohamed Siad Barre came into power (UNEP 2005). He declared Somalia a socialist state, and the establishment of co-operatives became the basis for the socio-economic development in the country

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[1] Fish has actually been considered as unfit for human consumption in many parts of Somalia (Simoons 1974).

(Laitin and Samatar 1984). Despite the introduction of around 500 mechanized boats in the early 1970s, the lack of any fishing tradition and poor maintenance resulted in poor outcomes (Anon. 1982; FAO 2005a). In the late 1980s, a civil war started in the northwestern part of Somalia, and in 1991 the Siad Barre regime ended. The fight among different clans for power and control of the capital city of Mogadishu and other areas has impacted the country ever since. In 1991, former British Somaliland in the northwest claimed independence (as 'Somaliland'), and in 1998 the northeastern part of Somalia claimed an autonomous state of Puntland (UNEP 2005). Neither Somaliland nor Puntland have been recognized by the international community (UNEP 2005). The population in Somalia was about 2.2 million at the time of independence in 1960, and in the most recent census in 1986, it was 6.4 million (www.populstat.info; accessed January 2010). Due to the fighting, recent population numbers are highly uncertain and range from about 8–10 million (Kelleher 1998; Anon. 2009b).

After the fall of the Siad Barre regime in 1991, Somalia was not able to effectively manage its natural resources due to the lack of effective national governance (Kelleher 1998; Jennings 2001). Although foreign fishing in the offshore waters off Somalia was prevalent during the early decades from 1950 to 1980, no major illegal fishing incidents or confrontations with foreign vessels was reported during that time period (Sabriye 2005). Given that EEZs were not internationally recognized until the late 1970s or early 1980s, and Somalia's status and recognition of their claim for jurisdiction beyond 12 nm territorial waters remains uncertain and challengeable (but see below), any such offshore fishing was only considered 'illegal' in the context of international law with the ratification of UNCLOS by Somalia in 1989. As Somalia declared a 200 nm *territorial* sea in 1971 that is contested and not based on accepted international law (Schofield 2008), but ratified UNCLOS in 1989, this ratification could be argued to supersede Somalia's previous territorial sea claim and replace it with a legitimate 200 nm EEZ since 1989 (C. Schofield, *pers. comm.*). Furthermore, the effective collapse of the national government in 1990 also exposed its coastal waters to uncontrolled access by foreign fleets (Samatar 2007). During the post-regime period, the state failed to exercise its rights both at land and sea due to a dysfunctional government (Dupont 2003).

Several issues contributed to the problem with unregulated and unlicensed fishing vessels. The majority of Somalia's maritime neighbours are not equipped with adequate monitoring, control and surveillance infrastructure to address violations by foreign fishing vessels. This includes Kenya (Anon. 2008a,b,d; also see Le Manach *et al.* this volume), Tanzania (Anon. 2008e; also see Bultel *et al.* this volume),[2] and Yemen (Anon. 2009a). None of these countries have regular or adequate fisheries observer schemes, port state control, mandatory vessel monitoring system requirements or aerial surveillance for foreign vessels operating in their own EEZs. After the fall of Siad Barre regime in the early 1990s, the majority of Somali licensed foreign vessels re-flagged their vessels to Kenya or Flag of Convenience countries (e.g., Belize, Honduras) to conduct illegal fishing operations in Somali waters (Kulmiye 2001; Anon. 2008c). Starting in the mid 1990s, foreign illegal fishing vessels started encountering increasing resistance from local clans along Somalia's coastline, and started paying local warlords and militia a nominal amount for protection to fish in local waters. The majority of fishing vessel arrests locally during this time appear to be for failing to pay the clans for illegal fishing, rivalries between two clans claiming authority over the same territory (Anon. 2005; von Hoesslin 2006) or for fishing too close to the coast (Anon. 1998).

For the purpose of the present catch reconstruction, we did not deal with the illegal foreign fishing presence in Somali waters, despite its historic significance and likely massive scale. Data presented here pertain only to domestic Somali fisheries and licensed foreign and joint venture operations.

Material and Methods

Fisheries development

Of the two former colonial powers, the United Kingdom and Italy, only Italy is known to have tried to establish a fishing industry (e.g., by building three canning factories on the north shore in the mid-1930s), but without much success (Haakonsen 1984). After independence in 1960, the fisheries sector was not paid much attention until Siad Barre came to power in the late 1960s. To increase fisheries production, the government launched fisheries development programs and created about 20 fishing co-operatives that were supplied with, e.g., motorized boats, fuel, and fishing gear. In 1974, the nomadic population was heavily affected by a severe drought that killed much of their livestock. Consequently, fifteen thousand nomads were resettled into four fishing co-operatives. The fisheries development programs were largely supported by the former Soviet Union.

Pre-1991: industrial and foreign fishing

Somalia has never had a large domestic industrial fishing fleet, and most of the industrial fishing in Somali waters has been carried out by what were essentially foreign fleets, for many years through so-called 'joint ventures'. During the 1950s, the Italians were fishing mostly for their canning industry on the north coast, with 95% of the production exported to Italy and the remainder marketed locally or sent to Yemen. Occasional Japanese longlining occurred offshore on the east coast (Johnson 1956), and in the 1960s, Japan undertook test fishing for tuna (Lawson *et al.* 1986). Some Greek trawlers also operated in Somali waters in the mid-1960s (Haakonsen 1983). In 1974, SOMALFISH was established as a joint venture between Somalia and the Soviet Union. It operated ten trawlers and one fishmeal factory ship until late 1977, when political relations between the two countries broke down and the

[2] "Tanzania, SADC join forces against illegal fishing". Available at: www.stopillegalfishing.com [Accessed in February 2010].

Soviet Union withdrew their boats and support (Haakonsen 1983). According to national statistics, these vessels caught 2,000–5,000 $t \cdot year^{-1}$ of finfish and spiny lobster (FAO 1978; Haakonsen 1983). However, according to Yassin (1981) SOMALFISH exported between 10,000–20,000 $t \cdot year^{-1}$.

After the Soviets terminated their operations in Somalia, industrial fishing was carried out through joint ventures and licensing of foreign vessels from countries such as Italy, Japan, Greece, Singapore and Egypt (Van Zalinge 1988) as well as China.[3] SOMALFISH itself purchased two Australian-built shrimp trawlers and nine Yougoslavian-built trawlers (Lawrence 1980). The two Australian vessels started operating in the late 1970s, but it is unclear if the nine Yugoslavian trawlers ever operated (Haakonsen 1983). An Italian company called 'Amoroso e Figli' operated three freezer trawlers off the north east coast in 1978 and 1979 (Stromme 1987). SIDACO, a joint venture between Somalia and Iraq was formed in 1977 (FAO 1978). However, according to Haakonsen (1983), their vessels never operated, while another source stated that in 1982, SIDACO operated four trawlers (Anon. 1982). SOMITFISH, a joint venture between Somalia and Italy, operated three Italian-built trawlers between 1981 and 1983 (Van Zalinge 1988). In 1983, ten Japanese longliners were fishing for large pelagic fish, and in 1984 six Japanese and eighteen Korean longliners fished in Somali waters. In 1983 and 1984, Romanian trawlers fished for small pelagic fish as a scientific expedition. Italian and Japanese bottom trawlers as well as several pelagic pair trawlers from Singapore operated in Somali waters in late 1984 (Elmer 1985). In 1985, ten licenses were issued to foreign vessels from four different countries (Anon. 1987). After a few years of inactivity, SOMITFISH was re-established as SHIFCO, and with new and rehabilitated vessels started operations in 1987 (Anon. 1988; Sabriye 2005). In addition, five Italian trawlers and one French trawler were licensed to fish in Somali waters (Anon. 1988). During the 1980s, China increasingly supported the Siad Barre regime with direct supplies of weapons and other military supplies. In exchange, Somalia transferred fishing rights to China, which was formalized through an agreement signed in 1989. It is likely that with the fall of the Siad Barre in 1990, this fishing may have continued uncontrolled for some time.

Post-1991: collapsed government

The Siad Barre regime maintained a surveillance force to protect the offshore waters of Somalia, although nothing is known about its effectiveness. When the government collapsed in 1991, the waters were left unmonitored and unguarded, and this was exploited by fishing vessels from various countries (Qayad 1997; Jennings 2001; Mohamed and Herzi 2005; UNEP 2005; Mwangura 2006b; Samoilys *et al.* 2007; Schofield 2008; Weir 2009). This unlicensed exploitation by foreign vessels has been proposed as a major reason for the initial rise of piracy in the waters of Somalia (Lehr and Lehmann 2007). It is argued that local fishers who were deprived of their livelihoods, and the warlords who saw an opportunity to make money, formed 'coast guards' to enforce the waters of their perceived 'territories'. These 'coast guards' attacked foreign fishing vessels and demanded compensation for fish caught. Local warlords also started to sell 'licenses' for fishing (Jennings 2001; Menkhaus 2009), thus creating what can be called 'semi-illegal' licensing schemes for foreign vessels.

For example, in 1996–97, 43 longliners, 61 purse seiners and a few Kenyan trawlers were fishing in Somali waters through such local warlord agreements. In addition, four Saudi-Arabian trawlers and some Pakistani vessels occasionally fished along the coast, and three Sri Lankan vessels based in Berbera fished for sharks. Two Syrian and one Taiwanese vessel were captured and accused of illegal fishing by the 'Somali Salvation Army' (Kelleher 1998). In 2005, Somaliland had about 36 Egyptian trawlers operating in their waters, landing about twice as much as the small-scale fleet was assumed to land (Gulaid 2004). Interestingly, the remaining 'domestic' industrial fleet (operating under the joint venture SHIFCO) had been operating out of Aden (Yemen) since the late 1990s (Jennings 1998; FAO 2005).

Small-scale fisheries

The small-scale fisheries development programs during the Siad Barre era were not only supported by the Soviet Union, but by other countries through foreign aid. However, the desired growth of the sector failed to materialize. The absence of fishing traditions translated into a lack of fishing experience and infrastructure such as storage and processing facilities. There was also a lack of equipment and knowledge on how to repair boats, which made it hard to maintain the fishing fleet. For example, more than 50% of the new motorized boats distributed in the mid-1970s were out of commission after only a few years. The marketing of fish from the co-operatives was centralized during the 1970s and early 1980s, diminishing incentives for increased production (Haakonsen 1983). Fishing activities increased when the government started to liberalize the sector during the 1980s (Pierconti and Dunn 1990).

After the collapse of the central government in 1991 and during the ensuing civil war, much of the existing small-scale fishing sector was reduced, which amplified the already existing shortage of spare parts and infrastructure. The small-scale fishers also suffered from the cessation of government support (Lovatelli 1996) and their catches declined (Kelleher 1998). However, in later years, the absence of government control of the fishing industry resulted in increased influence of the private sector and entrepreneurs, which was the main force behind the gradual revival of the fishing trade (Lovatelli 1996). In more recent times, the investment from the private sector together with foreign aid, and also the change in consumption habits of Somalis seem to have resulted in an expansion of the small-scale fisheries sector and substantially increased small-scale catches in the post-war period (Gulaid 2004; Mohamed and Herzi 2005; Sabriye 2005).

[3] Country Studies Series by Federal Research Division of the Library of Congress. Available at www.country-data.com/cgi-bin/query/r-12055.html [Accessed August 2012].

Lack of statistics and reliable data

Lack of sufficient and reliable statistics was identified as a major problem for the development and management of fisheries in the Indian Ocean (IOFC 1982). The Somali Ministry of Fisheries does not seem to have had a tradition of collecting fisheries statistics. For example, Elmer (1985) reported that it was difficult to make the Ministry pay the people responsible for gathering of data, as there was a lack of understanding of the importance of data collection. The national legislation in Somalia (i.e., the Maritime Code) also hindered the gathering of fisheries statistics since it did not give the Ministry of Fisheries the authority to collect fishing data. The national statistics law did cover data collection to some extent, however, it did not include provisions ensuring the Ministry of Fisheries would receive data on fisheries (Lawrence 1980). The absence of workable government institutions since the late 1980s prolonged and exacerbated the problem of unreliable data (UNEP 2005).

The existing fisheries statistics from the 1970s and the 1980s are thought to be incomplete. For example, the 'production from all sectors' in 1985 as reported by the Somali government (Anon. 1985), was based solely on catches by the 23 co-operatives and re-settlements, the offshore catches, and the purchases by companies from small-scale artisanal fishers. The reported production from the cooperatives and re-settlements was deemed to represent the artisanal (i.e., small-scale, commercial) production and was reported as 6,223 t in 1985. This is thought to be an underestimate, since it excluded data from fishing villages along the coast that were not part of a co-operative. For example, Jennings (1998) reported 31 fishing communities, while Mohamed and Herzi (2005) suggested that before the civil war there were about 50 fishing villages. Furthermore, the FAO also reported in its country profile that there were about 50 fishing villages along the coast (FAO 2005). Hence, the artisanal fish production from villages that were not associated with the 20 co-operatives or the three re-settlements, together with non-commercial catch (i.e., subsistence catch), seemed to be missing from reported data. In addition, the Ministry of Fisheries acknowledged that a substantial part of the landed catch was sold directly at the beach landing sites to the public, and deemed the amount sold as 'unquantifiable' (Anon. 1987). Shaves (1984) also reported that sales of fish occurred outside the controlled market during the time when, according to national law, all fish had to be sold through the co-operatives at a fixed price.

Furthermore, the total production reported by the Ministry in 1985 was 11,938 t (Van Zalinge 1988). This included 2,039 t of artisanal landings that were purchased by public companies, 1,130 t of large pelagic fish caught by Korean longliners, and 240 t of small pelagic fish caught by Romanian survey trawlers (Van Zalinge 1988). If the artisanal catch component and the Korean and Romanian catches were subtracted, the remaining production (i.e., 8,529 t) matched what was reported as demersal industrial production (i.e., 8,528 t) in 1985 (Van Zalinge 1988).

The Food and Agriculture Organization of the United Nations (FAO) is mandated to report data provided by their member countries. The examples described above matched what FAO reported as Somali catch for 'marine fishes nei' in FAO FishStat for 1985. This suggests that FAO data for Somalia are incomplete due to the use of national data reported by the Somali Ministry of Fisheries.[4]

Discards

Industrial fisheries

Tropical waters have a large number of species, and one species rarely makes up more than 20% of the catch (Tussing *et al.* 1974). In Somali waters, there is a large diversity of fish, but only a few species are of commercial interest (Lovatelli 1996). Trawl surveys in the late 1970s reported non-commercial bycatch of more than 50% (Kelleher 1998). Van Zalinge (1988) reported that only the high value species, accounting for less than 50% of the catch, were retained on demersal trawlers. Therefore, discarding was likely high in demersal trawl fisheries. Depending on the species composition, the acceptability for various species by markets, onboard storage capacity, and distance to port, between 40% and 80% of the total catch was discarded (Tussing *et al.* 1974). In the shrimp trawl fishery, discards may have been as high as 90% (Hariri 1985). For later years, Kelleher (2005) reported that the general discard rates in the western Indian Ocean were 9% in the tuna fishery, 92.3% in the shark fin fishery, 30–40% in the long-range longline fishery, 5% in the purse seine fishery, and 21.7% in regular longline fisheries. Kelleher (2005) did not report a specific demersal trawling discard rate for the western Indian Ocean, but his global weighted average discard rate for demersal finfish trawling was 19.6%.

Small-scale fisheries

In the small-scale fishery, a large number of different species are fished and consumed (Mohamed and Herzi 2005), although pelagic species such as tuna and mackerel are commonly favoured (Costello *et al.* 2012). Furthermore, in some cases or areas, this fishery may focus on a narrow range of species for retention (UNEP 2005). Kelleher (2005) reported that east African artisanal fisheries have negligible discards. However, due to the eating habits of the Somalis, the lack of storage/processing facilities and market opportunities, some sources acknowledged that discarding occurred also in the small-scale fishery (e.g. Lovatelli 1996; Mohamed and Herzi 2005).

[4] As part of our search for information on Somali fisheries statistics, we attempted repeatedly to contact Mr. Graham Farmer who apparently is (or was) the officer in charge of the FAO Somali program, but without success.

Here, discarding by small-scale fisheries was considered negligible overall, and was not included in the catch reconstruction. Discarding of shark meat as part of the shark fin fishery, however, has been estimated here. Many of the small-scale fishers target shark for their fins and only a few of the fishers retain the meat (Lovatelli 1996).

Overall, we followed a catch reconstruction approach as described by Zeller *et al.* (2007), with the main purpose of comprehensively estimating total catches taken from the EEZ-equivalent waters of Somalia since 1950, by domestic fisheries.

Methods

Somalia's domestic fisheries

Landings data for Somalia supplied to FAO were reported as 'marine fishes nei', 'cephalopods nei' and 'tropical spiny lobster nei', and were assumed to represent industrial catches, the production from the co-operatives and purchases of some artisanal catches by smaller companies. Here, the total reported landings were assigned to small-scale and industrial fisheries based on a breakdown of landings between 1974 and 1987 reported by the Ministry of Fisheries (Van Zalinge 1988). For the years where no breakdown was available (prior to 1974 and after 1987) the averages of the first and last three years of the breakdown were used, respectively. Thus, prior to 1974, 25% of landings were assigned to industrial landings, and after 1987, 49% were assigned to industrial. 'Tropical spiny lobsters nei' were split using these proportions with no further adjustments made. The 'marine fishes nei' and 'cephalopods nei' were then added together and the total was split using the proportions listed above. This was done because all cephalopod catches were determined to be small-scale, and doing the split this way allows the total catch to be split using the determined proportions, while allowing allocation of a greater proportion of the 'marine fishes nei' to the industrial sector and all. This is addressed further in the description of the species breakdown below. The FAO data that were assigned to industrial fisheries were taken at face value, while a separate reconstruction of the small-scale fisheries allowed us to determine an add-on to the small-scale portion of reported FAO data derived here. For this reconstruction, we used the 2010 FAO data as our baseline.

Small-scale catches

Small-scale catches (i.e., artisanal and subsistence catches) were estimated using the number of operational boats and catch rate per operational boat per year. The earliest reported small-scale catch (Thurow and Kroll 1962) was taken at face value and extrapolated back to 1950. The most recent records of catches were reports for the fisheries in the three regions of former Somalia: southern central Somalia (Sabriye 2005), Puntland (Mohamed and Herzi 2005), and Somaliland (Gulaid 2004). The reported catches for Puntland and southern central Somalia were taken at face value. For the third region, Somaliland, shark catches were missing and were estimated based on the fraction of shark in catches in southern central Somalia. The estimated shark catch was then added to the reported fish catch for Somaliland (Table 1), and these data were used as the 2005 anchor point.

The total estimated small-scale catch for 2005 (Table 1) was carried forward to 2010 unchanged. For 1962, Thurow and Kroll (1962) report small-scale catches of 16,500 t, which we carried back to 1950 unaltered (Table 2). The small-scale catches in the period between 1963 and 2004 were estimated by deriving anchor points for the number of operational boats for 1978, 1980, 1988, and 1995 based on available information and assumptions (see below). The number of operational boats was then multiplied by a catch rate per boat based on Elmer (1985) to create anchor points for small-scale catch (Table 2). To complete the time series, linear interpolation was done between the derived catch anchor points and the catches reported in 1962 and 2005 (Table 2).

Table 1. Small-scale catches reported and estimated for 2005 for Somalia.

Region	Fish (t)	Shark (t)	Total (t)	Shark (%)	Source
South-central Somalia	14,825	6,113	20,938	29	Sabriye (2005)
Puntland	2,144[a]	8,990	11,134	81	Mohamed and Herzi (2005)
Somaliland	6,030	2,486[b]	8,516	29	Gulaid (2004)
Total Somalia	22,999	17,589	40,588	43	-

[a] A substantial part of the finfish catches from Puntland are sold to Yemen and not included in the reported catches for Puntland; [b] Estimated using the fraction of shark catches from south-central Somalia

Table 2. Anchor points used for interpolation of small-scale catch for Somalia. Values in italics are interpolated.

Year	Operational boats[a]	Catch anchor points (t)	Source
1950	-	*16,500*[b]	-
1962	-	16,500	Thurow and Kroll (1962)
1978	1,874	18,740[c]	Thurow and Kroll (1962), Haakonsen (1983)
1980	1,725	17,250[c]	Lawrence (1980)
1988	1,725	*17,250*[c]	-
1995	792	7,920[c]	Kelleher (1998)
2005	-	40,588[d]	Gulaid (2004), Mohamed and Herzi (2005), Sabriye (2005)
2010	-	*40,588*[e]	-

[a] See text for sources; [b] Assumed equal to 1962 value; [c] Based on average catch rate of 10 $t \cdot boat^{-1} \cdot year^{-1}$ (Elmer 1985); [d] Estimated shark catches for Somaliland were added; [e] Assumed equal to 2005 value.

Number of operational boats

The traditional boats in Somalia are the wooden canoe called '*houri*', and the less common sail boats called '*beden*' or '*mashua*' (Lovatelli 1996). According to Thurow and Kroll (1962), the small-scale fishing fleet in the early 1960s consisted of 1,875 *houris* (of which 1,500 were always active), 175 *beden* (of which 150 were always active), and 25 other boats (called '*dunnis*'), together accounting for a total catch of 16,500 t (Table 2). Thus, the fraction of traditional boats that were operational at any one time was about 80%. This fraction was applied to the reported total number of traditional fishing boats in later years (see below).

During the 1970s, a number of motorized boats were issued through fisheries development programs. Haakonsen (1983) reported that 685 motorized boats had been provided during the previous years and that 500 of those boats were issued during the five year development program 1974–1978. According to Hariri (1985), 700 motorized boats were issued from 1972 onwards, and by the late 1970s only 40% were working. UNDP/FAO (1992) reported that 600 motorized boats were issued between 1974–1978 and that in 1979, 150 new engines were provided by the UK to rehabilitate some of these boats. Jennings (1998) reported that 600 motorized boats were issued and that within five years only 20% were working. According to Lovatelli (1996), 450 boats had been issued by 1982. As the number of motorized boats reported by the above sources are all in the same range, we used the earliest source (i.e., Haakonsen 1983). The year 1978 is in the middle of the ten year period reported on by Haakonsen (1983) for the distribution of 685 boats, hence we assumed that all boats were distributed by 1978 to create an anchor point. By the time the report was written (1983), more than 50%, and maybe as much as 75%, of the distributed motorized boats were not operating due to lack of spare parts and knowledge on maintenance (Haakonsen 1983). Hence, we assumed that 40% were working and applied this to the total number of motorized boats to derive a total of 274 operational motorized boats for 1978 (i.e., 685 × 0.4 = 274).

The traditional boats are thought to have had a much higher fraction that were operational, due to lower mechanization and easier, more traditional maintenance requirements. Therefore, the fraction of operating traditional boats (80%) from Thurow and Kroll (1962) was used. Haakonsen (1983) reported that the traditional fleet was 2,250 boats, but he also mentioned that use of traditional boats was declining due to the introduction of motorized boats and lack of maintenance. Therefore, for 1978, we assumed 2,000 traditional boats and a working rate of 80%. Together with the assumed 274 working motorized boats, this resulted in an anchor point in 1978 of a total of 1,874 operational boats (Table 2).

In 1980, Lawrence (1980) reported that about 125 motorized boats were working and that the traditional fleet was about 2,000. Hence, we derived a 1980 anchor point of 1,725 working traditional and motorized boats ([2,000 × 0.8] + 125 = 1,725; Table 2).

In 1988, the civil unrest started in northern Somalia, and by 1991 the government had collapsed. The civil war damaged much of the fishing sector; hence, there was a decline in the number of operational boats after 1988. Due to lack of other information, the anchor point in 1980 was carried forward to 1988 (i.e., 1,725 operational boats; Table 2).

Kelleher (1998) reported that the artisanal fleet in 1995 was made up of 627 *houris* and sailboats (i.e., 627 × 0.8 = 502 operational traditional boats) and 290 functional motorized boats. This was used to form an anchor point of 792 operational boats in 1995 (Table 2).

<u>Catch rate</u>

Elmer (1985) reported that around 737 operational boats caught 8,288 t. Thus, the average catch rate was 11.25 t per operational boat per year (8,288 / 737 = 11.25). To remain conservative, we used a catch rate of 10 t per operational boat per year as a default measure to derive the estimated tonnage of small-scale catch for 1978, 1980, 1988 and 1995 (Table 2). For years between anchor points, data were linearly interpolated.

<u>Small-scale catches: artisanal *versus* subsistence</u>

Although the majority of data sources used here for estimating small-scale catches related to artisanal fisheries, we assumed that a fraction of these catches could be deemed subsistence, i.e., were not for sale but for direct consumption or local barter. Thus, we assumed that the estimated total small-scale catches derived here were split into the two sectors as follows: For 2010, we assumed 80% artisanal and 20% subsistence, while for 1950 we assumed a 60% artisanal and 40% subsistence split. We interpolated these percentages over time to derive full time-series for each sector.

Species composition

We assigned the estimated catch to different species, by sector, based on information found in various sources (see Table 3).

<u>Industrial catch</u>

The domestic industrial catch was assumed to consist of demersal species caught by trawl (80%), and pelagic species (20%). The pelagic catch was in turn split between large (80%) and small (20%) pelagic taxa. Individual taxa were assigned percentages within each category (Table 4) based on the general information contained in the sources in Table 3.

Small-scale catch

Much of the literature suggested that sharks and rays made up a substantial part of the small-scale catch (artisanal sector only; shark fishing assumed to be a commercial endeavour); therefore they were treated as their own category. Thurow and Kroll (1962) reported that sharks made up 21% of the total catches in the early 1960s. The fraction of sharks and rays in the small-scale catch increased to about 40% during the 1980s (Anon. 1987), and to 55–65% by the 1990s (Lovatelli 1996). We assumed 55% of the catch in the mid-1990s was sharks. For each of these anchor points, in order to be conservative, it was assumed that these percentages applied to the artisanal catch only. For the most recent time periods, the fraction of sharks was 29% of the total small-scale catch in southern central Somalia (Sabriye 2005), whereas in Puntland it was 81% of the reported catches, although substantial finfish catches were missing from the data (Mohamed and Herzi 2005). We estimated the shark catches in Somaliland by assuming the same shark to finfish ratio as for south-central Somalia (i.e., 29%; Table 1), and added them to the reported artisanal catches (Gulaid 2004), which resulted in a total fraction of sharks of 43% in 2005 for Somalia (Table 1). Considering that the Puntland percentage was an over-estimate and that the Somaliland tonnage had to be estimated, we applied the 43% in 2005 to the artisanal catch only, in order to remain conservative. Note that this in turn resulted in a slightly lower shark tonnage for 2005 within our reconstruction than was found in the literature. All of this information was used to create a time series of the shark and ray fraction within the artisanal sector. Linear interpolation was done between the anchor points in 1962 (21%), 1985 (40%), 1995 (55%) and 2005 (43%). Data for 1962 was carried back to 1950 unaltered and the anchor point in 2005 was carried forward to 2010 unaltered. Species composition of shark catches were derived from a variety of sources (Table 3) and applied in seven taxonomic groups (3 species, 2 families and 2 general groupings, Table 5).

Table 3. Sources used for species composition for the catch reconstruction for Somalia, by fishing sector.

Source	Fisheries sector				
	Industrial	Artisanal	Pelagic	Demersal	Sharks & rays
Corfitzen and Kinzy (1950)					✓
Ogilvie *et al.* (1954)		✓	✓	✓	
Johnson (1956)		✓	✓	✓	
Thurow and Kroll (1962)	✓	✓			✓
Losse (1970)		✓	✓	✓	✓
FAO (1972)	✓	✓			
FAO (1978)		✓			✓
Anonymous (2011)		✓	✓	✓	✓
Bihi (1984)	✓	✓			
Johnsen (1985)	✓			✓	
Anonymous (1985)		✓			✓
Van Zalinge (1988)	✓	✓	✓	✓	
Sanders and Morgan (1989)	✓	✓	✓	✓	
Lovatelli (1996)		✓	✓	✓	✓
Marshall (1997)		✓			✓
Kelleher (1998)	✓	✓	✓	✓	✓
Jennings (1998)	✓	✓	✓	✓	✓
Anonymous (2004)		✓			✓
Sabriye (2005)		✓			✓
UNEP (2005)	✓	✓			✓
IUCN (2006)		✓			
IOTC database[a]	✓		✓		

[a] Indian Ocean Tuna Commission (IOTC) database available at www.iotc.org/English/index.php [Accessed: March, 2011]

The remaining, non-shark artisanal catch was split into demersal (40%) and pelagic (60%) catches, based on information from sources in Table (3). Artisanal finfish catch is thought to be dominated by pelagic taxa (60%), in contrast to industrial catch, in which demersal taxa (80%) predominate (Tables 4, 6). Individual taxonomic assignment of catches (Table 6) was derived from sources in Table 3.

The breakdown for the subsistence catches was derived from the artisanal breakdown, taking into account sectoral differences. Sharks and rays were excluded and the proportion of large pelagic fish was greatly reduced. Subsistence catches were disaggregated using the proportions shown in Table 9.

Table 4. Species breakdown of industrial catches for Somalia, as derived for the present study, based on qualitative information from sources listed in Table 3. Percentage breakdown relates to the total industrial catch.

Category	Size[a]	Family/group	Species	Common name	Industrial catch (%)
Pelagic	Large	Scombridae	*Thunnus albacares*	Yellowfin tuna	7.7
Pelagic	Large	Scombridae	*T. obesus*	Bigeye tuna	5.9
Pelagic	Large	Istiophoridae	*Tetrapturus audax*	Striped marlin	0.7
Pelagic	Large	Istiophoridae	*Makaira mazara*	Indo-Pacific blue marlin	0.3
Pelagic	Large	Xiphiidae	*Xiphias gladius*	Swordfish	0.4
Pelagic	Large	misc. billfish	-	Other billfish	0.1
Pelagic	Large	misc. pelagic fishes	-	Pelagic fishes	0.9
Pelagic	Small	Clupeidae	*Sardinella longiceps*	Indian oil sardine	1.9
Pelagic	Small	Clupeidae	*Etrumeus teres*	Round herring	0.8
Pelagic	Small	Scombridae	*Scomber japonicus*	Chub mackerel	0.8
Pelagic	Small	Carangidae	*Decapterus* spp.	Scad	0.3
Pelagic	Small	misc. pelagic fishes	-	Pelagic fishes	0.2
Sub-total pelagic					20.0
Demersal		Lethrinidae	*Lethrinus nebulosus*	Spangled emperor	11.3
Demersal		Lethrinidae	*L. lentjan*	Pink ear emperor	5.7
Demersal		Lethrinidae	*L. olivaceus*	Longfaced emperor	5.7
Demersal		Lethrinidae	-	Misc. emperors	5.7
Demersal		Serranidae	*Epinephelus areolatus*	Areolate grouper	10.4
Demersal		Serranidae	-	Misc. groupers	2.6
Demersal		Lutjanidae	*Etelis* spp.	-	4.1
Demersal		Lutjanidae	*Aprion* spp.	-	4.1
Demersal		Lutjanidae	-	Misc. snappers	2.0
Demersal		Haemulidae	*Diagramma pictum*	Painted sweetlips	19.0
Demersal		Mullidae	*Parupeneus indicus*	Indian goatfish	9.4
Sub-total demersal					80.0
Total					100.0

[a] Large = 80%, small =20% of the pelagic fraction of the industrial catch.

Catches reported to FAO included cephalopods. However, there was no specific information on cephalopod catches in our sources. Therefore, the reported cephalopod catches were proportionally assigned to the artisanal and subsistence sectors using the same proportional split applied to the total small-scale catches. The tonnage determined for each sector was then assumed to be contained within the 'marine fishes nei' tonnage that was estimated above and subtracted out to determine the remaining amount of 'marine fishes nei' for each sector.

Table 5. Species breakdown of small-scale shark and ray catches for Somalia, based on sources in Table 3.

Category	Family	Species	Common name	Catch (%)
Sharks	Carcharhinidae	*Carcharhinus melanopterus*	Blacktip reef shark	15.0
		C. amblyrhynchos	Grey reef shark	7.5
	Alopiidae	*Alopias vulpinus*	Thintail thresher	15.0
	Lamnidae	-	Mako sharks	15.0
	Sphyrnidae	-	Hammerhead sharks	15.0
	-	-	Other sharks	7.5
Rays	-	-	Rays and mantas	25.0

Table 6. Species breakdown of artisanal catches (excluding sharks and rays) for Somalia, based on qualitative information from sources listed in Table 3.

Category	Family	Species	Common name	Catch (%)
Pelagic	Scombridae	*Thunnus albacares*	Yellowfin tuna	15.0
		T. tonggol	Longtail tuna	5.0
		Euthynnus affinis	Kawakawa (Little tuna)	5.0
		Scomberomorus commerson	Narrow-barred Spanish mackerel	10.0
		-	-	5.0
	Clupeidae	*Sardinella longiceps*	Indian oil sardine	4.0
		-	-	1.0
	Carangidae	*Selar crumenophthalmus*	Bigeye scad	2.0
		Trachurus indicus	Arabian scad (Horse mackerel)	2.0
		-	-	1.0
	Coryphaenidae	*Coryphaena hippurus*	Common dolphinfish	5.0
	Istiophoridae	*Tetrapturus audax*	Striped marlin	1.7
		Makaira mazara	Indo-Pacific blue marlin	0.8
	Xiphiidae	*Xiphias gladius*	Swordfish	2.0
	Misc. billfish	-	Other billfish	0.5
Sub-total pelagic				60.0
Demersal	Lethrinidae	*Lethrinus nebulosus*	Spangled emperor	8.0
		L. lentjan	Pink ear emperor	4.0
		L.olivaceus	Longfaced emperor	4.0
		-	Emperors	4.0
	Lutjanidae	*Etelis* spp.	-	2.0
		Aprion spp.	-	2.0
		-	Snappers	1.0
	Serranidae	*Epinephelus areolatus*	Areolate grouper	4.0
		-	Groupers	1.0
	Mullidae	*Parupeneus indicus*	Indian goatfish	2.5
	Misc. marine fish	-	-	7.5
Sub-total demersal				40.0
Total				100.0

Discards

Industrial fisheries

Due to a lack of gear specific information in the Somali domestic industrial fisheries, we assumed that half of the pelagic fish in the industrial catch was caught with longliners and half with purse seiners, and applied associated discard rates (21.7% for longliners and 5% for purse seiners) reported by Kelleher (2005). For the demersal fraction of the domestic industrial catch, the global average discard rate for demersal finfish trawlers of 19.6% (Kelleher 2005) was used, as specific discard rates for demersal fisheries in the western Indian Ocean were not available. The bycatch of sharks in industrial trawlers has been estimated to be 5% of the total weight of the catch. Of this bycatch, only the fins were kept and the rest was discarded (Marshall 1997). The discard of shark meat was assumed to be included as part of the 19.6% discard rate. The demersal discard rate was split between sharks (4.5%) and fishes (15.1%). The sharks were taxonomically disaggregated using the artisanal shark breakdown, and fishes were disaggregated by family using the industrial demersal breakdown (Table 7). Pelagic discards were broken down using the proportions shown in Table 8.

Table 7. Breakdown by family name for industrial demersal fish discards.

Family	Percentage
Lethrinidae	28.4
Serranidae	13.0
Lutjanidae	10.2
Haemulidae	19.0
Mullidae	9.4

The crustacean fishery incurred a small amount of discards as well. Discards were estimated to equal 1.1% of the crustacean landings.

Table 8. Breakdown by family name for industrial pelagic discards.

Family	Percentage
Scombridae	20.0
Istiophoridae	20.0
Coryphaenidae	20.0
Clupeidae	20.0
Marine fishes nei	20.0

Small-scale fisheries

Although references have been made to some discarding of fish in the small-scale fisheries (e.g., Lovatelli 1996; Jennings 1998; Mohamed and Herzi 2005), they may be low (except for artisanal fisheries supplying Yemeni mother boats).

Here, we focused specifically on discards in the shark fin fishery which have been estimated. In Somalia, dried shark meat was an export commodity, hence, sharks were not only targeted for their fins (Lovatelli 1996; Jennings 1998). In 2005, it was reported that dried shark meat was collected in Mogadishu from all regions and thereafter exported to Mombasa in Kenya (Sabriye 2005). In the mid-1990s, Lovatelli (1996) reported that only a small percent of fishers retained the meat, and Gulaid (2004) reported that only fins were retained by fishers in Somaliland. Thus, overall discards of sharks (except fins) were assumed to be relatively large. To estimate the shark discards in the small-scale fisheries, data from IUCN (2003) and Mohamed and Herzi (2005) were used. According to IUCN (2003), the community of Eyl produced 200 t of shark fins, which requires about 10,000 t of live-weight sharks. In addition, Mohamed and Herzi (2005) stated that Eyl's estimated yearly locally landed and utilized shark catch (not finned) was 1,830 t in 2004. Thus, we assumed that the discards of shark meat in Eyl due to shark finning alone were about 8,170 t (10,000 t minus 1,830 t = 8,170 t), which was 69% of the total estimated shark and ray catch in 2004 in Eyl (8,170 t / 11,830 t = 0.69). In order to remain conservative, and also because the retained fin weight was not taken into account in this calculation, we reduced this to 49.1%, and used this as a total small-scale shark discard rate in 2004 for all of Somalia. Half of the 2004 discard rate was used as an anchor point in 1990 (i.e. 24.5%) to reflect the rapidly growing demand for shark fins reported during the 1990s (Clarke 2004). Thurow and Kroll (1962) reported that dried sharks were exported from Somalia and that shark fins fetched a higher price, however, there were no indications of shark meat discards in the report. Therefore, we conservatively assumed that shark discards were 0% in 1960. Linear interpolation was done between the 1960, 1990 and 2004 discard rates to derive the fraction of artisanal shark meat discards over time, and the 2004 rate was carried forward to 2010 unaltered.

Table 9. Breakdown for subsistence catches.

Taxon	Percentage (%)
Marine fishes nei	7.50
Scombridae	10.00
Clupeidae	2.04
Indian oil sardine	8.15
Carangidae	2.04
Bigeye scad	4.07
Arabian scad/Horse mackerel	4.07
Lethrinidae	8.15
Spangled emperor	16.30
Pink ear emperor	8.15
Long faced emperor	8.15
Lutjanidae	2.04
Aprion spp.	4.07
Serranidae	2.04
Areolate grouper	8.15
Mullidae	5.09

Adjustments

From 1992 to 1996, reported catches were greater than reconstructed catches. Therefore, catches in these years were assumed to be 100% reported (except for discards which are known to be unaccounted for in reported data) and a negative adjustment of the reported data was done. Previously, when the reported cephalopod catches were subtracted from the total artisanal and subsistence 'marine fishes nei', the result was a negative catch in these years (1992–1996). Therefore, the cephalopods were adjusted independently of the rest of the catch. All of the 'marine fishes nei' were assigned as cephalopods for 1992–1996 and the difference was allocated as a negative adjustment to the reported cephalopod catches. 'Tropical spiny lobster' catches were left unadjusted as they were assumed to be well reported. The remaining catch was compared to the 'marine fishes nei' reported catch. The difference between these totals represents the negative adjustment applied to the 'marine fishes nei' category of the reported data. Please note that all comparisons of reconstructed data to the reported FAO data refer to the adjusted baseline derived here.

Results

Reported catches

Total landings reported by FAO on behalf of Somalia were 922,930 t (944,999 t before adjustment) from 1950–2010, with catches varying between 5,000–15,000 t·year^{-1} from 1950 to the early 1980s, before increasing rapidly to around 25,000 t·year^{-1} by the early 1990s. Following a decline in landings during the 1990s, reported landings increased again to 30,000 t·year^{-1} in the early 2000s and have been fixed at this amount since (Figure 2A). Here, we split these data into assumed industrial and small-scale components of reported landings, and added unreported catches as well as discarding to both components.

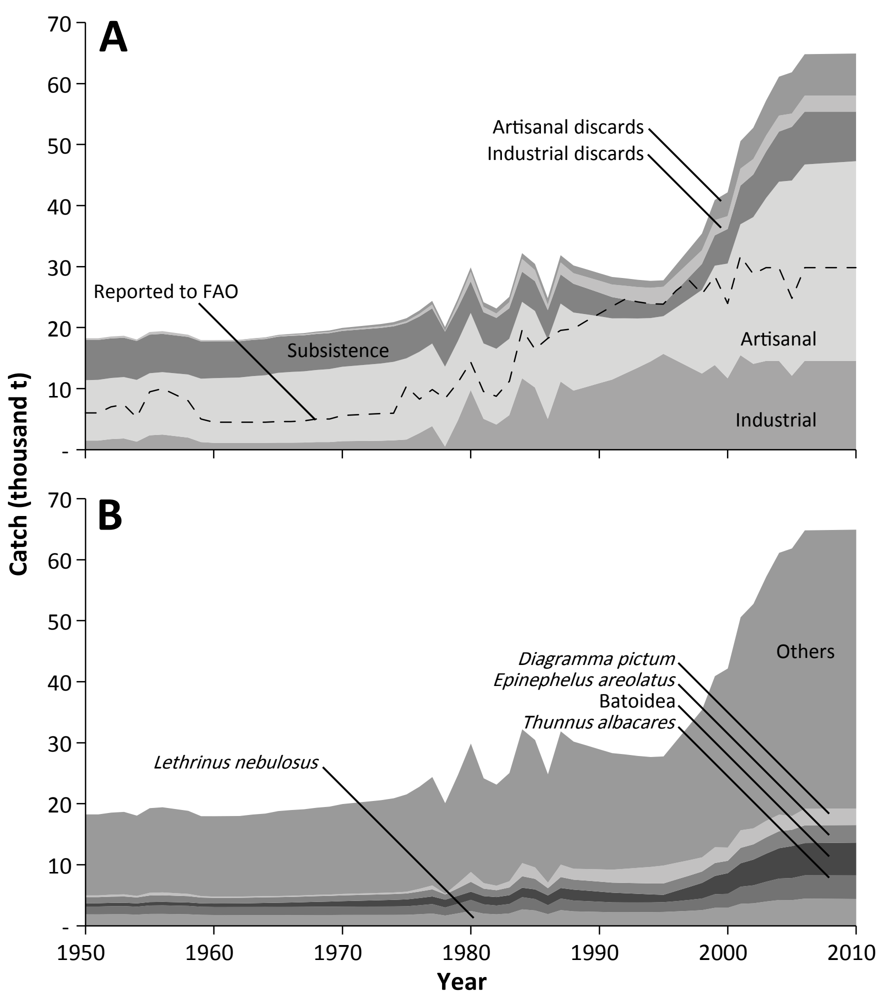

Figure 2. Reconstructed total catch in Somali waters, 1950–2010, A) by sector with reported catches overlaid as a dashed line, B) by major taxa. 'Others' includes 42 additional taxonomic categories. See Appendix Table A1 and Appendix Table A2 for details

Industrial catch

Of the total FAO reported landings, about 420,700 t, or 46%, were assigned to industrial landings from 1950–2010 (Figure 2A). Prior to 1975, industrial landings accounted for about 25% of total landings reported by Somalia to FAO. After the mid 1970s, industrial landings started to increase until 1995, when they peaked at around 15,700 t·year^{-1}, or 66% of total FAO reported landings (Figure 2A). The erratic nature of reported industrial landings, especially during the 1980s, was largely driven by serial failures of joint venture operations. The only source of unreported catch we examined and estimated for the industrial fishery was discards, which contributed 15% of the reconstructed total industrial catch (75,200 t).

The overall species composition of the industrial catches suggested that *Diagramma picta* was the most important individually identifiable taxon for the industrial fisheries (15.7%), consistently contributing between 14.5–16.1% of the catch each year. This was followed by *Lethrinus nebulosus* (9.3%) and *Epinephelus areolatus* (8.6%), while the most important pelagic species were yellowfin tuna (*Thunnus albacares*; 6.4%) and bigeye tuna (*Thunnus obesus*; 4.9%). Discards accounted to 15% of the reconstructed total industrial catches (Figure 2A).

Small-scale catch

Reconstructed total small-scale catches were over 1.3 million t for the entire period (Figure 2A), which was just over 2.6 times the volume of FAO landings assumed to represent small-scale catches. The reconstructed total small-scale catches during the colonial era (1950s) were estimated to be 16,500 t·year^{-1}. After 1960, total small-scale catches started to increase to almost 20,000 t·year^{-1} by 1977, before declining during the 1980s to about 18,500 t·year^{-1}. After the collapse of the national government in the early 1990s, catches dropped substantially to a low of 9,200 t·year^{-1} in 1995. Small-scale catches increased substantially thereafter to approximately 47,700 t·year^{-1} by the late 2000s. Small-scale catches were estimated to consist to 74% of artisanal catches and 26% subsistence catches. Discards contributed 10% to the overall artisanal catch.

The species breakdown of small-scale catches, based on information available to us, suggested that sharks and rays dominated catches. Their fraction of the landed artisanal catch (subsistence fisheries were assumed not to target sharks) increased from about 21% in the earlier period (2,100 t·year^{-1}), steadily rising from the mid-1960s to a peak of almost 54% in 1996 (4,600 t), and then declined to about 43% (14,000 t·year^{-1}) in the most recent years (2005–2010). Discards of shark meat (the result of targeted shark finning) were estimated at around 100,000 t between 1950 and 2010.

Although sharks and rays as a group were dominant in the small-scale catches, the most dominant individual taxa in the total small-scale catch were *Lethrinus nebulosus* (7.5%) and *Thunnus albacares* (6.1%).

Total catches

The reconstructed total catch was around 1.8 million t from 1950–2010, which was 98% larger than the adjusted landings of 922,930 t reported to FAO on behalf of Somalia for the same period (Figure 2A). For the first 20 years (1950–1969), reconstructed total catches averaged around 18,600 t·year^{-1}. During the 1970s and the 1980s, catches increased to around 22,000 t·year^{-1} and 28,000 t·year-1, respectively. After the government collapsed in 1991, total catches stabilized at 28,000 t·year^{-1} until 1995, before rapidly increasing to 41,000 t·year^{-1} by the end of the decade. This increase continued into the 21st century and levelled out at almost 65,000 t·year^{-1} after 2006.

The spangled emperor (*Lethrinus nebulosus*) and yellowfin tuna (*Thunnus albacares*) were the most prevalent species in the total reconstructed catch, contributing 8.0% and 6.2% respectively. Rays and mantas (Batoidea) made up 6.0%, whilst the areolate grouper (*Epinephelus areolatus*) was 5.1% of the total catch, followed by the painted sweetlip (*Diagramma pictum*) at 4.3% (Figure 2B).

Discussion

Since the early 1990s, Somalia has been a failed state without a functioning central government (Nincic 2008). The country is suffering extensively from poverty and violence, and its fisheries statistics are highly unreliable (Anon. 2001). Based on the information and data available to us, and the assumptions outlined in the methods, catches from 1950–2010 were reconstructed in an attempt to gain a better understanding of likely total Somali domestic catches. The reconstructed total catch estimates were nearly two times the data reported by FAO on behalf of Somalia, with reconstructed small-scale catches as the major contributor to the difference.

Interestingly, industrial catches showed an increase during the initial phase of the civil war instead of the expected decline. This reflects the loss of monitoring and enforcement capacity of Somalia during that time, which seems to have been taken advantage of by foreign vessels engaging in illegal fishing. Unlike industrial catches, the reconstructed small-scale catches were thought to better reflect the unstable situation in Somalia starting in the late 1980s, with a rapid decline after the collapse of the legitimate government in 1991. After this initial decline, small-scale catches started to increase substantially after 1995. Increased involvement and private investments in the domestic artisanal fisheries sector was the main reason for the observed increase in catches (Lovatelli 1996).

Other contributing factors could have been the change in seafood consumption habits among the Somalis (Gulaid 2004), the relocation of displaced people due to war, and the increased use of motorized boats by artisanal fishers (Anon. 2001).

The landings data reported by FAO on behalf of Somalia were for many years incomplete or highly uncertain. This is not surprising, given the lack of a central government and administration, and FAO is to be commended for being able to provide any estimates at all, given that national reporting of catches collapsed in the late 1980s due to civil unrest (Anon. 2001).

Foreign illegal and semi-illegal fishing

Since the Siad Barre regime collapsed in 1991 (and possibly even before that), Somalia has not been able to comprehensively patrol and protect its waters. Numerous vessels from various countries are thought to have exploited the situation by fishing illegally in Somali waters (e.g. Qayad 1997; Jennings 2001; Mwangura 2006b; Schofield 2008). There are contradictory reports about the number of illegal fishing vessels operating off the Somali coastline. Some of the more recent numbers suggest a decline from 500 foreign fishing vessels in 2006 (Mwangura 2006a) to 200 fishing vessels in 2009 (Anon. 2009c). However, exact numbers are not known due to the absence of monitoring and enforcement capacity within Somali waters. Furthermore, the number of foreign fishing vessels operating in Somali waters is also difficult to monitor due to the lack of transparency in data sharing among international monitoring agencies working in the Indian Ocean. As a matter of fact, misleading the public seems commonplace, as many fishing vessels, even while being attacked by Somali pirates, systematically withheld accurate position reports from relevant agencies, such as the International Maritime Bureau and International Maritime Organization, and these agencies avoid reporting positions in favour of likely dubious self-reporting by vessels (Hansen 2009). In contrast, the commercial MaRisk system, using position data collected *via* satellites and remote sensors from the military coalition fleet, showed that fishing vessels were deep within Somalia's EEZ when captured by pirates (Hansen 2009).

The autonomous, but unrecognized territories of Somaliland and Puntland had some limited success in controlling illegal fishing for short periods. For example, the Puntland administration assigned responsibility for controlling coastal resources to private security companies such as Hart Security (British) for 2000–2001, SOMCAN (United Arab Emirates) from 2001–2006, and Al Hababi Marine Services (Saudi Arabia) in 2006 (Hansen 2008). However, these initiatives met with limited success as most foreign vessels escaped into international waters whenever the private security vessels approached. Thus, for example, only four fishing vessels were arrested by Hart Security. None of the private security arrangements survived the interplay of local clan politics and changing political equations in these territories (Hansen 2008; Kinsey 2009).

It has been suggested that illegal foreign fishing in Somali waters has been the social reason for the resurgence of piracy in the region during the 2000s (Jennings 2001; Lehr and Lehmann 2007; Menkhaus 2009). Our catch reconstruction illustrates that domestic artisanal catches did decline after the start of the civil war and the collapse of central governance control. At the same time, foreign fishing fleets started to substantially increase their illegal fishing activities in Somali waters. The initial decline of artisanal catches was most likely caused by the lack of gear and boats, as well as the increased risk due to civil war, but might also have been impacted by the illegal foreign fleets. It has been reported that foreign vessels fished very close inshore and destroyed local fishing gears (Lehr and Lehmann 2007), which would have fuelled anger towards foreign fishers. Irrespective of the initial reasons and drivers for the resurgence of piracy, it did not take long for it to grow into big business for warlords and criminals utterly unrelated to domestic fisheries, who increasingly used foreign fishing as an excuse to hijack vessels and demand ransoms (Menkhaus 2009).

One example was the 'National Volunteer Coast Guard of Somalia' which in 2005 took over three Taiwanese-owned trawlers and demanded ransom for the crew, claiming it was a fine for fishing illegally within Somali waters (Lehr and Lehmann 2007). At the time (2005), the argument that pirates were deprived local fishers appeared to be already out of date, since our reconstruction suggests that by the mid-late 2000s, domestic artisanal fisheries catches had increased considerably. This is also supported by other observations (Gulaid 2004; Mohamed and Herzi 2005; Sabriye 2005). Therefore, the increasing piracy activities in the 2000s may have reduced illegal foreign fishing in coastal waters, permitting and enabling an increasing domestic artisanal sector to re-emerge.

Irrespective of the issue of piracy, the problem of foreign fishing fleets illegally exploiting Somali waters illustrates a severe failure of flag-state control, and further illustrates that illegal fishing is a matter of international, trans-boundary criminal activity rather than a fisheries management failure (Österblom *et al.* 2011; UNODC 2011). The value of illegal catches taken out of Somali waters in 2005 was estimated as being at least US$300 million (Lehr and Lehmann 2007). This lucrative illegal business is thought to have contributed to the prolongation of instability in the country, since neither foreign fishing interests or local authorities (warlords) would have benefited as much from properly controlled legal operations (Coffen-Smout 1998; Jennings 2001). Importantly, the value taken out of Somali waters by the illegal foreign fleets would not be available to the Somali people and society (David Ardill *pers. comm.*). In contrast, with fully transparent and legal licensing through foreign fishing access agreements, a functional national government would have been able to derive benefits for all of Somali society from one of their largest natural resources. Such controlled access would be an important source of foreign exchange income for legal national authorities, and may contribute to stability in the country (UNEP 2005).

If one examines semi-illegal fishing, i.e., foreign fishing based on 'licenses' and protection bought from local or regional authorities in contravention of international law, one finds that fishing companies that bought semi-illegal licenses were often treading a thin line, as being licensed by one warlord or local authority did not ensure safe treatment by another if the vessel entered the perceived local territories of another warlord. Furthermore, the UN Monitoring Group on Somalia has documented misuse of revenues generated from the sale of semi-illegal fishing licenses to the benefit of local warlords to maintain militias and purchase weapons (UN 2006). This concern is not restricted to central and southern Somalia, but is also prevalent along the coast of Somaliland, where Yemeni vessels exchanged arms for fishing rights (UN 2008).

Conclusions

Overall, the likely total catches taken from the waters of Somalia by domestic vessels, as derived through our catch reconstruction, increased from 18,250 t in 1950 to 64,900 t in 2010, and total catches were 98% higher than officially reported data. The occurrence of extensive illegal foreign fishing in the waters of a sovereign state, mainly during a time of severe internal instability, although not quantified here, illustrates an astounding lack of flag-state control by predominantly European and Asian fleets, and a global failure of control over rampant unregulated fisheries exploitation. It seems a poor testimony of international affairs that, in the 21st century, the global community continues to be incapable or unwilling to act decisively in the interest of poor and developing countries. The clear show of unanimous inaction with respect to the renewable resources in the waters of Somalia can only be called 'commercial colonialisms' in the name of globalization and the pursuit of unfettered profit.

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References

Anon. (1982) Somali fishing industry has potential for growth. Foreign Fishery Developments, Marine Fisheries Review 44: 25–26.
Anon. (1985) Fisheries joint venture guidlines. Ministry of Fisheries and Marine Resources, Somali Democratic Republic, Mogadishu. 18 p.
Anon. (1987) Yearly fishery report 1986/87. Ministry of Fisheries and Marine Transport, Somali Democratic Republic, Mogadishu. 46 p.
Anon. (1988) Yearly fisheries and marine transport report 1987/1988. Ministry of Fisheries and Marine Transport, Somali Democratic Republic, Mogadishu.
Anon. (1998) Taiwanese fishermen fined for fishing in Somalia. Agence France Presse, February 28, 1998.
Anon. (2001) Strategic action programme for the Red Sea and Gulf of Aden. Country reports. Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA), February 2001, Washington, D.C.
Anon. (2004) Somaliland in figures 2004. Ministry of National Planning and Coordination Republic of Somaliland, Hargesia. 101 p.
Anon. (2005) Two killed as Somalia hijackers clash over ransom. Awdal News, December 18, 2005.
Anon. (2008a) Kenya loses 10,000 tonnes of fish annually. The Standard, July 14, 2008.
Anon. (2008b) The MV Faina Piracy Crisis Chronicle — IX, News from abducted ships. Ecoterra News International, December 8, 2008.
Anon. (2008c) Official pirate-fishing in the Somali Indian Ocean flourishing. Mareeg Online, November 16, 2008.
Anon. (2008d) Pirate fishing boats target Africa. BBC News, July 3, 2008.
Anon. (2008e) Tanzania to curb illegal fishing. IPP Media, September 25, 2008.
Anon. (2009a) 40,000 tons of Yemen fish trafficked annually, Minister reveals. Yemen Post, November 9, 2009.
Anon. (2009b) Footprint factbook. Africa 2009. Securing human development in a resource constrained world., Global Footprint Network, October 2009, Oakland, California, United States of America. 123 p.
Anon. (2009c) Illegal EU vessels adding to piracy. Intrafish, edition of June 23, 2009.
Bakun A, Claude R and Lluch-Cota S (1998) Coastal upwelling and other processes regulating ecosystem productivity and fish production in the western Indian Ocean. Pp. 103–142 *In* Sherman K, Okemwa, E. N., and M. J. Ntiba (ed.), Large marine ecosystems of the Indian Ocean: assessment, sustainability and management. Blackwell Science, Oxford, U.K.
Bihi A (1984) L'impact potentiel des activités socio-économiques sur l'environnement marin et côtier de la région de l'Afrique de l'Est: rapports nationaux. PNUE : rapports et études des mers régionales nº 51.
Bultel E, Doherty B, Herman A, Le Manach F and Zeller D (this volume) An update of the reconstructed marine fisheries catches of Tanzania with taxonomic breakdown.
Clarke S (2004) Understanding pressures on fishery resources through trade statistics: a pilot study of four products in the Chinese dried seafood market. Fish and Fisheries 5: 53–74.
Coffen-Smout S (1998) Pirates warlords and rogue fishing vessels in Somalia's unruly seas. Available at: http://www.chebucto.ns.ca/~ar120/somalia.html [Accessed 13th October, 2009].

Colléter M, Darar Djibril A, Hosch G, Labrosse P, Yvergniaux Y, Le Manach F and Pauly D (this volume) Le développement soutenu de pêcheries artisanales : reconstruction des captures marines à Djibouti de 1950 à 2010.

Corfitzen W and Kinzy G (1950) Preliminary report on Somalia agricultural projects. Economic Cooperation Administration, September 8, 1950, Rome (Italy). 42 p.

Costello C, Kinlan BP, Lester SE and Gaines SD (2012) The economic value of rebuilding fisheries, OECD Food, Agriculture and Fisheries Working Papers, No. 55. OECD Publishing, Paris (France). 68 p.

Dupont B, Grabosky, P. and Shearing, C. (2003) The governance of security in weak and failing states. Criminal Justice 3(4): 19.

Elmer S (1985) Somalia; technical assistance for marketing and cooperatives. A report prepared for the Technical Support to the Ministry of Fisheries Project. Food and Agriculture Organization of the United Nations (FAO), Sweden Funds-In-Trust, Field Document 2, June 1985, Rome (Italy).

FAO (1972) Fishery resources survey Somali Democratic Republic. Report prepared for the Fishery Survey Project, based on the work of the research vessel Zheleznyakov. FI:SF/DP SOM 67/513/4. November 6 1972, Rome (Italy). 48 p.

FAO (1978) Development of fisheries in the exclusive economic zone of Somalia: report. Food and Agriculture Organization of the United Nations (FAO), 1978, Rome (Italy).

FAO (2005) The Somali Republic — General information. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 10 p.

Gulaid A (2004) Feasibility report on the fisheries sector in Somaliland. Current status, opportunities and constraints., United Nations Development Programme (NDP). Discussion Paper Consultant's Findings, April–June 2004. 35 p.

Haakonsen J (1984) Scientific socialism and self-reliance. The case of Somalia'a "instant" fishermen. Department of Social Anthropology University of Bergen, 1984. 166 p.

Haakonsen JH (1983) Somalia's fisheries case study. FAO Fisheries Report No. 295, FIPP/R295, Food and Agriculture Organization of the United Nations, Rome (Italy).

Hansen SJ (2008) Private security & local politics in Somalia. Review of African Political Economy 118: 585–598.

Hansen SJ (2009) Piracy in the greater Gulf of Aden, myths, misconceptions and remedies. NIBR Report 2009, Norwegian Institute for Urban and Regional Research, Oslo (Norway). 72 p.

Hariri K (1985) Fisheries development in the North West Indian Ocean. The impact of commercial fishing arrangements. Ithaca Press, 1985, London (UK). 158 p.

IOFC (1982) Major fisheries issues in the region; progress and problems (and total landings). Food and Agriculture Organization of the United Nations (FAO), Indian Ocean Fishery Commission (IOFC), Committee for the Development and Management of Fisheries in the Southwest Indian Ocean, Second Session, 13–15 December 1982 Mahé (Seychelles).

IUCN (2003) Information on shark finning: conversion factors for shark fin to body weight., Available at: http://www.flmnh.ufl.edu/fish/organizations/ssg/finconversion.html [Accessed February 25, 2010].

IUCN (2006) Country environmental profile for Somalia. Prepared for the European Commission Somalia Operations Office by The World Conservation Union (IUCN), March–August 2006, Nairobi, Kenya.

Jennings T (1998) Marine living resource governance in the absence of a central authority: a study of Somalia. Master of Marine Affairs thesis, University of Washington, Seattle, WA (USA). 135 p.

Jennings T (2001) Controlling access in the absence of a central government: the Somali dilemma. Pp. 403–427 *In* Mann Borgese E, Chircop A and McConnell M (eds.), Ocean Yearbook 15. The University of Chicago Press, Chicago, IL (USA).

Johnsen T (1985) Commercial trawling for fish and deep sea lobster (*Puerulus spp.*) off Somalia. Food and Agriculture Organization of the United Nations (FAO). RAF/79/065/WP/13/84. June 1985.

Johnson R (1956) Fisheries reconnaissance Somalia, East Africa. United States of America operations mission to Italy, June 18, 1956, Rome (Italy). 29 p.

Kelleher K (1998) Approaches to marine fisheries governance in Somalia. Draft report, the protection and sustainable development of Somalia marine environment, seaports and coastal areas. United Nations Development Programme (UNDP), Project SOM/97/013A/08/19, Food and Agriculture Organization of the United Nations (FAO), FAO/TCP/SOM/6713, Field document. March 1998. 39 p.

Kelleher K (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper 470, Food and Agriculture Organization (FAO), Rome (Italy). 131 p.

Kinsey CP, Hansen, SJ and Franklin G (2009) The impact of private security companies on Somalia's governance networks. Cambridge Review of International Affairs 22(1): 15.

Kulmiye AJ (2001) Militia versus trawlers: Who is the villain? The East African Magazine, July 9, 2001.

Laitin D and Samatar S (1984) Somalia and the world economy. Review of African Political Economy 30: 58–72.

Lawrence C (1980) Fisheries legislation in Somalia. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

Lawson T, Lablache G, Simeos F and Ali AF (1986) The Western Indian Ocean tuna fishery from 1980 to 1985 — A summary of data collected by coastal states. Technical Report, SFA/R & D/001, Seychelles Fishing Authority, 26 August 1986, Mahé (Seychelles).

Le Manach F, Abunge CA, McClanahan TR and Pauly D (this volume) Tentative reconstruction of Kenya's marine fisheries catch, 1950–2010.

Lehr P and Lehmann H (2007) Somalia–Pirates' new paradise. Pp. 1–21 *In* Lehr P (ed.), Violence at sea: piracy in the age of global terrorism. Taylor and Francis Group LLC, New York, NY (USA).

Losse G (1970) Fishery survey Somalia: the tuna fishery of the Gulf of Aden. Report prepared for the Government of Somalia by the Food and Agriculture Organization of the United Nations acting as executing agency for the United Nations Development Programme (UNDP), Technical Report 1, FI:SF/SOM 13, Rome (Italy).

Lovatelli A (1996) Artisanal fisheries final report. European Commission Rehabilitation Programme for Somalia. EC Somalia Unit, Nairobi (Kenya).

Marshall N (1997) The Somali shark fishery in the Gulf of Aden and the Western Indian Ocean. Pp. 24–30 *In* Marshall N, and R. Barnett (eds.), Trade in sharks and shark products in the Western Indian and Southeast Atlantic Oceans. TRAFFIC East/Southern Africa, Nairobi (Kenya).

Menkhaus K (2009) Dangerous waters. Survival 51: 21–25.

Mohamed M and Herzi M (2005) Feasibility report on the fisheries sector in Puntland. Current status, opportunities and constraints. United Nations Development Programme (UNDP) Somalia, Poverty Reduction and Economic Recovery. Ocean Training and Promotion (OTP) Bossaso supported by UNDP Somalia.

Mukhtar MH (1996) The plight of the agro-pastoral society of Somalia. Review of African Political Economy 23(70): 543–553.

Mwangura A (2006b) IUU fishing and Indian Ocean piracy. Workshop on Fishing Communities and sustainable Developments in Southern and Eastern Africa: A samll-scale fisheries perspective, Dar-es-Salaam (Tanzania).

Nincic D (2008) State failure and the re-emergence of maritime piracy. Presented at the 49th Annual Convention of the International Studies Association, March 26–29, 2008, San Francisco, CA (USA).

Ogilvie H, Fraser-Brunner A and Byrd D (1954) Report to the government of Italy as the administering authority for the Trust Territory of Somalia on the exploratory fishery survey in Somalia–1952/53. Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 83 p.

Österblom H, Constable A and Fukumi S (2011) Illegal fishing and the organized crime analogy. Trends in Ecology and Evolution 26(6): 261–262.

Pierconti G and Dunn I (1990) Fishery project formulation mission report. Intergovernmental authority on drought and development. Food and Agriculture Oraganization of the United Nations (FAO), FI:TCP/RAP/8970 (F), May 1990, Rome (Italy).

Qayad M (1997) Assessment mission to Somalia in connection with alleged dumping of hazardous substances. Mission report. Joint UNEP/DHA environmental unit and the UN coordination unit (UNCU) for Somalia, 10 May through 8 June, 1997.

Rykaczewski R and Checkley JD (2008) Influence of ocean winds on the pelagic ecosystem in upwelling regions. Proceedings of the National Academy of Science 105: 1965–1970.

Sabriye A (2005) Feasibility report on the fisheries sector in South and Central Somalia. Current status, opportunities and constraints., United Nations Development Programme (UNDP), poverty reduction and economic recovery. Discussion paper. 36 p.

Samatar AI (2007) Somalia's post-conflict economy: a political economy approach. Bildhaan 7(8): 43.

Samoilys M, Domingue G, Kariuki J, Payet R, Hersi A and Ali. M (2007) Application of the PROFISH global list of irresponsible fishing vessles as a tool to combat illegal unregulated and unreported fishing in Eastern Africa. The World Conservation Union, Nairobi (Kenya).

Sanders M and Morgan G (1989) Review of the fisheries resources of the Red Sea and Gulf of Aden. FAO Fisheries Technical Paper 304, Rome (Italy).

Schofield C (2008) Plundered waters; Somalia's maritime resource insecurity. Pp. 102–115 (332) *In* Doyle T, and M. Risely (eds.), Crucible for survival; environmental security and justice in the Indian Ocean region. Rutgers, New Jersey (USA).

Shaves G (1984) Somalia technical assistance for marketing and cooperatives. Sweden Funds-In-Trust, Food and Agriculture Organization of the United Nations (FAO). Prepared for the Technical Support to the Ministry of Fisheries Project. Field document, FI:UTF/SOM/028/SOM. Rome (Italy). 16 p.

Simoons FJ (1974) Rejection of fish as human food in Africa: a problem in history and ecology. Ecology of Food and Nutrition 3(2): 89–105.

Stromme T (1987) Annex IV Sectoral report on marine living resources. Pp. 87–110 *In* Burbridge P (ed.), Coastal and marine environmental problems of Somalia. UNEP Regional Seas Reports and Studies No. 84, UNEP.

Sumaila UR, Cheung WWL, Lam V, Pauly D and Herrick S (2011) Climate change impacts on the biophysics and economics of world fisheries. Nature Climate Change 1: 449–456.

Thurow F and Kroll D (1962) Report on the fisheries conditions in Somalia. Kiel (Germany). 36 p.

Tussing A, Hiebert RA and Sutinen J (1974) Fisheries of the Indian Ocean: issues of international management and law of the sea. Paper no. 5 in a series prepared for The Program of International Studies of Fishery Arrangements, Washington, DC (USA). 55 p.

UN (2006) United Nations Security Council, May 4, 2006, Report of the Monitoring Group on Somalia pursuant to Security Council resolution 1630 (2005). United Nations Security Council, United Nations. 69 p.

UN (2008) United Nations Security Council, April 24, 2008, Report of the Monitoring Group on Somalia pursuant to Security Council resolution 1766 (2007). United Nations Security Council. 83 p.

UNDP and FAO (1992) Development of inshore fisheries North West coast : Somalia: project findings and recommendations. United Nations Development Programme (UNDP) and Food and Agriculture Organization of the United Nations (FAO), Rome (Italy).

UNEP (2005) The state of the environment in Somalia. A desk study. United Nations Environment Programme (UNDP), Nairobi (Kenya). 67 p.

UNODC (2011) Transnational organized crime in the fishing industry. United Nations Office on Drug and Crime, Vienna (Austria). 140 p.

Van Zalinge NP (1988) Summary of fisheries and resources information for Somalia. Pp. 142–154 *In* Sanders MJ, Sparre P and Venema SC (eds.), Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. Food and Agriculture Organization of the United Nations (FAO). FAO/UNDP: RAF/79/065/WP/41/88/E, Rome (Italy).

von Hoesslin K (2006) Taiwan and piracy along the Horn of Africa. Taiwan Journal XXV, Number 1.

Weir G (2009) Fish, family, and profit. Piracy and the Horn of Africa. *In* Elleman B, Forbes, A., and D. Rosenberg (eds.), Piracy and maritime crime: historical and modern case studies. Newport paper 35. Naval War College Press, New Port, RI (USA).

Yassin M (1981) Somali fisheries development and management. Report for the 506A Project Resource Management, Mogadishu (Somalia). 63 p.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fisheries catches for U.S. flag island areas in the Western Pacific: The last 50 years. Fishery Bulletin 105(2): 266–277.

Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector, with discards shown separately, for Somalia, 1950–2010.

Year	FAO landings[a]	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discards
1950	6,000	18,300	1,480	9,900	6,600	272
1951	6,000	18,300	1,480	9,960	6,550	272
1952	7,000	18,500	1,730	10,010	6,490	317
1953	7,400	18,700	1,830	10,070	6,440	335
1954	5,300	18,000	1,310	10,120	6,380	240
1955	9,500	19,300	2,340	10,170	6,330	430
1956	10,000	19,400	2,470	10,230	6,270	453
1957	9,000	19,100	2,220	10,280	6,220	407
1958	8,000	18,800	1,970	10,340	6,160	362
1959	5,000	18,000	1,230	10,390	6,110	226
1960	4,500	18,000	1,110	10,600	6,050	195
1961	4,500	18,000	1,110	10,660	6,000	213
1962	4,500	18,000	1,110	10,710	5,940	231
1963	4,500	18,200	1,110	10,930	5,930	249
1964	4,500	18,400	1,110	11,080	5,930	272
1965	4,600	18,800	1,130	11,450	5,920	289
1966	4,600	19,000	1,130	11,600	5,910	315
1967	4,700	19,100	1,160	11,670	5,910	353
1968	5,000	19,300	1,230	11,820	5,900	398
1969	5,000	19,500	1,230	11,970	5,880	435
1970	5,600	19,900	1,380	12,200	5,870	494
1971	5,700	20,200	1,410	12,350	5,860	537
1972	5,800	20,400	1,430	12,500	5,850	583
1973	5,900	20,600	1,460	12,660	5,830	631
1974	5,980	20,900	1,520	12,870	5,820	685
1975	10,350	21,500	1,650	13,320	5,800	766
1976	8,268	22,800	2,690	13,330	5,780	980
1977	9,830	24,400	3,850	13,530	5,770	1,225
1978	8,384	20,100	510	13,090	5,750	745
1979	10,984	24,700	4,780	13,010	5,460	1,495
1980	14,330	29,900	9,760	12,650	5,180	2,285
1981	9,523	24,200	5,040	12,360	5,120	1,648
1982	8,730	23,100	4,110	12,420	5,060	1,542
1983	11,195	25,000	5,640	12,530	5,000	1,869
1984	19,639	32,200	11,690	12,530	4,950	3,034
1985	16,467	30,400	10,180	12,540	4,890	2,828
1986	18,255	24,800	5,020	13,000	4,830	1,971
1987	19,546	31,900	11,150	12,780	4,770	3,154
1988	19,827	30,200	9,680	12,790	4,720	2,999
1989	21,046	29,600	10,270	11,900	4,300	3,090
1990	22,295	28,900	10,880	10,970	3,890	3,178
1991	23,500	28,300	11,470	10,040	3,490	3,295
1992	24,620	28,100	12,450	9,080	3,100	3,465
1993	24,212	27,800	13,420	8,070	2,720	3,623
1994	23,904	27,700	14,450	7,110	2,340	3,755
1995	23,851	27,800	15,690	6,180	1,980	3,900
1996	26,044	30,300	14,620	8,670	2,760	4,265
1997	27,750	32,800	13,540	11,180	3,520	4,606
1998	25,550	35,400	12,470	13,710	4,250	4,972
1999	28,400	40,900	13,860	16,290	4,970	5,798
2000	23,950	42,200	11,690	18,800	5,660	6,009
2001	31,700	50,600	15,470	21,460	6,330	7,295
2002	28,800	52,800	14,060	24,050	6,980	7,663
2003	29,800	57,200	14,540	26,700	7,610	8,369
2004	29,800	61,100	14,540	29,370	8,210	9,001
2005	24,800	61,800	12,100	32,000	8,790	8,947
2006	29,800	64,800	14,540	32,190	8,660	9,415
2007	29,800	64,800	14,540	32,320	8,520	9,444
2008	29,800	64,900	14,540	32,460	8,390	9,472
2009	29,800	64,900	14,540	32,590	8,250	9,501
2010	29,800	64,900	14,540	32,730	8,120	9,530

[a] These are the adjusted FAO landings.

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxonomic group, for Somali, 1950–2010. 'Others' contain 42 additional taxonomic categories.

Year	*Lethrinus nebulosus*	*Thunnus albacares*	Batoidea	*Epinephelus areolatus*	*Diagramma pictum*	Others
1950	1,870	1,290	533	1,005	281	13,300
1951	1,860	1,290	536	1,002	281	13,300
1952	1,890	1,320	541	1,025	328	13,400
1953	1,890	1,330	545	1,032	347	13,500
1954	1,830	1,300	543	976	248	13,200
1955	1,940	1,390	555	1,081	445	13,900
1956	1,950	1,400	559	1,091	469	14,000
1957	1,910	1,390	560	1,062	422	13,800
1958	1,880	1,380	561	1,034	375	13,600
1959	1,790	1,330	557	954	234	13,100
1960	1,770	1,320	558	933	202	13,200
1961	1,760	1,330	565	931	202	13,200
1962	1,760	1,330	573	928	202	13,200
1963	1,750	1,340	608	926	197	13,400
1964	1,750	1,340	644	927	197	13,500
1965	1,750	1,340	681	922	187	13,900
1966	1,750	1,340	719	922	187	14,000
1967	1,760	1,350	759	927	197	14,100
1968	1,760	1,360	801	935	211	14,300
1969	1,760	1,360	844	935	211	14,400
1970	1,780	1,370	888	947	234	14,700
1971	1,780	1,370	933	949	239	14,900
1972	1,780	1,380	980	951	244	15,000
1973	1,780	1,380	1,027	953	248	15,200
1974	1,780	1,390	1,076	956	257	15,400
1975	1,800	1,400	1,129	971	285	16,000
1976	1,890	1,470	1,189	1,060	451	16,700
1977	2,010	1,540	1,251	1,165	646	17,800
1978	1,680	1,320	1,279	862	95	14,900
1979	2,040	1,560	1,308	1,230	839	17,800
1980	2,430	1,820	1,336	1,619	1,621	21,000
1981	1,990	1,520	1,348	1,223	910	17,200
1982	1,880	1,440	1,384	1,123	742	16,600
1983	2,020	1,550	1,443	1,267	1,018	17,700
1984	2,690	2,000	1,544	1,884	2,159	21,900
1985	2,510	1,870	1,578	1,724	1,881	20,900
1986	1,910	1,460	1,600	1,184	912	17,800
1987	2,560	1,900	1,724	1,793	2,042	21,800
1988	2,360	1,780	1,783	1,629	1,792	20,800
1989	2,320	1,720	1,723	1,636	1,901	20,300
1990	2,270	1,670	1,654	1,641	2,017	19,700
1991	2,220	1,620	1,586	1,642	2,128	19,100
1992	2,220	1,610	1,508	1,689	2,318	18,700
1993	2,230	1,600	1,419	1,741	2,513	18,300
1994	2,240	1,590	1,316	1,795	2,708	18,000
1995	2,270	1,600	1,201	1,868	2,938	17,900
1996	2,360	1,680	1,694	1,861	2,734	20,000
1997	2,450	1,780	2,128	1,857	2,530	22,100
1998	2,570	1,900	2,555	1,865	2,326	24,200
1999	2,950	2,220	2,994	2,121	2,585	28,000
2000	2,950	2,280	3,393	2,019	2,183	29,300
2001	3,600	2,810	3,832	2,522	2,890	34,900
2002	3,680	2,950	4,215	2,498	2,626	36,800
2003	3,980	3,250	4,599	2,668	2,717	40,000
2004	4,220	3,520	4,968	2,791	2,717	42,900
2005	4,200	3,620	5,239	2,667	2,263	43,900
2006	4,450	3,820	5,282	2,906	2,717	45,600
2007	4,440	3,830	5,304	2,899	2,717	45,600
2008	4,420	3,840	5,326	2,891	2,717	45,700
2009	4,410	3,850	5,348	2,883	2,717	45,700
2010	4,390	3,860	5,369	2,875	2,717	45,700

South Africa's Marine Fisheries Catches (1950–2010)*

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Abstract

The official fisheries catch data reported by South Africa to the Food and Agriculture Organization of the United Nations (FAO) is thought to focus on commercial catches, and exclude subsistence (i.e., small-scale non-commercial fishing for self- and family-consumption) and recreational (i.e., small-scale non-commercial fishing for pleasure) catches. The reconstruction of fisheries catches from 1950 to 2010 was undertaken, and combined official data reported to the FAO with estimates of unreported catches for the recreational and subsistence sectors, illegal artisanal catch, and discards from industrial fishing. Total recreational and subsistence catches were estimated to be approximately 3,400 t·year^{-1} and 1,600 t·year^{-1} in the 1950s, respectively, and increased steadily to almost 6,400 t·year^{-1} and 4,300 t·year^{-1} in the 2000s (of which about 65% of the respective catches came from the South African Exclusive Economic Zone [EEZ] in the Western Indian Ocean; FAO area 51). In comparison, domestic industrial catches averaged 370,000 t·year^{-1} in the early 1950s, peaked at 2.1 million t in 1968, and have been around 720,000 t·year^{-1} in the 2000s. Reconstructed artisanal catches increased from about 45,000 t·year^{-1} in the early 1950s to 42,000 t·year^{-1} in the 2000s. Discards by the industrial sector totalled 3.6 million t from 1950 to 2010, making up about 6% of total reconstructed catch. Almost all industrial catches were from South Africa's EEZ in the Southeast Atlantic Ocean (FAO area 47). South African catches taken in Namibian waters during the South African occupation of Namibia (1915–1990) were identified and assigned as South African flagged catches taken in Namibian waters. These catches from Namibian waters totalled 18 million t from 1950 to 1990, and were on average 200,000 t·year^{-1} in the 1950s before peaking at 1.6 million t in 1968, then dropping to 162,000 t·year^{-1} in the late 1980s. Once reported landings were adjusted for the spatially reassigned catches taken in Namibian waters, reconstructed total catches for South Africa proper were 1.1 times the adjusted landings reported by FAO on behalf of South Africa. Although reconstructed subsistence and recreational catches made up less than 1% of annual domestic commercial catches, these sectors are of considerable socio-economic importance for a large fraction of South Africans. The reconstruction of fisheries catches in these marginalized sectors emphasizes the necessity for political action in support of new management measures, and for ensuring a sustainable and equitable use of ecologically, socially and economically important marine resources in South Africa.

Introduction

In times of dwindling natural marine resources and ever increasing pressure on the marine environment induced by human activities such as overfishing, pollution and global warming, there is the need for more comprehensive and sustainable approaches in fisheries management and a shift in the exploitation of marine resources in general. Global fisheries overall are in a crisis of overexploitation and ongoing stock depletion (Pauly *et al.* 2002; Myers and Worm 2003). It has been suggested that a combination of traditional management methods (e.g., catch quotas) and closed areas (marine protected areas in which fishing is prohibited), gear and effort restrictions, as well as new management approaches in general hold promise for rebuilding of stocks (Worm *et al.* 2009).

In order to facilitate adequate fisheries management and to account for fisheries in an ecosystem-based setting, comprehensive knowledge on stock status and the amount of withdrawal from these stocks is required. Despite the socioeconomic importance of recreational and subsistence/small-scale fisheries, catch data for these sectors are seldom available and catches are therefore unreported. The marginalization of these sectors and the neglect in quantifying respective catches, systematically tend to underestimate both the actual extent of catches and subsequently the potential adverse effects on marine ecosystems (Pauly and Zeller 2003; Cooke and Cowx 2004; Pauly 2006).

In recent years, increased scientific effort has been undertaken in order to quantify and map formerly unreported catches, by reconstructing or reestimating historic catches for various countries and regions, in order to complement existing time series of catches of the Food and Agricultural Organization of the United Nations (FAO) and to examine relationships between fishing and ecological changes (Watson *et al.* 2004; Pauly 2007).

This report is the first attempt to reconstruct previously unreported catches in South African fisheries, following the catch reconstruction methodology of Zeller *et al.* (2007a). Reconstructed catches were taxonomically assigned and spatially split to various Exclusive Economic Zones (EEZ) within FAO areas.

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South Africa has a long coastline that spans two oceans, the Atlantic Ocean in the west and the Indian Ocean in the east (Figure 1). The Benguela ecosystem of the west coast is one of the most productive ocean ecosystems in the world in terms of biomass production and fishery resources due to the upwelling of cold, nutrient rich water (Cochrane *et al.* 2009). South African waters are characterized by high endemism due to the distinct oceanographic conditions and the variety of habitats (Van der Elst *et al.* 2005). Today, the fishing industry in South Africa provides employment and income for at least 27,000 people, but contributes less than 1% of the country's Gross Domestic Product (GDP; FAO 2010). South Africa is the largest fishing countryn in Africa, and ranked 30th in the world in the 1990s (Hersoug and Holm 2000). The fisheries of South Africa can be separated into three components: the commercial/industrial, recreational, and subsistence/artisanal fisheries, jointly all targeting over 250 marine species (FAO 2010). Here, we distinguished between four fishing sectors: industrial (i.e., large-scale commercial), artisanal (small-scale commercial), subsistence (small-scale non-commercial) and recreational (small-scale non-commercial).

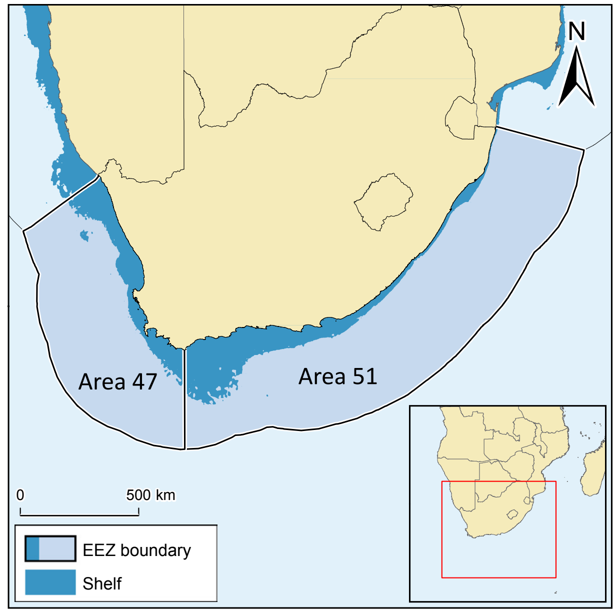

Figure 1. Map of the South African's Exclusive Economic Zone (EEZ) in both Atlantic and Indian Oceans, as well as the extent of the continental shelf (dark blue).

Commercial fisheries

The commercial fishing industry is being separated into large-scale (i.e., industrial) and small-scale (i.e., artisanal) in the present context, and each consists of several fisheries. The most important fishery is the deep-sea trawling subsector and the smaller inshore trawl fishery (both deemed industrial) mainly targeting hake stocks (*Merluccius paradoxus* and *M. capensis*; Burgener 2011). There are also small fisheries for hake using demersal longlines and handlines (FAO 2010), which are deemed artisanal.

There is also a pelagic purse-seine fishery targeting sardine (*Sardinops ocellatus*), anchovy (*Engraulis capensis*) and round herring (*Etrumeus whiteheadi*) for the production of fishmeal, oil and canned fish (this fishery represents 25% of the value of commercial fisheries in South Africa; Hersoug and Holm 2000; Okes and Burgener 2011a). A midwater trawl fishery is targeting horse mackerel (*Trachurus capensis*) on the Agulhas Bank. Both these fisheries were treated as industrial.

There are two important rock lobster fisheries in South Africa. On the West Coast, an inshore fishery is targeting West Coast rock lobster (J*asus lalandii*), and on the South Coast a deep water fishery is targeting *Palinurus gilchristi;* Okes and Burgener 2011b). Rock lobster contributes less than 1% by mass to the total fishery, but its contribution by value is approximately 9–10%. Lobster fisheries were treated as artisanal.

There is also a very valuable, but politically highly disputed abalone fishery (*Haliotis midae*), which has been operating since the late 1940s (DAFF 2012). High levels of poaching and resulting overexploitation led to the temporary closure of the industry in the late 2000s (Hauck and Sweijd 1999; Raemaekers and Britz 2009). This fishery was treated as artisanal.

Other smaller fishing sectors include trawl fleets targeting shrimp off the coast of Kwa-Zulu Natal (industrial; Okes and Burgener 2011c), a pelagic longline fishery targeting various tuna species, sharks and billfishes (industrial; Okes and Burgener 2011d,e), a tuna bait and pole fishery (industrial), a small squid jig fishery (artisanal fishery targeting chokka squid [*Loligo vulgaris reynaudi*] for export; Okes and Burgener 2011f), and a linefish sector (artisanal) that is large in terms of area fished and people employed, targeting a great diversity of fish species including sharks, tunas, and groupers (FAO 2010).

In general, catch data for the South African commercial fisheries appeared to be well documented and catch statistics were readily available. South African national statistics made provision for illegal fishing by adding on an illegal catch component to the commercial lshaandings of some fisheries, but the true level of illegal fishing that actually takes place remains unknown (DAFF 2012).

Foreign fishing in South Africa

There appear to be a few South African commercial fisheries that have foreign involvement (David Japp, CapFish, pers. com.), notably:

- A large pelagic fishery, which at present has about 15 joint venture arrangements between South African fishing rights holders and mainly Japanese and Chinese fishing entities (Okes and Burgener 2011d);
- A deep-water hake trawl fishery, which has catch arrangements with Spanish vessels that are not officially sanctioned, and hence could be deemed illegal; and

- A patagonian toothfish (*Dissostichus eleginoides*) fishery, which seems to include at least two vessels with foreign beneficial ownership holding South African joint venture fishing rights.

Here we did not estimate catches of these foreign operations, as we had to assume that legal joint venture operations engaged in proper reporting procedures, and hence such catches would need to be reported to South African authorities (except possibly the potentially illegal operations of non-sanctioned Spanish hake fishing; see item 2 above).

Recreational fisheries

In recent years, the exploitation of marine resources by various types of recreational fisheries has become a topic of increasing concern for some countries. It is now acknowledged that the recreational fishing sector has the potential to negatively affect fish stocks and may lead to overexploitation of marine resources (Coleman *et al.* 2004; Cooke and Cowx 2004). In countries such as Australia and the USA, the scientific community acknowledges that public perception and the *modus operandi* of managing recreational fisheries needs to change, bearing in mind that recreational fisheries have various long-term effects on fish stocks and marine ecosystems (McPhee *et al.* 2002). Thus, information about total catches, total number of fishers, fishing effort and species composition is crucial. Unfortunately, due to the diversity and spatial and temporal dispersion of the recreational fisheries sector, it is often difficult to obtain such data. As there are no comprehensive estimates for the recreational sector and no official catch statistics for the marginalized subsistence sector in South Africa, this report is the first attempt to reconstruct the total marine recreational catch in South Africa for the period 1950–2010.

The South African marine recreational fishing sector is a large and economically important component of South African fisheries. An extensive coastline and a rich and diverse marine fauna offer thousands of recreational fishers the right conditions for their hobby. Major recreational fisheries target abalone, West Coast rock lobster and around 200 pelagic and demersal species targeted using line fishing (of which 31 contribute significantly to the overall total catch; Griffiths and Lamberth 2002). The recreational linefish component can be separated into various sectors: boat- and shore-based estuarine fishers, including recreational fishers using cast nets; marine inshore rock and surf anglers; a boat-based offshore sector; and the spearfishing sector operating both from the shore and from boats. Additionally, there is a charter boat sector offering sport and big game fishing, which has become increasingly popular in recent years, especially in the province of Kwa-Zulu Natal (Pradervand and Van der Elst 2008).

Historically, recreational fishing permits for most species were not required in most parts of South Africa until 1999, when new fishing legislation (Marine Living Resource Act of 1998) was put in place. In Kwa-Zulu Natal, a licensing system was implemented in 1971 under a Provincial Ordinance. Nationwide size limits, bag limits, marine protected areas and closed seasons for some species were the only measures implemented in order to manage the recreational fisheries (Cockcroft *et al.* 1999; Griffiths and Lamberth 2002). In contrast to subsistence fishing, which has existed in South Africa for thousands of years, and commercial fisheries that were initiated by Dutch colonists in the 17th century, recreational shore-based fisheries were introduced by British settlers in the early 19th century (Van der Elst 1989). According to Horne (1974), boat-based recreational angling was only introduced after World War II. Around the same time, various technological developments with respect to gear and fishing methods led to recreational fishing becoming an increasingly popular pastime. Already in the early 1960s, there were an estimated 250,000 recreational fishers in South Africa engaging in shore- and boat-based angling (Schoeman 1962). World record catches of giant bluefin and yellowfin tuna, various types of sharks, marlins, sailfish and giant barracuda were recorded from South African waters before 1950 (Schoeman 1962). Due to its popularity and the economic importance of generating 81% of employment and 82% of revenue of the total South African line fishery sector (Griffiths and Lamberth 2002), the recreational fishing sector can be regarded as an integral part of the South African economy, as well as the fishing industry as a whole.

It is accepted that recreational fishing is responsible for the decline of various fish stocks, crustaceans and other marine organisms in South Africa. Both boat- and shore-based anglers have substantially contributed to the collapse of several stocks (Griffiths and Lamberth 2002) and catch declines are reported in various scientific papers (e.g., Brouwer *et al.* 1997; Sauer *et al.* 1997). In the early 2000s, the South African Government officially declared the marine linefish fishery as being in a state of emergency due to the collapsed or overexploited state of many linefish stocks (Griffiths and Lamberth 2002).

Estimating recreational catches, especially for periods in the past, is a difficult task. The management of the recreational fisheries sector in South Africa appeared complicated due to its numerous species, multi-user nature and temporal and spatial diversity and variability. This report made a first attempt to reconstruct the total recreational catch from 1950 to 2010 as accurately as possible in order to acquire a better understanding of the extent of catches.

Subsistence fisheries

Subsistence fisheries provide food (and occasional income from selling surplus catch or high value catch) for millions of people throughout the world. In South Africa, despite its importance in terms of food security and poverty alleviation, this sector has not been sufficiently integrated into management and policy systems (Sowman 2006). The reforms of the post-apartheid transformation process and the implementation of the new Marine Living Resource Act in 1998 have not yet reached its aims of sustainability, equity and stability (Isaacs 2006). Many traditional fishers have been excluded from the new fisheries management framework and consequently were left without fishing rights and adequate support (Sowman and Cardoso 2010). Nevertheless, the Marine Living Resource Act contains the initial legal recognition of subsistence fishers in South Africa, and some progress has been made since then. In Kwa-Zulu Natal, a system of co-management has been implemented in some communities and a limited commercial sector for historically disadvantaged individuals (HDI) in South Africa was created in 2001 (Sowman 2006), thus turning some former subsistence fishers into artisanal fishers.

Scientific studies have concentrated on political, socio-economic and management-related issues concerning the subsistence sector in South Africa (Hauck and Sowman 2001; Branch *et al.* 2002a,b; Harris *et al.* 2002a,b; Hauck *et al.* 2002; Sowman 2006; van Sittert *et al.* 2006; Sowman and Cardoso 2010). Some studies identified the present number of subsistence fishers and the type of resources they exploit in South Africa (Clark *et al.* 2002; Cockcroft *et al.* 2002; Napier *et al.* 2009). This report attempted to reconstruct the marine fisheries catches for the subsistence sector in South Africa for the 1950–2010 period. Several studies have identified the extent and economic importance of underreporting of subsistence fisheries catches in various countries in which official statistics mainly focus on commercial fisheries only (Zeller *et al.* 2006, 2007a,b; Jaquet and Zeller 2007).

There is a general consensus that subsistence fishers are poor fishers who catch marine resources as food source although they may sell or exchange surplus catches to meet basic needs of food security (Branch *et al.* 2002a; Sowman 2006). Furthermore, they catch resources near or on the shore, as well as in estuaries, apply low-technology gear and mostly live in close proximity to the fishing area (Branch *et al.* 2002a). Thus, here we defined subsistence fishing as small-scale non-commercial fishing with the primary purpose of feeding one's family, while recognizing that subsistence fishers may sell part of their catch, especially if catches exceed their immediate food security needs or can provide needed cash (e.g., from high-value specimen).

Artisanal fishers are also often poor fishers but have a principle commercial involvement with fishing marine resources. Artisanal fishers go fishing to primarily sell their catches rather than using it primarily for their own consumption (Branch *et al.* 2002a). Thus, here we defined artisanal fishing as small-scale commercial fishing with the primary intent of generating cash income. We recognize the overlap between these two sectors, and hence the potential arbitrariness of differentiation at times.

Many fishers in South Africa, defined as subsistence or artisanal fishers, actually intend to gain small-scale commercial rights in order to legally sell high-value resources such as abalone and rock lobsters (Branch *et al.* 2002a). The idea of creating a small-scale commercial fisheries sector was to enable subsistence/artisanal fishers to generate revenues by allocating specific fishing rights. The potential socioeconomic benefits of the commercialization of some subsistence fisheries in South Africa have been documented (Arnason and Kashorte 2006). The process of implementing a management strategy for the small-scale sector by means of creating sufficient numbers of fishing rights and providing adequate support is continuing. The government's lack of experience with a subsistence sector lead to the appointment of a Subsistence Fisheries Task Group (SFTG) in 1999 to advise the government in various issues regarding the management of the new subsistence sector (Sowman 2006).

Material and methods

Human population data[1]

Recreational fisheries

The various components of recreational fisheries have been subject to numerous individual studies and offer information for estimating the total recreational marine catch if one accepts some assumptions. Available information included data on catches, catch rates and targeted species composition, geographic and socio-economic information, as well as historical and general background information

Marine inshore surf and rock recreational fisheries

In general, shore angling data are sparse for South Africa. An exception to this is the province Kwa-Zulu Natal, where several investigations have been undertaken to estimate catches and effort, species compositions, the economic importance of recreational shore fishing, and anglers' attitudes towards and compliance with fishery regulation (Brouwer *et al.* 1997). Information obtained from government shore patrols, voluntary catch and effort data, and inspections, are collected in the National Marine Linefish System (NMLS; Brouwer *et al.* 1997). Due to the fact that almost no recreational data are collected for provinces other than Kwa-Zulu Natal, the flexibility of data sources and the unreliability of voluntary and compulsory catch data from individual fishers; the NMLS is unfortunately perceived as being a poor and unrepresentative data source (Sauer *et al.* 1997). Therefore, the focus has been on obtaining additional data from individual studies, reports and scientific papers.

[1] Population data for South Africa were obtained from the United Nations World Population Division (United Nations 2009) and the World Bank (World Bank 2010).

Boat-based marine inshore recreational fisheries

Gears used are the same as in the shore angling sector, i.e., rod and reel or handlines. Even though there are varying levels of competition between all recreational fishing sectors and the commercial linefishery sector, the commercial and recreational boat sectors compete most directly. Similar vessels and gear are used and the same fish species are targeted in the same geographic regions and marine environments. The resulting user conflicts were reported in the literature, which highlighted the difficulty in distinguishing between recreational and commercial fishers due to the fact that many operate in both sectors, depending on seasonal availability of fish and the availability of supplementary incomes (Sauer *et al.* 1997). Collection of information about catch rates, effort, total catches and targeted species started in the 1970s, similarly to the shore angling sector. Data on commercial and recreational boat-based fisheries were separate until 1982, when the NMLS database was initiated. As with the other recreational sectors, numerous scientific studies have been done, which reveal important information on the nature of recreational boat-based fisheries in South Africa.

Spearfishing

Spearfishing is regarded as one of the most dangerous forms of fishing in South Africa, as it often occurs in challenging underwater conditions, requiring excellent mental and physical fitness of its participants. Nevertheless, this form of fishing has enjoyed great popularity since the 1950s along the South African coast, where fishers operate both from shore or from boats (Mann *et al.* 1997).

Estuarine recreational angling

Along the South African coastline, there are approximately 250 well-defined estuaries and many are used as recreational fishing sites. Due to the lack of inlets and bays in South Africa, estuaries offer popular fishing grounds, as they are sheltered from rough seas and are productive fishing grounds attracting mainly recreational boat-based and shore-based fishers who also use cast nets to catch baitfish such as mullet. Linefishing and netfishing (mostly gillnets and seine netting) for commercial and subsistence purposes also occurs in estuaries (Lamberth and Turpie 2003). The most important ecological role of estuaries is that they provide nursery areas for many fish, contributing to healthy fish stocks and a healthy marine environment (Whitfield 1994). It is estimated that the estuarine catch in the early 2000s totalled 2,480 tonnes per year (including commercial, subsistence and recreational catches), and that recreational fisheries generate by far the biggest share of the GDP value in comparison to the commercial fisheries within estuaries (Lamberth and Turpie 2003).

Abalone

Recreational diving for abalone has a long tradition in South Africa and has become a highly sought-after marine resource for illegal poachers in organized crime networks in recent years. The increasing pressure on the abalone stocks both in western and eastern provinces of South Africa led to the closure of recreational fisheries for abalone in 2003 (Raemaekers and Britz 2009). Before the increase of illegal abalone poaching activities in South Africa in the early 1990s, recreational and commercial abalone fisheries in the Western Cape provinces were stable (Raemaekers and Britz 2009). Nevertheless, early concern over declining commercial catch rates resulted in stricter management regulations, introduced in 1970. The regulations included annual catch quotas (total allowable catch), which have been gradually lowered (Cockcroft *et al.* 1999).

Rock lobster

There are several different species of rock lobster that are targeted by recreational divers or trappers. The main species, however, are the West Coast rock lobster, which inhabit near shore areas from about 23° S (Walvis Bay, Namibia) to about 28° S near East London, and the East Coast rock lobster, which inhabit shallow reef habitats from Port Elisabeth to north to Mozambique (Cockcroft and Payne 1999). This report focused on the recreational fisheries for West Coast rock lobster, since it is the largest recreational rock lobster fishery in South Africa, both in terms of catches and number of fishers (Okes and Burgener 2011b)

According to Cockcroft (1997), commercial exploitation of West Coast rock lobster began in the late 19th century. By 1933, the same regulations applied to both the recreational and commercial sectors, and it was not until 1961 that the authorities differentiated these sectors by introducing a bag limit for recreational fishers. The selling of recreational catches was prohibited and non-conformity continues to be heavily penalized. Over the years, regulations regarding the recreational fishery were steadily updated as fishing pressure increased, e.g., legal minimum sizes and catch bans for specific times of the day were implemented. Legal obligations for the possession of catch permits was introduced in the 1983–84 season (Cockcroft and Mackenzie 1997). In comparison to the recreational abalone fishery, which has been banned since 2003, the recreational rock lobster fishery continues to be a popular pastime for South Africans (Okes and Burgener 2011b).

Charter boat fishing

Charter boat fishing was practiced in South Africa before 1950, and gained popularity during the apartheid period (1948–1994). During this time, mainly wealthy white South Africans went fishing for marlin, swordfish and tuna along the South African coast (Schoeman 1962). Today, hundreds of different operators offer fishing trips to customers in South Africa, particularly in the Kwa-Zulu Natal Province.[2] According to Pradervand and van der Elst (2008), the introduction of stricter legal obligations and resulting economic disincentives for commercial fishing has led some commercial fishers to switch to operating charter boat trips. In comparison to the commercial linefish industry, income from the charter boat business is not directly linked to total catch but rather to the experience. Since estimates of annual participation in South Africa are sparse, this report quantified total retained catch only, based on the assumption that at least 50% of nationwide total annual catches were made in Kwa-Zulu Natal, the province where charter boat fishing has been the most popular.

Number of recreational fishers

The number of fishers was derived from the literature (Mann *et al.* 1997; Sauer *et al.* 1997; Griffiths and Lamberth 2002; Lamberth and Turpie 2003). For the years when the number of fishers were missing, linear interpolations were used between time spans of known data, or missing data were derived by applying compound annual growth rates.

Information on the number of participants in the charter boat sector was not available. Thus, the focus was on deriving estimates for total annual retained catches. Abalone and rock lobster fisheries participation was derived from the number of licenses sold and directly translated into the number of fishers or divers, thus assuming one license equalled one fisher or diver. Missing data were derived by applying a ratio of total population to number of licenses sold, based on respective years, and linear interpolation between years of known data.

The purpose of deriving the number of recreational fishers by sector was to determine an estimate of the total number of recreational fishers, in order to calculate the proportion of recreational fishers in the total population, and to derive total catches for each sector using catch rates per fisher.

Recreational catch rates

The annual average fishing effort per fisher was assumed to have remained stable in the recreational fishing sector over the study period. Catch rates varied significantly over-time for the recreational boat-based, estuarine, shore and rock fisheries. Catch rates for abalone and West Coast rock lobster did not experience significant changes and therefore were kept at a constant rate, based on estimates obtained from the literature. Information and data from scientific papers and grey literature suggested trends of decreasing catch rates over-time (Coetzee *et al.* 1989; Guastella 1994; Pradervand and Baird 2002) and states that many important linefish stocks have been heavily overfished and in a state of overexploitation (Griffiths 1997a,b, 2000; Griffiths and Lamberth 2002). According to Griffiths (2000) and Griffiths and Lamberth (2002), most of the overexploitation of linefish already occurred in the 1970s. Therefore, a catch trend scenario was developed reflecting these changes.

The nationwide catch rates for the shore and rock, boat-based and estuarine recreational fisheries were adjusted conservatively, in relation to documented catch rates for 1995 (Lamberth and Turpie 2003). Catch rates for 1950 were set 25% higher than the 1995 rate, based on the assumption that stocks were much less exploited and not overfished in the 1950s. The technological advances in fishing gear, boats, knowledge and fishing methods, as well as the increasing popularity of fishing as a pastime (Schoeman 1962), was reflected in the assumption that from the 1950s onwards, catch rates increased steadily, peaking in 1970 at a rate 50% higher than in 1995. Catch rates for missing years between 1950 and 1970, as well as for the period 1970–95, were derived through linear interpolation. The decreasing trend was carried forward unaltered to 2010.

Shore and rock anglers

Shore and rock angling is considered the most popular form of recreational angling in South Africa and is practiced all along the South African coast and, therefore, is the biggest recreational sector in terms of number of participants. It was estimated that in 1991, there were roughly 365,000 recreational shore fishers (Van der Elst 1993), increasing to 412,000 by 1995 (McGrath *et al.* 1997). Contrary to the suggested annual compound growth rate of 6% by van der Elst (1993), a slightly smaller rate of 2% annual compound growth was suggested by McGrath *et al.* (1997). Estimates of shore anglers were based on those data anchor points. Missing numbers of participants were estimated for 1950–91 and from 1995–2010 by applying an annual compound growth rate of 2%, backward (declining) and forward (increasing), respectively. A linear interpolation between 1991 and 1995 provided estimates for the number of anglers in this time-period. Using the 2% growth rate (McGrath *et al.* 1997) supported a conservative approach in estimating the number of recreational fishers, especially for the post-1995 period.

An annual average catch rate of 7.37 $kg \cdot fisher^{-1} \cdot year^{-1}$ was calculated for the year 1995 based on the total catch estimates (3,037 tonnes) for the recreational shore angling sector (Brouwer *et al.* 1997; Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

[2] However, these operators do not restrict their activities to South African waters. See, e.g., Le Manach and Pauly (this volume) and their discussion on recreational fishing by South Africans in the EEZ and Bassas da India (France).

Boat-based inshore anglers

Numbers of recreational boat-based inshore marine fishers for similar periods varied in the literature. Sauer *et al.* (1997) suggested that there were 13,800 fishers in 1996. For this report, the more conservative estimate of 12,000 participants in 1995 was chosen as an anchor point (Lamberth and Turpie 2003). It was assumed that the development and popularity of boat-based recreational fishing in South Africa followed the same consistent growth trend as the shore and rock sector. Therefore, the same annual compound growth rate of 2% (McGrath *et al.* 1997) was applied to calculate missing numbers of fishers over the period 1950 to 2010.

An annual average catch rate of 106.92 kg·fisher^{-1}·year^{-1} for the year 1995 was calculated, based on 12,000 fishers catching 1,283 tonnes (Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

Spearfishers

It was estimated that in 1987, there were 4,000 recreational spearfishers in South Africa (Van der Elst 1989). The number of participants rose to 7,000 in 1995 and an annual growth rate of approximately 6% was suggested (Mann *et al.* 1997). For the time-period of 1987–95, linear interpolation provided the missing data, whereas a growth rate of 6% was applied to calculate the remaining years.

Mann *et al.* (1997) report that there was neither evidence for declining catch rates, nor a change in species composition between 1984 and 1995 for the recreational spearfishing sector in Kwa-Zulu Natal (i.e., where most spearfishing activity is occurring). Thus, it was assumed that no significant changes in catch rates between 1950 and 2010 occurred. The respective annual catch rate per fisher for 1995 was estimated at 30 kg·speafisher^{-1}·year^{-1}, based on 7,000 spearfishers catching 210 tonnes in 1995 (Mann *et al.* 1997; Lamberth and Turpie 2003). Consequently, this constant catch rate was applied to the estimated number of recreational spearfishers in order to derive total annual catches.

Estuarine boat-based & shore anglers

It was estimated that there were 72,000 recreational estuarine fishers in 1995 (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). The reconstructed number of fishers for the period 1950–2010 was derived by applying an annual compound growth rate of 2% (McGrath *et al.* 1997) to the fixed data point of 1995 (Lamberth and Turpie 2003), based on the assumption that the development of recreational estuarine fisheries followed a similar trend as inshore marine shore and rock angling.

In 1995 an estimated 72,000 recreational estuarine fishers were catching roughly 1,068 tonnes of fish and other marine organisms from boats or the shore, using handlines, rods and reels, or nets (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). This translated into an average catch rate of 14.83 kg·fisher^{-1}·year^{-1}, which was used here. The 1995 catch rate was adjusted for 1950 (25% higher) and 1970 (50% higher), and the declining trend was carried forward from 1995 to 2010 by linear interpolation.

Abalone

Participation in the abalone fisheries was represented in the literature by the annual number of licenses sold, and for the purpose of this report, was directly translated into actual number of fishers using a ratio of 1 to 1 (one license equalled to one fisher). The period 1989–2003 was fairly well documented in scientific reports in regards to annual number of licenses and the associated total catch. From 2003 onwards, recreational permits were no longer sold due to the closure of the fisheries. In order to estimate participation before 1989, a ratio of total population to abalone fishers was derived for the year 1989 (total population of 34,490,549) in which 20,000 recreational licenses were sold (Cockcroft *et al.* 1999). This ratio of 0.0006 was applied to the total South African population in the years prior to pre-1989, to estimate likely numbers of participants.

For abalone, a catch rate of 14.80 kg·fisher^{-1}·year^{-1} for the year 1989 was calculated from reports stating that 20,000 individual recreational divers and fishers caught 296 tonnes of abalone in that respective season (Cockcroft *et al.* 1999). This rate was held constant from 1950 to 1989 and applied to the reconstructed number of participants in order to derive total annual catches for the period 1950–1989.

West Coast rock lobster

Due to the fact that permit requirements were nonexistent before 1983, it was difficult to estimate the actual amount of fishers before this period. The most reliable data found in the literature involve voluntary cooperation of fishers and indirect estimation methods such as questionnaires (Cockcroft and Mackenzie 1997; Cockcroft *et al.* 1999).

A total population to licenses ratio was established based on the fixed data point of 38,000 sold licenses in 1989 (total population of 34,490,549). This ratio of 0.0011 was applied to population data over the period 1950–89 in order to reconstruct participation. From 1989 to 1998, the actual number of licenses purchased, and thus the number of fishers/divers, was known (using the same approach as abalone where the ratio of one license equalled to one fisher). From 1999 onwards, the number of permits sold was unknown and thus not represented, but annual catch estimates were available from government reports (Anon. 2010a,b).

For the rock lobster sector, an annual catch rate of 6.2 kg·fisher^{-1}·year^{-1} in 1995 was derived based on 54,000 participants catching 336 tonnes and applied to the reconstructed number of participants for times, in which data were unavailable (Cockcroft and Mackenzie 1997; Cockcroft *et al.* 1999; Cockcroft and Payne 1999). For the period 1999–2010, government estimates for recreational catches were available (Anon. 2010a).

Charter boat fishing

Estimates of retained catch for the charter boat sector in Kwa-Zulu Natal in 2003 amounted to approximately 200 t (Pradervand and Van der Elst 2008). Based on the estimated number of operators throughout South Africa, it was assumed that this represented only 50% of the total annual retained charter boat catch (Africa 2010; Directory 2010). Consequently, it was assumed that the nationwide retained catch totalled 400 t in 2003. Assuming that this industry was still underdeveloped in the early 1940s (Schoeman 1962), the total catch for the year 1945 was set at zero and a linear interpolation for the period 1945–2003 provided annual, nationwide catch estimates for 1950–2002. The increasing trend was carried forward to 2010.

Targeted species

The development of sound fisheries management policies and the process of assessing the fisheries impact on marine ecosystems were not solely based on improvements of spatial and quantitative information. Another vital part was the improvement of taxonomic information about the overall catches. Griffiths and Lamberth (2002) collected catch contribution information from various sources and assigned the most important species by weight, targeted by recreational anglers (grouped into shore angling, boat angling, estuarine angling and spearfishing) to the five main coastal geographical regions, namely Western Cape, Southern Cape, Eastern Cape, Transkei and Kwa-Zulu Natal.

Subsistence fisheries

Both academic and grey literature was reviewed for data and information about subsistence fisheries in South Africa. The findings of the SFTG comprised information about the social and economic background (Branch 2002; Branch *et al.* 2002a,b) and the number and geographical distribution of subsistence fishers and fishing communities in South Africa (Clark *et al.* 2002). This information was combined with individual studies about the localized subsistence catch of marine resources in order to derive nationwide estimates of subsistence catches (Lamberth and Turpie 2003; Steyn *et al.* 2008; Napier *et al.* 2009).

The number of subsistence fishers and their geographical distribution

It was difficult to derive accurate estimates for the number of subsistence fishers in South Africa for several reasons. Due to the interchangeable usage of different definitions for 'subsistence fishers', the numbers varied in the literature. Furthermore, many subsistence fishers operate with recreational permits. Subsistence linefishers are known to be dispersed within the recreational shore and estuary fisheries (Griffiths and Lamberth 2002). No more than 10% of the 27,000 commercial fishers in South Africa could be defined as purely subsistence or artisanal (Elst *et al.* 2005). They represent the poorer participants of the industrial fisheries sector in South Africa. McGrath *et al.* (1997) estimated that at least 25,000 households in South Africa (excluding Transkei) depend on shore angling only in order to meet their needs for protein supply. In the early 2000s, 147 fishing communities comprising 28,338 fisher households and 29,233 individual subsistence fishers were identified in South Africa (Clark *et al.* 2002). Most of these subsistence fishers are found on the East Coast of South Africa and more than 75% (more than 22,500) live in Kwa-Zulu Natal and the Transkei (Clark *et al.* 2002). It is reported that the lion's share of subsistence linefishers is located in the Transkei and Kwa-Zulu Natal (Griffiths and Lamberth 2002). The breakdown of the number of subsistence fishers into respective geographical areas along the South African coastline demonstrates that most subsistence fishers catch marine resources in the eastern provinces. Approximately 82% of subsistence fishers operate in marine environments and only 18% catch marine resources in estuaries (Table 1). For this report, it was assumed that these distribution patterns were similar throughout the period 1950–2010 and that the number of participants and the catch rates or effort varied over-time.

It is believed that subsistence fisheries activities on the East Coast of South Africa have been carried out rather unchanged throughout the years (Siegfried *et al.* 1994; Griffiths and Branch 1997). Being confined to so-called 'homelands' during apartheid and the lack of alternative ways of generating income, many traditional fishers in the eastern provinces were restricted to a subsistence lifestyle (Clark *et al.* 2002). On the contrary, subsistence fisheries on the west and south coast disappeared with the arrival of settlers from Europe for various reasons. Many traditional fishers were enslaved, killed or died because of diseases (Siegfried *et al.* 1994). However, the current perception that subsistence fisheries are exclusively confined to Kwa-Zulu Natal and the Transkei region is erraneous. Clark *et al.* (2002) suggested that subsistence fishers did not disappear altogether, but rather changed their catch and consumption behaviour and adapted to new social and cultural circumstances. Advances in fishing gear after World War II enabled fishers to target a greater variety of marine resources, requiring less effort (Schoeman 1962). The introduction of a cash economy and the growth of tourism incentivized many subsistence fishers in western and southern coastal regions to catch more and sell the surplus, as well as live closer to urban areas in order to improve access to markets (Clark *et al.* 2002). These facts have contributed to the public erroneous perception that subsistence fishers solely live in rural areas in eastern South Africa.

Population density was highest in the eastern provinces. This trend still remains unchanged and is also reflected in the overall geographical distribution of subsistence fishers, of which approximately 70% live and fish in eastern South Africa (see Table 1).

Table 1. Breakdown of the number of households and subsistence fishers in eight coastal regions in South Africa and the number of ocean fishers vs. estuarine fishers in percentage for the early 2000s. Sourcemodified from Clark et al. 2002.

Region	Households	Subsistence fishers	Fishers in ocean	Fishers in estuaries
Namibia border to Olifants River	411	458	320 (70%)	138 (30%)
Olifants River up to and including Hout Bay	675	643	630 (98%)	13 (2%)
Hout Bay to the Breede River	1,352	1,272	1,247 (98%)	25 (2%)
Breede River to the western boundary of Tsitsikamma National Park	1,269	1,424	712 (50%)	712 (50%)
The western boundary of Tsitsikamma National Park to Kei River	1,031	1,452	842 (58%)	610 (42%)
Kei River to Mtamvuna River	4,830	4,239	3,391 (80%)	848 (20%)
Mtamvuna River to Umvoti River	16,811	18,399	16,191 (88%)	2,208 (12%)
Umvoti River to Mocambique border	1,959	1,346	538 (40%)	808 (60%)
Total	28,338	29,233	23,871 (81.7%)	5,362 (18.3%)

It was assumed that subsistence fishers were and still are mainly non-white South Africans. In order to estimate historic participation in the subsistence sector, a ratio between total non-white population and subsistence fishers was calculated based on the 'anchor' point of 2002, for which 29,233 subsistence fishers were reported in South Africa (Clark *et al.* 2002). A time-series for the total non-white population was derived by linear interpolation between six data points of known statistical population data. The resulting ratio of 0.000713 subsistence fishers per non-white South African was applied to the estimates for total non-white population over the period 1950–2010. Additionally, the estimated total numbers of subsistence fishers were classified into two groups (estuarine and ocean fishers), as well as subdivided in accordance to their geographical distribution (Clark *et al.* 2002).

Taxa targeted by subsistence fishers

There is a great variety of marine resources caught by subsistence fishers in South Africa. In general, there is an increasing trend in diversity of exploited organisms from the west to the east coast. This gradual increase is closely linked to biogeographic conditions and based on the fact that most subsistence fishers live in the eastern coastal regions (Cockcroft *et al.* 2002). The uneven regional distribution of marine resources is also reflected in the fact that approximately 95% of all commercial fishing activities in South Africa operate from the Western Cape (Hersoug 1998). This is related to the high biomass productivity of the Benguela ecosystem due to upwelling, making it one of the most productive ocean areas in the world (Cochrane *et al.* 2009). Subsequently, most jobs in the commercial fishing and processing industry are concentrated in the Western Cape. There is also still an extremely uneven distribution of resources between whites and blacks[3] in South Africa, especially in regards to the main commercial and industrial fishing resources (Branch *et al.* 2002b). The legacy of apartheid, the political neglect and the resulting marginalization of subsistence fishers in South Africa, as well as specific socioeconomic and biogeographical factors, affected the state of resource use by subsistence fishers. It was assumed that the subsistence resource use was fairly similar throughout the study period, but that individual catch rates varied over time due to several reasons. Technological advances in fishing gear may have enabled fishers to fish more efficiently, as it has been shown in the case of the recreational fishing sector. Additionally, reported overfishing and collapsed stocks of several linefish species, rock lobsters and abalone would have had adverse effects on the resource availability of subsistence fishers (Cockcroft *et al.* 1999; Griffiths and Lamberth 2002).

Fish and various intertidal rocky-shore invertebrates are the most commonly targeted resources by subsistence fishers in South Africa. Various fish species are targeted both in estuaries and the open ocean (Branch *et al.* 2002b). The species composition varies along the coastline, but a general trend of increasing diversity of fish species from the west to the east coast is apparent (Branch *et al.* 2002b; Clark *et al.* 2002; Cockcroft *et al.* 2002). Mullets (Mugilidae) were identified as the most commonly caught family along the entire South African coast. Additionally, grunts (*Pomadasys* spp.), rock cod (*Epinephelus* spp.), kob (*Argyrosomus* spp.) and elf (*Pomatomus saltatrix*) were identified as very important and commonly targeted fish species (Branch *et al.* 2002b). Table 2 summarizes the most important species and groups caught by subsistence fishers in South Africa in decreasing order of importance.

The group of rocky-shore invertebrates comprises mainly the mussel *Mytilus galloprovincialis* on the west coast and *Perna perna* on the east coast, as well as different species of oysters (*Striostrea margaritacea*, *Saccostrea cuccullata*), octopus, winkles and limpets.

Other groups of marine organisms caught throughout South Africa — often used as bait — are sandy-beach invertebrates (e.g., worms and redbait) and estuarine invertebrates (e.g., sand and mud prawns *Callianassa*

Table 2. Most important fish species targeted by subsistence fishers in South Africa, listed in decreasing order of importance. Sourcemodified from Branch *et al.* 2002b.

Name	Taxonomic Name
Harders, mullet	*Liza* and *Mugil* spp.
Kob	*Argyrosomus* spp.
Elf	*Pomatomus saltatrix*
Grunters	*Pomadasys* spp.
Rock cod	*Epinephelus* spp.
Galjoen	*Dichistius capensis*
Stumpnose	*Rhapdosargus* spp.
Bronze bream	*Pachymetopon* spp.
Steenbras	*Lithognathus lithognathus*
Hottentot	*Pachymetopon blochii*
River bream	*Acanthopagrus berda*
Roman	*Chrysoblephus laticeps*
Yellowtail	*Seriola lalandii*
Leervis	*Lichia amia*
Blacktail	*Diplodus sargus capensis*
Musselcracker	*Sparodon durbanensis*
Snoek	*Thyrsites atun*
Geelbek	*Atractoscion aequidens*
Strepies	*Sarpa salpa*

[3] 'Black' includes groups and people that were identified as 'African', 'Indian' or 'Coloured' during the apartheid regime in South Africa. Contrary to usage in other parts of the world, in South Africa the term 'Coloured' does not refer to 'black' people only.

kraussi, *Upogebia africana*; Branch *et al.* 2002b; Clark *et al.* 2002). Furthermore, some high value species are also targeted by subsistence fishers. West and East Coast rock lobsters are caught by subsistence fishers, mainly to generate much needed income, rather than for personal consumption. Abalone is a less frequently caught marine resource (Branch *et al.* 2002b; Clark *et al.* 2002). Table 3 summarizes the most important marine resources in decreasing importance, based on interviews and scientific studies (Branch *et al.* 2002b).

Table 3. Most commonly caught marine resources by subsistence fishers in South Africa, listed in decreasing order of importance. Sourcemodified from Branch *et al.* 2002b; Clark *et al.* 2002; Cockcroft *et al.* 2002.

Resources	Taxon
Fish	Different species (see Table 3)
Mussels	*Mytilus galloprovincialis* (West Coast) *Perna perna* (South/East Coast)
Octopus	*Octopus vulgaris*
Rock lobster	*Jasus lalandii* (West Coast) *Panulirus homarus* (South/East Coast)
Redbait	*Pyura stolonifera*
Worms	Nereids, eunicids, sabellarids, etc.
Abalone	*Haliotis midae*
Oysters	*Striostrea margaritacea* (South Coast) *Saccostrea cuccullata* (East Coast)
Squid	*Loligo vulgaris reynaudii*
Crabs	*Sesarma meinerti, Scylla serrata* *Ocypode* spp.
Other misc. marine organisms	various

Catch rates for the subsistence sector

Most scientific studies about subsistence fisheries in South Africa focused on socioeconomic issues, but neither adequately quantified relevant catches, nor explicitly mentioned individual catch rates for various marine organisms (Branch 2002; Branch *et al.* 2002a,b; Clark *et al.* 2002; Cockcroft *et al.* 2002; Harris *et al.* 2002a,b; Hauck *et al.* 2002). Due to the lack of sufficient catch information, it was difficult to derive estimates for catch rates and subsequently for total catches for the purpose of this report. Despite the insufficient data on a nationwide scale, there were some individual studies on local catch rates and annual catch estimates for some regions (Steyn *et al.* 200; Napier *et al.* 2009). These studies provided information about catch rates for some main subsistence marine resources, such as fish, sand and mud prawns, and rock lobster. Individual catch rates were applied on a nationwide scale in order to extrapolate total annual catches for the subsistence sector for the period 1950–2010.

Napier *et al.* (2009) identified annual subsistence catch rates for mud prawns and fish in the Knysna estuary in South Africa in 2004. Approximately 230 part- and full-time subsistence fishers caught an annual amount of 600,000 mud prawns, 5,000–7,500 spotted grunters, 5,000–7,500 white steenbras (*Lithognathus lithognathus*) and approximately 36,000 cape stumpnose (*Rhabdosargus holubi*), as well as more than 13,000 other bait organisms such as worms, shrimp and sand prawns. An average annual catch rate per fisher was derived by applying specific average weights for fish and mud prawns. Based on an average wet weight for *U. africana* of 4.83 grams, the total annual catch was estimated at 2.898 $t \cdot fisher^{-1}$ for fish and 0.0126 $t \cdot fisher^{-1}$ for mud prawns in 2004 (Richardson *et al.* 2000). Based on a weight/length regression for cape stumpnose (Van der Elst and Adkin 1991) and an average size of 15–20 cm (Napier *et al.* 2009), an average weight of 0.135 grams per fish resulted in a total annual catch of 4.86 tonnes of cape stumpnose. A total annual catch estimate for white steenbras and spotted grunters was derived by applying an average weight of 2 kg per fish, based on a conservative assumption and taking into account that many undersized and juvenile fish are caught and retained by subsistence fishers in general, especially in estuaries (Griffiths and Lamberth 2002; Whibley 2003). It was assumed that 6,000 individuals of each of these species were removed by subsistence fishers, resulting in a total annual catch of approximately 24 tonnes. In total, approximately 28.86 tonnes of fish were thought to have been caught by 230 subsistence fishers in 2004 in the Knysna estuary. Hence, an annual average catch rate of 0.125 $t \cdot fisher^{-1} \cdot year^{-1}$ of fish and 0.0126 $t \cdot fisher^{-1} \cdot year^{-1}$ of mud prawns was estimated in 2004.

Based on the current overexploited or collapsed state of many fish species in South Africa, historical catch rates for fish were assumed 25% higher for the period 1950–1960, reflecting a more pristine stock biomass (Griffiths and Branch 1997; Griffiths 1997a,b, 2000; Griffiths and Lamberth 2002). Technological advances in regards to fishing gear did not have a significant influence on catch rates, as it has been reported for the recreational sector, since subsistence fishers mainly used low technology gear and continue to do so (Schoeman 196; Branch *et al.* 2002b; Napier *et al.* 2009). From the 1960s onwards, catch rates were assumed to have been declining to current levels. The assumption of declining catch rates matched reported decreasing internal per capita fish consumption in South Africa, which has been declining since the 1970s (9.7 kg in 1970; 9.4 kg in 1980s; 8.2 kg in the 1990s; 7.6 kg in 2002; and 7.23 kg in 2003; Crosoer *et al.* 2006). Catch rates for mud prawns have been kept constant over this period. Catch rates for subsistence fishers operating in the ocean were indirectly derived from estuary subsistence catch rates. Based on the assumption that estuaries function as nursery areas and fishers would generally catch bigger fish in the ocean, catch rates were assumed 15% higher than estuarine catch rates in any given year (Whitfield 1994). Individual catch rates for the period 1950–2010 were then applied to the number of subsistence fishers in order to derive total annual catch estimates.

Due to insufficient subsistence catch information for rock lobster, abalone and oysters, as well as for other subsistence marine resources, no total catch estimates could be derived at this point. Further research should be undertaken in order to quantify respective catches.

South African industrial catch taken from Namibian waters

Namibia was occupied by South Africa from 1915–1990, and South African fleets, amongst a large number of other distant-water fishing fleets fished in Namibian waters until the Declaration of Independence and subsequently the declaration of the Namibian 200-mile EEZ in 1990 (Lees 1969; van Zyl n.d.). South African flagged vessel catches taken from Namibian waters are therefore represented in FAO catch information for South Africa for the period 1950–1990.

We identified South African catches taken in what we deemed Namibian waters through a comparison with 'national' data from Namibia for the 1950–1990 period (Belhabib *et al.* 2015), and relabelled these quantities as landings by South African vessels from Namibian waters. We focused on species that contributed most to South African landings — these were South African anchovy, South African pilchard, Cape Hake, Cape horse mackerel, and Cape rock lobster, which together made up almost 87% of total landings. Quantities of these species were analyzed in two time-periods, from 1950–1990, and 1991–2010. We assumed those species that showed a large decline in landed quantity after 1990 were likely those that were being caught in Namibian waters. Of the identified species, South African anchovy, South African pilchard, Cape rock lobster, and Cape horse mackerel declined by 40%, 80%, 83%, and 50%, respectively, between the two periods, while Cape hake catches remained relatively stable. We then cross-referenced these species with Namibian catch statistics that were attributed to South Africa (see Belhabib *et al.* 2015). Of the foreign fleets that exploited Namibia's fisheries prior to 1990, the former Soviet Union and Spain caught the majority of fish off the Namibian coast, while South Africa's share was 10–12% (Belhabib *et al.* 2015). Of the five identified species, data for Cape rock lobster, South African pilchard, and South African anchovy caught in Namibia by South African vessels were directly available. Catch data for Cape horse mackerel and Cape hake taken by foreign fleets in Namibia were not broken down by country, therefore, we allocated 10% as being from South Africa. To adjust South African landings from South African waters, we subtracted Namibia-sourced catches from South African landings; this yielded the amount of domestically caught fish (i.e., from within South African waters).

Discards

As for most countries in the world, South African reported data do not account for fish that are caught but discarded at sea (Attwood *et al.* 2011). Estimated discard rates of South African trawlers range from an overall rate of 4.1% (Kelleher 2005) to 31% for south coast trawlers (Japp 1997), and 19% and 5% for sole and hake trawlers, respectively (Walmsley *et al.* 2007), while another observer-based study estimated a discard rate of about 16% for the inshore fleet (Attwood *et al.* 2011). We omitted the high discard rate of 31% and rather used a conservative average discard rate of 7% to estimate the quantity of discarded fish. South Africa's trawl fishery dates back to the 1880s when it was concentrated in inshore areas before substantial offshore expansion beginning in the 1950s (Sink *et al.* 2012). Thus, we accounted for discards from 1950 to 2010.

Illegal fishing

Illegal fishing (poaching) has been implicated for declines in some of South Africa's fisheries, most notably the abalone, lobster and linefish fisheries (DAFF 2012). The Department of Agriculture, Forestry and Fisheries (DAFF) accounts for illegal fishing by adding on an amount to national landing statistics of some fisheries. For example, since 1990, 500 $t \cdot year^{-1}$ has been added to total landed West Coast lobster in South Africa's national fisheries statistics (DAFF 2012). This amount is not reflected in FAO statistics, but is added in this reconstruction. The extensive black market trade in abalone has been well documented, and illegal abalone catch estimates exist starting from 1980 (Raemaekers *et al.* 2011). We visually approximated the proportion of illegal catch to national legal landings from a bar graph (Raemaekers *et al.* 2011) for the period 1980 to 2000. From 1980 to 1991 illegal catch was relatively stable at 10% of national legal landings, then increased to an average of 50% until 2000. We applied these percentages to FAO landing statistics to estimate illegal abalone catch from 1980 to 2000. From 2001 to 2008 annual illegal catch of abalone averaged 2000 t (Raemaekers *et al.* 2011). Illegal activity in the linefish fishery is high but the level is unknown (DAFF 2012). To approximate the level of illegal linefish activity, we considered that: i) illegal abalone catch in the past decade has been up to 10 times the commercial catch in some years; ii) the amount of poached lobster estimated by (DAFF 2012) ranged between 16% and 33% of commercial catch; and iii) the linefish fishery encompasses subsistence, recreational, and small-scale commercial fishers (DAFF 2012), which are difficult to monitor. We remained on the conservative side and took the average lobster illegal catch percentage, i.e. 24%, and applied this to total linefish landings to estimate illegal catch in the linefish fishery starting from 1985, the year that the first management framework for South Africa's linefish fishery was introduced (DAFF 2012).

Fishing sector allocation

Marine fisheries statistics reported to the FAO were allocated to the industrial sector from 1950 to 2010, with the exception of small-scale commercial species. So-called 'subsistence' catches in South Africa are either consumed, sold, or used as bait (Branch *et al.* 2002b), thus, these fisheries have an artisanal (i.e., small-scale commercial) component. A comprehensive socioeconomic survey found that 84% of fishing households identified themselves as being 'subsistence', i.e. fishing primarily for household consumption, while the remainder fished to make a profit (Branch *et al.* 2002b). Thus, we allocated 84% of the reconstructed subsistence catch to the true 'subsistence' sector as defined here, and 16% to the 'artisanal' sector in 2000, and maintained these values to 2010. We assumed that subsistence fishing in 1950 was close to 100% and linearly increased this percentage to the anchor point in 2000.

Small-scale commercial species were allocated to the artisanal sector. West Coast/Cape rock lobster was caught primarily with hoop nets prior to the 1960s, before motorized boats and traps came into use (DAFF 2012). Therefore, we allocated lobster catches to the artisanal sector from 1950 to 1960, and thereafter to the industrial sector. The domestic jigging fishery for squid began in 1984 (DAFF 2012). We allocated Cape Hope squid catches from 1984 to 2010 to the artisanal sector and all other squid catches to the industrial (trawl) fishery. A small amount of Cape hakes are taken by the small-scale commercial longline and handline sectors. Based on annual catch statistics of

Cape hakes kept by the DAFF (2012), we estimated that from 1986 onwards approximately 3–5% of total hake catches were taken by handlines and/or longlines, and allocated this portion to the artisanal sector. Abalone catches were also allocated to the artisanal sector, as were fish species identified as belonging to the linefish fishery (Mann 2013; Table 4).

Table 4. Species allocated to the linefish fishery.

FAO name	FAO name
Albacore	Red steenbras
Bigeye tuna	Sargo breams nei
Black marlin	Sea catfishes nei
Blue shark	Shortfin mako
Bluefish	Skipjack tuna
Broadnose sevengill shark	Smooth-hound
Canary drum (=Baardman)	Snoek
Cape elephantfish	Southern meagre (=Mulloway)
Chub mackerel	Swordfish
Common dolphinfish	Tope shark
Copper shark	Tuna-like fishes nei
Daggerhead breams nei	White steenbras
Dusky shark	White stumpnose
Geelbek croaker	Yellowfin tuna
Hector's lanternfish	Yellowtail amberjack
Panga seabream	-

Species composition

The composition of industrial catches was based on that of reported fish landings. Recreational fish catch was broken down according to the percentage contribution of species listed in Appendix Table A1. The composition of discards was based on the top 10 species from observer records from South Africa's trawl fishery (Attwood *et al.* 2011). Reconstructed total subsistence catch had two components, fish and mud prawn. The subsistence fish component was made up of seven major taxa (Table 5), of which Mugilidae was the most commonly caught fish group, while Sciaenidae, Pomatomidae, Haemulidae, and *Epinephelus* spp. were also very important and commonly targeted fish species by so-called 'subsistence' fishers (Branch *et al.* 2002b). Based on this qualitative assessment, we assigned highest weighting to Mugilidae, followed by equal medium weightings for Sciaenidae, Pomatomidae, Haemulidae, and rock cod, and finally equal and lowest weighting to the remaining two taxa, Dichistidae and Sparidae. Besides fish, bivalves, cephalopods, and prawns are also commonly targeted species (Branch *et al.* 2002b). Eighty-one percent of sampled fishing households from a socio-economic survey reported catching fish, and those catching rocky shore invertebrates ranged from 6% for urchins to 58% for mussels (Branch *et al.* 2002b). Surveyed households caught fish for commercial intent, whereas invertebrates were used mainly for consumption (Branch *et al.* 2002b). Given the importance of fish as a source of income and the high proportion of households that caught fish, we assumed that fish comprised the bulk (85%) of the so-called 'subsistence' catches, and the remaining 15% was equally distributed between bivalves and cephalopods.

Table 5. Composition of subsistence fish catch.[a]

Species	Percentage
Mugilidae	21.3
Sciaenidae	12.8
Pomatomidae	12.8
Haemulidae	12.8
Epinephelus spp.	12.8
Dichistidae	6.4
Sparidae	6.4

[a] Derived from Branch *et al.* (2000)

Results and Discussion

After accounting for South African catches taken in Namibian waters, reconstructed total catches taken by South Africa in South African waters increased from 340,000 t in 1950 2.3 million t in 1968, and have been around 770,000 t·year^{-1} in the 2000s (Figure 2). Unreported catches made up 77.3% of total reconstructed catches in the Western Indian Ocean (FAO area 51; Figure 2A), but only 6.9% in the Southeast Atlantic (FAO area 47; Figure 2B). Of the 153,000 t of unreported subsistence catch primarily intended for household consumption, almost two thirds were taken from the Western Indian Ocean. The taxonomic composition in the two oceans was also very different, with a high diversity in the Indian Ocean (e.g., Sparidae, Scianidae, Haemulidae, Mugilidae; Figure 3A), and an overwhelming small pelagic component in the Atlantic (Figure 3).

Due to lack of data, we only started accounting for illegal catches in 1980, the earliest year for which we could find any hard evidence. Illegal catches estimated in this reconstruction thus likely represent an underestimate of the true level of poaching in South African waters.

Discards by the industrial sector totalled 3.6 million t from 1950 to 2010, with only 100 t attributed to the Western Indian Ocean.

Industrial catch statistics reported to the FAO included catches taken by South Africa in what we considered Namibian waters, which accounted for around 24% of all reported South African catches in FAO area 47 from 1950–1990, with highest discrepancy occurring between 1968 and 1970, when approximately 41% of South African reported landings were likely sourced from Namibian waters. South African pilchard made up the bulk of catches from Namibian waters (72%), followed by South African anchovy (21%).

Small pelagic taxa targeted by industrial fleets in western South Africa's EEZ comprised well over half of the country's marine catches in this area, with South African pilchard and anchovy accounting for 36% and 26% of reconstructed total catches, respectively. The artisanal, subsistence and recreational fisheries were more diverse, with many taxa of small pelagics (e.g., *Scomber japonicus*; 34%) and demersal species making up the catch.

Recreational catches

The total number of recreational fishers in South Africa increased substantially over the 1950–2010 time-period. In 1950, the total estimated number of recreational fishers was more than 225,000 actively targeting marine organisms on a regular basis in various subsectors. This represented roughly 1.65% of the total population. The biggest sector in terms of participants in the past was shore- and rock-based angling with more than 160,000 participants. This is not surprising, given that this type of fishing would have required less technological expertise and equipment than for the relatively small boat-based sector, with an estimated 4,000 participants in 1950. Spearfishing was only practiced by very few recreational divers at that time, but the number steadily increased at a rate of 6% per year, and in 2010 it was estimated that there were 16,000 recreational spearfishers operating throughout South Africa. The second biggest sector was, and still is, estuarine fisheries with nearly 30,000 fishers in 1950 and almost 100,000 estimated recreational estuary anglers today.

Participation in abalone and West Coast rock lobster fisheries was relatively low in 1950 with 9,000 and 19,000 fishers, respectively. Both sectors experienced peak participation in the 1990s. The abalone sector was shut down in 2003 which slowed down the overall rate of increase in total number of fishers.

It is estimated that there were approximately 250,000 recreational fishers in South Africa in the early 1960s (Schoeman 1962). This estimate, which is mostly based on fishing club membership data, supports our estimates suggesting a total of 280,000 recreational fishers among all sectors for the same period.

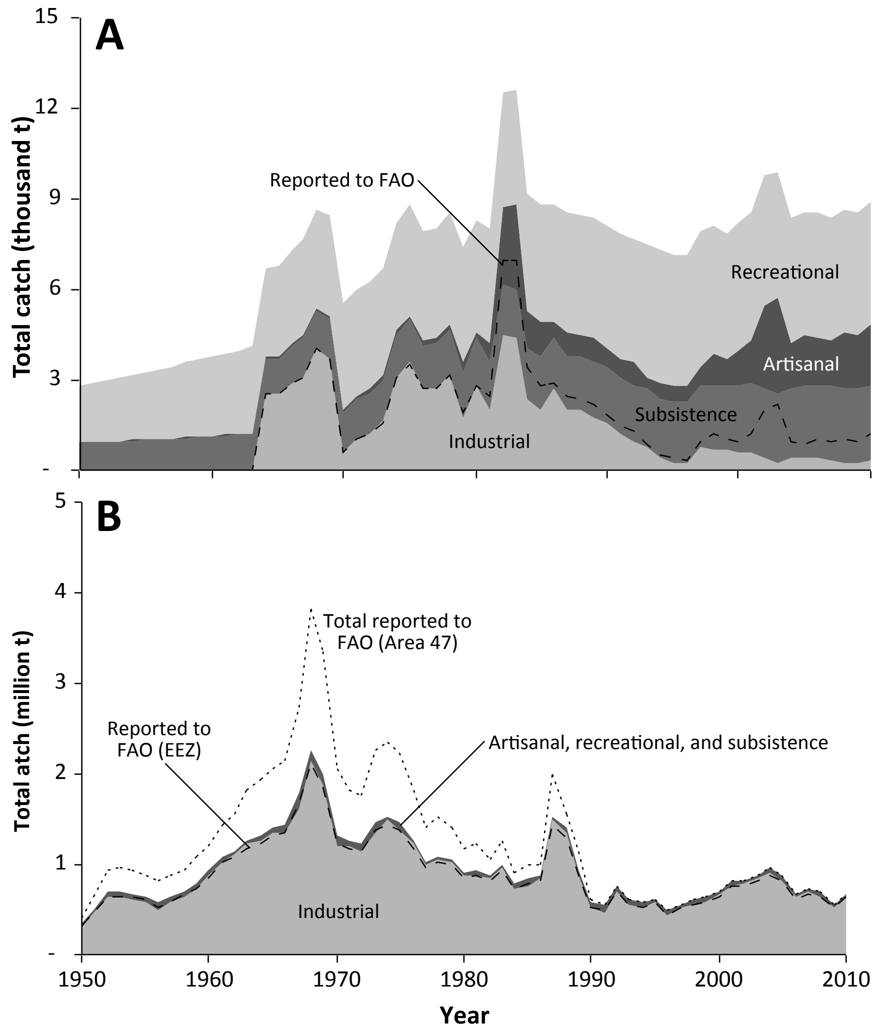

Figure 2. Reconstructed catch by sector in A) the Indian Ocean and B) the Atlantic Ocean, 1950–2010. See Appendix Table A2 for details.

We found that in the mid-1990s there were nearly 600,000 recreational fishers, which seems to be an underestimate compared to government appraisals at more than 750,000 marine recreational fishers for the same period (Anon. 1997). Furthermore, government information reported on one million individual participants in 2010 (Anon. 2010b), whereas our estimates suggest a more conservative number of 700,000. Our estimates suggest that approximately 1.5% of the total population of South Africa participate in recreational fishery activities of various kinds. Griffith and Lamberth (2002) suggest that approximately 0.5% of South Africans engage in recreational linefishing only. In other countries, recreational fishing seems to be more popular. The average participation in Europe is estimated at 4.7% of the total population. In Germany, roughly 2.1% of the total population are fishing recreationally in freshwater only, whereas in some northern European countries such as Norway, participation reaches up to 50% (Toivonen 2002). In Australia, estimates vary from 4% to 26% (Kearney 2002; Lyle *et al.* 2002). Hence, our estimates for South Africa appear to be realistic and may even be an underestimate due to conservative assumptions.

The actual number of recreational fishers is difficult to obtain and official government estimations vary greatly and lack comprehensible statements and references. For the purpose of deriving long-term estimates and growth trends for the period 1950–2010, more conservative choices were made. Furthermore, there is a certain degree of overlap between the individual sectors. For instance, it is impossible to distinguish between recreational fishers who fish from the shore on a regular basis, but sometimes also participate in boat-based recreational fishery activity. The exclusive categorization of fishers is impossible to attain and therefore conservative choices are more sensible and consequently more meaningful if it comes to reconstructing catches landed in the past.

Estimated recreational catches for the shore- and rock-based sector totalled approximately 157,000 t over the 1950–2010 period. Estimated at roughly 1,500 t in 1950, the annual total catches increased due to growing participation and catch rates, and peaked in 1995 at 3,040 t. Since 1996, a decreasing trend in annual catches is noticeable, mainly due to diminishing individual catch rates.

Estimated recreational catches for the boat-based sector totalled approximately 68,000 t for the 1950–2010 period. While the catches totalled 658 t in 1950, they peaked in the early 1990s at 1,283 t. It is estimated that even with continuously increasing number of participants over the entire period, landings were relatively stable at approximately 1,200 t·year^{-1}, due to decreasing individual catch rates. As stated earlier, many linefish species targeted by recreational boat fishers are heavily overexploited and some stocks have even collapsed. Many of those species are also targeted by the commercial linefish sector and direct user conflict and competition is reported in the literature

(Griffiths and Lamberth 2002). This recreational sector has the highest per fisher catch rate, estimated at 75 kg·fisher^{-1}·year^{-1} in 2010. The precarious stock conditions of some main targeted species raises concerns for the future of this specific sector.

The total spearfishing catches for the 1950–2010 period was estimated at 8,440 t. In 1950, annual catches were very small due to the fact that spearfishing was not commonly practiced in South Africa. Increasing availability of equipment (e.g., masks and spear guns) resulted in a sharp increase in the number of participants and an estimated 38-fold increase in annual catches between 1950 and 2010, estimated at around 14 t and 503 t, respectively. The time series shows a nearly exponential growth trend of annual spearfishing catches.

Estimated recreational catches for the estuary sector totalled approximately 57,000 t over the 1950–2010 period, making this the third most important recreational sector in terms of landed tonnage. In 1950, an estimated 29,000 fishers landed around 550 t of fish. Total catches peaked in 1995 at 1,070 t and decreased slightly to an estimated 1,000 t in 2010.

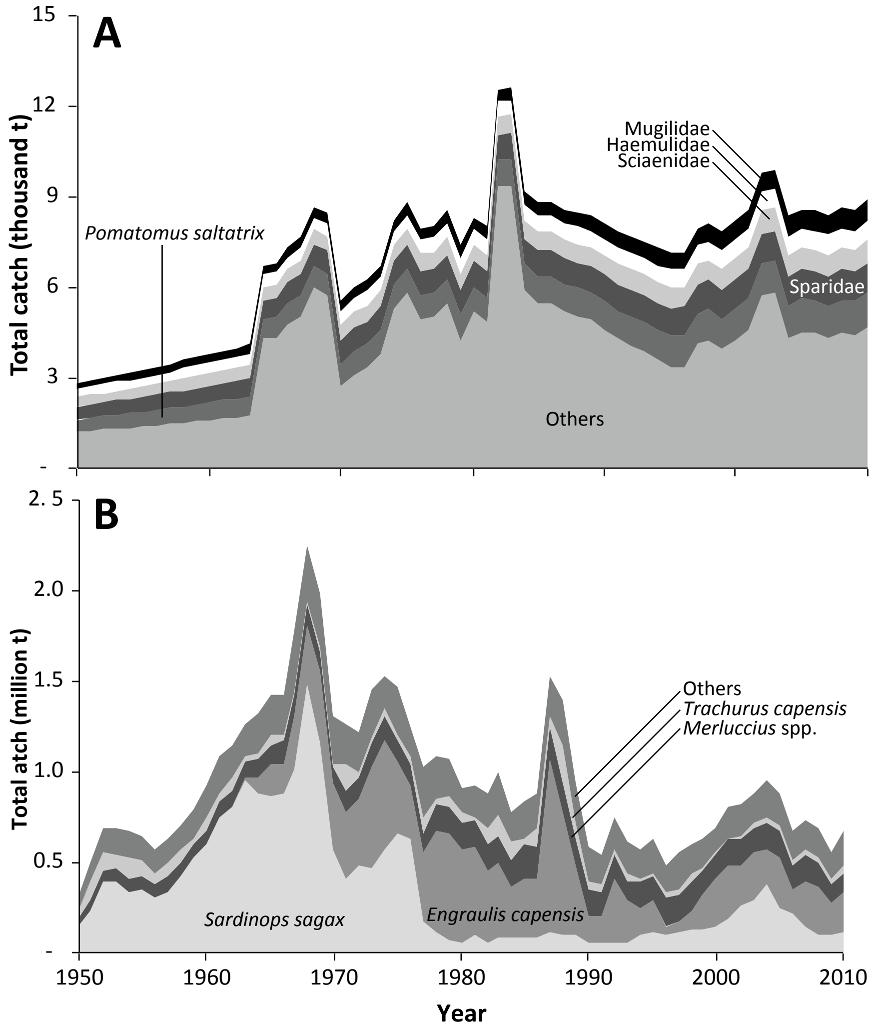

Figure 3. Reconstructed catch by taxon in A) the Indian Ocean and B) the Atlantic Ocean, 1950–2010. See Appendix Table A3 for details.

The total estimated recreational catch for abalone was approximately 12,100 t of whole weight for the period 1950 to 2003. Recreational catches were estimated at around 120 t in 1950. Total annual catches increased steadily with rising rates of participation, peaking in 1994 at 540 t. The sharp decrease of catches in 1997–1998 was a result of declining effort because a moratorium was placed on the sale of recreational permits in order to allocate catch quotas to subsistence fishers in line with the implementation of the new Marine Living Resources Act 18 (MLRA) in 1998; the new post-apartheid regulation scheme regarding marine management (Cockcroft *et al.* 1999). Downward adjustments with respect to permits sold to compensate for over exploitation since 2000, exacerbated by illegal harvesting, ended in the closure of the recreational abalone sector in 2003. Illegal activity continues to thrive and puts additional pressure on the already heavily exploited resource.

Estimated recreational catches of lobster totalled approximately 13,300 t over the 1950–2010 period. Starting off at around 100 t·year^{-1} in the 1950s, catches increased steadily until the 1990s. Catches fluctuated in the 1990s, peaking at nearly 600 t in the 2002–2003 season. The increase in catches in the mid-1990s is related to the decrease of the legal minimum size for recreationally-caught lobster, as well as an increased season length in that period (Cockcroft *et al.* 1999).

The total retained catch for the charter boat sector was estimated at 14,700 t over the 1950–2010 period. In 1950, catches were estimated to be very low (35 t), accounting for its recent introduction and assumed slow evolution. Technological advances in tackle and gear and greater availability of boats since the end of World War II are reflected in the expansion of the industry and continuous increase of annual catches. Due to the lack of sufficient data and information, reconstructed catches for this sector may underlie the highest degree of uncertainty. Furthermore, estimating retained catches exclusively may under represent actual mortality in this sector. Post-release mortality and severe impairments of released fish due to barotrauma-induced stress is believed to be very high (Bartholomew and Bohnsack 2005; Gravel and Cooke 2008). It is estimated that approximately 37% of the total catch in this sector in Natal is released, with the remaining 63% retained (Pradervand and Van der Elst 2008). The reasons for releasing catch are varied, including unwanted species, undersized or protected fish or the general underlying catch-and-release policy, which is common in this industry with respect to sharks, sailfish and swordfish. Therefore, the reconstructed catch estimates are conservative and if also accounting for mortality of released catch, estimates would likely be much higher.

Estimated recreational catches for all sectors totalled approximately 332,000 t over the 1950–2010 period. In 1950, catches totalled just under 3,000 t, increasing rapidly to 5,400 t in 1970. The overall reduction in catch rates due to overfishing is reflected in the decreased growth rate of total catches from 1970 onwards. Total catches peaked in 1997 at nearly 7,000 t and decreased to an estimated 6,300 t in 2010. This decrease is mainly due to the closure of the abalone sector in 2003 and the decreased effort for West Coast rock lobster. Based on increasing participation and overall population growth, catches are likely to continue to increase.

In comparison to the landings of several hundred thousand tonnes each year by the commercial fishing fleet in South Africa, the reconstructed catch estimates for the recreational sector seem to be negligible in terms of weight. For most years, this amount represented less than 1% of the overall industrial landings. So far, these catches are not reported to the FAO and therefore not represented in official reports. Nevertheless, with regards to the overall sustainability of the marine ecosystems and its productivity, these catches play an important role. Bearing in mind that many endemic fish species are fully or nearly fully exploited, severely overexploited or have even collapsed, the influence and effects of recreational fishing becomes apparent. According to Griffiths and Lamberth (2002), recreational fishers are directly responsible for the depletion of many species. Additionally, for some user groups such as subsistence and artisanal fishers, who rely on fish for monetary income and as their primary source of protein, decreased availability of marine resources threatens their livelihood and food security.

The estimated catches in this report may be under reported due to various facts. As a result of the multi-sector nature of this industry, smaller categories such as the east coast rock lobster fisheries were excluded. Additionally, individual effort and catch rates were solely based on diurnal fishing activity in all sectors. Night fishing, which is commonly practiced in South Africa, was excluded in all scientific studies used and therefore not represented in this report. Furthermore, rather conservative choices for catch rate trends and number of recreational fishers were made.

Subsistence catches

The total number of subsistence fishers in South Africa was estimated at around 7,800 in 1950, and increased to about 32,700 by 2010. Based on the information for the early 2000s, it was assumed that approximately 82% of the total number of fishers operated in the open ocean, whereas the remaining 18% fished in estuaries only (Clark *et al.* 2002).

Due to the lack of further information about historic numbers of subsistence fishers, estimates were solely based on data for the year 2002 (Clark *et al.* 2002). By applying a constant ratio of subsistence fishers per single non-white South African over the period 1950–2010, the resulting trend corresponds to the increasing population development and may underestimate socioeconomic circumstances in regards to food supply during apartheid. During the 1960s, many black South Africans were restricted to regions in the eastern part of South Africa, such as Transkei, Ciskei and Kwa-Zulu Natal. The subsequent high population density and competition for resources in those areas forced many people to go fishing for their daily protein supply (Clark *et al.* 2002). It is very likely that the actual number of subsistence fishers was higher during apartheid due to the lack of alternative food and income sources. Therefore, the estimated number of fishers used here is based on conservative assumptions.

Reconstructed fish catches for the subsistence fisheries sector in South Africa totalled approximately 153,000 t for the period 1950–2010. The majority of the catches were taken in the eastern provinces where most subsistence activity took place. Therefore, approximately 65% of reconstructed subsistence catches were taken in FAO area 51. Total annual catches steadily increased over the period, from approximately 1,400 t in 1950 to an estimated 4,600 t in 2010. Despite assumed declines in individual catch rates and per capita consumption rates for fish, partly linked to overexploitation and unsustainable catches, total annual subsistence fish catches increased over time.

Due to the lack of information and catch data on other marine subsistence resources, no estimates could be derived for the respective subsectors. Reconstructed total subsistence catches are likely to be underestimated (likely substantially) due to various reasons. Firstly, not all targeted organisms were included in the reconstruction process. Secondly, individual catch rates were likely underestimates since they were based on conservative assumptions.

Despite the rather small amount of total subsistence catches in comparison to commercial catches for South Africa, subsistence fishing plays a crucial role for many households and communities alongside the South African coastline, generating much needed income, as well as providing a daily source of protein for thousands of people. Thus, subsistence fishing (including artisanal) is fundamental for domestic food security purposes. The subsistence fishery is worth many millions of USD per year, with some full-time fishers earning at least USD 1,500 per year from estuarine fishing and bait-collecting activity (Napier *et al.* 2009). In general, subsistence fisheries play an integral role in the livelihood and socioeconomic stability for subsistence fishers. Poverty levels are high among subsistence fishing households, education levels are low and unemployment is widespread (Branch *et al.* 2002b). These factors decrease food security and emphasize the importance of subsistence fishing activities and the availability of marine resources in alleviating poverty.

Despite the high degree of dependence on marine resources by fishers and their families (Clark *et al.* 2002), policies and laws were focused primarily on recreational and the export-oriented commercial fisheries sectors, systematically neglecting the needs of subsistence fishers until the promulgation of the MLRA in 1998.

Subsistence fishers directly compete with the recreational and artisanal sectors for various marine resources. Many fish species, some targeted by recreational and artisanal as well as subsistence fishers, are severely overexploited in South Africa (Griffiths 2000; Branch *et al.* 2002a; Griffiths and Lamberth 2002). Subsistence fishers are known to retain undersized fish due to lack of compliance with, and enforcement of existing rules indicating general problems due to unsustainable catch methods (Griffiths and Lamberth 2002). Illegal fishing activity and poaching is common, especially for high value resources (Hauck and Sweijd 1999; Harris *et al.* 2002b).

Conclusions

This reconstruction focused on quantifying catches from the recreational and small-scale (i.e., subsistence and artisanal) sectors that are not included in the officially reported catch data of South Africa (primarily industrial catches only). In comparison to industrial catches reported to the FAO, the reconstructed catches for the recreational and the subsistence fisheries sector in South Africa do not appear to be significant in terms of tonnage, amounting to less than 1% of the annual total commercial landings in most given year. The importance of these two fisheries becomes more apparent when catches of the eastern and western coasts are viewed separately. Then, the recreational and subsistence sectors along the eastern coast (i.e., the Western Indian Ocean; FAO area 51) combine to make up 73% of reconstructed total catches (see Figure 2 and Appendix Table A2).

Poor compliance and inadequate management measures for recreational fisheries sectors have led to overfishing of many species. This report shows the actual extent of annual catches and emphasizes the necessity for further research in regards to modeling the ecosystem effects of recreational fishery in South Africa; and the need for a more complex management approach geared towards the sustainable use of marine resources, to meet the requirements of this diverse fishing sector.

The legacy of apartheid and the marginalization of the subsistence fishery sector in South Africa, in terms of political neglect, constitute a threat to the livelihood of subsistence fishers and their families. The catch reconstruction for this sector has given an indication of the likely extent of catches. For this report, catches of some subsectors could not be quantified due to the lack of data and information. Therefore, the catch estimates derived are conservative. More scientific research should be undertaken in order to improve and continuously update catch information in order to optimize management approaches that guarantee a sustainable resource use and allow a harvest of marine organisms, so that the livelihood of thousands of people in South Africa can be preserved and can continue to function as a potential safety net that can be relied upon, especially in times of hardship. Of major importance would be the inclusion of annual subsistence, artisanal and recreational catch estimates in the officially reported catch data provided by South Africa to FAO and thus to the international community.

Given the overexploited state of many important marine resources in South Africa, it becomes apparent that there is no room for expansion (Griffiths and Branch 1997; Griffiths 1997a,b, 2000; Cockcroft *et al.* 1999; Hauck and Sweijd 1999; Griffiths and Lamberth 2002; Raemaekers and Britz 2009). Pressure on marine resources is likely to increase with population growth and may lead to further deterioration of stocks.

Many challenges remain in finding and applying appropriate management measures given the diverse nature of the fishery sectors in South Africa. This report was the first attempt to quantify formerly unreported subsistence, artisanal and recreational catches in South Africa. Further research and continuous updates should be undertaken in order to improve data, fill the gaps of knowledge, and facilitate appropriate natural resource management aimed at sustainable, efficient and equitable use of marine resources in South Africa.

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References

Anon. (2010b) Recreational fishing. Available at: www.nda.agric.za/doaDev/fisheries/09_recreational_fishing/index.html [last accessed: 15/12/2010].

Arnason R and Kashorte M (2006) Commercialization of South Africa's subsistence fisheries? Considerations, criteria and approach. International Journal of Oceans and Oceanography 1(1): 45–65.

Attwood CG, Petersen SL and Kerwath SE (2011) Bycatch in South Africa's inshore trawl fishery as determined from observer records. ICES Journal of Marine Science 68: 2163–2174.

Bartholomew A and Bohnsack JA (2005) A review of catch-and-release angling mortality with implications for no-take reserves. Reviews in Fish Biology and Fisheries 15: 129–154.

Beckley L, Fennessy S and Everett B (2008) Few fish but many fishers: a case study of shore-based recreational angling in a major South African estuarine port. African Journal of Marine Science 30(1): 11–24.

Belhabib D, Willemse NE and Pauly D (2015) A fishery tale: Namibian fisheries between 1950 and 2010. Fisheries Centre Working Paper #2015 -65, University of British Columbia, Vancouver, 17 p.

Branch GM (2002) Subsistence fisheries in South Africa: a preface. South African Journal of Marine Science 24(1): 403–404.

Branch GM, Hauck M, Siqwana-Ndulo N and Dye AH (2002a) Defining fishers in the South African context: subsistence, artisanal and small-scale commercial sectors. South African Journal of Marine Science 24(1): 475–487.

Branch GM, May J, Roberts B, Russell E and Clark BM (2002b) Case studies on the socio-economic characteristics and lifestyles of subsistence and informal fishers in South Africa. South African Journal of Marine Science 24(1): 439–462.

Brouwer SL, Mann BQ, Lamberth SJ, Sauer WHH and Erasmus C (1997) A survey of the South African shore-angling fishery. South African Journal of Marine Science 18(1): 165–177.

Burgener M (2011) The Namibian and South African hake trade. TRAFFIC East/Southern Africa, Cape Town (South Africa). 59 p.

Clark BM, Hauck M, Harris JM, Salo K and Russell E (2002) Identification of subsistence fishers, fishing areas, resource use and activities along the South African coast. South African Journal of Marine Science 24(1): 425–437.

Cochrane KL, Augustyn CJ, Fairweather T, Japp D, Kilongo K, Iitembu J, Moroff N, Roux JP, Shannon L, Zyl Bv and Velho Fv (2009) Benguela Current large marine ecosystem — Governance and management for an ecosystem approach to fisheries in the region. Coastal Management 37: 235–254.

Cockcroft AC and Mackenzie AJ (1997) The recreational fishery for West Coast rock lobster *Jasus lalandii* in South Africa. South African Journal of Marine Science 18(1): 75–84.

Cockcroft AC and Payne AIL (1999) A cautious fisheries management policy in South Africa: the fisheries for rock lobster. Marine Policy 23(6): 587–600.

Cockcroft AC, Griffiths MH and Tarr RJQ (1999) Marine recreational fisheries in South Africa: status and challenges. Pp. 64–70 *In* Pitcher TJ (ed.) Evaluating the benefits of recreational fisheries. Fisheries Centre Research Reports 7(2). University of British Columbia, Fisheries Centre, Vancouver (Canada).

Cockcroft AC, Sauer WHH, Branch GM, Clark BM, Dye AH and Russell E (2002) Assessment of resource availability and suitability for subsistence fishers in South Africa, with a review of resource management procedures. South African Journal of Marine Science 24(1): 489–501.

Coetzee PS, Baird D and Tregoning C (1989) Catch statistics and trends in the shore angling fishery of the east coast, South Africa, for the period 1959–1982. South African Journal of Marine Science 8(1): 155–171.

Coleman FC, Figueira WF, Ueland JS and Crowder LB (2004) The impact of United States recreational fisheries on marine fish populations. Science 305(5692): 1958–1960.

Cooke SJ and Cowx IG (2004) The role of recreational fishing in global fish crisis. Bioscience 54(9): 857–859.

Crosoer D, van Sittert L and Ponte S (2006) The integration of South African fisheries into the global economy: past, present and future. Marine Policy 30(1): 18–29.

DAFF (2012) Status of the South African marine fishery resources. Department of Agriculture, Forestry and Fisheries, South Africa.

Elst Rvd, Everett B, Jiddawi N, Mwatha G, Afonso PS and Boulle D (2005) Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. Philosophical Transactions of the Royal Society A 363: 263–284.

FAO (2010) National fishery sector overview: South Africa. Fishery and Aquaculture Country Profiles, Food and Agriculture Organization, Rome (Italy).

Gravel MA and Cooke SJ (2008) Severity of barotrauma influences the physiological status, post-release behavior, and fate of tournament-caught smallmouth bass. North American Journal of Fisheries Management 28: 607–617.

Griffiths CL and Branch GM (1997) The exploitation of coastal invertebrates and seaweeds in South Africa: historical trends, ecological impacts and implications for management. Transactions of the Royal Society of South Africa 1997(52): 121–148.

Griffiths MH (1997a) The application of per-recruit models to *Argyrosomus imdorus*, an important South African sciaenid fish. Fisheries Research 30: 103–115.

Griffiths MH (1997b) Management of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. South African Journal of Marine Science 18(1): 213–228.

Griffiths MH (2000) Long-term trends in catch and effort of commercial linefish off South Africa's Cape Province: snapshots of the 20th century. South African Journal of Marine Science 22(1): 81–110.

Griffiths MH and Lamberth SJ (2002) Evaluating the marine recreational fishery in South Africa. *In* Pitcher TJ and Hollingworth CE (eds.), recreational fisheries: Ecological, economic and social evaluation. Blackwell Publishing Ltd, Oxford (UK).

Guastella LA-M (1994) A quantitative assessment of recreational angling in Durban Harbour, South Africa. South African Journal of Marine Science 14(1): 187–203.

Harris JM, Branch GM, Clark BM, Cockcroft AC, Coetzee C, Dye AH, Hauck M, Johnson A, Kati-Kati L, Maseko Z, Salo K, Sauer WHH, Siqwana-Ndulo N and Sowman M (2002a) Recommendations for the management of subsistence fisheries in South Africa. South African Journal of Marine Science 24(1): 503–523.

Harris JM, Sowman M, Branch GM, Clark BM, Cockcroft AC, Coetzee C, Dye AH, Hauck M, Johnston A, Kati-Kati L, Maseko Z, Salo K, Sauer WHH, Siqwana-Ndulo N and Beaumont J (2002b) The process of developing a management system for subsistence fisheries in South Africa: recognizing and formalizing a marginalized fishing sector in South Africa. South African Journal of Marine Science 24(1): 405–424.

Hauck M and Sowman M (2001) Coastal and fisheries co-management in South Africa: an overview and analysis Marine Policy 25(3): 173–185.

Hauck M and Sweijd NA (1999) A case study of abalone poaching in South Africa and its impact on fisheries management. ICES Journal of Marine Science 56: 1024–1032.

Hauck M, Sowman M, Russell E, Clark BM, Harris JM, Venter A, Beaumont J and Maseko Z (2002) Perceptions of subsistence and informal fishers in South Africa regarding the management of living marine resources. South African Journal of Marine Science 24(1): 463–474.

Hersoug B (1998) Fishing in a sea of sharks-reconstruction and development in the South African fishing industry. Transformation 35: 77–102.
Hersoug B and Holm P (2000) Change without redistribution: an institutional perspective on South Africa's new fisheries policy. Marine Policy 24(3): 221–231.
Horne C (1974) Game fishing transformed. Don Nelson, Cape Town.
Isaacs M (2006) Small-scale fisheries reform: Expectations, hopes and dreams of "a better life for all". Marine Policy 30(1): 51–59.
Japp DW (1997) Discarding practices and bycatches for fisheries in the Southeast Atlantic region (Area 47). Papers presented at the Technical Consultation on Reduction of Wastage in Fisheries, Tokyo, Japan, 28 October-1November 1996. FAO Fish. Rep. No.547, Suppl., : 235–256.
Jaquet JL and Zeller D (2007) National conflict and fisheries: Reconstructing marine fisheries catches for Mozambique. Pp. 35–47 *In* Zeller D and Pauly D (eds.), reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia, Vancouver (Canada).
Kearney RE (2002) Recreational fishing: value is in the eye of the beholder. *In* Pitcher TJ and Hollingworth CE (eds.), Recreational fisheries: ecological, economic and social evaluation. Blackwell Publishing Ltd, Oxford (UK).
Kelleher K (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No.470. FAO, Rome (Italy).
Lamberth SJ and Turpie JK (2003) The role of estuaries in South African fisheries: economic importance and management implications. African Journal of Marine Science 25(1): 131–157.
Le Manach F and Pauly D (this volume) First estimate of unreported catch in the French Îles Éparses, 1950–2010.
Lees R (1969) Fishing for fortunes. The story of the fishing industry in Southern Africa and the men who made it. Purnell, Cape Town (South Africa). 283 p.
Lyle JM, Coleman APM, West L, Campbell D and Henry GW (2002) New large-scale survey methods for evaluating sport fisheries. *In* Pitcher TJ and Hollingworth CE (eds.), recreational fisheries: ecological, economic and social evaluation. Blackwell Publishing Ltd, Oxford (UK).
Mann BQ (2013) Southern African marine linefish species profiles. South African Association for Marine Biological Research, Durban (South Africa).
Mann BQ, Scott GM, Mann-Lang JB, Brouwer SL, Lamberth SJ, Sauer WHH and Erasmus C (1997) An evaluation of participation in and management of the South African spearfishery. South African Journal of Marine Science 18(1): 179–193.
McGrath MD, Horner CCM, Brouwer SL, Lamberth SJ, Mann BQ, Sauer WHH and Erasmus C (1997) An economic valuation of the South African linefishery. South African Journal of Marine Science 18(1): 203–211.
McPhee D, Leadbitter D and Skilleter GA (2002) Swallowing the bait: is recreational fishing in Australia ecologically sustainable? Pacific conservation biology 8(1): 40–51.
Myers RA and Worm B (2003) Rapid worldwide depletion of predatory fish communities. Nature 423(6937): 280–283.
Napier VR, Turpie JK and Clark BM (2009) Value and management of the subsistence fishery at Knysna Estuary, South Africa. African Journal of Marine Science 31(3): 297–310.
Okes N and Burgener M (2011) South African small pelagics trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 19 p.
Okes N and Burgener M (2011) South African rock lobster trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 23 p.
Okes N and Burgener M (2011) South African prawn trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 19 p.
Okes N and Burgener M (2011) South African tuna trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 26 p.
Okes N and Burgener M (2011) South African shark trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 19 p.
Okes N and Burgener M (2011) South African squid trade profile. TRAFFIC East/Southern Africa, Cape Town (South Africa). 23 p.
Pauly D (2006) Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. Maritime Studies (MAST) 4(2): 7–22.
Pauly D (2007) The *Sea Around Us* Project: documenting and communicating global fisheries impact on marine ecosystems. Ambio 36(4).
Pauly D and Zeller D (2003) The global fisheries crisis as a rationale for improving the FAO's database of fisheries statistics. Fisheries Centre Research Reports 11(6). Fisheries Centre, University of British Columbia, Vancouver.
Pauly D, Christensen V, Guenette S, Pitcher TJ, Sumaila UR, Walters CJ, Watson R and Zeller D (2002) Towards sustainability in world fisheries. Nature 418(6898): 689–695.
Pradervand P (2004) Long-term trends in the shore fishery of the Transkei coast, South Africa. African Zoology 39(2): 247–261.
Pradervand P and Baird D (2002) Assessment of the recreational linefishery in selected Eastern Cape estuaries: trends in catches and effort. South African Journal of Marine Science 24(1): 87–101.
Pradervand P and Van der Elst RP (2008) Assessment of the charter-boat fishery in KwaZulu-Nata. South Africa African Journal of Marine Science 30(1): 101–112.

Pradervand P, Beckley LE, Mann BQ and Radebe PV (2003) Assessment of the linefishery in two urban estuarine systems in Kwazulu-natal, South Africa. African Journal of Marine Science 25(1): 111–130.

Raemaekers SJ-PN and Britz PJ (2009) Profile of the illegal abalone fishery (*Haliotis midae*) in the Eastern Cape Province, South Africa: organised pillage and management failure. Fisheries Research 97: 183–195.

Raemaekers SJ-PN, Hauck M, Burgener M, Mackenzie AJ, Maharaj G, Plaganyi EE and Britz PJ (2011) Review of the causes of the rise of the illegal South African abalone fishery and consequent closure of the rights-based fishery. Ocean and Coastal Management 54: 433–445.

Richardson AJ, Lamberts C, Isaacs G, Moloney CL and Gibbons MJ (2000) Length-weight relationships of some important forage crustaceans from South Africa. Naga, The ICLARM Quarterly 23(2).

Sauer WHH, Penney AJ, Erasmus C, Mann BQ, Brouwer SL, Lamberth SJ and Stewart TJ (1997) An evaluation of attitudes and responses to monitoring and management measures for the South African boat-based linefishery. South African Journal of Marine Science 18(1): 147–163.

Schoeman S (1962) Strike!–A handbook of angling in South African coastal waters. A. A. Balkema, Cape Town.

Siegfried WR, Hockey PAR and Branch GM (1994) The exploitation of intertidal and subtidal biotic resources of rocky shores in Chile and South Africa — An overview. Pp. 1–15 *In* Siegfried WR (ed.) Rocky shores: exploitation in Chile and South Africa. Springer Verlag, Berlin (Germany).

Sink KJ, Wilkinson S, Atkinson LJ, Sims PF, Leslie RW and Attwood CG (2012) The potential impacts of South Africa's demersal hake trawl fishery on benthic habitats: historical perspectives, spatial analyses, current review and potential management actions Unpublished report, South African National Biodiversity Institute.

Smale MJ and Buxton CD (1985) Aspects of the recreational ski-boat fishery off the Eastern Cape, South Africa. South African Journal of Marine Science 3(1): 131–144.

Sowman M (2006) Subsistence and small-scale fisheries in South Africa: a ten-year review. Marine Policy 30(1): 60–73.

Sowman M and Cardoso P (2010) Small-scale fisheries and food security strategies in countries in the Benguela Current Large Marine Ecosystem (BCLME) region: Angola, Namibia and South Africa. Marine Policy 34(6): 1163–1170.

Steyn E, Fielding P and Schleyer M (2008) The artisanal fishery for East Coast rock lobsters *Panulirus homarus* along the Wild Coast. South Africa African Journal of Marine Science 30(3): 497–506.

Toivonen A-L (2002) A survey of the economic value of nordic recreational fisheries. *In* Pitcher TJ and Hollingworth CE (eds.), recreational fisheries: ecological, economic and social evaluation. Blackwell Publishing Ltd, Oxford (UK).

United Nations (2009) World population prospects: the 2008 revision population database. Available at: http://esa.un.org/UNPP/p2k0data.asp [Accessed on: 19/12/2010].

Van der Elst RP (1989) Marine recreational angling in South Africa. Pp. 164–176 *In* Payne AIL and Crawford RJM (eds.), oceans of life off southern Africa. Vlaeberg Publishers, Cape Town (South Africa).

Van der Elst RP (1993) Marine recreational angling in South Africa: management strategies and their implementation. Pp. 15–23 *In* Dovers S (ed.) Australian recreational fishing. Policies for Resource Management.

Van der Elst RP and Adkin F (1991) Marine linefish: priority species and research objectives in southern Africa. Oceanographic Research Institute, Durban.

Van der Elst RP, Everett B, Jiddawi N, Mwatha G, Afonso PS and Boulle D (2005) Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. Philosophical Transactions of the Royal Society A 363(1826): 263–284.

van Sittert L, Branch G, Hauck M and Sowman M (2006) Benchmarking the first decade of post-apartheid fisheries reform in South Africa. Marine Policy 30(1): 96–110.

van Zyl BJ (nd) Managing Namibia's marine fisheries — A decade of rebuilding. Availabe at: http://www.unep.org/bpsp/Fisheries/Fisheries Case Study Summaries/VanZyl%28Summary%29.pdf [Accessed on: 01/03/2011].

Walmsley SA, Leslie RW and Sauer WHH (2007) Bycatch and discarding in the South African demersal trawl fishery. Fisheries Research 86: 15–30.

Watson R, Kitchingham A, Gelchu A and Pauly D (2004) Mapping global fisheries: sharpening our focus. Fish and Fisheries 5: 168–177.

Whibley I (2003) The South African fisherman. Struik Publishers, Cape Town (South Africa).

Whitfield AK (1994) An estuary-association classification for the fishes of southern Africa. South African Journal of Science 90(7): 411–417.

World Bank (2010) Population South Africa. Available at: http://databank.worldbank.org [Accessed on: 12/12/2010].

Worm B, Hilborn R, Baum JK, Branch TA, Collie JS, Costello C, Fogarty MJ, Fulton EA, Hutchings JA, Jennings S, Jensen OP, Lotze HK, Mace PM, McClanahan TR, Minto C, Palumbi SR, Parma AM, Ricard D, Rosenberg AA, Watson R and Zeller D (2009) Rebuilding global fisheries. Science 325(5940): 578–585.

Zeller D, Booth S, Davis G and Pauly D (2007a) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266–277.

Zeller D, Booth S and Pauly D (2007b) Fisheries contribution to the gross domestic product: underestimating small-scale fisheries in the Pacific. Marine Resource Economics 21: 355–374.

Zeller D, Booth S, Craig P and Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950–2002. Coral Reefs 25: 144–152.

Appendix Table A1. Percentage of catch contribution (by mass) of the most important recreational species according to subsectors. RegionsW = Western Cape, S = Southern Cape, E = Eastern Cape, T =Transkei, K = Kwa-Zulu Natal.

Subsector	Family	Taxon. Name	Common name	Region W	S	E	T	K	S+E
Shore and rock angling	Dichistidae	*Dichistius capensis*	Galjoen	29.8	14	1.1	1		
	Haemulidae	*Pomadasys commersonni*	Spotted grunter		0.3	0.7	4.1	1.1	
		P. olivaceum	Piggy/Olive grunt		1.7	13	2.5	3.1	
	Mugilidae	*Liza richardsonii*	Harder/Mullet	9.5	1.6	5.8			
	Pomatomidae	*Pomatomus saltatrix*	Bluefish/Elf	0.1	52	22	19	25	
	Sciaenidae	*Argyrosomus inodorus*	Mild meager	1.7	4.6				
		A. japonicus	Dusky kob			2.9	3.5	1	
		Umbrina spp.	Baardman		1.4	0.2			
	Scorpidae	*Neoscorpis lithophilus*	Stonebream			1.6	15	4.3	
	Sparidae	*Diplodus sargus*	Blacktail/Dassie	1	1.5	7.8	16	8.9	
		Lithognathus lithognathus	White steenbras	0.5	4.7	1.4	0.3		
		Pachymetopon blochii	Hottentot	12.5	0.6				
		P. grande	Bronze bream			4	13	0.1	
		Sarpa salpa	Strepie	0.3	3.3	24	11	44	
	Misc. marine fish	Other	Other	<45	<15	<17	15	<13	
Boat-based angling	Carangidae	*Seriola lalandii*	Yellowtail amberjack	1.1	20				
	Gempylidae	*Thyrsites atun*	Snoek	58.4	21				
	Merluccidae	*Merluccius capensis*	Cape hake	0.2	0.3	23			
	Pomatomidae	*Pomatomus saltatrix*	Spotted grunter	0.1	1.3	0.4		1.2	
	Sciaenidae	*Argyrosomus inodorus*	Piggy/Olive grunt	0.1	7.3	18			
		A. japonicus	Harder/Mullet					0.6	
		Atractoscion aequidens	Geelbeck croaker	0.1	9.1	13		3.3	
	Scombridae	*Scomberomorus commerson*	Spanish mackerel					33	
		S. plurilineatus	Queen mackerel					2	
		Thunnus alalunga	Albacore tuna	28.4	0.3				
		T. albacares	Yellowfin tuna	0.7	0.4	10		19	
	Sparidae	*Argyrozona argyrozona*	Carpenter	0.1	14	2.2			
		Cheimerius nufar	Santer seabream		0.2	3.2		2.4	
		Chrysoblephus laticeps	Roman seabream	0.1	1.7	2.5			
		C. puniceus	Slinger seabream	0.1				3.8	
		Pachymetopon blochii	Hottentot	3.8	3.5				
	Misc. marine fish	Other	Other	< 7	<22	<27	-	<35	
Estuary angling	Carangidae	*Lichia amia*	Leervis/Garrick		3.9	1.8			
	Haemulidae	*Pomadasys commersonni*	Spotted grunter		62	33		18	
	Mugilidae	*Liza richardsonii*	Harder/Mullet	2	0.1				
	Pomatomidae	*Pomatomus saltatrix*	Bluefish/Elf	92.1	0.1	0.7		0.6	
	Sciaenidae	*Argyrosomus japonicus*	Dusky kob		7.8	51		64	
	Sparidae	*Diplodus sargus*	Blacktail/Dassie		0.7	0.1			
		Lithognathus lithognathus	White steenbras	0.7	14	2			
		Sarpa salpa	Strepie		0.6	0.1			
		Sparodon durbanesis	Musselcracker seabream		0.6	0.1			
	Misc. fish	Other	Other	< 6	<11	<12	-	<19	
Spearfishing	Carangidae	*Lichia amia*	Gerrick				4.7		0.6
		Seriola lalandii	Yellowtail amberjack	4.3			0.3		1.9
	Dichistiidae	*Dichistius capensis*	Galjoen	6.1			0.3		6.7
	Oplegnathidae	*Oplegnathus conwayi*	Cape knifejaw				3		15.4
	Sciaenidae	*Argyrosomus inodorus*	Piggy/Olive grunt	0.1					
		Umbrina spp.	Baardman				3.8		4.8
	Scombridae	*Scomberomorus commerson*	Spanish mackerel				17		
		S. plurilineatus	Queen mackerel				31		
	Sparidae	*Chrysoblephus laticeps*	Roman seabream	0.1					19.3
		Diplodus sargus	Blacktail/Dassie	0.1					1
		Gymnocrotaphus curvidens	Janbruin			11			
		Pachymetopon blochii	Hottentot	88.1					6.7
		P. grande	Bronze seabream				9.8		6.7
		Sparodon durbanensis	Musselcracker seabream				2.8		2.9
	Misc. marine fish	Other	Other	< 2		-	<27		< 24
Charter boat	Coryphaenidae	*Choryphaena hippurus*	Dolphinfish				20		
	Scombridae	*Thunnus albacares*	Yellowfin tuna				14		
	Sparidae	*Chrysoblephus puniceus*	Slinger seabream				11		
	Misc. marine fish	Other	Other (reef fish, sharks, billfishes, tuna)			55			
	Lethrinidae	*Lethrinus nebulosus*	Blue emperor				16		
Charter boat (by number)	Sparidae	*Chrysoblephus puniceus*	Slinger seabream				34		
		Cheimerius nufar	Santer seabream				14		
		Chrysoblephus anglicus	Englishman seabream				11		
	Misc. marine fish	Other	Other (reef fish, sharks, billfishes, tuna)			25			

Appendix Table A2. Total reconstructed catch by sector and Ocean, 1950–2010.

Year	Indian Ocean						Atlantic Ocean						
	Reconstructed catch						Reconstructed catch						
	Artisanal	Industrial	Recreational	Subsistence	Total	Reported to FAO	Artisanal	Industrial	Recreational	Subsistence	Total	Reported to FAO in EEZ	Reported to FAO in Area 47
1950			1,923	902	2,825		44,200	291,906	1,035	486	337,627	316,600	390,745
1951	3		1,984	922	2,909		46,402	453,869	1,068	497	501,835	470,100	635,536
1952	6		2,047	942	2,995		50,803	638,202	1,102	507	690,615	646,700	930,681
1953	9		2,111	962	3,083		53,605	633,288	1,137	518	688,547	644,500	961,536
1954	13		2,177	981	3,171		52,707	618,240	1,172	528	672,647	629,500	932,728
1955	16		2,244	1,001	3,261		66,609	582,030	1,208	539	650,386	608,700	886,575
1956	20		2,313	1,024	3,358		69,611	499,260	1,246	551	570,668	533,700	805,056
1957	24		2,384	1,048	3,456		45,213	576,990	1,284	564	624,051	583,600	859,702
1958	28		2,458	1,071	3,557		55,915	647,495	1,324	577	705,310	659,601	938,346
1959	32		2,532	1,095	3,659		63,317	724,875	1,363	589	790,145	738,401	1,069,375
1960	37		2,608	1,118	3,764		57,320	859,996	1,405	602	919,322	858,901	1,205,081
1961	42		2,689	1,144	3,875		72,222	1,014,346	1,448	616	1,088,632	1,016,500	1,438,402
1962	47		2,768	1,169	3,984		40,625	1,101,335	1,491	629	1,144,080	1,068,201	1,548,330
1963	52		2,854	1,189	4,094		31,219	1,225,207	1,537	640	1,258,602	1,175,014	1,823,272
1964	57	2,500	2,937	1,209	6,703	2,500	68,461	1,243,461	1,582	651	1,314,154	1,226,607	1,921,861
1965	62	2,500	3,024	1,226	6,812	2,500	59,743	1,356,955	1,629	660	1,418,986	1,324,710	2,047,415
1966	67	2,900	3,111	1,244	7,322	2,900	74,928	1,350,315	1,675	670	1,427,589	1,332,693	2,147,477
1967	73	3,100	3,203	1,263	7,639	3,100	156,740	1,614,486	1,724	680	1,773,631	1,655,702	2,731,690
1968	78	4,000	3,295	1,283	8,656	4,000	106,843	2,145,285	1,774	691	2,254,593	2,104,802	3,835,787
1969	84	3,700	3,390	1,304	8,479	3,700	104,946	1,879,911	1,826	702	1,987,385	1,854,802	3,362,996
1970	91	601	3,493	1,325	5,509	601	105,850	1,195,133	1,881	713	1,303,576	1,217,203	2,042,557
1971	97	1,001	3,524	1,347	5,969	1,001	71,753	1,186,340	1,897	725	1,260,716	1,176,403	1,828,388
1972	104	1,201	3,554	1,370	6,229	1,201	81,311	1,139,034	1,914	738	1,222,997	1,141,657	1,771,351
1973	111	1,608	3,586	1,392	6,697	1,600	112,825	1,341,370	1,931	750	1,456,876	1,362,078	2,264,116
1974	118	3,081	3,614	1,417	8,229	3,073	44,415	1,481,383	1,946	763	1,528,507	1,426,265	2,346,088
1975	125	3,567	3,645	1,439	8,775	3,548	83,348	1,375,489	1,962	775	1,461,574	1,363,620	2,242,844
1976	133	2,690	3,674	1,461	7,957	2,690	16,985	1,227,073	1,978	787	1,246,823	1,163,256	1,829,868
1977	140	2,728	3,702	1,482	8,052	2,728	47,488	979,181	1,994	798	1,029,461	962,172	1,389,817
1978	148	3,149	3,731	1,506	8,534	3,144	24,319	1,054,273	2,009	811	1,081,411	1,009,268	1,524,649
1979	351	1,729	3,759	1,529	7,369	1,913	42,649	1,017,857	2,024	823	1,063,354	993,749	1,405,848
1980	165	2,811	3,787	1,555	8,318	2,778	28,375	880,392	2,039	837	911,643	850,870	1,168,972
1981	563	2,030	3,815	1,583	7,991	2,413	41,907	875,595	2,054	852	920,409	859,936	1,235,974
1982	2,609	4,502	3,843	1,614	12,568	6,927	35,541	835,043	2,070	869	873,522	815,513	1,063,203
1983	2,777	4,363	3,870	1,645	12,655	6,946	31,519	959,926	2,084	886	994,414	928,124	1,250,323
1984	1,256	2,352	3,898	1,677	9,182	3,398	39,992	739,721	2,099	903	782,715	730,946	898,610
1985	1,159	2,028	3,925	1,711	8,823	2,789	77,874	757,714	2,113	921	838,622	772,720	978,597
1986	480	2,680	3,951	1,743	8,853	2,884	42,928	834,578	2,127	939	880,572	816,943	986,203
1987	814	2,006	3,976	1,777	8,573	2,470	47,289	1,479,711	2,141	957	1,530,097	1,423,096	2,006,383
1988	694	1,973	4,004	1,807	8,479	2,331	58,101	1,335,258	2,156	973	1,396,488	1,297,941	1,565,957
1989	759	1,765	4,024	1,835	8,382	2,166	78,613	862,411	2,167	988	944,179	873,385	1,124,854
1990	625	1,569	4,065	1,862	8,121	1,853	65,446	509,490	2,189	1,002	578,127	531,908	601,364
1991	657	1,171	4,112	1,887	7,827	1,471	63,808	469,759	2,214	1,016	536,797	494,001	536,797
1992	745	906	4,091	1,915	7,657	1,267	47,960	694,751	2,203	1,031	745,946	690,241	745,946
1993	404	751	4,393	1,946	7,494	826	50,413	553,839	2,365	1,048	607,665	560,717	607,665
1994	505	371	4,417	1,976	7,269	517	46,308	516,206	2,379	1,064	565,957	522,130	565,957
1995	523	224	4,374	2,009	7,129	373	46,781	571,969	2,355	1,082	622,187	574,966	622,187
1996	525	210	4,397	2,041	7,173	349	44,230	429,395	2,368	1,099	477,091	439,540	477,091
1997	634	722	4,508	2,077	7,941	936	44,630	506,966	2,427	1,118	555,141	511,412	555,141
1998	1,093	666	4,237	2,113	8,110	1,238	56,466	543,702	2,282	1,138	603,587	555,947	603,587
1999	854	635	4,196	2,153	7,838	1,000	38,715	590,646	2,259	1,159	632,780	585,324	632,780
2000	1,100	621	4,250	2,192	8,162	986	34,411	653,513	2,288	1,181	691,393	640,000	691,393
2001	1,430	621	4,263	2,240	8,554	1,175	39,027	766,478	2,296	1,206	809,006	747,719	809,006
2002	2,714	430	4,349	2,276	9,769	2,046	41,460	779,631	2,342	1,226	824,658	763,482	824,658
2003	3,181	211	4,174	2,306	9,871	2,170	37,103	843,359	2,248	1,241	883,951	819,034	883,951
2004	1,486	387	4,124	2,336	8,332	898	47,521	905,059	2,220	1,258	956,058	885,717	956,058
2005	1,704	391	4,124	2,365	8,584	863	47,335	828,954	2,221	1,273	879,783	815,322	879,783
2006	1,643	384	4,111	2,397	8,534	1,073	33,759	629,668	2,213	1,291	666,931	616,174	666,931
2007	1,542	329	4,080	2,426	8,377	986	37,321	690,270	2,197	1,306	731,094	676,396	731,094
2008	1,830	266	4,076	2,456	8,628	1,065	38,879	652,332	2,195	1,322	694,728	642,107	694,728
2009	1,728	262	4,071	2,485	8,545	950	41,257	509,060	2,192	1,338	553,847	510,086	553,847
2010	1,993	282	4,066	2,547	8,888	1,206	41,906	632,256	2,190	1,371	677,723	625,828	677,723

Appendix Table A3. Total reconstructed catch by taxon and Ocean, 1950–2010.

Year	Indian Ocean						Atlantic Ocean							
	Sparidae	*Pomatomus saltatrix*	Sciaenidae	Haemulidae	Mugilidae	Others	*Sardinops sagax*	*Engraulis capensis*	*Merluccius* spp.	*Trachurus capensis*	*Etrumeus whiteheadi*	*Merluccius capensis*	*Scomber japonicus*	Others
1950	421	431	305	263	221	1,183	155,700	-	47,600	36,700	-	8,972	5,700	82,954
1951	435	444	314	271	227	1,219	226,600	-	59,200	101,900	-	13,878	6,000	94,258
1952	450	456	323	279	233	1,255	395,800	-	58,900	103,800	-	19,459	5,900	106,756
1953	464	469	332	286	239	1,293	399,300	-	61,900	85,900	-	19,498	12,200	109,749
1954	479	482	341	294	244	1,330	338,900	-	69,900	120,500	-	19,062	13,100	111,185
1955	494	496	350	302	250	1,369	349,100	-	74,100	80,700	-	18,368	26,500	101,618
1956	509	510	360	311	257	1,410	307,700	-	76,000	47,200	-	16,173	36,900	86,694
1957	525	525	371	319	264	1,452	335,000	-	80,800	85,600	-	17,751	11,400	93,500
1958	542	540	381	328	271	1,495	418,300	-	83,600	65,100	-	20,145	20,100	98,065
1959	559	555	392	337	278	1,538	531,500	-	69,500	22,100	-	22,896	33,100	111,049
1960	576	571	402	347	285	1,583	600,800	-	76,600	67,800	-	26,862	29,100	118,161
1961	594	587	414	356	293	1,631	744,700	-	95,000	46,100	-	32,221	52,300	118,311
1962	612	603	425	366	300	1,677	805,400	0	93,900	72,700	-	33,918	21,200	116,962
1963	630	620	437	376	307	1,725	947,600	23,300	90,700	26,700	-	37,436	13,400	119,466
1964	649	636	448	385	313	4,272	878,400	95,400	102,200	26,900	2,500	39,231	52,000	117,524
1965	668	653	459	395	319	4,319	868,900	178,300	99,600	57,800	2,100	42,299	39,500	130,487
1966	687	670	470	404	325	4,765	882,300	159,900	124,400	29,400	4,500	42,557	54,900	129,632
1967	707	688	483	414	332	5,016	1,005,100	297,500	118,700	12,000	12,700	53,123	138,900	135,607
1968	727	706	495	424	339	5,966	1,481,000	331,000	118,600	4,700	13,500	67,751	90,100	147,942
1969	748	724	508	435	346	5,718	1,159,700	397,400	104,300	31,700	14,300	59,805	92,800	127,380
1970	771	745	520	446	353	2,674	576,200	358,300	94,100	16,000	23,900	38,516	77,900	118,660
1971	780	752	526	451	360	3,101	412,900	367,000	111,400	150,300	23,700	37,554	54,600	103,262
1972	788	759	531	456	366	3,328	477,600	372,200	118,100	28,100	20,600	36,171	56,600	113,626
1973	796	766	537	462	373	3,763	470,300	558,200	133,000	21,200	30,000	42,347	58,800	143,029
1974	804	773	543	467	380	5,263	572,017	595,778	134,870	43,712	1,779	45,756	30,670	103,925
1975	812	780	549	472	386	5,776	659,395	400,949	113,083	29,901	29,628	43,769	69,344	115,505
1976	820	787	555	477	393	4,926	630,043	299,405	118,205	39,926	18,510	37,136	545	103,052
1977	828	793	560	482	399	4,990	173,957	376,913	101,583	97,886	35,979	29,634	21,336	192,173
1978	836	800	566	488	406	5,439	110,973	564,291	143,115	25,136	67,165	31,852	2,443	136,436
1979	844	807	572	493	413	4,242	65,188	587,693	153,294	62,146	14,095	30,670	11,139	139,129
1980	851	813	577	498	420	5,158	57,629	508,750	150,241	57,014	14,132	26,557	4,213	93,106
1981	860	820	584	504	428	4,795	91,254	492,970	143,905	22,284	24,301	26,404	10,943	108,348
1982	868	828	590	510	437	9,335	57,868	389,571	156,858	83,453	31,491	25,253	13,643	115,385
1983	876	835	597	516	446	9,385	79,189	424,011	137,619	126,906	69,662	29,049	13,271	114,707
1984	884	842	604	523	455	5,874	78,205	285,962	152,499	103,998	29,551	22,352	6,962	103,186
1985	893	850	610	529	464	5,477	85,475	323,239	183,228	36,237	42,461	22,860	6,818	138,304
1986	901	857	617	535	474	5,470	86,527	315,110	182,089	99,749	57,521	25,364	5,990	108,222
1987	909	864	624	542	483	5,152	106,841	969,401	168,918	61,042	34,820	44,887	6,990	137,198
1988	918	871	630	548	492	5,020	101,080	682,079	161,023	199,645	62,006	40,510	9,197	140,947
1989	927	877	636	553	500	4,890	101,461	372,916	153,484	83,828	44,363	26,180	22,278	139,669
1990	935	882	641	558	508	4,596	56,871	150,100	135,168	51,074	44,710	15,482	17,759	106,963
1991	944	887	647	563	516	4,270	52,011	150,560	136,484	35,564	33,484	14,266	16,783	97,644
1992	959	898	653	570	525	4,053	53,436	347,312	135,805	33,640	47,341	21,074	5,286	102,051
1993	973	909	660	576	535	3,840	50,702	235,606	108,336	35,429	56,329	16,801	5,854	98,608
1994	987	919	667	588	545	3,564	93,438	155,554	136,917	20,031	54,147	15,649	5,590	84,630
1995	1,005	934	683	594	555	3,358	115,205	170,308	137,742	10,262	76,858	17,334	5,799	88,679
1996	1,013	939	688	597	565	3,371	105,210	40,712	155,155	31,995	47,117	13,043	5,132	78,727
1997	1,021	944	693	609	576	4,098	116,995	60,095	141,076	31,206	92,209	15,417	9,968	88,175
1998	1,029	950	692	620	586	4,231	128,019	107,548	151,317	46,384	52,476	16,546	3,969	97,328
1999	1,038	956	699	621	598	3,926	131,316	180,542	141,165	17,970	58,856	17,936	2,189	82,806
2000	1,046	961	706	623	610	4,216	136,060	267,840	135,000	15,000	37,750	19,868	1,984	77,891
2001	1,054	966	712	631	621	4,569	192,160	287,190	146,393	9,659	55,330	23,260	2,009	93,006
2002	1,062	969	716	635	630	5,756	260,710	213,440	149,548	21,883	54,800	23,647	1,086	99,544
2003	1,069	971	720	637	637	5,838	289,994	258,876	139,160	28,285	42,529	25,580	1,647	97,880
2004	1,075	973	723	641	644	4,276	373,827	190,093	153,252	34,131	47,236	27,447	2,287	127,785
2005	1,082	974	726	644	651	4,507	246,777	282,728	143,987	35,105	28,896	25,142	3,084	114,064
2006	1,089	975	729	646	659	4,436	217,328	134,360	132,943	27,016	42,660	19,101	1,071	92,452
2007	1,096	975	731	647	666	4,262	139,489	252,782	141,357	31,740	48,108	20,939	1,022	95,658
2008	1,102	985	734	655	673	4,479	90,969	265,823	132,426	30,502	64,701	19,788	2,939	87,580
2009	1,109	974	736	652	679	4,395	94,362	174,465	107,489	35,219	40,632	15,439	1,364	84,877
2010	1,119	978	742	658	694	4,696	112,386	217,042	112,870	33,458	88,574	19,172	1,741	92,480

An Update of the Reconstructed Marine Fisheries Catches of Tanzania with Taxonomic Breakdown*

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Abstract

Reconstructed catch estimates of the marine fisheries sectors in Tanzania were updated to 2010 from a previous study by Jacquet and Zeller (2007), which covered 1950 to 2005. In addition, a taxonomic breakdown was developed and applied to the annual catches for the 1950–2010 time-period. The reconstructed catch for 1950–2010 totalled 4.2 million t, 77% higher than the 2.4 million t reported by the Food and Agriculture Organization of the United Nations (FAO) on behalf of Tanzania. On average, discards represented 2% of the total catch and sectors were represented as follow: artisanal (83%), subsistence (14%), and industrial (3%). Overall, Tanzanian catches were dominated by Clupeidae (14%), Lethrinidae (13%), Scombridae (9%) and Elasmobranchii (7%). Noteworthy is that the unreported portion (i.e., the difference between the reconstructed and FAO totals) has decreased from over 50% in the 1950s to 30% in the 2000s. Also, the number of taxonomic groups included in the catch reported to FAO has increased since 2005, thus decreasing the proportion of undetermined taxa previously reported as 'marine fishes nei'.

Introduction

The United Republic of Tanzania (referred throughout as 'Tanzania') is located along the Mozambique Channel, and its Exclusive Economic Zone (EEZ) covers over 240,000 km^2 (Figure 1). The overwhelming bulk of its land area, which corresponds to the former 'Tanganyika', is situated between Mozambique in the South and Kenya in the North (Figure 1). Tanzania also includes three large islands: Mafia, Pemba and Zanzibar, the latter two forming the region of Zanzibar (hence the name 'Tan-Za-nia'). Zanzibar has an autonomous institutional and legal structure for managing fisheries, so both mainland and Zanzibar regions have separate reporting systems (Jacquet and Zeller 2007). Tanzanian fisheries are mainly composed of small-scale fisheries, which represent about 95% of the total marine catch (Jiddawi and Öhman 2002; Abdallah 2004). Large industrial fishing vessels are few and those that exist are mainly involved in the shrimp fishery (Kimaro 1995). Since 1998, artisanal longliners have also targeted pelagic species such as tuna and billfishes (Kimaro 1995; Shao *et al.* 2003; Mngulwi 2006). Marine resources are used for subsistence and as a source of income for people living along the coast (Jiddawi and Öhman 2002), and exported products include holothurians, shells, lobsters, octopuses and shrimps (Marshall *et al.* 2001; Jiddawi and Öhman 2002; Abdallah 2004).

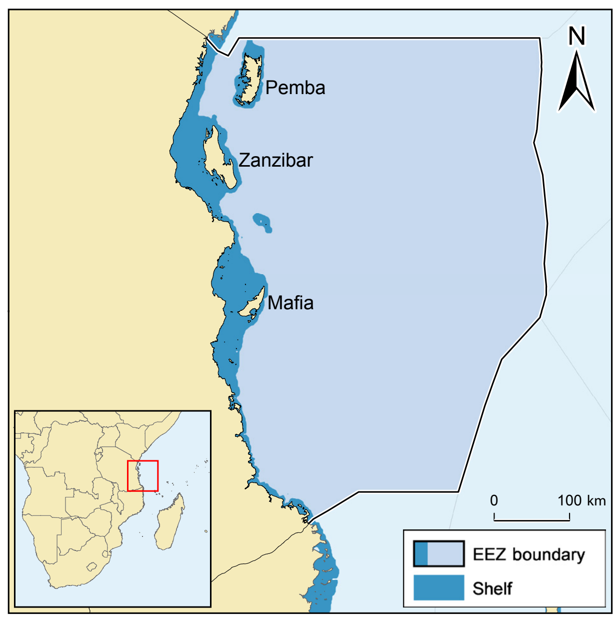

Figure 1. Map of the Tanzanian Exclusive Economic Zone (EEZ), showing the extent of the shelf and the islands of Mafia, Pemba, and Zanzibar.

Accurate historical baselines are useful for fisheries management and monitoring long-term changes in marine ecosystems. Data reported to the Food and Agriculture Organization of the United Nations (FAO) are the only source of global catch statistics and are often used to evaluate the status of both global and regional fisheries (Garibaldi 2012). These data often underreport small-scale fisheries, though, and do not include other important sectors such as recreational fisheries and industrial discards, nor do they include illegal catches (Garibaldi 2012; World Bank 2012). Furthermore, a large portion of FAO catch statistics are often reported as 'marine fishes, nei' or assigned to high taxonomic levels (i.e., higher than family), and although the number of reported species in the database has

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increased in recent years (Garibaldi 2012), there is still a need to further disaggregate FAO catch statistics into more specific taxa, particularly for earlier years. The present study aims to improve the initial catch reconstruction published by Jacquet and Zeller (2007) updating it to 2010, refining some of the previous estimates, and providing taxonomic and sectoral breakdowns.

Methods

Small-scale boat-based catches

Mainland

Baseline reported catch data for marine fisheries from 1950 to 2010 were extracted from FishStatJ (FAO 2012), the fisheries catch database of the FAO. These data reported to FAO were treated as the baseline of reported catches and were considered representative of boat-based catches, assuming that they did not include any catch by shore fishers (Jacquet and Zeller 2007). Changes occurred in the FAO database between this new extraction and the one made by Jacquet and Zeller (2007), as member countries can retroactively modify the data they submitted to FAO, and FAO staffers also modify submitted data if they judge it necessary (Anon. 2013). Indeed, several new taxa were added, but *Thunnus maccoyii* (southern bluefin tuna; accounting for 3 t in the 2000s) was removed. Total annual tonnages also differed from 2000 to 2008, but there has been little change in quantities reported as 'marine fishes nei', implying that this category has not been further disaggregated.

The primary phase of our work was to update to 2010 the reconstructed data of Jacquet and Zeller (2007), using their methodology by applying a 35% unreported catch increase to FAO data from 1970–2010 (distributed proportionally to the reported taxa). We then improved the FAO taxa disaggregation for the early years. There were only two taxa reported to FAO for mainland Tanzania in the 1950s, but this figure has since increased to 48 in 2010.

First, the poor taxonomic resolution in FAO data from 1950 to 1974 (less than nine taxa before 1969) was improved using the catch composition of the 26 reported taxa from the FAO data for the 1975–1979 period. For each year from 1950–1974, the 'marine fishes nei' group was further divided into these 26 taxonomic groups based on the average catch composition from the 1975–1979 period, which also contained a 'marine fishes nei' portion. There were two exceptions: the catch of large pelagics and holothurians were assumed to be zero prior to the first year they were reported to FAO (1974 and 1963, respectively), as they were not being targeted then: large pelagic fisheries (tuna and billfishes) started in the late 1970s in the Western Indian Ocean (Majkowski 2007) and the exploitation of holothurians started in the 1960s with the arrival of Chinese settlers (Marshall *et al.* 2001). The FAO data were therefore consistent with trends observed in the literature and the zero catch of large pelagics and holothurians in earlier years was considered accurate.

Once the taxonomic resolution of the early time-period was improved, we addressed the remaining 'marine fishes nei' and the 'percoids' catch (Table 1). 'Percoids' were considered to be mostly comprised of reef species and were disaggregated using the same method. The taxonomic breakdown used for these two categories was developed from i) a study by Jiddawi and Stanley (1999), who sampled landings from two auction sites on Zanzibar Island from 1995 to 1997; and ii) a study by Silva (2006), who surveyed households from

Table 1. Taxonomic breakdown (%) used to disaggregate 'marine fishes nei' and 'percoids nei' reported in FAO landings for mainland Tanzania and Zanzibar.

Family	Original (%)		Applied (%)	
	Silva (2006)	Jiddawi and Stanley (1999)	Mainland[a]	Zanzibar[b]
Acanthuridae	9.1	14.5	7.2	14.5
Arridae	-	3.3		3.3
Balistidae	-	0.8	0.4	0.8
Belonidae	-	7.8	4.1	7.8
Caesionidae	-	3.9	2	3.9
Chaetodontidae	-	0.2	0.1	0.2
Clupeiformes	-	1.3		1.3
Coryphaneidae	-	2.1	1.1	2.1
Diodontidae	-	5.5	2.9	5.5
Drepaneidae	-	1.5	0.8	1.5
Echeneidae	-	0.1	0.1	0.1
Ephippidae	-	0.1	0.1	0.1
Fistulariidae	-	1.8	0.9	1.8
Gerreidae	14.4	10.2	11.5	10.2
Haemulidae	3.6	13.5	2.8	13.5
Hemiramphidae	-	4.1		4.1
Labridae	-	8.2		8.2
Leiognathidae	-	0.1	0.1	0.1
Lutjanidae	22.4	-	17.9	-
Mullidae	18.7	-	14.9	-
Muraenidae	-	11.3	5.9	11.3
Nemipteridae	-	4.9		4.9
Ostraciidae	-	0.3	0.1	0.3
Platycephalidae	-	0.4	0.2	0.4
Pleuronectiformes	-	0.3	0.1	0.3
Pomacentridae	-	1.5	0.8	1.5
Rachycentridae	5.5	1	4.4	1
Scaridae	26.5	-	21.2	-
Sciaenidae	-	0.2	0.1	0.2
Teraponidae	-	0.5		0.5
Tetraodontidae	-	0.1	<0.1	0.1
Trichiuridae	-	0.5	0.2	0.5

[a] Fish families documented in these two studies and unreported in the FAO landings were similar. Those reported in Silva (2006) made up approximately 80% of those documented by Jiddawi and Stanley (1999). We thus assumed that the remaining families observed should also make up 20% of the 'marine fishes nei' breakdown for mainland Tanzania and we rescaled the taxonomic breakdown to reflect this.
[b] Zanzibar breakdown was calculated based on the frequency of observation of fish families sampled by Jiddawi and Stanley (1999), but not included in the FAO landings.

six coastal sites on both the mainland and Zanzibar, asking them to rank the top five species in order of their importance in the catch. Table 1 summarizes the taxonomic breakdown derived from these two studies and applied to both the 'marine fishes nei' and 'percoid' pooled categories.

Lobster catches were also not reported in FAO landings until 2010 and were not considered to have previously been included in the 'marine fishes, nei' category. It is known that they have been fished in Zanzibar since at least 1958 (Mutagyera 1975), and thus we assumed that the lobster catch was zero prior to 1958. Catch and export statistics for crustaceans were available in Bwathondi and Mwaya (1984) for 1966, 1968–1972, 1974–75 and 1980. These data were used as anchor points and linear interpolations were used to reconstruct lobster catches for missing years.

Zanzibar

Landing data for Zanzibar have only been reported to FAO since 2000, but separately from mainland Tanzania. They were also considered to account for boat-based catches only. Landing data for Zanzibar for 1950–1999 were completely missing from the FAO database and were previously reconstructed by Jacquet and Zeller (2007). However, fisheries catches reconstructed prior to 1982 remained lower than annual catches from 1982–2010 and there was no explanation for the increase in catches from 1980 to 1982 (an increase of 64%). Furthermore, catch data from 1980 and 1981 were incomplete and did not include landings from Pemba Island (Jacquet and Zeller 2007). These had been previously adjusted by Jacquet and Zeller (2007), but, based on catches from 1982–1999, they still appeared underreported. The first year where accurate catch data were available for both of Zanzibar's islands was 1982, so we used this year as an anchor point to generate estimates for earlier years. Since population data for Zanzibar were sparse, we used the Tanzanian population growth as a proxy. This seemed reasonable, as census data for Zanzibar (www.nbs.go.tz) during the period of interest (1967, 1978, and 1988) showed that Zanzibar's population followed a trend similar to that of the rest of the country and has consistently accounted for 3% of the overall population. We divided the 1982 boat-based catch by Tanzania's population in 1982 to estimate the boat catch per person, and then multiplied this ratio by the Tanzanian population from 1950 to 1981.

To disaggregate Zanzibar's catch from 1950 to 1999, we used the taxonomic proportions reported in the 2000–2010 FAO data along with additional information from the literature. The FAO taxonomic composition reported from 2000–2010 consisted of 19 groups, all of which could be attributed to larger taxonomic groups (demersal species, small and large pelagics, sharks and rays, octopuses and squids, lobsters and other marine species; see Table 2) that were reported by Jiddawi and Shehe (1999) and Mhitu and Jiddawi (1999) for both the 1989–1995 and 1996–1999 periods. Reconstructed catches for these periods were allocated to these larger groups and then further disaggregated to taxa reported by FAO based on their average proportions from 2000–2010. Based on the landings reported by Jiddawi and Shehe (1999) and Mhitu and Jiddawi (1999), it seems likely that more specific taxonomic catch data do exist, but they were not available to us.

Table 2. Taxonomic breakdown (%) of reconstructed catch from 1989–1995 and 1996–1999, based on relative abundances of major taxonomic groups from Jiddawi and Shehe (1999), Mhitu and Jiddawi (1999) and 19 taxa reported in the FAO landings from 2000–2010

Major taxa	FAO Taxa in group	1989–1995 (%)	1996–1999 (%)
Demersals	Barracudas nei	4	5
	Carangids nei	4	5
	Emperors(=Scavengers) nei	8	11
	Goatfishes, red mullets nei	3	4
	Groupers, seabasses nei	2	2
	Mullets nei	1	1
	Parrotfishes nei	4	5
	Snappers, jobfishes nei	2	3
	Spinefeet(=Rabbitfishes) nei	4	5
Large pelagics	Marlins,sailfishes,etc. nei	6	5
	Seerfishes nei	5	4
	Tuna-like fishes nei	9	7
Lobsters	Tropical spiny lobsters nei	3	1
Octopus and squids	Marine molluscs nei	6	7
Sharks and rays	Sharks, rays, skates, etc. nei	7	5
Small pelagics	Anchovies	7	6
	Clupeoids	17	16
	Sardinellas	5	5
Others	Marine fishes nei	3	3

We found no catch composition data prior to 1989 and applied the 2000–2010 FAO taxonomic breakdown for 1950–1988, excluding taxa that were not targeted during this period (similarly to mainland; see above). As previously stated, the fishery for large pelagics (recorded as 'marlins', 'sailfishes' and 'tuna-like' in the FAO data) did not begin in the Western Indian Ocean until the late 1970s (Majkowski 2007), and the lobster fishery did not start until 1958 (Mutagyera 1975). From 1950 to these respective years, these two taxa were therefore not included in the improved taxonomic composition. The 'marine fishes nei' portion of Zanzibar catches was redistributed to the taxa present in Jiddawi and Stanley (1999), but missing from the FAO data (Table 1).

Overall, a few taxa were missing from Zanzibar's FAO data (marine shells, shrimps and holothurians), although they were known to be targeted in this area, mainly for export (Bwathondi and Mwaya 1984; Jiddawi and Muhando 1990; Newton *et al.* 1993; Marshall *et al.* 2001; Sabel 2005; Hampus Eriksson *et al.* 2010). Nevertheless, we did not add any 'shell' catches to the boat-based catch data, as it was unknown whether they were already included in the 'marine mollusks' FAO category. It was assumed that shrimp and holothurians catches were not included in the 'marine fishes nei' category and were thus unreported. Due to lack of any additional data, we also assumed a similar proportion of these taxa in the overall boat-based catches in Zanzibar as what was observed on the mainland, and estimated their catch using the annual percentages obtained from the reconstructed mainland catch.

Small-scale shore-based catches

Shore fishing activities are an important source of subsistence for coastal communities, and are most often performed by women and children (Jiddawi and Muhando 1990; Marshall *et al.* 2001; Guard and Mgaya 2002; Jiddawi and Öhman 2002; Silva 2006). As a result, they usually are not included in official catch statistics, and thus, not reported to the FAO. In this study, shore fishing activities refer to all fishing activities that do not use boats. These most commonly involve shore collection on foot, beach seines, fixed fences, cast nets, spears, reef gleaning, and diving. Catches from divers using boats were assumed to be included in the boat-based catches and were not part of the shore-based catch estimate. Shore-based fishers target a variety of taxa such as small pelagics, small and juvenile reef fish, shrimps, crabs, octopuses, rays, holothurians and shells (Table 3).

Table 3. Estimated percentages of shore fishing catch by different activities and taxonomic breakdown for Tanzania

Activity		Targeted taxa	Source	Catch (%)
Diving, shore collection (20.0%)		Holothuroidea[a]	improved FAO; Silva (2006)	0–83[b]
		Panuliridae	improved FAO; Bwathondi and Mwaya (1984); Silva (2006)	0–62[b]
		Shells	improved FAO; Silva (2006)	3–100[b]
Nets	Beach seines (22.2%)	'Marine fishes nei'	Assumed 5% of beach seines	5
		Acetes spp.	Jiddawi and Öhman (2002)	8
		Atherion africanum	Jiddawi and Öhman (2002)	23
		Carangidae	Hoekstra *et al.* (1990)	8
		Clupeidae	Hoekstra *et al.* (1990)	8
		Gerres oyena	Jiddawi and Öhman (2002)	23
		Plotosus lineatus	Jiddawi and Öhman (2002)	23
		Portunus pelagicus	Bwathondi and Mwaya (1984)	1
	Cast nets (7.8%)	'Marine fishes nei'	Assumed 5% of cast nets	5
		Acetes spp	Jiddawi and Öhman (2002)	19
		Anguilliformes	Jiddawi and Öhman (2002)	19
		Ariidae	Jiddawi and Öhman (2002), Silva (2006)	19
		Gerres spp	Jiddawi and Öhman (2002), Silva (2006)	19
		Mugilidae	Jiddawi and Öhman (2002), Silva (2006)	19
	Fixed fences (3.3%)	'Marine fishes nei'	Assumed 5% of fixed fences	5
		Labridae	Jiddawi (ND)	14
		Lethrinidae	Jiddawi (ND), Silva (2006)	14
		Mugilidae	Jiddawi (ND), Silva (2006)	14
		Penaeidae	Shunula (2000)	14
		Rastrelinger carnaguta	Shunula (2000), Silva (2006)	14
		Scylla serrata	Shunula (2000), Silva (2006)	14
		Siganidae	Jiddawi (ND), Silva (2006)	14
Spears (47.0%)		'Marine fishes nei'	Assumed 5% of spear fishing	5
		Diodon holocanthus	Jiddawi and Öhman (2002)	4
		Echidna nebulosa	Jiddawi and Öhman (2002)	4
		Lethrinus harak	Jiddawi and Öhman (2002)	4
		Myliobatiformes	Jiddawi and Stanley (1999), Jiddawi and Öhman (2002), Silva (2006)	15
		Octopus cyanea	Jiddawi and Stanley (1999), Jiddawi and Öhman (2002), Silva (2006)	60
		Sepia latimanus	Jiddawi and Öhman (2002)	4
		Teuthida	Jiddawi and Muhando (1990), Silva (2006)	4

[a] At least 20 species of holothurians are traded in Tanzania (Marshall *et al.* 2001; Jiddawi and Öhman 2002). High value species are *Holothuria scabra*, *H. nobilis*, *H. spinifera*, *H. lessoni*, and *Theleonota ananas*, but they also exhibit the most marked declines (Marshall *et al.* 2001; Hampus Eriksson *et al.* 2010).
[b] Collected taxa percentages varied significantly between years depending on FAO catches. Ranges are shown in the table and their average percentages are 62% (shells), 16% (Panuliridae) and 22% (Holothuroidea).

Estimates of shore-based catches for the mainland by Jacquet and Zeller (2007) were based on a census of shore fishers by the National Fisheries Division for 2001 and 2005, with 576 and 796 shore fishers, respectively. Given that the number of shore fishers in Zanzibar for the same period ranged from 4,724 to 5,338 (Jacquet and Zeller 2007), and that Silva (2006) found that 20% of households were involved in shore fishing activities, we believed that earlier estimates by Jacquet and Zeller (2007) underestimated the shore fishing catches in mainland Tanzania. Therefore, we re-estimated shore fishers' numbers and their catches from 1950 to 2010 based on the methods outlined below.

Silva (2006) reported that one out of five fishing households fished on foot in 2005. Therefore, we used this ratio to estimate the number of shore fishers based on the number of boat fishers in 2005. In Zanzibar, the number of shore fishers and boat fishers is known for 1980, 1985 and 1989 (Ngoile 1982; Carrara 1987; Mongi 1991). The ratios of shore fishers to boat fishers for these years were 0.35, 0.1 and 0.16, respectively, showing a potential decline in the number of shore fishers from 1980 to 1989. A linear regression fitted to these three points suggested that the ratio was 0.5 in 1970 in Zanzibar. We assumed a similar trend for the mainland, but adopted a slightly more conservative ratio of 0.4 for 1970. We then applied a linear interpolation between the 1970 and 2005 ratios to estimate the number of shore fishers.

Before 1970 and after 2005, boat fisher data were not readily available. Thus, for the 1950–1969 period, we used the ratio of reconstructed shore fisher catch to boat catch from 1970 (i.e., 0.07) to estimate shore fishing catch. The ratio of shore fishers to the mainland population in 2005 (0.15×10^{-3} shore fisher per inhabitant) was used to estimate the number of shore fishers from 2006 to 2010. From 1970 to 2010, the corresponding shore fishing catch was calculated by multiplying the number of shore fishers with a catch rate of 0.96 t·year^{-1} (Jacquet and Zeller 2007).[1]

Information on the catch rates and composition of shore fishing activities was limited. To estimate the taxonomic breakdown of shore-based catches, we first estimated the proportion of catch derived from three main fishing activities (see Table 3) using effort data documented in Silva (2006):

- The use of nets was estimated to account for 33% of shore-based catch. This catch was further subdivided into catch by beach seine, fixed fence and cast nets (66%, 10% and 24%, respectively), based on effort information from Mgawe (2005);
- Diving and shore collection were estimated to account for 20% of shore-based catch; and
- Spearfishing was estimated to account for 47% of shore–based catch.

We then estimated a catch composition for each of these activities based on taxa and proportions reported in the literature (Table 3).

Jiddawi and Öhman (2002) reported that *Plotonus lineatus* (striped eel catfish), *Atherion africanum* (pricklenose silverside) and *Gerres oyena* (common silver-biddy) accounted for approximately 70% of the catches from beach seine activity. Due to a lack of any other information, we divided this percentage equally among these three species (i.e., 23.3% each). Miscellaneous marine fishes (i.e., 'marine fishes nei') were assumed to make up 5% of the beach seine catch, and 1% was allocated to *Portunus pelagicus* (flower crab), which is occasionally caught (Bwathondi and Mwaya 1984). *Acetes* spp. (paste shrimp) were also reported to be spatially and temporally very common (Jiddawi and Öhman 2002), and Clupeidae (sardines) and Carangidae (jacks) were documented as target species in Hoekstra *et al.* (1990). Therefore, the remaining percentage was allocated to these three groups proportionately (i.e., 8% each).

Taxonomic breakdowns for fixed fences and cast nets were based on Jiddawi (ND), Shunula (2000), Jiddawi and Öhman (2002), and Silva (2006), who reported taxa commonly caught in these fisheries in both Zanzibar and Tanzania. Since there was no information regarding the proportion of these species in the catch, we divided the fixed fence and cast net catches equally among the taxa that were reportedly targeted by these gears (see Table 3). We attributed 5% of the catch to 'marine fishes nei', unaccounted for in the literature that was reviewed.

Taxa collected by diving and shore collection were primarily composed of marine shells, holothurians and lobsters (Mutagyera 1975; Jiddawi and Muhando 1990; Jiddawi and Öhman 2002; Silva 2006). These taxa were also caught by boat fishers to a lesser extent, and were included in the reconstructed boat catches for the mainland and Zanzibar. These fisheries are often highly variable due to changes in market demands and boom and bust characteristics (Anon. 1990; Anderson *et al.* 2011). Therefore, it was difficult to assume one breakdown to divide diving and shore collection catch among these taxa for the 1950–2010 period. As there was no information on the relative proportion of these taxa for any given year, we assumed that these taxa were being collected in the same proportions as those occurring by boat for mainland Tanzania.

Octopuses dominated spear fishing (Jiddawi and Stanley 1999), but other species are also targeted. For example, Jiddawi and Stanley (1999) reported large volumes of Myliobatidae (rays). Based on this information, we allocated 60% of the spear fishing catch to *Octopus cynaea* (octopuses; Guard and Mgaya 2002) and 15% to Myliobatidae. Miscellaneous marine fishes ('marine fishes nei') were assumed to make up 5% of the spearfishing catch and the remaining catch was equally divided among the other taxa reported in Jiddawi and Muhando (1990), Jiddawi and Öhman (2002) and Silva (2006; see Table 3).

Sectoral breakdown

Industrial shrimp trawlers accounted for approximately half of the total shrimp catch[2] and started in 1966 (Bwathondi and Mwaya 1984). Thus, we assumed 50% of shrimp caught by boats were industrial from 1966 onward. We estimated a *discard:shrimp* ratio of 2:1 in order to remain consistent with the values documented in Jacquet *et al.* (2010) for Mozambique (2.8:1; see also Doherty *et al.* this volume). This was likely conservative, given reported shrimp to bycatch ratios of 1:5 and 1:8 in Tanzania (Silas 2011). However, it is unknown how much of this bycatch may be landed. Bycatch species from shrimp trawling were documented in Silas (2011), but their relative proportions were not available. Thus, we allocated 10% of discards as 'marine fishes nei' and divided the remaining discards equally among the eight species listed (*Pellona ditchela*, *Pomadasys stridens*, *Pelates quadrilineatus*, *Leiognathus equulus*, *Equulites leuciscus*, *Aurigequula fasciatus*, *Secutor insidiator* and *Gazza minuta*).

Most of the boat-based catch came from the artisanal sector, except for a small portion, which was often retained for home consumption (i.e., subsistence) and reported to be less than 5% by Jiddawi and Stanley (1999). We assumed that the proportion of catch retained by boat fishers for subsistence purposes has likely been in this range since the early 1980s. Thus, we considered that 5% of boat catch was used for subsistence purposes from 1980–2010. However, Haji (1999) reported that, due to tourism development, the fishery sector in Zanzibar had been redirected from subsistence to commercial fishing, and it is likely that the proportion of catches used for subsistence was higher in earlier years for all Tanzania. As there was no additional information for the earlier period, we assumed that 15%

[1] This catch rate was based on an estimate of shore fisher catch by Jiddawi and Stanley (1999) of 4 kg·day^{-1}·person^{-1} and an assumed effort of 20 days per month (240 days per year).

[2] The five main components of artisanal shrimp fishery used to be *Penaeus indicus*, *P. semilsulcatus*, *P. latisulcatus*, *P. monodon* and *Metapenaeus monoceros* (Bwathondi and Mwaya 1984). In recent years, *P. indicus* made up the majority of the catch and *P. latisulcatus* was replaced by *Marsupenaeus japonicus* in the five most dominant species (Silas 2011).

of total boat-based catch was being taken home for subsistence in 1950. We used linear interpolations to estimate the proportion of take-home catch from 1950–1980. The annual subsistence catch was allocated proportionally to all taxa except for lobster, shrimp, holothurians, and large pelagics, which were considered to be exclusively artisanal (i.e., commercial).

All shore-fishing catches were assumed to be exclusively used for subsistence (except for lobsters, penaeid shrimps and holothurians).

Results

The reconstructed total catch for Tanzania during the 1950–2010 period reached over 4.2 million t, which is 77% higher than the landings of 2.4 million t reported to the FAO by Tanzania (Figure 2). Reconstructed catches for mainland and Zanzibar represented 3.1 and 1.2 million t, respectively, as opposed to 2.1 and 0.25 million t reported to FAO. Total catches gradually increased from 18,100 t·year^{-1} in 1950 to around 114,600 t·year^{-1} in 2010, but peaked at 115,000 t·year^{-1} in 2005. Tonnages were greater than 100,000 t·year^{-1} for the 2000–2010 period, averaging over 105,500 t·year^{-1}. There were noticeable declines in the catch in the early 1980s and mid-1990s (Figure 2). Overall, Tanzanian marine fisheries catches for the whole period were dominated by Clupeidae (14%), Lethrinidae (13%), Scombridae (9%) and Elasmobranchii (7%; Figure 3).

Small-scale boat- and shore-based catches accounted for 4.1 million t for the 1950–2010 period, 85% of which was artisanal and 15% of which was subsistence. Shore fishing activities were an important part of small-scale catches, accounting for 10% of total small-scale catch and 64% of the total subsistence catch. Artisanal catches ranged from over 13,000 t·year^{-1} in 1950 to over 95,000 t·year^{-1} in 2010, while subsistence catches ranged from nearly 5,000 t·year^{-1} in 1950 to almost 15,500 t·year^{-1} in 2010. Artisanal catches peaked at around 96,000 t·year^{-1} in 2005, while subsistence catches peaked at almost 15,500 t·year^{-1} in 2010 (Figure 4).

Industrial shrimp catches ranged from 360 t in 1966 to 1,300 t in 2010, peaking at nearly 2,300 t in 1998 (Figure 4). Total industrial shrimp catches and discards accounted for 2.4% and 4.8% of Tanzania's reconstructed catch at their peak in 1998 and overall accounted for 1% and 2%, respectively over the 1950–2010 period.

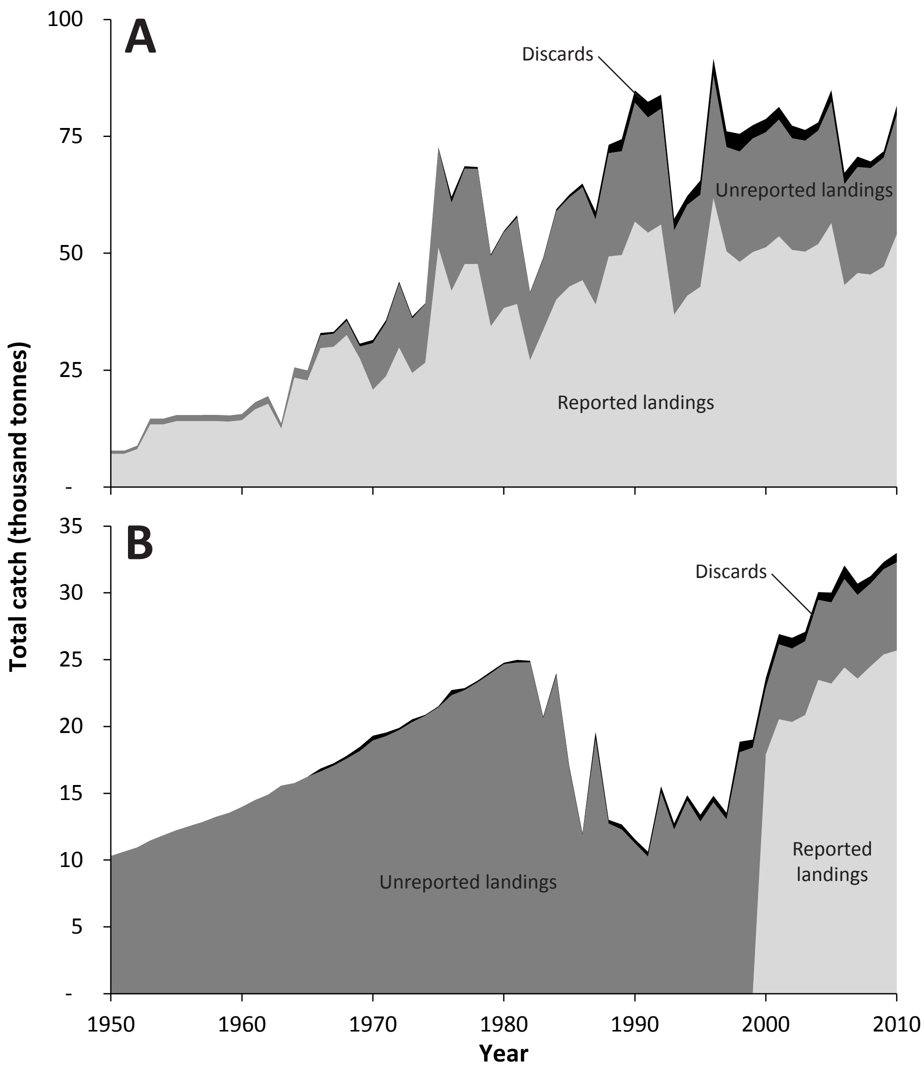

Figure 2. Total reconstructed catches by type ('reported landings' corresponds to the data published by FAO) for A) mainland Tanzania, and B) Zanzibar.

Discussion

The catch reconstruction completed for Tanzania (for both mainland and the Zanzibar islands) allowed for a more comprehensive baseline of the development of Tanzanian fisheries since 1950. The peak observed in the mid-1970s is synchronous with the increasing number of boat and shore fishers at that time (Jacquet and Zeller 2007). The declines observed in the 1980s and 1990s are interpreted as a sign of overexploitation by Jiddawi and Öhman (2002), but they reported that there were insufficient data for full resource assessments during these periods, and thus it is also possible that these declines were artifacts of poor catch accounting. The last ten years have produced the highest catches in Tanzania's history, a trend which was observed for both mainland and Zanzibar. It could be due to i) increased fishing effort due to larger coastal populations and improved technologies; ii) improved fisheries management; and/or iii) the fact that the reconstructed catches for the earlier period are still underestimated.

It is likely that the increase in coastal populations and fishers (Bagachwa *et al.* 1994), together with the use of motorized and commercial boats (Jiddawi and Öhman 2002; Muhando and Rumisha 2008), has led to higher catches. Indeed, with modernization of the fishing fleet, fishers could exploit fishing grounds further offshore and target new taxa, as was the case, e.g., in Mayotte and the Seychelles (see Doherty *et al.* this volume and Le Manach *et al.* this volume). This is the case for tunas and other large pelagics, which were absent from catch prior to 1970, but make up as much as 7% of the total catch in recent years, and may be a case of spatial expansion driving local fisheries (Swartz *et al.* 2010).

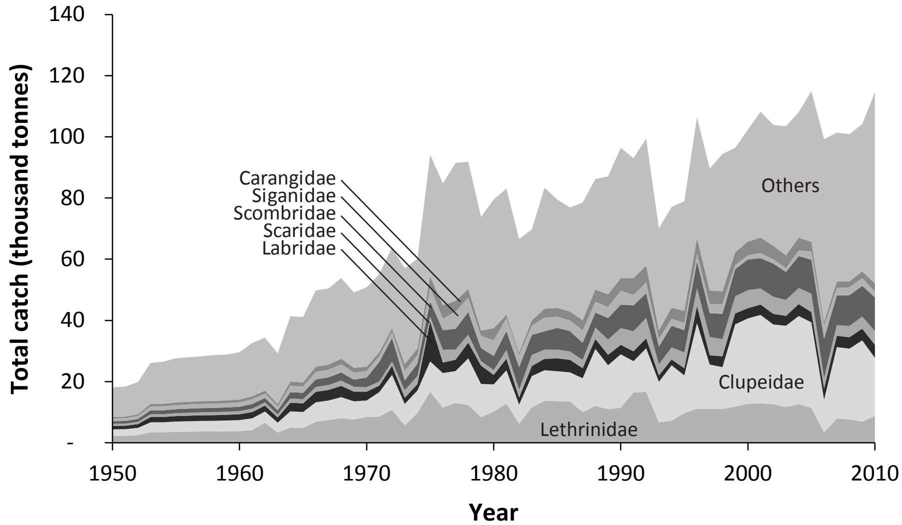

Figure 3. Breakdown of total marine fisheries catches for Tanzania (mainland and Zanzibar combined) by major taxa. 'Others' includes 85 additional taxa. Details are provided in Appendix Table A1.

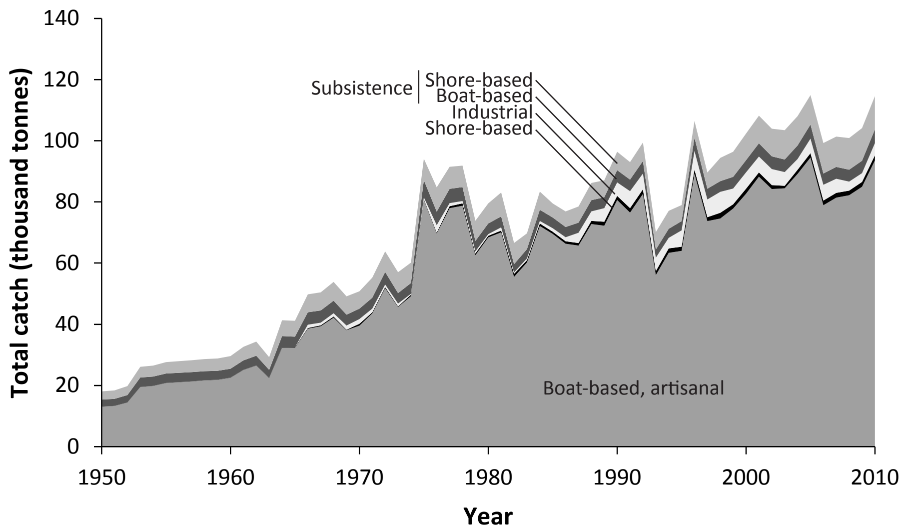

Figure 4. Breakdown of total marine fisheries catches for Tanzania (mainland and Zanzibar combined) by fishing sectors, which includes small-scale (artisanal and subsistence) and industrial fisheries. Details are provided in Appendix Table A2.

New legislation (e.g. enforcing bans on dynamite fishing in 1995 and beach seines in 1997) and participatory management plans (Verheij *et al.* 2004) may have also contributed to increased catches since 2000 (similarly to Kenya; see Le Manach *et al.* this volume). The establishment of marine parks and development of ecotourism in the 1990s (Riedmiller and Carter 2000; Mngulwi 2006) may have also played a role.

It is possible that some holothurians included in the boat catches may contain some shore-based catch, resulting in an overestimate. Indeed they are mainly collected while gleaning (Jiddawi and Öhman 2002; Hampus Eriksson *et al.* 2010), and since they are mostly exported they may have been included in the FAO database (which was assumed to contain only boat catches). However, catches of holothurians are also often underreported and/or illegally exported, as is the case in Mayotte or Madagascar (Pouget 2004; Le Manach *et al.* 2011, 2012, this volume; Doherty *et al.* this volume), in which case they would not appear in the FAO database. Thus, there is some uncertainty in our estimates of holothurians catches; however, it is apparent that they have been overfished in Tanzania, as catches have dramatically declined since the 1990s and there has been a severe decline in observed size and abundance (Marshall *et al.* 2001; Hampus Eriksson *et al.* 2010).

There is also inherent uncertainty associated with the assumed taxonomic breakdown for the shore-based catch, given that there was essentially no catch reporting for this sector. This study is a first attempt to estimate the contribution and species composition of shore-based catches to Tanzania's national fisheries and we hope our estimates may serve as a starting point, which may be improved through future efforts. Our results do demonstrate that shore-based catches are not negligible, accounting for 10% of Tanzania's total catch and the majority of subsistence catches. This is a sector that warrants further investigation and monitoring, particularly for species heavily exploited by shore fishing activities such as gastropods, lobsters, octopuses, holothurians and other reef fish species outlined in Table 3, which may not be typically targeted by boat-based fisheries.

It should be acknowledged that some improvements in the catch data reported to FAO have occurred. The taxonomic resolution of catch reported to FAO has improved since the previous work by Jacquet and Zeller (2007), as several new taxa were included between 2005 and 2010, and a lower proportion of catch was reported as 'marine fishes nei'. Also, perhaps as a result of the contribution by Jacquet and Zeller (2007), Zanzibar's catches are now included in the FAO data for the years 2000 to 2010 (but are still missing from 1950–1999). This latter improvement was documented in Jacquet *et al.* (2010), contrary to comments in Garibaldi (2012).

It is our hope that this study may be used to further improve the historic time-series of catch data that is reported to FAO, and serves as a useful tool for improved catch data monitoring and estimation for all areas and sectors in Tanzania's fisheries.

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References

Abdallah AM (2004) Management of the commercial prawn fishery in Tanzania. UNU-Fisheries Training Programme, The United Nations University (UNU). iv + 42 p.

Anderson SC, Flemming JM, Watson R and Lotze HK (2011) Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12(3): 317–339.

Anon. (1990) The trade in lobsters from Tanzania. *In* Proceedings of the Zanzibar Artisanal Fishery Sector Seminar, September 3, 1990, Zanzibar (Tanzania). 76 p.

Anon. (2013) Interview de José Graziano da Silva, directeur général de la FAO–"Produire plus avec moins". Sciences au Sud 69: 1–16.

Bagachwa MSD, Hodd MRV and Maliyamkono TL (1994) Fisheries and development in Tanzania. MacMillan, London (UK).

Bwathondi POJ and Mwaya G (1984) The fishery of crustacea and molluscs in Tanzania. *In* Iversen AS and Myklevoll S (eds.), The Proceedings of the Norad-Tanzania Seminar to Review the Marine Fish Stocks and Fisheries in Tanzania, 6–8 March, 1984, Mbegani (Tanzania). 19–28 p.

Carrara G (1987) Artisanal fishery catch assessment survey plan Zanzibar. FAO, Victoria (Seychelles). 8p + appendices.

Doherty B, Le Manach F, Herfaut J, Harper S and Zeller D (this volume) Reconstructing domestic marine fisheries in Mayotte from 1950–2010.

Garibaldi L (2012) The FAO global capture production database: a six-decade effort to catch the trend. Marine Policy 36(3): 760–768.

Guard M and Mgaya YD (2002) The artisanal fishery for *Octopus cyanea* Gray in Tanzania. Ambio 31: 528–536.

Haji MF (1999) The artisanal fishery sector in the Zanzibar economy. *In* Jiddawi NS and Stanley RD (eds.), Proceedings of the National Workshop on the Artisanal Fisheries Sector, September 22–24, 1997, Zanzibar (Tanzania). 20–25 p.

Hampus Eriksson B, de la Torre-Castro M, Eklöf J and Jiddawi NS (2010) Resource degradation of the sea cucumber fishery in Zanzibar, Tanzania: a need for management reform. Aquatic Living Resources 23(4): 387–398.

Hoekstra TM, Ngoile MAK, Jiddawi NS and Rotteglia C (1990) Census of the marine fishing units of Zanzibar in 1989. FAO, Victoria (Seychelles). 14 p.

Jacquet JL and Zeller D (2007) Putting the 'United' in the United Republic of Tanzania: reconstructing marine fisheries catches for Tanzania. Pp. 49–60 *In* Zeller D and Pauly D (eds.), Reconstruction of marine fisheries catches for key countries and regions (1950–2005). Fisheries Centre Research Reports 15 (2). University of British Columbia, Vancouver.

Jacquet JL, Fox H, Motta H, Ngusaru AS and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science 32(2): 197–206.

Jiddawi NS (ND) Mangrove and associated fishery resources from the fence trap (uzio) in Kisakasaka village, Zanzibar. Institute of Marine Sciences, Zanzibar (Tanzania). Available at: http://fishbase.us/Training/Abstracts/Kenya/Nariman%20Jiddawi.html [Accessed: July 18 2013].

Jiddawi NS and Muhando C (1990) Zanzibar environmental study. The Commission for Lands and Environment, Zanzibar. 15 p.

Jiddawi NS and Öhman (2002) Marine fisheries in Tanzania. Ambio 31(7–8): 518–527.

Jiddawi NS and Shehe MA (1999) The status of the shark fishery in Zanzibar, East Africa: A case study. *In* Jiddawi NS and Stanley RD (eds.), Proceedings of the National Workshop on the Artisanal Fisheries Sector, September 22–24, 1997, Zanzibar (Tanzania). 104–111 p.

Jiddawi NS and Stanley RD (1999) A study of the artisanal fishery in the villages of Matemwe and Mkokotoni, Zanzibar, Tanzania. Pp. 48–72 *In* Jiddawi NS and Stanley RD (eds.), Fisheries stock assessment in the traditional fishery sector: The information needs. Proceedings of the National Workshop on the Artisanal Fisheries Sector, September 22–24, 1997. Canadian International Development Agency, Zanzibar (Tanzania).

Kimaro PN (1995) A Review of the Tuna Fishery in Tanzania (Mainland) from 1989 to 1993. IOTC-1995-EC601–14, Indian Ocean Tuna Comission (IOTC), Victoria (Seychelles).

Le Manach F, Abunge CA, McClanahan TR and Pauly D (this volume) Tentative reconstruction of Kenya's marine fisheries catch, 1950–2010.

Le Manach F, Bach P, Boistol L, Robinson J and Pauly D (this volume) Artisanal fisheries in the world's second largest tuna fishing ground — Reconstruction of the Seychelles' marine fisheries catch, 1950–2010

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36: 218–225.

Le Manach F, Gough C, Humber F, Harper S and Zeller D (2011) Reconstruction of total marine fisheries catches for Madagascar (1950–2008). pp. 21–37 *In* Harper S and Zeller D (eds.), Fisheries catch reconstructions: islands, part II. Fisheries Centre Research Reports 19 (4). University of British Columbia, Vancouver (Canada).

Majkowski J, ed. (2007) Global fishery resources of tuna and tuna-like species. FAO Fisheries Technical Paper No. 483. Food and Agriculture Organization of the United Nations (FAO), Rome. 54 p.

Marshall N, Milledge SAH and Afonso PS, editors (2001) Stormy seas for marine invertebrates: trade in sea cucumbers, sea shells and lobsters in Kenya, Tanzania and Mozambique. TRAFFIC East/Southern Africa, Kenya. 70 p.

Mhitu H and Jiddawi NS (1999) The octopus fishery in Matemwe and Mkoktoni, Zanzibar. Pp. 88–95 *In* Jiddawi NS and Stanley RD (eds.), Fisheries stock assessment in the traditional fishery sector: The information needs. Proceedings of the National Workshop on the Artisanal Fisheries Sector, September 22–24, 1997. Canadian International Development Agency, Zanzibar (Tanzania).

Mngulwi B (2006) Country review: United Republic of Tanzania. Pp. 447–458 *In* De Young C (ed.), Review of the state of the world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper No. 488, Rome (Italy).

Mongi H (1991) Review of the marine fisheries sub-sector for Tanzania mainland. *In* Ardill JD and Sanders MJ (eds.), Proceedings of the seminar to identify priorities for fishereries management and development in the southwest Indian Ocean, Albion, Maritius, 3–5 September, 1991, Rome (Italy). 153–171 p.

Muhando CA and Rumisha CK (2008) Distribution and status of coastal habitats and resources in Tanzania–Draft Report. WWF, Dar Es Salaam (Tanzania). 112 p.

Mutagyera WB (1975) A preliminary report on the spiny lobster fishery of Zanzibar. The African Journal of tropical hydrobiology and fisheries 4: 51–59.

Newton LC, Parkes EVH and Thompson RC (1993) The effects of shell collecting on the abundance of gastropods on Tanzanian shores. Biological Conservation 63: 241–245.

Ngoile M (1982) A survey of fishing units in Zanzibar and Pemba. Tanzania Notes and Records 88/89: 89–95.

Pouget A (2004) Sea cucumber fisheries in the Mayotte reef system, Indian Ocean. SPC Beche-de-mer Information Bulletin 19: 35–38.

Riedmiller S and Carter E (2000) Ecotourism in a private Marine Protected Area: Chumbe Island, Tanzania. *In* Wittmer H and Hassan Z (eds.), INCO-DEV International Workshop on Policy Options for the Sustainable Use of Coral Reefs and Associated Ecosystems, 19–22 June, Mombasa (Kenya). 140–152 p.

Sabel E (2005) A temporal study on the ornamental shell trade in Dar Es Salaam & Tanga, Tanzania. SIT Tanzania, Dar Es Salaam.

Shao FM, Mlay EE and Mushi VE (2003) Understanding fisheries associated livelihoods and the constraints to their development in Kenya and Tanzania. Food, Agriculture, and Natural Resources Management Research Consultants. 78 p.

Shunula JP (2000) Towards sustainable utilization of mangrove resources in Zanzibar: A brief review. *In* Wittmer H and Hassan Z (eds.), Proceedings of the INCO-DEV International Workshop on Policy Options for the Sustainable Use of Coral Reefs and Associated Ecosystems, 19–22 June 2000, Mombasa (Kenya). 136–139 p.

Silas MO (2011) Review of the Tanzanian prawn fishery. Master of Science in Fisheries Biology and Management thesis, University of Bergen, Department of Biology, Norway. 59 p. Available at: https://bora.uib.no/bitstream/handle/1956/5584/84856931.pdf?sequence=1 [Accessed: November 6 2013].

Silva P (2006) Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania. World Bank Policy Research Working Paper 3831. 43 p.

Swartz W, Sala E, Tracey S, Watson R and Pauly D (2010) The spatial expansion and ecological footprint of fisheries (1950 to present). PLoS ONE 5(12): 6.

The World Bank (2012) The hidden harvests, the global contribution of capture fisheries. Economic and sector work. 69 p.

Verheij E, Makoloweka S and Kalombo H (2004) Collaborative coastal management improves coral reefs and fisheries in Tanga, Tanzania. Ocean & Coastal Management 47: 309–320.

Appendix Table A1. Total reconstructed catch by major taxa ('Others' includes 85 additional taxa).

Year	Lethrinidae	*Sardinella* spp.	Elasmobranchii	Carangidae	Siganidae	Scombridae	*Rastrelliger kanagurta*	Scaridae	Labridae	Clupeidae	Others
1950	2,243	988	1,156	1,111	681	633	219	893	489	1,345	8,310
1951	2,269	1,000	1,170	1,124	694	643	220	906	493	1,383	8,481
1952	2,485	1,093	1,277	1,233	739	691	249	982	549	1,421	9,076
1953	3,436	1,502	1,743	1,721	905	885	388	1,300	811	1,460	11,950
1954	3,443	1,506	1,748	1,724	915	892	386	1,307	810	1,498	12,263
1955	3,564	1,558	1,809	1,785	944	921	401	1,351	840	1,536	12,922
1956	3,616	1,581	1,836	1,810	964	938	405	1,373	850	1,583	12,990
1957	3,667	1,604	1,863	1,835	983	954	408	1,396	859	1,630	13,054
1958	3,687	1,613	1,874	1,845	993	962	409	1,405	862	1,659	13,322
1959	3,737	1,635	1,900	1,869	1,012	979	413	1,427	872	1,705	13,275
1960	3,807	1,666	1,936	1,904	1,035	999	419	1,455	886	1,751	13,742
1961	4,108	1,796	2,085	2,058	1,097	1,066	461	1,560	966	1,803	15,629
1962	6,594	1,678	1,953	1,919	1,067	1,018	418	1,475	886	1,857	15,478
1963	3,328	1,496	1,747	1,694	1,007	942	346	1,341	759	1,913	14,664
1964	4,978	2,451	2,835	2,831	1,385	1,390	672	2,082	1,372	1,971	19,357
1965	4,818	2,430	2,812	2,803	1,390	1,389	659	2,072	1,351	2,031	19,388
1966	6,867	2,947	3,402	3,419	1,603	1,636	833	2,476	1,681	2,093	22,834
1967	7,411	2,967	3,427	3,440	1,625	1,653	835	2,498	1,687	2,157	22,741
1968	8,059	3,177	3,667	3,687	1,720	1,759	901	2,666	1,816	2,223	24,174
1969	7,602	2,751	3,184	3,174	1,573	1,571	747	2,344	1,531	2,292	22,371
1970	8,402	2,504	2,904	2,881	1,498	2,461	658	2,161	1,366	2,365	23,578
1971	8,546	2,164	5,858	2,111	1,370	3,984	2,369	1,948	1,237	2,167	23,490
1972	10,755	4,212	7,235	2,945	1,395	3,721	3,991	1,972	1,245	2,238	24,117
1973	5,674	1,670	5,334	2,021	2,455	2,735	481	3,065	2,270	2,311	29,003
1974	9,746	2,458	4,877	2,095	2,655	3,263	807	2,744	2,187	2,387	26,938
1975	16,680	3,977	5,935	13,059	1,574	3,552	1,398	4,764	3,422	2,465	37,326
1976	11,510	5,484	5,790	3,424	4,151	4,598	1,834	3,735	4,401	2,544	37,305
1977	13,017	5,562	4,852	3,698	3,358	5,554	1,183	5,660	3,492	2,625	42,483
1978	12,355	8,006	7,248	5,121	2,616	4,492	2,905	4,670	2,859	2,708	38,885
1979	8,360	3,830	7,041	5,988	1,461	3,564	712	3,991	1,715	2,794	34,399
1980	10,149	3,990	4,942	3,087	1,598	3,513	1,068	5,129	3,969	2,883	39,197
1981	12,853	4,549	6,284	3,775	2,826	4,090	2,121	4,257	1,055	2,975	38,302
1982	6,267	2,477	3,724	2,349	2,515	5,139	2,247	3,983	802	3,070	34,009
1983	11,598	4,437	5,756	3,280	3,638	4,403	2,140	3,066	1,676	2,560	27,165
1984	13,701	4,571	5,430	3,724	3,037	3,578	2,383	4,505	2,876	3,094	36,478
1985	13,607	4,165	5,611	4,192	2,907	3,745	3,305	3,668	2,874	2,174	33,255
1986	13,491	4,044	5,476	4,093	2,738	3,245	3,411	3,506	2,910	1,444	32,535
1987	10,010	7,268	3,805	3,267	2,727	3,292	2,307	4,083	3,255	2,381	36,112
1988	12,003	14,201	4,491	3,231	3,721	3,231	1,679	3,553	3,962	1,488	34,639
1989	10,993	9,200	5,153	3,411	4,965	3,436	3,590	3,607	4,157	1,626	36,933
1990	11,479	11,584	5,840	3,090	5,478	4,441	3,229	4,557	4,100	1,501	41,096
1991	16,426	3,778	6,474	3,209	6,566	3,225	5,237	3,384	5,519	1,351	37,847
1992	16,599	7,374	6,900	3,270	6,643	3,929	4,131	3,562	5,505	1,990	39,516
1993	6,684	7,886	5,347	2,113	3,595	2,298	3,507	2,524	2,848	1,589	31,731
1994	7,178	12,148	5,992	1,912	3,949	2,586	4,464	2,297	3,589	1,875	31,104
1995	9,657	5,581	6,774	2,342	5,160	2,501	4,783	2,436	3,885	1,653	34,198
1996	11,125	19,880	8,112	5,598	5,809	2,438	6,308	2,509	5,130	1,735	37,802
1997	11,069	7,241	7,248	3,019	5,998	2,320	5,471	3,018	4,415	1,567	38,253
1998	11,058	6,680	6,993	3,515	5,616	2,679	5,569	3,203	4,185	2,145	42,749
1999	11,787	19,612	7,303	3,555	5,593	2,683	6,178	1,329	4,189	2,271	31,902
2000	12,726	20,547	7,371	3,349	5,917	3,814	6,186	1,384	4,450	1,424	35,181
2001	12,888	21,497	7,391	3,393	5,271	3,030	6,862	1,694	5,050	3,202	37,921
2002	12,599	19,799	6,270	3,460	5,617	3,616	7,199	1,427	4,365	3,772	35,808
2003	11,648	19,881	6,713	3,218	5,209	2,297	6,862	1,285	4,119	4,882	37,334
2004	12,616	21,383	7,431	3,877	5,269	3,576	6,868	1,816	4,188	4,055	36,974
2005	11,383	21,881	6,092	3,343	6,039	3,564	7,544	2,692	3,161	5,267	43,950
2006	3,385	5,689	4,979	3,663	3,389	5,182	7,684	4,363	1,256	3,110	56,551
2007	7,928	17,471	5,874	3,695	3,475	4,338	5,382	2,432	2,079	2,374	46,310
2008	7,639	17,139	5,990	3,718	3,698	4,890	5,170	2,582	1,950	2,405	45,700
2009	6,930	20,477	6,064	3,803	3,979	4,668	5,329	2,569	2,166	2,446	45,700
2010	8,703	12,019	7,021	4,248	4,524	5,024	5,987	1,950	2,598	2,473	60,039

Appendix Table A2. Total reconstructed catch by sector compared to the total catch reported to FAO.

Year	Artisanal	Industrial	Subsistence	Total reconstructed	Reported to FAO
1950	13,079	-	4,988	18,067	7,100
1951	13,332	-	5,053	18,385	7,100
1952	14,444	-	5,351	19,795	8,100
1953	19,509	-	6,590	26,099	13,400
1954	19,874	-	6,617	26,492	13,400
1955	20,834	-	6,799	27,633	14,100
1956	21,090	-	6,855	27,945	14,100
1957	21,345	-	6,907	28,252	14,100
1958	21,703	-	6,927	28,630	14,100
1959	21,880	-	6,945	28,825	14,000
1960	22,579	-	7,022	29,602	14,300
1961	25,110	-	7,518	32,628	16,600
1962	26,558	-	7,786	34,344	17,800
1963	22,573	-	6,665	29,238	12,500
1964	32,541	-	8,783	41,324	23,400
1965	32,474	-	8,668	41,142	22,800
1966	38,788	1,079	9,926	49,793	29,700
1967	39,662	868	9,910	50,440	30,000
1968	42,537	1,069	10,246	53,851	32,500
1969	38,230	1,365	9,545	49,140	27,500
1970	40,159	1,547	9,071	50,777	20,820
1971	43,907	1,210	10,127	55,244	23,701
1972	52,160	844	10,821	63,826	29,826
1973	45,860	918	10,240	57,019	24,392
1974	49,661	296	10,200	60,158	26,616
1975	80,959	549	12,645	94,153	51,210
1976	69,974	2,426	12,377	84,776	41,960
1977	78,601	1,007	11,876	91,484	47,669
1978	79,528	768	11,569	91,865	47,709
1979	63,167	685	10,003	73,855	34,389
1980	68,929	543	10,053	79,526	38,292
1981	70,641	1,047	11,399	83,087	39,137
1982	56,484	466	9,632	66,582	27,132
1983	60,937	576	8,206	69,720	33,559
1984	72,944	833	9,599	83,376	40,091
1985	70,267	1,140	8,096	79,503	42,883
1986	67,141	1,314	8,438	76,893	44,230
1987	66,555	3,362	8,591	78,508	39,065
1988	73,795	3,109	9,296	86,201	49,306
1989	73,523	4,440	9,108	87,072	49,626
1990	81,971	4,413	10,012	96,395	56,762
1991	77,967	5,551	9,500	93,018	54,410
1992	84,128	5,147	10,144	99,420	56,133
1993	57,357	4,403	8,360	70,120	36,868
1994	64,811	3,445	8,837	77,093	40,907
1995	65,356	5,347	8,267	78,970	42,826
1996	90,553	6,106	9,789	106,447	61,740
1997	75,005	5,800	8,815	89,619	50,393
1998	76,443	6,852	11,098	94,392	48,155
1999	79,223	5,152	12,028	96,403	50,250
2000	84,316	5,347	12,686	102,349	69,186
2001	89,646	5,191	13,361	108,198	74,175
2002	85,497	5,245	13,188	103,930	71,042
2003	85,267	4,491	13,688	103,447	71,194
2004	90,520	3,507	14,025	108,052	75,453
2005	95,934	4,747	14,233	114,914	79,645
2006	80,442	5,156	13,653	99,252	67,613
2007	82,959	4,621	13,777	101,356	69,340
2008	83,697	2,942	14,244	100,883	69,966
2009	86,532	2,870	14,728	104,130	72,526
2010	95,225	4,006	15,355	114,586	79,770