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Fisheries catch reconstructions: Islands, Part IV

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Fisheries Centre, University of British Columbia, Canada

Edited by

Kyrstn Zylich, Dirk Zeller, Melanie Ang and Daniel Pauly

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Content

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Preface

This is the fourth of our Fisheries Centre Research Reports featuring catch reconstructions for islands. Like its predecessors, a wide variety of islands is covered; some are countries in their own right, e.g., Iceland, while others are overseas territories of other countries, e.g., the British Virgin Islands.

This set of reconstructions is particular, however, in that it includes the largest island in the world, Greenland, where all living resources, including seabirds and marine mammals are exploited, as well as the Chagos Archipelagos in the Indian Ocean, where all legal exploitation ceased when its Exclusive Economic Zone was declared a marine reserve in 2010, at the very end of the period covered here.

There are six reconstructions from the Caribbean Islands, ranging in size from Cuba to tiny Anguilla, and five from the Pacific, ranging from wealthy Singapore, with a minuscule EEZ to impoverished and tiny Kiribati, with an immense EEZ.

As well, we present here, as an appendix, a reprinted version of 'Notes on the Completion of FAO Form Fishstat NS1 (National Summary)' by S.P Marriott, a now deceased author then based in Kiribati. His contribution, originally published in 1984, and meant to be humorous, contained more than a grain of truth and it seems appropriate to reprint it here as the catch reconstructions presented herein are meant to correct for the deficient process to assemble catch statistics that he took issue with.

We hope that these 15 contributions, which were assembled as part of our attempt to re-estimate the history of global fisheries, will be found to be useful on their own as well.

We thank The Pew Charitable Trusts for funding the *Sea Around Us*, and the Paul G. Allen Family Foundation for supporting the publication of this work, and the subsequent release of data. We take this opportunity, finally, to thank the several external colleagues and the *Sea Around Us* team members who contributed to the reconstructions documented herein.

The Editors
July 2014

Reconstruction of total marine fisheries catches for Anguilla (1950-2010)[1]

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Abstract

Accurately recording marine fisheries catches is difficult in both space and time and thus under-reporting of fisheries catches occurs worldwide. Inconsistencies in fisheries data collection in Anguilla mean that fisheries statistics are deficient for this British overseas territory in the Caribbean. Reconstructed total catches were estimated at approximately 49,000 t for the period 1950-2010, which is 2.75 times the official landings of 17,854 t reported by the FAO on behalf of Anguilla. The difference can be attributed to under-reporting from artisanal, subsistence and recreational sectors. Under-reported fisheries catches can lead to over estimations of available marine resources.

Introduction

Anguilla is the most northerly of the Leeward Islands in the Eastern Caribbean, located between 18° N and 63° W. It is an arid, low lying coralline island, with a land area of 91 km², which borders the Atlantic Ocean in the North and the Caribbean Sea in the South (Figure 1). Anguilla's submarine platform is shared with Saint Martin, Sint Maarten and Saint Barths. The island has a declared Exclusive Economic Zone of slightly over 92,000 km² (www.seaaroundus.org).

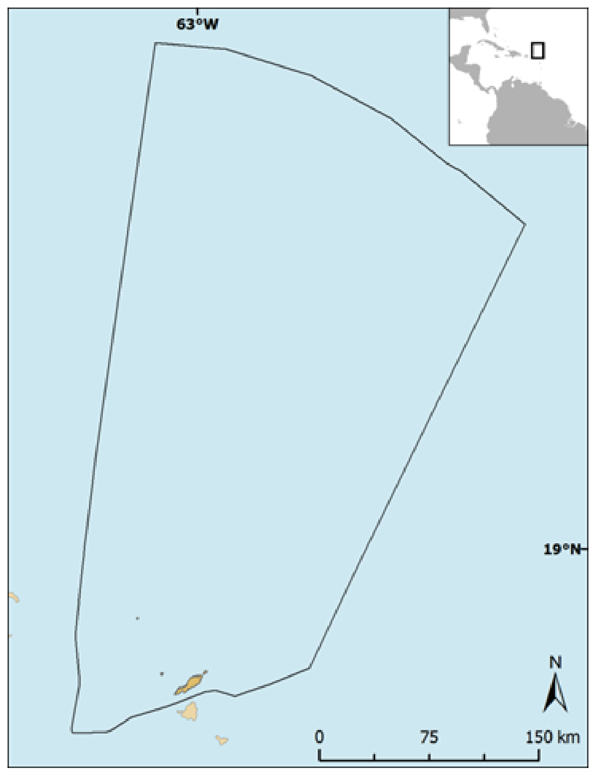

Figure 1. Map showing position of Anguilla with line demarcating EEZ.

The first known residents of Anguilla were the Arawak Indians, originating from South America. Rene Laudonniere, the French explorer, was probably the first European to formally recognise the island, calling it Anguille (French for 'eel') because of its elongated shape (Kozleski 2004). The British Government created a federation between Anguilla and St. Kitts in 1871, with Nevis joining soon after (Kozleski 2004). However, soon after the federation was formed, Anguillans became resentful about the way St. Kitts dominated the tri-island grouping. In 1967, Anguilla rebelled and police from St. Kitts were employed to defend the federation. Another rebellion ensued in 1969 (Ferguson 1997) and Britain had to intervene. In 1980, with support from Britain, Anguilla succeeded in separating from St. Kitts and Nevis. Today, Anguilla remains a British overseas territory in the Caribbean (Ferguson 1997).

Historically, salt production, lobster fishing and overseas employment were the main sources of income in Anguilla. In the early 1980s, the government began an aggressive marketing campaign to position Anguilla as a luxury tourist destination. With its white sand beaches and turquoise seas, Anguilla has a tourism industry that today contributes around 50% to national GDP, whilst fishing accounts for approximately 2% (Lum Kong 2007). The fisheries of Anguilla are multi-gear and multi-species. The majority of fishing in Anguilla is done with traditional Antillean arrowhead traps (Richardson 1984) which are used to target lobsters and finfish, such as parrotfish (Scaridae), goatfish (Mullidae) and squirrelfishes (Holocentridae). There is also a small fishery for queen conch, with most conch fishers using SCUBA gear (Wynne 2010) on trips organised to fill specific orders (Lum Kong 2007).

The lobster fishery is the most prosperous fishery in Anguilla (Olsen and Ogden 1981; Lum Kong 2007). Spiny lobsters, *Panulirus argus* and *P. guttatus*, known locally as 'crayfish', are caught using traps baited with cow hide. A small but growing hand-capture fishery also exists, where fishers snorkel at night to capture foraging individuals (Wynne 2010). Hook and line techniques are commonly used by fishers targeting deep slope species such as groupers and hinds (Serranidae), as well as snappers (Lutjanidae), while seine nets are used on occasion to land small schooling pelagics, such as jacks (Carangidae) and herrings (Clupeidae). There is an emerging offshore FAD (fish aggregating

[1] Cite as: Ramdeen, R., Zylich, K. and Zeller, D. (2014) Reconstruction of total marine fisheries catches for Anguilla (1950-2010). pp. 1-8. *In:* Zylich, K., Zeller, D., Ang, M. and Pauly, D. (eds.) Fisheries catch reconstructions: Islands, Part IV. Fisheries Centre Research Reports 22(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

device) fishery targeting dolphin fish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), tuna, marlin and swordfish on a request basis. These large pelagics are also targeted by a small recreational sector made up of locals and hotel operated vessels, as well as foreign vessels from St. Martin (Lum Kong 2007). Spearfishing for subsistence purposes is done on occasion by locals (Murray *et al.* 1999), whereas this activity is strictly prohibited for tourists visiting the island.

The population of fishers operating in Anguilla has increased substantially since 1975. Olsen and Ogden (1981) noted that there were 89 active fishers in 1974 (Table 1). This number has increased over the years, with the most recent estimate being 500 active fishers in 2007 (Gumbs and Rawlins 2007). The open access nature of the fishing industry has contributed to over-fished inshore resources (Gumbs 2003). Fishing is usually done twice weekly and catches are landed at several sites, including Island Harbour, Cove Bay, Sandy Ground, Sandy Hill Bay, Forest Bay, Little Harbour, Blowing Point and Crocus Bay (Lum Kong 2007). Additionally, fishers on the west will land catches on neighbouring St. Martin biweekly. Fish is mainly marketed unprocessed to hotels, restaurants and central markets, with lobsters mainly sold to hotels and restaurants.

Table 1. Data sources on number of fishers in Anguilla.

Year	No. active fishers	Source
1974	89	Olsen & Ogden (1981)
1978	320	Olsen & Ogden (1981)
1984	332	Jones (1985)
2007	500	Gumbs (2007)

There are no trade data in the FAO database for Anguilla. However, colonial records for the islands of St. Kitts, Nevis and Anguilla show seafood imports of, on average, 450 t·year^{-1} from 1955-1962 for the tri-island federation. Thus, it can be assumed that some portion of this seafood was supplied to Anguilla. Since the early 1960s, Anguilla's lobster trap fishery has supported a lucrative lobster trade of around 2.5 t·month^{-1} (FAO 1969) to neighbouring islands such as St. Martin, which is the largest export market for Anguillan seafood products (Jones 1985). Before the 1990s, it was estimated that about 40% of all finfish and 75% of all lobster caught in Anguilla were exported to St. Martin, St. Thomas and Puerto Rico. However, since the growth of the tourist industry on Anguilla, it is now estimated that export figures are below 10% (Gumbs 2003).

Sampling for catch and effort data was initiated in 1986, however data collection was carried out opportunistically depending on the availability of a vehicle for transport (Gumbs 2003). In 1991, the Department of Fisheries and Marine Resources was established, although regular fisheries data collection began only in 2008 (J. Gumbs, pers. comm., Fisheries Department). Presently, data on fisheries landings are collected in three categories: finfish, lobster and conch. Data collection takes place during weekdays at 5 sites: Island Harbour, Crocus Bay, Road Bay, Cove Bay and Blowing Point. Meanwhile, boats also land catches at three other well known sites: Forest Bay, Little Harbour and Meads Bay (Ken Rawlins, pers. comm., Department of Fisheries and Marine Resources) as well as Sandy Hill Bay. Although it is known that fish are landed at these other sites, only recorded landings are included in the statistics and no estimates are made to account for landings made at unmonitored sites. Further, due to the direct exporting of fish to St. Martin, analysis of landings by local fishers becomes difficult, as no customs records are available for these exports (Jones 1985).

Without reliable island-wide catch data as well as trade data, it is difficult to make informed fisheries management decisions. A complete review of all available fisheries reports was undertaken to reconstruct Anguilla's total fisheries catches for the period 1950-2010.

Methods

Studies on fisheries catches in Anguilla have been presented by FAO (1969), Olsen and Ogden (1981), Richardson (1984), Jones (1985), Gumbs (2003), Lum Kong (2007), and Gumbs and Rawlins (2007). The most comprehensive description of Anguilla's fishing industry is that of Jones (1985). Using information on household and non-household seafood consumption from Jones (1985), together with local and tourist population data for Anguilla, we reconstructed the seafood demand in Anguilla from 1950-2010. To estimate seafood exports from Anguilla, we utilised trade proportions presented by Gumbs (2003) along with reconstructed domestically-consumed catches to deduce catches being exported from the island. Finally, we apply a minimal recreational catch per tourist to estimate catches made by the recreational sector.

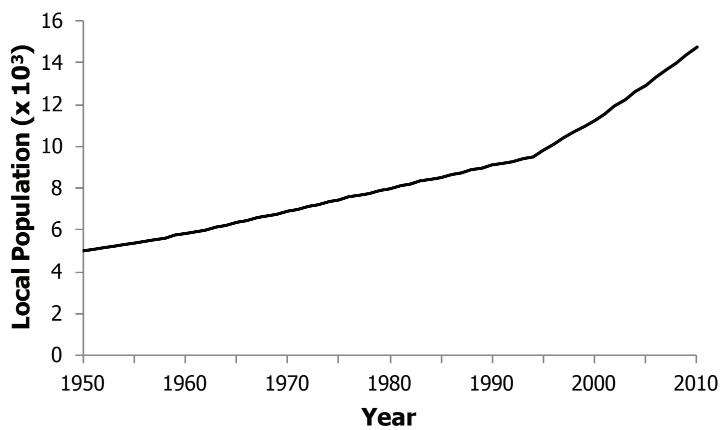

Figure 2. Total local population data for Anguilla during the period 1950-2010.

Domestic and tourist population

Data on Anguilla's local population were available for 1960, 1994 and 2001 from the national statistics website (gov.ai/statistics/statistics.htm). Using linear interpolation between anchor points, and carrying this trend backward to 1950 and forward to 2010 we reconstructed the human population of Anguilla 1950-2010. Over a 40 year period, Anguilla's population has doubled from 5,810 in 1960 to over 11,550 in 2001 (Figure 2).

Data on the number of stop-over tourists (travelers who stay on the island for more than one day) were available from the Statistics Department of Anguilla[2] for 1981-1998 and from the Caribbean Tourism Organisation[3] for 2000-2010. We assumed tourism started in 1950, so a direct linear interpolation was done to estimate the tourist population in years with missing data. The population of stop-over tourists has increased by an order of magnitude from around 6,500 in 1980 to over 60,000 in 2010 (Figure 3).

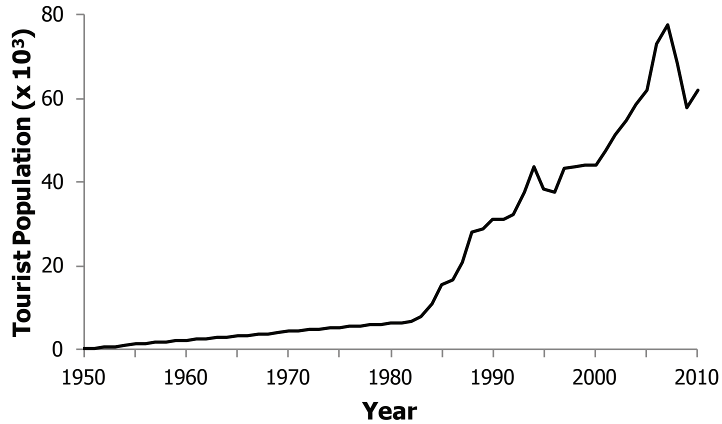

Figure 3. Stop-over tourists population for Anguilla during the period 1950-2010.

Small-scale catches

Domestically-consumed catches

Seafood consumption by locals and tourists in Anguilla in 1984 was assessed by Jones (1985). Per capita consumption of fresh finfish, lobster and conch were surveyed in households as well as hotels, restaurants and guesthouses (Table 2).

Table 2. Fresh seafood consumption rates in Anguilla (Jones 1985).

	Consumption (kg/person/year)		
	Fish	Lobster	Conch
Households	23.6	0.8	1.8
Hotels & restaurants	7.7	5.3	2.5

Using seafood consumption rates for households and non-households, together with population data for local Anguillans and stop-over tourists on the island, we reconstructed the domestically-consumed seafood demand. In order to avoid over-estimation, we assumed the seafood consumption rates presented by Jones (1985) are in whole (wet) weights, although they likely represent product weights. FAO applies conversion rates from product to wet weight for conch and lobster. Thus, in certain instances FAO values were slightly higher than our reconstructed catches. Thus, we accepted FAO values for queen conch from 1974-1989, 1992 and 2009-2010 and for lobster from 1977-1983.

Exported catches

Based on Gumbs (2003), we attributed 40% of finfish and 75% of lobster catches in 1950 to exports. Thus, reconstructed domestically-consumed catches of finfish and lobster which were not exported accounted for 60% and 25% of total finfish and lobster catches in 1950, respectively. The rapid rise in tourism created increased demand for seafood on the island, and thus less that 10% of finfish and lobster was exported from Anguilla from 2000 onwards (Gumbs 2003). Thus, reconstructed domestically-consumed catches of finfish and lobster, only accounted for 90% of total catches by the 2010. Using direct linear interpolation, we scaled the export proportions from 40% finfish and 75% lobster exports in 1981 to 10% each in 2010. In this way, we were able to reconstruct the catches exported from Anguilla for the period 1950-2010.

Since it is known that fishers engage in subsistence fishing (Mukhida and Gumbs 2007), we assumed some proportion of our domestically-consumed catches to comprise not only artisanal catches but subsistence catches as well (Lum Kong 2007). To assign small-scale catches to artisanal and subsistence sectors, it was assumed that in 1950, 80% of near-shore catches were for subsistence purposes and 20% were for sale (artisanal). In 2010, 60% of near-shore catches were attributed to the subsistence sector and 40% to the artisanal sector. A linear interpolation was done between these two years to derive an assumed assignment by sector for the entire 1950-2010 time-period.

Table 3. Taxonomic breakdown applied to reconstructed catches from Anguilla, based on FAO data for St. Kitts and Nevis as well as Lum Kong (2007).

	Proportion	
Taxon	**1950**	**2010**
Acanthocybium solandri	0.005	0.003
Acanthuridae	0.050	0.010
Atherinidae	0.000	0.010
Balistidae	0.000	0.005
Belonidae	0.000	0.013
Carangidae	0.050	0.008
Carangidae	0.050	0.275
Decapterus	0.050	0.126
Clupeidae	0.050	0.172
Corryphaenidae	0.005	0.008
Dasyatidae	0.000	0.010
Engraulidae	0.050	0.126
Exocotidae	0.050	0.011
Haemulidae	0.100	0.006
Holocentridae	0.050	0.003
Lutjanidae	0.150	0.022
Meluccius spp.	0.000	<0.001
Mullidae	0.050	0.015
Myliobatidae	0.000	0.010
Pomacanthidae	0.000	0.010
Scaridae	0.000	0.012
Scombridae	0.010	0.091
Sardinella	0.010	0.037
Serranidae	0.200	0.009
Sparidae	0.050	0.001
Trichiuridae	0.000	0.002
Misc. marine fishes	0.020	0.008

[2] http://www.gov.ai/statistics/ [Accessed August 2012]
[3] http://www.onecaribbean.org/ [Accessed: August 2012]

Recreational fishery

Klausing (1978) conservatively estimated catches from the recreational sector of the Anguilla, which averaged to a rate of about 1.0 kg·tourist^{-1}·year^{-1}. Assuming participation of tourists in recreational fishing in Anguilla was 10% in 1950 and 20% in 2010, we calculated the number of recreational fishing tourists. Applying the modest rate from Klausing (1978), we conservatively estimated catches from Anguilla's recreational sector for the time period 1950-2010. These may be substantial underestimates.

Taxonomic composition

Lum Kong (2007) presented a list of marine species targeted by fisheries, but without quantitative information. To further disaggregate finfish catches into more informative taxonomic components, we used the 2000-2010 FAO landings composition breakdown for St. Kitts and Nevis, both neighbouring islands. This was the time period when the most disaggregated species breakdown was available. Conch and lobster data were removed since these were reconstructed separately. Taking the 2000-2010 average species composition from St. Kitts and Nevis, together with some additions from Lum Kong (2007), we derived an assumed taxonomic breakdown for Anguilla reconstructed catches in 2010. For the 1950 anchor point, we re-allotted proportions to each species based on our knowledge of changes in reef species over time (Table 3). We interpolated between these anchor points to derive a taxonomic breakdown for Anguillan finfish catches for the period 1950-2010.

Catches of conch were designated to queen conch, *Strombus gigas,* based on the predominance of this strombid species in Caribbean catches. The Caribbean spiny lobster fishery for *Panulirus argus* was established since the early 1960s (Olsen and Ogden 1981; Lum Kong 2007), but over the past 20 years fishers have also increasingly targeted *Panulirus guttatus* as well (Lum Kong 2007). Since this smaller lobster species averages 2-3 lbs (0.91-1.36 kg), it is preferred by restaurants because of its simpler and more profitable portion control (Hodge 1993; Gumbs 2003a). To disaggregate lobster catches by species, we assumed in 1950 that 95% of lobster catches comprised *P. argus*, while 5% comprised *P. guttatus.* From 2000-2010, we assumed a 50:50 split between these two species. Interpolating between the 1950 anchor point and the 2000 anchor point, we disaggregated catches of lobster for the period 1950-2010.

Results

Domestically-consumed catches were estimated at slightly over 34,100 t, while exported catches amounted to nearly 15,000 t. Examining reconstructed catches by sector, subsistence catches dominated with nearly 22,500 t, while artisanal and recreational catches comprised around 26,400 t and 230 t, respectively for the time period 1950-2010 (Figure 4a). Thus, total reconstructed catches were approximately 49,000 t for the period 1950-2010, which is 2.75 times the official landings of 17,854 t reported by the FAO on behalf of Anguilla (Figure 4a). Total unreported catches from 1950-2010 were around 31,300 t, being on average nearly 510 t·year^{-1} for the time period 1950-2010.

Catches of lobster were dominant, with *Panulirus argus* comprising 16% and *P. guttatus* 11% of total catches (Figure 4b). Groupers (Serranidae; 12%), queen conch (10%), snappers (Lutjanidae; 9%) and grunts (Haemulidae; 6%) were also dominant in catches. Small, schooling pelagic species such as jacks (Carangidae; 6%), clupeids (3%) and sardines (*Sardinella*; 3%) were common as well. The remaining 22% comprised 17 families and a pooled 'marine fishes' category (Figure 4b).

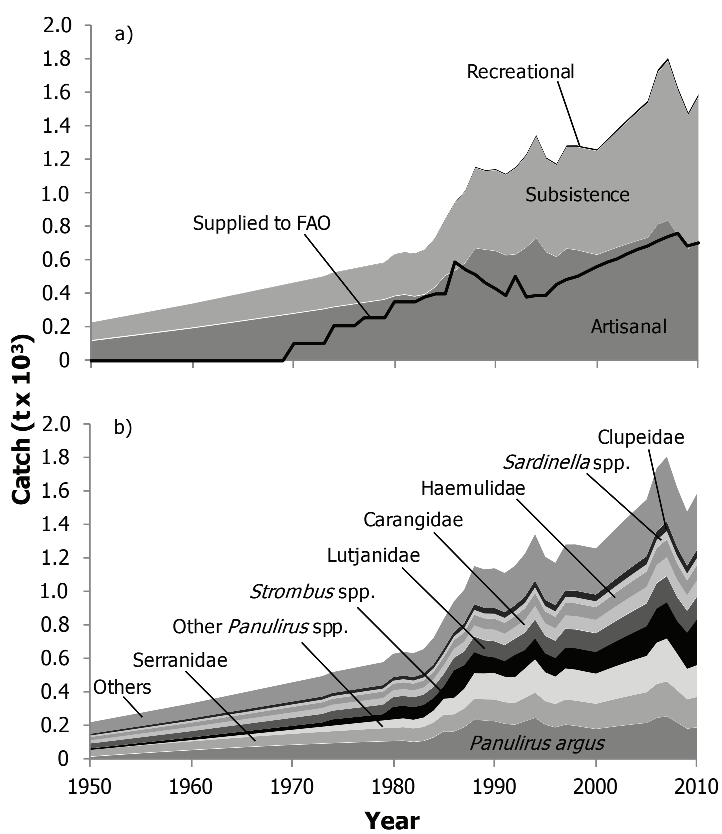

Figure 4. Reconstructed total catch for Anguilla a) by fishing sector, with data reported by FAO on behalf of Anguilla overlaid as line graph; and b) by major taxa, with 'others' representing contributions from 17 minor families plus 'marine fishes nei'.

Discussion

In 1984, seafood products worth an estimated US$2.2 million were caught by Anguillan fishers (Jones 1985). This included some US$1.3 million worth of exports, making the fishing industry the most valuable foreign currency earner after tourism (Jones 1985). A census in the same year indicated that 7% of the working population were full-time fishers.

However, despite the evident socio-economic importance of Anguilla's small-scale fisheries, government spending for the effective management of fisheries is severely lacking in Anguilla. Several limitations in the Department of Marine and Fisheries Resources have been reported and include inadequate staffing and additional workloads (Gumbs 2003). Consequently, comprehensive data-collection, analysis and reporting is poor in Anguilla. When fisheries managers use poor catch data as a basis for management measures, it is likely that under-reported catches will lead to over-estimates of resource availability. Total catches for Anguilla as reconstructed here were more than twice the landings reported to the FAO by national agencies. The difference can be attributed to under-reporting of small-scale fisheries, from artisanal, subsistence and recreational sectors. Without reliable island-wide catch data, it is difficult to make informed fisheries management decisions.

Already, fishers are fishing at increasingly further distances from the traditional inshore reef area, due to declining catches near-shore (Mukhida and Gumbs 2007). With the trend of stop-over tourists increasing, the impact of tourists on the island's marine resources should not be overlooked. The estimate of recreational catches taken by tourists totalled over 200 tonnes and is rather conservative but highlights that the sector exists and proper monitoring and accounting is needed.

Our reconstruction did not estimate catches made by foreign fishers in Anguilla's EEZ. Historically, the presence of St. Martin fishers has been documented, but data on their effort and catches were not available (Jones 1985). This needs addressing by Anguillan authorities. Thus, total removals in Anguillan waters are likely higher than our reconstructed estimates. Our reconstruction of Anguilla's historic fisheries catches should be viewed as a first-order improvement of the historic catch data, which should lead to improved monitoring and estimation of actual total annual catches in Anguilla.

Acknowledgements

This work was completed as part of *Sea Around Us*, a scientific collaboration between The University of British Columbia and The Pew Charitable Trusts. We are grateful to Mr. James Gumbs and Mr. Kenroy Rawlins of the Department of Fisheries and Marine Resources in Anguilla for their assistance in understanding the fisheries sector of Anguilla.

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Appendix Table A1. List of marine fish taxa targeted in Anguilla (Lum Kong 2007).

The finfish (reef fish) trap fishery	
Shallow reef and grass areas	Red hind (*Epinephelus guttatus*)
	Butterfish (*Epinephelus fulvus*)
	Spotted eagle ray (*Aetobatus narinari*)
	Stingray (*Dasyatis* spp.)
	Blue Tang (*Acanthurus coeruleus*)[a]
	Yellow tail snapper (*Ocyurus chrysurus*)[a]
	Grunts (Haemulidae)
	Doctorfish (Acanthuridae)
	Parrotfish (Scaridae)
	Porgy (Sparidae)
	Goatfish (Mullidae)
	Squirrelfish (Holocentridae)
	Triggerfish (Balistidae)
	Angelfish (Pomacanthidae)
Deep reef areas	Deepwater red snapper (Lutjanidae)
	Blackfin snapper (*Lutjanus buccanella*)
	Silk snapper (*Lutjanus vivanus*)
	Queen snapper (*Etelis oculatus*)
	Groupers (Serranidae)
The line fishery	
Shallow reef	Snappers (Lutjanidae)
	Groupers and Hinds (Serranidae)
Deep reef	Snappers (Lutjanidae)
	Groupers (Serranidae)
The seine net fishery	
	Horse eye jack (*Caranx latus*)
	Crevalle jack (*C. hippos*)
	Bar jack (*C. ruber*)
	Bonito (*Euthynnus alleteratus*)
	Ballyhoo (*Hemiramphus* spp.)
	Scads (*Decapterus* spp.)
	Herrings (Clupeidae)
	Silversides (Atherinidae)
The lobster trap fishery	
	Spiny lobster (*Panulirus argus*)
	Spotted spiny lobster (*Panulirus guttatus*)
The conch fishery	
	Queen conch (*Strombus gigas*)

[a] (Abernethy, 2005)

Appendix Table A2. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector for Anguilla, 1950-2010.

Year	FAO landings	Reconstructed total catch	Artisanal	Subsistence	Recreational
1950	-	222	117	105	-
1951	-	233	124	109	-
1952	-	244	132	112	-
1953	-	256	139	116	-
1954	-	267	147	120	-
1955	-	278	154	124	-
1956	-	290	162	127	-
1957	-	301	170	131	-
1958	-	312	177	135	-
1959	-	323	185	138	-
1960	-	335	193	142	-
1961	-	347	201	146	-
1962	-	360	210	150	-
1963	-	372	218	154	-
1964	-	385	227	158	-
1965	-	398	236	162	-
1966	-	410	244	165	-
1967	-	423	253	169	-
1968	-	435	262	173	1
1969	-	448	271	177	1
1970	101	460	279	180	1
1971	101	473	288	184	1
1972	101	486	297	188	1
1973	101	498	306	191	1
1974	207	522	318	203	1
1975	207	534	327	206	1
1976	207	546	336	209	1
1977	257	558	345	212	1
1978	257	569	354	214	1
1979	257	581	363	217	1
1980	345	631	384	247	1
1981	345	643	393	249	1
1982	345	635	382	252	1
1983	375	659	394	264	1
1984	395	727	436	290	2
1985	395	840	506	331	2
1986	585	944	537	404	3
1987	542	1,012	582	426	3
1988	507	1,154	670	479	5
1989	465	1,134	661	469	5
1990	421	1,141	653	482	5
1991	383	1,113	627	480	5
1992	503	1,155	634	515	6
1993	382	1,228	674	547	7
1994	391	1,344	729	607	8
1995	390	1,210	646	557	7
1996	455	1,173	618	548	7
1997	480	1,283	667	607	8
1998	505	1,283	659	616	8
1999	530	1,271	644	618	8
2000	560	1,259	631	620	8
2001	585	1,319	653	657	9
2002	610	1,380	675	695	10
2003	635	1,438	696	732	11
2004	660	1,495	715	769	11
2005	685	1,550	733	805	12
2006	710	1,737	812	910	14
2007	735	1,807	835	956	15
2008	759	1,625	744	868	14
2009	681	1,478	667	799	12
2010	701	1,589	708	868	13

Appendix Table A3. Reconstructed total catch (in tonnes) by major taxa for Anguilla, 1950-2010. 'Others' contain 22 additional taxonomic categories.

Year	*Panulirus argus*	Serranidae	*Panulirus* spp.	*Strombus* spp.	Lutjanidae	Carangidae	Haemulidae	*Sardinella* spp.	Clupeidae	Others
1950	15	39	1	9	30	20	20	10	10	69
1951	20	40	1	10	30	21	20	11	10	71
1952	24	41	2	10	31	21	21	11	11	73
1953	28	42	2	11	32	22	21	11	11	75
1954	32	43	3	12	33	23	22	11	11	77
1955	36	45	4	12	33	23	22	12	12	79
1956	40	46	5	13	34	24	23	12	12	81
1957	44	47	6	14	35	25	23	12	12	84
1958	47	48	7	14	36	25	24	13	12	86
1959	51	49	8	15	37	26	25	13	13	88
1960	54	50	9	16	38	26	25	13	13	90
1961	58	52	10	16	39	27	26	14	13	92
1962	61	53	12	17	40	28	27	14	14	95
1963	65	54	13	18	41	28	27	14	14	97
1964	68	56	15	19	42	29	28	15	15	100
1965	71	57	16	19	43	30	29	15	15	102
1966	74	59	18	20	44	31	29	15	15	105
1967	77	60	20	21	45	31	30	16	16	107
1968	80	61	22	21	46	32	31	16	16	110
1969	83	63	24	22	47	33	31	17	16	112
1970	86	64	26	23	48	34	32	17	17	115
1971	88	65	28	24	49	34	33	17	17	117
1972	91	67	30	24	50	35	33	18	17	120
1973	94	68	32	25	51	36	34	18	18	122
1974	96	70	35	37	52	36	35	18	18	125
1975	98	71	37	37	53	37	35	19	18	127
1976	101	72	40	37	54	38	36	19	19	130
1977	103	74	43	37	55	39	37	19	19	132
1978	105	75	45	37	56	39	38	20	20	135
1979	107	76	48	37	57	40	38	20	20	137
1980	109	78	51	75	58	41	39	21	20	140
1981	110	79	54	75	60	41	40	21	21	142
1982	103	79	53	75	60	42	40	21	21	142
1983	109	82	58	75	61	43	41	22	21	147
1984	131	88	72	75	66	46	44	23	23	159
1985	166	98	96	75	74	52	49	26	26	178
1986	166	101	99	165	76	53	50	27	26	182
1987	191	110	118	142	82	57	55	29	29	199
1988	235	125	152	127	94	65	63	33	33	227
1989	231	126	155	105	94	66	63	33	33	229
1990	227	129	157	94	97	68	65	34	34	236
1991	211	128	153	94	96	67	64	34	33	233
1992	206	129	154	135	97	68	64	34	34	235
1993	226	140	175	111	105	73	70	37	36	255
1994	246	151	198	126	113	79	75	40	39	276
1995	206	140	172	114	105	73	70	37	36	256
1996	190	138	165	112	103	72	69	36	36	252
1997	206	149	185	127	112	78	74	39	39	273
1998	199	150	185	129	113	79	75	40	39	275
1999	189	150	183	130	113	78	75	40	39	275
2000	180	150	180	130	112	78	75	40	39	275
2001	188	156	188	140	117	82	78	41	41	287
2002	196	163	196	150	122	85	82	43	42	300
2003	203	170	203	159	127	89	85	45	44	313
2004	210	176	210	169	132	92	88	47	46	325
2005	217	182	217	179	137	95	91	48	47	337
2006	247	201	247	206	151	105	101	53	52	373
2007	255	209	255	219	157	109	105	55	54	388
2008	219	192	219	196	144	101	96	51	50	356
2009	182	174	182	217	131	91	87	46	45	322
2010	190	181	190	277	136	95	90	48	47	335

Reconstruction of total marine fisheries catches for the British Virgin Islands (1950 – 2010)[1]

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Abstract

The problem of underreporting catches in fisheries is global. This report presents the reconstruction of total marine fisheries catches for the British Virgin Islands for the period 1950-2010, which includes estimates of misreported near-shore catches, reported offshore catches and un-reported recreational catches. The reconstructed total catches for the British Virgin Islands for the period 1950-2010 were estimated to be approximately 72,000 t, which is 2.3 times the reported catch of 30,271 t as presented by the FAO on behalf of the British Virgin Islands. This amount better reflects the importance of small-scale fisheries in providing seafood to consumers, livelihoods to fishers and recreation to visitors.

Introduction

The British Virgin Islands (BVI) consist of 60 islands, islets and cays situated in the Eastern Caribbean, located around 18° 30′ N and 64° 30′ W (Figure 1). The BVI have an Exclusive Economic Zone of approximately 81,000 km^2 (www.seaaroundus.org) with an estimated total population of around 22,000 persons (Anon. 2003). Sixteen of the islands are inhabited, but only four (Tortola, Jost Van Dyke, Virgin Gorda and Anegada) have major settlements.

Originally settled by Arawaks, (aboriginals originating from South America), the islands were rediscovered by Christopher Colombus in 1493, who claimed them for Spain. From about 1615 to 1640, the Dutch privateer Joost Van Dyk commanded a Dutch settlement on Tortola, farming cotton and tobacco. In 1640, Spain attacked Tortola and killed the Dutch. Subsequently, the British Virgin Islands came under British control in 1672 and have remained so ever since.

From 1925 to about 1950, the economic activities in the BVI involved small-scale agriculture, fishing, charcoal production and livestock rearing. From 1950 to 1960, tourism developed on the neighbouring US Virgin Islands (USVI). However, the development of tourism in BVI did not take place until about 1967, with the advent of constitutional reform and establishment of a ministerial government in BVI.[2] Eventually, with resorts and hotels being built to accommodate visitors, many immigrants from surrounding islands arrived to work in BVI in the construction and service sectors. Today, tourism and international financial services are the leading economic activities and *per capita* Gross Domestic Product (GDP) is approximately $20,000 US. The rapid population growth, particularly in the last ten years in which the population grew by 47%, has had a marked impact on the development of BVI.[3] For instance, the growth of total acreage of developed land on both Tortola and Virgin Gorda is 5 times greater today than in the mid 1970s.

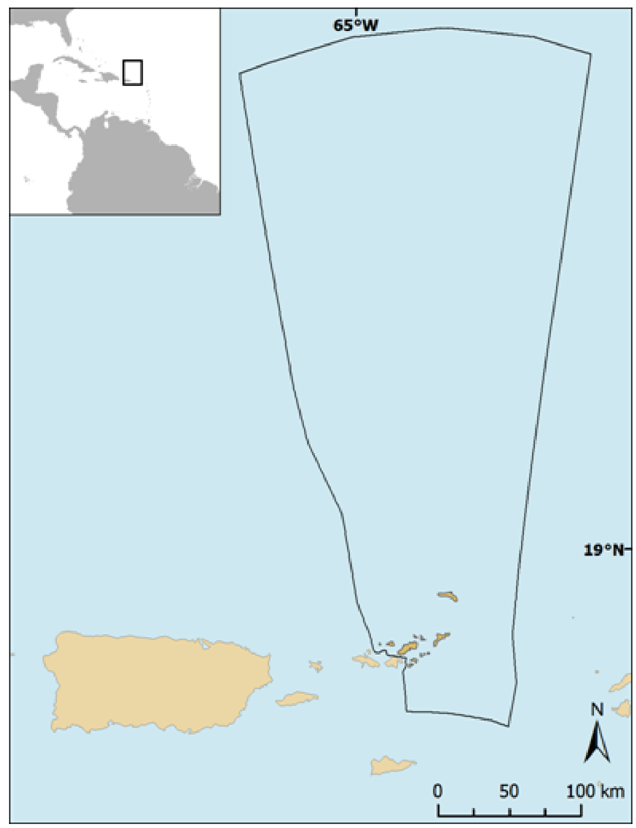

Figure 1. Map showing the British Virgin Islands with line demarcating EEZ.

The fisheries of the BVI are small-scale, multi-gear and multi-species (Alimoso and Overing 1996). The fisheries can be divided into three sectors: a near-shore fishery, the offshore pelagic longline fishery and the recreational fishery (Anon. 2003). However, fishers derive subsistence benefits too, as some portion of catches are retained by fishers for

[1] Cite as: Ramdeen, R., Harper, S., Zylich, K. and Zeller, D. (2014) Reconstruction of total marine fisheries catches for the British Virgin Islands (1950-2010). pp. 9-16. *In*: Zylich, K., Zeller, D., Ang, M. and Pauly, D. (eds.) Fisheries catch reconstructions: Islands, Part IV. Fisheries Centre Research Reports 22(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] http://www.dpu.gov.vg/ [accessed September 10th, 2012]

[3] http://www.dpu.gov.vg/ [accessed August 10th, 2012]

their families. Traps are the predominant gear used to catch lobster, as well as other shallow water reef species, e.g., doctor fish (*Acanthurus chirurgus*) and yellow-tail snapper (*Ocyurus chrysurus*). Haul seines, handlines and diving are also employed by the near-shore fishery. The offshore pelagic fishery targets tuna (Scombridae), dolphin fish (Corryphaenidae) and wahoo (*Acanthocybium solandri*) by longlining. Like the USVI recreational fishery, fishers in the BVI use rod and reel, handline, spearfishing, free diving, scuba diving and cast netting (Jennings 1992; Mateo 1999) to exploit a variety of species. However all billfishes are strictly catch and release in the BVI.

In the past, approximately half of the annual catch from the near-shore artisanal fleet was exported directly to USVI due to better pricing and marketing arrangements (CDB 1980). For example, in the late 1970s fishers from Anegada would sell processed fish to USVI vendors, who would collect the products in an airplane twice weekly (CDB 1980). Even though an export market existed, the locally retained catches were not sufficient to satisfy local and tourist demand in BVI, therefore, seafood products were also imported to supply the local market. There are no trade data in the FAO database for BVI or USVI; however, other sources reveal the level of seafood imports into the islands. For instance, according to an appraisal of the fisheries sector in the BVI in the mid 1970s, approximately 60 $t \cdot year^{-1}$ of seafood products were imported between 1974-1976 (CDB 1980).

Formal fisheries management in the BVI is less than twenty five years old and routine catch data collection at the Government Fishing Complex in Road Town in Tortola started in November 2001 (Mills *et al*. 2005). However only 25% of all fishers market their catches at this site, while the remaining 75% of fishers market their catch in the countryside (Alimoso and Overing 1996). Thus, fisheries data collection does not encompass all landing sites in Tortola, nor those of Jost van Dyke, Virgin Gorda and Anegada. Presently, data are collected by log-books, which are distributed to every licensed fisher on the main islands. Fishers record catches by species and return books to the fisheries office in Tortola once a month (A. Pickering, pers. comm., Conservation and Fisheries Department, September, 12th 2012).

The catches submitted by the Department of Conservation and Fisheries to the FAO reportedly consist solely of catches made by the offshore pelagic longline fishery, while data from the near-shore trap fisheries is not submitted to the FAO (A. Pickering, pers. comm., Conservation and Fisheries Department, September, 12th, 2012). Furthermore, FAO landings data for the BVI consist of both reported and estimated catches. Catch estimates are provided by the FAO when countries do not report any fisheries statistics for a given year (Garibaldi 2012). For the years 1976-1982 and 2005-2010, landings were estimated by the FAO. Despite the deficiency in data collection and reporting, implementation of regulations, monitoring and enforcement seem exceptional in the BVI. Spearfishing using SCUBA is not permitted in the BVI, charters must obtain licenses for recreational fishing and fines for illegal fishing can be up to US$15,000, and compliance seems high. In 2003, there were several cases of the USVI fishing illegally in the BVI. Penalties included detainment of a commercial fishing vessel, a fine of US$11,000 and jail time.[4] Unfortunately, historically catch data from this illegal foreign fishery were not available (Walters 1984) and the situation has not changed in present time.

Like many other Caribbean islands, the economy of the BVI is very dependent on the marine and coastal environment and its resources, and the tourism sector in particular. Lack of comprehensive fisheries catch data is hampering fisheries management in the BVI, as without reliable time series catch or effort data, it is difficult to make an informed analysis of the state of the fisheries resources. The fisheries of the BVI have been reported on by Peacock (1975), Klausing (1978), CDB (1980), Alimoso and Overing (1996), Pomeroy (1999) and Franklin (2007). Through review of all available fisheries literature (published and unpublished), we establish the level of fishing in the BVI for the period 1950-2010 in order to create a more accurate picture of the total catches in these islands.

Methods

Using information on the number of fishers from various sources (see below), together with catch per unit effort information from Klausing (1978), we reconstruct the total small-scale catches from the artisanal near-shore fishery from 1950-2010 in the BVI. No estimates of hand-line catches or haul seine catches were available; thus we conservatively assumed our reconstruction based on trap catch, effort and total number of fishers accounted for all near-shore catches. Since catches from the offshore pelagic longline fishery are captured by the current data collection system, we extracted these catches from the FAO dataset and assumed no unreported catches from this sector. Further, in 2003, reported landings were 2,771 t, which is double of that reported in the year before and after. Since we found no information to explain this sudden rise in catches, we did not accept the FAO reported value and instead used our own reconstructed total which was lower and assumed no unreported catches in this year. Finally we applied a minimal recreational catch per tourist to estimate catches made by the recreational sector. It should be noted that the FAO baseline was adjusted for one year, 2003, as detailed in the results section below.

Table 1. Data sources used to estimate number of fishers in the BVI.

Year	No. active fishers	Source
1950	98	Assumption based[a]
1978	151	Klausing (1978)
1991	280	Alimoso and Overing (1996)
1999	374	Pomeroy (1999)
2010	410	Assumption based[b]

[a] Based on a proportion of fishers to total population of 0.014 in 1978.
[b] Based on the proportion of fishers to total population of 0.022 in 1999.

[4] www.stthomassource.com [Accessed 2 October, 2012]

Small-scale fisheries

Details on the number of fishers were obtained from various sources for the years 1978, 1991 and 1999 (Table 1). Taking the proportion of fishers within the population as a ratio, and using direct linear interpolation between anchor points in 1978, 1991 and 1999, we estimated the population of fishers operating on the islands from 1950-2010 (Figure 2). For the period 1950-1978, we used the ratio of fishers to total population in 1978 (0.014) as a constant. Similarly, for the period 1999-2010, we used the ratio of fishers to total population in 1999 (0.022) as a constant.

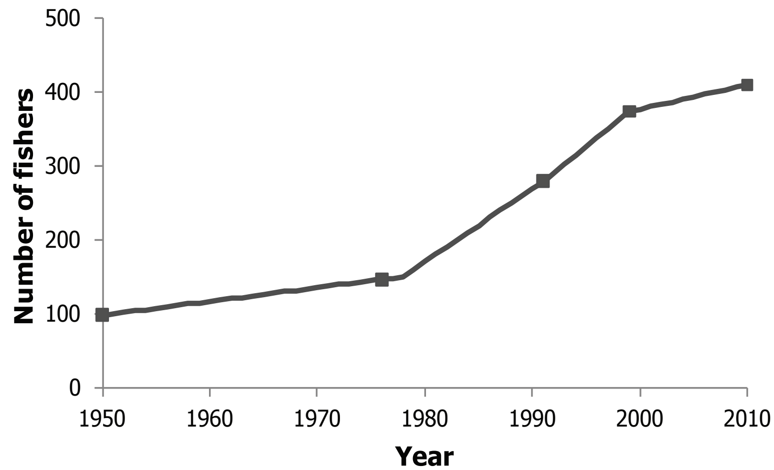

Figure 2. Time-series of the number of fishers in the British Virgin Islands during the period 1950-2010 (anchor points represented by solid points on graph).

Near-shore fishery

Klausing (1978) conducted a feasibility study for medium-scale fisheries in the BVI in 1975, as part of a United Nations funded project. He described the current effort of the near-shore trap fishery as 50 fishing weeks per year, 3 fishing days per week, 15 trap hauls per day and 5 lbs of catch per trap, giving a rate of 5.11 $t \cdot fisher^{-1} \cdot year^{-1}$. Assuming this rate remained constant, we combined this rate with the number of fishers, and estimated the catches from BVI's near-shore fishery as:

Catch = # fishers x 5.11 $t \cdot fisher^{-1} \cdot year^{-1}$

Since it is known that fishers take home a portion of their catch (Anon. 2003), we assumed some proportion of our reconstructed catches to be part of subsistence catches. To assign small-scale catches to artisanal and subsistence sectors, it was assumed that in 1950, 70% of near-shore catches were from the subsistence sector and 30% were from the artisanal sector. In 2010, it was assumed that 30% of catches were attributed to the subsistence sector and 70% to the artisanal sector. A linear interpolation was done between these two years to derive an assignment by sector for the entire 1950-2010 time-period.

Table 2. Derived taxonomic breakdown for the near-shore fisheries of British Virgin Islands.

	Percentage composition	
Family	**1950**	**2010**
Balistidae	2.00	2.30
Carangidae	1.20	2.30
Carcharhinidae	0.04	0.02
Centropomidae	0.90	0.50
Clupeidae	0.60	2.30
Exocotidae	0.40	0.50
Gereidae	0.40	4.60
Haeumulidae	18.50	4.60
Holocentridae	0.50	2.30
Labridae	1.00	2.30
Lobster	8.30	7.30
Lutjanidae	1.20	7.30
Lutjanus analis	1.50	2.30
Lutjanus synagris	2.90	2.30
Lutjanus vivanus	12.70	6.90
Ocyurus chrysurus	3.90	23.90
Miscellaneous marine fishes	4.80	4.60
Mullidae	7.10	6.90
Octopus	0.90	2.30
Ostraciidae	0.60	3.70
Scaridae	8.30	4.60
Scombridae (Mackerels)	3.30	0.05
Serranidae	11.30	0.50
Shellfish, whelks	0.80	4.60
Sparidae	0.90	0.50
Sphyraenidae	1.00	0.50
Strombidae	4.90	0.30

Offshore longline fishery

The offshore pelagic longline fishery is limited to a few active boats (Franklin 2007). Catches from this sector are reported to the FAO under the present data collection system (A. Pickering, pers. comm., Conservation and Fisheries Department, September, 12th, 2012). As such, we relied on the FAO data to represent catches for this sector. We assumed no unreported catch component for this sector. Kelleher (2005) describes discards from small-scale longline fisheries in the range of 7.5%–15%, thus taking 10% of the total offshore catches we reconstructed the discards associated with this sector.

Recreational fishery

During the 1975 assessment of BVI fisheries, Klausing (1978) conservatively assumed catches from the recreational sector were 23 t for that year. Assuming the recreational sector is comprised mainly of tourists, we divided this catch of 23 t by the number of stop-over tourists in the BVI[5] in 1975 to get an average *per capita* recreational catch rate of 0.001 $t \cdot tourist^{-1} \cdot year^{-1}$. Assuming conservatively that this rate remained constant, we combined this with the number of annual stop-over tourists (Figure 3), to estimate catches from BVI's recreational sector for the period 1950-2010.

[5] Caribbean Tourism Organisation website: http://www.onecaribbean.org/ [Accessed September 11th, 2012]

Taxonomic composition of catches

Island specific quantitative catch composition data for the near-shore were unavailable in the BVI fisheries literature accessed for this study. FAO data for BVI consists of 15 taxonomic groups from 13 families. A detailed breakdown of catches from Puerto Rico in the year 1975 was presented in the appraisal report on the fisheries of the BVI (CDB 1980). We applied the Puerto Rico catch breakdown to the year 1950 and took the average FAO breakdown for 2001-2010 and applied it to the year 2010. Given that the FAO breakdown only consisted of 13 families, whereas the Puerto Rico breakdown included 26 families, we further disaggregated the FAO breakdown based on our knowledge of changes in herbivores on Caribbean coral reefs and popularity of certain reef fishes in diets. The assumed and derived taxonomic breakdown of the catch can be seen in Table 2.

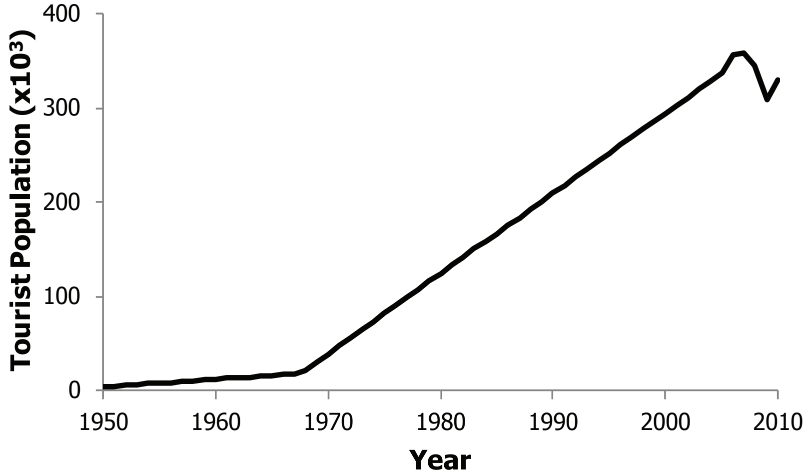

Figure 3. Stop-over tourist population for the British Virgin Islands during the period 1950-2010.

Results

Reconstructed catches from the near-shore fishery totalled just under 69,000 t for the BVI during the period 1950-2010. Catches from the offshore fishery totalled 400 t from its start in 1994 to 2010. The discards from this sector were estimated at approximately 40 t for the same period. Reconstructed catches from the recreational sector in BVI amounted to slightly over 1,800 t for the full time period (Figure 4a).

The increase in reported landings in 2001 coincides with the year in which systematic data collection began (Figure 4a). Except for the year 2003, reported landings for BVI fluctuated between 100 and 1,200 t·year^{-1}, with annual reported landings averaging 507 t·year^{-1}. In 2003, reported landings were 2,058 t, which is double of that reported in the year before and after. Since we found no information to explain this sudden and short-lived spike in reported landings, we did not accept the FAO record for 2003. Thus there were no obvious unreported catches in this year. Total unreported catches for the period 1950-2010 were estimated at slightly over 40,900 t, with average annual unreported catches of approximately 670 t·year^{-1} (Figure 4).

Catches from the subsistence sector were estimated at 17,800 t from 1950-2010, while those from the artisanal sector were estimated at 51,600 t for the same period (Figure 4a). Total reconstructed catches for the BVI for the period 1950-2010 were estimated to be just over 71,000 t, which is 2.3 times the reported landings of 30,272 t as presented by the FAO on behalf of BVI.

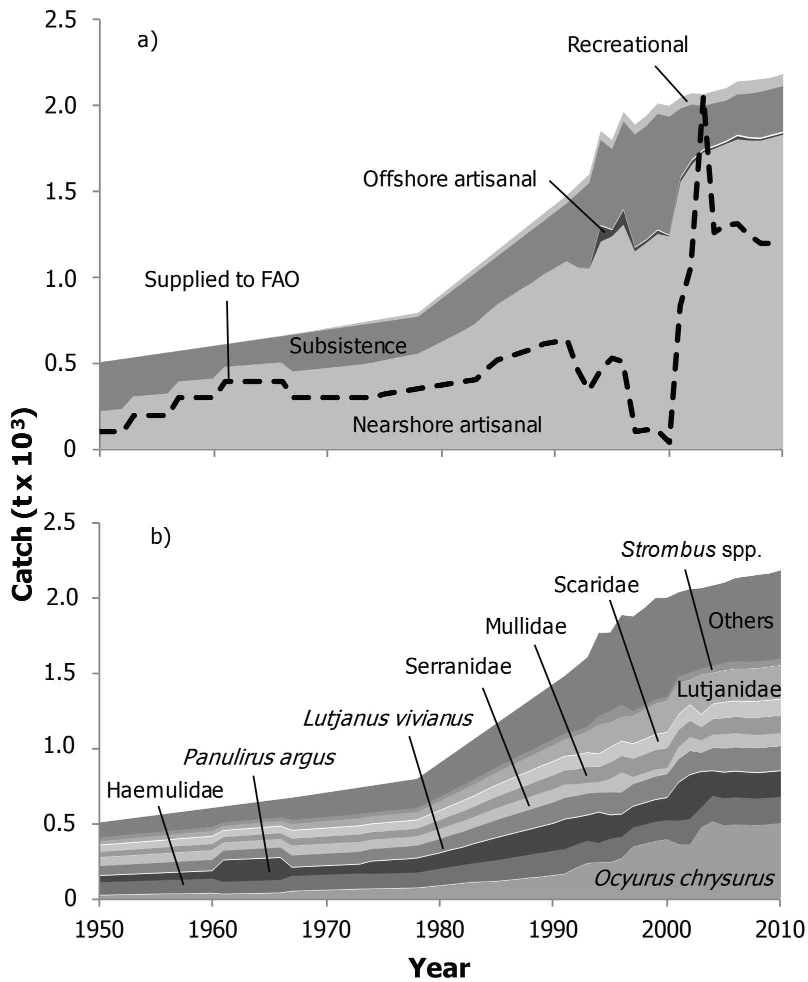

Figure 4. Reconstructed total catches for the British Virgin Islands; a) by sector with FAO reported landings shown as an overlaid line graph; and b) by taxa, with 'Others' consisting of 20 additional taxonomic groups.

Catches were dominated by reef species such *Ocyurus chrysurus* (yellowtail snapper 14%) and *Lutjanus vivanus* (silk snapper 9%), with 'other lutjanids' comprising 4% of total catches. Grunts (Haemulidae 11%) and groupers (Serranidae 6%) were also important in catches, as were goatfish (Mullidae 6%) and parrotfish (Scaridae 6%). Catches of marine invertebrates such as *Panulirus argus* (10%) and *Strombus gigas* (3%) were common. The 30% 'Others' category was comprised of 10 demersal families, 8 pelagic families, miscellaneous marine fishes, and miscellaneous marine invertebrates (Figure 4b).

Discussion

A report by the Development Planning Unit of the Ministry of Finance stated that fishing contributed 2.5% to the GDP of the BVI in 1988. However, this report failed to indicate that fish provided a valuable protein source to the local population (Anon. 2003) and was likely based on reported landings only. Despite the economic and cultural significance of marine fisheries to these islands, fisheries administration is lagging, with less than 25 years of formal fisheries management in the BVI (Mills *et al.* 2005). On the other hand, there have been major improvements since routine data collection began in 2001 (Mills *et al.* 2005). This is illustrated by the steep increase in FAO reported landings in the later period. Furthermore, surveillance and enforcement of fisheries legislation is routinely conducted in the BVI. All fishers must have valid licenses to fish, and monitoring and enforcement is routine, while illegal fishing is being combated with fines up to US$15,000 (A. Pickering, pers. comm., Conservation and Fisheries Department, September, 12th 2012).

Despite increased vigilance in monitoring and enforcement, our reconstructed catches were 2.3 times higher than those reported to the FAO over the 1950-2010 time period, and for the most recent decade the discrepancy was still 940 t·year^{-1} (or 65%). Our study of total reconstructed catches for the BVI contains under-reported catches from the near-shore fishery, which is the major fishing sector in the islands (CDB 1980; Alimoso and Overing 1996), as well as unreported catches from a popular recreational sector. To what extent mis- or under-reporting occurs also in the offshore pelagic sector could not be determined in the present study, but it is likely. Furthermore the discards from this sector should not be overlooked.

There seems to be some distrust by the Conservation and Fisheries Department, which collects near-shore catch data but treats it as confidential, and does not report it to the FAO. Such withholding of data on a public resource is surprising and should be rectified by the responsible authorities. In addition, catches from the recreational sector are not being captured by the present data collection system. Reconstructed recreational catches amounted to approximately 1,800 t for the period 1950-2010. Thus, the impact of tourists is being underestimated. This should be of particular concern for islands such as the BVI, where tourist populations are an order of magnitude greater than local resident populations, and where tourist experience is a major economic factor.

Data reported by the FAO on behalf of the BVI were presented in 13 taxonomic categories. Reconstructed catches were disaggregated into 26 families, which is a major improvement over the reported data. Given that no quantitative catch composition data were available, our reconstruction is the best representation of likely total catches made in the BVI at present. With greater transparency from and some targeted investigations by the Conservation and Fisheries Office, these estimates could be improved upon.

Acknowledgements

This work was completed as part of *Sea Around Us*, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts. We are grateful to Mr. Pickering of the Conservation and Fisheries Department, for his assistance in understanding the fisheries sector of British Virgin Islands. We would also like to thank Ms. Jeanel Georges for her help in accessing documents at the Caribbean Development Bank in Barbados.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector for the British Virgin Islands, 1950-2010.

Year	FAO landings	Reconstructed total catch	Nearshore artisanal	Offshore artisanal	Subsistence	Recreational
1950	100	505	221	-	283	1
1951	100	515	227	-	287	1
1952	100	525	233	-	291	1
1953	200	534	307	-	226	1
1954	200	544	312	-	231	2
1955	200	554	317	-	235	2
1956	200	564	323	-	239	2
1957	300	573	394	-	177	2
1958	300	583	399	-	181	2
1959	300	593	405	-	186	2
1960	300	602	410	-	190	3
1961	400	612	478	-	131	3
1962	400	622	483	-	136	3
1963	400	632	488	-	140	3
1964	400	641	494	-	145	3
1965	400	651	499	-	149	3
1966	400	661	505	-	153	4
1967	300	671	452	-	215	4
1968	300	681	458	-	218	5
1969	300	693	465	-	221	7
1970	300	704	472	-	224	8
1971	300	715	478	-	227	10
1972	300	727	485	-	229	12
1973	300	738	492	-	232	14
1974	306	750	503	-	231	16
1975	318	761	517	-	227	18
1976	330	772	530	-	223	19
1977	340	784	543	-	220	21
1978	350	795	555	-	217	23
1979	360	848	588	-	235	25
1980	370	900	622	-	252	27
1981	380	953	656	-	269	28
1982	390	1,005	690	-	285	30
1983	407	1,058	729	-	297	32
1984	470	1,111	789	-	287	34
1985	520	1,163	844	-	283	36
1986	543	1,216	886	-	292	38
1987	565	1,268	928	-	301	39
1988	582	1,321	968	-	312	41
1989	615	1,373	1,016	-	315	43
1990	624	1,426	1,053	-	328	45
1991	634	1,479	1,091	-	340	47
1992	453	1,540	1,056	-	436	49
1993	343	1,602	1,052	-	500	50
1994	470	1,764	1,211	91	501	52
1995	532	1,766	1,242	36	470	54
1996	506	1,882	1,310	85	516	56
1997	105	1,872	1,154	20	660	58
1998	116	1,928	1,203	15	666	59
1999	115	1,996	1,256	20	679	61
2000	45	1,997	1,241	4	693	63
2001	837	2,032	1,561	19	406	65
2002	1,062	2,054	1,661	22	326	67
2003	2,058	2,059	1,732	10	258	69
2004	1,262	2,078	1,754	10	253	70
2005	1,300	2,095	1,783	9	241	72
2006	1,309	2,127	1,809	18	242	76
2007	1,250	2,137	1,801	12	259	77
2008	1,200	2,148	1,800	9	273	74
2009	1,200	2,157	1,818	9	273	66
2010	1,200	2,178	1,836	9	272	71

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for British Virgin Islands, 1950-2010. 'Others' contain 26 additional taxonomic categories.

Year	*Ocyurus chrysurus*	Haemulidae	*Panulirus argus*	*Lutjanus vivanus*	Serranidae	Mullidae	Scaridae	Lutjanidae	*Strombus* spp.	Others
1950	19	93	42	64	57	36	42	29	25	99
1951	21	94	42	65	57	36	42	30	25	102
1952	23	95	43	66	58	37	43	31	25	105
1953	24	96	44	67	58	38	44	31	26	107
1954	25	97	45	68	59	38	44	32	26	110
1955	27	98	45	68	59	39	45	33	26	113
1956	29	99	46	69	60	40	45	34	26	116
1957	28	101	47	71	61	40	46	34	27	117
1958	30	102	48	72	62	41	47	35	27	120
1959	31	103	49	72	62	42	47	36	27	123
1960	33	104	49	73	62	42	48	37	27	126
1961	27	89	142	62	53	36	41	31	23	107
1962	29	90	142	63	54	37	41	32	24	110
1963	30	91	143	64	54	37	42	33	24	112
1964	32	92	144	65	55	38	43	34	24	115
1965	34	93	145	66	55	39	43	35	24	118
1966	35	94	145	67	56	39	44	36	24	121
1967	47	109	54	79	64	47	51	44	28	147
1968	49	109	55	79	64	48	52	45	28	151
1969	51	110	56	80	64	48	52	47	28	156
1970	53	110	56	81	64	49	53	48	28	161
1971	56	111	57	81	64	50	53	49	28	166
1972	58	111	58	82	64	50	54	50	28	172
1973	60	111	59	82	64	51	54	51	28	177
1974	62	107	82	80	62	50	52	51	27	177
1975	63	108	83	81	62	51	53	52	27	181
1976	65	108	88	81	62	51	53	52	27	185
1977	66	109	89	82	62	52	54	53	27	189
1978	68	109	94	82	62	52	54	54	27	193
1979	75	115	98	87	65	55	57	59	28	208
1980	83	120	102	92	68	59	60	63	30	224
1981	90	125	111	96	69	62	63	68	31	239
1982	99	130	114	101	72	66	66	73	32	255
1983	106	133	127	104	74	69	68	77	32	268
1984	108	141	137	110	78	72	72	79	34	279
1985	112	148	147	115	82	75	75	83	36	291
1986	119	153	153	119	85	78	78	87	37	306
1987	127	158	160	124	87	81	81	91	38	321
1988	135	162	166	128	89	85	84	96	39	337
1989	142	168	174	132	92	88	87	100	40	351
1990	151	171	178	136	93	92	90	106	41	368
1991	161	172	196	139	93	94	91	110	41	382
1992	201	162	179	139	82	100	91	126	36	425
1993	231	157	168	140	76	105	92	139	34	460
1994	236	138	201	128	73	99	85	190	60	553
1995	237	167	153	147	93	109	97	164	79	519
1996	262	152	148	142	138	110	93	158	85	593
1997	340	137	137	144	53	121	95	184	32	628
1998	359	137	141	146	54	124	97	194	32	644
1999	378	137	144	150	53	129	99	201	31	674
2000	389	136	147	152	47	133	101	208	27	658
2001	356	167	250	150	87	113	99	208	46	555
2002	352	181	291	154	98	110	101	160	51	555
2003	469	141	236	121	89	88	80	262	42	532
2004	509	179	162	148	95	103	97	204	50	531
2005	481	190	170	155	101	107	102	208	53	530
2006	488	189	171	155	100	108	102	211	53	550
2007	485	187	169	157	97	111	103	213	50	564
2008	482	187	168	160	95	115	105	216	47	574
2009	489	185	169	160	94	116	105	219	46	573
2010	496	184	170	160	92	117	105	222	46	586

Reconstruction of domestic fisheries catches in the Chagos Archipelago: 1950-2010[1]

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Abstract

The British Indian Ocean Territory (at the centre of which is the Chagos Archipelago) covers 640,000 km² in the central Indian Ocean, halfway between Indonesia and Madagascar. Most islands were used for copra farming from the late 1700s to about 1970 when the plantations were closed and the people moved to Mauritius and the Seychelles. At that time, the largest atoll, Diego Garcia, was turned into an American/British 'Joint Defense and Naval Support Facility'. In April 2010, the U.K. declared the entire EEZ of the Chagos Archipelago a 'no-take' marine reserve. This history is reflected in the catch history, with original Chagossian subsistence catch estimated at 90 t·year⁻¹ for the early 1950s, which declined to zero in 1972; and a recreational fishery by British and US military personnel, which started in 1973 and grew to 100 t·year⁻¹ in the 2000s. Thus, reconstructed domestic catches were likely around 12 times higher then reported data suggest for this time period. These catches, however, are relatively low compared to the large pelagic catches reported as taken by large-scale foreign fleets from these waters, which were reported as over 20,000 t in 2004/2005, and an unknown, but potentially significant illegal catch. These large pelagic catches taken from the same waters by either foreign vessels through licensed access agreements, or illegally, are not considered here. The transition in domestic fisheries from subsistence to recreational documented here will have implied a radical change in targets, from medium-sized reef fish and invertebrates to trophy-type fishes, i.e., larger reef fishes and reef-associated pelagic fish. The diversity of fish in the Chagos Archipelago is now in principle protected from fishing. Given the technology available to the current residents of the Chagos Archipelago, there is a good chance that the 'no-take' part of the Chagos marine reserve can be enforced against would-be illegal fishers.

Introduction

The British Indian Ocean Territory is 640,000 km², containing the Chagos Archipelago at its centre (Figure 1). The latter contains over 60,000 km² of shallow limestone, including 5 islanded atolls and a greater number of submerged banks and reefs. It was farmed for copra from the late 1700s. Two atolls ceased this activity in the 1930s, the remainder finally closing around 1970, having had persistent financial problems and declining product quality, and because of cold war politics requiring that one atoll, Diego Garcia, becoming a Naval Support Facility.

Occupation during plantation times was possible because of imported staple foods, the protein being produced locally, mainly through fishing and hunting for sea turtles and birds. The present military facility fishes recreationally, but food is generally imported. Diego Garcia's main island contains approximately half of the total landmass – there are about 54 other islands in the other atolls.

During the early days of the British Indian Ocean Territory there was no formal fisheries protection, and an unknown quantity of fish would have been taken; most islands had poachers' camps on them when fisheries protection or regulation began in the late 1990s. From then and until the creation of a large no-take MPA in 2010, fisheries (mostly for tuna) were licensed. All legal fishing ceased in late 2010.

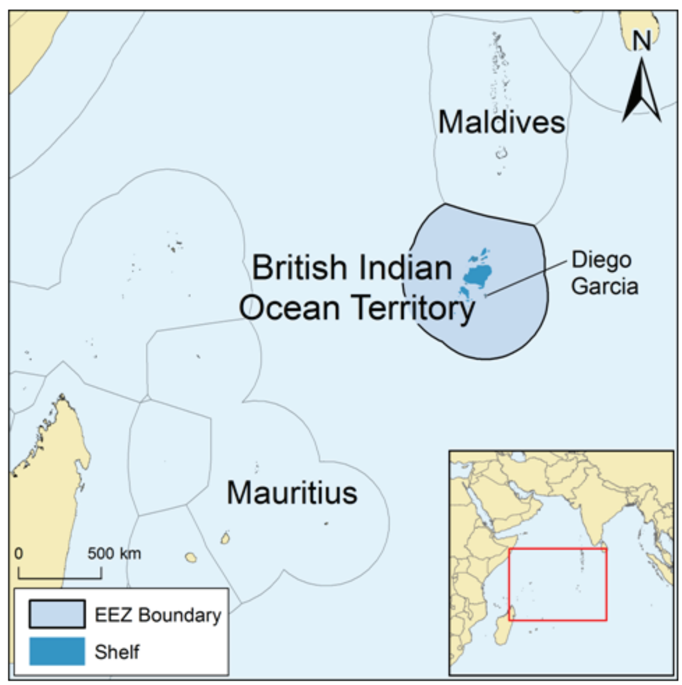

Figure 1. The Exclusive Economic Zone (EEZ) and shelf waters to 200 m depth for the British Indian Ocean Territory. Shown also is the location of Diego Garcia, currently a US/British military installation.

[1] Cite as: Zeller, D. and Pauly, D. (2014) Reconstruction of domestic fisheries catches in the Chagos Archipelago: 1950-2010. pp. 17-24 *In:* Zylich, K., Zeller, D., Ang, M. and Pauly, D. (eds.) Fisheries catch reconstructions: Islands, Part IV. Fisheries Centre Research Reports 22(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Methods

Subsistence fishing

Information on the human population in the Chagos Archipelago (excluding Diego Garcia's military installation as of 1972) was obtained from Wenban Smith (2012). Population data were interpolated for years between years of data to derive a population time series from 1950 to 1972 when all civilian residents were evacuated as part of the UK-US agreement (Table 1).

As this civilian population was directly associated with copra plantations in the Archipelago, and hence were largely employed on a cash basis, there was likely a smaller reliance on subsistence fishing compared to other nearby atoll societies, such as the Maldives. The companies were Mauritian or Seychellois, and supplied food staples to their workers. They fished for the protein. Thus, we assumed the Chagos civilian population had a *per capita* subsistence catch rate of half the estimated Maldives average *per capita* consumption rate of 161 kg·person^{-1}·year^{-1} (Hemmings *et al.* 2014), i.e., 80 kg·person^{-1}·year^{-1} (Table 1).

Table 1. Subsistence fisheries data for the Chagos Archipelago, excluding the military installation on Diego Garcia, showing derived total subsistence catch for the civilian human population from 1950 to 1972 when the remaining civilians were evacuated. A *per capita* subsistence catch rate of 80 kg·person^{-1}·year^{-1} was assumed throughout the time period, based on half the subsistence catch rate in the Maldives (Hemmings *et al.* 2014). A dash (-) indicates data interpolation.

Year	Human population[1]	Derived subsistence catch (t)
1950	1,141	91.3
1951	1,121	89.7
1952	1,158	92.6
1953	1,106	88.5
1954	1,142	91.4
1955	1,028	82.2
1956-1957	-	-
1958	985	71.6
1959-1961	-	-
1962	747	59.8
1963	-	-
1964	993	79.4
1965-1966	-	-
1967	797	63.8
1968	807	64.6
1969	577	46.2
1970	680	54.4
1971	630	50.4
1972	0	0.0

[1] Source: Wenban Smith (2012)

Recreational fishing

Recreational fishing occurs in the Chagos Archipelago only in relation to two opportunities: 1) the military personnel and civilian contractors working on the US military installation on the island of Diego Garcia; and 2) recreational yachts that stop off in the Chagos Archipelago during their transit of the Indian Ocean. As (2) consists of a relatively small number of boats with small crew and relatively short stays, we focused our estimation entirely on recreational fishing by personnel on Diego Garcia. Available data on the number of people stationed on Diego Garcia is difficult to obtain, as much relates to operational security by the US military and is thus not readily accessible. However, The CIA factbook states that in 2004 about 4,000 military personnel and civilian contractors were stationed on Diego Garcia.[2] GlobalSecurity.org suggests that normally the island is home to about 1,700 military personnel and 1,500 civilian contractors, i.e., around 3,200 personnel.[3] The British Foreign & Commonwealth Office indicates that in 2012, the population of Diego Garcia amounted to 2,800 personnel.[4]

As construction of the military installation started in 1971 and major developments were completed by the early 1980s, we assumed zero military personnel or civilian contractors in 1971, increasing to 2,000 personnel by 1985 and remaining at that level to the year 2000. We then assumed an increase to 4,000 in 2001 lasting to 2009 (reflecting increased activities during the Iraq and Afghanistan wars), and a subsequent reduction to 2,800 in 2010 (Table 2).

Data made available by the British Indian Ocean Territory authority within the British Foreign & Commonwealth Office indicated the level of recreational catches for some years. We converted these into hypothetical *per capita* recreational catch rates and applied these to the assumed personnel levels on Diego Garcia to derive a total time series of estimated recreational catches from 1972 to 2010 (Table 2).

Table 2. Assumed and derived population (military personnel and civilian contractors), *per capita* recreational catch rates and total recreational catches on Diego Garcia, from first establishment of the military installation in 1972 to 2010. A dash (-) indicates data interpolation.

Year	Population	Catch rate (kg·person^{-1}·year^{-1})	Catch (t)
1971	0	0.0	0.0
1972	-	14.5[a]	2.1
1973-1984	-	-	-
1985	2,000	-	-
1986-1997	2,000	-	-
2000	2,000	-	47.5
2001	4,000	24.1[b]	96.4
2002-2009	4,000	24.1	96.4
2010	2,800	24.1	67.5

[a] Assumed *per capita* rate based on recreational catch of 28.9 t reported by the British Foreign & Commonwealth Office for latter years, here assumed to apply also as catch rate to 1972 [b] Based on recreational catch of 96.4 t reported by the British Foreign & Commonwealth Office.

[2] https://www.cia.gov/library/publications/the-world-factbook/geos/io.html [Accessed: November 12, 2012]

[3] http://www.globalsecurity.org/military/facility/diego-garcia.htm [Accessed: November 12, 2012]

[4] http://www.fco.gov.uk/en/travel-and-living-abroad/travel-advice-by-country/country-profile/asia-oceania/british-indian-ocean-territory [Accessed: November 12, 2012]

Subsistence and recreational catch composition

The taxonomic composition for the local subsistence catches as derived in Table 1 was assumed to consist of reef and reef-associated species, as it was assumed that little if any subsistence fishing opportunity in pelagic waters existed. Likely, a substantial portion of subsistence seafood was sourced by women and children engaging in reef gleaning (Chapman 1987; Des Rochers 1992; Lambeth *et al.* 2002; Malm 2009; Harper *et al.* 2013), hence our assumed catch composition reflects this activity, which is generally defined by a predominance of invertebrates (Table 3).

The taxonomic composition of the recreational catches was derived based on information in Zeller *et al.* (2005) which reconstructed recreational catches on Johnston Atoll in the Pacific, that also hosts US government installations with military personnel and civilian contractors (Table 3).

The reconstructed catch data were reconciled with data reported on behalf of the British Indian Ocean Territory (Chagos Archipelago) to the FAO, which consisted only of small tonnages of several species of scombrids and the miscellaneous category 'marine fishes nei'.

Table 3. Assumed and derived taxonomic composition of subsistence and recreational fisheries catches in the Chagos Archipelago. Subsistence catches relate to the civilian population associated with copra plantations between 1950 and 1972, while recreational catches relate to military personnel and civilian contractors associated with the US military installation on Diego Garcia (from 1972 to 2010).

Taxon	Subsistence (%)	Recreational (%)[1]
Carangidae	15	25
Scombridae	-	25
Lutjanidae	10	10
Lethrinidae	10	-
Serranidae	15	20
Cephalpods	15	0
Molluscs	15	0
Crustaceans	15	0
Others	5	20

[1] Composition modified from Zeller *et al.* (2005).

Foreign fishing

Foreign fishing in the waters of the Chagos Archipelago has occurred for a long time. These fisheries consist of mainly licensed fisheries for large pelagic species using industrial longline and purse seine gears, but also of un-monitored illegal fishing, e.g., by Sri Lankan vessels (Koldewey *et al.* 2010). Illegal catches were not estimated here, but could be significant and require urgent attention, estimation and public accounting by national and regional authorities (i.e., IOTC). Foreign, licensed large pelagic catches were deemed to be relatively well monitored and were all assumed to be reported landings. Information on catch levels by gear type are also presented in Koldewey *et al.* (2010), with clear indications that longline catches are dominated by Taiwanese and Japanese fleets, while purse seine catches are dominated by Spanish and French vessels. Here, we deem these catches to be reported as part of the FAO and IOTC datasets for the Western Indian Ocean area 51, and were not further considered. However, discarding by these gears, especially longline gears, can be significant, and also warrants closer attention and reporting by the national and regional management entities (i.e., IOTC).

Mauritian fishers are also known to fish on banks within the EEZ of the Chagos Archipelago, at least until concerns about Somali piracy developed. Catches taken by Mauritian fishers within these waters have been estimated elsewhere (Boistol *et al.* 2011). These catches amount to a few hundred tonnes per year (Boistol *et al.* 2011), and were not detailed here.

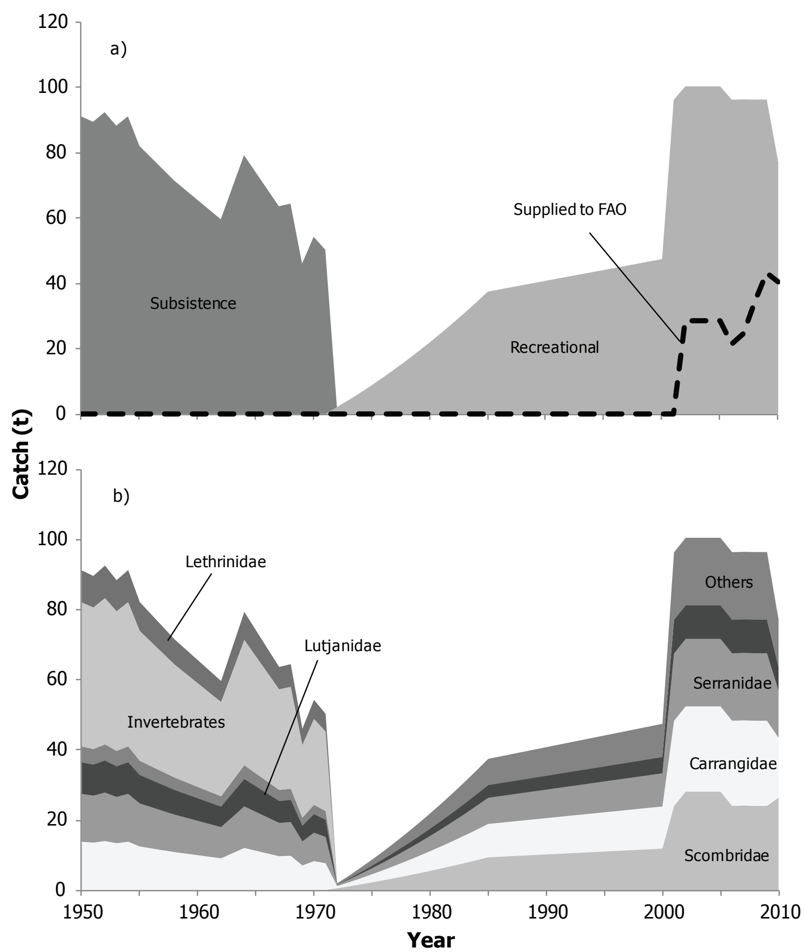

Figure 2. Reconstructed total domestic catches for the Chagos Archipelago/ British Indian Ocean Territory, showing (a) estimated subsistence and recreational catches as stacked area graph, with reported data according to FAO overlaid as a line graph; and (b) total reconstructed catches by taxon.

Results and Discussion

The catch reconstruction of what can be termed 'domestic' catches by Chagos Archipelago fisheries in the EEZ or EEZ-equivalent waters of the British Indian Ocean Territory (Figure 1) suggested that over 3,400 t were caught between 1950 and 2010, exclusively by subsistence and recreational fisheries. This contrasts with 286 t being reported by the UK on behalf of the British Indian Ocean Territory to the global community via FAO for the same time period (Figure 2a). Thus, total reconstructed domestic catches were likely around 12 times higher then reported data suggest for this time period.

These catches, however, are low compared to the large pelagic catches reported as taken by large-scale fleets from these waters, which were reported as, for example, over 20,000 t in 2004/2005, and an unknown, but potentially significant illegal catch (Koldewey *et al.* 2010). These large pelagic catches taken from the same waters by foreign vessels through licensed access agreements, or illegally, are not considered here.[5]

The present reconstruction clearly illustrates the fundamental shift from subsistence fishing by the former civilian employees associated with past plantation activities during the first two decades of the present time period, to exclusively recreational fishing by the military and civilian personnel on the only remaining inhabited island (Diego Garcia) over the more recent four decades. Subsistence catches were highest (around 90 $t \cdot year^{-1}$) at the start of the time period (early 1950s) when the largest number of employees still resided on the plantations (Figure 2a). Subsistence catches declined thereafter to 50-60 $t \cdot year^{-1}$ (Figure 2a), in line with the declining population associated with the demise of plantations in the Territory and in preparation of the de-population as part of the UK-US agreement to establish a military installation on Diego Garcia.

With the arrival of military engineers and associated personnel, followed later by civilian contractors stationed on Diego Garcia, fishing emerged as a recreational activity for residents. This suggested a gradual increase in recreational catches from around 20 $t \cdot year^{-1}$ in the early 1980s to over 40 $t \cdot year^{-1}$ by the 1990s (Figure 2a). Based on the assumption that the number of personnel stationed on Diego Garcia increased substantially with the terrorist events of 2001 and the subsequent wars in Afghanistan and Iraq, we also estimated that recreational catches likely increased to around 90 $t \cdot year^{-1}$, before declining slightly at the end of the time period due to an assumed draw-down of personnel with the approaching end of US military engagements in Afghanistan and Iraq (Figure 2a).

Taxonomically, the reconstruction suggested that besides readily caught reef fishes such as serranids, lutjanids, lethrinids and reef-associated pelagic (e.g., carangids), invertebrates dominated early subsistence catches, mainly cephalopods, molluscs and crustaceans (Figure 2b). The taxonomic composition of catches changed with recreational fishing, which likely focused more on pelagic species (i.e., reef-associated scombrids and carangids), which are known as challenging species to land on recreational rod-and-reel gears (Figure 2b).

Acknowledgements

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[5] *Sea Around Us* is reconstructing global large pelagic catches through a separate process, and the information on this topic derived through the present research, including the information on tuna catches in BIOT presented by Koldewey *et al.* (2010) will be incorporated in this separate process.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector, for Chagos Archipelago, 1950-2010.

Year	FAO landings	Reconstructed total catch	Recreational	Subsistence
1950	-	91	-	91
1951	-	90	-	90
1952	-	93	-	93
1953	-	88	-	88
1954	-	91	-	91
1955	-	82	-	82
1956	-	79	-	79
1957	-	75	-	75
1958	-	72	-	72
1959	-	69	-	69
1960	-	66	-	66
1961	-	63	-	63
1962	-	60	-	60
1963	-	70	-	70
1964	-	79	-	79
1965	-	74	-	74
1966	-	69	-	69
1967	-	64	-	64
1968	-	65	-	65
1969	-	46	-	46
1970	0.25	54	-	54
1971	0.25	50	-	50
1972	0.25	2	2	-
1973	0.25	4	4	-
1974	0.25	6	6	-
1975	0.25	9	9	-
1976	0.25	11	11	-
1977	0.25	14	14	-
1978	0.25	16	16	-
1979	0.25	19	19	-
1980	0.25	22	22	-
1981	0.25	25	25	-
1982	0.25	28	28	-
1983	0.25	31	31	-
1984	0.25	34	34	-
1985	0.25	38	38	-
1986	0.25	38	38	-
1987	0.25	39	39	-
1988	0.25	40	40	-
1989	0.25	40	40	-
1990	0.25	41	41	-
1991	0.25	42	42	-
1992	0.25	42	42	-
1993	0.25	43	43	-
1994	0.25	44	44	-
1995	0.25	44	44	-
1996	0.25	45	45	-
1997	0.25	46	46	-
1998	0.25	46	46	-
1999	0.25	47	47	-
2000	0.25	48	48	-
2001	0.25	96	96	-
2002	28.50	101	101	-
2003	28.50	101	101	-
2004	28.50	101	101	-
2005	28.50	101	101	-
2006	21.50	96	96	-
2007	24.50	97	97	-
2008	34.75	96	96	-
2009	43.25	96	96	-
2010	40.50	77	77	-

Appendix Table A2. Reconstructed total catch (in tonnes) by all taxonomic group for Chagos Archipelago, 1950-2010.

Year	Carangidae	Lethrinidae	Lutjanidae	Marine fishes nei	Scombridae	Serranidae	Invertebrates
1950	14	9	9	5	-	14	41
1951	13	9	9	4	-	13	40
1952	14	9	9	5	-	14	42
1953	13	9	9	4	-	13	40
1954	14	9	9	5	-	14	41
1955	12	8	8	4	-	12	37
1956	12	8	8	4	-	12	35
1957	11	8	8	4	-	11	34
1958	11	7	7	4	-	11	32
1959	10	7	7	3	-	10	31
1960	10	7	7	3	-	10	30
1961	9	6	6	3	-	9	28
1962	9	6	6	3	-	9	27
1963	10	7	7	3	-	10	31
1964	12	8	8	4	-	12	36
1965	11	7	7	4	-	11	33
1966	10	7	7	3	-	10	31
1967	10	6	6	3	-	10	29
1968	10	6	6	3	-	10	29
1969	7	5	5	2	-	7	21
1970	8	5	5	3	-	8	24
1971	8	5	5	3	-	8	23
1972	1	-	-	-	1	-	-
1973	1	-	-	1	1	1	-
1974	2	-	1	1	2	1	-
1975	2	-	1	2	2	2	-
1976	3	-	1	2	3	2	-
1977	3	-	1	3	3	3	-
1978	4	-	2	3	4	3	-
1979	5	-	2	4	5	4	-
1980	6	-	2	4	6	4	-
1981	6	-	2	5	6	5	-
1982	7	-	3	6	7	6	-
1983	8	-	3	6	8	6	-
1984	9	-	3	7	9	7	-
1985	9	-	4	8	9	8	-
1986	10	-	4	8	10	8	-
1987	10	-	4	8	10	8	-
1988	10	-	4	8	10	8	-
1989	10	-	4	8	10	8	-
1990	10	-	4	8	10	8	-
1991	10	-	4	8	10	8	-
1992	11	-	4	8	11	8	-
1993	11	-	4	9	11	9	-
1994	11	-	4	9	11	9	-
1995	11	-	4	9	11	9	-
1996	11	-	4	9	11	9	-
1997	11	-	5	9	11	9	-
1998	12	-	5	9	12	9	-
1999	12	-	5	9	12	9	-
2000	12	-	5	10	12	10	-
2001	24	-	10	19	24	19	-
2002	24	-	10	19	28	19	-
2003	24	-	10	19	28	19	-
2004	24	-	10	19	28	19	-
2005	24	-	10	19	28	19	-
2006	24	-	10	19	24	19	-
2007	24	-	10	19	24	19	-
2008	24	-	10	19	24	19	-
2009	24	-	10	19	24	19	-
2010	17	-	7	14	27	14	-

Reconstruction of total marine fisheries catches for Cuba (1950 – 2010)[1]

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Abstract

The reconstructed total catch for Cuba (within Cuba's EEZ) was estimated to be over 2.75 million t for the period 1950 to 2010. This is around 18 percent higher than the 2.33 million t reported by FAO on behalf of Cuba (although FAO data were adjusted to represent Cuban catches within the Cuban EEZ only). Reconstructed total catch including catch allocated to Caribbean waters outside the Cuban EEZ was estimated to be just over 3.15 million t, or 16% higher than the total landings reported for FAO area 31 on behalf of Cuba. These data include all reported commercial landings, as well as estimates of unreported catches generated from the artisanal, industrial, subsistence, and recreational sectors. Overall, catches within the EEZ peaked at over 76,700 t·year^{-1} in 1985 and have been declining ever since, with just under 28,500 t·year^{-1} in 2010. Present declines in marine catches are symptomatic of overexploitation and are of particular concern, as the fishing industry is a primary source of revenue and protein for thousands of Cubans.

Introduction

Cuba has increasingly been playing a larger role in the global seafood market as a producer of high-valued seafood (Adams *et al.* 2001; Baisre *et al.* 2003). While several policies have been introduced in recent years to address over-fishing, most of the Cuban fishery resources are considered fully- or over-exploited (Claro *et al.* 2001). The Caribbean spiny lobster (*Panulirus argus*) is the most valuable target species, accounting for about 15% of total near-shore catches and 60-65% of the national income from fisheries products (Claro *et al.* 2001; Muñoz-Nuñez 2009). The shrimp fishery is the second most valuable fishery and accounts for over 85% of the total commercial catches (Baisre *et al.* 2003). The shrimp fishery targets mainly two species, the pink shrimp (*Penaeus notialis*) and white shrimp (*P. schmitti*). Until the 1990s, the majority of Cuban fisheries were government owned and managed. The Ministry of Fishing Industries (Ministerio de la Industria Pesquera, MIP) was the authority in charge of managing marine resource use and the only authorized purchaser of commercial catches from fishers (Claro *et al.* 2001; Claro *et al.* 2009). As a result, commercial landings and fishing effort have been fairly detailed and reliably recorded (Claro *et al.* 2009).

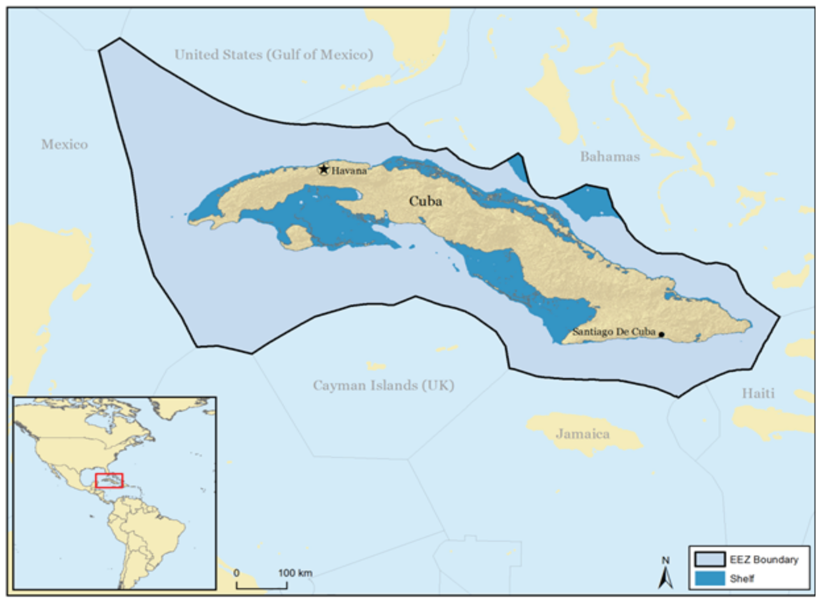

Figure 1. Cuban Exclusive Economic Zone (EEZ) and shelf area (to 200 m depth).

The Cuban Archipelago is located in the northern Caribbean Sea, adjacent to the Gulf of Mexico to the west and the Atlantic Ocean to the east (Figure 1). The mainland of Cuba is surrounded by four major groups of islands: Los Colorados, north-east of the Pinar del Rio Province; Sabana-Camagüey Archipelago, north of Matanzas, Villa Clara, Sancti Spirtus, Ciego de Avila and Camguey; Jardines de la Reina, south of Ciego de Avila and Camaguey; and Los Canarreos, south of Matanzas, Habana, and Pinar del Rio. The total land area is approximately 110,900 km^2 and the Exclusive Economic Zone (EEZ) covers an area of about 365,500 km^2 (www.seaaroundus.org, Figure 1). The coastline is marked by reefs, bays, keys and islets, while the southern coastline is dominated by swamps and lowlands. The country is divided into 14 provinces, 169 municipalities, and the Special Municipality of the Isle of Youth (www.cubadiplomatica.cu). As of 2010, the population of Cuba was over 11.2 million (WorldBank), with approximately a third of the population located along the coast. Major economic activities include the sugar agro-industry, tobacco harvest and manufacturing, nickel mining, tourism, and fishing.

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Prior to the 1960s, Cuban fisheries consisted mostly of small boats targeting near-shore, high-value species (Adams *et al.* 2001; Baisre *et al.* 2003). Support from the Soviet Union in the 1960-70s promoted the development of large, distant-water fleets that targeted low-valued stocks (Adams *et al.* 2001; Baisre *et al.* 2003). Cuban fisheries underwent a rapid growth phase which lasted until the end of the 1970s (Valle *et al.* 2011). The end of this period was marked by declines in several important commercial species in the finfish fishery (Claro *et al.* 2009). By the early 1990s, Cuban fishing efforts were curtailed as a result of the breakup of the Soviet Union (leading to an end of subsidies and cheap fuel supply) and stricter US embargo regulations (Adams *et al.* 2001; Baisre *et al.* 2003). This resulted in a reduction in distant-water landings and a return to focusing on near-shore, high-value finfish and shellfish (Adams *et al.* 2001; Baisre *et al.* 2003). In response to the economic crisis of the 1990s, the Cuban government initiated a series of reforms intended to improve efficiency and productivity of the fishing industry (Adams *et al.* 2001). This included an overall decentralization of the MIP and delegation of production activities to newly created Provincial Fishing Associations.

An earlier reconstruction of Cuba's commercial fisheries catches from 1950 to 1999 was undertaken by Baisre *et al.* (2003). Using national records obtained from the Cuban Ministry of Fishing Industries, and reported landings from FAO FISHSTAT (FAO area 31), the authors separated catches into 'inshore' (EEZ/shelf) and 'offshore' (area 31 outside of Cuban EEZ/shelf) components. In addition to this, national data on shrimp fisheries and studies on shrimp by-catch composition (Claro *et al.* 2001), were used to reassign a large portion of the 'miscellaneous' category 'marine fishes nei' to specific taxa. Overall, the reconstruction showed a rapid increase in commercial landings after 1959, peaking at 76,000 $t \cdot year^{-1}$ in 1987. Since then, landings have declined, evidence of over-exploitation of marine resources (Claro *et al.* 2004). Using the database constructed by Baisre *et al.* (2003), FAO reported landings data, and additional information obtained from published reports, here we estimated total marine catches for Cuba from 1950 to 2010. Although tuna and other large pelagic species are targeted by large scale Cuban fisheries, the catch of these species was not considered in the original reconstruction and will not be considered here either. These large-pelagic catches will be addressed in a separate global report focusing specifically on large pelagic catches by ocean basin. Therefore, in this reconstruction the following 12 species were not considered: albacore tuna (*Thunnus alalunga*), Atlantic bluefin tuna (*Thunnus thynnus*), Atlantic sailfish (*Istiophorus albicans*), Atlantic white marlin (*Kajikia albida*), bigeye tuna (*Thunnus obesus*), blackfin tuna (*Thunnus atlanticus*), blue marlin (*Makaira nigricans*), common dolphinfish (*Coryphaena hippurus*), little tunny (Atlantic black skipjack; *Euthynnus alletteratus*), skipjack tuna (*Katsuwonus pelamis*), swordfish (*Xiphias gladius*), and yellowfin tuna (*Thunnus albacares*).

Methods

Total marine catches in Cuba were estimated for the period 1950 to 2010. The original reconstruction by Baisre *et al.* (2003) was accepted as our starting point for the industrial and artisanal sectors with only minor adjustments made in order to meet the data definition requirements of *Sea Around Us*. We used FAO landings data (excluding the 12 large pelagic taxa) as our baseline for comparison and compared the database constructed by Baisre *et al.* (2003) (with our adjustments) to FAO data from 1950 to 1999. In order to extend the reconstruction to 2010, the average ratio of total reconstructed catch to reported FAO landings from 1997 to 1999 was applied to FAO landings from 2000 to 2010. Comparison of FAO landings data and information presented by Baisre *et al.* (2003) allowed us to calculate reported and unreported catches from industrial and artisanal fisheries. National records and FAO landings data do not account for catches generated by subsistence and recreational fisheries. Therefore, we used information from published reports, and assumption-based estimates to determine unreported catches generated by these sectors. Total marine catches in Cuba are equal to the sum of all reported and unreported catches from commercial, subsistence, and recreational fisheries.

Inshore and offshore catches

Baisre *et al.* (2003) separated catches from 1950-1999 into inshore (EEZ) and offshore (area 31 outside of the Cuban EEZ) components using FAO data and national records. In order to extend this to the 2000-2010 period, we determined the ratio of catches inside/outside the EEZ for species with offshore catch components in 1999, and then applied this ratio to the total catches of these species for each year between 2000 and 2010.

Industrial sector

The Cuban industrial sector includes the shrimp fisheries and associated by-catch species. Catches which had been allocated outside of the EEZ by Baisre *et al.* (2003) were also considered to be part of the industrial catch, as artisanal vessels (by definition) do not fish beyond the EEZ boundaries. However, the vessels making these catches may be considered semi-industrial by Cuban standards. Baisre *et al.* (2003) suggested that the majority of shrimp by-catch is included in the FAO data as 'marine fishes nei', as such by-catch is used for fishmeal production. The previous reconstruction provides tonnages of by-catch for the period 1969-1999. The species composition of the shrimp by-catch is summarized in Claro *et al.* (2001) and was used to derive the taxonomic breakdown for the shrimp by-catch from 1969-1999.

By-catch from 2000 to 2010

To determine the by-catch for the 2000-2010 period, the ratio of by-catch to FAO shrimp landings in 1999 was applied to the FAO shrimp landings in the following years. The resulting by-catch values were subtracted from the FAO category 'marine fishes nei', and the remaining FAO 'marine fishes nei' catches were considered artisanal. The taxonomic breakdown of the by-catch was derived using the same species proportions applied to the 1969-1999 shrimp by-catch by Baisre *et al.* (2003).

Discards

While Baisre *et al.* (2003) assumed that all shrimp by-catch was retained, landed and used for fishmeal production, here we assumed that a small portion of by-catch was likely not retained but rather discarded. These likely consisted of small hard-shelled organisms (e.g., small crabs) and other invertebrates or damaged fishes not suitable for retention and fishmeal production. Hence, we applied a conservative 2% discard rate to shrimp landings for the entire time period, which was assigned to 'Brachyura', 'marine invertebrates nei' and 'marine fishes nei' in equal proportions.

Taxonomic breakdown of the artisanal catch from 1950 to 2010

A large portion of the reconstructed catch from 1950 to 1999 was attributed to the 'marine fishes nei' category. Therefore, we used the species composition of the total catch (excluding the shrimp and associated by-catch that was deemed to be reported) each year to reassign a significant portion of the 'marine fishes nei' catch to better taxonomic resolution (i.e., family, genus or species). For the 2000 to 2010 period, we reassigned a significant portion of the FAO 'marine fishes nei' category to specific taxonomic groups using the FAO species proportions excluding the shrimp and already disaggregated by-catch. The new artisanal species proportions were then used to derive the species composition of the unreported artisanal catch for the same period.

Subsistence from 1950 to 2010

Cuban population data were obtained from Populstat (www.populstat.info) for 1950 to 1959, and from the WorldBank (data.worldbank.org/country/cuba) for 1960 to 2010 (Figure 2). Total annual coastal population was determined by applying the percent coastal population to the total population for each year. Coastal population data were known for 1990, 2000, and 2010 (CIESIN 2012). The percentages of population living on the coast were interpolated between 1990, 2000 and 2010, and the 1990 anchor point was carried back, fixed, to 1950. From 1950 to 2010, we assumed a decrease in *per capita* subsistence seafood consumption, and linearly interpolated from an assumed 2 kg·person^{-1}·yr^{-1} in 1950 to 1 kg·person^{-1}·yr^{-1} in 2010. These rates were applied to the total coastal population to determine the total subsistence catch per year. The total subsistence catch was disaggregated at the family level using the artisanal family composition for the same period, excluding catch associated with the 'Caribbean spiny lobster' and 'Stromboid conchs nei'.

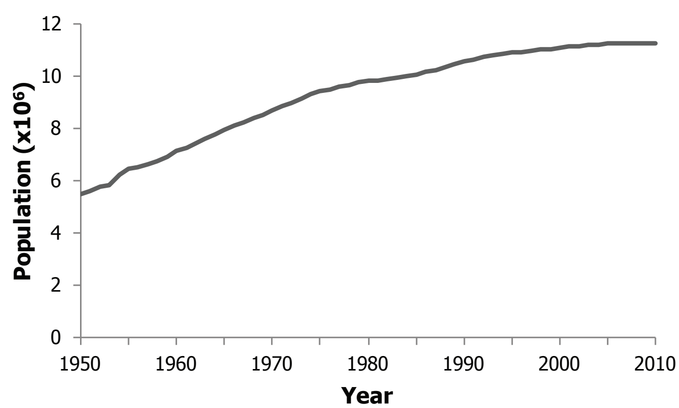

Figure 2. Population estimates for Cuba, 1950-2010.

Cuban tourism and recreational fishing from 1950-2010

There has been a rapid increase in tourist arrivals to Cuba since the late 1980s (Espino 2008). Recreational fishing is a popular attraction for tourists; however few attempts have been made to quantify the extent of recreational fishing in Cuba (Figueredo Martin *et al.* 2010). We estimated recreational catches based on the assumption that recreational fishers make up 20% of tourists arriving to Cuba. We then estimated the number of recreational fishers using available data on tourist arrivals from 1950 to 2010. Tourism data from 1950 to 1961 and 1990 to 2000 were based on estimates made by Jayawardena (2003). We assumed minimal tourist arrivals after the Cuban revolution in 1959, until around 1975 when efforts to promote the tourism industry renewed (Elliott and Neirotti 2008; Taylor and McGlynn 2009). Therefore, we set the number of recreational fishers to a very conservative zero from 1961 to 1975 and interpolated between 1975 and 1982. From 1982 to 1989 and 2001 to 2007, tourist arrivals were based on estimates made by Espino (2008). Tourist arrivals from 2008 to 2010 were obtained from the Cuban National Statistics Office (Anon. 2012). Finally, we assumed a recreational catch rate of 5 kg·recreational fisher^{-1}·year^{-1} and assigned the estimated recreational catch to four fish families commonly associated with recreational catch: Serranidae (20%), Lutjanidae (30%), Haemulidae (20%), and Scombridae (30%).

Catch-and-release has become an increasingly popular option for recreational fishers, especially if they fish in marine protected areas (Figueredo Martin *et al.* 2010). This method reduces the impact of recreational fishing on marine ecosystems and has been considered more economically and ecologically favorable compared to recreational fishing for consumption purposes. Catch-and-release is the only permitted form of fishing practiced in the Jardines de la Reina reserve. This is the largest marine reserve in the Caribbean and a popular destination for recreational fishers around the world (Figueredo Martin *et al.* 2010).

Results

Reconstructed total catch 1950-2010

The reconstructed total marine catch for Cuba within Cuba's EEZ waters is estimated to be over 2.75 million t over the 1950 to 2010 period. This is 18% higher than the amount reported by FAO (after adjustment for catches within the EEZ only; Figure 3a). Total reconstructed catch including catches allocated to outside the EEZ was estimated to be over 3.15 million t (i.e., 16% higher than the landings reported by FAO for area 31, but excluding the large pelagics).

Reconstructed total catches within Cuba's EEZ waters increased from over 10,000 t·year^{-1} in 1950 to a peak of 76,700 t·year^{-1} in 1985, and then declined to approximately 28,500 t·year^{-1} in 2010. Of the reconstructed catch, the artisanal sector constitutes 66% (1.8 million t), industrial 23% (644,500 t), subsistence 10% (268,400 t), and recreational 1% (almost 36,000 t; Figure 3a). The Caribbean spiny lobster (*Panulirus* argus) was the largest contributor, accounting for nearly 21% (571,000 t) of the total catch. This was followed by *Lutjanus synagris* (5.6%), Elasmobranchii (5.0%), Haemulidae (4.9%), *Penaeus duorarum* (4.8%), and *Crassostrea rhizophorae* (4.1%; Figure 3b).

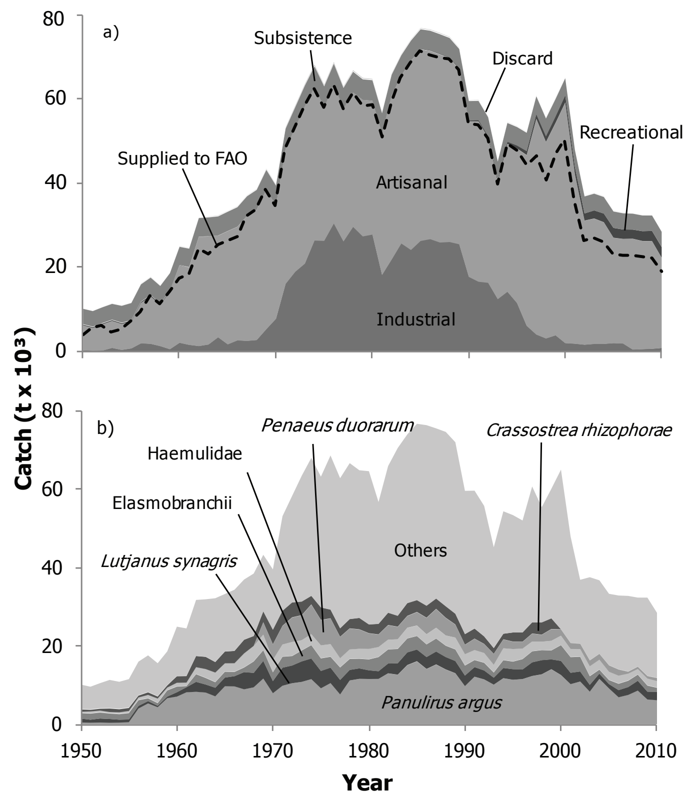

Figure 3. Reconstructed total catch by a) fisheries sector plus discards for Cuba (inside the Cuban EEZ) for 1950-2010. Note that data reported by FAO on behalf of Cuba are overlaid as line graph; and b) by major taxa with 'others' representing an additional 60 taxa.

Industrial shrimp fisheries and by-catch

Beginning in the late 1960s, estimated industrial catch, including by-catch associated with the shrimp fisheries, increased rapidly to an average of nearly 28,000 t·year^{-1} in the late 1970s. Between 1969 and 1989, industrial catch totaled 488,000 t. By the early 1990s, industrial catch began to decline, reaching 1,000 t·year^{-1} in 2010.

The total by-catch generated by the Cuban shrimp fisheries from 1969-2010 was about 442,300 t. Following 1969, recorded by-catch increased considerably to an average of almost 20,300 t·year^{-1} in the late 1970s. This was followed by a sharp drop to 13,750 t·year^{-1} in 1981 which then rose again to an average of 21,450 t·year^{-1} between 1983 and 1989. By-catch has significantly declined since the early 1990s, dropping to 265 t·year^{-1} in 2010. By-catch was largely composed of mojarras (Gerridae) including *Eucinostomus* spp. and *Diapterus rhombeus*, accounting for approximately 8% and 7%, respectively. In addition to this retained by-catch, we conservatively estimated a general discard of 3,345 t over the 1969 to 2010 time period (Figure 3a).

Artisanal fisheries

Reconstructed artisanal catch from 1950 to 2010 was just under 1.81 million t. Artisanal catch increased from less than 6,000 t·year^{-1} in 1950 to a peak of nearly 57,000 t·year^{-1} in 2000. Since the early 2000s, artisanal catches have rapidly declined to less than 21,400 t·year^{-1} in 2010. The Caribbean spiny lobster (*Panulirus argus*) contributed to the majority of the total artisanal catch, accounting for over 571,300 t (31.7%) of the catch from 1950-2010. This was followed by *Lutjanus synagris* (7.6%), Elasmobranchii (6.4%), *Crassostrea rhizophorae* (6.3%), and Haemulidae (5.5%).

Subsistence fisheries

Subsistence catches increased gradually from around 3,640 t·year^{-1} in 1950 to a peak of nearly 5,000 t·year^{-1} in 1976. It has been on a gradual decline ever since, dropping back down to 3,600 t·year^{-1} in 2010. Subsistence catches were dominated by Lutjanidae (23%), followed by Serranidae (15%), Haemulidae (10.5%), and Clupeidae (9%). Over the entire time period, catches of Serranidae exhibited a significant decrease, falling from an average of around 1,200 t·year^{-1} in the 1950s to an average of 27 t·year^{-1} in the 2000s.

Recreational fisheries

Recreational fishing averaged just over 200 t·year^{-1} from 1950-1959, dropping to a mere 4 t after the Cuban revolution. Recreational fishing was non-existent until the late 1970s, after which it increased gradually up until the 1990s. Following 1990, estimated catches increased rapidly to a maximum of 2,500 t·year^{-1} in 2010.

Discussion

The reconstructed total marine catches from 1950 – 2010 within the Cuban EEZ were estimated to be 18% higher than the amount reported by the FAO for the same time period. Our reconstruction demonstrates that, in general, commercial catches have been well reported to the FAO during this period (Figure 3a). Cuban marine catches follow a typical trend seen in many other fisheries, demonstrating a rapid growth phase followed by an over-exploited phase (Baisre *et al.* 2003). Trends in Cuba's fisheries are largely tied to the changes to its socio-economic context and its evolving management strategies.

Until the mid 1960s, there was relatively low demand for seafood products and Cuban marine resources were considered under-exploited (Claro *et al.* 2009). The period of rapid growth observed after the mid 1960s was largely fueled by economic support from the Soviet Union which promoted an increase in fishing effort and expansion of large-scale fisheries (Claro *et al.* 2009). Improvements to the organization and efficiency of the commercial fishery lead to a peak in total landings of over 76,700 t·year^{-1} in 1985 (Figure 3).

Associated with the rapid expansion of the fishing industry was a decline in several key commercial species, including Caribbean spiny lobsters, Nassau groupers, lane snappers, grey snappers, and mullets (Claro *et al.* 2009; Valle *et al.* 2011). The Caribbean spiny lobster is the most valuable commercial fishery in Cuba and is currently considered fully-exploited (Valle *et al.* 2011). Several management measures were introduced in the 1980s to address over-fishing, including a reduction in commercial fishing effort and increasing the length of the closed season. Despite these measures, we estimated a decline of 39% in spiny lobster landings from its peak in 1985 to 2010.

The decline in overall landings since the mid 1980s may be attributed to the combined effect of overfishing and habitat damage leading to a reduction in recruitment and population abundance since 1989 (Baisre *et al.* 2003; Puga *et al.* 2005). In addition to this, the end of economic support due to the collapse of the Soviet Union and tightening of US trade embargos largely impaired fishing effort after 1990. This led to reductions in commercial landings, especially also associated with distant-water fleets (Adams *et al.* 2001).

Presently, there is a lack of information available regarding fishery removals by subsistence and recreational fishing in Cuba. Catches from subsistence and recreational fisheries as estimated here accounted for only 9.8% and 1.3%, respectively, of the reconstructed catch from 1950-2010. The majority of subsistence catch is sold on the black market or used for domestic consumption, therefore these catches are not typically reflected in government landings data (Claro *et al.* 2009). Recreational fishing quotas, gear restrictions, and licenses were not introduced by the MIP until 1997, along with the establishment of the National Office of Fish Inspection (ONIP) which manages license distribution and compliance. Using anecdotal information and fishing license data obtained from the ONIP, Claro *et al.* (2004) estimated recreational catches in the Archipelago Saban-Camagüey alone to be around 1,800 t for the year 2000, which is already slightly higher than our country-wide estimate of 1,770 t.

Conclusion

The Cuban fishing industry has undergone considerable change over the past 50 years as a result of changing political environments and management strategies. By taking into account unreported catches from both commercial and non-commercial small-scale fisheries, our reconstruction provides a more comprehensive account of total marine resource use in Cuba. Several of Cuba's key commercial species are currently exploited at their maximum sustainable yield, and many are exhibiting signs of overfishing (Valle *et al.* 2011). Continued over-exploitation of marine resources will negatively impact the role of Cuban fisheries as a primary supplier of seafood to the global market and as a valuable source of domestic revenue and animal protein.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately, for Cuba, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational	Discard
1950	4,159	10,200	472	5,900	3,640	168	9
1951	5,758	9,600	351	5,410	3,690	189	7
1952	6,172	10,600	400	6,220	3,740	189	8
1953	4,591	11,400	1,020	6,400	3,750	192	20
1954	5,439	10,900	550	6,150	3,990	199	11
1955	7,266	11,600	900	6,370	4,080	214	18
1956	9,593	16,000	2,110	9,580	4,080	223	42
1957	13,204	17,600	1,990	11,210	4,130	272	40
1958	11,231	15,600	1,450	9,780	4,170	212	29
1959	14,258	18,700	718	13,540	4,210	180	14
1960	17,336	25,000	2,239	18,280	4,320	87	45
1961	18,244	24,500	1,744	18,370	4,370	4	35
1962	24,591	31,800	1,461	25,860	4,420	22	29
1963	23,157	32,000	1,830	25,610	4,480	-	37
1964	25,319	32,200	3,541	24,080	4,530	-	71
1965	26,234	33,300	1,874	26,810	4,590	-	37
1966	27,492	34,400	2,807	26,900	4,630	-	56
1967	32,271	37,000	2,690	29,580	4,670	-	54
1968	33,748	38,500	2,883	30,870	4,710	-	58
1969	38,466	43,300	5,461	33,010	4,750	-	88
1970	34,682	39,600	7,907	26,770	4,790	-	110
1971	48,207	53,200	16,177	32,030	4,820	-	132
1972	53,287	58,300	19,049	34,240	4,860	-	178
1973	58,343	63,500	20,974	37,430	4,890	-	180
1974	62,527	68,000	26,453	36,460	4,910	-	214
1975	58,144	63,200	26,368	31,780	4,920	-	182
1976	63,539	68,600	30,467	33,070	4,920	-	186
1977	57,742	62,900	26,221	31,520	4,920	43	154
1978	61,580	66,700	29,664	31,920	4,900	65	152
1979	58,189	64,900	27,430	32,340	4,880	86	140
1980	58,529	64,600	27,862	31,700	4,860	108	113
1981	50,850	56,800	18,278	33,450	4,830	129	91
1982	59,487	66,000	21,943	38,960	4,790	151	105
1983	65,107	70,600	25,749	39,790	4,760	174	90
1984	68,598	74,000	24,212	44,790	4,730	218	85
1985	71,381	76,700	26,361	45,330	4,710	243	96
1986	70,468	76,400	26,776	44,550	4,690	282	92
1987	69,920	75,600	25,988	44,510	4,680	294	95
1988	69,596	74,700	26,110	43,490	4,680	309	89
1989	66,980	72,000	25,573	41,410	4,670	326	66
1990	54,098	59,600	17,846	36,750	4,650	327	48
1991	53,756	59,700	16,705	37,880	4,620	415	57
1992	50,710	55,800	16,445	34,270	4,570	455	45
1993	39,821	45,200	12,568	27,530	4,530	544	55
1994	49,270	54,400	14,311	34,960	4,480	617	45
1995	47,912	53,400	11,635	36,570	4,430	763	37
1996	44,201	52,100	6,257	40,390	4,380	1,004	34
1997	46,632	60,700	4,190	51,020	4,320	1,170	40
1998	40,772	55,500	3,267	46,480	4,260	1,416	35
1999	47,090	60,200	4,002	50,290	4,200	1,603	59
2000	50,278	65,000	2,159	56,930	4,150	1,772	32
2001	35,816	48,000	2,017	40,060	4,100	1,775	30
2002	26,533	36,900	1,778	29,380	4,050	1,686	26
2003	26,959	37,600	1,967	29,690	4,010	1,900	29
2004	26,196	36,800	1,972	28,800	3,950	2,049	29
2005	23,085	33,400	2,150	24,950	3,900	2,319	32
2006	22,846	32,900	2,063	24,760	3,850	2,221	30
2007	22,866	32,800	631	26,240	3,790	2,152	9
2008	22,412	32,400	720	25,610	3,730	2,316	11
2009	22,387	32,400	809	25,490	3,660	2,405	12
2010	19,049	28,500	1,003	21,370	3,600	2,507	15

Appendix Table A1. Reconstructed total catches (in tonnes) by major taxonomic groups for Cuba, 1950-2010. 'Others' contain 55 additional taxonomic categories.

Year	*Panulirus argus*	Miscellaneous marine fishes	*Lutjanus synagris*	Elasmobranchii	Haemulidae	*Penaeus duorarum*	*Crassostrea rhizophorae*	Others
1950	588	14	1,001	1,390	423	-	571	6,210
1951	539	99	758	1,572	610	-	401	5,760
1952	583	91	1,014	1,534	571	-	449	6,400
1953	518	37	963	1,407	446	-	877	7,170
1954	559	25	747	1,416	539	-	763	6,880
1955	671	20	692	1,625	616	-	748	7,220
1956	4,158	47	662	1,458	732	-	471	8,560
1957	5,456	162	589	715	913	-	636	9,330
1958	4,488	102	367	692	1,194	-	505	8,390
1959	6,789	64	413	1,583	751	-	533	8,600
1960	7,190	14	1,112	1,451	993	-	1,630	12,590
1961	8,291	3	1,292	306	901	-	1,632	12,100
1962	8,409	438	2,545	1,971	1,765	-	2,806	14,290
1963	8,225	530	2,052	1,689	2,249	-	3,078	14,660
1964	7,257	412	2,199	1,424	2,454	-	2,639	16,250
1965	9,816	304	2,232	1,500	2,118	-	2,973	14,670
1966	9,788	363	2,620	1,094	2,186	-	3,107	15,600
1967	9,046	411	4,393	1,195	3,540	-	3,455	15,370
1968	9,551	312	3,699	2,929	3,890	-	2,507	15,940
1969	11,780	454	4,523	2,735	3,937	3,100	2,763	14,470
1970	8,053	549	3,097	2,261	3,186	3,900	3,684	15,400
1971	9,958	2,496	4,617	2,804	3,097	4,700	3,828	24,160
1972	10,605	3,335	4,522	2,433	3,558	6,200	3,797	27,210
1973	10,942	5,318	5,240	2,783	2,599	6,300	3,475	32,130
1974	11,633	4,736	5,282	3,432	2,744	7,500	2,202	35,240
1975	9,304	3,856	4,438	3,220	3,295	6,400	3,184	33,410
1976	10,623	4,725	3,962	2,785	3,203	6,500	2,219	39,360
1977	7,738	4,197	3,715	3,192	2,351	5,400	2,145	38,320
1978	11,309	5,243	2,694	2,811	2,411	5,300	2,355	39,820
1979	11,717	4,775	2,680	2,469	2,520	4,900	2,890	37,710
1980	11,681	5,459	2,220	2,800	2,654	3,940	2,224	39,120
1981	11,697	3,504	1,973	3,629	2,534	3,170	2,661	31,110
1982	13,133	4,519	2,507	3,606	2,455	3,670	3,124	37,460
1983	12,787	6,204	2,921	3,662	2,429	3,150	2,773	42,840
1984	15,247	6,819	3,232	3,570	2,686	2,960	3,256	43,090
1985	16,213	6,922	2,988	3,472	2,636	3,370	3,025	45,030
1986	14,248	7,319	3,040	3,252	2,550	4,140	3,062	46,100
1987	15,401	7,112	3,294	3,331	2,700	4,740	2,642	43,460
1988	14,128	7,141	3,160	2,909	2,570	4,450	2,934	44,520
1989	13,163	6,704	3,111	2,973	2,992	3,280	2,730	43,790
1990	9,861	6,116	2,705	2,571	2,876	2,380	2,667	36,560
1991	12,259	5,839	2,460	1,813	2,535	2,860	2,545	35,210
1992	11,581	5,649	2,283	1,978	2,485	2,260	1,896	33,300
1993	10,240	3,696	1,786	1,325	1,984	2,740	1,438	25,720
1994	11,888	4,914	2,609	2,007	3,013	2,230	1,407	31,260
1995	11,484	4,365	2,709	1,946	3,187	1,850	2,301	29,960
1996	11,662	3,949	2,456	2,659	2,655	1,710	2,350	28,570
1997	12,448	9,379	3,495	2,826	2,458	2,000	2,814	34,700
1998	12,878	7,882	3,621	2,563	2,129	1,730	3,121	29,420
1999	14,171	12,299	2,523	2,299	2,426	2,940	2,709	33,090
2000	12,696	12,546	3,609	4,042	2,354	1,590	-	40,750
2001	10,362	4,218	2,910	4,006	2,063	1,480	-	27,160
2002	11,035	1,184	2,569	3,770	1,952	1,310	-	16,290
2003	8,453	4,897	1,744	2,215	2,536	1,450	-	21,190
2004	11,696	3,390	1,358	1,032	2,529	1,450	-	18,740
2005	9,270	3,862	1,122	1,038	2,135	1,580	-	18,210
2006	7,024	3,872	1,821	1,638	2,089	1,520	-	18,830
2007	7,614	4,276	2,010	1,631	1,820	460	-	19,280
2008	8,717	2,894	2,514	1,584	1,451	530	-	17,590
2009	6,459	3,614	1,993	1,564	1,822	600	-	19,950
2010	6,265	1,065	2,165	1,022	1,747	740	-	16,560

Reconstruction of total marine fisheries catches for Dominica (1950-2010)[1]

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Abstract

Fisheries catch misreporting occurs world-wide, and Caribbean fisheries are no exception. Under-reporting catches may lead to erroneous expectations about trends and present or future resource levels, this must be addressed in order to create realistic national, regional or international policies. This report presents the reconstruction of total marine fisheries catches by Dominica for the period 1950-2010, which includes estimates of unreported small-scale fisheries catches. Reconstructed total domestic fisheries catches for the period 1950-2010 were estimated to be nearly 85,000 t, which is 1.8 times the official reported landings of 46,523 t as supplied to FAO. This substantially higher catch better reflects the historical importance of fisheries in meeting domestic food requirements, as well as the deficiency of the present accounting system.

Introduction

The Commonwealth of Dominica (referred to as 'Dominica' throughout this report) is located at 15 °18' N and 61° 23' W between the French islands of Guadeloupe (in the north) and Martinique (in the south) (Figure 1). It has an Exclusive Economic Zone (EEZ) of approximately 28,500 km² (www.seaaroundus.org). The rich diversity of ecosystems and wildlife has earned Dominica the title "Nature Island of the Caribbean." There are approximately 1,200 species of plants, 18 species of terrestrial mammals, 19 species of reptiles and the most diverse avifauna of the Lesser Antilles with 175 species of birds including two endemic parrots (Anon. 2001a). Originally settled by *Caribs* (Native Indians originating in South America) and visited by Christopher Columbus in 1493, Dominica went back and forth between French and British colonial rule for over a century (1627-1783; Honychurch 1995). In 1865, Dominica became a British crown colony and eventually gained independence from Britain in 1978. Since then, Dominica has experienced a relatively stable political history. The weather on the other hand, has been highly unstable. Between 1886 and 1996, Dominica experienced 59 tropical storms, of which 19 were hurricanes (Anon. 2008). These hurricanes have caused extensive damage to many of Dominica's assets, including its fisheries sector: in 1979, Hurricane David almost entirely demolished the island's fishing fleet; storms in 1996, 1997 and again in 1999 damaged coral reefs, seagrass beds, beach landing sites, and fisheries infrastructure, with estimated damages of EC$ 7.6 M (US$2.8 M; Anon. 2000).

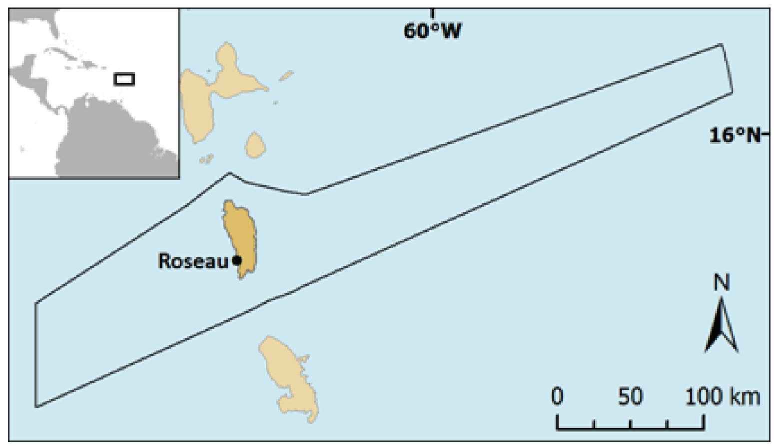

Figure 1. Extend of the Exclusive Economic Zone (EEZ) of Dominica. The inset map shows its location in the wider Caribbean region.

Human migration has been another major issue for this Eastern Caribbean island, both historically and at present. During the 1800s, many Dominicans emigrated to work in mines in Venezuela and French Guinea, and in the early 1900s to Panama to build the Canal. More recently, there have been two waves of migration from the island: from 1959 to 1962, with the majority of islanders settling in the United Kingdom, and from 1983 to 1992 to the United States. Lack of opportunity for education and employment is thought to be the major driving force behind this movement (Fontaine 2006).

Economically, Dominica's GDP per capita stands at 7,100 USD (2011 value; 73rd World position), which is approximately 2,000 USD less than the average GDP per capita of small Caribbean islands (www.data.worldbank.org). However, Dominica's eco-tourism sector may offer a brighter future as it is a growing source of revenue. Tourists are indeed attracted by Dominica's tall mountains, dense rainforests, fast-flowing rivers and waterfalls. Consequently, the Government is currently trying to revive the economic sector through promoting eco-tourism, along with developing an offshore banking sector.

Traditionally, Dominica has relied on agriculture and fishing as a means of self-sustenance. In the early 1900s, leading export crops included lime, bananas and vanilla (Fentem 1960), but the agricultural sector regularly suffered from hurricane damage and labor shortages. Thus, Dominica has always been heavily reliant on imported food

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commodities, including seafood, to meet domestic demand. The bulk of imported seafood products are in the form of salted cod from Canada (Mitchell and Gold 1983; Sebastien 2002; FAO 2011). Despite this trade reliance, small-scale fisheries in Dominica have always contributed to the food security of the island's small population (Anon. 2006a), although it appears not to be accounted for in official statistics. Here, we consider small-scale fisheries to include three sectors: subsistence, artisanal, and recreational. Subsistence fishing refers to any fishing activity that is not aimed at generating an income but at supplying necessary daily food. Artisanal fishing is on the contrary carried out with the primary aim of "fish for money", meaning that catches are usually being sold on local markets or exported. Recreational fishing refers to fishing where the main motivation is not consumption, trade or sale of the catch, but rather enjoyment.

Fishing in Dominica is largely artisanal in nature (Mitchell and Gold 1983; FAO 2002) and has been a traditional occupation for coastal inhabitants (Honychurch 1995) with many fishers operating at a subsistence (Anderson and Mathes 1985) and artisanal level. A small recreational fishing sector has developed in the last decade due to the development of the tourism sector. The artisanal sector consists predominantly of part-time fishers who operate from motorized vessels, including dugout canoes up to 6 m in length, "keel" boats which range from 4-7 m and fiber reinforced plastic vessels (FAO 2002). This fishery is seasonal, with a high season from January to June when pelagic species such as flyingfish (Exocotidae), tuna (*Thunnus* spp.), dolphinfish (*Corryphaena hippurus*) and kingfish (*Scomberomorus cavalla*) are targeted with trolling, gillnets, hand lines and beach seines, and a low season from July to December, when demersal species are targeted with handlines and fishpots (Anderson and Mathes 1985).

While there are minor reef and demersal fisheries, historically, pelagic species have been the major focus of the Dominican fisheries (FAO 1987). The island has a very narrow continental shelf, which drops very sharply into submarine valleys and canyons (FAO 2007). As a result, Dominica's nearshore waters tend to be very deep, and demersal resources such as conch (*Strombus gigas*) and lobster (*Panulirus argus*) are very limited (Mitchell and Gold 1983; FAO 2007). Fish Aggregating Devices (FAD) were introduced in Dominica in 1987, to increase catches of large migratory pelagics. However, due to the lack of knowledge about selecting mooring sites and the cost of constructing FADs, it took several training sessions by the Inter-American Institute for Cooperation on Agriculture for FADs to catch on in Dominica (Anon. 2005).

Nearshore fisheries resources are severely depleted in most Caribbean areas (Fanning *et al.* 2011) and the situation is no different in Dominica. By the mid-1980s, snappers (Lutjanidae), groupers (Serranidae), parrotfishes (Scaridae), grunts (Haemulidae) and squirrelfishes (Holocentridae) had already been overfished (Guiste and Gobert 1996) by locals and foreign fishers alike (Anderson and Mathes 1985). Illegal fishing is prevalent in Dominica, with local fishers complaining about competition from French fishers from Guadeloupe and Martinique operating without permission and using more advanced and efficient gears in Dominica's EEZ (Brownell 1978). However, Dominican fishers are also guilty of fishing illegally outside their water, at Aves Island. Aves Island, also known as Bird island, is a bird sanctuary made mostly of sand and coral (Fontaine 2002). Located 140 miles west of Dominica, the island is indeed a Caribbean dependency of Venezuela who has a coastguard station there since 1979, and to our knowledge, there is no fishing agreement between Venezuela and Dominica.

All catches of demersal and pelagic species are for local consumption (either for direct subsistence or sale at local markets), as there are no records of fish exports (Sebastien 2002; FAO 2011). Processing and marketing of catches is done by the fishers themselves, with few middlemen or vendors (Anderson and Mathes 1985). Cold storage facilities are often lacking at fishing centers and there is limited practice of drying and salting of fish (Goodwin *et al.* 1985). In 1997, the Roseau Fisheries Complex was established, with funding assistance from the Japanese Government, giving fishers a central market for dispersal of catches. Prior to this, fish was sold directly at landing sites (Anderson and Mathes 1985).

The number of people actively involved in Caribbean fisheries was estimated to be approximately 505,00 in the 1990s (Fanning *et al.* 2011). Despite the importance of fisheries in providing employment and high quality protein for the Caribbean people, the small-scale nature of fishing operations earns the sector a low ranking on government agendas. It is therefore not surprising that fisheries data collection in Dominica only began in 1986[2] and covers only major landing sites and major species landed (Guiste *et al.* 1996). Thus, several components of total fisheries removals have not been recorded. This problem is widespread, as evidenced for example for the two neighboring islands of Guadeloupe and Martinique (Frotte *et al.* 2009a, 2009b).

Using the approach as these authors, as described by Zeller *et al.* (2007), total marine fisheries catches for Dominica were reconstructed since 1950. We used the FAO Fish Stat database (FAO 2012) as reported catch baseline, as it offers the complete time series of official marine fisheries landings from 1950 to present. As this is based on national statistics supplied by each member country (Garibaldi 2012), its quality is dependent on the capacity of data collection within these countries. Due to weak institutional capacity, Dominica is one of the Caribbean islands which struggles with data collection, and therefore can only provide FAO with basic statistical data on its fishery sector. A thorough review of the Dominican fisheries literature (published and unpublished), complemented with local expert knowledge was therefore used to: (1) provide an improved, more realistic, estimate of total marine fisheries catches for Dominica for the period 1950-2010, and (2) improve the taxonomic breakdown of catches.

[2] However FAO FishStat show catches for Dominica beginning in the year 1950.

Methods

A regional nutrition survey by Adams (1992) provided a *per capita* fresh fish consumption rate which was combined with human population data for Dominica to independently reconstruct the likely total local demand for fresh fish from 1950 to 2010. Using tourism statistics on the number of stay-over tourists on the island, we estimated the tourist seafood demand from 1950 to 2010. Thus, combining local and visitor seafood demand we estimated total domestic marine fisheries extractions for Dominica from 1950-2010. Due to the lack of data, no estimate of sport-fishing was undertaken during this study.

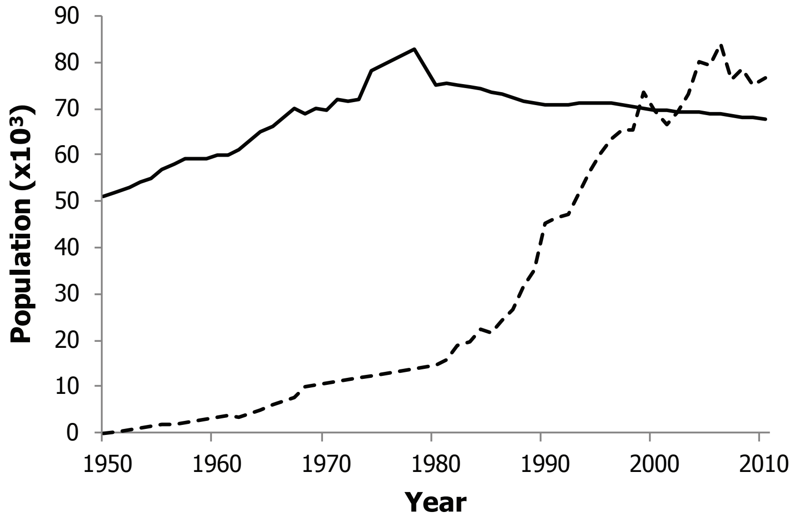

Figure 2. Local Dominican population (solid line) and number of stop-over tourist (dotted line). Note Hurricane David occurred in 1978.

Human population, numbers of fishers and tourists

Human population data were extracted from the World Bank database (data.worldbank.org). Data were available for most years, and a linear interpolation was done to estimate the population in years with missing data: 1975, 1976, 1977 and 1979 (see Figure 2). This total human population time-series was then used to estimate the number of fishers (Figure 3). There were 300 part-time fishers in 1960 (Fentem 1960), 1,700 in 1975 (Mitchell and Gold 1983) and 1,800 in 2000 (Sebastien 2002). Direct linear interpolations were used between anchor points to estimate the population of part time fishers from 1960-2000. The ratio of part-time fishers within the total population for the years 1960 and 2000 were calculated and applied to the human population for the periods 1950-1959 and 2001-2010, respectively.

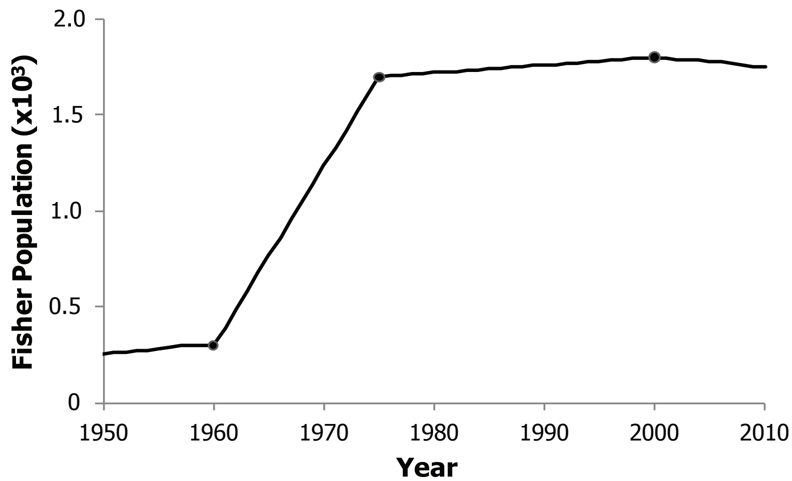

Figure 3. Number of part-time fishers in Dominica during the period 1950-2010. Solid points represent anchor points used for the interpolation (1960 from Fentem 1960; 1975 from Mitchell and Gold 1983; and 2000 from Sebastien 2002).

Data on the number of stop-over tourists (travelers who stay on the island for more than a day) were available from the Caribbean Tourism Organization (www.onecaribbean.org), the Ministry of Tourism in Dominica (tourism.gov.dm) and a case study of tourism and development in the region (Bryden 1973). Data were available for 1961-1962, 1967-1968 and 1980-2010. However we assumed tourism started in 1950, so a direct linear interpolation was done to estimate the tourist population in years with missing data.

Annual tourist population numbers were combined with data on the average length of stay of approximately 7 days (Anon. 2006b). Taken together with inferences about the frequency of seafood consumption (one serving of seafood per day) and a typical round weight serving proportion of 250 grams (determined by J. Adams regional household survey), we applied the following equation to estimate annual tourist seafood demand annually:

Small-scale fisheries

To independently estimate Dominica's total small-scale fisheries catches, we multiplied annual population numbers by 20 kg fish·person^{-1}·year^{-1}, a regional fresh fish consumption rate from (Adams 1992). This consumption rate was derived from 623 randomly surveyed households in Trinidad, Tobago, St. Vincent, St. Lucia and Belize between September 1980 and June 1981. The respondents reported serving a 250 gram portion (round weight) of fish on average 1.7 times weekly. Locally, the Dominica Food and Nutrition Council carried out a national survey of domestic food consumption patterns in 1996. The document was accessed at the local library and only contained data on the frequency of fresh fish consumption, i.e., 45% of Dominicans report eating fresh fish 2-6 times per week (Anon. 2001b). Due to the lack of detailed information in the national study, we used the regional consumption estimate (Adams 1992) and assumed that consumption rates remained constant from 1950 to 2010.

The Fisheries Division indicated that catch data recorded in the national database may include catches from subsistence, artisanal or -more dubiously- recreational[3] sectors, i.e. catch data are not easily distinguishable by sector (Derrick Theophile, pers. comm., Dominica Fisheries Division, February 2012). Thus, we assumed that reported catches consist of a mix of artisanal and subsistence catches. To assign catches to artisanal and subsistence sectors, it was assumed that in 1950, 80% of catches were from the subsistence sector and 20% were from the artisanal sector. In 2010, 50% of catches were attributed to the subsistence sector and 50% to the artisanal sector. A linear interpolation was done between these two years to derive an assignment by sector for the entire 1950-2010 time-period.

Taxonomic composition of catches

Fisheries division data for 2000 provided a breakdown of total landings by 4 fishery types : reef, deep slope, coastal and offshore (Sebastien 2002; Table 1). Based on the regional popularity of the fish pot (Munro 1983; Mahon and Hunte 2001) we assumed that 75% of reef fishery catches were made with fish pots and assigned 25% to catches made by bottom nets. For deep slope fisheries, we assumed 100% of catches were made by lines. Thus, total reconstructed catches were disaggregated by 5 fishery types: pot, net, line, coastal pelagic and offshore pelagic.

Using our knowledge on gear popularity in Dominica in the earlier and later time period, we derived a breakdown of total landings for 1950 and 2010. Given the popularity of pot fishing, hand lining and beach seining in the earlier time period (Mitchell and Gold 1983) we increased catches by these sectors in 1950, and assumed no offshore fishery was present back then. Therefore for 1950, landings by pot fishery were increased threefold to 36%, landings by nets were doubled to 8%, landings by hand lines were doubled to 12% and coastal pelagic landings were kept constant at 44%. Due to several developmental efforts in the past decade (Sebastien 2002; Anon. 2005), offshore fishing is becoming more prevalent today. Therefore in 2010, offshore pelagic landings were increased by 10% and coastal pelagic landings were decreased by 10%.

Thus, three anchor points were established for 1950, 2000 and 2010 (Table 1). Using linear interpolation between 1950, 2000 and 2010, total reconstructed catches were divided into 5 fishery types, mentioned above, for the entire time period. Finally catches were disaggregated to the family level, by applying catch compositions by fishery type from Guiste's island wide fisheries statistical analysis performed from 1990-1992 (Guiste *et al.* 1996) (Table 2).

Table 1. Status of major fisheries in Dominica with anchor points for disaggregation of catches by fishery type

Fishery type	Percentage contribution (%)[a]	Gear allocation (%)[b]	Anchor points (%)[c]	
			1950	2010
Reef fisheries	16	12 pots	36	12
		4 nets	8	4
Deep slope fisheries	6	6 line	12	6
Coastal pelagic fishery	44	44*	44	34
Offshore pelagic fishery	34	34*	0	44

[a] Based on Sebastien (2002).
[b]Assumed allocation of catch by gear type in 2000 for use in taxonomic breakdown in relation to Guiste *et al.* (1996).
[c] Percentage contribution of each fishery type based on assumptions of gear popularity in each period
* Taxonomic breakdowns for coastal and offshore pelagic catches were not broken down by gear type.

Table 2. Taxonomic breakdown (in %) applied to reconstructed catches based on Guiste *et al.* (1996).

Taxon	Common name	Pot	Net	Line	Coastal	Offshore
Acanthuridae	Surgeonfishes	2.00	-	-	-	-
Balistidae	Triggerfishes	3.00	-	9.00	-	9.00
Belonidae	Needlefish	-	-	-	1.00	-
Carangidae	Jacks	-	26.00	-	9.00	-
Carcharhinidae	Sharks	-	4.00	-	-	-
Clupeidae	Sprats	-	-	-	6.00	-
Coryphaenidae	Dolphin fish	-	-	-	-	32.00
Exocotidae	Flyingfish	-	-	-	-	21.00
	Ballyhoo	-	-	-	60.00	-
Haemulidae	Grunts	3.00	25.00	-	-	-
Holocentridae	Squirrelfishes	9.00	12.00	6.00	-	-
Lutjanidae	Snappers	12.00	12.00	45.00	-	-
Mullidae	Goatfishes	8.00	7.00	-	-	-
Muraenidae	Eels	5.00	-	-	-	-
Scaridae	Parrotfishes	8.00	-	-	-	-
Scombridae	Big eye[a]	-	-	-	0.04	0.26
	Blackfin[a]	-	-	-	0.88	5.72
	Skipjack[a]	-	-	-	1.00	6.50
	Tuna like species nei[a]	-	-	-	0.16	1.04
	Yellowfin[a]	-	-	-	1.88	12.22
	Kingfish	-	-	-	-	6.00
	Mackarel	-	-	-	17.00	-
Serranidae	Groupers	17.00	4.00	27.00	-	-
Miscellaneous	Others	33.00	10.00	13.00	5.00	6.00

[a] Guiste *et al.* (1996) provide a single 'tuna' category. The breakdown presented in this table is based on FAO data (1990-2010), i.e., the period for which Dominica reported tuna to FAO.

[3] Recreational catches were briefly assessed by telephone-interviews with 2 of the 3 tour operators operating on the island. Catches from this sector were considered minimal and were therefore not specifically assessed in this study.

Results

Reconstructed small-scale catches from the artisanal sector amounted to approximately 30,300 t over the time period. Reconstructed catches from the subsistence sector in Dominica totaled 54,600 t for the period 1950-2010. Artisanal catches supplying the tourist market totaled 2,272 t for the period 1950-2010. With an average annual catch of 37 t ·year^{-1} supplying this sector for the last decade.

Dominica's reconstructed total fisheries catches for the period 1950-2010 were estimated to be 84,900 t, which is 1.8 times the reported catch of 46,526 t as presented by the FAO on behalf of Dominica (Figure 4a). Reported landings fluctuate between a low of 400 t·year^{-1} and a high of 1500 t·year^{-1} over the period 1950-2010, with average annual reported landings of 765 t·year^{-1}. Total unreported catches for the period 1950-2010 were estimated at 38,415 t, with average annual unreported catches of 629 t·year^{-1}. There were no obvious unreported catches in three years: 1979, 1981 and 1982. The substantial decline in catches in 1979 was the result of damages from Hurricane David in August of that year (Goodwin *et al.* 1985; Anon. 2000, 2008). Thus FAO catch data were accepted as the best representation of total catches that year.

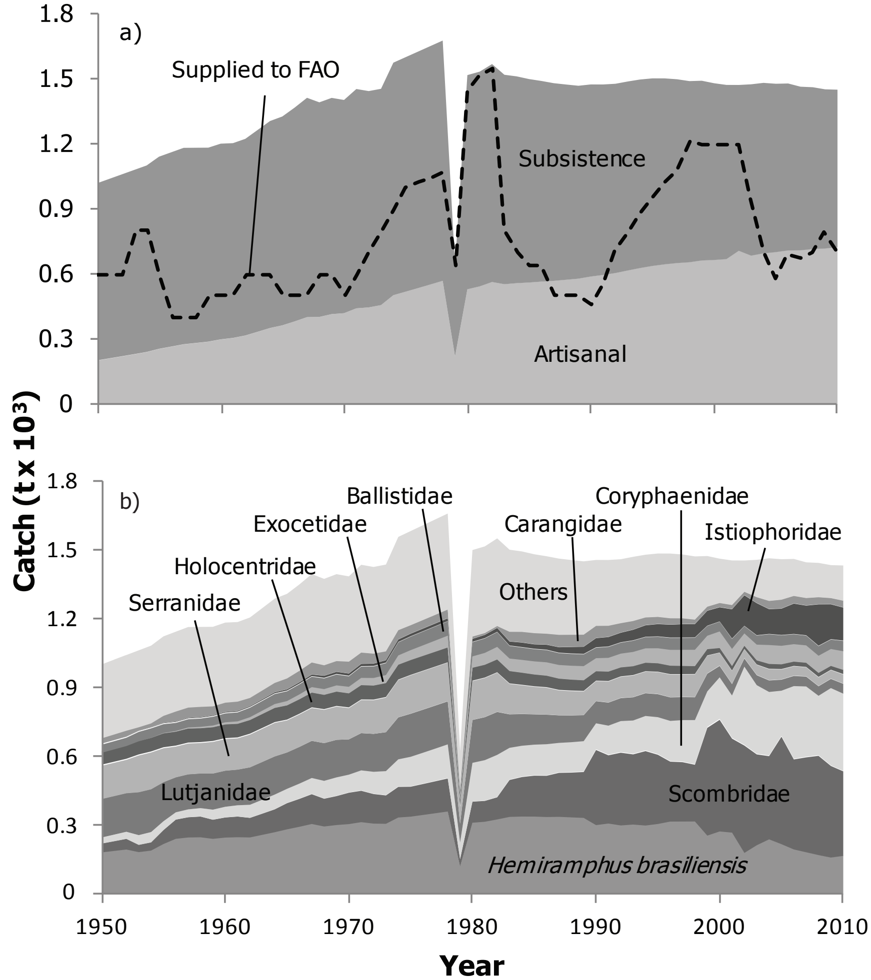

Figure 4. Reconstructed total catch of Dominica, 1950 to 2010; a) by sector with FAO reported landings overlaid as a line graph; and b) by main taxa. Note Hurricane David occurred in 1978.

Fisheries catches of Dominica were dominated by catches of ballyhoo (21% *Hemiramphus brasiliensis*) a small schooling coastal species which is commonly used as bait for catching the larger pelagic (LeGore 2007). Catches of larger migratory pelagics including 'dorado' or dolphin fish (Coryphaenidae 10%) and billfishes (Istiophoridae 5%) were important. Catches of smaller pelagics such as mackerel (Scombridae 14%), flyingfish (Exocotidae 3%) and triggerfish (Balistidae 3%) were also significant. Demersal species were also common, as was demonstrated by the importance of snappers (Lutjanidae 9%), groupers (Serranidae 8%) and squirrelfishes (Holocentridae 3%). The remainder of catches composed of 10 families and other unidentified fish species comprised 22% of the total reconstructed catch (Figure 4b).

Discussion

Traditionally, Dominicans have relied on agriculture and fishing for their food and livelihoods. It is still regarded as one of the least developed islands in the region. Tourism is a major and growing income earner for this small island developing state, and the success of the sector is based on a healthy natural environment which includes a healthy marine ecosystem.

Unfortunately, diminishing returns from agriculture on land in Dominica is transferring pressure to the sea, as is the case in Malthusian overfishing (Pauly 1994). The downturn in the banana industry resulting from Hurricane damage in the 1970s and insecure market prices in the 1990s caused farmers to move into the fishing industry as a primary source of income (Anon. 2006a). This trend possibly began even earlier, as we demonstrated the population of part-time fishers increased by a factor of 5 from 1960 to 1975. As more and more coastal inhabitants look to the sea for improved livelihoods, fishing pressure increases, as does the threat to marine biodiversity.

Dominica's total reconstructed fisheries catches for the period 1950-2010 were estimated to be nearly 85,000 t, which is 1.8 times the officially reported catch. The difference can be attributed to underreporting of small-scale fisheries, from both subsistence and artisanal sectors. This amount is substantial and shows that local fish products contribute significantly to the island's dietary requirements, something that had previously been understated in a market analysis of the sector (Goodwin *et al.* 1985). Though tourism has declined due to the global economic crisis, catches supplying visitors are important and should not be overlooked.

Our reconstruction did not estimate catches made by French fishers in Dominica's EEZ or recreational catches. Historically, the presence of French fishers (from Guadeloupe and Martinique) has been documented, but data on their effort and landings were not available (Mitchell and Gold 1983). Thus, total removals from Dominican waters are likely higher than our reconstructed estimates, which focused only on domestic catches, as foreign catches put additional pressure on local fisheries resources. The reconstruction of Dominica's fisheries can be viewed as an improvement of the data submitted to the FAO in terms of both total catch and taxonomic resolution.

Acknowledgements

This work was completed as part of *Sea Around Us*, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts. We are grateful to Mr. Norman Norris, and Mr. Derrick Theophile of the Dominica Fisheries Division for their assistance in understanding the fisheries data collection of Dominica. We would like to thank Ms. Jeanel Georges for her help in accessing documents at the local library in Dominica.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector for Dominica, 1950-2010.

Year	FAO landings	Reconstructed total catch	Artisanal	Subsistence
1950	600	1,020	204	816
1951	600	1,040	213	827
1952	600	1,061	223	838
1953	800	1,081	232	849
1954	800	1,101	242	859
1955	600	1,142	257	885
1956	400	1,162	267	895
1957	400	1,183	278	905
1958	400	1,183	284	899
1959	500	1,184	290	894
1960	500	1,203	301	902
1961	500	1,204	307	897
1962	600	1,224	318	906
1963	600	1,265	335	930
1964	600	1,307	353	954
1965	500	1,327	365	962
1966	500	1,368	383	985
1967	500	1,414	403	1,011
1968	600	1,393	404	989
1969	600	1,413	417	996
1970	500	1,403	421	982
1971	600	1,453	443	1,010
1972	700	1,445	448	997
1973	800	1,455	458	997
1974	900	1,575	504	1,071
1975	1,001	1,600	520	1,080
1976	1,024	1,627	537	1,090
1977	1,047	1,651	553	1,098
1978	1,070	1,677	570	1,107
1979	642	642	221	421
1980	1,445	1,518	531	987
1981	1,514	1,534	545	989
1982	1,545	1,569	565	1,004
1983	800	1,520	555	965
1984	700	1,512	559	953
1985	640	1,499	562	937
1986	644	1,491	567	924
1987	500	1,481	570	911
1988	500	1,474	575	899
1989	500	1,469	580	889
1990	458	1,475	590	885
1991	552	1,474	597	877
1992	711	1,478	606	872
1993	794	1,489	618	871
1994	882	1,498	629	869
1995	950	1,503	639	864
1996	1,030	1,503	646	857
1997	1,079	1,499	652	847
1998	1,212	1,491	656	835
1999	1,200	1,492	664	828
2000	1,200	1,480	666	814
2001	1,200	1,473	670	803
2002	1,198	1,472	708	764
2003	950	1,475	686	789
2004	700	1,482	697	785
2005	580	1,478	702	776
2006	694	1,479	710	769
2007	677	1,465	711	754
2008	697	1,462	717	745
2009	790	1,452	719	733
2010	700	1,450	725	725

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for Dominica, 1950-2010. 'Others' contain 10 additional taxonomic categories.

Year	Hemiramphidae	Coryphenidae	Lutjanidae	Serranidae	Scombridae	Istiophoridae	*Thunnus* spp.	Holocentridae	Exocoetidae	Balistidae	Other
1950	202	26	168	144	-	32	7	58	-	35	348
1951	208	28	168	144	-	34	9	58	1	36	353
1952	215	30	168	144	1	36	11	59	3	36	358
1953	203	42	187	159	1	22	9	59	4	41	353
1954	210	44	187	159	2	24	11	60	5	41	357
1955	239	38	170	147	3	43	17	61	7	38	379
1956	261	31	152	133	3	60	23	62	8	35	394
1957	267	34	153	134	4	61	25	62	10	36	398
1958	268	36	151	132	4	62	27	61	11	36	395
1959	261	43	157	137	5	54	27	60	13	38	388
1960	267	46	157	137	5	56	29	61	14	39	391
1961	268	49	155	135	6	56	31	60	16	39	389
1962	267	56	163	142	6	50	32	60	17	41	388
1963	279	60	164	143	7	54	35	62	19	42	399
1964	290	64	166	145	8	58	38	63	22	44	410
1965	303	62	158	139	9	68	43	63	24	43	418
1966	314	65	159	140	10	71	46	64	26	44	428
1967	326	70	161	142	11	75	50	65	28	45	439
1968	315	77	164	144	12	68	50	63	30	46	423
1969	322	80	163	144	13	70	53	63	32	47	427
1970	326	78	153	135	13	77	56	62	33	46	424
1971	334	88	162	143	14	74	59	63	36	49	433
1972	328	96	165	145	15	66	59	62	37	50	422
1973	327	105	169	149	16	59	59	62	39	52	418
1974	354	119	182	161	17	61	66	66	45	57	448
1975	358	129	187	166	18	56	68	66	47	59	448
1976	366	135	187	166	19	56	71	66	50	60	451
1977	373	141	187	166	20	57	75	66	53	61	454
1978	381	147	187	167	21	57	78	66	55	62	457
1979	140	72	83	74	6	-	27	25	22	27	166
1980	332	168	186	168	20	17	67	57	54	62	388
1981	336	176	187	169	22	14	69	57	56	63	386
1982	346	184	186	169	24	17	73	57	59	64	391
1983	357	139	145	131	24	70	84	55	59	55	401
1984	359	135	137	124	25	79	87	54	60	54	398
1985	358	133	132	118	25	82	90	52	61	53	393
1986	357	136	128	116	27	84	91	51	63	53	386
1987	357	129	119	107	28	93	95	50	64	52	387
1988	355	131	116	105	31	97	96	49	65	51	380
1989	353	133	113	102	36	99	97	47	66	51	373
1990	321	114	96	86	169	107	92	42	61	45	341
1991	328	127	100	90	138	107	94	42	64	48	336
1992	320	136	100	91	172	96	91	40	64	48	321
1993	324	146	101	93	166	94	93	40	66	49	318
1994	319	151	99	92	191	92	92	38	67	49	308
1995	326	162	100	94	172	90	94	38	69	50	308
1996	337	175	102	98	135	86	97	38	73	52	310
1997	337	181	100	96	136	84	97	37	74	52	304
1998	337	193	99	98	136	73	96	36	75	52	295
1999	275	156	77	76	374	81	81	28	62	42	239
2000	294	182	49	55	375	77	97	21	76	42	212
2001	288	185	49	55	295	142	101	21	79	43	213
2002	200	341	35	38	380	147	75	15	58	32	152
2003	233	299	43	43	269	171	97	19	73	40	189
2004	259	277	50	47	199	155	117	22	86	47	222
2005	238	198	48	43	300	167	117	22	85	46	216
2006	215	317	44	40	239	177	109	20	80	43	195
2007	203	306	43	39	261	174	108	19	80	43	189
2008	190	259	41	37	285	222	107	19	79	42	181
2009	180	337	40	37	262	187	104	18	78	41	171
2010	187	336	43	39	216	183	114	19	85	45	184

Reconstruction of total marine fisheries catches for the Dominican Republic (1950-2010)[1]

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Abstract

The reconstructed total catch for the Dominican Republic for the period 1950-2010 was estimated at almost 2.6 million tonnes, which is approximately 5.1 times the catch presented by the FAO on behalf of the Dominican Republic. Our study includes unreported catch estimates from the recreational and subsistence sectors. It also provides estimates of unreported artisanal catches satisfying tourist markets, such as hotels and restaurants. Better accounting of total fisheries extractions is urgently needed to better understand total resource use.

Introduction

The Dominican Republic shares the island of Hispaniola with Haiti. This popular tourist destination occupies 48,480 km² and lies between 19° 00' N latitude and to 70° 40' W longitude in the Caribbean. The north coast borders the Atlantic Ocean and the south coast borders the Caribbean Sea (Figure 1). It has an Exclusive Economic Zone (EEZ) of 269,285 km² (www.seaaroundus.org).

The Dominican Republic was first discovered by the Taino Indians, members of the larger Arawak group, who originated in the Orinoco-Amazon basin (Brown 1999). After being sighted in 1492 by Christopher Columbus, the first permanent European settlement was established in Santo Domingo, which is the Dominican Republic's present capital. After 300 years of Spanish, French and Haitian interludes, the country became independent in 1821. However, Dominicans experienced internal strife with American and Spanish interventions, civil wars and dictatorships. The most violent era in the country's history was almost certainly from 1930-1961, when Rafael Trujillo ruled the Dominican Republic with fear and violence. He was responsible for the deaths of thousands of Dominicans as well as Haitians; in the "Parsley Massacre" of 1937 he ordered the execution of all Haitians living along the border of the Dominican Republic. It wasn't until 1978 that the Dominican Republic successfully moved towards representative democracy.

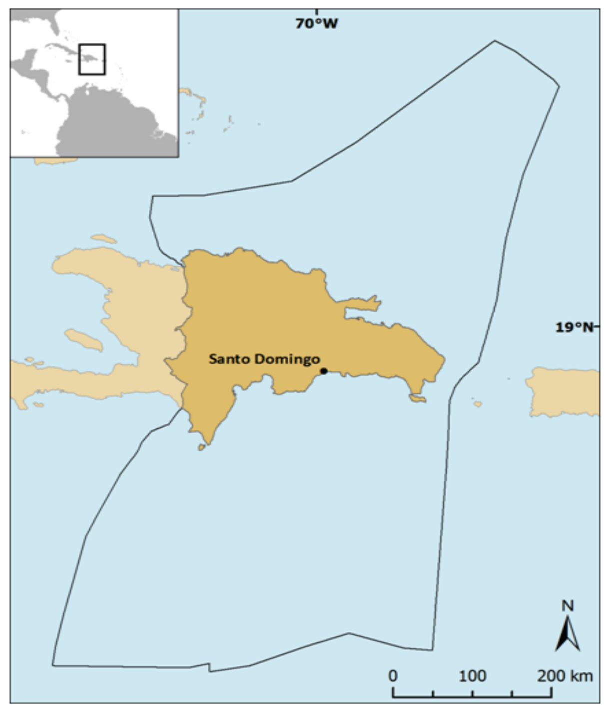

Figure 1. Map of the Dominican Republic with the black line demarcating the Exclusive Economic Zone (EEZ).

Historically, the Dominican Republic exported sugar, coffee and tobacco. However, in recent years, the service sector has overtaken agriculture as the economy's largest employer, which has been due to growth in telecommunications, tourism and free trade zones (OECD 2010). With a blend of European, African and native Taino cultures, and 1,400 km of coastline bordering the Atlantic Ocean and the Caribbean Sea, millions of tourists are attracted to the Dominican Republic each year. The Dominican tourist industry grew tremendously during the 1970s, thanks to the enactment of the Tourist Incentive Law in 1971, which provided investors a ten-year tax holiday (Malik 2001). Today, tourism accounts for 67% of its total GDP, followed by industry which accounts for 32%, of which agriculture contributes 11%. The Dominican Republic is the second largest country in the Caribbean after Cuba and has a population of 10 million people, with a tourist population that averages 4 million per year. Remittances from the US amount to about a tenth of the GDP, equivalent to almost half of exports and three-quarters of tourism receipts. However, the country suffers from marked income inequality; the poorest half of the population receives less than one-fifth of GDP, while the richest 10% enjoys nearly 40% of GDP (OECD 2010).

Fishing is and has always been important for the people of the Dominican Republic. The fisheries of the Dominican Republic are mainly artisanal and multi-gear. Fishers target more than 300 species of fishes, crustaceans, molluscs and echinoderms. Although fishing accounts for approximately 0.5% of the Dominican Republic's total GDP, fishing culture has a long history that has developed particularly rapidly in the last two decades (Herrera *et al.* 2011).

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Approximately 8,600 fishers were enumerated to be operating from 3,252 boats in the 1990 census (Anon. 2004). Boats are typically small wooden or fiberglass dinghies with an outboard engine and crews of two (Silva 1994). Fishing is carried out with more than 20 different fishing gear types, such as gillnet, line, longline, nets, and traps. Considered mainly artisanal in nature, fishers have maintained their technologies and knowledge throughout the years with little external intervention (McGoodwin 2001). Fishers land catches at approximately 200 fish landing sites among the 16 different provinces, distributed along over 1,570 km of coastline. Mangroves run along the coast for around 240 km and are considered of great economic importance, as they provide a rich habitat for marine species. Coral reefs cover several hundred square kilometers (Spalding *et al.* 2001) and approximately 48 species have been identified.

Marine species exploited in the Dominican Republic vary greatly within regions. Spiny lobster (*Panulirus argus*) is the most valued marine resource in the Dominican Republic (Anon. 2004). Also highly valuable, the queen conch (*Strombus gigas*) fishery represents 6-16% of the national fisheries value (Anon. 2004). The queen conch is linked to platform sea grass and algae areas located mostly in the south-eastern regions (Delgado *et al.* 1998). Small-scale fisheries also exploit shrimp. The shrimp fishery started in the early 1960s, when locals were forced to find alternative sources of income due to closures in train operations. White shrimp (*Litopenaeus schmitti*) is considered the prevalent species in this area and compromises 86% of total shrimp catch (Sang *et al.* 1997). Other shrimp species include pink shrimp (*Farfatepenaeus durarum*) and the Atlantic seabob (*Xiphopenaeus kroyeri*).

The coastal reef fishery takes place on the entire Dominican Republic shelf up to 30 meters of depth; here, more than 100 species are caught, with the majority being snappers (Lutjanidae) and groupers (Serranidae). This fishery is considered small-scale and is mostly directed to the local market, with a high tourist demand. There is also a semi-industrial fleet that operates year round with longline and handline gears to target snapper. Pelagic fisheries are prevalent on the south coast, and the main species targeted are tunas, mackerel (*Scomberomorus* spp.) and Atlantic sailfish (*Istiophorus albicans*). This is a seasonal small-scale fishery, which has recently developed (Anon. 2004).

Despite productive fishing grounds, and mechanised fishing fleets, fisheries production in the Dominican Republic has not been able to satisfy demand for seafood in the country. Thus, like many other Caribbean countries, the Dominican Republic imports seafood products, averaging 34,000 tonnes per year (Herrera *et al.* 2011). Most of the imported seafood is comprised of shrimp destined for touristic markets (Anon. 2010). The national data collection of the Dominican Republic consists of 282 registered inspectors, who gather data for inland and marine fisheries. Medley (2001) notes several problems in the data gathering process. First, the lack of training of the inspection personnel; second, that catch weight is estimated rather than measured directly; thirdly, that there is no systematic or standard practice implemented for the collection of data and inspection of vessel logbooks; finally, he also notes that statistical errors are not accounted for.

It is widely recognised that catch statistics are fundamental and crucial to fisheries management (Pauly 1998). Fisheries catch data for the Dominican Republic are scattered and scarce. A fishery census conducted in 1990 contains the most updated information available (Medley 2001). This study aims to gather information on fisheries catches and fishing practices to reconstruct the Dominican Republic's total fisheries catches for the period 1950-2010. The catch reconstruction method used here is based on the approach developed by Zeller *et al.* (2007) Using this well established methodology, we aim to improve the catch data both quantitatively and taxonomically.

Methods

Human population and tourist population

Local population statistics for the Dominican Republic were taken from Populstat[2] for 1950-1960 and from the World Bank3 for 1960-2010 (Figure 2). Data on coastal population (Figure 2) with urban and rural distribution were taken from the Word Bank database and were used to calculate subsistence fisheries catches and seafood demand for the period 1950-2010.

Data on the number of stop-over tourists (i.e., travelers who stay on the island for more than a day) were available from the Central Bank of the Dominican Republic.[4] Data were available from 1978-2010, although it was assumed that tourism began in 1961 (the end of the unstable Trujillo era). Setting the tourist population at zero for 1960 and utilizing the data from 1978-2010, we applied direct linear interpolation to derive a time series of the number of stop-over tourists visiting the Dominican Republic from 1961-2010 (Figure 2).

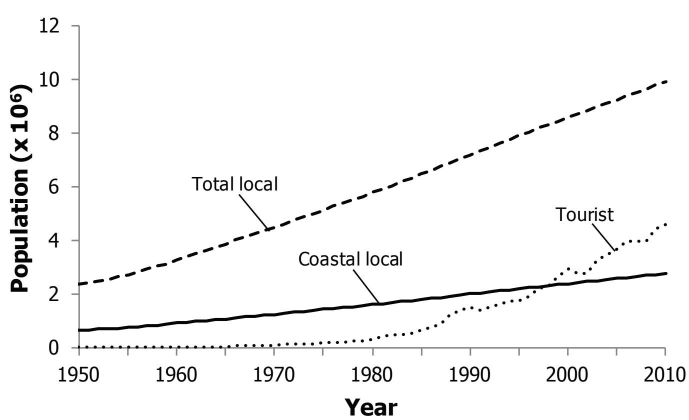

Figure 2. Total local population of the Dominican Republic (Populstat and World Bank statistics), local coastal population (WorldBank), and stop-over tourist population (Central Bank of Dominican Republic).

[2] www.populstat.info [Accessed August 23, 2012]
[3] http://data.worldbank.org/indicator/SP.POP.TOTL [Accessed September 21, 2012]
[4] http://www.bancentral.gov.do/english/index-e.asp [Accessed July 7, 2012]

Artisanal fisheries

Data on artisanal catches in the Dominican Republic were available for several years from various sources (Table 1). The most complete data series reported for artisanal fisheries in the Dominican Republic was found in Herrera *et al.* (2011), this time series included data from 1960 to 2009. Other sources, such as the ones mentioned in Table 1, were used to prove consistency. Using these data as anchor points and applying direct linear interpolation for the years with missing data, we derived a complete time series of artisanal catches for the study time period 1950-2010. The year 1960 was the first year where data were available, and we assumed a 40% increase in artisanal catches from 1950 to 1960. The reason for this is that the tourist boom started in 1960 increasing fish demand and coastal population.

Table 1. Artisanal catch (tonnes) in the Dominican Republic

Year	Artisanal catches (t)	References
1960	1,597	Herrera *et al.* (2011)
1970	4,791	Herrera *et al.* (2011)
1980	11,700	Colom *et al.* (1994)
1991	13,232	Anon. (1995)
2000	13,169	Mateo and Haughton (2004)
2004	11,093	Anon. (2004)

The data used for reconstruction purposes were national data reported by government statistics, and research thesis and NGO reports. The national data collection system captures about 60% of artisanal landings (Jeannette Mateo, pers. comm., Director of Fisheries Ministry of the Dominican Republic). Therefore, considering that 40% of the catches are not fully captured in the data collection system and standard error was not calculated in the weight of recorded catches, we applied a raising factor of 40% to the reported catch from 1950-2010.

Subsistence fisheries

Detailed data regarding subsistence fishers in the Dominican Republic were available for the local community of Buen Hombre. Buen Hombre is a small coastal fishing and farming village of about one thousand people located on the north coast of the Dominican Republic near the Haitian border (Stoffle 2001). The study was conducted in 1989 contained weekly subsistence catch rates and catch distribution information. Stoffle *et al.* (1994) reported an average consumption per household of 2.75 kg per fishing trip. According to Jeannette Mateo (pers. comm., Director of Fisheries Ministry of the Dominican Republic), it would be realistic to assume that a household goes out on one fishing trip per week. Based on government census information,[5] we assumed an average of 5 people per household, meaning each person consumes 0.55 kg·person^{-1}·week^{-1} (i.e., subsistence consumption of 28.6 kg·person^{-1}·year^{-1}). This was applied to the rural coastal population from 1950-1989. For 2010, we assumed that subsistence catch rates were 30% lower (i.e., 20.02 kg·person^{-1}·year^{-1}) and thus interpolated the rate from 28.6 kg·person^{-1}·year^{-1} in 1989 to 20.02 kg·person^{-1}·year^{-1} in 2010 (Table 2).

Table 2. Anchor points for domestic subsistence seafood consumption rates for the urban and rural populations in the Dominican Republic. Interpolation was done between anchor points.

Population	Consumption rate (kg/person/year)		
	1950	1989	2010
Urban	20.02	8.0	5.60
Rural	28.60	28.6	20.02

Urban population was assumed to be the population of Santo Domingo only, the capital of the Dominican Republic.[6] The urban population in general is assumed to consume less seafood than the rural population, as they have more access to other protein sources. For the period 1950-1989, we assumed that the urban population had a seafood consumption rate of 20.02 kg·person^{-1}·year^{-1} (i.e., 30% lower than the rate used for the coastal rural population). For the urban population in 2010, we decreased this subsistence consumption rate by an additional 30% to 14 kg·person^{-1}·year^{-1} (Table 2). In addition, it is known that imported seafood accounts for 60% of total urban consumption (Herrera *et al.* 2011). We assume that imported seafood consumption started to become important in the 1960s after supermarkets became the main source of food distribution in urban Santo Domingo. Thus, we assumed that imported seafood gradually began to constitute a greater proportion of the urban population's seafood consumption over the 1961-1980 time period, and this amount was removed for our calculations in order to establish domestically caught consumption. From 1950-1960, the consumption was stable at 20.02 kg·person^{-1}·year^{-1}. By 1970, 30% of consumption was satisfied by imported seafood, and by 1980, a further 30% came from imports (60% in total). From 1980 to 2010, the 60% of consumption that was attributed to imported seafood was kept constant and therefore our initially estimates were reduced by 60%.

Using the time series of these rural and urban subsistence seafood consumption rates rural and urban population data, we estimated subsistence fisheries catches in the Dominican Republic for the period of 1950-2010.

Industrial catches

The industrial fishery of the Dominican Republic operates year-round and takes place on the ocean banks of La Navidad and La Plata, as well as other small banks in the south. The fleet is composed of boats with decks, diesel engines, and freezing equipment, while using longline and handline as the main fishing gears. These vessels carry between 5 and 25 crew members. The species caught by the industrial fleet were described by Arima (1997, 1999). Amongst the most abundant species reported as caught are *Lutjanus vivanus, L. bucanella* and *Epinephelus mystacinus*. Although this fleet shares taxonomic affinity with parts of the artisanal fisheries, their fishing is

[5] www.one.gob.do [Accessed July 29th, 2012]

[6] Dominican Republic's demographic data. Available at: www.datamonitor.com [Accessed: June 2013]

completely separated since it is undertaken more than 90 miles from land, which makes it inaccessible to most artisanal fishers (Herrera *et al.* 2011). Arima (1999) estimates that 50% of the total catches reported for the species mentioned above are attributed to the industrial fleet. Since this is the only information we could access on industrial fisheries in the Dominican Republic, we assumed that it represented 50% of the commercial catches and that for the period 1950-2010 the total industrial catch was equal to the estimated tonnages of the artisanal catches of the taxonomic groups 'Lutjanidae' and '*Epinephelus* spp.' Herrera *et al.* (2011) estimate that industrial fisheries account for only 1% of total catches in the Dominican Republic.

Tourist sector

Investigations were done to assess the seafood sources at hotels in the Dominican Republic, which serve both imported and local seafood products on their menus. It is common for fresh seafood catches to be delivered daily by fishers directly to the hotel. Due to the fact that in these instances, fishers bypass landing sites, seafood catches supplying the tourist markets (such as hotels, guest houses and restaurants) are not accounted for and these catches were reconstructed separately. Annual tourist population data (1961-2010) were combined with data on the average length of stay, which was approximately 8.9 days according to the Caribbean Tourism Organisation. Taken together with inferences about the frequency of fresh seafood consumption (i.e., one serving of fresh seafood per day) and a typical serving proportion of 100 g (round weight), we applied the following equation to estimate tourist seafood demand annually:

Tourist seafood demand = # tourist days x average serving size x # servings/day

In this way, we were able to reconstruct small-scale catches satisfying the tourist market from 1961 to 2010.

Recreational sector

According to a global recreational study (Cisneros-Montemayor 2010), the number of recreational fishers in the Dominican Republic in 2003 was 19,863. Since sport fishing is an activity that is associated with tourism activities (Campos and Munoz-Roure 1987), we assumed all of these fishers were tourists. Therefore, by dividing the number of recreational fishers by the total number of stop-over tourists in 2003, we calculate the proportion of tourists who fish recreationally during their visit. We applied this rate of 0.006% constantly from 2003 to 2010. For the year 1961, we assumed a participation rate of 0.003% (half that of the later time period). Linearly interpolating between these two rates, we derived recreational fishing participation rates of the tourist population for the entire time period, 1961-2010. Assuming tourists are likely to participate in just one fishing tour during their stay of average 8.9 days[7] and assuming a conservative catch of 4.5 $kg \cdot tourist^{-1} \cdot year^{-1}$, we estimate catches from this sector.

Species composition

Detailed quantitative data for the taxonomic breakdown for all coastal regions of the Dominican Republic were found in PROPESCA reports for the years 1988 to 1990 and in a report by Appledoorn and Meyers (1993). In these sources, total daily catches by species were reported and classified for 12 months starting in November 1988 until November 1989. These catch amounts were turned into percentages. For all those species and families not mentioned in the above reports, but included in the FAO data, average proportions for the 1990-1995 period (the time period in which the FAO data had the greatest taxonomic disaggregation) were calculated and added to the percentage breakdown provided by the independent reports. Catches of Caribbean spiny lobster and queen conch fisheries have been (and continue to be) an important food source for locals but became even more important in the 1960s with the growth of the tourism sector (Melo and Herrera 2002). Taking the average proportional contribution of spiny lobster and queen conch to total catches in SERCM (Secretaria de estado del medio ambiente y recursos naturales [Secretariat of natural resources and environment]) catch data for 2000-2003, we then also added these two commercially important species to the breakdown. Overall proportions were re-scaled to 100% and applied constantly to the domestically consumed artisanal catches from 1950-2010 (Appendix Table A1). A slightly modified version of the artisanal breakdown (i.e., pooled to the family taxonomic level) was applied to the subsistence catches and artisanal catches for tourist consumption.

Information regarding the species composition of the recreational fishery in the Dominican Republic was not available. However, it is known that marlins (Istiophoridae), dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and tunas (Scombridae) are commonly caught species in most marine recreational fisheries. We therefore assumed equal proportionality of 25% for each of these taxonomic groups.

[7] http://www.onecaribbean.org/

Results

Artisanal catches

Reconstructed artisanal catches (including those for tourist consumption) increased steadily from 1,900 t·year^{-1} in 1950 to 6,900 t·year^{-1} in 1964, after which a series of hurricanes devastated coastal villages for 3 years, causing landings to drop slightly. Catches peaked at 40,600 t·year^{-1} in 1993 and then due to a series of unfavorable events (the economic crisis in 1990, tropical storms hitting coastal regions at the end of 1993, hurricane Hortense in 1996 and Hurricane Georges in 1998), there was a decline in catches to almost 17,300 t·year^{-1} in 1998. Another peak was reached in 2002 with just over 32,500 t·year^{-1}. The subsequent decline can be explained by the severe economic crisis that the Dominican Republic faced in 2003 (Figure 3a).[8] Total reconstructed catches from this sector were estimated to be over 1 million tonnes, which accounts for 40.5% of total catches. Of the total artisanal catch, 94% is for domestic consumption, with the other 6% contributing to tourist consumption.

Industrial catches

Reconstructed industrial catches for the Dominican Republic increased fairly steadily from 300 t·year^{-1} in 1950 to 4,400 t·year^{-1} in 1986, with catches subsequently fluctuating until 1993. After 1993, industrial catches declined to a low of 1,800 t·year^{-1} in 1998. After a short period of increase to 3,500 t·year^{-1} in 2002, catches declined to 2,100 t·year^{-1} in 2003, where they remained relatively stable up to 2010 with 2,300 t·year^{-1} (Figure 3a). Total reconstructed catches for this sector amounted to 124,500 t for the period 1950-2010, accounting for 4.9% of total catches (Figure 3a).

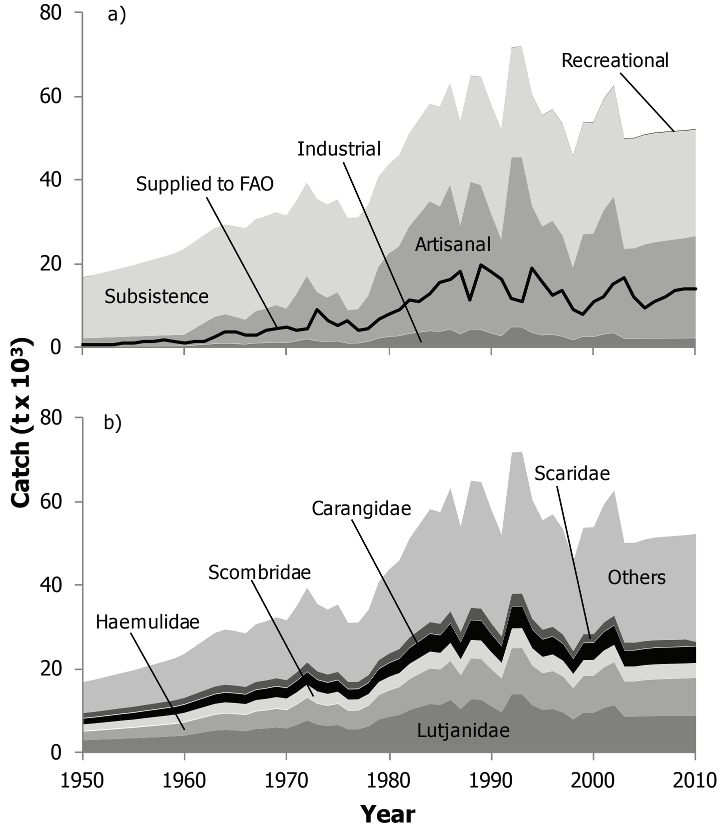

Figure 3. Reconstructed total catch for the Dominican Republic, 1950-2010, a) by sector, compared with data reported to the FAO (overlaid as solid line graph), and b) by major taxonomic categories. The 'others' category includes 100 additional taxonomic groupings.

Subsistence catches

Reconstructed subsistence catches for Dominican Republic increased steadily from 14,600 t·year^{-1} in 1950 to 25,600 t·year^{-1} in 2010 (Figure 3a). Total reconstructed catches for this sector amounted to just under 1.4 million t, which accounts for 55% of total reconstructed catches of the Dominican Republic (Figure 3a).

Tourist seafood consumption

Reconstructed seafood catches supplying tourist markets, such as hotel, guest houses and restaurants were estimated at 60,000 t for the period 1961-2010. This contributed about 2.4% to the total reconstructed catches.

Recreational catches

Reconstructed recreational catches for Dominican Republic were approximately 1,700 t from 1961-2010, accounting for only 0.07% of the total reconstructed catch (Figure 3a).

Reconstructed total catch

Total landings as presented by FAO for the Dominican Republic were 600 t·year^{-1} in 1950, steadily increasing to a maximum of 19,058 t·year^{-1} in 1994 (Figure 3a). FAO reported landings for the period 1950-2010 amounted to 503,655 t. The reconstructed total catch for the Dominican Republic for the period 1950-2010 was estimated at just under 2.6 million t, which is approximately 5.1 times that supplied to FAO on behalf of the Dominican Republic.

[8] The Dominican Republic resolving the banking crisis and restoring growth, July 20, 2004. Cato Institute Foreign Policy Briefing visited on March, 2013 http://www.cato.org/sites/cato.org/files/pubs/pdf/fpb83.pdf

Catch composition

Fisheries catches of Dominican Republic were dominated by reef and demersal species such as grey and silk snapper (Lutjanidae, 18.4%) and caesar and small grunt (Haemulidae, 14.9%; Figure 3b). Queen conch and lobster increase their importance throughout time, due to expansion of export markets and tourism. Since fishers do not discard any of their catch the species composition presents a large pool of taxa, and thus the 'others' category in Figure 3b consists of 93 additional taxonomic groups, accounting for 46.5% of the catch.

Discussion

The Dominican Republic's total catches from 1950-2010, as estimated in our reconstruction, were approximately 2.6 million t. Over the same period, FAO reported landings of only 503,656 tonnes on behalf of the Dominican Republic. Our reconstruction includes fisheries sectors that have been overlooked in other estimations, including catches from the subsistence fisheries in coastal regions and those from a popular recreational sector. Our reconstruction also improves what has been reported by the artisanal fisheries sector by filling in catches of several species that were previously recorded as zero; for instance, queen conch and Caribbean spiny lobster in the early time periods.

The difficulty of estimating total catch in the Dominican Republic is due to the dispersed nature of landing sites, as well as the multitude of gear-types employed and taxa fished. The artisanal sector in the Dominican Republic has not changed its structure since the Taino Indians; in fact, historians have found little change in the gear used by today's fishers (Chiappone 2001), although modern materials for lines and nets are being used. Thus, despite technological advances, the Dominican Republic's artisanal and subsistence fishing sectors remain relatively traditional.

In the Dominican Republic, fishes and invertebrates (lobster, conch) are critical marine resources, particularly for local communities. The most economically valuable species, specifically for tourist and export markets, are spiny lobster and queen conch. Thus, the importance of coral reef fisheries may not be so much in terms of absolute catch but in their contribution to the local income of fishers, who have few alternative opportunities for employment (Russ 1991).

Queen conch has been a principal source of food for the inhabitants of the Caribbean since at least the Taino Indians (Brownell and Stevely 1981; Appledoorn and Meyers 1993). Conch was valued as a protein source, second only to finfish in native diets during the past century. Queen conch is heavily fished throughout much of the Dominican Republic and represents the second most valuable fishery after the spiny lobster (Richards and Bohnsack 1990). In addition to the meat, the colorful shell is often sold for ornamental purposes and was once used in the manufacture of lime and porcelain (Randall 1964). Fishers in the Dominican Republic use free diving for collection of conch, and is therefore performed by artisanal and subsistence fisheries. Snappers (Lutjanidae) are also important top level predators in coral reef ecosystems and are among the most important food fishes in the tropics and subtropics (Chiappone 2001).

Catches from the subsistence sector contribute to the largest difference found in our reconstructed estimates, accounting for 55% of total catches in the period 1950-2010. Low level of development, widespread poverty, lack of basic services and infrastructure, and environmental degradation characterize the situation of many coastal communities. In these areas, large numbers of people depend on exploitation and commercialization of fisheries. In many cases, fisheries are their only source of livelihood (Mateo and Haughton 2004). Furthermore, a growing local and tourist population has increased the pressure on Dominican Republic's fisheries resources to an unsustainable level. Despite bringing much needed foreign currency to the island, the tourism sector is impacting marine resources, both through seafood consumption as well as recreational fishing. Reconstructed seafood catches supplying tourist markets such as hotel, guest houses and restaurants were estimated at 60,000 t for the period 1961-2010. This made up about 2.4% of the total reconstructed catches and should not be overlooked.

Recreational fishing is largely unreported globally. We estimated an average annual recreational fishing rate for tourists in the Dominican Republic of 35 $t \cdot year^{-1}$ since 1961. However, it was not possible to estimate recreational catches made by locals, though we know such a sector exists. Thus, it is mainly catches from the artisanal and industrial sectors that are being reported and even then only a few censuses have been conducted to determine the number of fishers. It is plainly evident that catches are missing from official reports, leaving fisheries managers with an incomplete picture of resource extraction, which can result in an overly optimistic analysis of fisheries' status.

Although assumptions were used to interpolate and infer fisheries catches, we believe that our estimate reflects more realistic levels of total catches than reported data alone (Zeller *et al.* 2007). Better accounting of total fisheries extractions is urgently needed to better understand total resource use. Given the difficulties in fisheries monitoring, especially subsistence fisheries, this can be best achieved through regular, albeit non-annual, surveys (Zeller *et al.* 2007).

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Appendix Table A1. Taxonomic breakdown for the artisanal sector in the Dominican Republic. The breakdown was based on PRODESUR (South Branch of PRODEPESCA) and Appledoorn and Meyers (1993)

	Percentage composition			Percentage composition	
Taxon name	**1950**	**2010**	**Taxon name**	**1950**	**2010**
Albula vulpes	0.37	0.37	*Agonostomus monticola*	0.01	0.01
Anguilla rostrata	0.01	0.01	Mugilidae	0.23	0.23
Anomura	0.01	0.01	Mullidae	3.96	1.00
Aulostomidae	0.06	0.06	Muraenidae	0.56	0.56
Balistidae	1.42	1.42	*Mobula* spp.	0.01	0.01
Belonidae	0.41	0.41	Myliobatidae	0.13	0.13
Brachyura	0.25	0.25	*Octopus vulgaris*	0.09	0.09
Calappidae	0.08	0.08	Octopodidae	0.08	0.08
Majidae	0.48	0.48	Ostraciidae	1.32	2.32
Caranx crysos	0.31	0.31	*Crassostrea rhizophorae*	0.06	0.06
Caranx spp.	0.31	0.31	*Panulirus argus*	1.26	1.26
Seriola spp.	0.17	0.17	Palinuridae	1.91	1.91
Trachinotus spp.	0.16	0.16	Pempheridae	0.37	0.37
Carangidae	7.36	7.36	Penaeidae	0.31	0.31
Carcharhinidae	2.02	2.02	Polynemidae	0.32	0.32
Cassidae	0.20	0.20	Pomacanthidae	0.37	0.37
Centropomus spp.	0.17	0.17	Pomacentridae	0.42	0.42
Chaetodontidae	0.30	0.30	Priacanthidae	0.42	0.42
Harengula spp.	0.18	0.18	Rajiformes	0.12	0.12
Opisthonema oglinum	0.31	0.31	Scaridae	7.28	3.28
Clupeidae	0.57	0.57	*Cynoscion* spp.	0.13	0.13
Coryphaena hippurus	0.79	0.79	*Acanthocybium solandri*	0.99	0.99
Crustacea	0.03	0.03	*Katsuwonus pelamis*	0.28	0.28
Cyprinus carpio carpio	0.63	0.63	*Scomberomorus cavalla*	1.57	1.57
Dasyatidae	0.39	0.39	*Scomberomorus regalis*	0.19	0.19
Diodontidae	1.89	2.89	*Thunnus alalunga*	0.01	0.01
Echeneidae	0.07	0.07	*Thunnus albacares*	0.11	0.11
Exocoetidae	0.01	0.01	*Thunnus atlanticus*	0.31	0.31
Fistulariidae	0.03	0.03	*Thunnus thynnus*	0.11	0.11
Gempylidae	0.02	0.02	Scombridae	7.46	5.42
Gerreidae	0.36	0.36	Scorpaenidae	0.06	0.06
Ginglymostoma cirratum	0.07	0.07	Scyllaridae	0.16	0.16
Ginglymostomatidae	3.81	3.81	*Epinephelus morio*	0.35	0.35
Haemulidae	12.32	18.00	*Epinephelus* spp.	0.19	0.19
Hemiramphidae	0.10	0.10	Serranidae	2.07	2.07
Holocentridae	1.66	1.66	*Archosargus rhomboidalis*	0.01	0.01
Istiophorus albicans	0.27	0.27	*Calamus* spp.	0.63	0.63
Makaira nigricans	0.03	0.03	Sparidae	3.58	3.58
Labridae	0.45	0.45	*Sphyraena* spp.	1.54	1.54
Loligo spp.	0.07	0.07	Sphyraenidae	0.85	0.85
Lutjanus purpureus	0.60	3.00	Sphyrnidae	0.64	0.64
Ocyurus chrysurus	0.47	0.47	*Strombus* spp.	0.17	2.01
Lutjanidae	15.57	11.00	Synodontidae	0.06	0.06
Branchiostegus spp.	0.02	0.02	Triakidae	0.11	0.11
Malacanthidae	0.02	0.02	Triglidae	0.02	0.02
Mollusca	0.04	0.04	Urolophidae	0.15	0.15
Monacanthidae	0.65	0.65	Xanthidae	0.34	0.34
			Miscellaneous marine fishes	3.16	4.81

Appendix Table A2. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector, for the Dominican Republic, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational
1950	600	16,800	300	1,900	14,600	-
1951	600	17,300	310	1,980	15,000	-
1952	600	17,900	321	2,050	15,500	-
1953	600	18,500	331	2,130	16,000	-
1954	900	19,100	341	2,210	16,500	-
1955	1,100	19,600	351	2,280	17,000	-
1956	1,300	20,400	361	2,360	17,700	-
1957	1,400	21,100	371	2,430	18,200	-
1958	1,700	21,800	380	2,510	18,900	-
1959	1,400	22,500	390	2,590	19,500	-
1960	1,100	23,600	399	2,660	20,500	-
1961	1,400	25,300	580	3,900	20,800	0.25
1962	1,400	27,000	759	5,140	21,100	0.52
1963	2,700	28,600	935	6,380	21,300	0.79
1964	3,702	29,400	1,006	6,910	21,500	1.08
1965	3,601	29,100	926	6,420	21,700	1.38
1966	2,901	28,500	829	5,800	21,900	1.70
1967	2,804	30,700	1,085	7,620	22,000	2.02
1968	4,202	31,400	1,149	8,120	22,100	2.36
1969	4,502	32,400	1,252	8,890	22,200	2.71
1970	5,002	31,600	1,137	8,150	22,300	3.07
1971	4,103	35,100	1,561	11,210	22,300	3.44
1972	4,602	39,500	2,088	15,030	22,400	3.83
1973	8,901	35,600	1,598	11,620	22,300	4.22
1974	6,448	34,200	1,430	10,500	22,300	4.63
1975	5,243	35,400	1,580	11,650	22,200	5.05
1976	6,390	31,000	1,048	7,860	22,100	5.31
1977	4,187	31,100	1,073	8,100	21,900	5.57
1978	4,431	34,100	1,451	10,920	21,800	5.83
1979	6,729	40,900	2,267	17,030	21,600	6.67
1980	8,032	43,800	2,628	19,840	21,300	7.59
1981	8,981	46,000	2,802	21,310	21,800	9.08
1982	11,391	51,200	3,343	25,520	22,300	9.82
1983	10,803	54,700	3,677	28,200	22,800	10.44
1984	12,783	58,300	4,006	30,920	23,400	11.87
1985	15,631	57,600	3,834	29,870	23,900	14.15
1986	16,087	63,300	4,405	34,500	24,400	16.25
1987	18,231	54,100	3,248	25,900	24,900	19.92
1988	11,421	65,100	4,403	35,210	25,400	25.01
1989	19,772	64,800	4,279	34,550	26,000	27.71
1990	18,189	58,200	3,480	28,540	26,100	30.09
1991	16,106	52,200	2,787	23,100	26,300	27.53
1992	11,816	71,900	4,934	40,540	26,400	33.54
1993	10,820	72,100	4,904	40,620	26,500	36.26
1994	19,058	60,600	3,586	30,330	26,600	39.33
1995	15,768	55,600	3,001	25,920	26,700	43.82
1996	12,606	57,100	3,122	27,190	26,700	48.14
1997	13,468	53,500	2,686	24,020	26,700	56.00
1998	9,076	45,900	1,841	17,260	26,700	59.23
1999	7,804	53,800	2,653	24,420	26,700	68.97
2000	10,828	54,000	2,623	24,600	26,700	78.32
2001	12,059	59,500	3,206	29,560	26,600	76.73
2002	15,159	62,700	3,544	32,540	26,600	75.75
2003	16,591	50,200	2,169	21,430	26,500	89.51
2004	12,243	50,200	2,153	21,560	26,400	94.10
2005	9,499	51,000	2,211	22,400	26,300	100.66
2006	11,045	51,500	2,232	22,940	26,200	108.14
2007	12,228	51,700	2,252	23,260	26,100	108.53
2008	13,674	51,900	2,271	23,560	25,900	108.54
2009	13,801	52,100	2,291	23,890	25,800	108.88
2010	14,140	52,300	2,310	24,320	25,600	112.49

Appendix Table A3. Reconstructed total catch (in tonnes) by major taxa for the Dominican Republic, 1950-2010. 'Others' contain 93 additional taxonomic categories.

Year	Lutjanidae	Haemulidae	Scombridae	Carangidae	Scaridae	Others
1950	3,020	2,030	1,750	1,350	1,200	7,440
1951	3,100	2,110	1,800	1,390	1,220	7,660
1952	3,200	2,200	1,850	1,440	1,250	7,930
1953	3,300	2,290	1,910	1,490	1,280	8,200
1954	3,400	2,380	1,960	1,540	1,310	8,490
1955	3,490	2,470	2,010	1,580	1,340	8,740
1956	3,610	2,580	2,080	1,640	1,380	9,080
1957	3,720	2,680	2,140	1,700	1,410	9,390
1958	3,830	2,790	2,210	1,750	1,440	9,720
1959	3,950	2,910	2,280	1,810	1,470	10,050
1960	4,130	3,080	2,380	1,900	1,530	10,570
1961	4,530	3,300	2,490	2,020	1,620	11,330
1962	4,920	3,530	2,600	2,130	1,700	12,090
1963	5,300	3,750	2,700	2,240	1,770	12,850
1964	5,470	3,880	2,760	2,300	1,800	13,230
1965	5,340	3,860	2,730	2,280	1,770	13,080
1966	5,170	3,830	2,700	2,250	1,720	12,850
1967	5,690	4,130	2,830	2,390	1,820	13,870
1968	5,830	4,240	2,870	2,440	1,840	14,190
1969	6,040	4,400	2,920	2,500	1,870	14,650
1970	5,820	4,330	2,870	2,460	1,810	14,310
1971	6,660	4,800	3,070	2,680	1,970	15,940
1972	7,690	5,380	3,320	2,970	2,170	17,940
1973	6,720	4,920	3,070	2,710	1,950	16,180
1974	6,370	4,780	2,980	2,630	1,860	15,590
1975	6,650	4,970	3,040	2,710	1,900	16,170
1976	5,580	4,430	2,770	2,420	1,660	14,160
1977	5,600	4,470	2,760	2,420	1,650	14,230
1978	6,310	4,890	2,920	2,620	1,770	15,650
1979	7,880	5,820	3,280	3,050	2,060	18,790
1980	8,550	6,240	3,430	3,240	2,170	20,180
1981	8,980	6,580	3,560	3,390	2,250	21,210
1982	10,120	7,350	3,870	3,740	2,460	23,690
1983	10,850	7,880	4,070	3,980	2,590	25,370
1984	11,570	8,430	4,280	4,220	2,720	27,070
1985	11,320	8,400	4,250	4,190	2,660	26,780
1986	12,530	9,260	4,570	4,570	2,870	29,510
1987	10,340	8,040	4,070	3,980	2,450	25,200
1988	12,710	9,660	4,690	4,720	2,880	30,430
1989	12,550	9,690	4,680	4,710	2,830	30,350
1990	11,000	8,800	4,320	4,280	2,520	27,250
1991	9,630	8,000	3,980	3,890	2,240	24,440
1992	13,900	10,910	5,030	5,190	3,000	33,870
1993	13,860	11,000	5,030	5,200	2,960	34,010
1994	11,280	9,380	4,410	4,460	2,470	28,550
1995	10,150	8,720	4,140	4,140	2,250	26,230
1996	10,400	8,990	4,200	4,240	2,270	26,960
1997	9,580	8,510	4,010	4,010	2,100	25,280
1998	7,910	7,420	3,610	3,510	1,790	21,640
1999	9,540	8,670	4,020	4,040	2,050	25,520
2000	9,510	8,740	4,020	4,050	2,020	25,620
2001	10,630	9,640	4,280	4,410	2,180	28,340
2002	11,270	10,190	4,420	4,630	2,250	29,970
2003	8,600	8,310	3,790	3,810	1,800	23,890
2004	8,570	8,360	3,780	3,810	1,770	23,950
2005	8,690	8,540	3,810	3,870	1,760	24,370
2006	8,740	8,660	3,820	3,900	1,740	24,630
2007	8,750	8,740	3,810	3,910	1,720	24,780
2008	8,750	8,820	3,800	3,920	1,690	24,900
2009	8,760	8,890	3,780	3,930	1,660	25,030
2010	8,780	8,980	3,780	3,950	960	25,880

The catch of living marine resources around Greenland from 1950 to 2010[1]

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Abstract

The catches of marine living resources taken in Greenland's waters are estimated from 1950 to 2010, including estimates of discards, unreported commercial catch and subsistence catch. Reconstructed total catch by Greenland in its own waters is just over 7 million t, which is around 30% higher than the 5.5 million t of landings reported by FAO and ICES on behalf of Greenland. The commercial fisheries make up the majority of the total catch, with the industrial sector representing 61% and the artisanal sector representing 37%. Unreported subsistence catches contribute 141,000 t to the time series and represent only 2% of the total catch. Atlantic cod (*Gadus morhua*) is the most important species in the subsistence sector, representing 56% of that catch. The northern prawn (*Pandalus borealis*) represents 54% of the total reconstruction and is the greatest single species contribution. The discrepancies between the reported baseline and the reconstructed catch are mostly due to discards in the commercial fisheries, which represent 20% of the total reconstruction. Overall, Greenland's catches in its own waters are estimated to have increased from 29,000 t in 1950 to 202,000 t in 2010, but this still only accounts for less than half the annual catch taken from Greenland waters due to large catches by foreign vessels. Together, catches reported by foreign vessels and the reconstructed domestic catches increased from approximately 208,000 t in 1950 to 482,000 t in 2010. The Marine Trophic Index for the foreign and domestic catches declined by 0.26 t·trophic level per decade, and is the largest decline noted for this index due to the fishery changing from one primarily targeting Atlantic cod to one targeting shrimp. The mean maximum lengths of the marine living resources in the catch also declined with fisheries having a mean decline of 18.0 cm per decade, and a downward trend is noted for marine mammals and seabirds, as well. The catch of seals, narwhal and harbour porpoises has been increasing, but the catch of beluga whales has declined, and the population size is of concern. There has also been a steep decline in the number of seabirds caught since 1993 with an approximate 5-fold drop in the number of thick-billed murres caught.

Introduction

Greenland is the third largest country in North America, and its coastline spans the Arctic Sea, the Northeast Atlantic and the Northwest Atlantic (Figure 1). Currently, Greenland's economy is highly dependent upon commercial marine fisheries, mining, tourism, as well as transfer payments from Denmark. Being mainly an Inuit culture, there is also a high dependence on living marine resources including fish, marine mammals and seabirds for local consumption. Since 1950, the people of Greenland have shifted from a subsistence-based economy to a mixed economy, and as they have undergone this transition, there have also been changes in the use of living marine resources. Here, I use reported catches of fisheries, marine mammals, and seabirds and add estimates of unreported catches to examine the change in living marine resource use in Greenland from 1950 to 2010.[2] Reported catches by foreign fishing fleets area also included because of their importance throughout the time period.

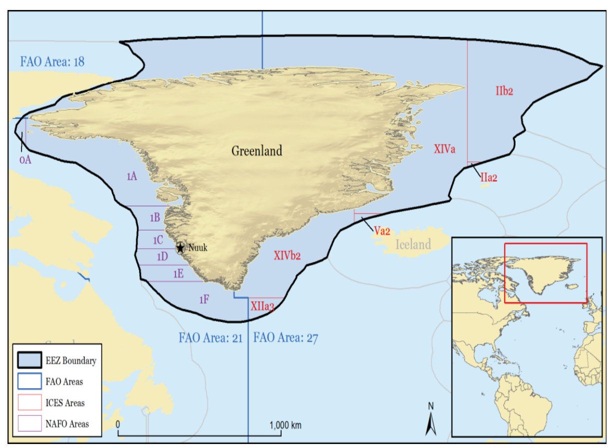

Figure 1. Exclusive Economic Zone (black line), and FAO areas (solid blue line), ICES areas (solid red line) and NAFO areas (purple lines) of Greenland. Greenland's fisheries occur in NAFO area 1 within FAO area 21, and in ICES area XIV within FAO area 27. Currently no fisheries occur in the Arctic (FAO area 18).

Similar to Canada's east coast, the commercial fishery switched from one concentrated on Atlantic cod (*Gadus morhua*) to one primarily targeting northern shrimp (*Pandalus borealis*) during the 1990s, as a result of overfishing and poor cod recruitment linked to decreasing ocean temperatures (Hamilton *et al.* 2003).

Whaling of large cetaceans continues as part of the Aboriginal Subsistence Whaling program of the International Whaling Commission with minke whales being numerically most important. Small mammals, especially ringed seals (*Pusa hispida*), beluga (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*) are culturally important, but the current population status of belugas within Greenland are of concern—the population is estimated to be 22%

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[2] For database purposes of the *Sea Around Us*, marine mammal and seabird catches are not considered.

of the size it was in 1954 and they are no longer found in many areas where they were previously harvested (Alvarez-Flores and Heide-Jørgensen 2004). Several species of seabirds are still hunted and eggs are collected for personal use; this has detrimental effects on some seabird's populations, such as thick-billed murres (Christensen 2001).

Currently, fisheries and the fish processing sector account for approximately 92% of exports and 25% of employment, making it the key driving force of the economy (Anon. 2005). Greenland changed from a hunting economy, targeting mainly seals, to a fishing economy in the early 1900s, primarily targeting cod when it became apparent that hunting could no longer support the rapidly growing population (Mattox 1971). More recently, Greenland became reliant on earnings from the shrimp fishery. Cod became more abundant from 1917 due to increasing ocean water temperatures. However, this also adversely affected seal hunting because of changes in climatic conditions that affected the occurrence and extent of pack ice—seals are more abundant when there is heavy pack ice. The seal hunt off Newfoundland may also have decreased the numbers migrating to Greenland's waters after the breeding season (Mattox 1971). More recent research has shown that the climatic conditions are linked to changes in the North Atlantic Oscillation Index and atmospheric pressure fields that affect recruitment and population levels of some of the main commercial species (Buch *et al.* 2004). Thus, over the past 100 years, there has been a transition from hunting to fishing, and then to shrimping because of human population growth, climatic fluctuations affecting marine animal populations, and overexploitation.

In addition to reported catch, estimates of unreported catches of marine resources are included here, as they are not generally accounted for in reported statistics. The responsible and sustainable use of living marine resources is paramount for Greenland since it is the only renewable resource that it can depend on. The Marine Trophic Index (MTI) is used as an index to account for changes in the mean trophic level of fisheries landings through time (Pauly *et al.* 1998). In the case of Greenland, there should be a sharp signal because of the noted transitions in fisheries abundance and use. In order to note changes in the use of the other living marine resources used, we also look at the change in the mean maximum length of the resources used.

Methods

Fisheries related data include reported landings from the International Council for the Exploration of the Sea (ICES 2011), the United Nations Food and Agriculture Organization (FAO 2012), and the Northwest Atlantic Fisheries Organization (NAFO 2011). Data from ICES are used for the east coast of Greenland, while for the west coast, FAO data are used. For foreign fleets fishing in the waters of West Greenland, NAFO data are used. Marine mammal data include reported data from a variety of publications, estimates of struck and lost animals, as well as unreported catches. For seabirds, we rely upon the reported catch data that have been collected since 1993—this is known to be an underestimate because it does not include illegal catches (Christensen 2001), or estimate of struck and lost birds.[3]

Human population data

We used human population data with regional consumption rates to estimate subsistence fisheries catches. Total population data for Greenland are available for the years 1951, 1956, and continuously since 1961, and also for each community since 1977 from Greenland's national statistics office (Statistics Greenland 2011). We interpolated between years to estimate the human population for years with no data, and used the annual predicted change from 1951-1956 to estimate the total population in 1950. To estimate the population in each region for the pre-1977 period, we used data in Mattox (1971) who describes the population of west Greenland in 1960 and for all of Greenland in 1966. We assigned each community to its current municipality in order to estimate each municipality's proportion of the total population in 1966. Since data for east and north Greenland are missing in 1960, we assumed that these areas represented the same proportion of the 1966 municipal population. We interpolated between the estimated proportions between 1960 and 1966, and to the ones reported in 1977. Prior to 1960, we assumed that each municipality's proportion of Greenland's total population was the same as in 1960.

Commercial fisheries

Commercial fisheries in Greenland, as in other northern countries, are dependent on only a few species. Targeted fisheries include those for Atlantic cod (*Gadus morhua*), northern shrimp (*Pandalus borealis*), Greenland halibut (*Reinhardtius hippoglossoides*), beaked and golden redfish (*Sebastes mentella*, and *S. norvegicus*), capelin (*Mallotus villosus*), lumpfish (*Cyclopterus lumpus*), and arctic charr (*Salvelinus alpinus*). In the past, the salmon (*Salmo salar*) driftnet fishery was also of importance, but with the Atlantic-wide decline of this species, the Organization of Fishermen and Hunters in Greenland received monetary compensation and agreed to suspend the commercial fishery and only fish for subsistence purposes (Chase 2003). Two invertebrates, the Iceland scallop (*Chlamys islandica*) and queen crab (*Chionoecetes opilio*), are also targeted in directed fisheries. Main bycatch species from targeted fisheries include Greenland cod (*Gadus ogac*), wolffishes (*Anarhichas lupus* and *A. minor*), and haddock (*Melanogrammus aeglefinus*) from the cod directed fishery (ICES 2009). Atlantic halibut (*Hippoglossus hippoglossus*) was also treated as a bycatch species, although currently part of the longline fleet does target them occasionally (Riget and Boje 1988; ICES 2009), but total landings for this species are very low.

[3] For the purposes of the *Sea Around Us* and the global database of reconstructed fisheries catches, marine mammal and seabird data were not used.

Fisheries landings data by weight are available from ICES and FAO for the period 1950-2010, but we treated the 2010 data as preliminary, and extend the data from 2009 forwards one year. These data were used as reported landings for all species, except for the fishery for Atlantic cod, northern shrimp, scallop, and wolffishes. For the Atlantic cod fishery, we relied on data provided by Horsted (2000) who provides a complete history of the fishery from 1911 to 1995; thereafter, we used the data reported by FAO and ICES. For shrimp, we relied on data from Hvingel (2001) who reviews the fishery from 1970 to 2001, and on the update from Arboe and Kingsley (2010). For the scallop fishery, we used data from Pedersen (1994) for 1984-1991 and Siegstad (2000) for 1999. For the wolffish fishery, we relied on data from Smidt (1981) for 1950 to 1979. Each of these studies has detailed accounts during the respective time periods. For salmon, data from ICES (Anon. 2010) are used because catches are reported from both coasts.

The commercial fisheries in Greenland are reported as being caught in either 'inshore' or 'offshore' waters based on distance from shore and vessel size classes (Statistics Greenland 2011). Offshore vessels (75 GRT) can only operate in waters 3 nm from shore, whereas the inshore fleet (75 GRT) is largely confined to waters within 3 nm from shore; however, some of the larger vessels of the inshore fleet operate in the offshore areas. Here, for convenience, inshore fisheries are considered to be part of the small-scale artisanal fleet, and offshore is considered to be large-scale industrial. Catches taken by foreign vessels in Greenland's waters (all deemed large-scale, industrial) are those reported to NAFO and ICES, and do not include estimates of unreported catches.

Industrial and artisanal IUU catches

Illegal, Unreported and Unregulated (IUU) commercial catches taken by Greenland include estimates from the Greenland shark (*Somniosus microcephalus*), arctic charr, and Atlantic halibut fisheries prior to them being reported to FAO or ICES, as well as some minor positive adjustments made to the reported data for Atlantic salmon (*Salmo salar*) and redfishes (*Sebastes* spp.). Export data from Mattox (1971) were used to estimate catches of arctic charr from 1950 to 1966, Atlantic halibut for 1953-1962, and Greenland shark from 1950-1969. Data are reported by ICES and FAO for arctic charr and Atlantic halibut in later years, but for Greenland shark, we assumed that the fishery ended in 1969 because the two main products, shark skins and liver oil, were in sharp decline by 1966, a result of low demand (Mattox 1971).

Discards

Discards from both the industrial and artisanal sectors were estimated for all targeted fishery species. Discard rates were applied to the reported commercial landings of targeted species to estimate the amount of discards by weight (Table 1).

Table 1. Discard rates applied to reported fisheries landings to estimate discards (by weight).

Common name	Discard rate	Sector	Source
Arctic charr[1]	0.050	Artisanal and Industrial	Kelleher (2005)
Atlantic cod	0.304	Industrial	Riget and Hovgård (1991)
Atlantic cod	0.172	Artisanal	Riget and Hovgård (1991); Kelleher (2005)
Blue whiting[2]	0.013	Artisanal and Industrial	Kelleher (2005)
Capelin[3]	0.010	Artisanal and Industrial	Kelleher (2005)
Atlantic herring	0.100	Artisanal and Industrial	Kelleher (2005)
Greenland halibut[4]	0.033	Artisanal and Industrial	Kelleher (2005)
Iceland scallop[5]	0.264	Artisanal and Industrial	Kelleher (2005); Garcia *et al.* (2006)
Lumpfish[6]	0.231	Artisanal and Industrial	Kelleher (2005)
Queen crab[7]	0.167	Artisanal and Industrial	Kelleher (2005)
Redfish[8]	0.077	Artisanal and Industrial	Kelleher (2005)

[1] Discard rate as average of Norway's coastal line caught fish and gillnet; [2] average of Norway and Iceland; [3] average of Norway's pelagic trawl and purse seine rates, and Iceland's purse seine rate; [4] average of Norway's line and gillnet fleet; [5] average of Canada's and Iceland's dredge fisheries; [6] rate for Norway's gillnet fleet; [7] rate for Canada's pot fishery; [8] average of Canada's and Iceland's trawl fleets.

Shrimp discards include those estimated from boat-based operations, and also from overpacking and quality discards at the processing plants (Hvingel 2003; Arboe and Kingsley 2010). Government regulations require that shrimp greater than 2 grams be kept, but in the offshore fleet, shrimp in this size-range are still discarded due to quality, while those less than this size are discarded due to value, and in some hauls can be as much as 50% (Lehmann and Degel 1991). Overpacking products led to an underestimate of the actual amount of shrimp sold, and quality discards are associated with inshore fisheries that land at processing plants, which discard low quality shrimp. Size-related discards in the offshore fisheries were reported to be 40% per year in 1990 (Lehmann and Degel 1991), 19% per year in 1991 and 14% per year in 1992 (Siegstad 1993), and discards due to low quality have been estimated to be 6% of the catch (Carlsson and Kanneworff 1992). We used the average of the first two years (29.8%) as the discard rate backwards in time to 1975 to estimate size-related discards for the offshore fleet. The large-scale commercial shrimp fishery was just starting in 1970, and so the discard rate is set to zero in 1969, and we interpolated to the value in 1975. After 2004, we used a discard rate of 6% per year to reflect the introduction of the mandatory use of sorting grids in 2002, and regulations concerned with overpacking (Appendix A1). Fish discards associated with the shrimp fishery are documented for 1977-2009 (Arboe and Kingsley 2010) and for 1950-1976 the average rate of fish discards for 1977 and 1978 was applied to the reported shrimp catches to estimate fish discards from the shrimp fishery.

Subsistence catches

Table 2. Community consumption rates used to estimate subsistence catches for Greenland (see text for details).

Year	Region	Communities	Consumption rate (kg·day^{-1})	Source
1953	CWG	Disko Bay & Ilulissat	0.629	(Hansen *et al.* 2008)
1996	CWG	Disko Bay & Ilulissat	0.067	(Johansen *et al.* 2004)
1976	NWG	Uummanaq	0.090	(Hansen *et al.* 2008)
1999	NWG	Uummanaq	0.065	Deutch and Hansen (2003)
2004	NWG	Uummanaq	0.047	(Hansen *et al.* 2008)
1987	NWG	Qaanaaq	0.040	(Hansen *et al.* 2008)
1978	SEG	Tasiilaq	0.200	(Hansen *et al.* 2008)
2001	SEG	Tasiilaq	0.096	Deutch and Hansen (2003)
2000	CEG	Ittoqqortoormiit	0.038	Deutch and Hansen (2003)
1953	SG	Qaqortoq	0.191	(Hansen *et al.* 2008)
2006	SG	Narsaq	0.031	(Hansen *et al.* 2008)

Subsistence catches are estimated using fish consumption rates from community survey data, and extending these rates to other communities within the same region that lacked estimates (Table 2). Consumption rates for each region were combined with the human population data for each region to estimate yearly catches taken for subsistence purposes. The four regions were based on communities that had consumption data, and these coincide with northwest Greenland (NWG), central western Greenland (CWG), southern Greenland (SG), central eastern Greenland (SEG) and southeastern Greenland (SEG). Each community was placed in one of these regions to assign a consumption rate from available data and we assigned each community to its present municipality. The communities in the municipalities of Qaasuitsup and Sermersooq were split between regions (Appendix A2), whereas the communities in Kujalleq and Qeqqata form part of the southern Greenland region. We assumed that the catches estimated for subsistence purposes do not form part of the reported statistics since Horsted (2000) states that a non-registered component of the cod catch for local consumption should be added to the reported landings, and Mattox (1971) also states that reported catches until 1966 did not include the portion of the catch taken for home consumption.

Marine mammal data

Marine mammal data include Greenland's reported and unreported catches by number. Unreported catches include estimates of the number of animals in years when no data are reported for all of Greenland, and also unreported catches of narwhals for the community of Qaanaaq. Estimates of struck and lost animals that are shot, but not retrieved are also included as unreported catches. Reported data for seal species are taken from statistics provided to FAO, and data for the large whales are taken primarily from publications of the International Whaling Commission. For narwhals and belugas, data are reported in publications from the North Atlantic Marine Mammal Commission (Heide-Jørgensen and Rosing-Asvid 2002; Heide-Jørgensen 2009).

The number of bearded seals (*Erignathus barbatus*), harbour seals (*Phoca vitulina*), harp seals (*Pagophilus groendlandicus*), hooded seals (*Cystophora cristata*), and ringed seals (*Pusa hispida*) are reported in FAO statistics, but these records are incomplete, particularly during the early period. Data are reported for harp and hooded seals since 1954, ringed seals since 1969 and for bearded and harbour seals since 1970. The data gaps for bearded seal (1950-1965), harbour seal (1950, 1954-1968) and ringed seals (1950-1968) are taken from Kapel (1975). Stenson (2008) provides data on the number of harp seals taken in 1953 and 1952, and we used the same number (16,400) for 1950 and 1951. For hooded seals, a five-year average (861) from the first years of reported data (1954-1958) is used.

Struck and lost rates are considered to represent a rate of the reported catch for each seal species. Struck and lost rates vary by species, and seasonally, due to weather and different sinking rates of seals after being shot (Anon. 2006). Struck and lost rates from 1950-2010 were 100% per year for bearded seals assuming 68% of the reported catch is taken by rifle, 14% per year for harbour seals using data from Alaska (Anon. 2003; Angliss and Outlaw 2006), 100% per year for hooded seals (Stenson 2008), and 17% per year for harp and ringed seals. Ringed seals are hunted primarily by rifle (68%), and, for harp seals, 34% of the full-time and leisure hunters report struck and lost seals, having a combined mean shot and lost rate of 0.22 (Anon. 2006). We assumed that 68% of the total annual catch for both species is by rifle with a shot and loss rate of 0.22·year^{-1}. Thus, unreported catches associated with struck and loss for harp and ringed seals were estimated as a ratio of the unreported fraction (0.22*0.66) to the reported fraction (1-(0.22*0.66)) to derive the rate of 17% per year.

Blue whales (*Balaenoptera musculus*), sperm whales (*Physeter macrocephalus*), and northern bottlenose whales (*Hyperoodon ampullatus*) were taken in small numbers until 1976 with sperm whales being the most important. The numbers of animals taken each year are provided in Kapel (1979). We did not expand the reported statistics to account for struck and lost animals as we excluded these species from subsequent analysis. Bowhead (*Balaena mysticetus*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*) and minke (*Balaenoptera acutorostrata*) whales are taken under the jurisdiction of the Aboriginal Subsistence Whaling program of the IWC and catches including the number of struck and lost animals are reported by the IWC for the year 1985 onwards (IWC 2012). Prior to 1995, the numbers of fin whales taken are reported in Kapel (1979) for 1950-1976, and in the IWC white paper on the hunting of large whales in Greenland for 1977-1984 (Ugarte 2007). Humpback whale catch numbers are reported in Witting (2007) for the period 1950 to 1972, and also in Ugarte (2007) for 1973-1984. The catch of minke whales from 1950 to 1976 are reported in Kapel (1979), and we interpolated from the number of whales reported in 1976 to the reported number of whales in 1985 to estimate the catches in missing years.

Smaller cetaceans including belugas (*Delphinapterus leucas*), narwhals (*Monodon monoceros*), killer whales (*Orcinus orca*), harbour porpoises (*Phocoena phocoena*), and pilot whales (*Globicephala melas*) are also hunted in Greenland. Belugas and narwhals have always been important culturally and account for the largest portion of catches. Beluga catches are rare on the east coast, and the belugas caught along this coast are believed to originate from the Svalbard population (Anon. 2000), and thus, here we only considered catches to occur along the west coast. Beluga whale catch statistics from 1954 to 1998 were reviewed by Heide-Jørgensen and Rosing-Asvid (2002) and we used the average of the medium and high option as the reported catch including the estimates of the number associated with ice entrapments and unreported catches. After 1999, we relied on reported catches from Statistics Greenland and estimate the unreported catches by using a three-year average ratio (0.15) of unreported catch to reported catch from the last three years of data (1996-1998) in Heide-Jørgensen and Rosing-Asvid (2002).

Narwhal catch statistics for 1949 and 1954 to 2008 including reported and unreported data were reviewed by the Joint Working Group, with members from NAMMCO and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Working Group (Anon. 2009). We interpolated between catches in 1949 and 1954 to fill in the first few years of missing total catches, and after 1996 we used data from Greenland's national statistical agency as reported catches (Statistics Greenland 2011). The community of Qaanaaq, on the northwestern coast of Greenland, reports no catches from 1950-1960, 1965-1973, and from 1985-1992 and, since it is an important community in terms of narwhal catches, we estimated the unreported catches for the missing time periods. In 1949 and 1961, Qaanaaq accounted for approximately 62% and 66% of the total narwhal catch, respectively. We used the average (64%) as the fraction of unreported catches to estimate the number of narwhals taken by Qaanaaq from 1954-1960 from the reported total. For 1965-1973, we interpolated between the proportion of the total catch reported in 1964 (0.88) and 1974 (0.51), to estimate Qaanaaq's unreported catches. Similarly, for 1985-1992, we estimated unreported catches by interpolating between Qaanaaq's proportions of the total catch between 1984 and 1993.

Traditionally, harbour porpoises were taken in small amounts, but since the late 1990s catches have increased. Data concerning the catch are available for 1950, and from 1954 to 1992 (Teilmann and Dietz 1998), and for 1998 to 2009 (Statistics Greenland 2011). We interpolated between the reported catch amounts for years of missing data (1951-1953) to estimate catches in missing years. Pilot whales are irregularly reported in catch statistics with catches ranging between 2 and 365 whales·year^{-1} for the period 1978-2009 with 9 years having no reported data. We considered pilot whales to be hunted every year, and use a five-year average (33 animals) taken from the first five years of reported data (1978-1982) to use as an estimate of the average yearly catch between 1950 and 1977. NAMMCO reports the number of pilot whales taken between 1978 and 1999, and Statistics Greenland (2011) reports the number of whales taken from 2000-2009. To fill in years of no reported data, we interpolated between reported catch numbers. Killer whales are reported for the period 1998 to 2009 (Statistics Greenland 2011), but catches are not extended backwards in time.

Seabird data

Seabirds are part of the traditional Inuit diet, and are hunted extensively. Hunting data for seabird species have been collected since 1993 for thick-billed murres (*Uria lomvia*), common eider (*Somateria mollissima*), king eider (*Somateria spectabilis*), black guillemot (*Cepphus grylle*), little auk (*Alle alle*) and black-legged kittiwakes (*Rissa tridactyla*). Data concerning the number of birds taken each year are available from Christensen (2001) for 1993 to 1996 and from Statistics Greenland (2011) for 1998-2009. We interpolated between the reported catch in 1996 and 1998 to estimate the catch of each species in 1997. Formerly, during the commercial salmon driftnet fishery, a large number of seabirds were caught as bycatch, leading to significant mortalities especially of thick-billed murres (Piatt and Reddin 1984), but these are not considered here.

Ecosystem indices

The Marine Trophic Index (MTI) is a metric used to estimate the changes in fisheries catches based on the mean trophic level of catches from marine ecosystems. The annual proportion of each species catches relative to the total catches is multiplied by the trophic level of the species, *i.e.*,

$$MTI = \sum(Y_{ik}/Y_k)*TL_{ik}$$

where Y_{ik} represents the catch of species/group *i* in year *k*, Y_k is the total annual catch, and TL_{ik} represents the trophic level of species/group *i* in year *k*. We used this metric for fisheries catches for each year to compute a time series of the MTI.

We also estimated the mean maximum length of catches through time to reflect the changes in the size of catch through time. The mean maximum length of the catch can be defined as the annual proportion of each species catches relative to the total catches multiplied by the maximum length measurement of the species, *i.e.*,

$$MML = \sum(Y_{ik}/Y_k)*ML_{ik}$$

where ML_{ik} represents the maximum length of species/group *i* in year *k*. We used standard length for fishes (Table A3; www.seaaroundus.org),[4] carapace length for invertebrates (www.sealifebase.org)[5] and the wingspan of seabirds (Table A4; www.bto.org).[6] A mean maximum length for marine mammals is estimated from the mean weight (Trites and Pauly 1998) using length-weight relationships from SeaLifeBase (www.sealifebase.org). The mean maximum lengths from fisheries and those for marine mammals and seabirds are computed separately.

[4] http://www.seaaroundus.org [Accessed: June 2012]

[5] http://www.sealifebase.org [Accessed: June 2012]

[6] http://www.bto.org [Accessed: May 2012]

Results

Human population

The human population of Greenland increased from approximately 23,000 people to 56,000 from 1950 to 2010 (Figure 2). The population growth was greatest from 1960 to 1970, increasing at approximately 4% per year, but has since slowed and from 2000-2010 it declined to 0.1% per year. The municipalities of Qaasuitsup and Sermersooq, where the capital Nuuk is located, have seen the greatest increase in population.

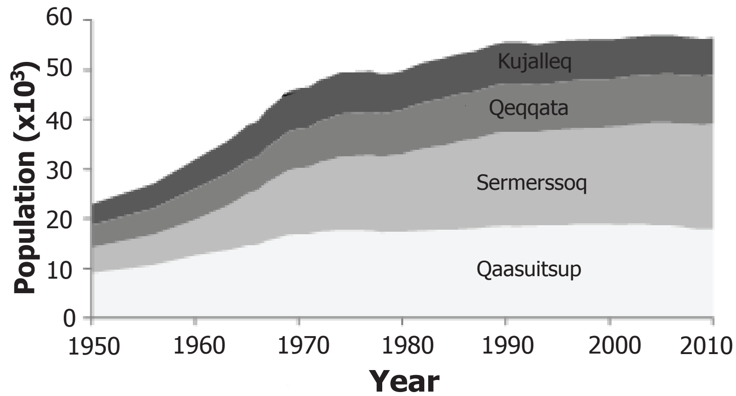

Figure 2. Estimated total population of Greenland by municipality, 1950-2010.

Fisheries catches

Total fisheries catches for Greenland's domestic fishing fleet in its western and eastern waters, including reported landings and all unreported catches, exceeded 7 million t and were estimated to increase approximately 7-fold from over 29,000 t in 1950 to approximately 202,000 t in 2010 (Figure 3a). Catches were dominated by northern shrimp and Atlantic cod (Figure 3b). From 1950 to 1979, Atlantic cod dominated, making up approximately 60% of the catches, but from 1980 onwards, Atlantic cod only represents 16% of the fisheries catches. Northern shrimp catches averaged 25% of the catches from 1950 to 1979, but increased in importance, accounting for approximately 63% of the catches from 1980 onwards. Greenland halibut is also important, averaging 5% of the total catches between 1950 and 1989, but increased afterwards to average 14% of the total catches between 1990-2010. All other taxa make up 11% of the total catches during 1950-2010. Catches are overwhelmingly taken in the waters of West Greenland (94%).

Greenland's commercial catch totalled 6.9 million t for the 1950 to 2010 period (Figure 3a). Until 1968, Greenland's commercial fisheries were strictly small-scale artisanal, but by 1980 catches by the large-scale industrial fleet had reached 50% of the catch. In 1989, catches by the industrial fleet accounted for 68% of the commercial catch, and since then have averaged approximately 73%. Discards from the commercial fishery increased from 3,700 t in 1950 to 69,000 t in 1976, and since then have averaged 34,000 t·year^{-1} from 1977-2010. Discards represent 21% of the reconstructed total catch, and were dominated by shrimp (72%).

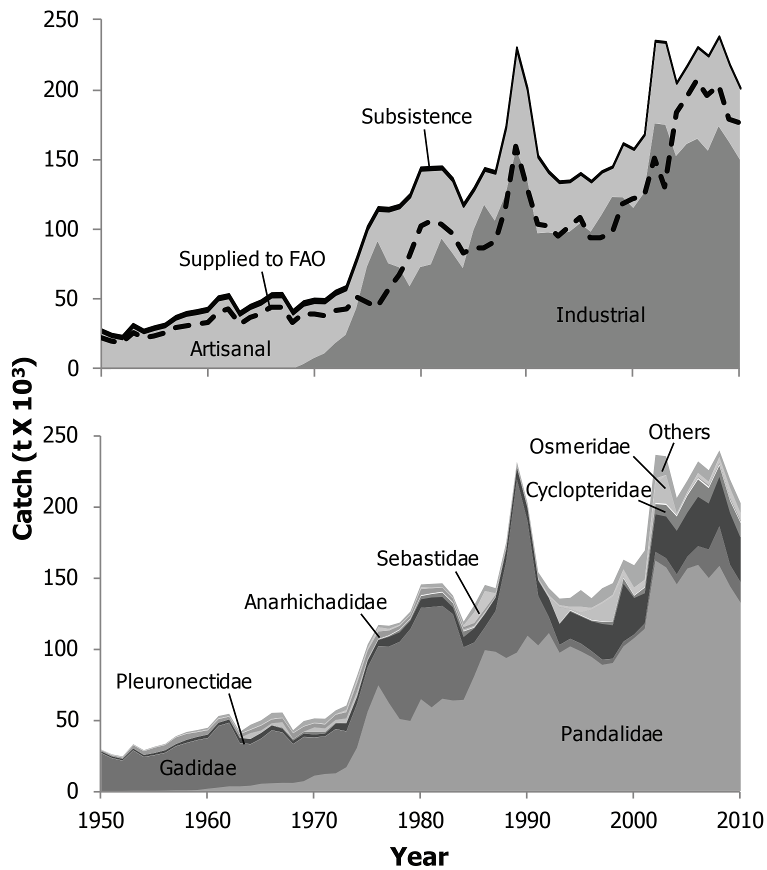

Figure 3. Reconstructed total catch of Greenland, during the period 1950-2010 (a) by sector with data as reported by FAO overlaid as line graph; and (b) by taxonomic group, others represent 10 other families.

The unreported landings component of Greenland's catches was estimated to decrease from 2,700 t in 1950 to approximately 800 t in 2010, and was dominated by Atlantic cod (47%). The majority of IUU came from subsistence fishing (78%), while 16% and 6% was represented by the artisanal and industrial sectors, respectively. IUU catches from commercial fisheries of Greenland shark were approximately 9,500 t from 1950 to 1969. IUU catches of Atlantic halibut from 1953 to 1962 were estimated to be approximately 350 t and IUU catches of arctic charr from 1950-1964 were approximately 400 t. Subsistence catches were estimated to increase from about 2,600 t in 1950, peaking at approximately 3,500 t in 1969, and is currently estimated to be less than 1,000 t annually (Figure 3a). Consumption rates associated with subsistence fisheries catches fell from approximately 112 kg·person·year^{-1} in 1950 to 14 kg·person·year^{-1} in 2009.

Marine mammal catches

Unreported catches of seals were higher in the 1950s and 1960s because of the limited amount of FAO data, but after this time the unreported catches are associated mainly with struck and lost animals (Figure 4a). Of the five species of seals, ringed seals and harp seals are the most important in catches accounting for, on average, 65% and 26% of the total catches, respectively (Figure 4b). Hooded and bearded seals account for approximately 7% and 1% respectively, and harbour seals comprise less than 1% of the catches. Unreported catches of seals from 1950-1968 average 86% of the total estimated catches, but decline afterwards to average 0.18 t·year^{-1}, although in 1986 unreported catches were estimated to be 79%. Seal catches are distributed more evenly than fisheries catches with the west coast accounting for, on average, 80% of the total estimated catches (Figure 4c).

Blue, bottlenose and sperm whales catches from 1950 to 1973 (the last year of a reported catch) were reported to be 122 whales, with sperm whales being by far the most important at 110. We excluded these whales from further analysis and concentrate on the remaining marine mammals still targeted. For the remaining large whales, we relied on reported numbers, since the IWC Aboriginal Subsistence whaling statistics from 1985 onwards include struck and lost whales. Catches of bowhead, fin, humpback, and minke whales are dominated by minke whales, although from 1950-1957 fin whales and minke whales were taken in nearly equal numbers (Figure 5). Bowhead whales have only begun to be hunted again in the last two years with 3 individuals taken in 2009 and 2010. From 1950 to 1962, reported catches of large whales were estimated to average 50 individuals·year^{-1}, but reported numbers increased to average 200·year^{-1} afterwards. Similar to fisheries catches, 95% of large whales are taken in the west.

Small cetaceans (belugas, narwhals, killer whales, harbour porpoises, and pilot whales) have slowly increased over time (Figure 6a). Unreported catches of small cetaceans during the period from 1950-1995 were highly variable ranging from 4%-72%, but since 1996 have averaged only 0.02 t·year^{-1} (Figure 6a). From 1950-1969, catches averaged 1,860 t·year^{-1}, increased to 2,402 t·year^{-1} during 1970-1989, and since 1990 have averaged 3,091 t·year^{-1}. However, the composition of the catches through time has changed. Beluga whale catches have been declining in catches since the early 1980s. During the 1970s and 1980s catches averaged 1,039 t·year^{-1}, but have declined to 585 t·year^{-1} since the 1990s (Figure 6b). Narwhal catches have increased in importance averaging 265 t·year^{-1} from 1950-1969, 463 t·year^{-1} from 1970-1989, and since 1990 have increased to 626 t·year^{-1} (i.e., 100 t·decade^{-1}). Harbour porpoises have increased in importance, especially in the last decade. From 1950-1989, annual catches averaged 870 t·year^{-1}, increased slightly during 1990-1999 to 1,190 t·year^{-1}, but have nearly doubled that amount in the last decade rising to 2,277 t·year^{-1}. Estimated pilot whale catches average 33 t·year^{-1} from 1950-1977, and for the remaining years catches fluctuate from a low of 2 t·year^{-1} to a high of 365 t·year^{-1}. Killer whale catches from 1998 to present average 7 t·year^{-1} with none reported in 2006 and a high of 26 taken in 2008. The area in which most small cetaceans are taken is not recorded, but for narwhal 88% of the annual average catch is taken in western waters.

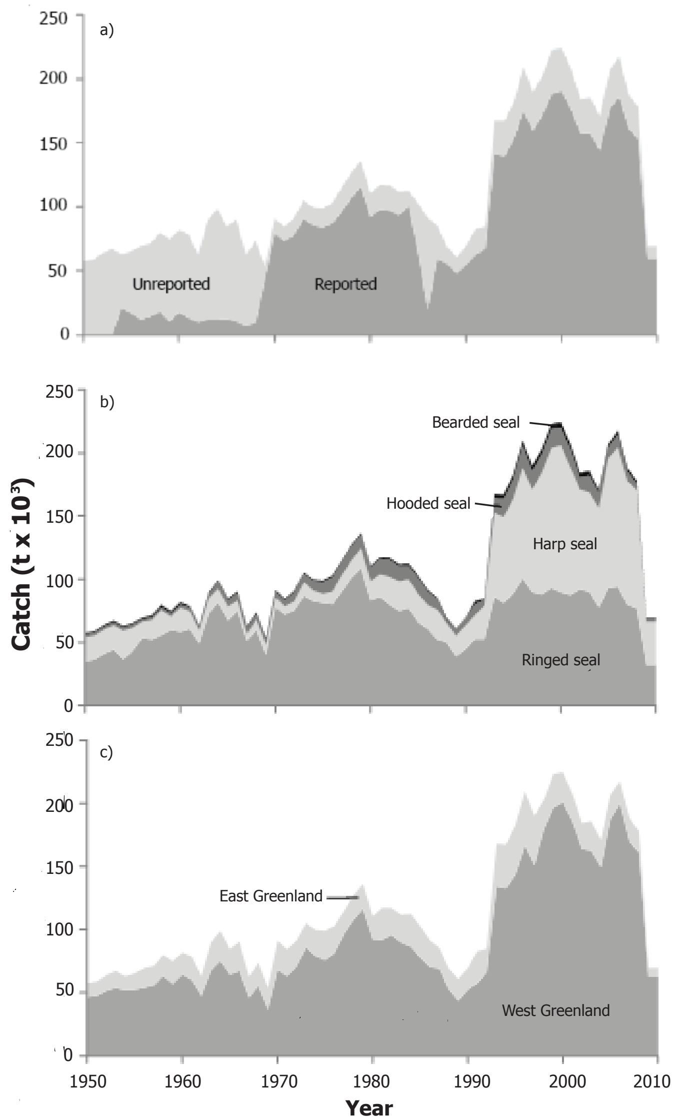

Figure 4. Estimated marine mammal catches (in t x 10³), including (a) reported and unreported seal catches; (b) seal catches by species; (c) seal catches by coast.

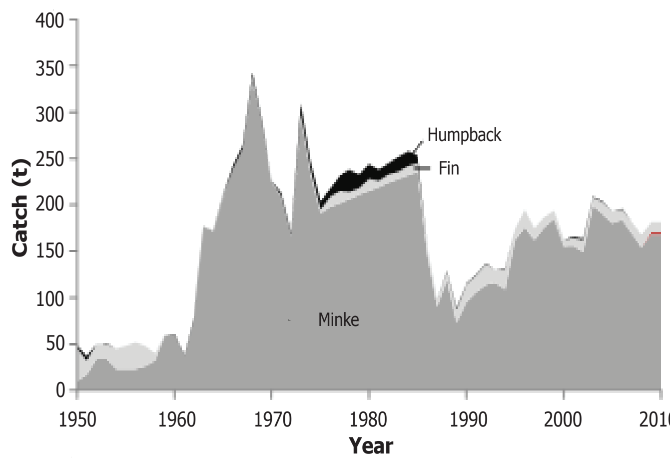

Figure 5. Estimated large whale catches by species, during the period 1950-2010.

Seabird catches

Seabird data are limited, but catches have declined nearly 4-fold between 1993 and 2008, declining from approximately 450,000 birds in 1993 to approximately 114,000 in 2008 (Figure 7). Preliminary numbers for 2009 are just over 46,000 and this would indicate a 10-fold drop from the number reported in 1993. Thick-billed murres are the most important species, accounting for 50% of the catches, with eider being the next most important, averaging 16% of the reported total catches.[7]

Ecosystem indices

The MTI has decreased from 4.39 in 1950 to 3.26 in 2010, due mostly to the declining importance of Atlantic cod and the increasing importance of northern shrimp (Figure 8). The rate of decline is approximately 0.26·trophic level·decade^{-1}. In order to exclude bottom-up effects (Caddy *et al.* 1998), the MTI was also calculated for species of trophic level 3.5 and above, and the decline in the MTI is then 0.07·trophic level·decade^{-1}.

The various length measurements of the catch have also decreased since 1950, although for marine mammals it is noticeable only after the moratorium on the hunting of large whales (Figure 6). The mean maximum length of estimated fisheries catches have declined from 149 cm in 1950 to 40 cm in 2010 (18 cm·decade^{-1}), and the average wingspan of seabird harvests have declined from 72 cm in 1963 to 65 cm. The mean maximum length of marine mammals have not declined significantly since 1950, but there is a slight trend downwards from 1976 (181 cm) to 2010 (169 cm).

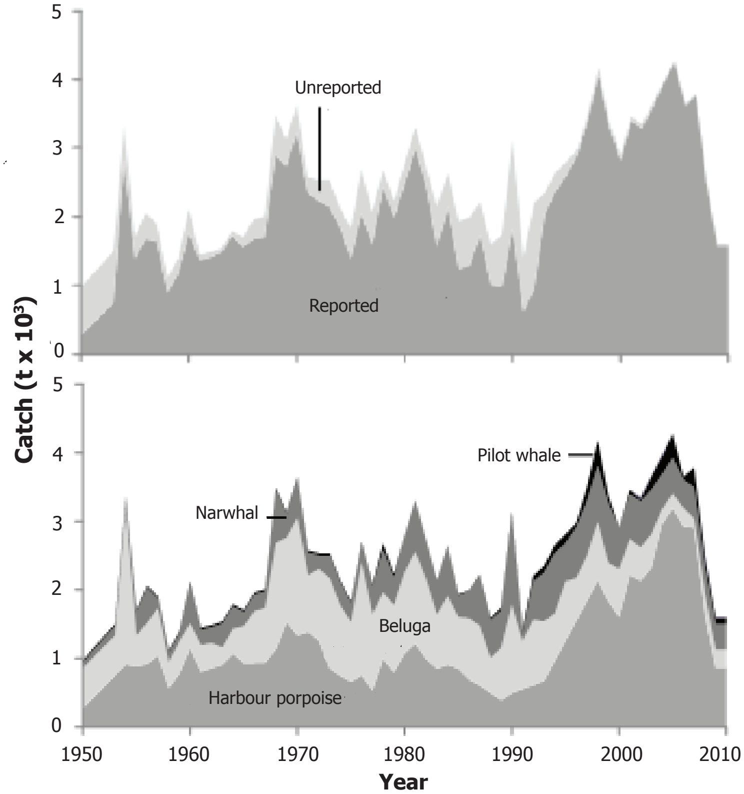

Figure 6. Estimated marine mammal catches (in t x 10³), including (a) reported and unreported small cetacean catches; (b) small cetacean catches by species.

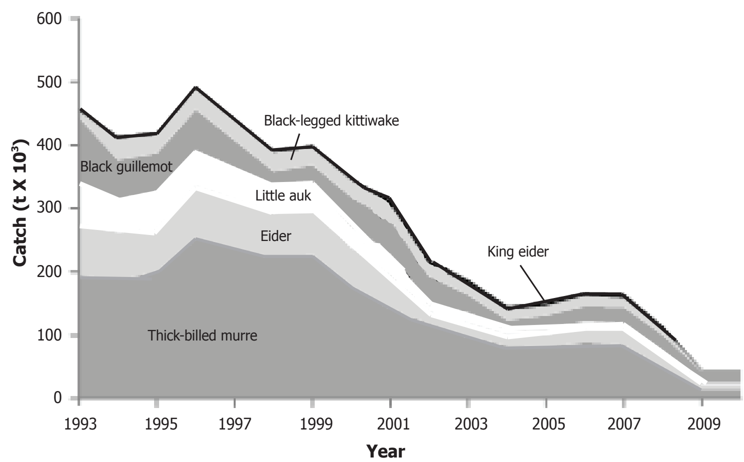

Figure 7. Reported catches of seabirds in Greenland from 1993-2010.

Discussion

The decline of the MTI in the Greenland fishery is the most dramatic case recorded so far (Table 3), and reflects a change in the fishery of one primarily targeting Atlantic cod to one primarily targeting shrimp. The recent collapse of Atlantic cod in Greenland waters is due in part to climatic forcing, but also due to overfishing. The profit of the fishery went to foreign countries' fishing fleets prior to Greenland declaring its EEZ in 1977 when, from 1950 to 1976, the foreign fleets caught over 6 million t of cod in West Greenland waters, approximately 10 times the Greenland catch during the same period.

The decline in the length of the catch is also indicative of an ecosystem that is moving towards smaller sized individuals. In fisheries, because size is related to trophic level, this is also a sign of fishing down marine food webs, but other living marine resources of the ecosystem are also moving towards one comprised of smaller individuals. Seabirds and marine mammals, in comparison to fish, have a relatively stable trophic level throughout their lives, whereas fish have trophic level changes as they grow and age (Cheung *et al.* 2007). Although here, we used one measure of trophic level for fish, the trophic level of fish would change

Table 3. The rate of decline in the Marine Trophic Index (MTI) for several marine ecosystems.

Ecosystem	Study Period	MTI rate of change	Source
Greenland	1950-2010	0.26 TL·decade^{-1}	This study
Canada's east coast	1950-mid 1997	0.16 TL·decade^{-1}	(Pauly *et al.* 2001)
Canada's west coast	1900-mid 1996	0.03 TL·decade^{-1}	(Pauly *et al.* 2001)
Iceland	1950-2000	0.05 TL·decade^{-1}	(Valtýsson and Pauly 2003)
India	1950-2000	0.06 TL·decade^{-1}	(Bhathal and Pauly 2008)

7 For the purposes of *Sea Around Us* and the global database of reconstructed fisheries catches, marine mammal and seabird data were not used.

through time, reflecting the change in size of the fish and therefore the diet composition; however it has been shown that this effect is small (Pauly *et al.* 2001). Including marine mammals and seabirds in the MTI dampens the decline, but it still declines as a result of the decline in the mean trophic level of fisheries landings.

Fisheries, in the case of Greenland and other Arctic countries, are only one living marine resource that Inuit rely on. Ringed seals, belugas, and seabirds are also important in terms of subsistence use and therefore food security. After 1990, when the Atlantic cod had all but disappeared, Greenland halibut catches increased, but there was a significant increase in the catch of ringed and harp seals, and also of small whale species. Ringed seals and small whales are an important component of the diet of Greenlanders, and the decline of the beluga population since 1950 is of special concern.

The economy of Greenland is presently reliant on export earnings from fisheries, particularly shrimp. However, the country must be resilient to changes to its marine ecosystems, given that the Arctic is most affected by climate change. The transition from cod to shrimp was also associated with social effects because of differences between communities' abilities to adapt to shifts in marine resource distributions (Hamilton *et al.* 2003). As is the case for other Inuit, there is a high reliance on living marine resources for cultural, subsistence and economic use, and some of these marine populations will decline if global warming continues, adversely affecting food security for communities that are not able to adapt.

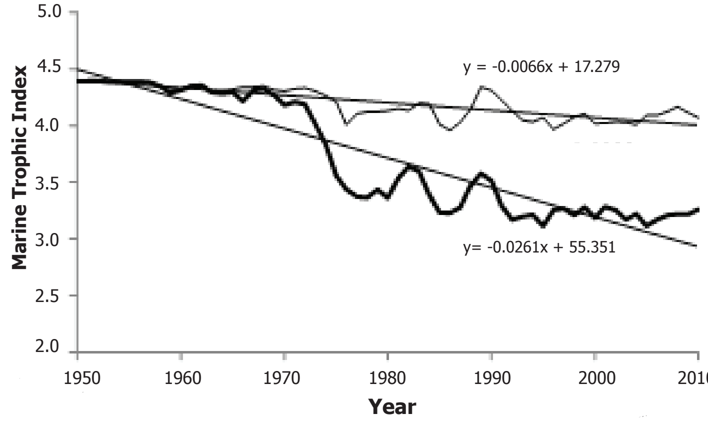

Figure 8. The decline in the Marine Trophic Index, 1950-2010.

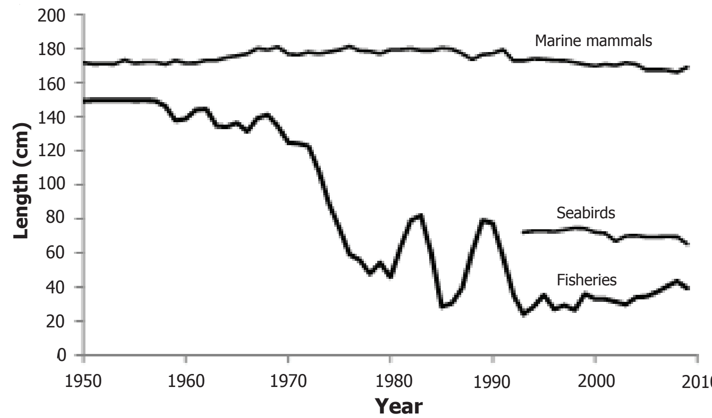

Figure 9. Changes in the mean maximum length measurement of catches of fisheries, marine mammals, and seabirds.

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Appendix Table A1. Unreported discard rates of shrimp as a rate of reported landings. Unreported catches include estimates for boat-based discards, and overpacking and quality discards that are processor-based (see text for details).

Year	Large-scale	Small-scale
1950-1969	n.a.	0.063
1970	0.310	0.310
1971	0.365	0.365
1972	0.691	0.691
1973	1.085	1.085
1974	1.993	1.993
1975	4.705	4.705
1976	6.588	6.588
1977	3.153	3.153
1978	2.861	2.861
1979	1.447	1.447
1980	0.796	0.796
1981	0.638	0.637
1982	0.599	0.591
1983	0.598	0.587
1984	0.547	0.534
1985	0.509	0.496
1986	0.549	0.525
1987	0.511	0.484
1988	0.563	0.527
1989	0.558	0.528
1990	0.580	0.544
1991	0.401	0.389
1992	0.364	0.360
1993	0.271	0.267
1994	0.274	0.267
1995	0.199	0.193
1996	0.310	0.303
1997	0.388	0.382
1998	0.291	0.288
1999	0.285	0.281
2000	0.249	0.245
2001	0.320	0.317
2002	0.525	0.525
2003	0.859	0.862
2004	0.073	0.041
2005	0.073	0.047
2006	0.072	0.047
2007	0.070	0.051
2008	0.065	0.068
2009	0.061	0.082
2010	0.061	0.082

Appendix Table A2. Communities located in the municipalities of Qaasuitsup and Sermersooq and the region they were assigned for estimating subsistence catches.

Community	Region[1]	Municipality	Community	Region[1]	Municipality
Aasiaat	CWG	Qaasuitsup	Ukkusissat	NWG	Qaasuitsup
Akunnaaq	CWG	Qaasuitsup	Upernavik	NWG	Qaasuitsup
Ikamuit	CWG	Qaasuitsup	Upernavik Kujalleq	NWG	Qaasuitsup
Illimanaq	CWG	Qaasuitsup	Uummannaq	NWG	Qaasuitsup
Ilimanaq	CWG	Qaasuitsup	Attu	SG	Qaasuitsup
Ilulissat	CWG	Qaasuitsup	Iginniarfik	SG	Qaasuitsup
Kangerluk	CWG	Qaasuitsup	Ikerasaarsuk	SG	Qaasuitsup
Kitsissuarsuit	CWG	Qaasuitsup	Kangaatsiaq	SG	Qaasuitsup
Oqaatsut	CWG	Qaasuitsup	Niaqornaarsuk	SG	Qaasuitsup
Qasigiannguit	CWG	Qaasuitsup	Illoqqortoormuit	CEG	Sermersooq
Qeqqertaq	CWG	Qaasuitsup	Itterajivit	CEG	Sermersooq
Qeqertarssuatsiaq	CWG	Qaasuitsup	Nerlerit Inaar	CEG	Sermersooq
Qwqertarsuaq	CWG	Qaasuitsup	Sermiligaaq	CEG	Sermersooq
Qeqertat	CWG	Qaasuitsup	Uunarteq	CEG	Sermersooq
Saqqaq	CWG	Qaasuitsup	Orsuiassuaq	SEG	Sermersooq
Aappilattoq	NWG	Qaasuitsup	Pikuillit	SEG	Sermersooq
Dundas	NWG	Qaasuitsup	Ikkateq	SEG	Sermersooq
Ikersak	NWG	Qaasuitsup	Isortoq	SEG	Sermersooq
Illorsuit	NWG	Qaasuitsup	Kulusuk	SEG	Sermersooq
Innaarsuit	NWG	Qaasuitsup	Kuumiut	SEG	Sermersooq
Kangersuatsiaq	NWG	Qaasuitsup	Narsalik	SEG	Sermersooq
Kullorsuaq	NWG	Qaasuitsup	Qernertuarsuit	SEG	Sermersooq
Maarmorilik	NWG	Qaasuitsup	Tasiilaq	SEG	Sermersooq
Moriusaq	NWG	Qaasuitsup	Timmiarmiut	SEG	Sermersooq
Naajaat	NWG	Qaasuitsup	Tinit eqilaaq	SEG	Sermersooq
Niaqornat	NWG	Qaasuitsup	Arsuk	SG	Sermersooq
Nutaarmiut	NWG	Qaasuitsup	Avigaat	SG	Sermersooq
Nuugaatsiaq	NWG	Qaasuitsup	Ivittuut	SG	Sermersooq
Nuussuaq	NWG	Qaasuitsup	Kangeq	SG	Sermersooq
Qaanaaq	NWG	Qaasuitsup	Kangerluarsoruseq	SG	Sermersooq
Qaarsut	NWG	Qaasuitsup	Kapisillit	SG	Sermersooq
Qeqertarsuaq (Herbert Island)	NWG	Qaasuitsup	Nuuk	SG	Sermersooq
Saattut	NWG	Qaasuitsup	Paamiut	SG	Sermersooq
Savissivik	NWG	Qaasuitsup	Qeqertarsuatsiaat	SG	Sermersooq
Siorapaluk	NWG	Qaasuitsup	Qooqqut	SG	Sermersooq
Tasiusaq	NWG	Qaasuitsup	Qoornoq	SG	Sermersooq
Tunugassoq	NWG	Qaasuitsup	-	-	-

[1] CWG: central western Greenland; NWG: northwest Greenland; SG: southern Greenland; CEG: central eastern Greenland; SEG: southeastern Greenland)

Appendix Table A3. Trophic level (TL) and mean maximum standard length measurements of fisheries catches used for estimating changes in Greenland's marine ecosystem from 1950-2010.

Common name	TL	Length (cm)	Common name	TL	Length (cm)
Aesop shrimp	2.3	16	Lanternfishes	3.2	10
American angler	4.5	102	Lemon sole	3.3	52
American plaice	3.7	67	Ling	4.3	185
Angler	4.5	200	Lumpfish	3.9	49
Arctic charr	4.3	9	Megrim	4.2	49
Argentines	3.3	52	Monkfishes	4.1	97
Atlantic cod	4.4	150	Moras	4.0	280
Atlantic halibut	4.5	219	Navaga	4.2	35
Atlantic herring	3.2	45	Northern shortfin squid	4.0	27
Atlantic horse mackerel	3.6	62	Northerm shrimp	2.5	14
Atlantic mackerel	3.7	46	Northern wolffish	3.8	180
Atlantic redfishes	3.9	60	Ocean perch	3.9	60
Atlantic salmon	4.4	135	Ocean pout	3.4	54
Atlantic wolffish	3.2	165	Onion-eye grenadier	4.5	82
Baird's slickhead	3.9	100	Orange roughy	4.3	58
Beaked redfish	3.7	33	Pandalus shrimps	2.5	11
Black dogfish	3.9	82	Piked digfish	4.3	106
Black scabbardfish	4.5	110	Polar cod	3.1	35
Blue ling	4.5	145	Pollack	4.2	115
Blue skate	4.0	285	Porbeagle	4.5	227
Blue whitnig	4.0	42	Portugese dogfish	4.4	99
Bramble, sleeper, dogfish sharks	4.2	149	Queen crab	2.3	20
Brill	3.8	62	Rabbit fish	3.8	101
Capelin	3.2	18	Raja rays	3.8	117
Common dab	3.3	40	Ratfishes	3.9	74
Common sole	3.1	70	Rays, stingrays, mantas	3.8	135
Dealfishes	4.5	278	Redfishes	3.9	60
Deepwater rose shrimp	2.4	22	Roughhead grenadier	4.5	82
Dogfish shark	4.3	130	Roundnose grenadier	3.5	106
European conger	4.3	246	Ruffs, barrelfishes	3.9	150
European flounder	3.2	50	Saithe	4.4	107
European hake	4.4	130	Shagreen ray	3.5	98
European plaice	3.3	100	Silvery lightfish	3.0	6
European smelt	3.0	40	Skates	3.7	100
Forkbeards	4.0	65	Spotted ratfish	4.0	74
Golden redfish	4.0	87	Spotted wolffish	3.5	165
Greater forkbeard	3.7	97	Tusk	4.0	98
Greenland cod	3.6	65	White hake	4.2	115
Greenland halibut	4.5	72	Whiting	4.4	63
Greenland shark	4.2	606	Witch flounder	3.1	60
Haddock	4.1	86	Wolffishes	3.5	136
Iceland scallop	2.0	11	-	-	-

Appendix Table A4. Mean maximum length of marine mammals and the wingspan of seabirds used to estimate the change in lengths of catches from 1950 to 2010.

Common Name	Species Name	Length (cm)
Bearded seal	*Erignathus barbatus*	260
Beluga whale	*Delphinapterus leucas*	270
Bowhead whale	*Balaena mysticetus*	2010
Fin whale	*Balaenoptera physalus*	2110
Harbour porpoise	*Phocoena phocoena*	130
Harbour seal	*Phoca vitulina*	140
Harp seal	*Pagophilus groendlandicus*	150
Hooded seal	*Cystophora cristata*	260
Humpback whale	*Megaptera novaeangliae*	1330
Killer whale	*Orcinus orca*	480
Minke whale	*Balaenoptera acutorostrata*	810
Narwhal whale	*Monodon monoceros*	270
Pilot whale	*Globicephala melas*	420
Ringed seal	*Pusa hispida*	170
Black guillemot	*Cepphus grylle*	55
Black-legged kittiwake	*Rissa tridactyla*	108
Eider	*Somateria mollissima*	94
King eider	*Somateria spectabilis*	94
Little auk	*Alle alle*	44
Thick-billed murre	*Uria lomvia*	67

Appendix Table A5. FAO and ICES landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Greenland, 1950-2010.

Year	FAO	ICES	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discards
1950	22,703	-	6,390	-	26,500	2,590	3,690
1951	19,620	-	6,170	-	23,100	2,670	3,170
1952	18,286	-	6,070	-	21,600	2,750	2,920
1953	25,751	-	7,170	-	30,100	2,830	3,950
1954	22,132	-	6,580	-	25,900	2,850	3,270
1955	23,887	-	7,250	-	28,300	2,870	3,460
1956	25,528	-	7,580	-	30,200	2,890	3,690
1957	29,093	-	9,420	-	35,600	2,960	4,310
1958	31,002	915	9,520	-	38,400	3,020	4,690
1959	32,177	642	10,000	-	39,700	3,080	4,960
1960	33,095	1,646	9,720	-	41,300	3,130	5,100
1961	40,660	1,199	10,840	-	49,500	3,170	6,270
1962	42,388	903	11,030	-	51,100	3,200	6,520
1963	32,386	904	8,310	-	38,400	3,210	4,470
1964	36,333	1,136	9,110	-	43,300	3,260	4,350
1965	39,743	887	9,100	-	46,400	3,330	4,780
1966	43,599	881	10,470	-	51,600	3,310	5,610
1967	44,116	753	10,290	-	51,700	3,420	5,440
1968	33,665	630	8,460	209	39,100	3,460	4,270
1969	38,745	627	9,800	3,452	42,200	3,500	5,160
1970	38,961	501	11,540	7,787	39,800	3,450	7,130
1971	37,754	535	12,490	11,182	36,200	3,360	7,750
1972	41,490	282	14,910	18,455	34,900	3,360	10,630
1973	42,411	251	17,380	24,452	32,300	3,270	13,200
1974	51,193	71	29,670	43,506	34,200	3,230	25,580
1975	47,369	226	55,390	73,214	26,600	3,120	51,300
1976	44,138	506	72,080	91,500	22,200	3,030	68,940
1977	58,013	1,852	56,290	75,654	37,600	2,930	53,200
1978	66,856	1,377	50,100	72,871	42,700	2,800	47,200
1979	80,360	2,775	42,940	59,183	64,200	2,720	39,680
1980	101,826	1,907	41,400	72,923	69,600	2,650	38,620
1981	106,443	1,043	38,100	74,864	68,100	2,600	35,370
1982	104,189	2,015	39,730	93,361	50,000	2,540	37,050
1983	97,402	1,919	38,030	83,225	51,700	2,470	35,490
1984	83,299	2,953	32,780	72,237	44,400	2,390	30,010
1985	86,539	8,411	35,610	99,373	28,900	2,320	31,920
1986	86,519	16,384	41,830	117,504	25,000	2,240	38,550
1987	91,411	9,002	42,070	106,166	34,200	2,160	38,310
1988	116,311	8,063	50,600	124,642	48,200	2,090	47,840
1989	158,850	9,770	62,660	157,118	72,200	2,010	60,300
1990	132,575	10,755	58,890	137,502	62,800	1,920	56,580
1991	103,025	11,137	39,610	97,161	54,800	1,820	37,100
1992	101,982	4,765	35,830	97,646	43,200	1,710	33,990
1993	94,938	14,593	25,680	96,816	36,800	1,610	24,050
1994	101,950	6,070	27,730	98,165	36,100	1,520	26,210
1995	108,574	9,527	23,090	104,264	35,500	1,420	21,640
1996	94,356	13,177	27,940	98,253	35,900	1,330	26,590
1997	94,096	17,561	30,770	110,095	31,100	1,280	29,470
1998	97,953	21,811	26,200	123,031	21,700	1,220	24,970
1999	118,461	14,461	29,600	122,900	38,500	1,170	25,090
2000	121,885	9,940	26,770	115,259	42,200	1,110	25,660
2001	124,149	10,414	34,430	125,955	42,000	1,050	33,380
2002	151,533	21,070	63,510	175,695	59,400	1,000	62,500
2003	130,367	25,198	79,590	174,746	59,500	940	78,640
2004	183,660	5,913	16,300	152,340	52,600	890	15,390
2005	194,620	6,774	16,860	161,012	56,400	850	15,990
2006	206,296	6,966	18,290	164,717	66,000	810	17,400
2007	196,170	9,973	19,170	156,176	68,300	810	18,270
2008	203,247	15,669	20,280	173,724	64,700	800	19,400
2009	178,611	22,143	18,160	162,235	55,900	800	17,270
2010	175,919	9,894	16,350	149,808	51,600	800	15,550

Appendix Table A6. Reconstructed total catch (in tonnes) by major taxa for Greenland, 1950-2010. 'Others' contain 27 additional families.

Year	Pandalidae	Gadidae	Pleuronectidae	Cyclopteridae	Osmeridae	Anarhichadidae	Sebastidae	Others
1950	319	26,400	1,080	89	118	852	119	156
1951	319	22,900	1,100	92	121	745	123	375
1952	319	21,200	1,120	95	125	889	127	451
1953	425	28,200	1,260	97	129	2,233	130	422
1954	425	23,600	1,300	98	130	2,568	131	460
1955	425	24,900	1,390	99	131	3,655	132	413
1956	531	26,400	1,690	99	131	3,636	133	487
1957	744	30,800	1,390	102	134	4,639	236	462
1958	744	33,100	2,060	104	137	4,142	306	867
1959	956	34,900	2,130	106	140	3,244	376	999
1960	1,903	35,400	2,330	108	142	2,969	445	1,155
1961	2,704	43,100	2,150	109	144	2,451	492	1,547
1962	3,573	44,400	2,260	110	145	1,862	281	1,652
1963	3,550	30,200	3,480	111	146	2,617	316	1,136
1964	4,006	29,000	3,530	112	4,188	2,238	372	3,110
1965	5,367	31,500	3,900	115	1,798	3,430	419	3,176
1966	5,715	37,000	3,400	114	1,523	2,633	444	4,081
1967	5,995	35,200	2,650	700	3,927	2,861	332	3,517
1968	5,955	27,100	2,380	981	359	3,974	295	1,721
1969	7,164	30,900	2,290	1,164	336	3,520	299	3,503
1970	11,045	26,700	2,010	1,816	3,312	2,864	330	2,968
1971	12,207	26,200	1,950	1,107	2,646	2,771	479	3,453
1972	12,668	30,900	3,820	620	2,088	3,621	399	2,568
1973	16,967	25,000	5,620	186	3,395	4,340	1,353	3,206
1974	30,656	30,500	5,100	155	3,653	5,898	2,563	2,442
1975	55,850	31,100	4,710	224	1,187	5,834	1,552	2,553
1976	74,198	27,500	4,480	247	617	5,068	2,965	1,631
1977	61,802	39,600	7,090	635	459	3,146	1,234	2,152
1978	50,696	54,000	7,010	1,588	427	2,296	803	1,488
1979	49,361	64,300	6,180	1,051	387	2,269	377	2,105
1980	64,560	64,000	6,410	2,271	405	4,143	1,343	2,001
1981	58,851	70,300	7,140	2,395	262	3,434	605	2,562
1982	64,905	65,000	6,740	3,105	223	2,902	405	2,672
1983	63,669	60,400	5,240	3,021	411	2,430	611	1,533
1984	64,099	36,800	7,420	3,992	1,188	1,710	1,194	2,602
1985	80,731	23,500	10,190	595	1,106	1,923	7,497	5,046
1986	98,910	16,000	9,550	310	1,276	1,844	12,607	4,278
1987	97,779	28,500	9,520	90	536	1,543	928	3,618
1988	93,419	68,000	8,020	313	229	1,995	361	2,626
1989	97,232	121,400	8,410	269	325	1,105	255	2,248
1990	108,977	80,100	9,320	94	370	802	405	2,101
1991	102,224	34,700	11,160	258	258	467	421	4,282
1992	110,829	11,200	13,490	201	203	273	1,374	5,016
1993	97,109	5,400	14,880	358	11,359	237	1,245	4,591
1994	101,549	5,300	19,390	765	716	178	1,555	6,264
1995	98,105	5,400	19,360	600	1,948	122	3,924	11,714
1996	94,170	4,000	21,320	570	7,314	121	1,167	6,778
1997	88,648	3,600	25,380	1,468	12,342	133	1,221	9,643
1998	89,932	2,900	23,850	2,679	17,142	92	1,281	8,141
1999	101,544	3,300	41,020	3,803	1,958	85	3,985	6,803
2000	107,347	2,500	26,060	1,529	73	111	5,303	15,693
2001	113,897	3,700	21,620	3,995	1,831	107	3,269	20,556
2002	161,605	6,200	27,100	7,233	13,682	201	3,537	16,575
2003	156,866	6,500	30,000	8,130	19,387	443	639	13,195
2004	144,999	7,000	31,220	10,165	310	364	712	11,138
2005	156,054	8,400	31,690	11,972	383	539	1,143	8,032
2006	158,602	13,200	35,420	12,308	77	802	2,975	8,156
2007	149,387	20,100	33,010	10,862	524	917	2,451	8,088
2008	157,865	27,900	35,510	7,950	177	1,267	3,906	4,666
2009	143,622	15,100	37,060	8,583	222	1,207	7,143	6,023
2010	131,967	14,300	31,730	10,642	127	1,235	5,065	7,084

Reconstructing Icelandic catches from 1950 to 2010[1]

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Abstract

Marine resources have always been important in Iceland and they have gradually become more and more so. During earlier centuries they were important as food for Icelanders, after the 14th century fish products, mainly dried cod also became important as export commodity. During the 19th century more species were added to the fisheries and technological advantages allowed increased catches and economic growth. This trend continued during the 20th century, when the mechanization of fisheries fueled the continuing growth of the economy. This domination of fisheries in the economy reached a zenith in 1949 when marine products were 97% of all exports. The fishing industry has continued to grow to the present, but its relative importance has declined as other industries have evolved and grown. The reported landings by the Icelandic fleets within the EEZ from 1950 to 2010 have ranged from 411,000 $t \cdot year^{-1}$ to 2,017,000 $t \cdot year^{-1}$. The most important species in term of value has nearly always been the Atlantic cod (*Gadus morhua*), but the highest catches have usually been from capelin (*Mallotus villosus*). Discards and unreported catches are estimated to have ranged from 3.3% to 6.7% of the reported landings. An overview is given on catches of all species reported by the Icelandic fleets.

Introduction

The purpose of this study is to account for the total extractions from Icelandic waters from 1950 to 2010. It is an update of previous work (Valtýsson 2002) incorporating more recent data and research. The catches, including discards and illegal, unreported and unregulated catch (IUU), is estimated for each and every species reported by the Icelandic fleets, split into large and small boats, and for as small a spatial scale as possible. The number of boats in the Icelandic fleets by size categories is also estimated. Catch statistics were gathered from as many sources as possible and they were compared to find possible errors.

Icelandic waters

Iceland covers around 103,000 km^2. It is the second largest island in Europe, slightly larger than Ireland but smaller than Great Britain. It is located just below the Arctic Circle (Figure 1). The country is highly volcanic, and uninhabitable glaciers, highlands and deserts cover a very large part of the interior. Vegetation only covers about 23% of the country. Iceland was first settled in the ninth century from the Nordic countries, chiefly Norway, but there was also a sizeable component from the British Islands (Helgason *et al*. 2000).

The county was an independent republic until 1262; when after a civil war it entered into a union with the Norwegian monarchy. Gradually, Norway came under Danish rule and Iceland followed along. However, during this time, Iceland was fairly independent, ruled mostly by Icelandic laws, and the Icelandic parliament (Althing) was more or less operational from 930 to the present day. Since the 19th century, more independence was gradually gained and Iceland became a fully sovereign state in 1918, but shared a king with Denmark until 1944 when it became a republic.

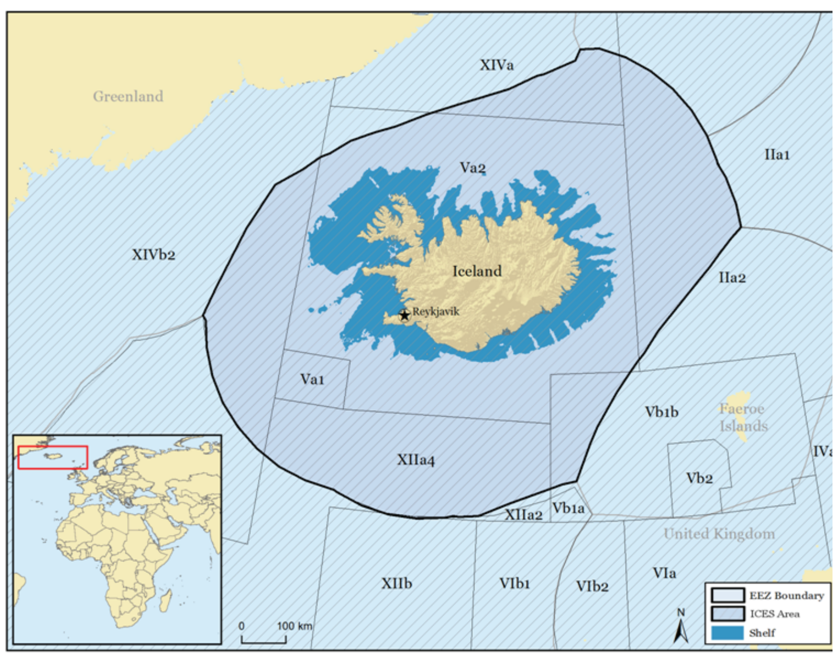

Figure 1. Icelandic Exclusive Economic Zone (EEZ) waters showing shelf area (to 200 m depth) and ICES statistical areas.

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Most of the population lives along the coast, and the highest population density is now around the capital Reykjavík. The population of Iceland was 318,452 in 2011 (Statistics Iceland) and the population density is similar to Canada. Although Iceland is considered part of Europe, half of the country is geologically speaking on the North American continental plate. Iceland is not a member of the European Union (EU) but has close ties to the EU through the European Economic Area (EEA). In 2009, Iceland did submit an application for membership after a serious recession due to the collapse of its banks. This has proved controversial within the country and the most challenging part of the application is considered to be the Common Fisheries Policy (CFP), as Iceland wants to have full control of its fishing grounds (Popescu and Poulsen 2012).

The Icelandic EEZ borders Greenland in the west, Jan Mayen (Norwegian) in the north and Faroe Islands in the east. It borders two international high seas areas, the so-called 'herring loophole' in the northeast and the Mid-Atlantic high seas to the south (Figure 1). The total size of the EEZ is 758,000 km² (Statistics Iceland) and the size of the continental shelf with less than 200 m deep is 109,000 km² (www.seaaroundus.org, Figure 1)

The ocean around Iceland includes the boundary between warm Atlantic waters in the south and colder polar waters from the north. The deeper waters are quite stable, and the temperature is less than 1°C north of Iceland and around 7°C south of Iceland. The surface waters average about 4°C north of Iceland and 8°C to the south, but are much more variable both inter- and intra-annually, depending on seasons and the strength of the currents. The Irminger current keeps the waters south and west of Iceland relatively warm. The current flows clockwise around the country but gradually cools off due to influence from the cold currents flowing in from the north.

The productivity of Icelandic waters is moderately high, and the primary productivity on the Icelandic shelf has been estimated to be between 150-350 g $C \cdot m^{-2} \cdot yr^{-1}$, higher over the shelf than offshore. The total primary production is estimated to be around 55 million t $C \cdot year^{-1}$ (450 million t wet weight) on the continental shelf, but 122 million t within the entire EEZ (Þórðardóttir 1994; Guðmundsson *et al*. 2004).

Iceland's fisheries after WWII

After WWII, the Icelandic fishing fleet was old and worn out, as lost boats could not be replaced and spare parts were difficult to get during the war. However, funds were available to modernize the fleet. Furthermore, these funds were used to build processing plants and improve harbors. This meant that in 1950, at the beginning of the period under consideration here, the Icelandic fishing industry was technologically stronger than at any pervious time and the fleet was among the most modern in the world. Many of the trawlers were diesel powered and were equipped with fish finders and radars, equipment mostly invented during the war. The fisheries did also dominate the economy at that time; exports of fish products reached a peak of 97% of all exports in goods from Iceland in 1949.

The fleet in 1950 consisted of 48 trawlers, 52 motor boats (other than trawlers) larger than 100 GRT, 487 motor boats between 12 and 100 GRT and 51 smaller than 12 GRT (Jónsson and Magnússon 1997). The composition of the fleet changed very little during the 1950s, except that open boats seem to have almost doubled in numbers. It is difficult to verify if this is reality or an artifact of better registration. The rowing boats had almost disappeared from a peak of 5,240 in 1885 to 209 in 1940 and only 5 in 1950. There were no sailing vessels left in 1950, the last one being phased out in 1927.

The Icelandic fishing fleet continued to modernize rapidly during the 1950s, although the number of boats did not increase greatly. Modern trawlers continued to be built and the first motor boat made from steel arrived in 1955. Perhaps more importantly, purse seine boats begin experiments with fish finders in 1954 and power blocks in 1959, followed by rapid increases in herring catches. The Icelandic trawlers conducted minor distant water fisheries in the Barents Sea from 1950 to 1956 and on larger scale in Greenlandic waters from 1951.

The 1960s saw further development of technology. Fish finders and power blocks became standard equipment for purse seiners, and sonars and radars for trawlers. However, the trawl fisheries began to decline, as the operational costs of these vessels was very high, and they were gradually pushed out from shallow water fishing grounds, as the gradual extension of the Iceland EEZ did also apply to Icelandic trawlers. The more economically efficient motor boats flourished until the collapse of the herring stocks in 1967. After the collapse of the herring, the Icelandic pelagic fleet temporarily fished for pelagic fishes in the North Sea, primarily herring and mackerel. Icelandic trawlers fished for cod and redfish in Greenlandic waters during this decade, but catches declined towards the end of the decade.

The fleet composition changed considerably during the 1960s. The number of open boats is thought to have increased somewhat and the trawler fleet declined. The largest changes in the 1960s were in the decked motor boats, which increased in size. Some of the older sidewinder trawlers were also converted to purse seiners with the arrival of more efficient stern trawlers, and subsequently reclassified as decked motor boats. This classification is still used today when boats are registered, but the difference can be spurious. Many of today's largest motor boats that are primarily fishing for pelagic species are in fact larger than most trawlers.

As the foreign catches declined due to the extension of the EEZ during the 1970s, Icelandic catches increased. This increase was mostly due to two factors. Capelin fisheries increased after the herring stock collapse and soon surpassed the herring fisheries in catches. The second factor was the rapid modernization of the trawler fleet where about 22 old sidewinder trawlers in 1970 were by 1980 replaced by 86 new stern trawlers.

The introduction of the Individual Transferable Quota (ITQ) system began in 1975 with individual ship quotas on the slowly recovering herring stocks. First use of rapid area closures was in 1977. This was to protect areas where by-catch of juveniles was high. The same year, a rudimentary effort control system was established for the trawlers where they could only target cod for a certain number of days per year, the other days they could target ('scrape up') other less valuable species, thus it was called the 'scraping day system'.

Further limitations were set on the Icelandic fleet as the fishing capacity continued to grow. Individual catch quotas were set on capelin in 1980, and an effort based management system was established for trawlers in 1981. This proved unsuccessful and an individual quota system was established on the most important demersal stocks in 1984. This only applied to boats 10 GRT and larger. The quotas for each boat were based on the catch history the three previous years. Effort limitations were set on boats from 6 to 10 GTR in 1988.

The number of stern trawlers continued to increase during the 1980s, and the first freezer trawler arrived in 1982. Number of trawlers reached a peak of 115 in 1989. The number of medium and large decked motor boats declined somewhat but most importantly the small boat sector more than doubled in numbers. This was largely driven by technological advances, as more cumbersome and slower timber boats were replaces by faster and lighter boats made of fiberglass. Another important new technology was the computerized jigging reels. This allowed one person to operate several handlines, and therefore multiplied the efficiency of the handline fleet. Icelandic boats fished almost exclusively in Icelandic waters during the 1980s.

The 1990s were the first decade that management measures for the Icelandic fleet began to become truly effective. The last free fisheries in Iceland, for boats less than 6 GRT were abolished in 1990 as the small boat fleet had grown out of control. In 1991, all fisheries in Iceland were based on ITQs to limit the catch and size of the fleet. Boats less than 6 GRT could opt for an effort based system. As a consequence of more strict management measures, the fleet began to shrink again for most of this decade. The TAC for many species, most importantly cod, were for the first time severely restricted by the Ministry of Fisheries to reduce overfishing. This is the decade where the size of the cod stock reached its lowest point, but also the decade where it began to grow again (Sigurðsson and Magnússon 2012).

As severe limits were set on fisheries for the most important Icelandic species, vessel operators began to look for alternative ways to use the boats. Many new species began to appear in landings, both because more species were retained and more were targeted. Examples of these are grenadiers, blue whiting, argentines, orange roughy, oceanic redfish, long rough dab, shagreen ray, starry ray, rabbit fish, sea urchin and whelk. For the same reason, Icelandic boats began again to fish in distant waters, trawlers went to the Barents Sea to fish for cod and to the Flemish cap off Canada to fish for northern shrimp. The pelagic boats went to the Norwegian Sea to fish for herring.

The final remnants of the effort based management system for small boats was abolished in 2004, and a new system for the smallest boats was introduced in 2009, for the summer coastal fisheries. A special tax on fisheries, the fishing fee, was established in 2004. This fee was originally 6% of catch value minus operating cost but changed over time.

During the 2000s, both trawlers and open boats declined in numbers while the decked motor boats increased in the early part but then continued to decline as well in the later part. A few new species appeared in the fisheries such as the silvery lightfish and sea cucumber, but most importantly the mackerel that was not fished at all in 2000, but by 2011, mackerel was the second most important species in Icelandic waters.

On the whole, fisheries have been an extremely important part of the Icelandic economy through the centuries. During the 20th century, seafood exports have been 60-95% of total exports, the labour share in fisheries has been between 10-20% and the direct contribution to the GDP between 10-35%. It is thought that the importance of the fishing industry is even more important than official statistics reveal, as the fisheries directly affect other sectors of the economy (Ágnarsson and Árnason 2007). The relative importance of fisheries has been declining in more recent decades, not due to decline in the fisheries but rather growth in other sectors.

Foreign fisheries in Icelandic waters

The first references to distant water fisheries in Icelandic waters are of English boats in 1412 (Þór 2002). However, the beginning of the time period under consideration here was characterized by high foreign catches, reaching a peak of 868,190 t in 1955, about half of this was herring and a quarter cod. The largest foreign fishing countries were England in demersal fisheries, and Norway and Germany in herring fisheries. The first active steps in extending the Icelandic EEZ were in 1950, when the 4 nm fishery protection zone was declared off the north coast. This applied to all trawl and Danish seine fisheries (including Icelandic) and foreign herring fisheries. The fishery protection zone was extended to 4 nm all around Iceland in 1952. In 1958, the fishery protection zone was extended to 12 nm, pioneering the worldwide trend at that time to declare EEZs. This was followed by the first 'Cod War', as the British declared this to be illegal and activated the Royal Navy to protect the British trawlers.

Despite the extension of the EEZ, foreign demersal catches continued to be high during the 1960s or at a similar level as the Icelandic fisheries. The foreign herring fisheries diminished in 1967 due to the collapse of the stocks. The 1970s were marked by a dramatic change in foreign catches as the Icelandic fishery protection zone was expanded in steps to 50 nm (1972) and 200 nm (1975), followed by the second and third 'Cod Wars'. Foreign catches (mostly demersals) were about 300,000 t at the start of this decade, the beginning but had almost disappeared by the end of the 1970s.

Foreign catches were low during the 1980s and 1990s. The only significant catches were by Norwegian boats on the shared capelin stock. Foreign demersal catches consisted mostly of Faroese and Norwegian bottom longliners allowed to continue fishing in Icelandic water and a few hundred tonnes by Belgian trawlers.

Foreign catches in Icelandic waters were also negligible during the first decade of the 21st century, except for the shared pelagic stocks, with Faroese, Norwegian and Greenlandic boats fishing for capelin and Faroese boats fishing for blue whiting. Although the amounts were low, there was some revival of foreign demersal fisheries in Icelandic waters due to reciprocal fishing rights with the European Union. Faroese longliners also continued to fish demersal species in the Icelandic EEZ.

Targeted species

About 340 fish species have been recorded within the Icelandic EEZ (Jónsson and Pálsson 2006). Roughly half of these are demersal and the other half pelagic. About 25 of those species are of commercial importance, but only a handful dominate the catch. From these, only one species has until lately provided more than half of the export earnings from marine products, this is the cod. Another important species, the capelin, is of much lower value per kg, but has recently provided up to half of the total catch. In recent decades, total catches of all species have fluctuated between 1-2 million t·year^{-1} (Figure 2b).

The main benthic feeding fish species, or groups, are haddock, wolffishes, skates and flatfishes. Most of these also eat other fishes, mostly capelin when available. The redfishes are common but both found in the demersal and pelagic zone, they feed mainly on zooplankton. Higher in the trophic level are the piscivorous fishes, dominated by cod in warmer waters and Greenland halibut in colder seas. Other species at this trophic level are mostly gadoids, such as saithe, whiting, tusk, and lings. A number of smaller or much rarer species are also found around Iceland, living in the shadow of these larger and more abundant species.

Demersal fisheries usually target a seasonally changing mixture of codfish, flatfish and redfish species. Other species of commercial importance are wolffishes, monkfish and lumpsucker. A few species of sharks and skates are also fished but are of low economic importance. Many species are migratory, but most of the demersal species do not leave the Icelandic EEZ, the only substantial exception to this is the Greenland halibut that migrates from Greenlandic waters, through Icelandic to Faroese waters.

The highest catches in Icelandic waters are from the few but abundant pelagic species. These fisheries are also characterized by large fluctuations, as the stock size and migration routes of these species can change dramatically. The herring is the most important species historically. After the collapse of the herring stocks in the 1960s, the Icelandic boats turned to capelin, previously virtually unfished. This fishery rapidly grew to around 1 million tonnes annually, in some years as much as for all other species in Icelandic waters combined. Three other pelagic fisheries have developed in Icelandic waters in recent years, all on international stocks. These are oceanic redfish, blue whiting and Atlantic mackerel.

Another character of the pelagic species, as opposed to the demersal ones, is that their migration routes are much more extensive, making these ‘international’ and transboundary stocks. The pelagic fisheries are consequently spread over a wider area. The capelin fisheries are sometimes conducted far north of Iceland at the start of the spawning migration and then follow the spawning migration around Iceland. The fishery for the Atlanto-Scandian herring is mostly in the Norwegian Sea, northeast and east of Iceland, but can go all the way to the Barents Sea. This stock also used to provide a large part of the herring fisheries in Icelandic waters before 1967. The blue whiting fisheries are in international waters, as well as within the Icelandic EEZ, east and southeast of Iceland. In the last years, mackerel has made an appearance southwest of Iceland. Further west, over the Reykjanes Ridge, on the south western part of the EEZ and also outside it, considerable fisheries are conducted on oceanic redfish. The only commercial pelagic stock that only occurs over the Icelandic continental shelf is the Icelandic summer spawning herring. These fisheries are now exclusively carried out by vessels operating purse seines or pelagic trawls. Previously some quantities of herring were also fished with driftnets.

There is a variety of invertebrate species found in Icelandic water whose numbers are not very well known. However, the species harvested are rather few in comparison to the fishes. Furthermore, invertebrate fisheries are characterized by instability and fluctuations. Fisheries for invertebrates began after the middle of the 20th century, initially mostly on northern prawn and Norway lobster. The only invertebrate to reach the top 10 list of commercial importance was the northern shrimp that was for a time the second most important marine species for the Icelandic fleet, but this fishery later collapsed. Other invertebrate species have been harvested sporadically. The only invertebrate fishery that has not been marked by this boom and bust cycle is the Norway lobster.

Current fishing sectors

Recreational fisheries

Recreational fisheries are popular in Iceland, but are mostly conducted on trout and salmon in rivers and lakes. These are outside the scope of this report. These same species are in turn not the target of any substantial commercial fisheries today. However, recreational fisheries in the ocean have been growing in popularity. Tourists can go on organized trips to fish mainly for cod, and many Icelanders also own small boats that they use to go fishing on good days. However, one can argue that this is rather a subsistence fishery than recreational and is therefore included in the subsistence category. Thus, the recreational fisheries fall roughly into two classes and catch statistics are usually poor.

1) Freshwater fisheries for salmon, arctic char and brown trout. This sector is outside the scope of this study.

2) Recreational marine fisheries for tourists. Several companies offer organized boat tours for tourists where they are provided with equipment and supervision. Each boat can only have 7 fishing rods and only 7 fishes are allowed during a trip. This catch is not registered but the boats need special licenses. Usually medium sized boats (10 GRT) are used. These primarily catch cod.

Subsistence fisheries

Subsistence fisheries are very difficult to discern from recreational fisheries. Some farmers fish for trout with gillnets in their own lakes or rivers. There is a mandatory reporting of this catch but it has not been monitored strictly, as the lakes are usually privately owned and it is the owner's responsibility to manage. Many Icelanders own small boats that they use on good days to go fishing on the ocean. This is especially popular among retired fishers. In this case, one is only allowed to catch fish for personal consumption, not for selling the catch and only use non-mechanical fishing rods or handlines. Mainly cod fishes are targeted while other demersal species such as mackerels are the least sought after. Another aspect of subsistence catches is that fishers on commercial boats are also allowed to retain a small part of the catch for personal and crew consumption, either onboard or to take home. This can include many species but haddock is the most popular food fish in Iceland.

3) Subsistence fisheries by Icelanders. The primary species fished in these fisheries are cod and haddock. This is mostly fished on small boats, but also from larger boats and from the shore. This catch is not registered but is estimated here from domestic fish consumption.

Small-scale, commercial fisheries (artisanal)

There is a large sector of small boats in Iceland committed to commercial fisheries, defined here as the artisanal sector. The definition of "small boat" has changed with time and is variously based on length or weight, often 10 to 15 m or 6 to 15 GRT or GT. These boats use longlines, gillnet or handlines depending on season and area. There is an overlap between this sector and the recreational sector and the large boat sector. However, as opposed to the recreational and subsistence sectors, all the catch in the artisanal sector is reported and included in the country fisheries statistics. As opposed to the large boat sector that now has only one management regime (the ITQ system), there are and have been several management methods to manage the small boat fisheries. The sectors are described below, but note that individual boats can fall into several sectors depending on the season:

4) Tourist can rent boats with fishing gear and a quota. They can keep part of the catch for their own consumption (20 kg of fillets), but the rest goes to a fish market. This catch is included in the national catch statistics. Total catch was only 243 t of cod, 14 t of Atlantic wolffish and about 5 t of other species in 2010. Small boats are used.

5) Sea angling associations have their own quota for sea angling competitions. To be able to participate, one has to be a member in Icelandic Sea angling association or European Federation of Sea Anglers. Special quotas are provided for these events and the catch is registered in the national catch statistics. Small or medium size commercial boats are usually used.

6) Recently, a new system has been introduced for the small boats, intended to ease the transition from the recreational fisheries to the commercial fisheries. This is the summer coastal fishery. Essentially, all small boats with fishing licenses (everyone can have a fishing license given a few preconditions) can enter this fishery, even boats that are already in the other systems. The only preconditions are that the boats can only use one system each month. The boats need no quota for this system but there are strict regulations on the catch that can be fished each day, only 4 automated handlines are allowed on each boat, no other fishing gear can be used and so on. The system is effort based. A maximum quota is given for each region each month and when the quota has been reached, the fishery is closed for the rest of the month. This catch is registered and included in the country statistics. Licenses for coastal fisheries were 747 in 2010 and total catch was about 5,000 t of cod, 1,200 t saithe and 140 t other species.

7) Lumpsucker fisheries are outside the fisheries management systems above. Lumpsuckers are fished for the roe in the spring when they migrate to very shallow waters to spawn. The fishery is only by small boats (no larger than 15 GT) that have a lumpsucker license. There is no cap on the catch but the season is limited, there is a limit on number of nets used and a limited number of lumpsucker licenses are available (349 in 2010). Thus, if one wants to enter the lumpsucker fishery, one has to buy the license from someone else that is leaving the fishery. This catch is registered and included in the country statistics.

8) The most common system for commercial fishers on small boats is the 'hook and longline quota system' exclusively for the smaller boats. This is limited to boats smaller than 15 GT using only handlines or longlines. However, in essence this system is similar as the 'large' ITQ system described below.

9) Many small boats are in the same ITQ system as the large boats (hence the overlap). In this system there is no limit on the size of the boat and virtually all fishing gear can be used. Transfer of quota within each quota system is allowed but not between systems. See description of this system below.

For a summary of the above itemized fisheries components for Iceland, and their assignment to *Sea Around Us* fishing sectors see Table 1.

Large-scale, commercial fisheries (industrial)

The large boat commercial fleet (here labeled 'industrial' in contrast to the above 'artisanal') essentially operates under one system, item 9 described above. This is the ITQ system, where each species has a TAC decided by the

Minister of Fisheries based on advice from the Marine Research Institute. The quota is divided among the fishing boats according to their quota share. This quota can then be traded. This fisheries management system has been largely successful in curbing the growth of the fishing fleet (Hoof, 2010).

Table 1. Overview of current fisheries in Iceland.

Item	Type	Species	Fishing gear	Boats	In statistics	Sector
1	Freshwater	Salmon and trout	Fishing rods, gillnets	None or small	Only FAO	Recreational
2	Tourist	Mostly cod, haddock and other demersals	Fishing rods	Small/ medium	No	Recreational
3	Pers. consumption	Mostly cod, haddock and other demersals	Non-mechanical handlines or fishing rods	None or small	no	Subsistence
4	Rent-a-boat	Mostly cod, haddock and other demersals	Handlines or fishing rods	Small	Yes	Artisanal
5	Sea angling clubs	Mostly cod, haddock and other demersals	Fishing rods	Small/ medium	Yes	Artisanal
6	Summer coastal	Mostly cod, haddock and other demersals	Handlines	Small	Yes	Artisanal
7	Lumpsucker	Lumpsucker	Gillnets	Small	Yes	Artisanal
8	Hook and longline	Mostly cod, haddock and other demersals	Handlines or longlines	Small	Yes	Artisanal
9	ITQ system	All species	Various	All	Yes	Artisanal/ commercial

There are a few minor species that do not have a TAC. Anyone with a valid fishing license can fish for those. Through history, more and more species have received a TAC. As a new species has gained the attention of fishers, more and more of them have entered the fishery and finally the government has intervened and put the species under quota to prevent overfishing. The reverse has occurred, but is much rarer. A combination of low international prices, low stock size and high oil price rendered the offshore shrimp fisheries unprofitable, and the very limited quotas were not reached. The fishery was subsequently opened for all again.

The items described above only apply for the last few years. When we go further back in time, the picture becomes more and more muddled as the fishery regime has changed considerably and differently for different sectors of the fleet. For a period, small boat fisheries were managed by an effort based system, further back the large boats were as well for a few years. Prior to that, the fishery was open access but with various fishing gear limitations and area restrictions.

The commercial and artisanal fleets in 2012 can broadly be divided into 6 groups based on size and fishing gear used:

- 56 commercial trawlers that mostly use bottom trawls to fish for various demersal species, but also use pelagic trawls to fish oceanic redfish and mackerel. Some of these process the catch onboard (freezer trawlers).
- 23 commercial decked vessels larger than 1000 GT primarily fishing pelagic fishes. The largest boats in this class process the catch onboard.
- 200 commercial decked vessels ranging from 26 to 1000 GT. These are primarily fishing demersal fish species and invertebrates with various types of fishing gear. The large boats in this category mostly use longlines and trawls but the smaller ones gillnets, longlines and Danish seines.
- 243 decked vessels ranging from 11-25 GT primarily fishing for demersals with longlines. These can both be part of the commercial or artisanal sector.
- 312 decked vessels smaller than 11 GT primarily fishing for demersals with handlines and longlines. These are part of the artisanal sector.
- 856 undecked vessels primarily fishing for demersals with handlines and are part of the artisanal and subsistence sector.

Methods

Number of boats

Official information on numbers of fishing boats have been published annually, first from 1966 to 1974 in Ægir (Anon. 1970), from 1975 to 1998 in Útvegur (Anon. 1978), and from 1999 to the present in Statistics Iceland (www.statice.is). To supplement this, information on number of boats is also available in Bulletin Statistique des Pêches Maritimes from 1950 to 1978 (ICES 1903) and from Tölfræðihandbókin from 1950 to 1964 (Anon. 1967). See compilation of all information sources in Table 2.

As the data sources above do not agree perfectly and give information in different size formats (Table 2), I had to reconstruct the number of boats and split these into small and large. I define small boats as boats less than 11 or 13 GRT (or later GT) depending on information available for each year. However, the Icelandic motor boat fleet has traditionally been split into open (or undecked) boats, decked boats and trawlers. Open boats clearly fall into the small boat category and trawlers into the large boat category. Decked boats, however, can range widely in size and can fall into both categories. There is no sharp boundary between large and small boats and all fleet sectors have changed considerably since 1950.

Table 2. Sentences for violation on the Fisheries Management Act.

Year	Felony	Amount
1998	Not weighting the catch	227 kg lobster tails
2000	Not weighting the catch	1,110 kg ungutted cod
2000	Not weighting the catch	45 kg cod fillets, 172 kg gutted cod, 30 kg haddock fillets, 5 kg halibut
2000	Not weighting the catch	136 kg cod fillets
2000	Not weighting the catch	121 kg cod fillets and 83 kg headless cod
2002	Not weighting the catch	404 kg gutted headless cod
2002	Not weighting the catch	324.4 kg cod
2002	Wrongly identify catch	Tusk disguised as wolffish
2003	Discarding	At least 53 cods
2003	Wrongly identify catch	Cod disguised as spotted wolfish and undersize cod
2003	Wrongly identify catch	Plaice disguised as American plaice and dab
2004	Not weighting the catch	7,542 kg ungutted cod
2005	Not weighting the catch	1,823 kg gutted cod, 73 kg dab, 741 kg plaice, 842 kg haddock and 16 kg cod fillets
2005	Not weighting the catch	109 kg cod fillets, 53 kg plaice, 48 kg lemon sole, 5 kg monkfish
2005	Not weighting the catch	431 kg ling
2006	Not weighting the catch	6,030 kg ungutted cod
2008	Not weighting the catch	200 kg haddock, 100 kg cod, 80 kg wolffish, 15-20 kg skate and 30 kg tusk
2008	Wrongly weighting the catch	203 kg unidentified catch
2009	Fishing without quota	83,823 kg gutted cod
2009	Not weighting the catch	499 kg lobster tails, 20 kg gutted monkfish
2010	Not weighting the catch	150 kg plaice
2011	Not weighting the catch	2,335 kg unidentified catch
2011	Not weighting the catch	7,968 kg unidentified catch
2011	Not weighting the catch	1,055 kg monkfish

Trying to compile the total number of Icelandic fishing boats and separate them into small and large boats was therefore a puzzle where some of the pieces were lost. The total numbers for decked boats and trawlers largely agree, but open boats are sometimes included and sometimes not. Furthermore, the size categories the boats are split into vary between periods (Table 2). Some approximations and assumptions had to be made to separate the small boats from the large prior to 1965. By far the most difficult class was the open boats prior to 1977.

Currently all boats larger than 6 m have to be registered and it is safe to assume that the catch by unregistered boats (6 m) is negligible. It is also important to realize that all registered fishing boats are not necessarily participating in the fisheries. Some lie idle, some are only used in distant waters, while others, especially open boats, are primarily used as recreational vessels.

In the analysis I use the number of open boats with registered catch. The data available on the actual numbers of open boats are too vague and these boats are often used for other purposes than fishing, or they might not be used at all. Data are available for both registered open boats and open boats fishing for a few years. From 1990 to 2001, about 69% of them did register some catch annually, but from 1969 to 1977 only 47% of them did register catch (Anon. 1978).

For decked boats and trawlers, I use actual numbers registered, as most of these boats are fishing each year. After 1967, when reliable data are available, more than 97% of all registered trawlers or decked boats did register some catch annually (Anon. 1978; Jónsson and Magnússon 1997).

In summary, the number of trawlers is accurate. The total number of decked boats should also be accurate, although how it is split between small, medium and large vessels is less clear. The largest uncertainties are on the decked boats, as the total numbers are not known for many years.

Catch statistics

In Iceland, it has been mandatory for boats to report catch since 1897 (Jónsson and Magnússon 1997). From 1942 to 1998, the Fisheries Association of Iceland was responsible for all fisheries statistics. Initially, they were published in the monthly periodical Ægir (Anon. 1970), and since 1976 in the annual report Útvegur (Anon. 1978). In 1999, Statistics Iceland took over the responsibility and all the information is now published online (www.statice.is).

These are the official sources, but information on catches is also available from other sources (see below), originating from the Fisheries Association and later Statistics Iceland. However, the sources do not all agree. Some have only catch in a given area (ICES, FAO or EEZ) while others have total catch for all areas. The general picture on total catch is often rather clear, but when one goes into finer scale details, the picture becomes murkier, especially with older data, less important species and highly migratory species.

The apparently simple task to establish the baseline catch, before trying to estimate more complicated issues such as discards and illegal and unreported catches, was therefore challenging, as these are many species, many years, many areas and many sources. Furthermore, I try to split this catch into small spatial scale and into catch by small boats and large.

The databases and information sources are listed below. In general, catch numbers from the ICES and NAFO databases were used until 1992, and data from Statistics Iceland thereafter. However, there were several exceptions as described in the subsequent species summary.

FAO

This is the globally most significant database, as this is what is presented to the world as the Icelandic catch. The main drawback is the large areas used. All of the catch in Icelandic waters and most of the catch by Icelandic boats in foreign waters are in FAO area 27 (North-east Atlantic), but it is not possible to separate catch in Icelandic waters from catch in the North Sea or Barents Sea. Consequently, this database does not give any information on foreign catch in Icelandic waters or Icelandic catches in distant waters except outside FAO area 27. Nevertheless, this database is used as the baseline on the catch by the Icelandic fleet.

ICES

The ICES database is also based on data provided by national governments. It provides data on all catches (not including aquaculture) in FAO area 27, but on a much smaller, more detailed spatial scale. This database has information on all catches in Icelandic waters and catch by the Icelandic fleet outside Icelandic waters (provided it is in FAO area 27).The database is nevertheless problematic, since it does not give information on catches by EEZs, but rather ICES statistical areas. This is not too much a problem for demersal species in Icelandic waters, where the vast majority of the catches are both within ICES area Va and within the Icelandic 200 nm EEZ (Figure 1). However, it is problematic for the migratory pelagic species that are fished further offshore , often along the outer edge of the EEZ, or beyond it in high seas waters or other countries' EEZs. Almost all the Icelandic continental shelf is within ICES area Va, and almost all the area Va is within the Icelandic EEZ (Figure 1). However, the outer edges of the Icelandic EEZ stretch into ICES areas IIa[2] (Norwegian Sea), Vb1b (Faroe Islands), XIIa4 (N Atlantic), XIVb[2] (SE Greenland) and XIVa (NE Greenland).

Bulletin Statistique des Pêches Maritimes (Bull. Stat.)

These are annual reports published by ICES from 1905 to 1990, when they were replaced by the ICES electronic database. The numbers are generally the same as in the ICES database. However, the printed reports do give some additional information that is useful. For example, catch by ICES countries outside the ICES area is given in the reports from the 1950s. This is especially useful as the NAFO database only goes back to 1960.

NAFO

The NAFO database is similar to the ICES database in terms of finer scale spatial resolution, but for FAO area 21 (NW Atlantic). This is valuable as it supplements the ICES database on Icelandic fisheries in distant waters, as Icelandic boats have fished extensively in West Greenlandic and Newfoundland waters. The drawback of this database is that information is only available since 1960.

Statistics Iceland (http://www.statice.is/Statistics/Fisheries-and-agriculture)

This is where official statistics on various aspects of the Icelandic economy are gathered and stored. It has extensive information on the Icelandic fisheries, such as export, processing, catch value, number of boats, number of people employed in the fishing industry, the economic performance of the fishing industry and of course information on catches. However, it is not easy to find information in the manner needed here, i.e., catch by Icelandic boats by areas, except after 1992. Furthermore, minor species are lumped together under 'other demersals', 'flatfishes', 'pelagics' or 'shellfish'. Catch by fishing gear, boat type and month is available in this database after 1992.

The Directorate of Fisheries (http://www.fiskistofa.is/veidar/aflaupplysingar)

The Directorate is responsible for gathering information on all catches in Icelandic waters. Real time information is sent to the Directorate each time a boat lands its catch in an Icelandic port, or with special arrangements in foreign ports. All commercial landings in Iceland are weighted by government officials or in small harbors by government approved agents. The Directorate then sends this information to Statistics Iceland, where it is published after being revised. The data from the Directorate is therefore not the official Icelandic catch data, but rather its precursor. However, its value comes from the fact that it is updated in real time, and, more importantly for the present purpose, it includes all the minor species. The data from the Directorate is available on the web since 1993. Furthermore, information is also available from the Directorate on Icelandic catch on migratory pelagic species by EEZ.

Hagskinna

This is a single publication from Statistics Iceland (Jónsson and Magnússon 1997) with compilation on various historical statistics in Iceland. It has information on catch by Icelandic boats on major species from 1898 to 1990. This provided supplementary information.

State of Marine Stocks in Icelandic Waters 2011/2012–Prospects for the Quota Year 2012/2013

This publication is produced by the Marine Research Institute (MRI), and is the latest version of annual reports with analysis of the stock status of Icelandic fishing stocks. This provides total catch information on the most important commercial species. This is mostly used as supplementary information, but is the only reliable source of information on lumpsucker catch. It has also detailed information on redfish catch by stocks.

Útvegur, annual reports

These are the precursor of the data that is now provided in Statistics Iceland website. These reports provide excellent information on effort and catch by gear from 1977 to 1999, and also some information on total landings since 1968. These reports also provide information on various aspects of Icelandic fisheries, such as the size and capacity of the fishing fleet, effort by fishing gear, landings and catch value of the fishing fleet by fishing gear or port of landing. This is mostly used as supplementary data, but is particularly valuable for splitting the total catch between small and large boats.

Catch by size category

Catch by size category of boat is available from 1992 to the present day (Statistics Iceland). Total catch (not separated to species) by boat size is available from 1977 to 1991 (Anon. 1978), and this was split according to known species composition from 1992 to 2001. There is one problem with these data, they are available for all open boats but only decked boats smaller than 20 GRT (except for 1991), but in this analysis I use 10 GRT as the split point for small boats. I therefore assume that 50% of the 20 GRT catch is by boats smaller than 10 GRT. Catch by size category is not available before 1977, so I used catch per boat and species composition from 1977 to 1988 to estimate the catch from numbers of boats, assuming that catch per boat is the same for the entire period from 1950 to 1976.

Unreported and unregulated catch

Unreported landings of marine species fall into two categories (Table 1), operators that offer sea angling trips for tourists are allowed to catch a certain amount of fish that the tourists can keep. Cod is by far the most common species in these fisheries and I only assume that this applies to cod. There are plenty of assumptions when estimating these catches. The current numbers of operators with this license are 11, but a web search shows that 31 operators offer sea angling for tourists. This has been growing in popularity lately and can probably be linked to the approximately linear growth since 1995 of another marine based tourism, whale watching (Anon. 2011). I assume 30 operators in 2010, each taking 7 fishers, each catching 7 fishes per day, each fish weighting 2 kg and operating for 60 days a year = 176 t. A further assumption is that the number of operators declines by 2 each year back to zero in 1995.

The other category is the fish Icelanders eat themselves. It can both be from small boat owners that fish for themselves and their family using small boats or from shore, as is allowed without reporting. This is at the border of recreational and subsistence fisheries, but is classified as subsistence fisheries here. Commercial fishers on larger boats can also retain some part of the catch to take home to their families or to eat onboard. A part of this is actually reported and is available as domestic consumption in Statistics Iceland. This has been 5,000 to 6,000 t·year^{-1} since 1992, and 98% of this is groundfishes and mostly haddock.

I set out to compare this with estimates of actual fish consumption from consumption surveys. This could reveal a gap that should be the unreported catch described above. I first looked at the information from FAOSTAT. This does in fact show much larger seafood consumption in Iceland than Statistics Iceland indicates. For example FAO shows 27,917 t consumed in 2009 compared to 5,940 t in Statistics Iceland. However, Statistics Iceland shows that most of the consumption is demersal fishes while a very large part of the FAO information is crustaceans, pelagic fish and molluscs. While Icelanders eat these, the consumption should be much lower than for demersal fishes. Still, demersal fish consumption is higher in the FAO database than Statistics Iceland. One could assume that the difference is the unreported Icelandic catch for local consumption. However, there is another problem. When we go further back in time in the FAO database there is unrealistically high variability between categories. The FAO database has also been criticized for not being up to date, it shows an increase in fish consumption *per capita*, while the opposite is probably true (Steingrímsdóttir *et al.* 2002).

Icelandic reports since 1990 (Steingrímsdóttir *et al.* 1991; Anon. 1999; Þorgeirsdóttir *et al.* 2011) usually show that each Icelander eats the equivalent of 45 kg of fish annually. Previously, they probably did eat more as elderly people eat much more fish. When converted to total live weight this is about 13,000 t·year^{-1} for the last decade. Part of this, or 50%, is reported in national statistics which leaves about 6,500 t·year^{-1} as unreported. I assume that the composition of this is the same as is available in national statistics and does not changes over time. It is very likely that consumption *per capita* is decreasing, but no information was available on how much of the catch for local consumption before 1990 was reported in national statistics.

Illegal catch

Table 3. Summary of discard rates used.

Species	Baseline (%)	Notes	Source
Cod	5.5	Known discard rates or interpolations after 1990	Various, see text
Haddock	5.5	Known discard rates or interpolations after 1987	Various, see text
Demersal redfish	13.0	Includes *S. marinus*, *S. mentella* and *S. viviparous*	Anon. (2001)
Oceanic redfish	16.5	High due to external parasite	Anon. (2001)
Other demersals	5.5		Kelleher (2005)
Capelin	1.5	Norwegian discard rate	Kelleher (2005)
Blue whiting	1.5	Norwegian discard rate	Kelleher (2005)
Other pelagics	2.0		Kelleher (2005)
Shrimp	5.5	Norwegian discard rate	Kelleher (2005)
Norway lobster	35.0	Norwegian discard rate	Kelleher (2005)
Other invertebr.	5.5	-	Kelleher (2005)

There are always incentives to land the catch illegally to maximize the value of one's quota, especially with the introduction of the ITQ system. It is the responsibility of the Directorate of Fisheries to enforce laws and regulations regarding fisheries management, monitor fishing activities and impose penalties for illegal catches. Onboard observer programs exist and regular landing sites monitoring exist also. As there are rather few landing ports in Iceland, this is perceived to be effective. To try to get a sense of the scope of illegal catches, I did a throughout scan of sentences since 1998 on violations on the fisheries management act (Table 3). Twenty four cases were successfully brought to justice over a 14 year period. Only one involved discarding. Three involved wrongly identifying catch, usually by disguising valuable fish with less valuable. One was about fishing without a quota, actually done in protest of the fisheries management system. Finally, 19 cases were for landing the catch illegally, that is not weighting and registering the catch. In total, this amounted to about 2.7 t·year^{-1} of illegally caught fish, mostly cod. This is of course miniscule compared to the total registered catch. As it is currently impossible to estimate how large percentage is caught breaking the laws this was not included in our catch database. Further studies on this are therefore recommended.

Table 4. Summary of information available on number of Icelandic fishing boats. tr = trawlers, db = decked boats, ob = open boats.

Data source	Period	Data available	Data type
Hagskinna	1950-1966	Tr (side, stern), db (<100, >99), ob not available	Tr fishing for more than 100 days/ year, registered fishing boats
	1967-1976 and 1980	Tr (side, stern), db (<100, >99), ob not available	Boats with registered catch
	1977-1990 except 1980	Tr (side, stern), db (<100, >99), ob	Boats with registered catch
	1950-1990	Tr and db (<100, >99), ob not available	Registered fishing boats
Ægir	1966-1974	Db (0-12 GRT, 13-25 GRT, 26-50 GRT, 51-100 GRT, 101-150 GRT, 151-200 GRT, 201-250 GRT, 251-300 GRT, >300 GRT), ob not available	Registered fishing boats
Útvegurinn	1975-1977 1980-1981	Tr (<501 GRT and >500 GRT), db (0-12 GRT, 13-20 GRT, 21-50 GRT, 51-110 GRT, 111-200 GRT, 201-500 GRT, 501-800 GRT, >800 GRT), ob not available	Registered fishing boats
	1978-1979	Tr (<501 GRT and >500 GRT), db (0-20 GRT, GRT, 21-50 GRT, 51-110 GRT, 111-200 GRT, 201-500 GRT, 501-800 GRT, >800 GRT), ob not available	Registered fishing boats
	1982-1998	Tr (<501 GRT and >500 GRT), db (0-12 GRT, 13-20 GRT, 21-50 GRT, 51-110 GRT, 111-200 GRT, 201-500 GRT, 501-800 GRT, >800 GRT), ob	Registered fishing boats
Statistics Iceland	1999-2011	Tr (<1001 GT and >1000 GT), db (0-10GT, 11-25 GT, 26-100 GT, 101-300 GT, 301-500 GT, 501-1000 GT, >1000 GT), ob	Registered fishing boats
Bulletin Statistique	1950-1959	Tr and db combined (0-30 GRT, 31-100 GRT, 100-500 GRT and >500 GRT), ob not available	Boats with registered catch
	1960-1961	Db and Tr (0-25 GRT, 26-50 GRT, 51-100 GRT, 101-150 GRT, 151-500 GRT, 501-900 GRT, 901-1800 GRT, >300 GRT), ob	Boats with registered catch
	1962-1963	Db and Tr (0-25 GRT, 26-50 GRT, 51-100 GRT, 101-150 GRT, 151-500 GRT, 501-900 GRT, 901-1800 GRT, >300 GRT), ob not available	Boats with registered catch
	1964-1974	Db and Tr (0-25 GRT, 26-50 GRT, 51-150 GRT, 151-500 GRT, 501-900 GRT, 901-1800 GRT, >300 GRT), ob not available	Boats with registered catch
	1975-1979	Db and Tr (0-25 GRT, 26-50 GRT, 51-100 GRT, 101-150 GRT, 151-500 GRT, >500 GRT, ob not available	Boats with registered catch
Tölfræði-handbók	1950-1957	Tr, db (<13 and >12), ob	Boats fishing in the month where numbers are highest
	1958-1961	Tr, db (<31 and >30), ob	Boats fishing in the month where numbers are highest
	1960	Tr, db (<51 and >50), ob	Boats fishing in the month where numbers are highest
	1950-1964	Tr, db	Registered fishing boats

Discards

Discards are officially banned in Icelandic waters, but have been estimated to be 45,564 t·year^{-1} (Kelleher 2005) in 2001, or 2.3% of total catch. It has been claimed that ITQ systems, as used in Iceland, could encourage discards (Árnason 1994; Vestergaard 1996) and there were strong rumors that this might have happened in Icelandic fisheries after the introduction of the ITQ system. However, limited studies did indicate a discard rate of 5-6% for cod both before and after the ITQ system was established in 1984 (Anon. 1993; Valtýsson 2002). These studies were conducted in 1982, 1987 and 1990, but were not standardized. However, what these years had in common were very high catches. They did rank as the 4th, 3rd and 9th best years in Icelandic cod fisheries after 1950. Equally limited studies in the 1990s did indicate a much lower discard rate for cod of 0.4%. This year ranks as the 26th highest in Icelandic cod fisheries after 1950.

This seems to indicate that discards are somewhat related to total catches, that is as the catches are higher the relative discards are higher. This is not illogical, as in times of bumper catches there might be a tendency to use the limited storage space in the boat only for the most valuable catch (i.e., high-grading). This is reinforced by the fact that discarding seems to have been introduced to Icelandic waters by English trawlers in the late 19th century. The trawlers only retained the most valuable part of the catch such as flatfishes and haddock and discarded the rest, most notably cod (Þór 2003). The boats had limited storage space, there was no lack of fish and the time sailing to and from the fishing grounds was long. Therefore, the incentive to discard to maximize the value in the hold must have been high. Later, these stories waned, indicating that discarding might have declined. This might also indicate a decline of several stocks due to heavy fishing. As this mostly happened before 1906, when reliable catch data became available from ICES, it is difficult to verify.

Since 2001, there has been a marked improvement in discard monitoring, as there have been annual reports available on estimated discards by the Icelandic fleet (Pálsson *et al.* 2012) and back calculations for haddock to 1988 (Pálsson 2003). This is mostly for cod and haddock, but some estimates are also available for other species. These studies show low rates of discarding, averaging 0.9% by weight for cod and 2.0% for haddock. Discard rates for haddock seem to be about twice those for cod, but also fluctuate much more, from 0.8-22.3%, probably related to highly variable recruitment and thus amount of haddock in the catches (Pálsson 2003).

It seems therefore that the discard rate has declined, at least since the 1980s. This might be because the fleet does not fish randomly and can, under pressure, fish quite selectively, therefore reducing discards. However, there has also gradually been a move within fisheries management to discourage discards. For example, 5% of demersal catch from any trip can be excluded from quota restrictions, as long as this part is sold on the fish market and part of the value goes to a fund dedicated to fisheries research. A limited number of one species can also be converted" to another, so if you have accidentally caught saithe that you do not have a quota for, but you have enough haddock quota one can deduce this from the haddock quota using a conversion factor called cod equivalents. In this factor, cod equals one and all other species are valued relative to cod. It is also possible to buy quota for a species after you have caught it. In addition to this there is an active system of real time area closures if a large proportion of undersize fish is in the area.

Another aspect of discarding is low value species, mostly species that do not even have a TAC. Prime examples of these are long rough dab and starry ray that are fished in some amount as by-catch in most fishing gear. Fishers often don't bother with retaining these as the value is very low compared to traditional demersals (Pitcher *et al.* 2002). Thus, actual total discard rates (in contrast to the target species discard rates mentioned above) may actually be higher. However, many species that have filled this category have lately been found to be valuable, a prime example of that is the monkfish, once thought to be as worthless as it is ugly but is now one of the most valuable species in Icelandic fisheries per kg. The ITQ system has actually encouraged fishers to retain these species, as they usually do not have a TAC (the monkfish has now). To discourage further discarding of these species, a by-catch bank was established in 1989 to buy non-traditional species for processing. This proved successful, as many new species began to appear in Icelandic catch statistics in the 1990s. The role of the by-catch bank has now been taken over by traditional fish markets.

Based on studies on global discards (Kelleher 2005) and the examples mentioned above, the baseline discard rate for most demersal fishes and invertebrates was set at 5.5% and 2.0% for pelagic fishes. The exceptions are shown in Table 4. I assume that discard of cod was around 5.5% for all years prior to 1991. After 1991, known discard rates are used or numbers interpolated between known years. Similar applies to haddock, except that discards are known from 1988. Due to absence of other information, the discard rate for other demersal species is assumed to be 5.5% for all years. I acknowledge that the discard rate is probably lower for some species (for example the high value lemon sole and Greenland halibut) than for others (low value species such as dab and American plaice) but can only hope, until further information is available, that this cancels each other out. It is not possible to separate the estimated discard rate between large and small boats so the same rates were used for each class.

Results

The reconstructed catches for Iceland's industrial, artisanal, subsistence and recreational fisheries within the EEZ were compared to ICES statistics and national data (Figure 2a). The database indicates that the reconstructed total catches by Iceland within its EEZ increased from 411,000 t in 1950 to a maximum of 2.02 million t in 1997, before subsequently declining to 903,000 t in 2010 (Figure 2a). The reconstructed total catch for Iceland for the period

1950-2010 was estimated around 69.2 million t which is 37% higher than the data reported by ICES (50.6 million t; Figure 2a).

The reconstructed total catch by sector was dominated by capelin (*Mallotus villosus*) and cod (*Gadus morhua*) which accounts for 38% and 34% of the catch respectively (Figure 2b). Herring (Clupeidea) contributed 11.4% of reconstructed total catch while Sebastidae totalled 6.3%. Blue whiting and invertebrate catches both contributed 2.4% each to the total reconstructed catches. The remaining 42 families were grouped into "Others" (3.6%).

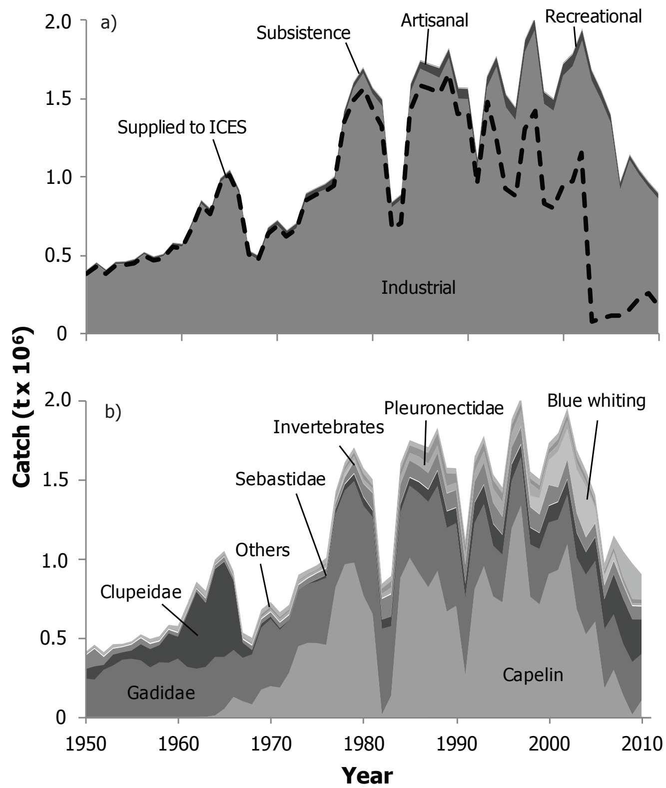

Figure 2. Reconstructed total catches for Iceland during the period 1950-2010 a) by sector with data reported by ICES overlaid as line graph; and b) by major families, "Others" represent 42 taxonomic categories.

Discussion

Several aspects make Iceland different in terms of fisheries.

1. Northern location at the boundaries of cold and warm ocean currents causes high productivity in the ocean and large fish stocks.
2. Distance from other countries and especially a continental shelf isolated from other shelves means that most of the demersal stocks are in a single and local management unit. This simplifies management.
3. Northern location and extensive windswept uninhabitable highlands keep the population low. This means that local consumption is low and most of the catch is exported.
4. Iceland is an island and rather far away from main markets for its seafood products. This means that exports are rather easily monitored.
5. Iceland has a long history of literature and record keeping and fisheries data is therefore considered good.
6. These factors taken together contribute to the fact that Icelandic fisheries are considered to be well managed and catch numbers considered accurate. Although Icelanders eat plenty of fish, the low population size and high catches means that most of the catches are exported, and exports (especially from an island) are more easily monitored than local consumption. The low population size and high catches are also contributing to the fact that subsistence and recreational fisheries are low compared to commercial fisheries and estimates on these are inevitably more inaccurate than commercial catches. Discards for the same period are 3.54% of the reconstructed catch and the IUU catch 0.45%. The total amount of unreported catch has ranged from 3.3% to 6.7% of total catch throughout this period.

The ICES database also reports many species fished in Icelandic waters that are not found there, or at least have not been found by scientist. This taxonomic mislabelling primarily applies to foreign fleets and therefore is outside the scope of this analysis. It may also represent deliberate spatial misreporting.

I must stress that these estimates should not be looked as the final for unreported catch estimates, but rather as a baseline to build on further studies. Currently, there are rather good estimates on size based discards on the most important species, but species based discards assumed here are based on rather weak assumptions. For low value species, the discard rates here are probably too low, but they are probably too high for more valuable species. There are also uncertainties about the catch that is illegally landed without weighting it.

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Appendix Table A1. ICES vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Iceland, 1950-2010.

Year	ICES	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	383,423	417,000	381,000	8,010	3,180	-	24,700
1951	427,053	475,000	434,000	8,350	3,250	-	28,700
1952	384,963	464,000	426,000	9,440	3,300	-	26,100
1953	434,603	490,000	449,000	11,800	3,360	-	26,100
1954	435,868	510,000	466,000	11,090	3,440	-	29,400
1955	449,871	553,000	505,000	11,260	3,520	-	33,000
1956	493,042	577,000	532,000	10,110	3,600	-	31,300
1957	467,354	551,000	508,000	9,960	3,670	-	29,400
1958	481,815	638,000	584,000	11,870	3,760	-	37,900
1959	553,461	695,000	639,000	13,820	3,830	-	38,200
1960	544,991	631,000	579,000	14,290	3,920	-	32,900
1961	681,457	745,000	695,000	15,660	4,000	-	30,200
1962	821,220	868,000	814,000	17,920	4,080	-	31,400
1963	763,175	820,000	764,000	19,210	4,150	-	33,300
1964	955,093	1,013,000	952,000	19,700	4,220	-	37,100
1965	1,009,265	1,244,000	1,179,000	19,820	4,300	-	40,600
1966	885,282	1,284,000	1,220,000	20,530	4,370	-	39,000
1967	505,721	935,000	877,000	21,190	4,450	-	32,300
1968	470,261	633,000	578,000	21,910	4,520	-	27,900
1969	642,202	726,000	666,000	23,260	4,570	-	32,100
1970	686,724	772,000	707,000	26,820	4,600	-	33,800
1971	622,953	723,000	658,000	28,560	4,620	-	31,800
1972	670,738	763,000	700,000	27,570	4,680	-	31,000
1973	851,312	952,000	882,000	31,680	4,760	-	33,600
1974	884,056	990,000	923,000	26,620	4,820	-	35,200
1975	910,367	1,040,000	968,000	30,360	4,890	-	36,700
1976	945,313	1,041,000	965,000	32,270	4,940	-	38,900
1977	1,355,354	1,432,000	1,350,000	31,800	4,980	-	44,600
1978	1,488,023	1,616,000	1,534,000	28,660	5,010	-	48,100
1979	1,559,340	1,707,000	1,618,000	28,580	5,060	-	54,500
1980	1,428,789	1,578,000	1,484,000	32,840	5,120	-	56,500
1981	1,326,728	1,511,000	1,409,000	37,240	5,170	-	59,400
1982	668,845	845,000	762,000	27,410	5,230	-	50,000
1983	705,149	894,000	814,000	26,840	5,310	-	48,200
1984	1,416,743	1,600,000	1,497,000	40,940	5,380	-	56,300
1985	1,580,861	1,747,000	1,640,000	43,760	5,420	-	58,100
1986	1,564,863	1,724,000	1,611,000	48,280	5,460	-	59,300
1987	1,536,901	1,703,000	1,580,000	56,360	5,500	-	61,400
1988	1,657,015	1,825,000	1,705,000	50,760	5,580	-	63,000
1989	1,403,428	1,573,000	1,448,000	60,610	5,680	-	58,700
1990	1,414,083	1,570,000	1,449,000	60,340	5,720	-	55,800
1991	956,066	1,119,000	1,014,000	45,580	5,770	-	54,400
1992	1,474,767	1,645,000	1,517,000	60,720	5,850	-	60,800
1993	1,238,935	1,787,000	1,664,000	56,930	5,910	-	60,500
1994	925,187	1,631,000	1,490,000	73,670	5,970	-	61,400
1995	874,051	1,687,000	1,547,000	70,460	6,020	-	63,800
1996	1,303,235	2,132,000	1,995,000	65,770	6,040	-	65,400
1997	1,421,906	2,284,000	2,142,000	67,590	6,080	24	68,500
1998	834,881	1,745,000	1,616,000	69,090	6,140	35	54,600
1999	797,357	1,795,000	1,671,000	65,920	6,210	47	51,600
2000	953,163	2,044,000	1,913,000	68,700	6,290	59	55,700
2001	975,341	2,038,000	1,912,000	71,090	6,390	71	48,900
2002	1,149,955	2,191,000	2,069,000	64,670	6,460	82	50,900
2003	82,226	2,038,000	1,921,000	59,670	6,500	94	49,900
2004	101,148	1,773,000	1,669,000	55,200	6,550	106	41,900
2005	111,212	1,712,000	1,616,000	46,580	6,620	118	42,800
2006	112,074	1,362,000	1,278,000	40,650	6,760	129	36,300
2007	150,815	1,429,000	1,357,000	27,940	6,940	141	37,000
2008	228,582	1,321,000	1,252,000	25,990	7,110	153	35,700
2009	261,822	1,174,000	1,106,000	27,780	7,200	165	33,000
2010	173,662	1,099,000	1,030,000	30,640	7,160	176	30,900

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for Iceland, 1950-2010. 'Others' contain 42 additional taxonomic categories.

Year	Capelin	Gadidae	Clupeidae	Sebastidae	Blue whiting	Invertebrates	Pleuronectidae	Others
1950	-	247,000	61,700	82,400	-	11	6,710	13,000
1951	-	239,000	86,500	109,900	-	12	7,850	14,400
1952	-	302,000	32,700	50,000	-	12	4,040	22,530
1953	-	328,000	70,900	37,200	-	12	1,950	23,330
1954	-	366,000	48,200	32,600	-	12	1,450	15,870
1955	-	371,000	53,600	37,000	-	853	940	15,720
1956	-	361,000	103,200	38,100	-	1,096	2,010	17,980
1957	-	317,000	117,700	31,600	-	529	4,970	23,850
1958	-	349,000	109,600	23,100	-	1,788	2,630	25,440
1959	-	347,000	186,300	22,500	-	4,010	3,290	20,410
1960	-	373,000	139,200	23,000	-	4,639	7,290	29,780
1961	-	320,000	332,400	17,400	-	3,731	9,500	30,640
1962	-	309,000	487,700	14,900	-	4,076	8,930	31,080
1963	1,100	319,000	404,400	25,800	-	7,674	6,580	33,870
1964	8,800	375,000	555,300	20,500	-	5,483	8,240	22,240
1965	50,500	333,000	602,300	26,800	-	6,149	10,170	21,140
1966	126,800	300,000	438,700	18,800	-	6,540	9,700	19,840
1967	98,600	279,000	96,200	20,200	-	5,409	7,810	27,230
1968	79,300	320,000	28,100	28,000	-	5,901	8,390	31,460
1969	173,200	396,000	24,000	27,500	-	8,556	19,370	31,760
1970	194,600	427,000	16,800	27,000	-	12,663	18,230	31,000
1971	185,600	369,000	12,100	33,000	-	16,863	14,880	32,080
1972	281,100	336,000	300	30,500	643	19,053	12,100	30,180
1973	448,200	357,000	300	30,000	2,936	16,405	8,120	36,300
1974	469,200	375,000	1,300	31,500	4,414	12,413	8,560	28,320
1975	467,700	392,000	13,600	37,000	1,316	11,226	7,530	29,690
1976	456,700	426,000	17,500	38,500	8,921	14,626	9,230	35,400
1977	821,400	464,000	29,500	31,800	10,765	15,727	18,390	31,510
1978	966,800	467,000	38,100	37,700	27,649	20,797	18,650	30,910
1979	978,000	514,000	46,000	70,400	14,445	22,228	24,750	31,600
1980	771,200	567,000	54,300	78,900	4,627	23,653	36,410	36,750
1981	652,100	614,000	40,300	105,500	4,880	22,566	21,750	39,140
1982	13,500	548,000	57,700	130,100	-	25,712	38,140	30,280
1983	135,500	443,000	60,100	138,800	5,990	33,131	40,730	36,050
1984	880,500	415,000	50,800	122,400	107	46,562	46,290	38,470
1985	1,008,300	455,000	50,400	103,300	-	46,893	49,500	33,130
1986	911,500	508,000	67,100	97,200	-	57,761	50,290	32,060
1987	822,200	540,000	77,000	99,200	-	58,624	67,570	38,410
1988	924,900	538,000	94,700	106,300	-	49,166	76,610	34,570
1989	668,100	530,000	103,000	107,800	5,052	41,493	81,260	36,200
1990	704,100	524,000	95,700	107,900	-	45,729	57,360	35,570
1991	262,300	492,000	90,900	119,300	-	53,152	58,090	43,400
1992	809,700	420,000	127,700	124,200	-	64,462	54,780	43,930
1993	955,100	393,000	120,200	135,100	-	71,901	59,190	40,080
1994	763,900	322,000	136,000	130,200	-	88,362	54,150	36,640
1995	726,300	303,000	123,900	111,000	375	91,546	55,520	36,630
1996	1,196,700	297,000	104,300	100,300	460	89,266	53,900	38,040
1997	1,339,000	307,000	75,800	104,600	10,581	95,457	46,670	38,540
1998	761,300	332,000	104,900	126,600	69,871	79,044	30,620	44,780
1999	714,200	351,000	98,900	113,800	102,910	47,672	31,720	41,140
2000	905,800	326,000	103,800	127,500	156,838	38,499	30,830	39,380
2001	931,800	319,000	109,200	88,400	224,957	43,851	34,510	38,910
2002	1,094,800	310,000	97,700	118,800	197,446	51,884	37,300	40,270
2003	685,800	325,000	156,400	121,400	273,670	43,258	38,780	43,390
2004	523,300	380,000	141,400	90,500	318,630	30,748	33,000	40,870
2005	603,600	385,000	150,600	84,000	96,419	11,187	28,950	43,200
2006	180,500	379,000	187,800	85,800	56,340	4,767	26,880	50,990
2007	298,500	354,000	253,400	81,400	47,203	10,421	22,920	79,160
2008	140,200	329,000	284,100	86,300	675	14,796	25,670	169,550
2009	14,100	338,000	269,200	82,900	891	10,531	30,050	226,280
2010	103,700	298,000	218,600	80,400	1,157	13,937	25,600	161,380

Reconstruction of marine fisheries catches for the Republic of Kiribati (1950-2010)[1]

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Abstract

As an isolated and scattered group of islands in the South Pacific, the Republic of Kiribati (hereafter Kiribati) has one of the highest seafood consumption rates in the world. With limited resources and expensive imports due to the difficulties in logistics of transport to and from the islands, the country's marine resources play a very important role in the subsistence needs of the I-Kiribati people as well as in revenue generation of the country. Upon analysis of the reported data presented by the FAO on behalf of Kiribati (being the only global data source), it was found that there was little transparency in the data, as well as potential errors in reporting. We also utilized better spatial resolution data from the Forum Fisheries Agency (FFA) and the Western and Central Pacific Fisheries Commission (WCPFC). Due to the essential nature of marine resources for the I-Kiribati, it is important that greater transparency is applied to the monitoring and reporting of all Kiribati fisheries, not just industrial tuna fisheries. Large-scale industrial catches were deemed to be not truly domestic and were analysed separately. They were found to be relatively well reported via the FFA and WCPFC, with only discards being unreported. Total small-scale marine fisheries catches (artisanal and subsistence sectors) were estimated to increase from an average of 9,000 t·year^{-1} in the 1950s, to approximately 21,000 t·year^{-1} in the 2000s. However, in additional to our small-scale catch estimate, there is unaccounted catch within the reported data, which ranges from 1,400 t·year^{-1} to almost 12,000 t·year^{-1} during the time period of 1983-2005 (as well as the year 2007). Comparing the artisanal, subsistence and unaccounted catch to the non-industrial portion of the FAO data, the reconstructed data are 15% higher than the data reported by FAO on behalf of Kiribati. The fact that the FAO data contain catch which we are not able to account for highlights the issues of data accountability and accuracy faced by Kiribati's (and other small developing countries') fisheries department, which is handicapped by limited financial and technical resources.

Introduction

Kiribati is a Pacific island group which consists of 33 islands spread out over a large area. There are three separate island groupings which, starting from the west, are the Gilbert Islands, the Phoenix Islands, and the Line Islands (Figure 1). The islands total only 820 km^2 in land area (Anon. 2003) but are surrounded by 3.5 million km^2 of Exclusive Economic Zone (EEZ) waters (www.seaaroundus.org). The distance between the furthest eastern and western points of the EEZ is over 4,500 km (Gillett 2011a). This distance also results in the islands being split between two FAO statistical areas. The Gilbert Islands and a small portion of the Phoenix Islands' EEZ fall into the Western Central Pacific (FAO area 71). The majority of the Phoenix Islands' EEZ, as well as the islands themselves, and the Line Islands fall into the Eastern Central Pacific (FAO area 77; Figure 1). Kiritimati (Christmas) Island, which is one of three inhabited islands in the Line Islands, is the largest coral atoll

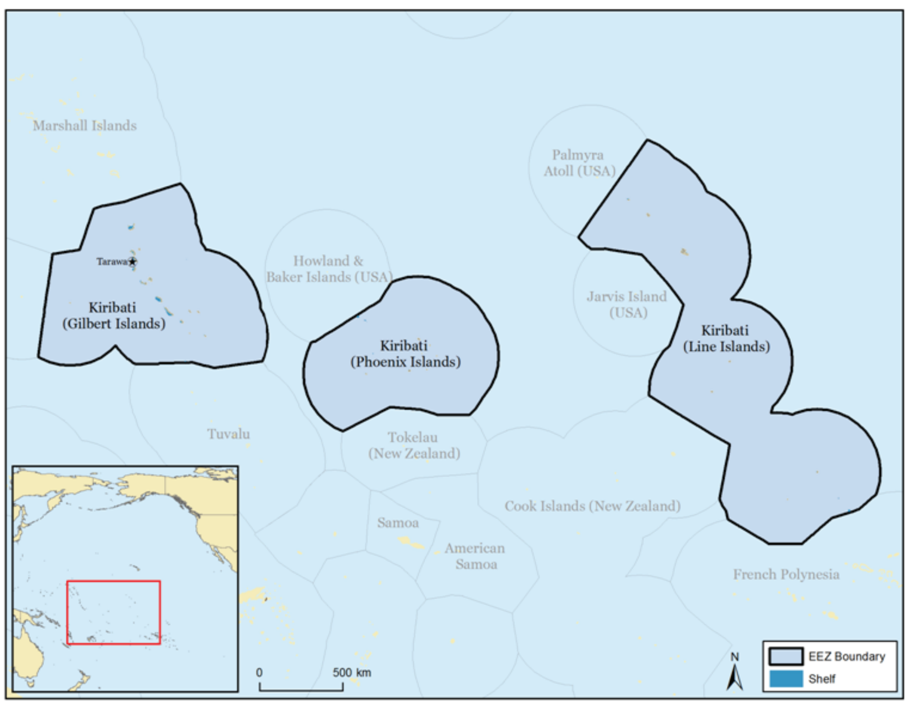

Figure 1. The three separate islands groups of Kiribati, and their respective Exclusive Economic Zones (EEZs).

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in the world and constitutes approximately 40% of the total land area of Kiribati (Anderson *et al.* 2000). South Tarawa, the official capital of Kiribati, is located on Tarawa Atoll (Gilbert Islands), and is home to approximately 40% of Kiribati's population (Dalzell *et al.* 1996). The people of Kiribati are referred to as I-Kiribati.

Kiribati became an independent republic in 1979 (Teiwaki 1988). Up until 1975, Kiribati and its southern neighbour Tuvalu (Figure 1) comprised the Gilbert and Ellice Islands Colony, which was under British control (Bertram and Watters 1984). In 1974, the Tuvaluans of Ellice Island held a referendum and a 92% majority voted in favour of separation (Bertram and Watters 1984). Tuvalu (Ellice Island) was officially separated from the Gilbert Islands (and the rest of Kiribati) in 1975 (Bertram and Watters 1984).

Kiribati is one of the poorest countries in the world, with an estimated *per capita* GDP of less than US$1,000 (Hannesson 2008). Kiribati's main export is copra, although exports tend to fluctuate dramatically, with declines largely attributed to poor pest control and declining crop yield (ADB 2002; Thomas 2003b). Kiribati's economy was previously principally dependent on the revenue brought in from phosphate mining on Banaba (Ocean) Island (Gilbert Islands), which is the only non-coral atoll of the country. In the late 1960s and early 1970s, the price of Banaba phosphate saw a dramatic increase, while at the same time imports continued to increase slowly, leading to a surplus in revenue (Bertram and Watters 1984). Once phosphate mining ended in 1979, the reserves of surplus income became an important source of revenue for Kiribati (Taumaia and Gentle 1983; Barclay and Cartwright 2007). Kiribati declared its EEZ in 1978, meaning that access fees from foreign fishing vessels were available to make up the deficit left from the termination of phosphate mining (Barclay and Cartwright 2007). The Government of Kiribati was eager to put major effort into developing the country's marine resources (Taumaia and Gentle 1983). In 1981, the government established Te Mautari Limited (TML), a company meant to develop a domestic pole-and-line tuna fishery (Gillett 2011a). However, the company mainly operated at a loss due to Kiribati's isolation from the nearest markets and the associated high transport and shipping costs (Gillett 2011a). The port in Betio, Tarawa, is insufficient in size to accommodate large vessels and the wharf in Kiritimati is too high for fishing vessels to dock at, as it was originally built for very large vessels bringing in rocket parts (Barclay and Cartwright 2007). Then, in 2001, TML, Kiritimati Marine Exports Limited (KMEL), and the Outer Islands Fisheries Project (OIFP), were joined together into Central Pacific Producers Ltd. (CPPL), which had a new processing plant in Betio (Barclay and Cartwright 2007; Gillett 2011a). In 1994, Kiribati gained ownership of a purse-seine vessel by signing a joint venture agreement with a Japanese fishing company (Barclay and Cartwright 2007). Kiribati has also run trials of longline fishing (mostly inside the EEZ) off and on, starting in the mid-1990s, without much success (Barclay and Cartwright 2007). Currently, there is a more substantial, national Kiribati fleet, due to an influx of vessels with foreign beneficial ownership being reflagged to Kiribati after 2008. In 2010, Kiribati registered 6 purse seines, 1 pole-and-line, 1 longline, 21 reefer carriers, and 9 bunkering vessels (WCPFC 2011a).

Another aspect of the large-scale fishery in Kiribati, is the large contingent of well trained I-Kiribati seamen. However, the majority of these men are trained to work on foreign fleets which operate in the Pacific Islands area (Sullivan and Ram-Bidesi 2008). I-Kiribati complete an eight to nine month course and are guaranteed a job at the end of training. The majority of trainees end up working on Japanese vessels but there are also I-Kiribati working on Korean and Taiwanese vessels. Currently there are no women in this program.

In addition to being a significant source of revenue, marine resources are a very important subsistence, and hence food security, resource to the I-Kiribati. Poor soils and inconsistent rainfall lead too often to shortages of food and fresh water (MacDonald 2001). With a lack of agriculture, the marine environment is an important food source. Kiribati's naturally harsh terrestrial environment, which is suitable for very few types of crops, is one of the reasons why Kiribati is said to have the highest *per capita* seafood consumption of any country in the world (Gillett 2011a), as they are not left with many other sources of domestic protein.

As in most Pacific Island countries, women's contribution to fishing in Kiribati is often understated and downplayed but the roles that they fill are extremely important (Harper *et al.* 2013). Women's roles in the fishing sector in Kiribati are mostly limited to fishing (reef gleaning) on the reef and in the lagoon, as well as selling fish on the roadside or in markets. However, times may be changing, as there are reports of some men taking their wives out fishing with them in recent years (Sullivan and Ram-Bidesi 2008). Regardless, the inshore resources that women collect contribute greatly to home consumption. As previously mentioned, many of the men take jobs on foreign vessels and are away for long periods. It is the woman's responsibility to provide for the family while her husband is away, as well as to take on community responsibilities and maintain the traditional patterns of village life (Schoeffel 1985). As well, in Tarawa, the majority of fish sellers are women, and they are responsible for the distribution of catch on the island (Tekanene 2006). They work long hours for little pay, often in unsanitary conditions, but continue the work as they are limited in their options (Tekanene 2006). It should be noted that (as an exception) there are no women fish sellers on Kiritimati Island, which is the second largest market for artisanal sales (Sullivan and Ram-Bidesi 2008). Women's involvement on Kiritimati is limited to inshore fishing.

In 2006, the Government of Kiribati declared the islands of the Phoenix Islands and surrounding ocean a marine protected area (MPA). In 2008, it was formally established under Kiribati law as the Phoenix Islands Protected Area (PIPA), with a total area of 408,250 km^2, making it the world's largest MPA at the time (De Santo 2012). The goal is to eliminate foreign commercial fishing in the area. Kiribati, with support from NGO partners Conservation International (CI) and the New England Aquarium, established an endowment fund (maintained by public and private contributions) that, in addition to allowing for substantial funding to manage the MPA, will compensate Kiribati for any loss of revenue from foreign access fees to fish in that part of the EEZ (Anon. 2006; Niesten and Gjertsen 2010; De Santo 2012). Lastly, the Phoenix Islands are all but uninhabited, with only a small population of less than 50 people, all government employees and their families stationed on Kanton Island. This population will also be allowed to continue subsistence fishing (Anon. 2006).

There has been some controversy over this protected area. In 2013, management of the PIPA came under scrutiny from scientists and politicians alike. Several articles were published (e.g., Pala 2013a; released in June) criticizing the organizations involved in the PIPA as well as the president of Kiribati, Anote Tong, for misleading the public in terms of what the PIPA has actually accomplished. According to these articles, the president and the organizations (CI and the New England Aquarium) were claiming until recently that the PIPA was closed off to all commercial fishing, or at least making it sound that way. Pala (2013a) reports that many officials of organisations who bestowed awards on President Tong for his creation of PIPA, as well as a large portion of the Kiribati population, believed that the area was entirely closed off to fishing. CI posted a press release to their website on September 24, 2013, combating the criticism they had received. CI acknowledged that there was a "misstatement" on their website which gave the impression that the entire MPA was closed off to fishing, but that when this was brought to their attention it was promptly corrected. CI goes on to clarify that the actions taken in regards to the PIPA are on target for what they set out to do. Although only 3% of the area has been closed to fishing, CI claims that the absolute area is large according to global standards and that these 3% represent critical reef habitats. Pala (2013a) argues that the 3% closed wasn't being fished in the first place and that tuna fishing continues to increase in the rest of the reserve.

Another point of controversy is the endowment fund. Pala (2013a) re-iterated what was also claimed by CI, that the management plan called for 13.5 million dollars to be raised by the end of 2014 for phase two, which would allow an additional 25% of the PIPA to be closed to fishing. However, at the time, Pala (2013a) stated that the fund was still empty. In the September press release, CI stated that they had raised USD 2.5 million and that the government of Kiribati was matching that to bring the endowment to USD 5 million. Money is also an issue due to the fact that President Tong claims that revenue will be lost if the PIPA is closed, which is why it needs to be closed gradually, and that the planned USD 50 million is not enough. However, experts have claimed that since PIPA only represents 11% of Kiribati's entire EEZ, vessels would still be able to catch the same amount of fish, albeit at a slight inconvenience. The PIPA illustrates some of the challenges that accompany large-scale conservation projects which also affect economic resources and therefore end up having many political implications.

The Food and Agriculture Organization of the United Nations (FAO) is the only source of world-wide, historic time series data on fisheries landings. The data that are presented by the FAO are submitted voluntarily to them by each member country. There are several issues with this process which the FAO, unfortunately, cannot avoid (Garibaldi 2012). This process depends entirely on the reporting country's willingness and ability to accurately report their catches (Garibaldi 2012). In many instances, such as for small developing countries, the country simply does not have resources to accurately monitor and hence report catches, especially when the majority of these catches are small-scale and thus do not go through any official reporting channels (Pauly 1997). Furthermore, some countries perceive this reporting as onerous and of less immediate importance than reporting to and cooperating in RFMOs (Regional Fisheries Management Organizations), such as the WCPFC (Western and Central Pacific Fisheries Commission), which focus on tuna as a cash and revenue source. This unfortunately results in potentially excessive focus on tuna resources only, often at the expense of coastal resources. Therefore, the objective of this paper is to analyze and estimate the different aspects of the Kiribati fishery using a catch reconstruction approach as outlined in Zeller *et al.* (2007), and to see how it compares with the reported catch data which is presented by the FAO on behalf of Kiribati.

Methods

The marine fisheries catches of Kiribati were estimated using human population data, seafood consumption rates, WCPFC and Forum Fisheries Agency (FFA) reports and data, as well as grey literature. Part of this report will be to compare our findings with the data reported by the FAO to the global community on behalf of Kiribati. Upon the initial review of the FAO data for Kiribati, it was observed that within the reported data there were two years of outlying data which result in substantial 'spikes' in reported data. Therefore, the catches for these years (1987 and 1999) were treated as a potential reporting error and have been smoothed out by interpolating the value between adjacent years of the specific taxa which were causing these spikes (Figure 2). Large increases of the pooled groups of 'marine fishes nei' and 'percoids nei' were the main contributors. In 1987 'jacks, crevalles nei' and 'sharks, rays, skates, etc.' also exhibited abnormal one year increases. For all comparisons in this report, the amended FAO data are used. Given that fisheries are embedded in and dependent on ecosystems, here we consider as 'catch' not only retained landings, but also discarded by-catch.

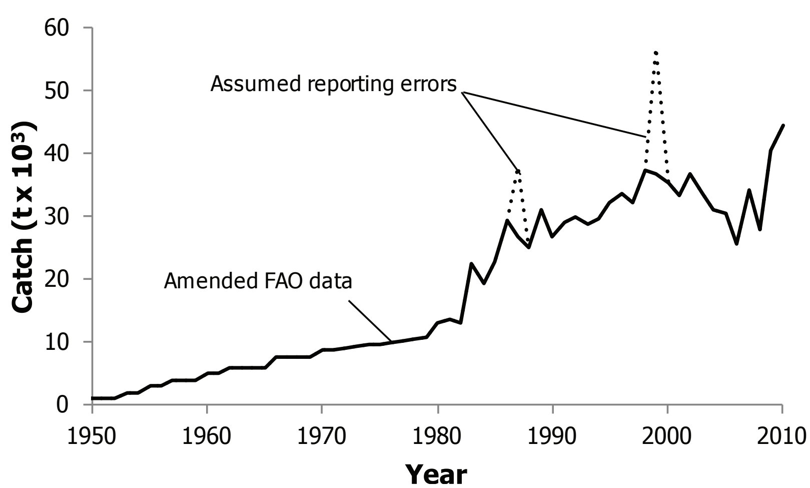

Figure 2. Amended FAO data with assumed reporting error in 1987 and 1999.

Human population data

Human population data were required in order to calculate annual domestic seafood consumption by the I-Kiribati, as part of the small-scale fishery estimate. Data for the years 1960-2010 were acquired from the World Bank database. The population for the years 1950-1959 was determined by linearly interpolating between the population in 1947 (Bertram and Watters 1984) and 1960 (Figure 3).

Large-scale commercial

<u>Reported landings</u>

Throughout the time period, Kiribati and Kiribati flagged vessels have been active in pole-and-line fishing, purse seining, and some longlining. FFA records for tuna catches by species and gear were available for the 1997-2010 time period (www.ffa.int). In addition to pole-and-line, purse seine, and longline catches, information on reported artisanal tuna catches was also included in the FFA data. Although those catches were labelled as 'other gear type' it was confirmed that these numbers corresponded to reported artisanal (small-scale) values through a WCPFC report (WCPFC 2011a). For the time period prior to 1997, catches for the individual fisheries (excluding artisanal) were available from the 2010 WCPFC Tuna Yearbook (2011b). The available data covers the time periods that the individual fisheries were active. Purse seine vessels were active during the time period 1994-2010, pole-and-line operated off and on from 1981-2009, and longline during 1995-2010. Total tuna catches of Kiribati were also available from this source, which corresponded to the FAO tuna totals and allowed for the calculation of the reported artisanal component for the entire time period. All references matched exactly or nearly exactly in their totals for each year which allowed the FAO tuna data to be completely disaggregated by gear type. In addition, information regarding marlin by-catch was also available in these reports and the data matched what was reported in the FAO data. Therefore, it was determined that all industrial landings were reported and only discards went unreported with respect to FAO (which traditionally does not ask for discards). Although the small-scale tuna component has been discussed here, as the reported artisanal tuna component is associated with reports of industrial catches, this sector will be discussed in greater detail when addressing the small-scale fisheries (see below).

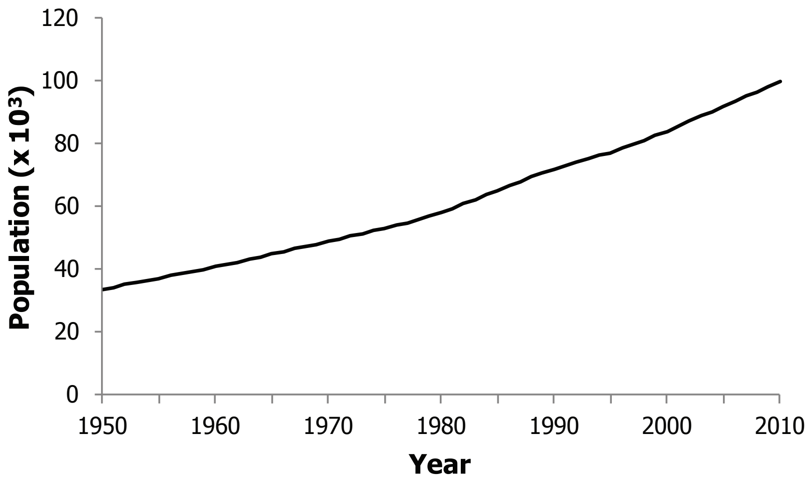

Figure 3. Estimated human population data of the Republic of Kiribati, 1950-2010.

<u>Discards</u>

Discards were calculated for the purse seine and longline fleets. Average discard rates of target species were available for these gear types which were specific to the SPC statistical area for foreign fleets. This was deemed to be a representative approximation for the Kiribati fleet. For purse seine catches, the discard rate of target species was 3.5% of the retained target catch and for the longline fleet it was 3.8% of the total catch (Lawson 1997). These discard rates were applied to the entire operating time period of each fleet. These discards are treated as unreported catch but identifiable as discarded catch.

<u>Baitfish</u>

The pole-and-line fleet requires the use of baitfish. An assessment of baitfish use in the pole-and-line fishery was carried out by the Australian Centre for International Agricultural Research (ACIAR) in 1990 (Rawlinson *et al.* 1992). Data on total baitfish usage by source were available from 1977-1990. The data from 1977-1980 were not used as this was carried out by the Japanese International Co-operation Agency (JICA), who was completing surveys on baitfish availability for the impending pole-and-line fleet that Te Mautari Ltd. launched in 1981 (Rawlinson *et al.* 1992). Data on baitfish use from 1981-1990 (excluding farmed baitfish) was accepted as the total baitfish used for these years. These values were then combined with the tuna catch data for the pole-and-line fleet for the corresponding years (WCPFC 2011b) to calculate an average tuna to baitfish ratio. The average tuna to baitfish ratio was used in combination with the tuna catch to determine the amount of baitfish used in each remaining year of pole-and-line activity (1991-1997 and 2009). We conservatively assumed that the baitfish used was included in the reported data.

Small-scale sectors

Due to the fact that all of the industrial catch is exported or landed outside of Kiribati (Gillett 2011a) and the majority of the fleet consists of joint venture or reflagged vessels, the industrial catch is considered separately to the small-scale sector which represents the truly domestic Kiribati fisheries. Therefore, all of the reported components of the large-scale industrial catch were segregated from the FAO data, in order to extract the reported domestic small-scale catches and allow for comparison after reconstruction. The small-scale sector consists of subsistence and artisanal catches (including artisanal tuna catches). Subsistence catches are defined as marine fisheries catches which are used primarily for home consumption. Artisanal catches are defined as catches which are primarily for sale at local markets as well as those made by small-scale fishers which are destined for export. Therefore, in order to calculate the small-scale catch, we determined how much seafood the I-Kiribati population consumes from both subsistence catch and purchases from the market (i.e., the demand) as well as what is being exported by the artisanal sector.

Consumption

The consumed catch was calculated using consumption rates (or catch derived consumption rates) and population data. Kiribati is said to have the highest *per capita* seafood consumption of any country in the world (Gillett 2011a). For 1950, a consumption rate of approximately 250 $kg \cdot person^{-1} \cdot year^{-1}$ was calculated from fish consumption data from a dietary survey (Turbott 1949) and used as the anchor point for the early time period. A second anchor point was derived from Gillett's (2009) small-scale catch estimate for 2007. Using Gillett's 2007 small-scale estimate and the 2007 population data from WorldBank, a domestic catch rate of approximately 205 $kg \cdot capita^{-1} \cdot year^{-1}$ was derived (i.e., a catch data based consumption rate). Interpolation was done between these two rates and the 2007 anchor point was kept constant from 2007-2010. These rates were then combined with the population data to estimate the small-scale (subsistence and artisanal combined) consumed catch for the entire time period.

Tuna

Tunas are not only important species for industrial fisheries (and hence foreign-exchange income) but also for the domestic small-scale sector. Schoeffel (1985) asserts that tuna are a major subsistence fishery in Kiribati. Gillett (2011b) estimates the small-scale tuna production of Kiribati at approximately 12,500 $t \cdot year^{-1}$ (in the late 2000s), making it the highest of all Pacific Island countries. From comparison of the different reports on tuna catches (WCPFC and FFA), we can see that there is a reported component of small-scale tuna catches within the FAO data. The 2007-2010 reported small-scale tuna figures are equal to the estimate by Gillett (2011b), suggesting that all small-scale tuna catches are reported for those years. Prior to 2007, the FFA data list the small-scale tuna catch at just over 2,000 $t \cdot year^{-1}$ for most years. As confirmation that the small-scale tuna catches did not only recently increase, a rough estimate based on Fisheries Division surveys in the late 1990s was calculated at approximately 10,000 $t \cdot year^{-1}$ (Gillett 2002). The results of this survey are also reflected in the reported data, as in 2000, the reported amount of small-scale tuna was 9,750 t. Although it appears that not all of the small-scale tuna catch is captured in the reported data, we assume that our consumption estimate includes the tonnage of all of the small-scale tuna catch.

Exports

Bêche-de-mer (dried, processed sea cucumber) has been a fairly consistent export for Kiribati, due to the demand from the Asian market. All sea cucumber catches within the FAO data were assumed to be exported as dried *bêche-de-mer* product. This is based on the fact that I-Kiribati do not consume sea cucumber domestically (SPC 1995). Sea cucumber catches only appear in FAO data starting in 1997; however, the fishery was exploited starting in 1990 (SPC 1995). Although there are earlier reports of *bêche-de-mer* projects (SPC 1977), it appears from the literature that this was a period of start-up and assessment of the fishery with sporadic and unreliable catches, processing, and exporting. Therefore, sea cucumber catches are only estimated starting in 1990. The weight of *bêche-de-mer* exports was available for 1991-1994 (SPC 1995). A conversion factor of 10 was used to convert the dried product to wet weight of sea cucumber (Preston 2008). Missing values were estimated by interpolation. First, interpolation was done between zero tonnes in 1989 and 120 t in 1991, and then between 300 t in 1994 and 408 t in 1997.

Shark fin exporting is another industry which has been born out of the demand by the Asian market. Dried weights of shark fins from Preston (2008) from 1999-2006, were used along with Biery and Pauly's (2012) mean conversion factors (as the specific shark species were unknown) to calculate round weights of sharks used in the shark fin trade. Although sharks do not appear in the FAO data prior to 1986, there is evidence that there were shark fin exports in the early 1980s (Baaro 1993). In fact, the first mention of a shark fin export operation was in 1977 (SPC 1977). Therefore, we set an anchor point of zero tonnes in 1976, and interpolated to the first data point in 1999 (239.8 t), which was converted from Preston (2008). The export figure for 2006 (214.6 t) was kept constant and carried forward to 2010, with the exception of the year 2008, where the FAO reported catch was slightly lower (209 t) and thus accepted as the correct tonnage. There is a large tonnage of reported shark catch (FAO category 'sharks, rays, skates, etc. nei'), and although it is known that I-Kiribati do like to eat shark (Johannes and Yeeting 2000), it seems highly unlikely that they are consuming such large quantities. Since we do not know the exact reporting procedure followed by Kiribati when it comes to reporting shark fins, we will assume that the fin weight is converted to whole wet weight and entered into the data given to the FAO. Also, this still leaves a substantial amount of shark which is domestically consumed, and therefore the assumption seems reasonable.

Other invertebrates are also a common export items. Crustaceans, molluscs, and other marine invertebrates appear in many lists of export items (Jones *et al.* 2006; UN 2008). However, the exact quantity of these exports is not always clear. Given the relatively small amounts and variability of crustacean catches present in the FAO data, it is assumed that all of these are exported. Lobster, in particular, is a common item included in export lists and is said to be entirely exported and rarely retained for domestic consumption (Anon. 2003; Jones *et al.* 2006; Gillett 2009). Rock lobster was first noted to be exported in 1979 (SPC 1979), which is four years before crustaceans appear in the FAO data. Therefore, crustacean tonnages were interpolated from zero tonnes in 1978 to the 16 t reported in the FAO data in 1983. Mollusc catches are mainly made up of the ark shell *Anadara maculosa* and giant clams (*Tridacna maxima*, *T. gigas*, and *T. squamosa*) (Thomas 2003a; Preston 2008). *Anadara maculosa* has been reported to be caught in the order of 1,000-1,400 t·year^{-1} by subsistence collectors with an approximately equal amount caught by commercial divers (Preston 2008). As it is known that the ark shell constitutes the majority of the mollusc catch, it is assumed that 50% of the reported catches are for subsistence use and the other 50% for export (formal and personal consignment exports). We assume that mollusc export began in 1981 when molluscs first appeared in the FAO data, and therefore have no unreported mollusc exports.

The live reef food fish trade (LRFF), which primarily exports live fish to Hong Kong for use in restaurants, began in 1996 (Sommerville and Pendle 1999; Preston 2008). Three companies were involved at the start, two of which were foreign-based (China Star and South China Sea), and the third was the locally based Marine Product Kiribati Ltd. (MPK) (Awira 2006). Another company, Lucky Bright (Asia) Co. Ltd. (a joint venture), began operation in 2003 and was the only company involved that year (Anon. 2003). In 1999, China Star and MPK pulled out of the business due to cases of ciguatera poisoning in Hong Kong from fish exported from Kiribati (Awira 2006). It is assumed that 'South China Sea' continued operating and exported a shipment in 2001 (as there are records of exports for 2001, 2003, and 2004 as well) but pulled out of operations after that. The 2003 shipment is entirely attributed to Lucky Bright and it is assumed that the 2004 catch was by them as well. However, all LRFF operations ceased in 2004 due to an outbreak of ciguatera poisoning (Preston 2008). Quantities of export for 1996-2001 were obtained from Awira (2006). Awira (2006b, in Preston 2008) provided the export numbers for 2003 and 2004. As the LRFF is very well documented, it is assumed that all exports are reported. Groupers (Serranidae) and wrasses (Labridae, essentially humphead wrasse *Cheilinus undulatus*) are known to be the major taxa associated with this trade, with groupers estimated to compose the majority of the catch (Awira 2006). Therefore, since the total yearly catches are small, it was assumed that all LRFF were from the family Serranidae.

Another export sector is the aquarium fish trade. Although it is known that there has been an active ornamental fish trade in Kiribati since 1980 (Awira 2006), we do not consider this sector part of our reconstruction.

Information regarding the earlier years of colonization on the Phoenix Islands indicated that there was a small fish export business which transported fish to Hawaii via planes that used Kanton as a stopover destination on route between Hawaii and Australia or New Zealand (Stone 2013, p. 22). Exports stopped in 1959 due to the introduction of long-range aircraft. Exports were estimated to be up to 8 t per month. At a maximum, this would be 96 t·year^{-1} and therefore we conservatively estimated 50 t·year^{-1} from 1950-1958 and 25 t in 1959 as exports declined and stopped sometime during this year. With no information indicating the species composition of these exports, we used an assumed composition of 20% each of Serranidae, Lutjanidae, Lethrinidae, Scombridae, and miscellaneous marine crustaceans.

It has been pointed out that the Fisheries Division has included a small amount of personal consignment exports in their estimates (Gillett and Lightfoot 2001; Gillett 2009). However, these have not been included separately as most of the types of marine products which are exported this way have already been estimated individually (crustaceans for example) and it is assumed that our estimates cover this small amount of personal consignment export.

<u>Subsistence versus artisanal</u>

As a result of the type of information used, the small-scale catch was calculated as a whole, rather than by the individual sectors. Therefore, it was necessary to disaggregate the catch into an artisanal and subsistence component in order to match the global patterns for fisheries sectors, as used by *Sea Around Us*. Several reports spanning the 2000s indicate that the subsistence catch contributed 60-70% (or about two-thirds) to the small-scale sector (Gillett and Lightfoot 2001; Gillett 2009). It was therefore assumed that from 2000-2010, the subsistence catch comprised 65% of the small-scale catch and the artisanal sector contributed the remaining 35% (including exports). For the early period, the artisanal sector began in 1960 (Tekanene 2006) and therefore the contribution of the artisanal sector was set to zero from 1950-1959, and then interpolated to a proportion of 35% in 2000. The subsistence sector therefore does the opposite, contributing 100% from 1950-1959 and then decreases to 65% in 2000. These percentages were applied to the total combined small-scale catch of consumed landings and artisanal exports.

<u>Sports fishing</u>

There is a small tourist sports fishery on Kiritimati atoll (Preston 2008). The main target of this fishery is bonefish. The sports bonefish fishery has been placed under a catch and release program, which is said to be followed by tourists in all areas, and was therefore not estimated as we assumed a zero or near-zero mortality rate (Anon. 2003).

Reported versus unreported

Large-scale commercial

Reporting coverage of large-scale commercial catches was quite good. All landed tuna and by-catch is included in the FAO data. It was also assumed that baitfish for the pole-and-line fleet was included. The only item deemed not reported in the FAO data was a small amount of discards from the purse seine and longline fleets.

Small-scale sectors

Reported small-scale catches within the FAO data were compared to our reconstruction of the small-scale sector. Reported amounts of small-scale tuna were determined by analysis of tuna catches as a whole, as described in the 'large-scale commercial' section of the methods. This reported small-scale tuna and all other non-industrial taxa formed the small-scale FAO baseline. Upon comparison of the reported small-scale catches (from the FAO data) and our reconstruction, it was found that for the years 1950-1982, 2006, and 2008-2010, catches were under-reported. It was assumed that for these years both the artisanal and subsistence sectors were equally under-reported and therefore reported and unreported catches were allocated proportionally between the subsistence and artisanal sectors.

For the years 1983-2005 and 2007, reconstructed small-scale catches were lower than the small-scale FAO data as determined here. No documentation as to where these catches are coming from or what they are used for could be found. Although there are some sectors which may not have been accounted for in our estimate, such as tourist seafood consumption, sports fishing which is not catch and release, and additional reef fish exports, the contribution of these sectors would likely be relatively small and nowhere near the magnitude of the difference seen between the FAO data and our reconstruction. Therefore, although we cannot be certain what the explanation for this difference is, we speculate that it is unlikely for these to be truly domestic Kiribati catches, and that these may be foreign catches taken, for example, under flag of convenience (here to mean a foreign vessel fishing under the flag of Kiribati). It is possible that there are foreign vessels which are flagged under Kiribati and are reporting their catches as Kiribati landings. We have no direct evidence for this, but there have been reporting issues concerning foreign fleets fishing within Kiribati waters. China was recently under scrutiny by the WCPFC for a discrepancy in the reported tonnage of bigeye tuna catch within Kiribati's waters, which China stated should be reported by Kiribati (Williams 2011). Although this may not be the most satisfactory explanation for the discrepancy in catches, a foreign, Kiribati-flagged vessel is the most likely explanation given the available information. Therefore, for the years 1983-2005 and 2007, all subsistence and artisanal catches are deemed reported. The remaining difference between our estimate and the FAO data is classified as 'unaccounted catch'. Due to the fact that the origin of this catch is still unknown, it will remain in the small-scale sector for analysis purposes. As stated earlier, although it appears that not all of the small-scale tuna catch is captured in the reported data, we assumed that our consumption estimate includes the tonnage of all of the small-scale tuna catch. Theoretically, we would then assume that our reconstruction should be higher than the FAO data as it contains small-scale tuna that does not appear to be captured in the reported data. However, there is a 22 year period (1983-2005) where there was 100% reporting coverage, leading to a taxonomic discrepancy. It appears that the tonnage is included in the FAO data but is not distinguished correctly taxonomically. At this time we are not able to sort out this discrepancy and therefore, small-scale tuna may be slightly underestimated in our reconstruction. This is an area for further study.

Total catches in the time period 1983-2005 and 2007 were high enough to account for the total estimated tonnage of catch; however, additional sources provided better species information which was used to partially disaggregate some of the highly aggregated taxonomic groupings in the FAO data. For example, sea cucumber exports were estimated for 1990-2010. Although there were no sea cucumber catches recorded in the FAO data for the years 1990-1996, we have no evidence to suggest that these exports were not recorded, and therefore it is assumed that these exports are included in the reported data and were simply included in a miscellaneous category ('marine fishes nei'). Shark fin exports were estimated for the 1977-2010 time period. Sharks did not appear in the FAO data until 1986. Again, as the reported data is sufficient in tonnage compared to our total reconstructed catch, it is assumed that for 1983-1985, sharks caught for fin export were grouped under the 'marine fishes nei' category. However, for 1977-1982, shark catches are considered unreported, as there was under-reporting of catches occurring from 1950-1982. Crustaceans first appear in the FAO data in 1983 and therefore all additionally estimated catches fall outside of the complete reporting coverage time period. From 1979-1982, crustacean exports are considered unreported. No additional mollusc catches were estimated for export and therefore they are all reported. Also, all live reef food fish trade exports are assumed to be reported (under 'percoids nei).

Spatial allocation

All catches reported by Kiribati to the FAO have been within the Western Central Pacific (FAO area 71). However, the country spans both area 71 and area 77 (Eastern Central Pacific). Although an overwhelming majority of the population lives in the Gilbert Islands, there are inhabited islands in area 77 and these I-Kiribati are landing subsistence catches; therefore, there must be some catches in area 77. As well, there are reports that in recent years the industrial fishing fleet has shifted its fishing grounds towards the east and does, now, also fish in the Eastern Central Pacific (area 77).

The pole-and-line fleet was assumed to operate solely in FAO area 71 from 1981-1997. This is based on the fact that all baitfish trials were run in the Gilbert Islands group (Rawlinson *et al*. 1992). It should be noted that in 1990, the Kiribati pole and line fleet did also operate within the Fiji and Solomon Islands EEZs due to poor conditions within Kiribati waters that year (Rawlinson *et al*. 1992). It was assumed that the fleet obtained 20% of that year's catch from Kiribati waters, and 40% each from the Fiji EEZ and the Solomon Islands EEZ waters. Despite this fact, all baitfish estimated in this report was caught within the Kiribati EEZ (due to the nature of the reference used) and for these years, was caught within area 71. However, in 2009 when the fleet began operating again after a 12 year hiatus, a spatial distribution map shows that the pole-and-line catch for that year was obtained from FAO area 77, with approximately 20% being caught within Kiribati's EEZ and 80% on the high seas. All baitfish used in 2009 was allocated to the Kiribati EEZ within area 77.

Information regarding the Kiribati-flagged longline fleet was difficult to find. As well, the available information is often contradictory. According to the FFA data, all longline catches from 1997-2010 were made within the Kiribati EEZ. Data from the SPC (P. Williams, pers. comm., Secretariat of the Pacific Community) covering the time period of 1990-2010, allocated all of the longline catch into the Gilbert Islands portion of the EEZ. However, at the same time, a WCPFC report (2011) describes the longline fishery during 2010, as operating mostly in the eastern high seas, as well as around the Cook Islands. Information regarding activity of the fleet prior to 2010 only discusses the issues involved in trying to build a longline fleet and the fact that Kiritimati (Line Islands) would be the ideal location to run the fleet out of. Therefore, from 1995-2008, all longline catches are allocated to within the EEZ in area 71 as the SPC data indicate, whereas the 2010 catches are all allocated to area 77, with 90% of the catches assigned to outside the EEZ and the other 10% within the EEZ. Discards were allocated using the same methods.

Purse seine catches were allocated by combining the information present in the FFA data, SPC data, and the distribution maps from the 2011 WCPFC report. The FFA data were used to allocate the catch to either within the EEZ, in the high seas, or in another country's EEZ (country not specified), for the time period of 1997-2010. Due to previous minor adjustments of total catches, proportions were utilized for certain years as exact totals would not match. The SPC data were used to determine that the catches from 1994-1996 (not covered by the FFA data), all came from outside the EEZ. According to the WCPFC report (2011), prior to 2009, all purse seine catches were within FAO area 71. The SPC data were also used to confirm this, and for 2009 and 2010, provided data to allocate the catches within the EEZ into areas 71 and 77. For the catches outside of the EEZ for 2009-2010, the distribution maps were used to determine which area the catches were taken from, as well as to confirm the proportion taken from the high seas versus another country's EEZ, as was provided by the FFA data. Discards were also allocated according to the above methods.

Small-scale catches which were not initially calculated for a specific island group were allocated between the three island groups in the two FAO areas based on population proportions. The population of Kanton in the Phoenix Islands was allocated to area 77, even though the EEZ of the islands spans both areas, as the majority of the EEZ as well as the islands themselves fall into area 77. As we were only allocating subsistence catch to the Phoenix Islands (early time period Phoenix artisanal catch calculated separately), the catch for this island group was determined by multiplying the population by the consumption rate time series that was used to calculate the total catch. Information from the colonial period of Kiribati indicates that there was a resettlement initiative that moved inhabitants to the Phoenix Islands in the early part of the time period. The population of the Gilbert Islands had expanded and the administration had decided to resettle part of the population on other islands. By 1940, 729 inhabitants of the Gilbert Islands had been transferred to the Phoenix Islands (Pala 2013b). The population peaked in the mid-1950s at approximately 1,300 people but by the early 1960s all inhabitants had been evacuated with most moving to the Solomon Islands. Therefore, we linearly interpolated the population from 729 in 1940 to 1,300 in 1955 and then to zero in 1964. Population information for all islands was available for six years: 1982, 1985, 1990, 1995, 2000, and 2005 (Bertram and Watters 1984; ADB 2002; SPC 2007). The Phoenix Islands remained uninhabited up to 1982. Interpolation of the population was performed between the six anchor points starting with the point of zero in 1982 up to the last point of 41 in 2005. The Phoenix Islands had one additional point of information in 2010 (24 inhabitants) and therefore one more interpolation was done. Using the full population time series for the Phoenix Islands group along with the consumption time series, a subsistence catch for the islands was calculated. This tonnage was removed from the subsistence total and the remaining subsistence catch and the artisanal catch were split between the Gilbert Islands and Line Islands. As the population for these islands was only available for the six years, the relative proportion of the islands' populations to each other was used as opposed to the actual population numbers. The six anchor points of data were turned into proportions of the total population of the Gilbert Islands and Line Islands only. Interpolation was done between all the anchor points: 1982, 1985, 1990, 1995, 2000, and 2005. The 2005 proportions were kept constant and carried forward to 2010. From 1964-1981 the 1982 anchor point was used. From 1950-1963, population migration routes did need to be considered. Working backwards, we assumed that from 1956-1963 the increase in proportion of the population in the Gilbert Islands and Line Islands was proportional to their respective populations as the majority of the Phoenix population was moving to the Solomon Islands and not to one of the other Kiribati Island groups. However, from 1950-1955, the increase in population in the Phoenix Islands was directly due to a decrease in the population in the Gilbert Islands, and thus the relative proportions of the Gilbert to Line Islands was adjusted to reflect this. Overall, as the Gilbert Islands contain such a large portion of the population, the changes make only minor differences in the proportions. Subsistence and artisanal catches were individually allocated to the two FAO areas using these proportions, with reported and unreported catches within each sector also being proportionally allocated. Subsistence catches for the Phoenix Islands were also proportionally allocated as reported and unreported, but artisanal catches in the early time period were all considered unreported. Although these assumptions may not be entirely valid, they are mostly for accounting purposes and do not affect the overall catch assigned to the Phoenix Islands. Due to the transparency issues in the reported data, these assumptions were for simplicity sake. Finally, the unaccounted catch in the years 1983-2005 and 2007 was kept in area 71, as it is unknown where this catch was taken from.

Taxonomic composition

Large-scale commercial

The SPC, FFA, and WCPFC data provided good species breakdown for the large-scale commercial tuna catches. For most years, this information corresponded perfectly with the FAO data. From 2007-2010, a 'tuna-like fishes nei' category was included in the FAO data and so the alternative sources were used to disaggregate the catch into specific tuna taxa. Baitfish catches were known to contain mostly species from the Clupeidae family. Due to the fact that the various baitfishing techniques brought up different species compositions (Rawlinson *et al.* 1992), catches were only classified to the family level (Clupeidae). Discards for the purse seine and longline fleets were disaggregated proportionally by target species.

Small-scale sectors

Information on the species composition of small-scale catches in Kiribati was not readily available. The limited information available was either only to the family level and corresponded fairly closely to the FAO data, or was too specific and too small of a sample to be able to extrapolate to the entire catch (i.e., SPC 1995; Awira *et al.* 2008). Therefore, the taxonomic breakdown of the FAO data was used to disaggregate reconstructed catches. Although there is information indicating that not all of the small-scale tuna may be represented in the reported data taxonomically, we also know that there are definitely years when it is fully incorporated. Therefore, we chose to not estimate any additional tuna taxonomically and the proportion of small-scale tuna may be slightly underestimated. Hence, small-scale tuna catches, as well as artisanal exports, have already been assigned taxonomically and are not included in this section. For reported exports, or specific years of reported exports, where the appropriate taxonomic category was not present, that item was assumed to have been reported under a miscellaneous category. It should also be noted that tuna and reported exports were removed from the FAO data before calculating taxonomic composition proportions. For the subsistence, artisanal, and unaccounted catch sectors, the data were divided into three separate time periods in terms of methodology used.

The first time period was 1950-1982. In this period, the species composition for the reported components of the subsistence and artisanal sectors were taken to be proportional to the FAO data. FAO taxonomic categories were adjusted to their corresponding scientific name (usually at family level), if appropriate. The unreported catch was broken down by using the average taxonomic breakdown from the FAO data for the years 1981 and 1982, as these years provided the greatest taxonomic disaggregation.

The next time period was 1983-2005 and 2007. This time period included the unaccounted catch sector as well. With that in mind, it should be noted that the reported tuna was not included in the calculation of taxonomic composition proportions for this time period. Reported and unreported tuna have already been taxonomically assigned as well as assigned by sector. All tuna is accounted for and therefore should not be allocated to the unaccounted catch. All remaining reported catches, by taxonomic category, in the FAO data for this time period were assigned proportionally to the remaining subsistence and artisanal sector catches and the unaccounted catch. The only unreported data in need of a taxonomic breakdown for this time period was the additional inshore estimate for the year 2000. The original proportions from the reported data for the inshore species in 2000 were used to assign a breakdown to this catch.

The last time period was 2006 and 2008-2010, and only contains subsistence and artisanal catches. As in the first time period, the FAO catches were assigned proportionally to the reported subsistence and artisanal portions. The average FAO taxonomic breakdown of 2008-2010 was used to breakdown the unreported portions for 2006 and 2008-2010.

After applying these breakdowns, it was noted that the FAO data contained large amounts of aggregated fish categories, such as 'marine fishes nei' and 'percoids nei' which are uninformative in analyses. Even within the few external species breakdowns available, there was a large miscellaneous fish category present as well, constituting up to 57% of the breakdown (SPC 1995; Pratchett *et al.* 2011). In order to reduce the amount of unclassified catch, the average species breakdown of the reported catch for the years 1986-2010 (the years with the greatest disaggregation of catch), excluding the 'marine fishes nei' and 'percoids nei' taxonomic categories and invertebrate categories, as well as the initially excluded catches (tunas, exports), was applied to the 'marine fishes nei' and 'percoids nei' catches of both the reported and unreported components of the artisanal and subsistence sectors and the unaccounted catch, with 5% of these categories remaining as 'marine fishes not identified' in order to account for less common fish families. This is clearly an approximation, and more detailed taxonomic compositions (at least at the family level) should be obtained in regular intervals, and applied to Kiribati catch data.

Foreign vessels

Kiribati licenses a large number of foreign vessels to fish in their waters. No specific information as to number of vessels or tonnage of fish caught could be found prior to 2001. Specific information was found within Kiribati country statement reports for the post-2000 time period (Tumoa 2006; WCPFC 2011a); however, this information was not all inclusive as certain agreements were excluded from the reports. Therefore, total foreign catch was not estimated. From the information that was available, it was seen that the number of licensed foreign fishing vessels in Kiribati waters during the time period of 2001-2010 ranged from 273-450 with the number of support vessels ranging from 6-114 (Tumoa 2006; WCPFC 2011a). These numbers do not include US or FSM arrangements for all years. Countries with vessels licensed to fish in Kiribati waters include Japan, South Korea, Taiwan, Vanuatu, China, New Zealand, Papua New Guinea, Panama, Philippines, Singapore, Spain, the United States, and the Federated States of Micronesia (Tumoa 2006). Estimates of total purse seine catches by foreign licensed vessels range from 81,000 to 333,000 t·year^{-1} and longline catches range from 3,000 to 17,000 t·year^{-1} (Tumoa 2006; WCPFC 2011a). It should also be noted that information on spatial distribution was only available for some of the fleets for a few of the years. Therefore, it could not be determined which FAO area most of the catches were coming from and these catches were not included in this reconstruction at this time. However, as part of *Sea Around Us*, reported catches by countries in areas outside of their home FAO area will be spatially allocated and so these catches will be at least partially accounted for during that allocation. Also, global work on tuna fisheries is being completed which will also account for these fleets.

There is another known incident of foreign fishing which occurred in the Phoenix Islands. In 2001, a Samoan boat stopped in the Phoenix Islands to catch sharks for their fins using longlines (Stone 2013; pp. 9-10). Even though this one boat fished for just three months (engine trouble caused it to have to leave the islands), it managed to remove almost all of the adult sharks around 4 of the islands. This raid has had a negative effect on islanders who fish the sharks for both their fins as well as for consumption purposes. Although there was no information on tonnage removed, it is important to include this event in our estimate as it had a large impact on the ecosystem and local population. Therefore, we assume that 100 t of shark was fished during this incident. This includes the fin weight and discarded carcasses. As it is unknown what species of shark these were, we used the mean fin weight to round weight ratio of 3% (Biery and Pauly 2012) to estimate that 3 t of shark fins were landed and 97 t of shark carcasses were discarded.

Results

Large-scale commercial

The reconstructed total large-scale commercial catch of Kiribati increased from an average of over 1,200 t·year^{-1} in the 1980s to over 7,800 t in 1998. Catches then stayed relatively constant at 5,500 t·year^{-1} from 1999-2008 and then rapidly increased to

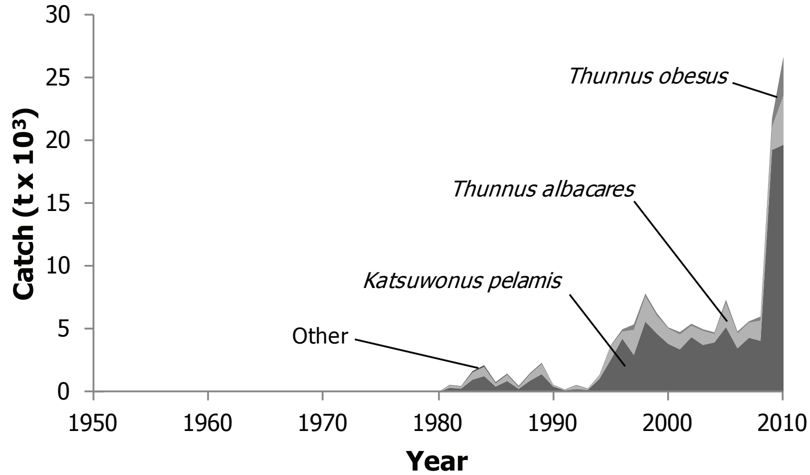

Figure 4. Total large-scale commercial reconstructed catches for Kiribati, 1950-2010, by species. 'Other' category constitutes *Thunnus alalunga* and Clupeidae catches.

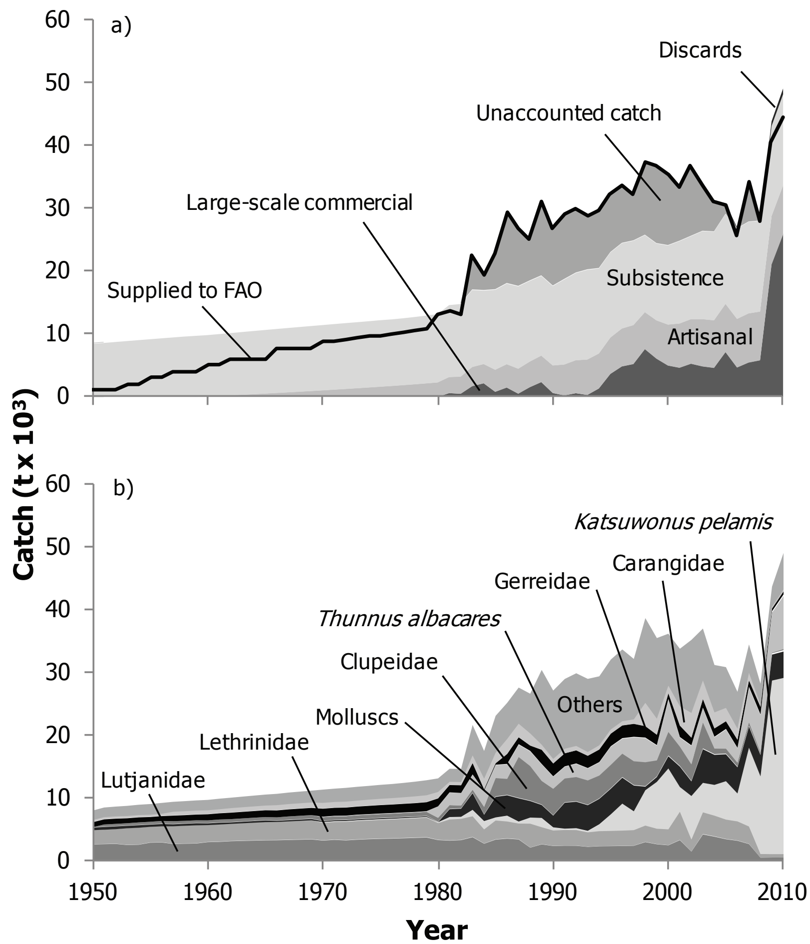

Figure 5. Reconstructed total catch of Kiribati, 1950-2010, a) by sector (FAO data overlaid as line graph) and b) by taxonomic composition. The 'other' category consists of 17 separate taxonomic categories. Please note that 'unaccounted catch' consists of catches from the FAO data which could not be accounted for in our reconstruction. Discards are shown separately but are only just visible at the end of the time period.

21,800 t and 26,700 t in 2009 and 2010, respectively (Figure 4). This reconstructed catch is only 3.1% higher than the reported large-scale commercial catch, with the only unreported component being discards. The dominant species of the large-scale commercial catch was skipjack tuna (*Katsuwonus pelamis*) with 74.2% of the catch. The majority of the skipjack tuna comes from the joint venture purse seine fleet (91.6%). Yellowfin tuna (*Thunnus albacares*) constitutes a further 20.7% of the catch and bigeye tuna (*Thunnus obesus*) only comprises 4.4% of the catch. Other species, including albacore (*Thunnus alalunga*) and baitfish (Clupeidae) make up 1% of the total large-scale commercial catch (Figure 4). Adjustment of the spatial distribution of catches resulted in an estimated 84% of catches being caught in FAO area 71 and the remaining 16% in area 77. However, since fleets started fishing in area 77 in 2009, 47% of the catch from 2009 and 2010 has been from area 77. It was also estimated that 75% of large-scale commercial catches were taken from outside of Kiribati's EEZ. Almost all of the catches in the 1980s and early 1990s were caught inside the EEZ, after which there was a shift to fishing outside the EEZ; from 1994-2010 83% of large-scale commercial catches were estimated to be taken outside the EEZ. Although catches from outside the EEZ were allocated to the high seas or another country's EEZ when information was available, not all catches could be allocated this way, and therefore results cannot be given in more specific detail. In 2001, there was 100 t of foreign fishing estimated inside the Phoenix Islands' waters. This catch of shark was very damaging to the ecosystem. There is additional foreign fishing occurring in Kiribati waters that was not estimated at this time.

Small-scale sectors

The reconstructed total small-scale catch (artisanal, subsistence, and unaccounted catch combined) of Kiribati was estimated to be approximately 15% higher than the small-scale catches reported by the FAO on behalf of Kiribati. Small-scale catches (including unaccounted catch) increased gradually at the beginning of the time period, from an average of 9,100 t·year^{-1} in the 1950s to 12,200 t·year^{-1} in the 1970s (Figure 5a). Then, in the early 1980s, catches increased by approximately 58% between 1980 and 1983. Catches peaked in 2002 at almost 31,500 t, and then proceeded to decrease by 41% between 2000 and 2008, when catches then stabilized. Subsistence catches were estimated to contribute 64% of the small-scale sector catch. Another 18% was estimated to be from the artisanal sector and the last 18% is unaccounted catch which is possibly from a flag of convenience vessel (Figure 5a). Small-scale exports were estimated to contribute 33% to the artisanal catch and 5.8% to the total small-scale catch. Total catches in the early time period were greatly under-reported. For 1950-1979, it was estimated that 42% of catches went unreported, compared to only 1.4% unreported catches in the time period of 1980-2010.

If only the artisanal and subsistence catches are considered, the reconstruction is 20% higher than the adjusted FAO landings (i.e., removing the unaccounted catch). Subsistence catches are estimated to contribute 78.5% and artisanal catches 21.5%. Subsistence catches increased steadily from 8,400 t in 1950 to almost 14,600 t in 2010. Artisanal catches exhibited a much more rapid increase from 50 t·year^{-1} in the 1950s (Phoenix exports), to 500 t·year^{-1}, 1,500 t·year^{-1}, 3,300 t·year^{-1} and 5,600 t·year^{-1}, in the 1960s, 1970s, 1980s and 1990s, respectively, peaking at 7,850 t in 2010. Artisanal exports were more variable. The general trend shows 50 t·year^{-1} in the 1950s, dropping to 25 t in 1959, followed by a period of zero exports until 1979. Exports then increased from 3 t in 1979 to a peak of almost 3,700 t in 1993. Exports decreased to just under 1,000 t in 1999 before increasing again to an average of 3,000 t·year^{-1} from 2003-2007. Exports then declined again to just over 2,000 t in 2010.

The subsistence catch was dominated by Lutjanidae with almost 20% of the catch. Other major contributing groups include Lethrinidae (17.3%), Gerridae (7.5%), Clupeidae (7.4%), yellowfin tuna (*Thunnus albacares*; 7.2%), Carangidae (7.1%) and molluscs (6.5%). The artisanal catch had a similar composition in terms of species but much different proportions. Molluscs (29.2%), Lutjanidae (9.1%), Lethrinidae (8.3%), yellowfin tuna (7.1%), *Katsuwonus pelamis* (skipjack tuna; 7.0%), and sharks etc. (5.3%) constituted the major taxonomic groups. The overall species composition of the small-scale sector (including the unknown component) was Lutjanidae (16.5%), Lethrinidae (15.0%), molluscs (9.3%), Clupeidae (8.5%), Gerreidae (6.9%) and Carangidae (6.9%; Figure 5b).

Spatial allocation was mostly based on population distribution. As a result, 95% of the catches were estimated to be caught in FAO area 71, and only 5% in area 77. Within area 77, 93.4% of the small-scale catch is from the Line Islands group and only 6.6% is from the Phoenix Islands group. If we exclude the unaccounted catch, which was assigned to Area 71 based purely on the fact that that is where it was originally reported from, we see that 93.6% of the small-scale catch is Gilbert Islands catch, 6.0% is Line Islands and 0.4% is from the Phoenix Islands. Again, these proportions may not completely accurately reflect the distribution of catches, especially if artisanal catch is being transferred between Island groups, but it is more accurate than the FAO data which lists all of Kiribati's catch in area 71.

The catch trend for the Gilbert Islands, again just looking at the artisanal and subsistence data (i.e. the data assigned to island groups), is the same as looking at the whole catch as it is dominant with almost 94% of the catch. The catch steadily increases from 7,800 t in 1950 to 20,300 t in 2010. The Line Islands show a slightly different trend, first increasing slowly from just over 300 t in 1950 to 670 t in 1985. Catches then increases more rapidly up to approximately 1,400 t in 1993. Catches then hovered around 1,400 t·year^{-1} from 1994-2000 before increasing again up to 2005, where catches then remained stable until 2010 with 2,100 t·year^{-1}. Catches in the Phoenix peaked in the early time period, in contrast to the other island groups. Catches peaked in 1955 at 370 t and declined to zero in 1964. Catches then increased again starting in 1983, up to a much smaller peak of almost 18 t in 1995. Catches then declined again to 5 t in 2010. In 2001, there was one incident of foreign fishing estimated in the Phoenix Islands of 100 t shark catch by a Samoan boat.

Reconstructed total catch

The reconstructed total catch of Kiribati for the time period 1950-2010 was approximately 14% higher than the catches reported by the FAO on behalf of Kiribati (Figure 5a). Catches increased steadily from 8,500 t in 1950 to 14,800 t in 1982. Catches increased sharply in 1983 to almost 22,500 t. Catches continued to increase to the first peak in 1998 with 37,500 t, before declining slightly to 27,000 t in 2006. Catches increased again to the second peak of 49,000 t in 2010. The peak in the last few years of the time period is driven by an increase in the large-scale commercial catches. The magnitude of the increase from the early 1980s to the early 2000s is amplified by the apparent unaccounted catch and this same sudden increase in 1983 is also seen in the FAO data. Of the total reconstructed catch, the large-scale commercial sector contributes 11.3%, the artisanal sector accounts for 15.6%, the subsistence sector equates to 57.0%, and the unaccounted catch makes up the last 16.1%. The species composition is dominated by Lutjanidae at 14.6% of the total catch. Lethrinidae (13.3%), *Katsuwonus pelamis* (12.4%), molluscs (8.3%), Clupeidae (7.6%), *Thunnus albacares* (7.6%), Carangidae (6.1%), and Gerreidae (6.1%) are also important contributors to the overall catch.

Discussion

The reconstructed total large-scale commercial catch of Kiribati was estimated to be 3.2% higher than the industrial catch reported to the FAO. This difference was due to unreported discards. The large-scale commercial catches of Kiribati experienced several abrupt increases in average yearly catch. The first increase in the mid-1990s was due to the start of the purse seine joint venture. The second increase, in 2009, was due to a massive re-flagging of foreign vessels (WCPFC 2011a). In the recent time period, there has been a shift of the industrial fisheries eastward, from operating solely in FAO area 71 to an increasing proportion of catches in area 77. This shift is partly influenced by the pattern of El Niño which influences the movement of skipjack tuna (WCPFC 2011a). Overall, it can be seen that the majority of the large-scale catch comes from re-flagged vessels or joint ventures which are mainly run by foreign countries with majority foreign beneficial ownership. Therefore, although these are Kiribati catches, they are not indicative of the marine fisheries catches of the I-Kiribati people. Also, given the fact that 75% of large-scale commercial catches were estimated to be taken from outside the Kiribati EEZ, this could indicate that large-scale fisheries do not have a great impact on small-scale fisheries resources. However, if large-scale fisheries are intercepting tuna stocks which would normally migrate through the EEZ to be available to the artisanal tuna fishers, then the increasing catches by Kiribati flagged large-scale vessels could begin to present a problem to the food security of the I-Kiribati. Furthermore, it is highly likely that foreign vessels have, and may continue to fish inside the EEZ of Kiribati, either under foreign access agreements, or illegally.

The reconstructed total small-scale catch (including unaccounted catches) of Kiribati was estimated to be 15% higher than the small-scale portion of the FAO data. The gradual increase of small-scale catches at the beginning of the time period was due to an increasing population. The early 1980s were a period of rapid increase which was most likely due to an increase in exports as well as an increase in the presence of overseas companies which most likely formed joint ventures with local businesses. Kiribati declared its EEZ in 1978 and became an independent nation in 1979. Therefore, it is reasonable to assume that in the following years, foreign fleets may have made the decision to try and coordinate joint ventures with the countries whose waters they previously used to fish unrestricted, in order to gain access to those resources once again. According to the data, the decline in recent years is due to a decline in inshore species. This is one possibility, and in all likelihood is occurring to some extent as it is known that specific inshore stocks are in decline. However, it is possible that the abruptness of the decline was due to reporting issues. Both of these factors are discussed in further detail below.

Kiribati has struggled with development of their offshore fisheries (Anon. 2003; Barclay and Cartwright 2007). Kiribati's isolation, lack of resources, and difficulties with transportation have stifled the development of domestic offshore fisheries. The most successful large-scale offshore fishery has been the purse seine fleet which is a joint venture with a Japanese company and re-flagged vessels. The vessels spends most of their time operating outside of the EEZ and often lands catch at other ports (Barclay and Cartwright 2007). This difficulty in developing an offshore fishery led to a shift towards operating in the inshore sector (Anon. 2003). Marine resources are a vital part of the country's economic development with many inshore species being important export items, such as sea cucumber, lobsters and molluscs. Although officials are aware that those resources are in decline, they continue to encourage both local and overseas companies to commercially exploit these resources (Anon. 2003).

With evermore fishing in the inshore sector being encouraged, it is not surprising that most of the heavily exploited inshore stocks have been reported to be in decline. Molluscs (both the ark shell and giant clams) have been reported to be greatly under pressure, and in some areas (South Tarawa most notably) the fisheries may even have collapsed (Thomas 2003a; Preston 2008; Sullivan and Ram-Bidesi 2008). Bonefish stocks are also in sharp decline. This is not only due to overfishing but also due to their spawning runs being disrupted by the construction of causeways (Johannes and Yeeting 2000; Sullivan and Ram-Bidesi 2008). As the subsistence and artisanal fishers overexploit bonefish stocks on Kiritimati, it leaves little to attract tourism, which is one of the only sources of revenue for the island (Anon. 2003). Kiribati's fisheries division did implement restrictions on bonefish capture in early 2008 (Gillett 2011a); however, information on the current status of the stocks could not be found. Comparison of areas targeted by the live reef food fish trade and non-target areas confirms that the fishery has had a negative impact on fish stocks, despite the fact that operations occurred over a short time period (Anon. 2003). The ornamental fish trade is also thought to have led to the decline of some reef fish stocks (Preston 2008).

Another issue that came to light during the reconstruction was the fact that Kiribati's marine fisheries catches seem abnormally high in the latter half of the time series. Even given the high consumption rate of the I-Kiribati, it still seems as though all of the reported catches cannot be accounted for. This also means that all of the catches which we can account for are deemed as reported. This is a noteworthy finding, given the fact that subsistence catches in the South Pacific are known to be under-reported due to a lack of resources available to monitor the sector (Dalzell *et al*. 1996). According to a Kiribati fisheries division report (Anon. 2003), data are in fact collected from subsistence fishers. However, it is interesting that although we accepted the reported small-scale tuna catch as it was recorded, we know that taxonomically some of the catch seems to be missing; although, due to this 100% reporting record for an approximately 20 year period, the tonnage of the tuna appears to be included. We know specifically that in the last few years (2007-2010), the total amount of small-scale tuna catch was reported taxonomically and interestingly, at the same time that complete tuna catches became incorporated into the data, the amount of reported reef fish and invertebrates plummeted (with this also occurring in the year 2000). It seems unusual that within a year there would be such a dramatic change in actual catches and diet. Therefore, this does support the possibility that the total actual tonnage of tuna was reported in the data, but was taxonomically incorrectly reported as something else.

Regardless of the taxonomic issues in reporting, there is also an issue with accounting for the tonnage of the catch. As stated earlier, some of the catches within the FAO data may be attributable to flag of convenience vessels. If there has been encouragement to exploit the inshore resources, it is possible that foreign re-flagged vessels are collecting inshore species. Another possibility is that re-flagged vessels are fishing tuna and are misreporting it taxonomically. The final possible explanation is that large amounts of reef fish caught by Kiribati flagged vessels are being processed into fishmeal. This, in fact, seems like the most satisfactory explanation. However, there is little evidence to support it. In an FAO country profile of Kiribati (Gillett 2011a) there is a single mention within a table that a large amount of fish is being used for "animal feed and other purposes" as opposed to a smaller amount "for direct human consumption." However, within the report there is no explanation or further mention of this and no reference as to where this number came from. Also, within the same report are estimated values of coastal commercial and coastal subsistence catches which have been taken from Gillett (2009). The total production within this table is the same as the first and the subsistence catch is roughly equal to the amount supposedly used for animal feed. Gillett (2009) defines coastal subsistence catches as those retained by the fisher for either their or another community members consumption. Thus under that definition, the large amount of fish meal would not be included in those numbers. These two values are contradictory. After an extensive literature search, no other information regarding fishmeal production or catches for fishmeal production by Kiribati could be found. Therefore, whether it is a matter of taxonomic misreporting, over-reporting, or reporting by flag of convenience vessels, there is a definite lack of transparency in Kiribati's marine fisheries data. Due to the multitude of issues that are present throughout the time span, it is extremely difficult to assess exactly what is occurring in Kiribati's waters.

It should also be recognized that due to the widespread and scattered nature of Kiribati's islands, assessing and reporting total catches is a challenge. However, due to a lack of comprehensive data on separate islands, it was necessary to analyze Kiribati's marine fisheries catches as a whole. Also, although it was estimated that only a small portion of the small-scale catches are taken from the waters of FAO area 77, this estimate was based on the assumption that catches were proportional to population distribution. This may not be the best indication of catch. It is known that some of the outer islands (include Kiritimati, which is located in area 77) export catches to Tarawa (area 71), in order to supply the high demand by the more densely packed population (Awira *et al*. 2008). However, this information could not be used directly to make an assumption of the spatial distribution of catches, as the study consisted of very small sample sizes that could not be extrapolated to the whole population. Thus island group specific separation of national catch data would be a useful step forward.

We have made the best possible estimates of total catches with the available information. Further research is required to assess the state of Kiribati's fisheries. Kiribati's isolation, which leads to high transport costs and thus high import costs, leads the population to rely on local resources. A lack of fertile soils means that the only local resource to satisfy their dietary protein needs is their marine resources. With a high *per capita* seafood consumption rate it is essential that measures be taken to ensure that the marine resources are sustainably caught, and this applies especially to inshore pelagic and non-pelagic resources that are of fundamental food security importance to the I-Kiribati. This also means that much better transparency is required in the officially reported data.

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Appendix Table A1. FAO landings[a] vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Kiribati, 1950-2010.

Year	FAO landings[a]	Reconstructed total catch	Large-scale commercial	Artisanal	Subsistence	Unaccounted catch	Discards
1950	1,000	8,500	-	50	8,410	-	-
1951	1,000	8,600	-	50	8,560	-	-
1952	1,000	8,800	-	50	8,710	-	-
1953	2,000	8,900	-	50	8,850	-	-
1954	2,000	9,000	-	50	9,000	-	-
1955	3,000	9,200	-	50	9,140	-	-
1956	3,000	9,300	-	50	9,290	-	-
1957	4,000	9,500	-	50	9,430	-	-
1958	4,000	9,600	-	50	9,570	-	-
1959	4,000	9,700	-	25	9,710	-	-
1960	5,000	9,900	-	82	9,770	-	-
1961	5,000	10,000	-	167	9,850	-	-
1962	6,000	10,200	-	254	9,920	-	-
1963	6,000	10,300	-	345	10,000	-	-
1964	6,000	10,500	-	438	10,070	-	-
1965	6,000	10,700	-	533	10,140	-	-
1966	7,500	10,800	-	632	10,200	-	-
1967	7,500	11,000	-	733	10,260	-	-
1968	7,500	11,100	-	836	10,310	-	-
1969	7,500	11,300	-	942	10,360	-	-
1970	8,801	11,500	-	1,050	10,400	-	-
1971	8,901	11,600	-	1,161	10,450	-	-
1972	9,101	11,800	-	1,274	10,490	-	-
1973	9,201	11,900	-	1,390	10,520	-	-
1974	9,475	12,100	-	1,508	10,560	-	-
1975	9,650	12,200	-	1,630	10,600	-	-
1976	9,824	12,400	-	1,751	10,610	-	-
1977	10,053	12,500	-	1,880	10,650	-	-
1978	10,606	12,700	-	2,017	10,720	-	-
1979	10,838	13,000	-	2,160	10,800	-	-
1980	12,929	13,200	-	2,309	10,890	-	-
1981	13,502	14,600	590	2,575	11,470	-	-
1982	13,009	14,800	490	2,744	11,570	-	-
1983	22,485	22,500	1,700	3,066	12,270	5,450	-
1984	19,380	19,400	2,160	3,081	11,710	2,440	-
1985	22,844	22,800	800	3,524	12,740	5,780	-
1986	29,271	29,300	1,480	3,729	12,850	11,220	-
1987	27,137	26,700	510	3,990	13,110	9,110	-
1988	25,002	25,000	1,530	4,094	12,850	6,530	-
1989	30,983	31,000	2,340	4,235	12,710	11,700	-
1990	26,852	26,900	610	4,404	12,640	9,190	-
1991	29,170	29,200	240	4,929	13,560	10,450	-
1992	30,023	30,000	580	5,268	13,890	10,290	-
1993	28,884	28,900	310	5,650	14,290	8,640	-
1994	29,569	29,600	1,330	5,579	13,550	9,110	39
1995	32,120	32,200	3,640	5,809	13,550	9,120	105
1996	33,687	33,900	4,840	6,056	13,580	9,210	169
1997	32,138	32,300	5,210	6,227	13,440	7,260	182
1998	37,284	37,500	7,580	5,913	12,280	11,510	265
1999	36,365	36,900	6,080	6,119	12,240	12,210	213
2000	35,446	35,600	4,980	6,541	12,600	11,330	174
2001	33,280	33,400	4,620	7,066	13,120	8,470	162
2002	36,694	36,900	5,260	7,121	13,220	11,080	184
2003	33,712	33,900	4,840	7,546	14,010	7,310	169
2004	31,062	31,200	4,600	7,595	14,110	4,760	161
2005	30,562	30,800	7,110	7,707	14,310	1,430	249
2006	25,661	27,000	4,660	7,757	14,410	-	163
2007	34,170	34,400	5,450	7,848	14,580	6,290	191
2008	28,000	28,200	5,810	7,782	14,450	-	204
2009	40,623	43,900	21,050	7,743	14,380	-	731
2010	44,599	49,200	25,830	7,849	14,580	-	904

[a]This represents the adjusted FAO time series.

Appendix Table A2. **R**econstructed total catch (in tonnes) by major taxa for Kiribati, 1950-2010. 'Others' contains 17 additional taxonomic categories.

Year	Lutjanidae	Lethrinidae	*Katsuwonus pelamis*	Molluscs	Clupeidae	*Thunnus albacares*	Gerreidae	Carangidae	Others
1950	2,700	2,210	-	430	345	-	796	463	1,520
1951	2,740	2,250	-	439	351	-	811	471	1,540
1952	2,780	2,300	-	447	356	-	827	480	1,570
1953	2,610	2,620	-	398	393	-	783	478	1,630
1954	2,650	2,660	-	406	398	-	798	486	1,650
1955	2,970	2,480	-	357	435	-	754	485	1,710
1956	3,020	2,520	-	365	440	-	769	493	1,730
1957	2,770	2,780	-	315	408	-	882	744	1,590
1958	2,810	2,820	-	324	413	-	896	752	1,610
1959	2,850	2,850	-	332	419	-	911	760	1,620
1960	3,060	2,670	-	282	455	-	967	758	1,660
1961	3,110	2,710	-	291	461	-	983	767	1,690
1962	3,210	2,710	-	243	471	-	1,024	848	1,670
1963	3,260	2,760	-	252	477	-	1,041	858	1,700
1964	3,310	2,810	-	262	483	-	1,057	867	1,720
1965	3,350	2,850	-	271	489	-	1,074	876	1,750
1966	3,370	2,860	-	193	535	-	1,098	965	1,810
1967	3,410	2,910	-	203	541	-	1,114	974	1,840
1968	3,460	2,950	-	212	546	-	1,130	983	1,860
1969	3,500	3,000	-	221	552	-	1,146	992	1,890
1970	3,320	2,810	100	154	550	100	1,255	1,055	2,110
1971	3,430	2,820	100	157	553	100	1,261	1,059	2,120
1972	3,350	2,940	100	155	578	100	1,274	1,074	2,200
1973	3,460	2,950	100	157	580	100	1,279	1,077	2,210
1974	3,540	2,960	100	150	589	100	1,311	1,120	2,190
1975	3,590	3,000	100	150	598	100	1,330	1,137	2,220
1976	3,630	3,030	100	147	605	100	1,345	1,153	2,250
1977	3,680	3,060	100	143	615	100	1,364	1,174	2,290
1978	3,750	3,090	100	123	630	100	1,394	1,213	2,340
1979	3,810	3,140	100	121	641	100	1,419	1,240	2,400
1980	3,400	2,700	100	13	591	1,810	1,259	1,162	2,170
1981	3,310	3,360	360	1,254	449	2,020	1,156	654	2,080
1982	3,390	3,380	290	1,300	486	1,980	1,222	661	2,100
1983	3,860	3,320	1,000	2,664	1,195	2,400	1,809	1,374	4,870
1984	2,820	2,280	1,280	1,018	2,953	2,560	220	1,838	4,410
1985	3,470	3,040	450	3,286	2,572	2,080	230	1,833	5,890
1986	3,620	2,730	890	3,255	6,554	2,340	1,580	2,548	5,760
1987	3,490	2,530	270	3,714	5,539	1,970	1,107	2,323	5,770
1988	2,190	3,820	930	2,649	3,789	2,360	848	2,099	6,330
1989	2,710	2,730	1,440	2,071	4,229	2,660	2,258	972	11,920
1990	2,450	2,470	450	1,880	3,826	1,960	2,040	874	10,910
1991	2,490	2,510	160	4,144	3,896	1,880	2,076	886	11,130
1992	2,490	2,500	250	4,230	3,909	2,120	2,080	862	11,590
1993	2,310	2,320	180	4,100	3,676	1,920	1,948	765	11,660
1994	2,410	2,410	1,050	4,060	3,760	2,090	2,000	832	11,000
1995	2,430	2,430	2,590	4,100	3,790	2,900	2,010	833	11,140
1996	2,450	2,460	4,250	4,150	3,834	2,390	2,033	835	11,450
1997	2,490	2,490	2,950	4,120	3,861	3,820	2,073	877	9,630
1998	3,070	2,640	5,600	571	2,605	3,850	1,828	3,882	13,510
1999	2,720	2,480	7,440	776	3,839	2,370	1,651	2,725	12,850
2000	2,560	2,540	9,680	1,947	3,139	5,140	936	1,389	8,280
2001	3,380	4,500	3,930	3,260	2,662	1,450	1,824	3,254	9,170
2002	1,550	1,950	6,890	2,337	4,211	2,970	1,222	4,104	11,650
2003	4,300	3,500	4,690	5,378	954	2,260	1,401	3,126	8,280
2004	3,940	3,330	4,890	4,800	846	1,800	1,340	2,714	7,560
2005	3,530	3,120	6,100	4,300	669	3,060	1,239	2,288	6,500
2006	3,290	3,070	4,420	4,186	610	2,320	1,290	1,935	5,870
2007	2,760	2,790	12,550	3,375	358	5,560	1,067	1,345	4,560
2008	580	630	12,310	3,415	265	5,960	1,229	537	3,320
2009	600	580	27,660	4,145	349	6,400	542	431	3,200
2010	630	560	28,070	4,215	312	8,510	601	437	5,830

Reconstruction of total marine catches for the Maldives: 1950 – 2010[1]

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Abstract

The republic of the Maldives has always relied on its marine resources for food and employment security, and for trade revenue. Traditionally, Maldivian fisheries focused on tuna, shark and live-bait. During the 1970s, rapid development, expansion and diversification (including reef fisheries) of marine fisheries and the tourist industry began. Catch statistics have been recorded by the Ministry of Fisheries, Agriculture and Marine Resources (MoFAMR) since 1959. A total enumeration system has evolved over time, initially focusing on catches by the pole-and-line tuna fishery, it has since been expanded to incorporate other gears types and species. A lack of financial and human resources has led to concerns over the accuracy of the catch data reported to the FAO. A catch reconstruction approach, using quantitative and qualitative sources, was used to reconstruct total marine fisheries catches for the 1950-2010 time period. Total reconstructed marine catches were estimated, which were 23% more than the tonnage reported by the Maldives to the FAO. Total catches increased from around 22,000 t·year^{-1} in the 1950s to a peak of 223,000 t in 2006, before declining to about 143,000 t·year^{-1} in the late 2000s. When tuna and non-tuna catches were examined separately, large skipjack tuna catches were found to be masking the under-reporting of other species such as grouper, sea cucumber, and sharks, all of which are known to be susceptible to over-fishing. The Maldives fishing and tourism industries, as well as food and employment security are dependent on healthy marine ecosystems, it is therefore imperative that reported catch statistics more accurately reflect total extractions from the marine environment.

Introduction

Marine fisheries are crucial for small island countries, providing food and employment security as well as foreign trade and investment (Zeller *et al.* 2007). To better understand the interactions between marine fisheries and marine ecosystems, it is important to have as complete a record of total marine extractions as possible, both past and present. Unfortunately, officially reported landings data are often incomplete (Zeller *et al.* 2006; Zeller *et al.* 2007; Le Manach *et al.* 2012).

The Food and Agriculture Organization (FAO) publishes marine capture landings data, as reported to them by most nations of the world. The data received, however, are generally missing discarded, subsistence and recreational catches, and even commercial catches are often under-reported or missing (Zeller *et al.* 2007). As catch statistics are often used to develop marine policy and management plans, and set catch quotas, under-reported total catches are a serious concern. A reconstruction methodology has been developed by Zeller *et al.* (2007), and is being used here to reconstruct total marine catches since 1950 for the Maldives.

The Maldives

The Republic of the Maldives is an atoll archipelago, 700 km south-west of Sri Lanka in the Indian Ocean (Figure 1). The country is comprised of 26 atolls and approximately 1190 islands, about 200 of which are permanently inhabited and a further 80 have been developed into tourist resorts (Anderson *et al.* 2003). The Maldives stretch for 840 km along the 73°E longitude, from 8°N to 1°S and have a total land area of only around 300 km², but an Exclusive Economic Zone (EEZ) of over 900,000 km² (www.seaaroundus.org). Fishing within the EEZ by other countries is

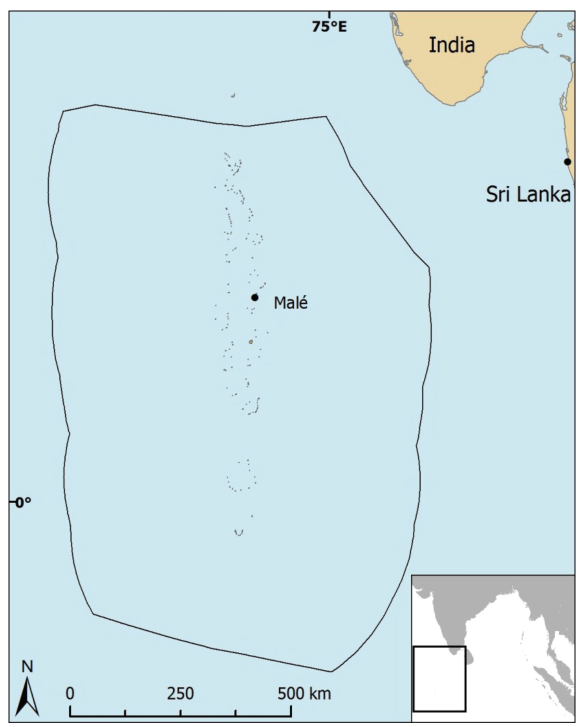

Figure 1. Map of Maldives and its Exclusive Economic Zone (solid line).

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permitted by license, however, a 75 mile exclusion zone exists around all atolls (the Coastal Fishery Zone), solely for Maldivian fishers. Coral reefs are the dominant ecosystem, covering an area of 4513 km^2. The country's atoll geomorphology, minimal terrestrial area, poor quality soil and lack of fresh water limit agricultural potential. The human population is therefore highly dependent on the marine resources for food, trade, employment and income (Weir no date).

Tourism began in 1972 (Firaag 1997; Bhat *et al.* 2010) and the industry expanded quickly. By 1985, tourism had surpassed fisheries as the largest revenue earner for the government and it provided a desirable, alternative form of employment. However, the large number of visitors has increased food demand, which is met by local fishers (Anderson *et al.* 2003). Additional fishing pressure comes from recreational fishing trips, targeting both reef and pelagic species.

Traditions, changes and developments in Maldivian Fisheries

Maldivian fisheries depend heavily on hook-and-line fishing techniques (Anderson 1986; Rochepeau and Hafiz 1990; Adam *et al.* 2003; Adam 2004, 2007), as pelagic net-based fishing gears are banned (Adam *et al.* 2003). The traditional Maldivian fishing fleet consists of three main vessel types, varying in size, range and utilisation: *Masdhnoi* (8-12 m; 8-14 fishers), *Vadhu Dhoni* (5-8 m; 3-5 fishers), and *Bokkora* (3-5 m; 2-3 fishers). Fishing activity has intensified from subsistence to artisanal levels, to supply the increasing demand. Local fishing pressure has been compounded by the increase in distant water fleets operating in the region (Pandya 2009), raising questions about the stock resilience of some species (Laipson 2009).

Traditional fishing activity includes subsistence fishing, as artisanal fishers were traditionally paid with fish from the daily catch (Cole 2001). The traditionally preferred fishing method was live-bait pole-and-line fishing for skipjack tuna (*Katsuwonus pelamis*) and surface swimming juvenile yellowfin tuna (*Thunnus albacares*) (Anderson 1988; Anderson and Hafiz 1988; Adam and Anderson 1996; Adam and Jauharee 2009). Incidental catches included bigeye (*Thunnus obesus*), frigate tunas (*Auxis thazard thazard*) and kawakawa (*Euthynnus affinis*). This fishery may have existed for over 1000 years (Anderson and Hafiz, 1997). A second approach utilized trolling gear to target tuna-like species, kawakawa, frigate and bullet tuna (*Auxis rochei rochei*) along the outer atoll reefs, although vessel numbers have declined significantly in recent years (Adam *et al.* 2003).

A traditional shark fishery existed to provide shark oil, used to waterproof the wooden hulls of boats. The main target species were tiger shark *Galeocerdo cuvier*, whale shark *Rhincodon typus* and six gilled shark *Hexanchus griseus* (Anderson and Ahmed 1993; Anderson and Hafiz 1997). In the 1960s, artisanal night-time long-lining for pelagic shark species began, and driven by the high prices for the Asian shark fin market, fishing pressure and catches increased (Anderson and Waheed 1999). A deep-water benthic shark fishery began in 1979-1980 to produce high value squalene-rich oil for Japanese markets (Anderson and Ahmed 1993).

Some hand-lining for reef and tuna-like species has also always been conducted, but mostly on a part-time basis (Shakeel 1995; Shakeel and Ahmed 1997; Sattar 2008), when tuna fishing conditions were poor (Anderson 1999). The dominance of and preference for tuna meant reef species and sharks were generally considered less important, which is reflected in the poorer quality and resolution of the landings data (Anderson and Hafiz 1988; Sattar 2008).

The 1970s saw rapid mechanization of fisheries and a major shift in the economic focus of the country (Anderson *et al.* 2003; Adam 2004; Ali 2004; Adam 2007). Modern technology further resulted in effort creep (Cole 2001; Adam *et al.* 2003; Ali 2004; Pauly and Palomares 2010). Throughout the 1980s and 1990s, vessels increased, and larger holds were incorporated in their design (Rochepeau and Hafiz 1990; Adam 2007).

The resulting catch increase prompted the development of post-harvest processing facilities. Frozen tuna were first exported in 1972 and canned in 1975 (Ali 2004). Revision of fisheries and export regulations in the 1990s attracted further investment (Adam 2007), encouraging the diversification of the fisheries and their export products, including a yellowfin hand-line fishery supplying the sashimi markets of Japan and Europe (Adam 2004; Adam and Jauharee 2009).

Statistics and data collection

The Ministry of Fisheries, Agriculture and Marine Resource (MoFAMR) began collecting tuna landings statistics using an enumeration system in 1959 (Anderson 1986; Nishida 1988). Initially focused on the *Masdhoni* fleet, both catch (numbers of fish caught) and fishing effort (numbers of days fished) were recorded (Rochepeau and Hafiz 1990; Anderson *et al.* 2003). Conversion factors were used to convert the fish count into weight estimates. The system proved to be adaptable and was expanded to include catch and effort data for other tuna and non-tuna species during the 1960s

Table 1. Taxa reported and categories used by the different organisations.

Basic fisheries statistics	MoFAMR	FAO
Skipjack tuna	Large skipjack tuna Small skipjack tuna	Skipjack tuna
Yellowfin tuna	Large yellowfin Small yellowfin	Yellowfin tuna
Tuna-like species	Tuna-like species	Tuna-like species
	Frigate	Frigate/Bullet
	Kawakawa	Kawakawa
	Dogtooth	Dogtooth
		Big Eye
Other marine species	Reef species	Misc. marine fishes
	Group 1 (e.g., Wahoo, Jacks)	Misc. marine fishes
	Group 2 (e.g., Rainbow Runner, Snapper)	Misc. marine fishes
	Group 3 (e.g., scads)	Misc. marine fishes
	Sharks	Sharks
	-	Bêche-de-mer
	-	Marine molluscs
	-	Lobster

and 1970s (Anderson 1986; Anderson and Hafiz 1996). These statistics are published by MoFAMR, however, some of the catches are aggregated into more general categories (Table 1). Of particular concern is the 'Other marine species' category which includes everything from sea cucumber to large sharks. The lack of catch data for tourist resorts and live-bait fisheries, the statistical errors in tuna records and the under reporting of subsistence catches raise questions about the accuracy of these catch data.

Methods

The national fisheries statistics published by the Ministry of Fisheries, Agriculture and Marine Resource (MoFAMR), consisting of four categories; skipjack, yellowfin, tuna-like and 'Other Marine Species' (Table 1) from 1971 to 2003 compared well with the data reported by FAO. Thus, data transfer between MoFAMR and FAO is well established.

However, literature review and data analysis suggested several sectors and taxa where the reported catch statistics do not properly reflect total catches. These included: tuna, live-bait, tourist consumption, lobster, shark, grouper, bêche-de-mer and local consumption of both tuna and non-tuna species. Independent, reconstructed estimates of catches for these components were made and combined with FAO statistics to give the total reconstructed catch for the Maldives from 1950-2010.

Tuna fishery

Historically, there were two main gear types being used, pole-and-line and trolling. More recently, a hand-line fishery for the sashimi export market has also developed. Pole-and-line fishing is highly selective, resulting in very little by-catch (Gillett 2010), we assumed the same for the troll fishery. However, low post-harvest processing capacity during the early years may have led to discarding of spoiled catches or smaller individuals. As 'per vessel purchasing quotas' were imposed at processing facilities (Anon. 1991; Van de Knaap *et al.* 1991), the available data may not fully represent total catches. Therefore, reconstructed tuna catches are assumed to be conservative.

Subsistence tuna catches prior to 1970 are thought to be poorly represented in the official data due to the low resolution of the enumeration system employed. Exports were low at this time and unreported catches would most likely have been consumed locally. Between 1970 and 1986, reported catches of tuna are known to have been under- as well as over-reported. After 1990 however, statistical error associated with conversion factors and catch categorisation suggested that skipjack and yellowfin tuna catches had to be increased by 5% and 15%, respectively (Parry and Rasheed 1995). However, to be conservative in our reconstructions, we reduced the suggested percentage by 60% and hence applied a 3% and 9% increase to skipjack and tuna catches, respectively.

Large yellowfin tuna catches have been reported separately in the national statistics since 1992 and an estimated 50% of the catches made by hand-liners were estimated to be unreported in 2008 (Adam and Jauharee 2009). To quantify the level of under reporting in other years, export statistics and product conversion factors were used. The primary export markets are for fresh, chilled whole fish (head on and gutted) or as fresh, chilled fillets and loins. Conversion factors of 1.15 and 2, respectively, were used to convert product weights published by the Ministry of Planning and National Development (1991-2003) and the Maldives Customs Services (2006-2008) into wet weights. When compared to the reported large yellowfin tuna catches, any differences were considered to be the unreported catch for this sector (Adam and Jauharee 2009).

Table 2. Summary of live-bait utilisation studies (Anderson *et al.* 2003).

Period	CPUB (kg/kg)	Tuna catch ($t\cdot year^{-1}$)	Live bait used ($t\cdot year^{-1}$)	Uncertainty (%)
1978-1981	8.0	26,267[a]	3,283.4	26.6[a]
1985-1987	10.6	54,158[a]	5,109.3	25.0[a]
1993	7.3	78,500	10,753.4	24.7
1994	8.3	89,599	10,795.1	25.5
2003	9.6	135,968	14,163.3	-

[a] Time period average

Tuna live-bait fishery

The increasing fishing effort and catches of the pole-and-line fleet have increased the demand for live-bait. Live-bait are caught and utilised directly by the fleet and consequently the annual catch is not included in the national landings statistics reported to the FAO (Adam 2004). Estimates of Catch per Unit Bait (CPUB) from several studies (Anderson 1994; Anderson and Hafiz 1996; Anderson 1997; Anderson *et al.* 2003), are displayed in Table 2. However to be conservative in our estimates, reduced live bait values were applied in our reconstructions, ranging from 1,973 $t\cdot year^{-1}$ from 1978-1981 to 8,509 $t\cdot year^{-1}$ in 2003. The resulting CPUB values ranges from 9.56 kg tuna per kg bait to 15.35 kg tuna per kg bait. Combining the derived bait catch rates with reconstructed pole-and-line tuna catches allowed us to derive a time series of live-bait catches from 1950-2008. The ratio between the 2008 live-bait amount and the 2008 reported tuna landings were extended for 2009 and 2010.

Table 3. Taxonomic breakdown of live-bait catch was derived from the average of 1994 and 1996 data. Names were updated to current valid names using FishBase. Source - Anderson (1994, 1997).

English name	Dhivehi name	Scientific name	%
Fusiliers	Muguraan	*Caesionid* spp.	37.25
Silver-stripe round herring	Rehi	*Spratelloides gracilis*	33.75
Cardinal fish	Boadhi & Fatha	*Apogonid* spp.	11.00
Anchovy	Miyaren	*Encrasicholina heteroloba*	8.75
Delicate round herring	Hondeli	*Spratelloides delicatulus*	5.75
Silver sides	Thaavalha & Boduboa	*Odonthestes* spp.	1.50
Damsel fish	Bureki & Nilamehi	Pomacentridae	1.25
Other		Misc. reef fishes	0.75

Live-bait catches were dominated by fusiliers (Caesionidae) and silver-stripe round herring (*Spratelloides gracilis*), which contributed over 70% of the catch (Table 3). Reconstructed live-bait catches were assigned to taxa based on available data (Table 3).

Tourist consumption

Seafood consumption by tourists, particularly reef species, have increased substantially since 1972. As these catches are sold directly to tourist resorts, it was assumed that these catches were unaccounted for in official statistics. Tourist consumption surveys have only been conducted twice in the Maldives. Van de Knaap *et al.* (1991) reported 1.67 kg·tourist^{-1}·night^{-1}, based on fish purchases in 1988, while Sattar (2008) estimated the 2006 consumption per tourist night (CPTN) as 1.29 kg·tourist^{-1}·night^{-1}. Here, we assumed the CPTN rate of 1.67 kg·tourist^{-1}·night^{-1} was constant between 1972 and 1988, linear interpolation of CPTN was used between 1988-2006, and the CPTN of 1.29 kg·tourist^{-1}·night^{-1} was held constant from 2006 onwards.

Table 4. Catch composition for local and tourist consumption of reef species. Source - Sattar (2008).

Scientific name	English name	%	Scientific name	English name	%
Carangidae	Jacks	51.0	Lutjanidae	Snapper	27
Alectis ciliaris	African pompano	6.0	*Aprion virescens*	Green jobfish	9
Carangoides caeruleopinnatus	Coastal trevally	4.5	*Aphareus rutilans*	Rusty jobfish	3
Carangoides ferdau	Blue trevally	4.5	*Lutjanus gibbus*	Humpback red snapper	3
Carangoides orthogrammus	Island trevally	4.5	*Lutjanus bohar*	Two spotted red snapper	3
Caranx ignobilis	Giant trevally	4.5	*Macolor niger*	Black and white snapper	3
Caranx lugubris	Black trevally	4.5	*Macolor macularis*	Midnight Snapper	3
Caranx melampygus	Bluefin trevally	4.5	Lethrinidae	Emperor	8
Caranx sexfasciatus	Bigeye trevally	4.5	*Lethrinus harak*	Thumbprint emperor	3
Gnathanodon speciosus	Golden trevally	4.5	*Lethrinus microdon*	Smalltooth emperor	1
Scomberoides lysan	Doublespotted queenfish	4.5	*Lethrinus olivaceus*	Longface emperor	1
Seriola rivoliana	Longfin yellowtail	4.5	*Lethrinus rubrioperculatus*	Spotcheek emperor	1
Sphyraenidae	Barracuda	10.0	*Lethrinus xanthochilus*	Yellowlip emperor	1
Miscellaneous marine fishes	-	4.0	-	-	-

Occupancy rates and tourist capacity were published by the Ministry of Planning and National Development (MoPND; 1972-1998) (www.planning.gov.mv) and by the Ministry of Tourism, Arts and Culture (MoTAC; 1998-2008) (www.tourism.gov.mv). Using these sources, we calculated total annual tourist-nights, which combined with the derived time series of CPTN allowed us to estimate total tourist consumption.

Table 5. Catch composition for the artisanal shark fisheries of the Maldives.

Scientific name	English name	%	Scientific name	English name	%
Oceanic sharks			Reef sharks		
Carcharhinus falciformis	Silky shark	75	*Carcharhinus albimarginatus*	Silver tip shark	25.0
Carcharhinus longimanus	Oceanic white tip shark	3	*Carcharhinus amblyrhynchos*	Blacktail reef shark	25.0
Carcharhinus altimus	Bignose shark	3	*Carcharhinus melanopterus*	Black tip reef shark	25.0
Galeocerdo cuvier	Tiger shark	3	*Triaenodon obesus*	White tip reef shark	25.0
Prionace glauca	Blue shark	3			
Carcharhinus albimarginatus	Silver tip shark	3	Benthic sharks		
Isurus oxyrinchus	Shortfin mako	3	*Centrophorus* spp.	Gulper shark	90.0
Alopiidae	Thresher sharks	3	*Hexanchus griseus*	Bluntnose sixgill	3.3
Sphyrnidae	Hammerhead sharks	3	*Odontaspis ferox*	Smalltooth sand tiger	3.3
Rhincodon typus	Whale shark	3	*Pseudotriakis microdon*	False catshark	3.3

Available literature (Anderson *et al.* 2003; Sattar 2008) suggested tourist preference is for reef-associated species, although some tuna consumption was assumed. Of the reconstructed total catches, 15% was assumed to be skipjack and yellowfin tuna at a 2:1 ratio. The taxonomic composition of the remaining tourist consumption (Table 4) was based on data from Sattar (2008).

Lobster catches are only reported in the data supplied to the FAO for 2000, 2001 and 2006, although it is known that tourist consumption is considerable. MoFAMR lobster data, as numbers caught (Anderson *et al.* 2003), were available from 1988-2002 (Table 5). It was assumed the reported landings were included in the 'Other Marine Species' category by MoFAMR. After 2002, it was assumed landings were included in the tourist consumption calculation as part of 'miscellaneous marine fishes' category (Table 4).

Shark fishery

Expanding global shark fin markets in Asia have caused dramatic changes to the fishery since 1950. The unfortunate pooling of sharks and reef species landings in the national statistics required catches to be reconstructed using alternative data sources (Anderson and Ahmed 1993; Anderson and Waheed 1999) and export estimates.

The FAO only started reporting shark landings in 1970. Traditional shark catches made prior to this were therefore unaccounted for. For 1950 to 1962, an estimate of 322 t·year^{-1} (Anderson and Ahmed 1993) was used. For 1963-1969, an export based average of 356 t·year^{-1} (Anderson and Waheed 1999) was applied.

The development of the artisanal shark fishery during the late 1960s and the low level of shark consumption locally (except for oil use) meant catches could be reconstructed based on fin and oil exports (Anderson and Ahmed 1993; Anderson and Waheed 1999). For 1970 to 1991, FAO landings and export based reconstructed values were comparable, therefore, no adjustment were made (Figure 2). Between 1992 and 2003, FAO shark landings increased substantially from 1,773 t in 1991 to a high of 13,523 t in 2000, followed by a decrease to 880 t in 2005 (Figure 2). However, catch estimates based on export statistics do not show this dramatic increase (Figure 2). The sum of FAO reported shark and 'miscellaneous marine fishes' catches were comparable to the 'other marine species' category reported by MoFAMR during this period (Figure 3). Therefore, it was assumed that the FAO shark catches were incorrectly allocated and were assigned back to the 'miscellaneous marine fish' category. Export based reconstructed values were used from 1992 to 2003.

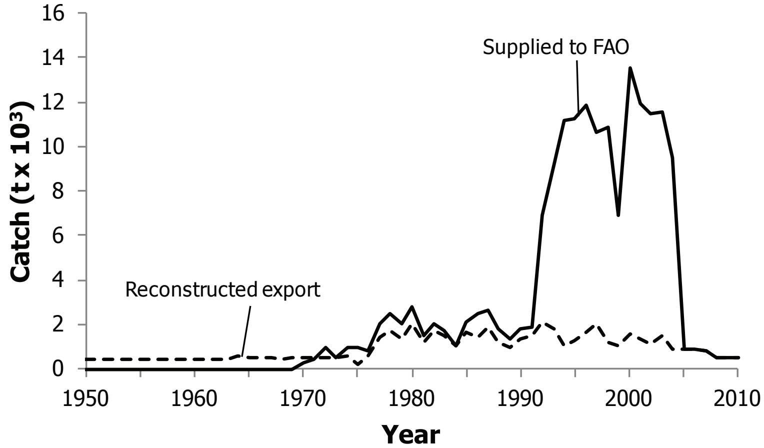

Figure 2. FAO landings vs. reconstructed exports for shark catch in Maldives, 1950-2010.

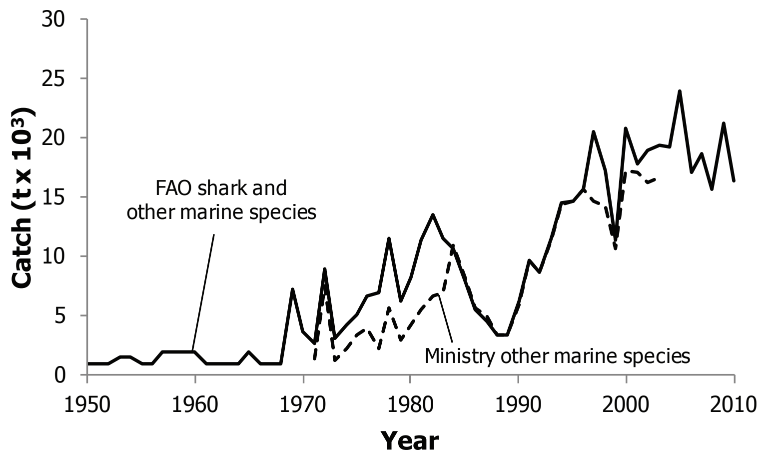

Figure 3. Reported FAO shark and other marine species landings vs. reported Ministry other marine species landings for Maldives.

Catch estimates for the traditional shark-oil fishery were approximately 460 t·year^{-1} prior to 1970 (Anderson and Ahmed 1993; Anderson and Waheed 1999). As alternative vessel-hull treatments were introduced after 1970, it was assumed catches from this sector declined to 55 t in 1993. Traditional catches were allocated equally to the three target species: tiger shark (*Galeocerdo cuvier*), whale shark (*Rhincodon typus*) and six gilled shark (*Hexanchus griseus*).

The taxonomic composition for the commercial (export-oriented) shark fisheries required the reconstructed catches to be considered by their three ecosystem components; deep water benthic, oceanic and reef sector. For 1963, it was assumed that oceanic sharks accounted for 10%, while reef sharks accounted for 90% of catches. By 1992, this ratio had changed to 50% each (Anderson and Ahmed 1993). By 1998, a 60% oceanic, 40% reef shark breakdown was assumed (Anderson and Waheed 1999). Deep water benthic catch estimates (1963-1996) (Anderson and Waheed 1999) and estimates made from oil export figures provided the benthic fishery contribution. The taxonomic composition for each component was based on all available information (Table 5).

Grouper fishery

A small artisanal grouper fishery developed in 1994, mainly to supply the Asian live reef-fish market. A comparison between catches reported by fishers and those estimated using export figures (Sattar and Adam 2005) showed as much as 90% of catch, by numbers, went unreported between 1994 and 2004 (Table 6). To assess the validity of the reported catches, they were compared to the export-based estimates.

Table 6. Taxonomic composition of grouper catches.

Grouper Species	%
Aethaloperca spp.	10
Cephalopholis spp.	10
Epinephelus spp.	40
Plectropomus spp.	25
Variola spp.	10
Serranidae	5

The reconstruction of total catches used conversion factors to calculate wet weights, as exploitation has reduced the size of individuals caught (Sattar and Adam 2005). Conversation factors declined from 0.9 kg·fish^{-1} in 1991 (Anderson *et al.* 1992) to 0.73 kg·fish^{-1} in 2008 (Table 6). After 2002, grouper catches were assumed to be included in 'Other Marine Species' category (MoFAMR). The ratio between the grouper amount and the reported 'marine fishes nei' landings for 2008 were extended for the rest of the period.

The taxonomic composition of the reconstructed grouper catches was generated using the assumption that higher valued species (e.g., *Plectropomus* and *Epinephelus* spp., Table 7) made up the largest proportions of the catch (Sluka 2000; Adam 2004).

Table 7. Reported grouper exports, landings and conversion factors (CF).

Year	Export (Nos.)	Catch (Nos.)	CF
1994	198,131	-	0.87
1995	846,722	4,072	0.86
1996	808,825	7,783	0.85
1997	1,004,404	90,298	0.84
1998	457,609	401	0.83
1999	637,695	12,577	0.82
2000	568,138	3,160	0.81
2001	595,901	45,998	0.80
2002	460,193	665,371	0.79
2003	460,218	-	0.78
2004	287,579	-	0.77
2005	338,336	-	0.76
2006	389,093	-	0.75
2007	428,081	-	0.74
2008	546,984	-	0.73

Bêche-de-mer fishery

The Ministry of Planning and National Development (MoPND) reports dried bêche-de-mer for 1991–2008. A conversion factor of 3 was used to convert the dried weight to wet weight of catch, based on the FAO conversion factor for the nearest reporting country (Tanzania). This is a highly conservative estimate, as other studies have suggested a conversion factor of 10 (Conand 1991; Dalzell *et al.* 1996). These tonnages matched the tonnage reported by FAO as sea cucumber landings, thus suggesting that data were transformed into wet weight equivalents. Stock collapses of some species (Joseph 1992) suggest that catch composition is best considered as total catches per species for 1986-1990 (Table 8).

Table 8. Total wet weight of bêche-de-mer caught by species (1986-1990).

Scientific name	English name	t
Actinopyga spp.	Blackfish	327
Halodeima atra	Lollyfish	296
Actinopyga mauritiana	Surf redfish	247
Microthele nobilis	White teat fish	232
Stichopus chloronotus	Greenfish	219
Bohadschia marmorata	Amberfish	192
Thelenota ananas	Prickly redfish	112
Microthele axiologa	Elephant trunkfish	68
Thelenota anax	Turtleshell	45

Local consumption

Local *per capita* consumption of fish has always been high in the Maldives. However, studies of local seafood consumption are rare and show variations from 74 kg·person^{-1}·year^{-1} (Maizan 1986) to 205 kg·person^{-1}·year^{-1} (Anon. 2003). Domestic seafood supply (MoFAMR; 1971-2003) figures were used in conjunction with population figures to calculate *per capita* supply, which ranged from 45 kg·person^{-1} in 1970 to 203 kg·person^{-1} in 2006. To determine a realistic consumption rate, the available datasets (Table 9) and the following assumptions were used:

Domestic supply = Landings + Imports – Exports;

Consumption rate = Domestic supply / Population;

Domestic demand = Consumption rate * Population;

Unreported catches = Domestic demand – Domestic Supply.

Table 9. Data available for local consumption calculation.

Source	Dates	Type
MoFAMR	1971-2008	Total domestic supply
	1971-2008	Total marine exports
	1971-2008	Basic fisheries statistics, aggregated (Table 2).
DoNPD	1991-2003	Detailed export data, by species and product weight.
MCS	2006-2008	Detailed export data, by species and product weight.
FAO	1950-2008	Tuna
	1950-2008	Other marine species
Sri Lanka	1950-1974	Import data

Population of the Maldives

Human population data were obtained from Populstat (www.populstat.info) for 1950–2001, and the World Bank (data.worldbank.org) for 1960-2008. The two sources matched closely for the period of overlap, thus the average was taken for these years and completed using data from each of the sources (Figure 4).

Import data

Import data were published by the Ministry of Trade for the Maldives (1988-2003). Figures were only reported as the total import cost per year, and are known to be mainly for tourist consumption. It was therefore assumed marine product imports had little impact on domestic consumption.

Export data

Records of total marine exports are published by MoFAMR from 1971-2008, while more detailed species and product data were published by the Department of National Planning (DoNP) for 1991-2003 and the Maldives Customs Service (MCS) for 2006-2008. Data for interim years

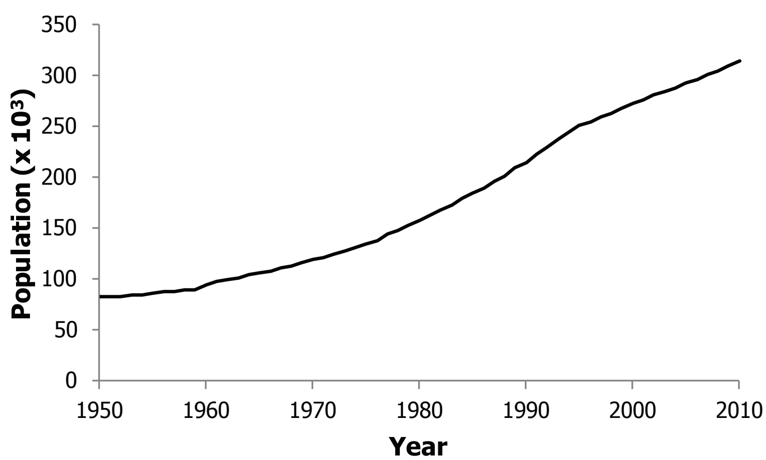

Figure 4. Local population of the Maldives from 1950-2008.

were estimated using linear interpolation. Wet weights were calculated using product conversion factors (Table 10). Datasets permitted separation of exports into tuna and non-tuna exports. It was assumed that product exports increased linearly from zero in the year they were first recorded, to estimate wet weights for years prior to 1991.

Table 10. Export product type conversion factors for the Maldives. Sources - MoFAMR, DoNP, MCS.

Product	Conversion Factor
Frozen fish	1.00
Dried fish	5.00
Salt-dried fish	3.00
Canned fish	3.00
Maldives Fish	5.00
Steamed/cooked fish	4.00
Shark fin	0.01
Shark oil	0.23

Exports of tuna (1950 – 1990): Skipjack tuna is the sole tuna species being exported in the form of 'Maldives Fish', either canned or frozen. Early exports of 'Maldives Fish' were predominantly to Sri Lanka (thus labelled 'Maldive Fish'), whose import records were available for 1951-1975 (Pathirana 1972). Interpolations were used for years with no data.

Exports of non-tuna (1970 – 1980): Here, we assume that no marine product exports (other than tuna) existed prior to 1970. We assume linear increases in exports from 1970 to first reported data in 1980. Up to 1998, exports of salt-dried shark meat were included in the 'salt-dried reef species' category. As shark meat is rarely consumed locally, we disaggregated exports of shark from reef species, using salted-dried shark meat estimates for 1991-1996 from Anderson and Waheed (1999), and salt-dried reef species exports between 1980 and 1991 from Anderson and Ahmed (1993).

Domestic supply

The domestic supply based on reported data between 1950 and 2008 was estimated using FAO landings data adjusted for exports as outlined above. The *per capita* rate calculated for 2008 was extended for the rest of the period. Data were separated into total domestic supply and domestic supply of tuna (Figure 5). On average, total and tuna *per capita* consumption rates were of 109 kg·person^{-1}·year^{-1} and 94 kg·person^{-1}·year^{-1}, respectively, suggesting a non-tuna local consumption rate of 15 kg·person^{-1}·year^{-1}. The estimated total average consumption rate of 109 kg·person^{-1}·year^{-1}, although high, does not seem excessive for an atoll country such as the Maldives, given other atoll-based island countries, such as Kiribati, have been found to have a *per capita* consumption rate of 200 kg·person^{-1}·year^{-1} (Gillett 2002). The difference between domestic supply and demand enabled us to estimate a minimum quantity of unreported catch. Unreported tuna catches were allocated to taxa in proportion to the breakdown of reported FAO landings. Non-tuna species were allocated using the same taxonomic composition as used for tourist consumption (see Table 4).

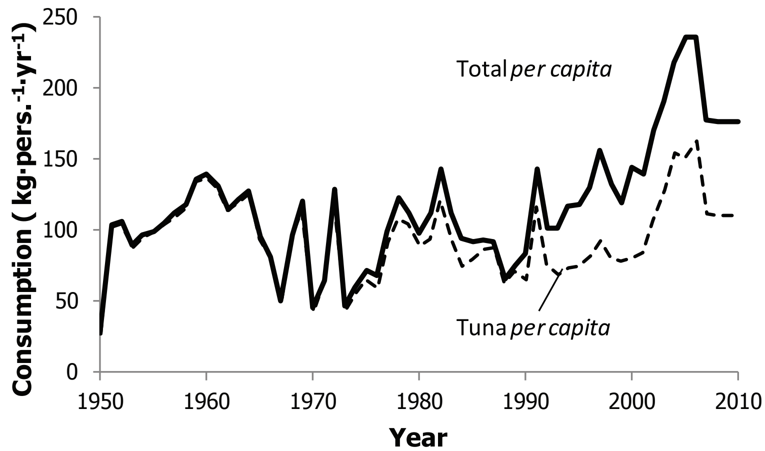

Figure 5. Total and tuna *per capita* local consumption rate for Maldives, 1950-2010.

Results

Reconstructed total catch

The reconstructed total catch was 23% higher than the reported landings for 1950-2010 (Figure 6a). The reconstructed total catch averaged 26,600 t·year^{-1} from 1950-1970 and subsequently increased to 66,400 t·year^{-1} in the 1980s. Catches reached a peak of 223,000 t in 2006, and declined to 150,000 t·year^{-1} for the rest of the period. The industrial sector comprises the majority of the total reconstructed catch of Maldives at 66%, while subsistence and artisanal compose 24% and 10%, respectively (Figure 6a).

Taxonomic composition

The majority of the reconstructed total catch consists of tuna (79%), followed by Carangidae (7%), Lutjanidae (4%) and Fusilier (2%). The remaining 18 taxa compose 1% of the total reconstructed catch (Figure 6b).

Tuna fishery

The reconstructed total catch of tuna from 1950-2010 was estimated to be approximately 3.7 million t, compared to the 3.3 million t reported to the FAO. During the early 1960s (just after records began in 1959), under reporting was at its highest. By the 2000s, reporting accuracy had improved, with an approximately 90% reporting accuracy, but 15,000 t·year^{-1} in missing tuna catches (Figure 7a).

Tuna catches are dominated by skipjack tuna, which in recent years contributed just under 80% of the total tuna landings (Figure 7b), the majority of which are caught by pole-and-line gear. The catches of yellowfin tuna have increased from 15,000 t (1998) to almost 30,000 t (2008), the majority of which were for export.

Non-tuna fisheries

Reconstructed total non-tuna catches for the time period 1950-2010 were estimated at 961,000 t, with 509,000 t being reported to the FAO (Figure 8a). Thus, on average, approximately 7,000 t·year^{-1} were missing from the reported statistics. In 1950, reported landings of non-tuna species were 1,000 t, whereas 2,550 t were estimated as unreported, or 72% of the catch. In recent years (2000s), the average reported catch has increased to 19,000 t·year^{-1}, while the total reconstructed catch averaged 33,000 t·year^{-1}, suggesting 57% of catches were reported. The reconstruction of non-tuna species consists of various taxas such as Carangidae (35%), Lutjanidae (18%) and Clupeidae (10%) (Figure 8b). It also encompasses catches for local consumption; tourist consumption; live-bait; sharks, grouper, sea cucumber and lobster.

Tuna live-bait fishery

The annual live-bait catch increased as tuna catches increased, and reconstructed total catches of live-bait was estimated to be 222,000 t over the full time period considered here, none of which were reported. Live-bait catches averaged 1,000 t·year^{-1} from 1950 to 1970 and increased in the 1990s to an average of 6,390 t·year^{-1}. Catches peaked in 2006 with 10,500 t and declined towards the late 2000s with 6,000 t·year^{-1}. Although at least seven species are utilized, fusiliers (*Caesionid* spp.) and silver striped round herring (*Sprattelloides gracillis*) are the two main bait species, contributing 37% and 34%, respectively.

Tourist consumption

Tourist consumption was estimated back to the start of tourism in 1972. Catches increased steadily, from 190 t in 1973 to 6,900 t in 2004, followed by a decline in 2005 after the tsunami of 2004, and increased to 8,280 t by 2010. Overall, around 83% of tourist consumption was reef species, including jacks (Carangidae), snappers (Lutjanidae), emperors (Lethrinidae) and lobster (*Panulirus* spp.), with the remainder being primarily skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*).

Shark fishery

Traditional shark catches for oil used on fishing vessels between 1950 and 1970 were not reported

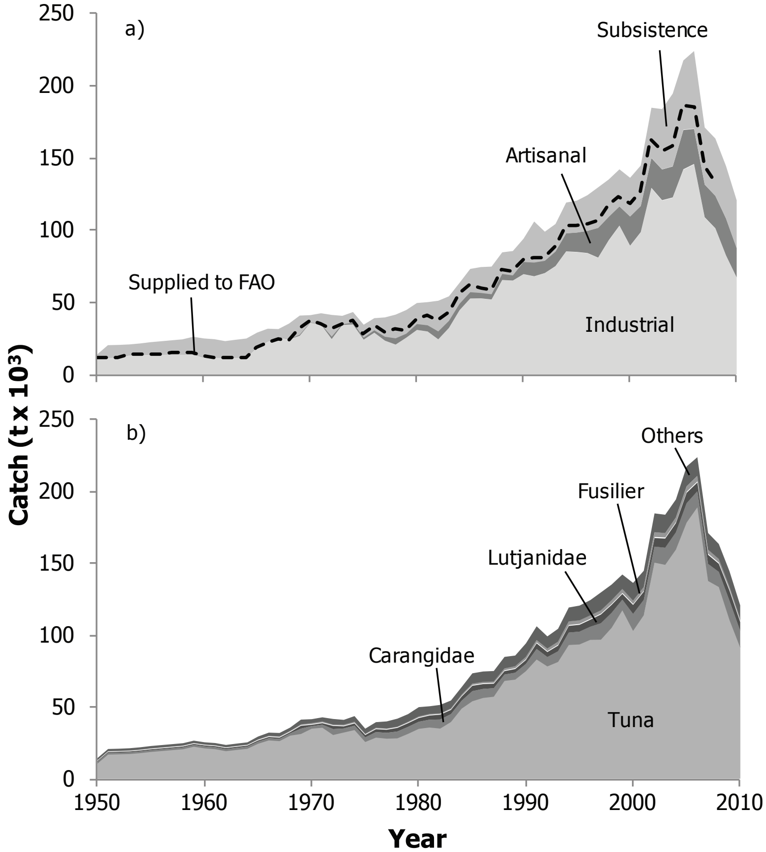

Figure 6. Reconstructed total catch for the Maldives, 1950-2010 a) by sector with data reported by the FAO overlaid as a line graph; and b) by major taxonomic groups. 'Others' represent an additional 18 taxonomic groups.

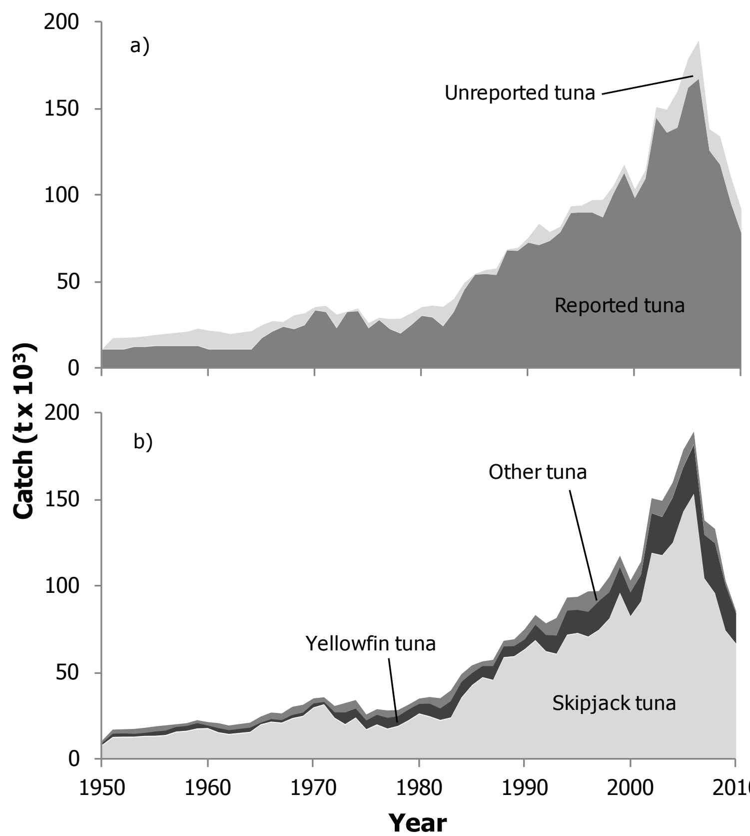

Figure 7. Reconstructed total tuna catch for the Maldives, from 1950-2008, by a) reported vs unreported status; and b) major tuna taxa.

to the FAO, and were estimated at 279 t·year^{-1} for the period. Between 1971 and 1991, reconstructed catches totalled 25,200 t with an annual average of 1,146 t·year^{-1}.

The sudden increase in FAO shark landings between 1992 to 2005 were considered to be a result of incorrect taxonomic allocation of the 'other marine species' catches reported by MoFAMR. Export based catch estimates for this period averaged 1,410 t·year^{-1}, compared to the 10,500 t·year^{-1} reported by the FAO. The over-estimated catch was re-assigned to 'miscellaneous marine fishes'.

Grouper fishery

The export-oriented grouper (Serranidae) fishery started in 1994, with an estimated total catch of 4,500 t. Catches peaked in 1997 at nearly 600 t, and have declining since to 276 t by 2010. As national statistics were available for some years, however, in 1999 reconstructed catches for this fishery were estimated at 360 t, whereas only 10 t were officially reported.

Bêche-de-mer fishery

Reported sea cucumber catches began in 1981 with 0.25 t, peaked in 1990 at 2,240 t and have declined to 629 t in 2010. Originally, fishers targeted the high valued prickily redfish (*Thelenota ananas*) and white teatfish (*Microthele nobilis*), but more recently over nine species are targeted.

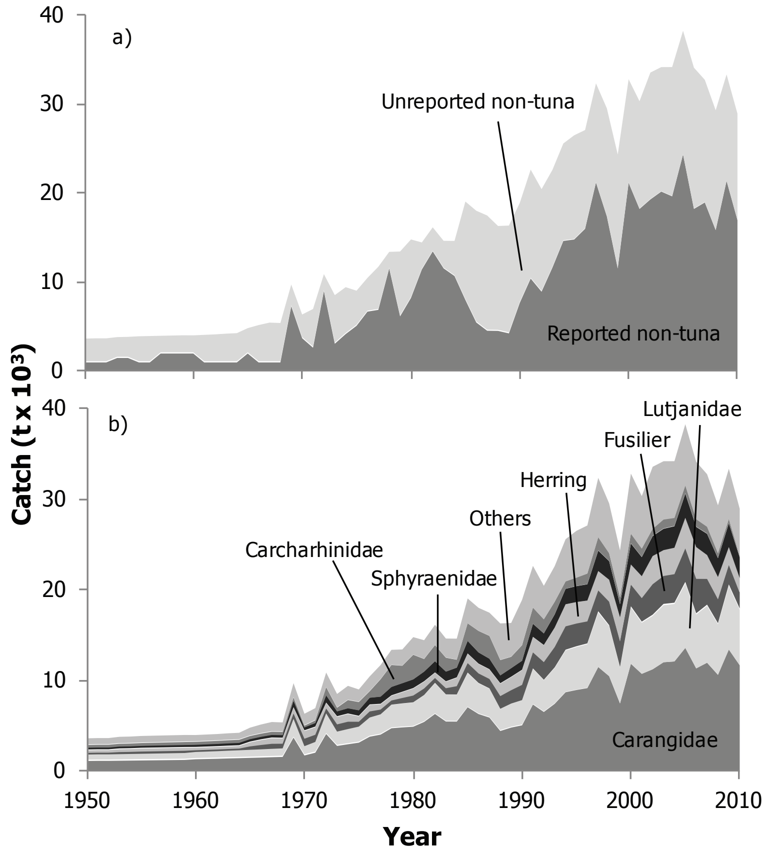

Figure 8. Reconstructed total non-tuna catch by a) reported vs unreported values and b) major groups. 'Others' contains an additional 65 taxas.

Local consumption

The total under-reported catch for local consumption was about 387,000 t for 1950-2008. Local consumption has increased from 1,260 t in 1950 to over 7,500 t in 2010, as the human population has increased.

Discussion

The catch reconstruction for the Maldives suggests that around 81% of actual total catches were reported. Under reporting was higher in the earlier periods, with more than 50% of the total catch being unaccounted for in some years. As total annual catches increased, particularly following the mechanisation of the fishing fleet and investment in the post-harvest facilities, reporting accuracy increased. The commercially and domestically important tuna species appear to be well reported, although some sources suggest up to 30% being not reported (Parry and Rasheed 1995). Significantly, it has been suggested that reporting accuracy has been deteriorating since the mid-1990s (Parry and Rasheed 1995; Anderson and Hafiz 1996). This deterioration of comprehensive accounting of the most crucial marine resource in the Maldives (i.e., tuna) requires addressing. Conversely, catches of non-tuna species were even more poorly accounted for, with poor taxonomic resolution and a significantly decreasing reporting accuracy.

Stocks of skipjack tuna have sustained the Maldivian population for more than a thousand years, and local fishers consider the ocean to be bountiful and its fish stocks inexhaustible (Anderson and Ahmed 1993). However, regional assessments point to increasing threats facing the Indian Ocean tuna stocks (IOTC 2010). It has become abundantly clear, however, that some of the other target species (grouper, sea cucumber etc.) are exhibiting signs of over-exploitation and in some cases stock collapse (Joseph 1992; Sattar 2008). There are also reports that bait-fish abundance may be declining in areas with high fishing intensities (Anderson 2006; Adam and Jauharee 2009). This can affect both the pole-and-line and hand-line tuna fisheries, possibly leading to less sustainable fishing methods being employed.

The Maldivian fishers local-scale view of tuna stocks is concerning, as it does not account for regionally increasing fishing pressure in the Indian Ocean (Gillett 2010) and the migratory nature of the target species. Tuna stocks may be responding negatively to the increase in fishing effort and unreported or illegal catches make it difficult to determine their real rate of regional and stock-wide exploitation. Although the stocks of tuna, in particular skipjack, in the Indian Ocean are believed to be high, concerns over declining yellowfin stocks in Maldivian waters are mounting

(Adam and Jauharee 2009). Interestingly, FAO skipjack landings for the Maldives do show a decrease of 51,000 t between 2006 and 2008, with a further decline of 29,000 t by 2010. It remains to be seen if this will be a continuing trend.

Tourist consumption estimates made in this study are considered conservative. They do not account for the growing recreational fishing sector targeting both reef and large pelagic species, with associated catches potentially large. Recreational fishers are not required to report catches or fishing effort, therefore, fishing pressure and its impacts are hard to determine.

The current catch reporting system once served the Maldives very well, but the nature of the fisheries has changed considerably since the 1950s and 1960s. The present system is fortunately now recognised by MoFAMR as being inadequate and in need of revision (Anderson *et al.* 2003; Adam 2007). Alternative systems, such as log book based accounting systems have been trialled. However, a main concern about such an approach at a country-wide level is the support system required for data entry and analysis. A potentially more suitable approach is that of regular, albeit non-annual (e.g., every 3-5 years) country-wide and all sector encompassing survey and estimation approaches, with intervening years being filled through interpolation (Zeller *et al.* 2007). Such a system of surveys, combined with country-wide expansion and interpolation can also be used for obtaining other administrative and governmental service related information, e.g., as obtained through household surveys and national census surveys. Utilizing such an approach for deriving comprehensive estimates of total fisheries catches (all sectors) as well as effort and catch composition data would go a long way towards addressing national and global data needs, without necessarily requiring extensive domestic resources (Zeller *et al.* 2007). Such an approach should also be supported through resource expertise by regional (e.g., Bay of Bengal Large Marine Ecosystem Project, www.boblme.org) and international agencies and institutions (e.g., UNEP and FAO).

A major challenge in the collection of accurate fisheries statistics is the lack of financial and human resources (Anderson *et al.* 2003; Adam 2004, 2007). It is concerning that a country so dependent on its marine resources is increasingly finding it difficult to finance the management and monitoring programs required to ensure sustainable exploitation and use of marine ecosystems. It has been suggested that even a small levy placed on each tourist night could cover 85% of current operating costs (Bhat *et al.* 2010). The recent ban on shark product export, driven by tourist perceptions and concerns, shows the weight tourist opinion carries in the eyes of the Maldivian policy makers. Educating tourists about Maldives marine resource and ecosystems and what is required to protect them may help drive policies and funding, ensuring the Maldives can prosper and develop without sacrificing their main natural resource.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector for Maldives, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence
1950	12,000	14,600	11,800	560	2,160
1951	12,000	20,900	11,800	560	8,510
1952	12,000	21,100	11,800	560	8,690
1953	14,000	21,400	13,400	610	7,360
1954	14,000	22,100	13,400	610	8,010
1955	14,000	23,000	14,000	560	8,420
1956	14,000	23,600	14,000	560	9,070
1957	15,000	24,300	14,000	660	9,630
1958	15,000	24,900	14,000	660	10,280
1959	15,000	26,700	14,000	660	12,040
1960	13,000	25,500	11,800	660	13,060
1961	12,000	25,000	11,800	560	12,620
1962	12,000	23,700	11,800	560	11,310
1963	12,000	24,600	11,800	570	12,230
1964	12,000	25,500	11,800	570	13,100
1965	19,600	29,600	18,900	670	9,960
1966	22,400	32,200	23,000	570	8,670
1967	25,100	32,000	25,900	570	5,520
1968	23,700	35,800	24,400	570	10,810
1969	32,300	41,300	26,900	1,200	13,190
1970	37,273	41,600	35,900	642	5,040
1971	35,176	42,900	34,600	667	7,570
1972	32,268	41,700	24,600	2,111	14,990
1973	35,706	41,100	34,400	941	5,770
1974	37,258	43,700	34,700	1,597	7,400
1975	28,325	35,000	24,200	1,835	8,920
1976	34,634	39,500	29,000	2,089	8,380
1977	29,636	40,000	23,500	3,174	13,340
1978	31,769	41,900	20,800	4,804	16,330
1979	31,175	45,100	25,600	3,193	16,320
1980	38,624	49,900	30,900	4,474	14,510
1981	40,916	50,500	29,900	4,687	15,970
1982	37,838	51,500	24,400	5,908	21,150
1983	44,110	54,500	32,300	5,268	16,960
1984	56,081	63,800	44,600	4,781	14,440
1985	62,076	73,400	52,700	4,676	16,040
1986	59,964	74,700	52,800	4,015	17,840
1987	58,502	75,000	52,000	3,935	19,040
1988	72,589	84,800	65,500	4,436	14,890
1989	72,065	85,700	65,100	3,802	16,820
1990	80,225	94,200	69,500	8,606	16,050
1991	81,523	106,000	68,100	9,676	28,280
1992	80,750	99,000	70,300	8,676	20,060
1993	88,740	104,300	75,100	10,190	19,000
1994	103,422	119,100	85,300	12,566	21,230
1995	103,813	120,400	84,900	13,430	22,020
1996	104,639	124,200	84,200	15,343	24,650
1997	106,821	129,600	81,000	20,610	27,970
1998	117,411	135,000	93,100	16,212	25,720
1999	123,461	142,000	103,200	13,271	25,550
2000	118,290	136,100	89,200	20,241	26,670
2001	126,687	144,600	98,600	18,076	27,870
2002	162,967	184,400	129,300	20,609	34,480
2003	155,090	183,400	120,800	21,250	41,450
2004	158,528	194,100	122,600	21,416	50,020
2005	186,274	217,000	142,200	27,150	47,650
2006	185,299	223,400	145,800	24,233	53,330
2007	144,508	170,800	108,900	22,614	39,250
2008	133,338	163,200	101,300	22,460	39,410
2009	11,7061	144,212	82,495	25,563	36,154
2010	94,953	120,602	67,234	20,330	33,037

Appendix Table A2. Reconstructed total catch (in tonnes), by major taxonomic group for Maldives, 1950-2010. 'Others' contain 18 additional taxonomic categories.

Year	Tuna	Carangidae	Lutjanidae	Fusilier	Others
1950	11,000	1,150	611	305	1,480
1951	17,300	1,170	619	305	1,490
1952	17,500	1,170	619	305	1,490
1953	17,700	1,180	626	347	1,560
1954	18,300	1,200	634	347	1,570
1955	19,100	1,210	641	361	1,600
1956	19,800	1,230	649	361	1,600
1957	20,400	1,240	656	361	1,610
1958	21,000	1,250	664	361	1,620
1959	22,800	1,270	671	361	1,620
1960	21,600	1,340	710	305	1,560
1961	21,000	1,370	725	305	1,570
1962	19,700	1,400	740	305	1,580
1963	20,500	1,430	759	305	1,610
1964	21,300	1,460	774	305	1,620
1965	24,800	1,500	793	488	1,950
1966	27,200	1,530	810	594	2,140
1967	26,600	1,570	830	669	2,290
1968	30,500	1,600	846	630	2,230
1969	31,600	3,720	1,971	694	3,260
1970	35,300	1,760	931	931	2,650
1971	36,000	2,060	1,093	902	2,830
1972	30,900	4,120	2,180	645	3,880
1973	32,600	2,810	1,486	905	3,260
1974	34,400	2,990	1,583	918	3,860
1975	26,000	3,170	1,676	644	3,470
1976	29,100	3,820	2,023	775	3,780
1977	28,400	4,050	2,144	631	4,830
1978	28,600	4,750	2,514	561	5,510
1979	31,700	4,840	2,563	694	5,280
1980	35,200	4,920	2,604	843	6,370
1981	36,100	5,440	2,881	818	5,260
1982	35,400	6,320	3,346	625	5,820
1983	40,000	5,490	2,905	777	5,420
1984	49,300	5,480	2,901	1,012	5,180
1985	54,400	7,060	3,736	1,132	7,090
1986	56,700	6,310	3,341	1,141	7,190
1987	57,600	5,920	3,135	1,130	7,260
1988	68,500	4,450	2,355	1,498	7,960
1989	69,400	4,820	2,554	1,573	7,360
1990	75,300	5,070	2,685	1,779	9,330
1991	83,400	7,360	3,895	1,850	9,520
1992	78,600	6,540	3,461	2,034	8,390
1993	81,700	7,430	3,936	2,324	8,900
1994	93,500	8,710	4,609	2,652	9,610
1995	93,900	8,950	4,740	2,582	10,220
1996	97,100	9,160	4,849	2,504	10,580
1997	97,200	11,470	6,074	2,358	12,450
1998	105,500	10,470	5,544	2,656	10,860
1999	117,600	7,460	3,951	2,886	10,020
2000	103,300	11,830	6,263	2,450	12,280
2001	114,300	10,730	5,678	2,659	11,280
2002	150,800	11,220	5,942	3,424	12,990
2003	149,300	12,000	6,353	3,144	12,690
2004	159,900	12,090	6,399	3,212	12,500
2005	178,700	13,590	7,192	3,744	13,770
2006	189,300	11,320	5,995	3,863	12,940
2007	138,000	11,950	6,325	2,903	11,580
2008	133,800	10,610	5,618	2,700	10,390
2009	110,850	13,404	7,096	2,199	10,663
2010	91,667	11,665	6,176	1,792	9,302

Reconstruction of the Republic of the Marshall Islands fisheries catches: 1950-2010[1]

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Abstract

Reconstructed total catches of the Republic of the Marshall Islands were estimated to be approximately 661,500 t over the 1950-2010 time period, which is 37% higher than the 483,364 t reported by the FAO on behalf of the Marshall Islands. The people of the Marshall Islands have been dependent on subsistence fisheries throughout their history. The subsistence sector contributes 78% (i.e., 116,800 t) to small-scale catches, with the remaining 33,800 t being artisanal (i.e., small-scale commercial). Large-scale commercial (i.e., industrial) fisheries for large pelagic species have only developed in the last decade, but still contribute 77% (i.e., 510,900 t) of the total catch for the 1950-2010 period considered here. This clearly highlights the substantial impact that large-scale fisheries may have on marine resources, and illustrates the need for effective fisheries management in order to ensure food security for the local population of the Marshall Islands.

Introduction

The Republic of the Marshall Islands (RMI) is located in the western Pacific, just west of the International Date Line and north of the Equator. It has a land area of only about 180 km[2] scattered over 1.2 million km[2] of ocean, and is a small Micronesian nation comprised of 29 atolls (24 of which are inhabited) and five single islands, which form two parallel groups: the 'Ratak' (sunrise) chain and the 'Ralik' (sunset) chain.[2] Two-thirds of the country's population of 67,180 live in the two major centers of Majuro and Ebeye. The outer islands have few inhabitants due to scarcity of employment and lack of economic development.[3]

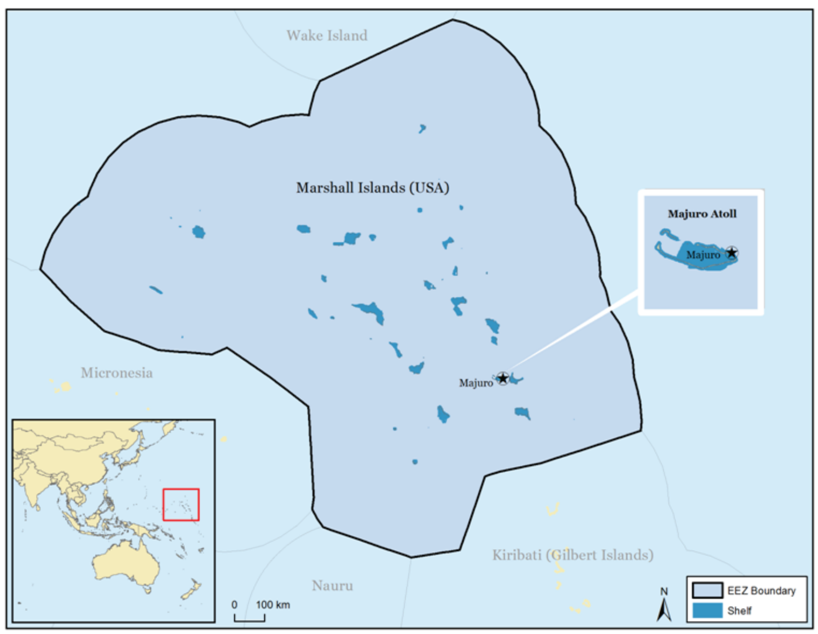

Figure 1. The Republic of the Marshall Islands in the western Pacific, its extensive Exclusive Economic Zone (EEZ) and shelf areas of less than 200 m depth.

The dates and origins of the first settlers to arrive in the Marshalls are uncertain. It is commonly believed that the first colonists to arrive were Micronesian navigators who called them the 'Aelon Kein Ad' (Our Islands).[2] Archeological finds on Bikini Atoll in the 1980s were carbon dated to 2000 years BC, indicating that people may have settled the Marshalls as far back as 4,000 years ago.[2] The RMI has been colonized by a succession of foreign countries. The first Spanish explorer, Alvaro Saavedra arrived in 1529. In 1788, British Naval Captain William Marshall sailed through the area while transporting convicts to Australia, and the area now known as the RMI was given its name for this captain. The RMI was governed by Germany in the late 1800s, before being captured by Japan at the onset of WWI, who were granted a mandate to rule by the League of Nations. The RMI was occupied by the Allies in 1944, and became one of six entities in the Trust Territory of the Pacific Islands (TTPI) established by the United Nations, with the United States as the Trustee.[2]

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From 1946 to 1958, the RMI served as the site of the Pacific Proving Grounds where the U.S. tested 67 nuclear weapons, including the largest test the U.S. ever conducted, code named Castle Bravo.[4] It was the first U.S. test of a dry fuel thermonuclear hydrogen bomb detonated on March 1, 1954 at Bikini Atoll with an anticipated yield of four to six megatons. However, Castle Bravo detonated with a yield of 15 megatons. Combined with other factors, this led to the most significant accidental radioactive contamination ever caused by the United States. In 1956, the Atomic Energy Commission regarded the Marshall Islands as "by far the most contaminated place in the world" (Cooke 2009, page 168). Health and damage claims resulting from nuclear testing in the Marshall Islands are ongoing, and health effects from these nuclear tests linger. From 1956 to August 1998, at least $759 million was paid to the Marshallese Islanders in compensation for their exposure to U.S. nuclear testing (Schwartz 1998).

In 1979, the Government of the Marshall Islands was officially established and the country became self-governing. In 1986, the Compact of Free Association with the United States granted the Republic of the Marshall Islands (RMI) its sovereignty.[5] The Compact provides for development aid in the form of annual grants and U.S. defense of the islands in exchange for continued U.S. military use of the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll (Smith 1992). The independence procedure was formally completed under international law in 1990, when the UN officially ended the Trusteeship status.[6] Government assistance from the U.S. is the mainstay of the economy.

The Marshallese culture, or *manit* is central to the way of life in the islands. As members of a clan (*jowi*), all people have right to land; however, the chief *(iroij*) has control over the use, distribution and tenure, in addition to settlements of disputes over the resources. Marshallese culture is matrilineal, meaning that assets, land and resources are passed down through the mother's side of the family.[7]

Fish is the primary protein source of sustenance in the Marshall Islands, as the land only lends itself to the most marginal agricultural crops: breadfruit, pandanus, swamp tare, and coconut.[6] Fish and other marine resources were traditionally caught using narrow canoes with an outrigger to one side. The hulls were made from breadfruit wood, while the sails were woven from pandanus leaves. A one-man canoe which would typically be used to fish inside a lagoon was known as '*tipnol'*, while the largest canoes known as '*walap'* were over 30 m in length, could carry forty people, and could sustain ocean voyages of up to one month.[7]

In addition to Marshallese boats, fishing vessels from other Pacific island states as well as Japan, Korea, Taiwan and China operate in the EEZ of the Marshall Islands.[8] The United States also fishes in the waters of the EEZ of the Marshall Islands under an agreement known as the 'US Multilateral [Tuna] Treaty'.[8,9]

The key agency responsible for the examination, development, regulation and administration of marine resource use in the RMI is the Marshall Islands Marine Resources Authority (MIMRA). The National Environmental Protection Authority, Marshall Islands Development Authority, Kwajalein Atoll Development Authority, and the local authorities also play important roles in the marine resources sector. Eliminating overlaps in jurisdiction is needed to avoid potential management problems (Smith 1992).

Almost all of the domestic fisheries in the Marshall Islands are of subsistence nature, except for artisanal (i.e., small-scale commercial) activities around the urban centers of Majuro, Kwajalein and Arno. Capture methods are varied, and both traditional and modern methods are utilized. Commonly used methods include: handlining, spearfishing, gillnetting, trolling and cast-netting. Most artisanal fishing is conducted in wooden or fibreglass boats of 15 to 20 feet length powered by outboard motors under 30 hp. Occasionally larger motors of 70 hp or more are used when fishing takes place from urban centers, but outside the atolls (Smith 1992). In the outer atolls, small paddling canoes remain the most common fishing vessels for subsistence fishing.

The importance of the fisheries sector, both to the daily lives and basic food security of the Marshallese, and for economic development of the country and region, is evidently clear. With this in mind, understanding the historical patterns and trends in total catches is fundamental and critical to understanding and managing their future (Pauly 1998). The objective of the present study is to provide a time series baseline by estimating the total catches taken domestically in the RMI from 1950 to 2010 using a catch reconstruction approach as outlined by Zeller *et al.* (2007).

Methods

Data presented by the Food and Agriculture Organization of the United Nations (FAO) on behalf of the Republic of the Marshall Islands (RMI) were obtained from the FishStat capture production database for FAO area 71. Using information presented by Gillett (2009), and following the reconstruction approach described by Zeller *et al.* (2007), we estimated demand for locally-sourced seafood, and compared this to the portion of FAO landings considered to remain in-country for domestic consumption in order to determine missing (i.e., unreported) catch amounts.

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[7] Embassy of the Republic of the Marshall Islands, Washington D.C. (2008) Culture [online]. Available from: http://www.rmiembassyus.org/Culture.htm [accessed 9 May, 2013].

[8] Embassy of the Republic of the Marshall Islands, Washington D.C. (2008) Economy [online]. Available from: http://www.rmiembassyus.org/Economy.htm

[9] Pacific Islands Forum Fisheries Agency (2008) US Treaty [online]. Available from: http://www.ffa.int/usa_pi_treaty#attachments [accessed 20 November, 2012].

Artisanal and subsistence fisheries

For the purposes of this report, small-scale catches are defined as being attributed to one of two sectors: artisanal or subsistence. Artisanal fisheries catches are defined as those catches which are made by small vessels in inshore coastal waters and are for commercial sale for local consumption. Subsistence fisheries are defined as those being made by small vessels in inshore coastal waters, but with the main purpose and intent of self- and family-consumption rather than sale as the primary driver (Gillett 2011b).

For the purposes of this reconstruction, we determined that all reported catches which were not large pelagic tunas or billfishes, were attributed to the small-scale sector. This includes various invertebrates and 'marine fishes nei'.

Small-scale sector

We used the anchor point in Gillett (2009) of 950 t of artisanal catch in 2005, and assumed artisanal (i.e., commercial) fishing started post WWII with a start of zero tonnes in 1945. We interpolated linearly between 1945 and 2005. For 2005-2010, we extrapolated and carried forward the same interpolation rate used between 1945 and 2005 (Table 1).

Table 1. Anchor points used to determine artisanal catch.

Year	Artisanal catch (t)	Source
1945	0	Assumption
1945-2004	-	Interpolation
2005	950	Gillett (2009)
2006-2010	-	Extrapolated (interpolation rate from 1945-2004 carried forward)

For subsistence, we used the 2005 subsistence production anchor point of 2,800 t in Gillett (2009), and converted this to a *per capita* subsistence rate of consumption for 2005 (i.e., 53.8 kg·person^{-1}·year^{-1}). For 1950, we assumed a *per capita* subsistence rate of consumption that was 25% higher (i.e., 67.25 kg·person^{-1}·year^{-1}) than in 2005, and interpolated linearly between these points (Table 2). This interpolation rate was carried forward in order to extrapolate to 2010. We then multiplied these derived, annual consumption rates by the annual human population of the RMI to derive an amount in tonnes of local fish being consumed for subsistence purposes.

Table 2. Anchor points used to determine local consumption rates used in the reconstruction of the subsistence sector.

Year	*Per capita* consumption rate (kg·person^{-1}·year)$^{-1}$	Source
1950	67.3	Assumption
1951-2004	-	Interpolation
2005	53.8	Gillett (2009)
2006-2010	-	Extrapolated (interpolation rate from 1950-2004 carried forward)

We used information from Dalzell *et al.* (1996) and Gillett (2011b) to derive a taxonomic breakdown of the artisanal and subsistence catches. This breakdown was applied to the reported catches labelled as 'marine fish nei', and the unreported subsistence and unreported artisanal catches as estimated here.

Aquarium trade

Catches of reef fish for the global aquarium trade are noteworthy in the Marshall Islands, and represent an important source of income of almost USD 400,000 in 2006 (Gillett 2009). The species being targeted are diverse; over 50 different species are taken (Gillett 2011b), and they are typically smaller than those targeted for food. They tend to come from the families Pomacanthidae, Chaetodontidae, Acanthuridae, Labridae, Serranidae, Pomacentridae, Balistidae, Cirrhitidae, Gobiidae and Blenniidae (Dalzell *et al.* 1996), and the most commonly taken fish is the flame angel (*Centropyge loriculus*) (Gillett 2011b). This fishery operates largely from the Majuro lagoon, and Gillett (2011b) estimates that approximately 3,000 fish are exported each week. Marine animals from the aquarium trade are not estimated as part of this reconstruction, as our focus is on food fisheries; however, the amounts could be substantial in terms of number of fish, though not in terms of tonnage.

Large-scale sector

Large-scale or industrial fisheries in the RMI typically take place in offshore waters, and are responsible for much greater tonnages than small-scale operations. They are conducted by Marshallese owned and operated vessels, or by foreign-owned vessels, and focus their efforts on tuna and other large pelagic species (Gillett 2011b). The locally-based RMI offshore fleet consists to 75% of purse seine vessels, with the remaining 25% being longline vessels (Gillett 2011b).We attributed all reported catches of tunas and other large pelagic species such as billfishes to the large-scale sector.

By-catch and discards

The industrial fleet in the RMI targets mainly four commercial tuna species: skipjack (*Katsuwonus pelamis*), albacore (*Thunnus alalunga*), bigeye (*T. obesus*) and yellowfin (*T. albacares*). However, other large pelagic species such as sharks and billfish are also inadvertently captured. Often, because billfishes are valuable and exportable, they are reported in data supplied to the FAO, while many other species are not (e.g., sharks). To estimate the amount of this non-targeted by-catch taken by the domestic industrial fleets in the RMI, we first separated the fleet by gear type. Based on information in Gillett (2011b), we attributed 75% of all catches of the four tuna species to the purse seine fleet, and 25% to the longline fleet. Using anchor points from Gillett (2009), we increased all purse seine catches by 5%, and all longline catches by 30%. We then compared this reconstructed offshore catch to the tonnages of tunas and billfishes reported by the FAO on behalf of the RMI to derive any missing (i.e., unreported) by-catch.

The taxonomic composition of this unreported by-catch was derived using data in MIMRA (2009), which details the non-target species caught in the locally-based offshore fleet (Table 3). The top 15 species by weight for the year 2008 were identified by the percentage of the by-catch reported by MIMRA, and these percentages were applied to the unreported by-catch.

Table 3. By-catch of pelagic species in the large-scale sector, based on MIMRA (2009).

Common name	Taxon name	% attributed to by-catch
Blue marlin	*Makaira mazara*	7.90
Black marlin	*Istiompax indica*	0.33
Striped marlin	*Kajikia audax*	4.20
Swordfish	*Xiphias gladius*	1.00
Other billfish	Istiophoridae	1.30
Blue shark	*Prionace glauca*	10.50
Mako shark	*Isurus oxyrinchus*	1.10
Oceanic whitetip shark	*Carcharhinus longimanus*	5.00
Silky shark	*Carcharhinus falciformis*	21.90
Other sharks/rays	Elasmobranchii	36.90
Rainbow runner	*Elegatis bipinnulata*	1.67
Wahoo	*Acanthocybium solandri*	3.50
Common dolphinfish	*Coryphaena hippurus*	2.70
Triggerfish	Balistidae	0.25
Opah	*Lampris guttatus*	1.70

Although by-catch is taken in the RMI's locally-based offshore fleet, it is unlikely that much of it is discarded. As Gillett (2011a) notes, discarding from fisheries in the Pacific Islands rarely occurs because all of the catch is seen to have economic value. We therefore assumed no discarding of by-catch in the domestic large-scale fishery (discarding patterns may be substantially different in foreign owned fleets, not covered here).

Results

Our reconstructed total catch for the RMI summed to approximately 661,500 t over the 1950-2010 time period. This is 37% higher than the 483,364 t reported by the FAO on behalf of the RMI for the same time period (Figure 2). Overall, the industrial sector contributed almost 510,900 t, or over 77% of total catches (Figure 2a), while the artisanal and subsistence sectors contributed 33,800 t and 116,800 t, respectively (Figure 2b). Unreported artisanal and subsistence fishing accounted for over 15,800 t and 111,000 t, respectively, and unreported by-catch in the industrial (large-scale) sector accounted for almost 51,300 t (Figure 2a). When examining the small-scale sectors only, the reconstructed total artisanal and subsistence catches are 6.3 times the amount of small-scale catches reported by the FAO on behalf of the Marshall Islands (Figure 2b).

Overall, fishes from the family Scombridae comprised the greatest portion (72%) of the total reconstructed catch, with skipjack tuna (*Katsuwonus pelamis*) comprising 88% of this family (Figure 3a). Carcharhinidae and other sharks and rays also comprised noteworthy amounts of the reconstructed catch, at just over 38,000 t over the time period. These catches were largely due to by-catch in the domestic industrial large pelagic fisheries.

When examining the taxonomic composition of the small-scale sector separately, invertebrates account for a large portion of this sector, over 38,000 t (25%), which was comprised of giant clam (*Tridacna maxima*), bear's paw clam (*Hippopus hippopus*), scaly or flute clam (*T. squamosa*), *Turbo* species of snails, *Octopus* species, and other miscellaneous invertebrates (Figure 3b). Lethrinidae and Scombridae were two other families which figured prominently in the small-scale reconstructed catch, at 17,000 t and 15,000 t, respectively. The Scombridae family in the small-scale catch is 40% yellowfin (*Thunnus albacares*), 40% skipjack tuna (*K. pelamis*), and 20% other scombrids.

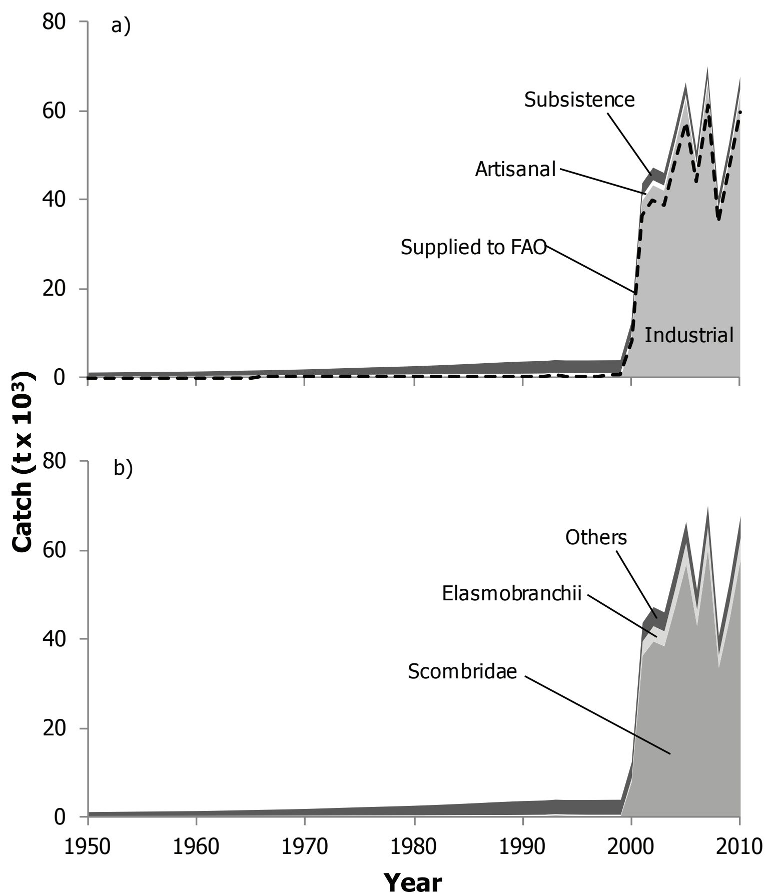

Figure 2. Reconstructed total catch of the Republic of the Marshall Islands, for the time period 1950-2010. a) by sector with data supplied to FAO overlad as line graph; and b) by taxonomic composition, 'others' represents 56 other taxonomic categories.

Discussion

The reconstructed total catch for the Republic of the Marshall Islands is estimated to be 37% higher than the landings reported by the FAO on behalf of the Marshall Islands. However, if one excludes the domestic, industrial fisheries for large pelagics from this examination, the total small-scale coastal fisheries catches as reconstructed here were found to be 6.3 times the data reported by FAO on behalf of the RMI. This is largely due to the unreported catches in the subsistence sector, which are difficult to monitor because of the widely dispersed nature of landings sites in the islands. The rapid development and deployment of the locally-based offshore tuna fishery (FAO 2009) at the turn of the millennium is evident (Figure 2a), and appears to have been accompanied by a dramatic improvement in reporting for the industrial sector.

Recreational fishing is generally not carried out by the inhabitants of the islands, but rather is an activity enjoyed by tourists to the islands. The RMI has approximately 25 charter boats based in the capital of Majuro, and another ten boats in Kwajalein and Arno (Gillett 2011b), and the Marshall's Billfish Club has hosted annual tournaments since 1982. As catch estimates are not readily available for this sector, it was not possible to derive estimates of the amount of fish taken by recreational fishers in the RMI; however, this should still been seen as a contribution to the overall marine harvests of the RMI, and accounted for in turn. Any tendency towards catch and release needs to consider potential post-release mortality rates of billfishes.

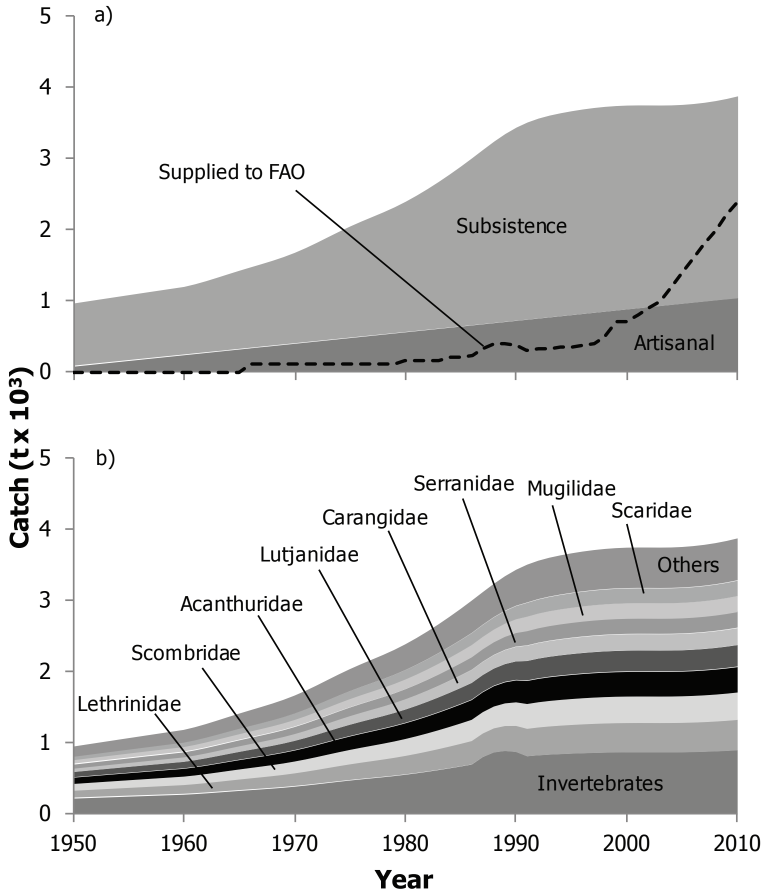

Figure 3. Reconstructed total small-scale catches for the Republic of the Marshall Islands, for the time period 1950-2010, a) by sector, catches 'supplied to FAO' overlaid as line graph (reported landings excluding reported large pelagic tunas and billfishes, which are targeted specifically by the large-scale industrial sector, and thus represent only those catches reported from the small-scale sector); and b) by family. 'Others' represents 22 families.

Foreign industrial fleets from the United States of America and Asian and Pacific island countries and territories are granted access to the EEZ waters of the RMI through the *Multilateral Treaty on Fisheries Between Certain Governments of the Pacific Island States and the Government of the United States of America*, also known as the US Treaty[8] (or the US Multilateral [Tuna] Treaty). However, catches in the RMI from the US and other Pacific islands countries are relatively small compared with those taken by Asian countries such as Japan, Korea and China. As of 2008, the RMI had bilateral agreements with these three Asian countries, as well as New Zealand, to fish the waters of the RMI (MIMRA 2009). The foreign industrial fleets consist mainly of purse seine vessels, some pole-and-line vessels, and comparatively few longline vessels. While the locally-based offshore fishery landed relatively small catches from 1970-1995 (on average 100 t), there was a sudden suspension of catches from 1996-1999. This is potentially due to the experimental fisheries which were being conducted to determine their potential prior to full-scale investment in the projects (Gillett 2007).

The access fees paid by foreign countries to fish in the waters of many Pacific island countries provide much needed foreign exchange income for the countries which receive them. In 2005, 2006 and 2007, the RMI received USD 2.65 million, 2.79 million and 1.9 million, respectively from these distant-water fishing countries for the access granted to the RMI's EEZ (Gillett 2009). Because the foreign-based catches are landed in foreign ports (mainly in Asia or the US) or are transshipped in Majuro (FAO 2009), they are assumed to be accounted for in the FAO fisheries landing reported by those foreign countries, and are therefore not included in this reconstruction of the Marshall Islands catches.

The RMI currently has an observer program in place to carry out the monitoring of the domestic large-scale fleet. With the support of the Secretariat of the Pacific Community (SPC) Oceanic Fisheries Programme, the observer program had nine observers with a total of 1,058 days at sea in 2005, and there were 26 active observers in 2006 (Muller 2006). As noted in our estimates of by-catch from the large-scale offshore fleets, many species are not reported in the FAO figures as being caught. One group of fishes in particular, the cartilaginous fishes (sharks, skates, and rays), are not well documented in FAO reported landings; however, frozen sharks and shark fin is documented frequently in national catch data (MIMRA 2009) and export data for the RMI (Gillett and Lightfoot 2002; Muller 2006; Gillett 2009). Our reconstructed estimates show that the amount of these fishes caught annually is noteworthy, and requires monitoring and reporting. Although the Marshall Islands have a plan of action for managing sharks in tuna fisheries, as of 2009, those plans had not yet been implemented (Gillett 2011a).

As we have seen from the results of this reconstruction work, accurate reporting and monitoring of fisheries is crucial for assessing the state of marine resources. Hanich *et al.* (2010) note some of the threats that management of Pacific island fisheries face due to lack of accurate data: increasing the level of uncertainty already intrinsic to fisheries management, and undermining the ability of Pacific islands to take stock of and develop the economic opportunities presented by the resource. While Kronen *et al.* (2012) found that the Marshall Islands were still displaying a positive balance in its reef productivity in relation to its annual artisanal catch, they note that "the risk of contemporary unsustainable artisanal fin fisheries in PICTs is high and widespread". This report also demonstrates the need to monitor or periodically estimate comprehensively small-scale artisanal and subsistence fisheries (see Zeller *et al.* 2007) to ensure that this risk is managed appropriately.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for the Republic of Marshall Islands, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence
1950	0.25	954	-	79	874
1951	0.25	977	-	95	882
1952	0.25	1,001	-	111	890
1953	0.25	1,025	-	127	898
1954	0.25	1,048	-	143	906
1955	0.25	1,072	-	158	913
1956	0.25	1,095	-	174	921
1957	0.25	1,118	-	190	928
1958	0.25	1,142	-	206	936
1959	0.25	1,165	-	222	943
1960	0.25	1,188	-	238	950
1961	0.25	1,225	-	253	972
1962	0.25	1,269	-	269	1,000
1963	0.25	1,317	-	285	1,032
1964	0.25	1,367	-	301	1,066
1965	0.25	1,416	-	317	1,099
1966	100.00	1,463	-	333	1,130
1967	100.00	1,509	-	348	1,160
1968	100.00	1,556	-	364	1,192
1969	100.00	1,609	-	380	1,229
1970	101.25	1,669	1	396	1,272
1971	101.25	1,736	1	412	1,324
1972	101.25	1,810	1	428	1,382
1973	101.25	1,889	1	443	1,445
1974	101.25	1,966	1	459	1,506
1975	101.25	2,040	1	475	1,564
1976	101.25	2,108	1	491	1,617
1977	101.25	2,173	1	507	1,666
1978	101.25	2,239	1	523	1,715
1979	101.25	2,309	1	538	1,770
1980	151.25	2,387	1	554	1,832
1981	151.25	2,474	1	570	1,903
1982	161.25	2,567	1	586	1,981
1983	161.25	2,667	1	602	2,065
1984	201.25	2,773	1	618	2,155
1985	201.25	2,884	1	633	2,250
1986	221.25	2,999	1	649	2,350
1987	321.25	3,119	1	665	2,453
1988	401.25	3,235	1	681	2,554
1989	396.25	3,341	1	697	2,644
1990	381.25	3,431	1	713	2,718
1991	301.50	3,503	1	728	2,774
1992	330.00	3,568	10	744	2,813
1993	489.00	3,752	153	760	2,839
1994	389.00	3,686	53	776	2,857
1995	376.00	3,686	25	792	2,869
1996	370.00	3,686	-	808	2,878
1997	401.00	3,706	-	823	2,883
1998	501.00	3,722	-	839	2,883
1999	701.00	3,734	-	855	2,879
2000	8,261.50	12,151	8,411	871	2,870
2001	36,581.50	43,541	39,799	887	2,856
2002	39,859.50	47,076	43,334	903	2,840
2003	38,886.25	45,878	42,137	918	2,823
2004	47,887.25	55,670	51,927	934	2,809
2005	57,583.00	66,232	62,482	950	2,800
2006	43,974.00	50,876	47,113	966	2,797
2007	61,229.00	69,872	66,091	982	2,799
2008	35,102.00	40,530	36,726	998	2,807
2009	46,246.25	52,754	48,920	1,013	2,821
2010	59,730.25	67,534	63,663	1,029	2,842

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for the Republic of Marshall Islands, 1950-2010. 'Others' contain 32 additional taxonomic categories.

Year	Scombridae	Elasmobranchii	Invertebrates[1]	Lethrinidae	Acanthuridae	Lutjanidae	Carangidae	Others
1950	95	-	219	108	89	74	58	310
1951	98	-	225	110	91	76	60	318
1952	100	-	230	113	93	78	61	325
1953	102	-	236	116	95	80	63	333
1954	105	-	241	118	97	82	64	341
1955	107	-	246	121	100	84	65	348
1956	110	-	252	124	102	85	67	356
1957	112	-	257	126	104	87	68	364
1958	114	-	263	129	106	89	70	371
1959	116	-	268	132	108	91	71	379
1960	119	-	273	134	110	93	72	386
1961	123	-	282	138	114	96	75	398
1962	127	-	292	143	118	99	77	413
1963	132	-	303	149	122	103	80	428
1964	137	-	314	154	127	107	83	444
1965	142	-	326	160	132	110	86	460
1966	146	-	336	165	136	114	89	476
1967	151	-	347	170	140	118	92	490
1968	156	-	358	176	145	121	95	506
1969	161	-	370	182	149	125	98	523
1970	167	-	384	188	155	130	102	542
1971	174	-	400	196	161	135	106	564
1972	181	-	417	204	168	141	110	588
1973	189	-	435	213	175	147	115	614
1974	197	-	453	222	182	153	120	639
1975	204	-	470	230	189	159	124	663
1976	211	-	485	238	196	164	129	685
1977	218	-	500	245	202	169	132	706
1978	224	-	515	253	208	174	136	727
1979	231	-	531	261	214	180	141	750
1980	239	-	549	270	222	186	146	776
1981	248	-	569	279	230	193	151	804
1982	257	-	591	290	238	200	157	834
1983	267	-	614	301	248	208	163	867
1984	278	-	638	313	257	216	169	901
1985	289	-	664	326	268	225	176	937
1986	300	-	690	339	279	234	183	975
1987	302	-	795	341	280	235	184	981
1988	309	-	860	348	287	240	188	1,003
1989	320	-	881	361	297	249	195	1,039
1990	333	-	867	376	309	260	203	1,082
1991	351	-	806	396	325	273	214	1,138
1992	365	1	819	402	330	277	217	1,156
1993	497	-	829	407	334	281	220	1,186
1994	411	4	836	410	337	283	222	1,182
1995	388	-	843	414	340	285	223	1,193
1996	368	-	848	416	342	287	225	1,198
1997	371	-	853	419	344	289	226	1,205
1998	372	-	857	421	346	290	227	1,210
1999	373	-	860	422	347	291	228	1,214
2000	7,964	640	861	423	347	292	242	1,382
2001	36,289	3029	861	423	348	292	295	2,004
2002	39,479	3299	861	423	348	292	301	2,074
2003	38,399	3205	861	423	347	292	299	2,052
2004	47,234	3951	861	423	348	292	316	2,246
2005	56,760	4750	863	424	348	292	334	2,463
2006	42,891	3573	865	425	349	293	309	2,170
2007	60,019	5023	869	427	351	295	342	2,545
2008	33,519	2732	875	430	353	297	292	2,032
2009	44,527	3675	882	433	356	299	315	2,268
2010	57,834	4775	890	437	359	302	342	2,595

[1] Invertebrates includes *Scylla serrata*, natantian decapods, *Trochus* spp., spiny lobsters (*Panulirus* spp.), *Tridacna* spp., *Hippopus hippopus, Asaphis violascens*, *Turbo* spp. and *Octopus* spp.

Reconstruction of total marine fisheries catches for St. Kitts and Nevis (1950 - 2010)[1]

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Abstract

Under-reporting of catches in fisheries is a global problem. This report presents the reconstruction of total marine fisheries catches for St. Kitts and Nevis for the period 1950-2010, which includes estimates of unreported catches of conch and lobster for the early time period, and under-reported artisanal and subsistence catches for the entire time period. Unreported catches from 1950-2010 were estimated to be 53% of the reconstructed total catch, with an average annual unreported catch of approximately 740 t·year^{-1} for both islands. Reconstructed total catches for St. Kitts and Nevis were estimated to be over 2 times the adjusted landings reported to FAO on behalf of St. Kitts and Nevis (adjusted for over reporting in a few years) for the same time period. This estimate, which more comprehensively accounts for total living marine resource extractions by St. Kitts and Nevis, reflects the importance of small-scale fisheries in providing seafood to locals and visitors, and livelihoods to fishers.

Introduction

St. Kitts and Nevis are islands in the Caribbean Sea located between latitude 17.3° north and longitude 62.7° west. St. Kitts and Nevis have a combined land area of 261 km^2 and a total population of 52,000. Both islands are of volcanic origin, with steep escarpments, and hills in the interior and gentle plains along the coasts. The islands are separated by a 3 km wide channel named 'The Narrows', and share an Exclusive Economic Zone (EEZ) of around 10,200 km^2 (www.seaaroundus.org) (Figure 1).

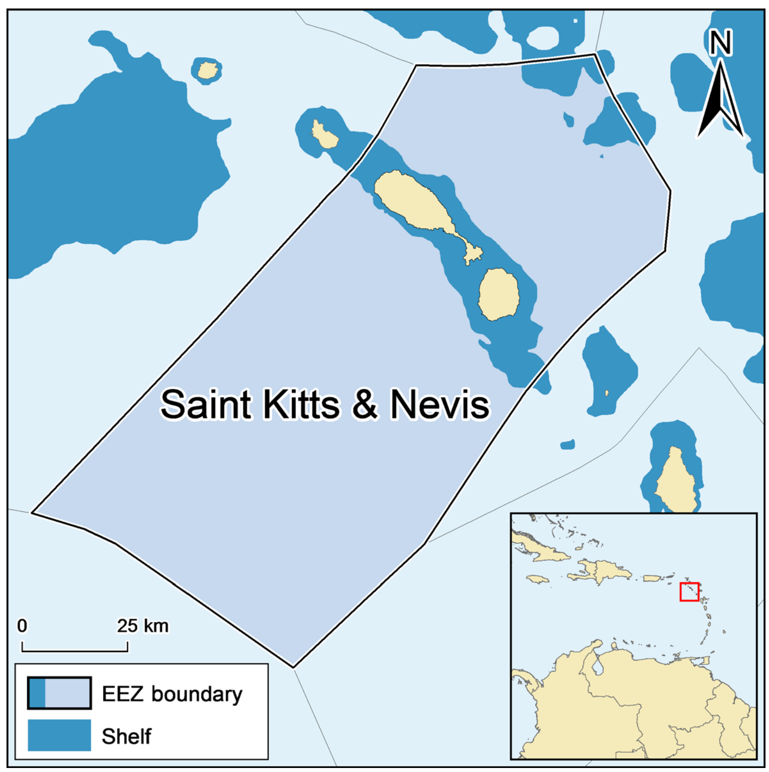

Figure 1. Map of St. Kitts and Nevis, showing it's Exclusive Economic Zone (EEZ) and shelf waters of 200m depth.

St. Kitts and Nevis is a federated state, which gained independence from British colonial rule in 1983. Historically, the competition for Caribbean supremacy between the British, French and Dutch, began in St. Kitts in the year 1623 when Sir Thomas Warner claimed the island for Britain. Just two years later, a French expedition arrived, and both groups agreed to share the island amicably. However the island's original native inhabitants, the Caribs (originating from South America), who had discovered St. Kitts long before the English or the French, were staking their claim. The Europeans and the Caribs signed an agreement to share the island peacefully. However, the Europeans wiped out the Caribs in a massacre at 'Bloody Point' in 1626 (Ferguson 1997). Apart from anthropogenic effects, the islands are also susceptible to natural disasters. Each year from June to November, hurricanes and tropical storms affect the islands. Most notable, Hurricane Hugo caused widespread damage to the islands' infrastructure in 1989, and Hurricane Georges left 3,000 people without homes in 1998.

The islands' economies are dependent on agriculture and tourism. In the past, major crops cultivated in St. Kitts included sugarcane, sea-island cotton and food crops (Colonial Office 1958). Today, the agriculture sector is defined in terms of sugar and cotton production on both St. Kitts and Nevis. Tourism is gradually replacing agriculture as a major economic contributor in St. Kitts (USAID 2008). Agriculture, tourism, fisheries, boat building, construction and a small manufacturing sector form the economic base on Nevis (USAID 2008).

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The fishing sector of each of these islands is primarily artisanal and subsistence oriented, with a small recreational sector. Furthermore, Japanese and other foreign fishing vessels have been observed fishing offshore the island's territorial waters (Wilkins 1984). The fishing fleet is comprised of wooden boats (4-7 m), usually powered by outboard engines, although some still use sails and oars (Goodwin *et al.* 1985). The fishing gears utilized include pots and boat seines, some hand-lining and beach seining, and skin-diving is also practiced. The species targeted include: reef and demersal species, such as snappers and groupers, lobster and conch. Starting in the 1960s, beach seines were used to capture small schooling pelagics such as gars, ballyhoo (Belonidae) and jacks (Carangidae). Today, trolling near Fish Aggregating Devices (FADs) is the fastest growing fishing technique in St. Kitts. Fishers concentrate their efforts on catching medium and large pelagics such as dolphinfish (Coryphaenidae) and tunas from January to June each year (Heyliger 2002).

Catches are landed at five major landings sites on St. Kitts: Basseterre East, Basseterre West, Old Road, Sandy Point and Dieppe Bay. On Nevis, there are eight important landing sites: Charlestown, Cane Bay, Indian Castle, Long Haul Bay, Newcastle, Jones Bay, Cotton Ground, and Jessups. There are two central markets on the islands: Bassetere fishing complex on St. Kitts, and a fisheries complex in Charlestown on Nevis. However, fishers also process and sell catches directly to customers at boat landing sites. If there is a surplus of fish, vendors will act as intermediaries. Seafood exports to Guadeloupe and Martinique include lobster, conch and finfish (Goodwin *et al.* 1985), though exact quantities are not published. Despite the importance of fish in exports and in the diet of the people on St. Kitts and Nevis, the islands are net importers of seafood since local landings are not sufficient to meet the local demand (Wilkins 1984; Goodwin *et al.* 1985). Indeed, colonial records state that approximately 545 t of fish (frozen, cured and canned) were imported to St. Kitts and Nevis in 1964.

Over time, there have been many changes in the reefs around the islands due to sediment runoff, hurricane damage and high fishing pressure. Fishers report declines in fish size, are spending longer periods of time at sea and are observing major declines in total catch (FORCE 2012a, 2012b). The Fisheries Departments on St. Kitts and Nevis are in charge of the management of coastal and marine resources on their respective islands. Both have the same method of data collection, which is based upon the CARICOM region data systems 'CARAFIS' (Heyliger 2011). Catch data on St. Kitts is collected from Monday to Saturday from main landing sites, while other sites are checked once a month. Raising factors are applied according to the number of fishing days and the gear type (Heyliger S., pers. comm., St. Kitts Fisheries Department). As for official reporting, it is unclear whether FAO contacts each island separately (Arthurton A., pers. comm., Nevis Fisheries Department) or if they report federal fisheries landings collectively (Helyiger S., pers. comm., St. Kitts Fisheries Department). Thus, the level of trust and collaboration between island administrations is obviously strained; therefore information may not be reliable.

Accurate catch data are important as the most fundamental baseline for evaluation of the state of fisheries resources. A review of all available fisheries literature on St. Kitts and Nevis was undertaken, along with data accessed from the Fisheries Department in St. Kitts in order to (1) provide an improved estimate of total marine fisheries catches for St. Kitts and Nevis for the time period 1950-2010, and (2) improve the taxonomic detail of the reported and unreported catch.

Methods

The fisheries of St. Kitts and Nevis have been reported on by FAO (1969), George (1976), Goodwin *et al.* (1985), Barrett *et al.* (1988) and Heyliger (2011). It was difficult to accurately analyze the catch data gleaned from these reports; therefore, we also relied on seafood consumption rates (Jones 1985) derived from the neighboring island of Anguilla to guide us in our estimation. Assuming a similar consumption pattern as on Anguilla, we combined the household consumption rates from Jones (1985) with local population data, and reconstructed the likely local seafood demand on St. Kitts and Nevis. We also estimated consumption by visiting tourists and catches from the small recreational sector. Taking the average species composition from the national catch dataset (1995-2010), we were able to improve on the likely taxonomic composition of catches presented in the FAO data for the early time period (1950-1995).

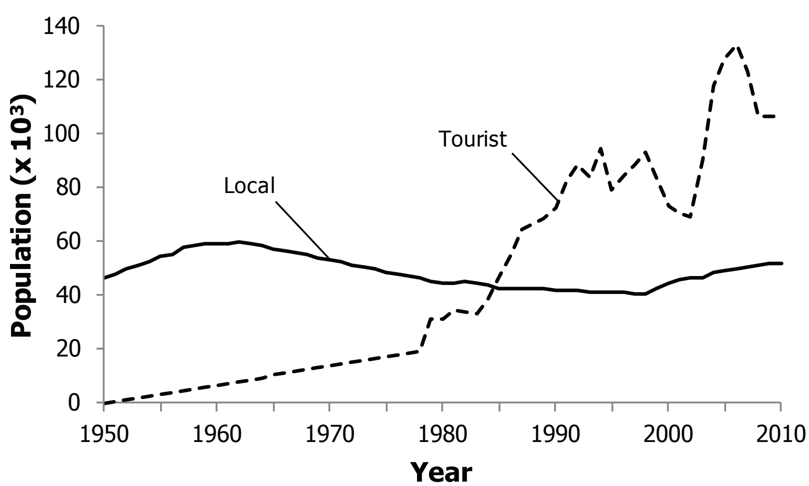

Figure 2. Human population data for St. Kitts and Nevis, showing total local population and stop-over tourists. Sources: World Bank, St. Kitts and Nevis Government Statistics Department, Caribbean Tourism Organization.

Human population and tourists

Human population data for St. Kitts and Nevis were available from the World Bank[2] for most years. Using linear interpolation for years with missing data, we reconstructed the local population on the islands from 1950-2010 (Figure 2).

[2] http://data.worldbank.org/ [Accessed: February 2013]

Data on the number of stop-over tourists (travelers who stay on the island for more than a day), were available from the Government Statistics Department for 1978-2006 and from the Caribbean Tourism Organization[3] for 2000-2010. We assumed tourism began in 1950, and a linear interpolation was done to estimate the tourist population in years with missing data (Figure 2).

Catches satisfying local demand

According to a household consumption survey (Jones 1985) on the neighboring island of Anguilla, annual *per capita* fresh seafood consumption was 23.6 kg fish, 0.8 kg lobster and 1.8 kg conch. Assuming these rates remained constant over time, we combined these rates with the St. Kitts and Nevis population data, to reconstruct the catches that would satisfy local demand of these islands. To assign small-scale catches to artisanal (i.e., commercial) and subsistence (i.e., non-commercial) sectors, it was assumed that in 1950, 90% of small-scale catches were for subsistence purposes and 10% were for sale (artisanal). In 2010, 40% of small-scale catches were attributed to the subsistence sector and 60% to the artisanal sector. A linear interpolation was done between these two years to derive an assumed percentage assignment by sector for the entire 1950-2010 time period.

Recreational

According to a global study of recreational fishing (Cisneros-Montemayor and Sumaila 2010), the proportion of recreational fishers in St. Kitts and Nevis in 2003 was 0.23%. Since sport fishing is an activity that is associated with tourism (Campos 1984), we assumed all of these fishers were tourists. We applied this rate constantly from 2000 to 2010. For the year 1950, we assumed a participation rate of 0.11% (half that of the later time period) of the tourist population. Linearly interpolating between these two rates, we derived recreational fishing participation rates of the tourist population for the time period 1950-2010. Assuming tourists are likely to participate in just one fishing trip during their stay, and assuming a conservative catch rate of 4.5 kg·tourist^{-1}·year^{-1}, we were able to estimate catches from this sector.

Catches satisfying tourist demand

In many parts of the world, fishers have so-called 'direct' customers, such as hoteliers and restaurateurs, whom they supply directly with fresh seafood catches, which often by-pass landings sites and monitoring procedures. Community reports from Jessups, Nevis and Dieppe Bay, St. Kitts, state that most fishers sell their catch to hotels (FORCE 2012a, 2012b). Thus, seafood supplying the tourist market, such as hotels and restaurants, were reconstructed separately. Annual tourist population data were combined with data on the average length of stay, i.e., approximately 10 days according to the Caribbean Tourism Organization. Taken together with inferences about the frequency of seafood consumption (i.e., one serving of seafood per day) and a typical serving proportion of 250 g (round weight), we applied the following equation to estimate tourist seafood demand annually. Using this calculation, we were able to reconstruct small-scale catches provided directly to the tourist market from 1950 to 2010, which we assumed did not enter the reporting system.

Table 1. Taxonomic breakdown used for fish catches from St. Kitts and Nevis (for both the reported 'marine fishes nei', as well as all unreported artisanal and subsistence fish catches) as derived for 1950 and as reported for 1995 based on FAO data. Intervening years were interpolated.

FAO common name	Scientific name	1950 (proportion)	1995 (proportion)
Bigeye scad	*Selar crumenophthalmus*	0.04	0.00
Flyingfishes nei	Exocoetidae	0.04	0.28
Needlefishes, etc. nei	Belonidae	0.04	0.16
Tuna-like fishes nei	Scombridae	0.00	0.01
Wahoo	*Acanthocybium solandri*	0.00	0.00
Common dolphinfish	*Coryphaena hippurus*	0.00	0.04
Grunts, sweetlips nei	Haemulidae	0.05	0.01
Goatfishes, red mullets nei	Mullidae	0.08	0.04
Parrotfishes nei	Scaridae	0.15	0.09
Squirrelfishes nei	Holocentridae	0.07	0.04
Surgeonfishes nei	Acanthuridae	0.08	0.07
Triggerfishes, durgons nei	Balistidae	0.05	0.04
Marine fishes nei	Miscellaneous marine fishes	0.05	0.05
Groupers nei	Serranidae	0.20	0.12
Snappers nei	Lutjanidae	0.15	0.05

Taxonomic breakdown

The dataset supplied to the FAO by St. Kitts and Nevis is dominated by the uninformative pooled group 'marine fishes nei', and marine invertebrates, such as Caribbean spiny lobster (*Panulirus argus*) and 'Stromboid conchs nei', that do not appear on record until 1970 and 1994, respectively. From 1995 onwards, a more detailed breakdown of catches was provided to the FAO. As mentioned previously, catches of lobster, conch and fish were reconstructed separately. To improve on the taxonomic breakdown for 'marine fishes nei', we created a new breakdown for 1950 based on ecological knowledge of Caribbean reefs and dominant fishing practices in the early time period (Table 1).

[3] http://www.onecaribbean.org/ [Accessed: August 2012]

Interpolating the percentage composition from 1950 to 1995, while leaving FAO breakdown from 1995 to 2010 as is, we provided species composition for fish catches in the following sectors: reported artisanal 'marine fishes nei', reported subsistence 'marine fishes nei' and all unreported fish catches (Table 1).

Results

Due to continued emigration, the local population trend has been flat to slightly declining between the mid 1960s and late 1990s, but began increasing again in the 2000s (Figure 2). However, the population of visitors to the island has steadily increased over the years, doubling in two decades from around 64,000 tourists in 1987 to over 120,000 in 2007 (Figure 2).

From 1950 to 2010, reconstructed catches for St. Kitts and Nevis for the artisanal (i.e., small-scale, commercial) sector contributed 39% of the catch, the subsistence sector amounted to almost 61% of the catch and the recreational sector in St. Kitts and Nevis contributed less than 0.1% to the total reconstructed catch (Figure 3a).

From 1976 to 1982, there was a peak in reported landings of fish and lobster in the St. Kitts and Nevis data supplied to FAO. Since we found no information to explain this sudden and short-lived spike in reported landings, we did not accept the FAO record from 1976-1982. The total reconstructed catch was estimated to be 2.1 times the adjusted reported landings. Total unreported catches for the period 1950-2010 were estimated at slightly over 53% of the catch, with average annual unreported catches of 740 t·year^{-1} (Figure 3a).

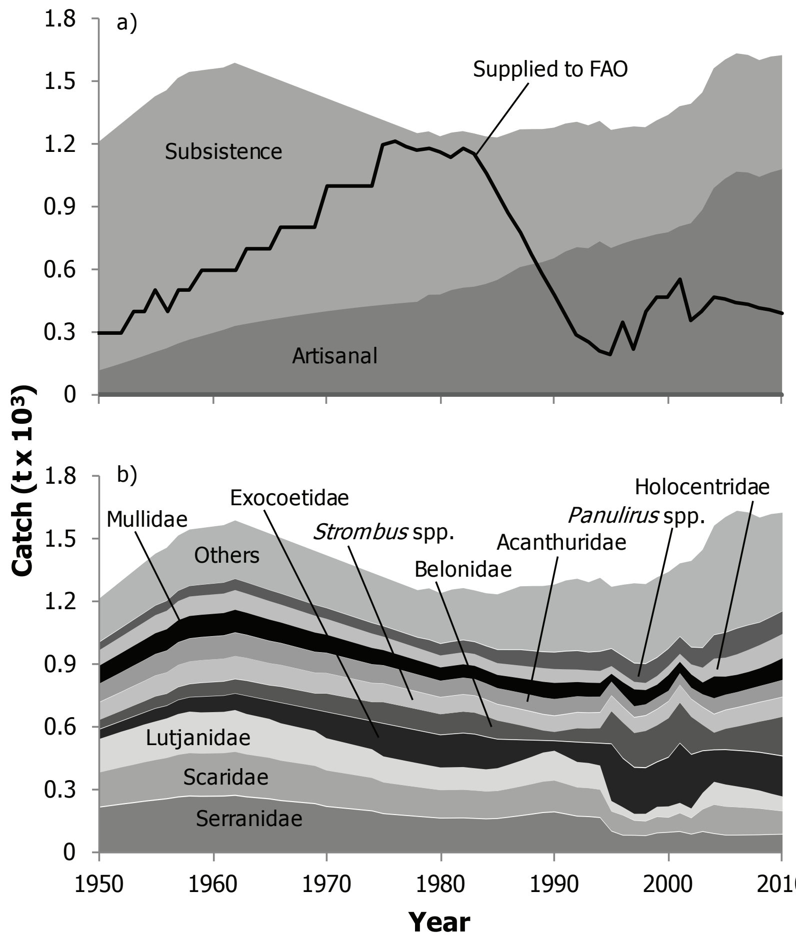

Figure 3. Reconstructed total catches for St. Kitts and Nevis by a) fisheries sector (recreational catches are included but are too small to be visible) with landings data as reported to FAO overlaid as line graph; and b) major taxa, with the 'others' category consisting of 9 additional taxa with smaller contributions.

Artisanal catches increase fairly steadily over the time period from an average of 200 t·year^{-1} in the 1950s, to over 1,000 t·year^{-1} in the late 2000s. Subsistence catches, in contrast, exhibited a fairly steady declining trend over the time period. Catches did increase for the first decade, climbing from just under 1,100 t·year^{-1} in 1950 to 1,260 t·year^{-1} in 1960. Catches declined from there to a low of 525 t·year^{-1} in 1998 and then leveled out, averaging 560 t·year^{-1} for the rest of the time period. Recreational catches have increased over the time period, for the most part. Catches increased slowly from just over 0.02 t·year^{-1} in 1950 to 0.17 t·year^{-1} in the late 1970s, and increased faster after that up to 0.86 t·year^{-1} in the mid- to late-1990s. After exhibiting a slight decline to 0.70 t·year^{-1} in 2001, catches rapidly increased to a peak of 1.36 t·year^{-1} in 2006, followed by a decline to just over 1.0 t·year^{-1} in 2010.

Catches were dominated by major reef taxa (Figure 3b) such as groupers (Serranidae; 13.0%), parrotfishes (Scaridae; 10.5%) and snappers (Lutjanidae; 9.5%). Small pelagic taxa including flyingfishes (Exocoetidae; 9.4%) and needlefish (Belonidae; 6.9%) were very significant, also. Smaller reef taxa, such as surgeonfishes (Acanthuridae; 6.0%), goatfishes (Mullidae; 5.9%) and squirrelfish (Holocentridae; 5.3%) were also important components of the catch. Catches of marine invertebrates such as *Strombus gigas* (6.3%) and *Panulirus argus* (4.8%) were also common. The 'others' category made up the remaining 22% of catches and comprised 5 pelagic families including Coryphaenidae, Scombridae and Sphyraenidae and 2 reef families, Balistidae and Haemulidae (Figure 3b).

Discussion

St. Kitts and Nevis are small island developing states in the Caribbean Sea. They have a narrow resource base and depend heavily on tourism for their economy. Fishing plays a vital role in St. Kitts and Nevis, especially for local food security. When there is a decline in other sectors, such as the tourism sector, islanders turn to fishing to supplement their income. However, since the 1980s, over-fishing has been documented on the reefs of St. Kitts and Nevis (Goodwin *et al.* 1985). From 1950 to 2010, we estimated average annual unreported fisheries catches to be approximately 740 t·year^{-1}, or as much as 80% of total catches in some time periods. Unfortunately, under-reporting of catches can mask over-fishing, and lead to erroneous interpretations of fisheries trends.

Our estimates show average annual unreported lobster and conch catches from St. Kitts and Nevis to be approximately 40 t·year^{-1} and 70 t·year^{-1}, respectively. Today, lobster and conch populations are considered to be over-exploited in near-shore areas (Heyliger 2010). With growing tourist populations, demand for high value species is placing unsustainable pressure on the local marine resources. Unreported fishing and rising tourist populations are challenges to St. Kitts and Nevis small-scale fisheries. In addition, catches from an associated recreational sector are not being captured by the present data collection system. Reconstructed recreational catches amounted to approximately 26 t for the study period, and though small, should not be overlooked.

Fish is recognized as an important source of protein for the local people and many prefer it over alternatives such as chicken, pork or beef. Both the local population and visiting tourists rely on or prefer seafood nutrition. Despite the economic and cultural significance of marine fisheries to these islands, the contribution of the small-scale fisheries to food and nutritional security, poverty alleviation and economic development is undervalued (FAO 2013). Low priority is given to the fisheries sector in Caribbean islands and the institutions in charge of fisheries management suffer from limited financial support and staffing. Plans for a federal reporting system for St. Kitts and Nevis have been discussed but are not yet realized (S. Heyliger, pers. comm., St. Kitts Fisheries Department, February 2013). It is unclear at this time whether both islands report separately to the FAO. Evidently there is a lack of trust between the fisheries departments of St. Kitts and Nevis, and information sharing is strained. A key objective is recognizing that reliable data and information are imperative for developing appropriate guidance for small-scale fisheries development (FAO 2013) and has yet to be achieved in St. Kitts and Nevis.

Our reconstructed catches were over 2 times the adjusted landings reported by the FAO on behalf of St. Kitts and Nevis over the 1950-2010 time period. There is also a small export market which was not addressed in the reconstruction. Our reconstructed catch used the reported FAO breakdown as a starting point, as such, only minor improvements to the reported taxonomic breakdown was achieved. Given that no quantitative catch composition data were available, our reconstruction is the best representation of total catches made by St. Kitts and Nevis at present.

Acknowledgements

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector, for St. Kitts and Nevis, 1950-2010.

Year	FAO landings	Reconstructed total catch	Artisanal	Subsistence	Recreational
1950	300	1,210	121	1,090	0.000
1951	300	1,260	138	1,118	0.004
1952	300	1,300	155	1,145	0.007
1953	400	1,340	172	1,171	0.011
1954	400	1,390	191	1,197	0.015
1955	500	1,430	210	1,222	0.019
1956	400	1,460	228	1,233	0.023
1957	500	1,520	250	1,269	0.028
1958	500	1,550	269	1,279	0.032
1959	600	1,560	285	1,271	0.037
1960	600	1,560	300	1,262	0.041
1961	600	1,570	316	1,254	0.046
1962	600	1,590	335	1,258	0.051
1963	700	1,570	345	1,227	0.057
1964	700	1,550	354	1,196	0.062
1965	700	1,530	364	1,166	0.067
1966	800	1,510	373	1,136	0.073
1967	800	1,490	381	1,106	0.079
1968	800	1,470	389	1,077	0.085
1969	800	1,450	397	1,048	0.091
1970	1,000	1,420	404	1,020	0.097
1971	1,000	1,400	411	992	0.103
1972	1,000	1,380	418	964	0.109
1973	1,000	1,360	424	937	0.116
1974	1,000	1,340	430	910	0.123
1975	1,200	1,320	436	883	0.130
1976	1,212	1,300	441	857	0.136
1977	1,192	1,280	446	831	0.144
1978	1,173	1,260	450	806	0.151
1979	1,183	1,260	484	781	0.255
1980	1,161	1,240	485	756	0.255
1981	1,141	1,260	506	752	0.286
1982	1,177	1,270	517	748	0.283
1983	1,157	1,250	522	732	0.283
1984	1,059	1,240	535	706	0.333
1985	963	1,240	554	681	0.402
1986	869	1,250	584	670	0.486
1987	774	1,270	616	658	0.577
1988	675	1,280	628	647	0.601
1989	576	1,280	640	635	0.623
1990	479	1,280	658	624	0.669
1991	385	1,300	690	611	0.772
1992	288	1,310	711	599	0.833
1993	250	1,290	706	587	0.798
1994	212	1,320	739	575	0.908
1995	192	1,270	707	564	0.768
1996	352	1,280	728	553	0.829
1997	216	1,290	746	543	0.878
1998	398	1,290	759	526	0.937
1999	471	1,320	773	544	0.853
2000	470	1,340	782	561	0.750
2001	556	1,390	811	574	0.724
2002	355	1,400	825	571	0.708
2003	400	1,450	889	561	0.929
2004	470	1,570	993	572	1.205
2005	459	1,610	1,039	569	1.310
2006	446	1,640	1,072	566	1.363
2007	433	1,630	1,068	562	1.263
2008	420	1,610	1,047	558	1.091
2009	407	1,620	1,068	554	1.091
2010	392	1,630	1,083	545	1.091

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa, for St. Kitts and Nevis, 1950-2010. 'Others' represents 9 additional taxonomic categories.

Year	Serranidae	Scaridae	Lutjanidae	Exocoetidae	Belonidae	*Strombus* spp.	Acanthuridae	Mullidae	Holocentridae	*Panulirus* spp.	Others
1950	218	163	163	45	44	83	87	87	76	37	207
1951	225	169	169	47	46	86	90	90	79	39	216
1952	233	175	174	49	48	89	93	93	81	40	224
1953	239	180	179	54	51	92	96	96	84	42	232
1954	246	185	184	56	53	95	99	98	86	44	241
1955	252	190	188	62	56	98	102	101	88	46	248
1956	258	194	193	60	56	100	104	103	91	47	255
1957	267	201	199	67	60	104	108	107	94	49	265
1958	271	204	202	68	62	105	110	108	95	50	271
1959	270	204	200	75	65	106	110	108	95	51	272
1960	271	204	201	76	66	106	110	108	95	51	274
1961	271	205	201	77	67	107	111	108	95	52	276
1962	275	207	204	79	68	108	112	110	96	53	281
1963	267	202	197	87	71	106	110	107	94	53	277
1964	263	199	193	87	71	105	108	105	92	53	274
1965	258	195	190	88	71	103	107	103	91	52	272
1966	250	190	182	98	76	102	104	99	88	52	267
1967	245	186	178	99	76	100	103	97	86	52	264
1968	240	183	175	100	76	99	101	95	85	51	262
1969	235	179	171	101	76	97	99	93	83	51	259
1970	222	170	158	125	88	96	96	88	78	51	253
1971	216	167	154	127	88	94	94	86	77	51	250
1972	211	163	149	130	89	92	93	84	75	50	246
1973	206	159	145	132	90	91	91	81	73	50	243
1974	201	155	141	134	90	89	89	79	71	50	240
1975	187	147	128	157	102	88	86	74	67	50	234
1976	183	143	125	157	101	86	84	72	65	49	232
1977	179	140	121	157	101	85	83	70	64	49	229
1978	174	137	118	157	100	83	81	68	62	49	226
1979	170	134	115	156	99	81	79	67	61	56	246
1980	166	131	112	155	99	80	78	65	59	55	241
1981	167	131	112	159	100	81	78	65	60	57	249
1982	167	132	112	162	102	81	79	65	60	57	249
1983	165	130	110	163	102	80	78	65	59	57	246
1984	162	128	109	155	98	79	76	64	58	59	252
1985	164	129	112	138	89	77	75	65	59	63	265
1986	171	132	119	119	80	77	76	67	61	69	284
1987	178	137	127	99	70	76	77	70	63	74	304
1988	185	141	134	78	59	76	78	74	65	75	310
1989	193	145	143	56	48	76	79	77	68	76	315
1990	196	147	146	46	43	76	79	78	69	79	324
1991	186	141	136	69	54	75	77	74	65	85	339
1992	175	135	125	94	67	75	76	70	62	88	345
1993	173	133	124	96	68	74	75	69	61	85	335
1994	169	130	119	105	72	74	74	67	60	92	353
1995	104	91	52	273	156	74	65	39	39	82	296
1996	85	92	41	233	172	74	59	59	41	85	341
1997	84	67	34	222	166	73	52	82	38	88	383
1998	82	66	38	219	178	72	52	70	36	90	382
1999	95	74	50	214	176	76	55	62	44	86	385
2000	99	67	55	235	187	80	49	77	46	81	367
2001	102	85	51	286	194	83	55	56	40	81	351
2002	90	74	48	258	181	84	52	65	50	80	414
2003	102	103	82	200	124	84	60	58	73	94	471
2004	92	135	113	152	83	87	75	106	88	112	525
2005	85	133	109	166	101	89	72	88	93	119	555
2006	85	130	102	171	115	90	72	84	100	123	565
2007	86	127	97	176	130	91	74	83	108	117	542
2008	86	122	89	182	148	92	76	86	114	107	504
2009	88	114	80	188	167	93	78	94	117	108	495
2010	89	107	73	193	188	94	80	105	118	108	473

Reconstructing Singapore's marine fisheries catch, 1950-2010[1]

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Abstract

This contribution presents a reconstruction of the marine fisheries catch by Singaporean fishers around Singapore, i.e., within what is now the Exclusive Economic Zone (EEZ) of Singapore (i.e., the 'inshore fishery'), and in the Malaysian EEZ and beyond. Reconciled data from various sources suggest that the marine fisheries of Singapore (including time series estimates of unreported subsistence and recreational catches) peaked above 30,000 $t \cdot year^{-1}$ in the early to mid 1980s, and then rapidly declined, with commercial activity in the 2000s yielding one tenth of their previous maximum.

Introduction

Singapore is a small island state located at the tip of the Malaysian Peninsula, in the Southern South China Sea (Figure 1). Formerly a British colony, Singapore, upon independence from Britain (in 1963) joined with present-day Malaysia the former 'Federation of Malaya', which it left in 1965.

Le Mare (1949) reported that the fishing industry of Singapore started rebuilding soon after the WWII Japanese occupation ended. Work was then focused on establishing effective service and information recording (e.g., licensing, number of fishers, prices) towards development of the fisheries, with the aim of providing for the growing population. Notably, the capacity for transporting catches was a concern, documented by their first known case of dumping catch back into sea (i.e., discarding).

A Fisheries Survey project was implemented starting in 1950, which addressed the issues of unmet fish demand, irregular supplies and quality, high prices, and to curtail the unfair practices that resulted in poor returns to fishers. Consequently, catch figures from Singapore's waters were made available, based on data gathering following a sound statistical design (Kesteven and Burdon 1952).

There were already signs of heavy exploitation of Singapore waters in the early 1950s, as the exceptional profitability of fishing in 1951 and early 1952 led to an intensification of fishing. However, catch did not increase correspondingly (Burdon 1952). Indeed, Burdon (1952) suggested that the maximum catch for Singapore's marine fishing grounds could not exceed 4,000 "long tons per annum."

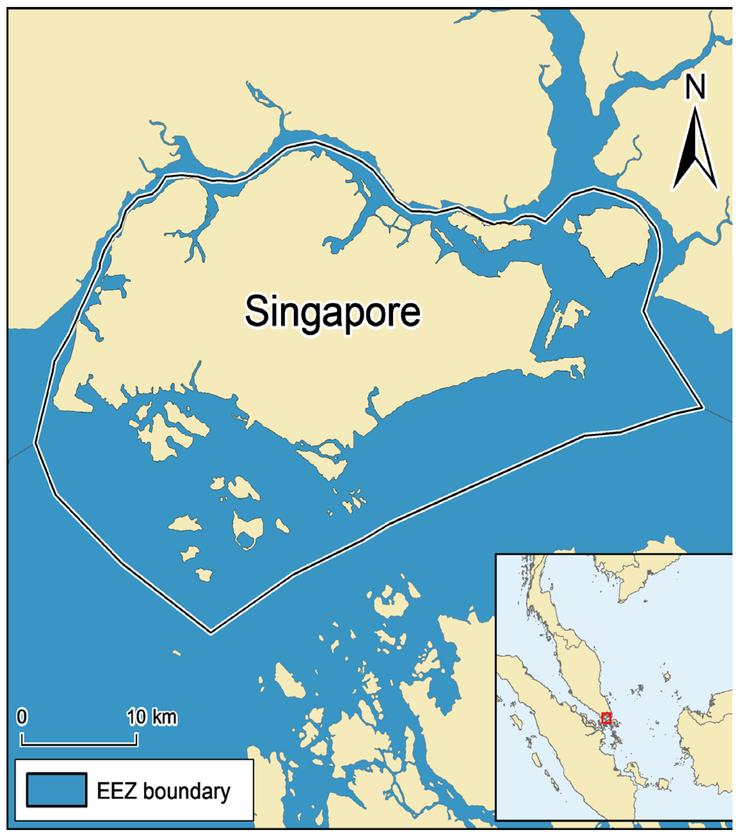

Figure 1. Exclusive Economic Zone (EEZ) for Singapore.

The fish survey project not only acquired detailed catch composition, number of fishers, fishing vessels and licensed gears by types (some of these data are now also available online), but also determined the importance of gear, depth, location as well as annual, lunar, daily and tidal cycles on Singapore's fishery and its productivity (Kesteven and Burdon 1952). Even low-value 'waste' (or 'trash') fish catches were reported, separately until 1956, before they were incorporated into the regular catch statistics. Thus, a practice of generating solid, quantitative data for the purpose of guiding the design, establishment, development and eventually management of the infrastructure of Singapore's fishing industry, attuned to its limiting factors (be these ecological, economic or political) was established early.

[1] Cite as: Corpus, L. (2014) Reconstructing Singapore's marine fisheries catch, 1950-2010. pp. 137-146. *In:* Zylich, K., Zeller, D., Ang, M. and Pauly, D. (eds.) Fisheries catch reconstructions: Islands, Part IV. Fisheries Centre Research Reports 22(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

The conflicts between the limited catch that could be extracted from Singapore's waters and the growing demand for fish in Singapore lead to an early geographic expansion of its marine fisheries. Thus, the report by Burdon (1952) mentions the exploitation by licensed Singaporean vessels of fishing grounds well outside of what was later to become Singapore's Exclusive Economic Zone (EEZ), notably off the Malaysian States of Johore and Trengganu. This included fishing for coral reef fishes with a very destructive method known as '*muro-ami*' (Butcher 2004) along the east coast of Peninsular Malaysia (which continued until 1959), and fishing for skipjack tuna (*Katsuwonus pelamis*) in the open waters of the southern South China Sea. This early, more or less spontaneous expansion later became explicit Government policy, along with an accelerated development of the aquaculture industry.

Table 1. National data sources with information on Singapore's fisheries catches.

Years	Primary sources	Complementary sources
1950 – 1952	Report of the Fisheries Department (Burdon 1951, 1952, 1953)	—
1953 – 1958	Report of the Fisheries Division (Singapore Department of Commerce and Industry 1955; Tham Ah Kow 1955; Singapore Department of Commerce and Industry 1956; Singapore Ministry of Commerce and Industry 1957, 1959)	—
1959	Report of Fisheries Division (Singapore Ministry of National Development 1961)	—
1960 – 1965	Review of the Primary Production Department (Singapore Primary Production Department 1966)	—
1966 – 1974	Primary Production Department Annual Report (Singapore Primary Production Department 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974)	—
1975 – 1999	Ministry of National Development Annual Report (Singapore Ministry of National Development 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1987, 1988, 1989, 1990, 1991)	Yearbook of Statistics (Singapore Department of Statistics 1974-75, 1975-76, 1976-77, 1977-78, 1978-79, 1979-80, 1980-81, 1981-82, 1982-83, 1983-84, 1985-86, 1986, 1987, 1988, 1989, 1990, 1991, 1996)
1976 – 2005	Southeast Asian Fisheries Development Center (http://fishstat.seafdec.org/; last accessed 12 July 2013)	—
2006–2007	Agri-Food & Veterinary Authority of Singapore (AVA).	www.ava.gov.sg/; last accessed 27 June '13; data for 2000-2011.

Time series data on marine capture fisheries landings in Singapore (1950-2010) were obtained from FAO, Southeast Asian Fisheries Development Center (SEAFDEC) and national publications (Table 1). Information in national publications is also helpful in identifying catches originating from within and outside the Singaporean EEZ. However, the available time series differ from each other (Figure 2), and thus require harmonization. This study, thus, aims at reconciling the available catch time series and, in the process, generate a credible catch time series of Singapore's marine capture fisheries within and outside of its EEZ.

Materials and Method

Singapore's population

Estimates of the population sizes of Singapore for 1960-2012 was downloaded from the World Bank online databank[2] and used for this contribution. Population sizes for 1950-1959 were estimated using interpolation based on data from the World Bank in addition to the census figures of Singapore for 1947 and 1957 (being 938,200 and 1,445,900 respectively).

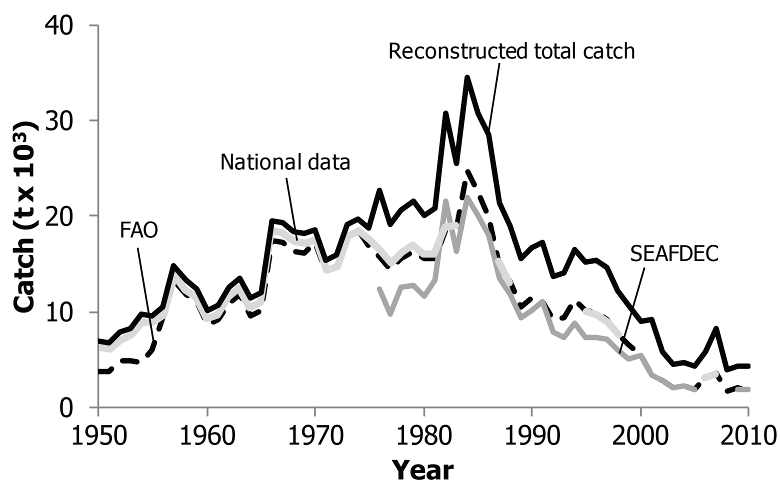

Figure 2. Reported and reconstructed catch for Singapore (including recreational and subsistence catches).

Fishery types

In this report, given the smallness of the Singaporean EEZ (Figure 1), 'inshore fisheries' are equivalent to small-scale fisheries within the EEZ of Singapore, while industrial fisheries are those that operate outside of the Singaporean EEZ. The inshore (or 'small-scale') fisheries are further subdivided into artisanal fisheries, which sell their catch to the market, recreational fisheries, where fishing is for pleasure, and subsistence fisheries, where catches are for the direct consumption of the fishers and their families. The small-scale fisheries uses mainly motorized crafts, with non-motorized units essentially phased out by the late 1990s (Table 2).

[2] http://databank.worldbank.org/data/home.aspx

Table 2. Details on Singaporean fishers, types and number of powered fishing, 1950-2010. Italicized values are interpolated.

Year	Licensed fishers	Recreational fishers	Subsistence fishers	Non-powered boats	Powered boat (GT)							Total Inboard powered boats	No. of powered boats engaged in fishing
					Outboard	Inboard							
						≤ 30	30-45	45-75	>75				
1950	4,488	24,151	3,372	1,831	15	154	15	-	-			184	33
1951	4,492	24,702	2,812	1,933	80	173	-	1	-			254	129
1952	4,483	25,266	2,787	2,047	355	198	3	3	1			560	378
1953	5,498	25,843	3,786	2,432	346	188	5	7	-			546	373
1954	5,550	26,434	3,756	2,572	327	166	7	6	-			506	351
1955	5,356	27,037	3,517	2,402	382	154	6	5	-			547	411
1956	5,330	27,655	3,355	2,209	393	153	7	4	-			557	434
1957	5,261	27,372	3,184	2,112	488	146	6	4	-			644	435
1958	5,203	28,932	3,001	2,059	620	149	6	5	-			780	584
1959	5,166	29,593	2,870	1,904	639	143	5	6	-			793	636
1960	4,831	31,159	2,637	1,774	603	151	4	9	-			767	611
1961	4,439	32,220	2,936	1,579	526	157	4	8	-			695	566
1962	4,296	33,128	2,899	1,407	486	171	5	11	-			673	584
1963	4,066	33,980	2,863	1,255	456	174	3	11	-			644	561
1964	3,858	34,870	2,827	1,148	454	169	4	12	-			639	578
1965	3,735	35,722	2,792	1,088	434	174	4	11	-			623	576
1966	3,954	36,611	2,757	1,014	442	238	4	12	-			696	655
1967	4,105	37,444	2,722	990	477	237	4	14	-			732	703
1968	3,861	38,088	2,688	890	474	233	5	14	-			726	697
1969	1,314	38,675	2,655	347	307	220	20	16	2			565	542
1970	1,919	39,281	2,621	361	298	232	21	8	19			578	558
1971	2,209	40,000	2,589	221	289	-	-	283	-			572	565
							≤ 100	≤ 150	≤ 200	≤ 300	>300		
1972	2,265	40,738	2,556	241	277	208	40	3	-	5	2	535	523
1973	2,277	41,514	2,524	287	284	194	42	3	-	5	1	529	518
1974	*2,133*	*42,215*	*2,493*	*252*	269	188	43	3	-	5	1	509	504
1975	*2,133*	*42,840*	*2,461*	*252*	-	-		-	-	-	-	-	517
1976	1,988	43,407	2,431	216	265	50	160	13	2	-	3	493	490
1977	2,078	44,013	2,400	197	289	51	183	13	2	-	1	539	529
1978	2,084	44,562	2,370	173	303	54	191	19	2	-	-	569	563
1979	2,114	45,130	2,341	139	300	50	173	14	4	-	5	546	546
1980	2,025	45,698	2,311	130	290	50	46	16	4	-	6	412	536
1981	2,019	47,951	2,282	129	317	49	137	15	2	-	6	526	392
1982	1,794	50,109	2,254	100	330	49	123	14	2	-	4	522	523
1983	1,641	50,752	2,226	56	285	35	122	12	1	-	5	460	451
1984	1,446	51,718	2,198	40	275	29	122	11	2	-	4	443	509
1985	1,321	51,794	2,170	31	243	25	125	13	3	-	6	415	329
1986	1,250	51,737	2,143	22	240	18	124	15	2	-	2	401	420
1987	1,154	52,532	2,116	17	-	18	100	12	1	-	3	134	379
1988	1,208	53,876	2,090	17	233	16	101	11	4	-	4	369	364
1989	987	55,485	2,064	14	186	14	104	11	2	-	4	321	323
1990	832	57,681	2,038	11	201	16	94	11	2	-	4	328	325
1991	832	59,349	2,012	11	184	16	89	9	2	-	4	304	300
1992	747	61,159	1,987	11	179	17	85	8	1	-	2	292	285
1993	617	62,726	1,962	9	162	16	78	9	1	-	1	267	263
1994	527	64,723	1,938	7	151	15	69	8	1	-	1	245	236
1995	394	66,720	1,913	5	145	15	67	9	1	-	-	237	238
1996	447	69,488	1,890	6	146	17	61	8	-	-	-	232	232
1997	476	71,860	1,866	5	142	17	63	8	-	-	-	230	140
1998	289	74,344	1,843	5	139	15	45	7	-	-	-	206	220
1999	277	74,940	1,819	2	126	15	41	6	-	-	-	188	188
2000	254	76,250	1,797	-	122	12	34	6	-	-	-	174	174
2001	221	78,334	1,774	-	115	10	21	5	-	-	-	151	151
2002	171	79,053	1,752	-	116	8	20	2	-	-	-	146	125
2003	172	77,895	1,730	-	117	5	21	-	2	-	-	145	145
2004	148	78,877	1,708	-	121	5	19	-	2	-	-	147	147
2005	112	80,753	1,687	-	118	5	21	-	2	-	-	146	146
2006	122	83,320	1,666	-	125	6	12	-	-	-	-	144	144
2007	122	86,864	1,645	-	88	2	4	-	-	-	-	94	94
2008	*60*	*91,612*	*1,625*	-	38	3	5	-	-	-	-	46	46
2009	45	94,417	1,604	-	-	-	-	-	-	-	-	-	36
2010	*49*	*96,104*	*1,584*	-	-	-	-	-	-	-	-	-	39

Commercial (artisanal and industrial)

Resources accessed for catch information, fisheries related development and political activities are available to the public through the National Library of Singapore or through the Internet. Sources used to complement the main data sets other than the FAO FishStat database are presented in Table 1. Other species composition data from 1976 onwards are available online through the website of the Southeast Asian Fisheries Development Center (SEAFDEC).[3] However, it could not be ascertained if local catch composition data for 1950 to 1975 have survived the successive transfers of the former Fisheries Department and its changes in strategy (see www.ava.gov.sg/AboutAVA/History/ accessed 18 March 2012). Currently the different components of the former Fisheries Department are subsumed under the Agri-Food & Veterinary Authority of Singapore (AVA).

Discards

The quantities of landed 'waste' or 'trash' fish, defined as fish used as animal feed and fertilizers in Burdon (1952), or as "small, low-valued species" in Sinoda *et al*. (1978) were published for the years 1950-1956 and 1974-1975 (Table 3). Data on 'waste' fish were added when available, and interpolated between years when they were not, and weight units, reported in 'long tons' until 1968, were all converted to (metric) tonnes. Data reported by Sinoda *et al*. (1978) for 1974-75 were portions of trawl catches only such that their proportions in relation to the total (1974, reconstructed; 1975, national) catch data for the years in question were calculated. Likewise, 1950-1956 figures were converted into proportions of total catch for their respective years, such that a mean 'waste' fish component could be calculated. Then, the resulting mean was multiplied by the values reported for '*marine fishes nei*' for the rest of the years to distinguish between '*marine fishes nei*' and '*marine fishes nei (waste)'*.

Table 3. Amount of so-called 'waste' fish that was landed in Singapore, 1950– 1975 for use as animal feed or fertiliser.

Year	Amount (t)	Source
1950	2,670	Burdon (1951)
1951	1,849	Burdon (1952)
1952	1,486	Burdon (1953)
1953	1,919	Tham Ah Kow (1955)
1954	2,615	Singapore Department of Commerce and Industry (1955)
1955	2,709	Singapore Department of Commerce and Industry (1956)
1956	3,641	Singapore Ministry of Commerce and Industry (1957)
1974	1,574	Sinoda *et al.* (1978)*
1975	1,156	—

* The amounts reported by Sinoda *et al.* (1978) pertain only to Kangkar fish market, which was, however, a major fish landing site.

Due to the early and detailed focus of Singapore authorities and fisheries on optimizing the utilization of resources, Singapore fisheries utilised and landed non-targeted by-catch efficiently, resulting in the virtual absence of discarding, so common in other fisheries and countries. Thus, no discards could be estimated here. While these landed and utilized 'waste' fish were nationally recorded, this study suggests these data were not incorporated into the data Singapore reported to the FAO.

Taxonomic composition (excluding discards)

The commercial reconstructed catches were disaggregated into taxa by maintaining the available inshore (artisanal) and offshore (industrial) catch compositions, and interpolating for years where this information was unavailable.

No national data were found on the taxonomic composition of marine fisheries catches for 1953-1955, and thus the mean catch composition for 1950-1952 was used for these years, as this was more detailed than FAO data for 1953-1955. FAO's taxonomic catch composition was used to disaggregate, for each year from 1956 to 1975 the highest of either Singapore national data or FAO data. From 1976-onwards, FAO and SEAFDEC data were used and compared to each other. Catches of taxa unique to each data set were adopted as presented. For taxa occurring in both sets of statistics, the higher value was used for reconstructing the amounts of each taxonomic category.

Exceptions were made when the catches were unusually low compared with preceding and succeeding entries (1980, artisanal; 1987, industrial; 1989, artisanal), i.e., when the number of fishers and fishing vessels indicated it was better to replace them also with interpolated values; also the catch composition for 2007 was used for 2008.

The number of commercial crabbers from 1971-2010 was set as the mean of crab licenses issued from 1950 to 1970 making it possible for '*Indo-Pacific swamp crab*' and *'marine crabs nei'* catches in the time series to be estimated for missing years (mainly in the first half of the series) using a regression of crab catch against number of reported crab licenses in the later years.

Recreational fishing

Weekends and public holidays are the usual days for recreational fishing in Singapore. For example, in June 2013, a photograph of a 40 kg giant trevally (*Caranx ignobilis*) caught and released within the local waters of Singapore was posted.[4] The earliest report of recreational fishing found in the present study was a feature in '*The Straits Times*', 24 July 1938, mentioning catches of almost 100 catties (60.5kg) from Singapore Straits. Highlights of the

[3] http://fishstat.seafdec.org/

[4] http://www.fishingkaki.com/forum/viewtopic.php?t=244278

day's catch were a 24 lbs (10.8 kg) bass and an 8 lbs painted sweetlip (3.6 kg). Presently, boats vary from 23 ft fiberglass open deck (outboard) to 53 ft wooden (inboard) boats[5] and they can be chartered for fishing any day of the week. Average number of anglers that could be taken is 8. Up to 50 boats with anglers may be seen around Singapore on weekends.[6] On 31 January 1971, the *The Straits Times* columnist Clement Mesenas wrote that 40,000 of Singapore's population of two million people are anglers of one kind or other.

The recreational catch of Singapore was estimated by combining information gathered from two fishing supplies stores with information from the websites of fishing interest groups in Singapore (Table 4). Photographs found within these websites (posted within the years 2009-2013 by months) that had fish from which the length could be estimated were selected (n =450), the fish they displayed were measured, and length-weight relationships (from www.fishbase.org) were used to compute individual weights. Data generated from the photos were used to determine a mean monthly catch estimate (n=19). To generate an annual catch estimate, mean monthly catch was multiplied by the number of charter boats (n=50), months in a year (n=12), and then doubled to provide for shore/beach catches, as the managers of fishing supplies stores interviewed estimated that the number of boat-based fishers is twice the number of regular shore-based fishers and equal to the number of irregularly fishing shore-based fishers. Finally, the numbers of recreational fishers from 1950 through 2010 were estimated by interpolation using the published 40,000 anglers in 1971 as anchor point, related to the population size of Singapore from 1950 to 2010.

Table 4. List of most accessible fishing interest groups in Singapore on the internet. Web addresses last accessed 5 August 2013.

Organization	Website	Members	No. of discussion threads		
			Total	Marine fishing	Crabbing[a]
Fishing Kakis	www.fishingkaki.com/	406,739	1,066,343	8,080	287
Singapore Bikers	www.singaporebikes.com/forums/archive/index.php/t-149965.html	225	612	5	2
Wat the Fish	www.wat-the-fish.com/search.php?searchid=206010	2,778	14,252	-	14
Go fishing	www.gofishing.sg/index	692	1,679	173	
Handline Fishing	http://forums.handlinefishing.com	717	2,003	475	25
Sum				8,733	328

[a]Proportion of crabbing to marine fishing topics (P) equals 0.0376.

The annual recreational catch estimated for 2009-2012[7] was divided by the mean of the number of fishers estimated above to generate an estimated catch per recreational fisher. This estimate of individual recreational fish catch was in turn multiplied with the estimated number of recreational fishers for each year from 1950-2010 to generate the recreational catch data series. Crab catch reports were available from postings of shore/beach fishers. Production of a recreational crabber was set at 10% of a commercial crabber following a comment that suggests commercial crabbers deploy at least 50 traps while recreational crabbers deploy 4-6 traps.[8] The number of recreational crabbers was estimated by first determining the proportion of online discussion threads on crabbing in relation to those on total marine fishing (*P*; bottom of Table 4). The proportion (*P*) was applied to the mean number of fishers in 2009-2012, and their catch was extended backward to 1950 in the same manner as the recreational fish catch.

Taxonomic composition

The taxonomic composition of the estimated recreational catch was assumed to be the same as that of the inshore commercial catch for the corresponding years (but without '*Indo-Pacific swamp crab*' and '*marine crabs nei*').

Subsistence fishing

Estimation of subsistence catch for Singapore was made possible by the link between subsistence fishers and non-powered vessels mentioned by the Singapore Ministry of Commerce and Industry (1957) and by the reported catches of 'minor gears' by the Singapore Primary Production Department (1966) for the years 1966-1972 (Table 2). The numbers of fishers using non-powered boats (i.e., subsistence fishers) for 1950-2010 were estimated using a spreadsheet growth function anchored in data gathered from 1951-1960. The percentage contribution to catches by minor gears for the years 1966-1972 were averaged, and the mean (4.35%) was then used to infer the catch of minor gears for the rest of the years in the series 1950-2010 from the reconstructed inshore catch values.

The subsistence catch was then calculated for the years 1951-1960 by multiplying the annual percentage of catch with minor gears (1951-1960) thus estimated by the fraction of subsistence catch to minor gears. A regression between catch by subsistence fishing and number of subsistence fishers for the period 1951-1960 was then performed and used to complete data for 1950-2010.

Taxonomic composition

The taxonomic composition of the subsistence catch was assumed to be the same as the reconstructed catch of the inshore (artisanal fishery).

5 http://www.handlinefishing.com/whosfishing/fishingcharters.htm
6 http://news.xin.msn.com/en/singapore/sport-fishing-gaining-popularity-in-singapore
7 http://databank.worldbank.org/data/views/reports/tableview.aspx
8 http://www.fishingkaki.com/forum/viewtopic.php?t=170558&highlight=crabbing

Results and Discussion

Reconstructed total catches during the period 1950-2010 were estimated at 893,000 t, which is 1.3 times the reported landings of 662,000 t as presented by the FAO, on behalf of Singapore. Reconstructed total catches averaged 8,130 t·year^{-1} in the early 1950s, steadily increased to a peak of 34,600 t in 1984 and subsequently declined to 5,130 t·year^{-1} in the late 2000s. Examining reconstructed total catches of Singapore by sector, industrial catches dominated with nearly 49% (all of which is taken outside the EEZ), while artisanal and recreational catches comprised approximately 42% and 8%, respectively (Figure 3a). Subsistence catches contributed the lowest proportion at 1% (Figure 3a).

The reconstruction, by accounting for industrial, recreational and subsistence catches, added on average about 50% to the reported landings data (Figure 2). Exclusive of recreational and subsistence catches, i.e., essentially a reconciliation of national data, FAO and SEAFDEC data, the reconstruction added on average about 30%. The differences between published and reconstructed data were greatest with SEAFDEC, and this was persistent throughout the time series (Figure 2).

The 'waste' fish which was separately reported by Singapore until 1956 (Table 3) accounts for the very visible difference between the FAO and national catches (Figure 2) for the early period of the time series. Thus, fish caught and retained for animal feed or fertiliser were not accounted for in national data reported to the FAO. For the period 1957-1975, Singapore's catch sums were consistently higher than FAO's. Also, from 1950-52, there were 24-26 taxonomic categories listed in the catch composition whereas FAO's lists only 5 taxa for the same period.

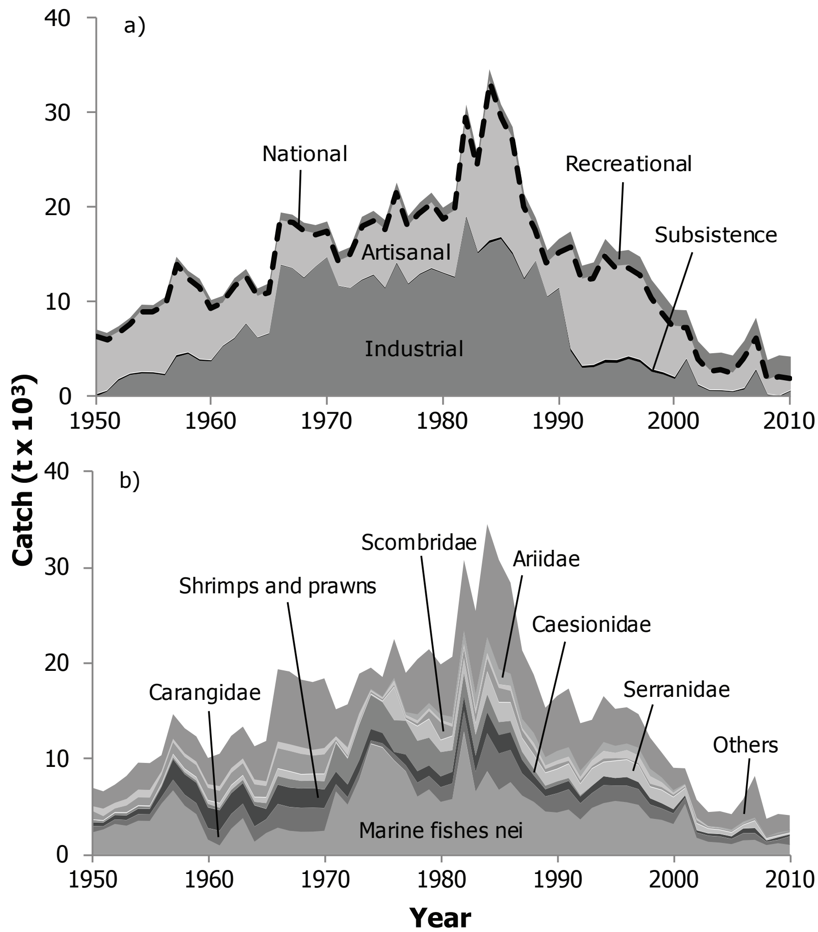

Figure 3. Reconstructed total catches of Singapore from 1950-2010, a) by fishing sectors, where artisanal, subsistence and recreational are deemed to occur within Singapore's EEZ, while industrial occurs outside their EEZ, mainly in neighbouring Malaysia and Indonesia. Data reported by FAO are overlaid as line graph; and b) by families, showing the 10 most abundant families individually, with the 'others' group accounting for 31 minor taxonomic categories.

Most of the high catch figures were reported around the first half of 1980s, including FAO's maximum value of 24,686 tonnes in 1984, which coincides with a period featuring relatively high numbers of fishing units in the range of 100 – 500 tons (Table 2).[9] Figure 3a shows commercial fisheries catches declined from 1984 on, and by 2008 reached levels below the catch of 1950, when the largest vessels were 45 tons (Burdon 1951). The decline in catches corresponds both to the decrease in the number of fishers and fishing vessels (Table 2). The small peak in 2007 is due to an exceptionally large inshore catch of blood cockles. The decline of catches, along with the decline in the number of fishers and fishing vessel from 1984 onwards (Table 2) suggests that fishing around Singapore and beyond ceased to be a profitable activity, given the state of the resource base. Furthermore, the declining catches may also suggest that the growing land-based economy of Singapore offered more interesting opportunities for investments and employment.

The number of recreational fishers, however, can be expected to continue growing. It was even reported that some 950 recreational sized speedboats were sold in 2012, about 200 more than in 2011.[10] The growing significance of marine recreational catches could be seen in Figure 3a as their amounts complement the commercial production for a sum of catches that hovered above 4,000 t. As expected, given the assumed trend in the number of recreational fishers (Table 2) and their assumed constant individual catch, the lowest and highest estimated recreational catch of 539 t and 2,137 t were obtained for 1950 and 2010, respectively.

The disappearance of non-powered boats by the early 2000s (Table 2) also means the disappearance of official records for subsistence fisheries. Nevertheless, online postings on "catching crabs after work" were found[11] together

[9] See also http://fishstat.seafdec.org/statistical_bulletin/mf_boat_action.php (last accessed 11 June 2013).

[10] http://news.xin.msn.com/en/singapore/sport-fishing-gaining-popularity-in-singapore

[11] http://www.fishingkaki.com/forum/viewtopic.php?t=102152&highlight=crabbing

with the author's personal knowledge of heads of families regularly fishing for their family`s consumption. However, it is difficult to differentiate recreational from subsistence fishing, especially for recent times, where the difference between personal drivers of 'pleasure' versus 'food needs' is increasingly blurred. Several anglers armed only with very basic fishing rods or simple baited lines tied to railings, trees or shrubs were seen during the field interviews conducted by the author. They generally avoided communication when approached because of language differences. Those willing to communicate did confirm that catches will be for personal consumption, that average catch is 3-6 fish, mostly sea catfish. This suggests continuation of subsistence fishing (Figure 3a, Table 2), although numbers of subsistence fishers is declining. Both the highest (199 t·year^{-1}) and lowest (88 t·year^{-1}) estimated subsistence catch were obtained for the 1950s. Estimated catches after 1957 were always above 100 t·year^{-1} and the number of subsistence fishers in 2010 was estimated to still be above 1,500. In contrast to many southeast Asian countries, the trend in subsistence catches was not consistent over time.

Fisheries catches of Singapore were dominated by 'marine fishes nei' (31%) and Carangidae (9.3%). Shrimps and prawns (7.5%), fusiliers (Caesionidae; 10%), groupers (Serranidae; 5.8%) and tuna (Scombridae; 5.0%) also contributed a significant portion to total catches. Clupeids, a small, schooling pelagic species (3.1%) and catfish (Arridae; 3.0%) were common as well. The remainder of the taxonomic composition comprised 31 families and contributed 29% to the total reconstructed catches (Figure 3b).

The presence of significant fractions of 'marine fishes nei' and 'marine fishes nei (waste)' illustrates the fact that a detailed taxonomic resolution down to the level of family or even species cannot be easily achieved, even by a statistical system as efficient as Singapore's. Overall, official marine capture fisheries data from within Singapore waters showed that catches did exceed the 4,000 "long tons per annum" estimated a sustainable by Burdon (1952) and that this development was possible because of the sound foundations set by the leadership of the Fisheries Department of the then Colony of Singapore.

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Appendix Table A1. FAO vs. reconstructed total catch (in tonnes), and catch by sector for Singapore, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational
1950	3,800	7,080	7	6,310	226	539
1951	3,800	6,690	544	5,510	88	552
1952	4,800	7,390	1,712	4,970	147	563
1953	4,800	8,300	2,310	5,290	125	575
1954	4,700	9,680	2,463	6,480	147	588
1955	5,900	9,640	2,448	6,450	137	602
1956	9,300	10,460	2,274	7,440	135	616
1957	13,300	14,750	4,194	9,750	197	609
1958	11,800	13,280	4,527	7,960	150	644
1959	11,000	12,420	3,796	7,820	146	658
1960	8,700	10,170	3,739	5,630	110	693
1961	9,200	10,610	5,296	4,530	74	717
1962	10,800	12,480	6,114	5,550	88	738
1963	11,800	13,450	7,655	4,960	76	757
1964	9,600	11,390	6,190	4,370	58	777
1965	10,200	11,950	6,627	4,460	66	796
1966	17,500	19,440	13,855	4,710	60	816
1967	17,200	19,210	13,525	4,800	48	834
1968	16,400	18,360	12,481	4,950	83	849
1969	16,100	18,100	13,680	3,510	50	864
1970	17,301	18,490	14,661	2,900	54	876
1971	14,303	15,260	11,652	2,680	40	887
1972	14,701	15,780	11,419	3,410	45	905
1973	17,802	18,980	12,265	5,710	79	923
1974	18,558	19,610	12,792	5,790	86	938
1975	16,929	18,630	11,411	6,180	92	952
1976	15,743	22,600	14,017	7,510	115	965
1977	14,352	19,070	11,842	6,160	89	977
1978	15,572	20,490	12,880	6,530	92	992
1979	16,331	21,540	13,468	6,970	94	1,004
1980	15,481	19,950	13,014	5,840	80	1,016
1981	15,531	20,750	12,559	7,030	97	1,067
1982	18,560	30,870	18,872	10,720	156	1,116
1983	18,817	25,530	15,121	9,150	135	1,132
1984	24,686	34,610	16,222	16,960	268	1,161
1985	22,411	30,880	16,626	12,880	214	1,159
1986	19,939	28,490	14,999	12,130	207	1,156
1987	14,839	21,420	12,385	7,730	138	1,169
1988	13,152	18,880	14,275	3,350	58	1,197
1989	10,587	15,430	10,510	3,610	71	1,233
1990	11,432	16,650	11,400	3,880	84	1,282
1991	11,068	17,430	4,838	11,020	239	1,326
1992	9,178	13,810	3,053	9,180	211	1,366
1993	9,280	14,160	3,125	9,400	238	1,400
1994	11,278	16,630	3,601	11,280	308	1,446
1995	10,102	15,310	3,569	9,940	306	1,488
1996	9,943	15,470	3,977	9,660	283	1,548
1997	9,250	14,750	3,636	9,250	263	1,602
1998	7,733	12,300	2,639	7,730	265	1,661
1999	6,489	10,740	2,353	6,490	225	1,670
2000	5,371	9,150	1,885	5,370	191	1,701
2001	3,342	9,090	3,884	3,340	123	1,743
2002	2,769	5,810	1,175	2,770	109	1,761
2003	2,085	4,520	622	2,090	82	1,732
2004	2,173	4,610	600	2,170	88	1,754
2005	1,920	4,300	506	1,920	81	1,796
2006	3,103	5,870	785	3,100	129	1,854
2007	3,522	8,290	2,735	3,480	146	1,930
2008	1,623	3,820	176	1,540	70	2,038
2009	2,121	4,320	-	2,120	99	2,102
2010	1,732	4,180	598	1,390	64	2,137

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for Singapore, 1950-2010. 'Others' contain 31 additional taxonomic categories.

Year	Marine fishes not identified	Carangidae	Shrimps and prawns	Caesionidae	Serranidae	Scombridae	Clupeidae	Ariidae	Others
1950	2,380	659	386	196	28	933	526	49	1,920
1951	2,700	312	381	129	41	441	787	88	1,810
1952	3,270	455	449	166	63	400	624	58	1,900
1953	3,090	574	476	192	53	731	690	86	2,400
1954	3,600	668	560	224	61	851	804	100	2,810
1955	3,590	665	557	223	61	848	800	100	2,800
1956	5,370	671	1,045	112	224	895	448	-	1,700
1957	6,750	1,107	2,106	221	332	1,218	443	-	2,570
1958	5,170	1,124	2,117	225	337	1,236	450	-	2,620
1959	4,290	1,130	2,114	226	339	1,243	452	-	2,630
1960	1,650	1,176	2,145	353	353	1,293	470	-	2,740
1961	1,040	1,509	2,124	232	464	1,277	580	-	3,380
1962	2,780	1,507	2,152	348	464	1,276	580	-	3,370
1963	3,880	1,484	2,130	342	457	1,256	571	-	3,320
1964	1,430	1,554	2,188	359	478	1,315	598	-	3,470
1965	2,340	1,402	1,082	584	584	1,168	584	-	4,210
1966	2,890	2,441	2,010	888	777	2,108	777	-	7,560
1967	2,570	2,454	2,017	893	781	2,120	781	-	7,600
1968	2,460	2,462	2,016	783	671	2,126	783	-	7,060
1969	2,470	2,475	2,023	787	675	1,912	675	-	7,080
1970	2,560	2,350	1,922	855	748	2,030	748	-	7,280
1971	6,640	750	1,304	2,999	107	214	321	107	2,820
1972	5,280	755	1,312	2,695	108	216	755	216	4,440
1973	7,910	748	1,215	3,741	107	214	748	214	4,080
1974	11,620	317	1,202	3,586	97	203	157	215	2,210
1975	11,240	392	1,088	3,257	88	184	142	195	2,040
1976	9,870	659	208	3,348	3,467	179	436	368	4,060
1977	8,740	627	1,114	3,557	106	196	248	385	4,100
1978	6,120	1,432	1,193	3,186	1,522	266	293	732	5,750
1979	6,850	1,388	1,098	2,921	1,946	793	276	643	5,620
1980	5,570	1,514	1,117	2,552	1,242	1,833	238	655	5,230
1981	5,860	1,609	1,199	2,269	1,477	949	294	811	6,290
1982	12,860	2,156	1,497	2,504	1,526	1,061	391	1,485	7,390
1983	6,620	2,056	1,676	2,218	1,192	948	505	1,628	8,690
1984	8,740	3,950	2,197	1,915	2,372	1,372	516	1,729	11,820
1985	6,810	3,769	1,940	1,374	2,060	1,481	368	1,662	11,420
1986	7,600	3,351	1,852	1,214	1,916	1,198	508	1,345	9,510
1987	6,210	2,294	1,411	872	1,417	785	221	1,064	7,140
1988	5,570	1,819	911	694	1,455	778	430	1,144	6,080
1989	4,560	1,554	740	370	1,331	380	356	966	5,160
1990	4,460	1,971	868	378	1,269	475	393	1,089	5,740
1991	4,770	2,088	869	309	1,471	296	420	1,084	6,120
1992	3,740	1,656	715	119	1,183	326	360	752	4,950
1993	4,940	1,522	742	25	1,774	228	605	371	3,950
1994	5,430	1,853	927	1	1,470	345	795	1,018	4,790
1995	5,660	1,584	784	1	1,783	265	548	819	3,860
1996	5,520	1,721	875	28	1,798	107	869	764	3,790
1997	5,250	1,622	720	10	1,747	195	811	890	3,500
1998	3,860	1,416	637	22	1,168	297	790	860	3,250
1999	3,690	1,169	535	16	1,344	285	507	594	2,590
2000	3,270	1,080	433	13	1,225	227	200	362	2,340
2001	5,350	619	254	1	716	158	186	194	1,620
2002	1,830	525	228	5	670	321	193	168	1,870
2003	1,420	620	227	4	433	120	88	159	1,450
2004	1,330	621	253	11	362	138	49	191	1,650
2005	1,180	523	259	17	327	124	27	241	1,600
2006	1,570	726	475	5	309	133	42	262	2,340
2007	1,620	694	517	3	706	171	6	224	4,350
2008	1,080	317	137	7	124	217	2	88	1,840
2009	1,270	333	255	7	101	215	2	199	1,940
2010	1,100	866	195	7	85	225	2	118	1,590

Reconstruction of total marine fisheries catches for the Republic of Vanuatu, 1950-2010[1]

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Abstract

Vanuatu is an archipelago with one of the lowest per capita consumption rates of seafood among the South Pacific islands. Despite this fact, seafood is still an important contributor to the Ni-Vanuatu diet and economy. The reconstruction of total marine fisheries catch of Vanuatu showed that the reconstructed total catches of 886,700 t were 9.5% higher than the 810,021 t reported by the FAO on behalf of Vanuatu for the period 1950-2010. However, if only small-scale catches are considered (i.e., large-scale tuna and shark fisheries are excluded), it is estimated that reconstructed catches (164,100 t) are 64% higher than the 99,842 t reported catches assumed to represent the small-scale sector. The subsistence sector was found to be most important amongst small-scale fisheries with almost 84% of the small-scale catches. Exports were estimated to contribute 4.1% to the small-scale catch and tourist consumption 1.7%.

Introduction

The Republic of Vanuatu (referred to hereafter as Vanuatu) is an archipelagic country consisting of 83 islands (63 permanently inhabited) in the southwestern Pacific Ocean between 13°-21°S and 166°-171°E (Figure 1). Neighboring countries include New Caledonia to the southwest, Fiji to the east and Solomon Islands to the northwest. Vanuatu comprises a land area of over 12,000 km^2 (Anon. 2011), with an Exclusive Economic Zone (EEZ) of over 827,000 km^2, mostly located in the Food and Agriculture Organization (FAO) statistical area 71 (www.seaaroundus.org). The area of the EEZ includes the waters surrounding Matthew and Hunter islands. Vanuatu's claim to these islands and the water surrounding them is disputed by France (Amos 2007). We include the area here as it is the stated policy of the government of Vanuatu that their EEZ includes these waters.

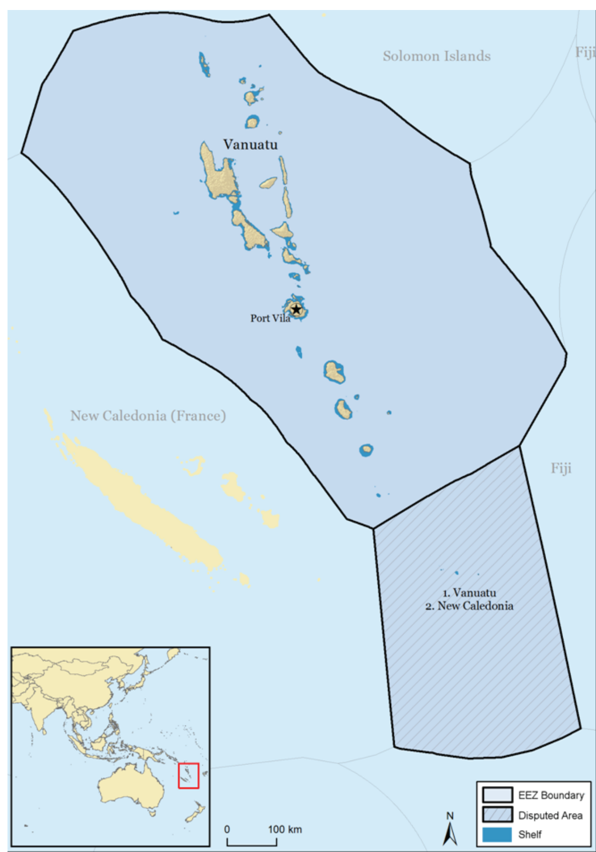

Figure 1. Vanuatu Exclusive Economic Zone (EEZ) and shelf waters to 200 m depth.

During colonial times, this archipelagic country was called New Hebrides and was governed jointly by the United Kingdom and France through a British-French condominium (i.e., both nations have equal rights over the territory) since 1906. As a result of an independence effort in the 1970s, the country became the Republic of Vanuatu in 1980 (Amos 2007).

Vanuatu has limited inshore waters, with only narrow fringing reefs (Aylesworth and Campbell 2009). The reefs drop off rapidly and thus deep ocean waters lie close to the coast (David and Cillaurren 1988). The islands are located in the hurricane belt making travel between islands dangerous at times (van Pel 1956).

In the 1950s, the more urban business centers, such as Port Vila and Luganville, were already in short supply of fish (van Pel 1956). However, beef cattle were plentiful on the plantations and provided an alternative source of animal protein (van Pel 1956). There were many large commercial plantations which had a high demand for laborers, leaving no shortage of work for the Ni-Vanuatu (people of Vanuatu). Other, more dangerous ventures, such as fishing, which provided little more pay, did not offer much incentive (van Pel 1956). Personal gardens which provided fresh vegetables were also popular, and they also required time to maintain (van Pel 1956). Ni-Vanuatu who did fish in some capacity were most likely also taking part in farming or other work. Fishing was not realistically a full-time occupation. That being said, a 1983 survey of the small-scale fishing sector showed that

[1] Cite as: Zylich, K., Shon, S., Harper, S. and Zeller, D. (2014) Reconstruction of total marine fisheries catches for the Republic of Vanuatu, 1950-2010. pp. 147-156. *In:* Zylich, K., Zeller, D., Ang, M. and Pauly, D. (eds.) Fisheries catch reconstructions: Islands, Part IV. Fisheries Centre Research Reports 22(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

fishing was more important to local economies than what was popularly believed (David and Cillaurren 1988). Another study carried out over the course of 1993-2001 on marine resource management in Vanuatu stated that within the 21 villages studied, 67% of the households participated in subsistence fishing and 23% sell some of their catch (Johannes and Hickey 2004). This study also illustrated the presence of customary marine tenure in Vanuatu, which means that "rights to the coastal waters contiguous to traditional land holdings usually extend to the clans, chiefs or villages that own the land" (Johannes and Hickey 2004, p. 17). These rights can be allocated amongst individual families within the clans and villages as well. Fishing is carried out with either the traditional outrigger canoe (majority) or outboard motorboats (David and Cillaurren 1988). Fishing with explosives has been a problem in the past and has caused damage to the reefs (van Pel 1956).

In 2009, the majority of the population was involved in the agriculture sector (ADB 2009). Subsistence fishing is second to agriculture in terms of a food source (Aylesworth and Campbell 2009). Vanuatu's economy is dominated by agriculture and tourism. Copra is an important export item, as well as timber, beef, cocoa and kava (Friedman *et al*. 2008). Subsistence fisheries are important to local economies, both in terms of food security and income. Here, we reconstructed the total marine fisheries catches for Vanuatu using the approach outlined in (Zeller *et al*. 2007).

Methods

The total marine fisheries catches of Vanuatu were estimated using population data, derived seafood consumption rates, and information from the grey literature. All sectors of Vanuatu's marine fishery were estimated including subsistence, artisanal, recreational, tourist consumption, and exports. Industrial catches were also estimated, although these catches were deemed to be not truly domestic (i.e., dominated by foreign beneficial ownership).

Domestic seafood consumption

In order to calculate annual domestic seafood consumption by the Ni-Vanuatu, human population data were required for the entire time period. Data for the years 1960-2010 were acquired from the World Bank database.[2] Prior to 1960, data were obtained from the historical demography website Populstat (www.populstat.info). This gave a complete time series of population data for Vanuatu (Figure 2). Consumption rates were determined by using anchor points of small-scale annual catch and dividing by the population for that year to obtain a catch derived consumption rate. Gillett (2009) provided estimates for the 2007 coastal commercial (artisanal) and subsistence catches. Combining these and dividing by the population for that year (222,377) gave an approximate domestic *per capita* catch of 15 kg·person^{-1}·year^{-1}. This value is carried forward unaltered to 2010. A second anchor point was derived from a 1983 subsistence survey which also included what we would consider the artisanal sector (David and Cillaurren 1988, 1992). Within these reports, there are several different totals and subtotals of the small-scale catch and in some cases freshwater species are also included. Gillett (2009) also mentions this study and quotes that it gave an annual production by village fisheries from near-shore habitats as 2,849 t. As this value falls in the middle of the various quotes given by the two papers, we accept this value as an average estimate of the small-scale catch for 1983. Combined with the population, a consumption rate of 22.9 kg·person^{-1}·year^{-1} is derived as the second anchor point. The *per capita* catch rate was interpolated between 1983 (22.9 kg) and 2007 (15 kg), and the rate of decrease was carried forward to 2010. For the early time period, an assumed *per capita* catch rate was derived from information regarding consumed imports. Information was available on fish imports for 1950-1955 (van Pel 1956) as well as 1984 (David and Cillaurren 1992). Taking the average of the *per capita* rate of imports for 1950-1955 and comparing it to the rate in 1984 showed that Ni-Vanuatu were consuming approximately 5 kg·person^{-1}·year^{-1} more canned fish in 1984 than in the early 1950s. Therefore, we assumed that the *per capita* consumption rate of fresh seafood in 1950 was 5 kg greater than in 1984 to account for this missing component of their diet, giving an assumed 1950 rate of 27.5 kg·person^{-1}·year^{-1}. It should be noted that we did not convert the canned weight of the imports

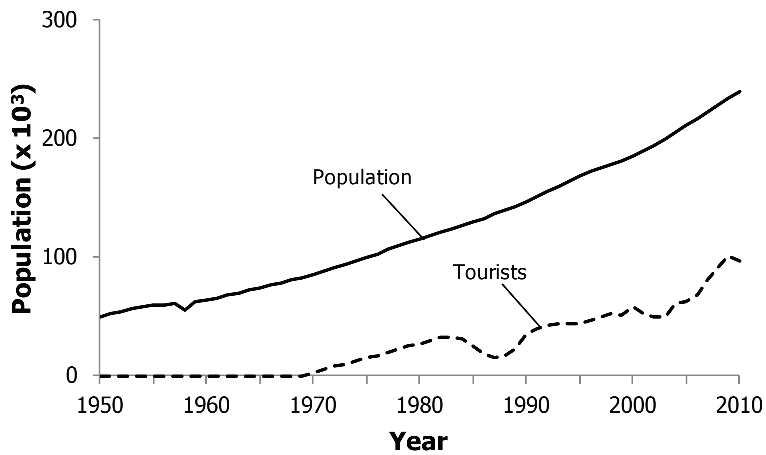

Figure 2. Total human population of Vanuatu and tourist population, 1950-2010.

Table 1. Aggregated taxonomic groupings split anchor points (%) for the artisanal and subsistence sectors.

Taxonomic group	Artisanal			Subsistence		
	1950-1970	1983	2010	1950-1970	1983	2010
Deep-water fish	0.0	21.3	26.8	0.0	23.9	9.1
Shallow-water fish	24.6	19.4	13.4	20.0	15.3	45.5
Octopus	2.3	1.8	1.8	3.9	2.9	9.1
Lobsters	55.2	43.4	26.8	16.8	12.8	4.5
Marine shellfish	11.8	9.3	4.4	53.0	40.3	27.3
Tuna/tuna-like fish	6.1	4.8	26.8	6.3	4.8	4.5

[2] http://data.worldbank.org/country/vanuatu [accessed September 25, 2012]

into the whole fish weight equivalent. However, this allowed us to be conservative in our estimate and so we accepted the values as they were. Interpolation was done between the 1950 rate (27.5 kg·person^{-1}·year^{-1}) and the 1983 anchor point (22.9 kg·person^{-1}·year^{-1}).

Reports indicated that in the 1950s, small-scale fishing activities were mainly geared toward meeting subsistence needs (van Pel 1956). As well, due to the high demand of laborers for agriculture on land, there was little incentive to take on the more dangerous work of fishing out at sea (van Pel 1956). It was therefore assumed that 95% of the catch for domestic consumption came from the subsistence sector and the other 5% was artisanal in 1950. The 2007 anchor point for the consumption rate was derived from Gillett's (2009) catch estimates, which were given separately for the subsistence and artisanal sectors. Therefore, the proportions of these estimates were used as a second anchor point with 85% subsistence catches and 15% artisanal catches. Proportions were interpolated between 1950 and 2007. The 2007 anchor points were carried forward unaltered to 2010.

Table 2. Taxonomic breakdown of the deep-water fish category of both the artisanal and subsistence sectors, 1950-2010.

Species	Percentage
Etelis carbunculus	15.8
Etelis coruscans	17.3
Etelis radiosus	2.7
Pristipomoides multidens	5.1
Pristipomoides flavipinnis	2.0
Pristipomoides filamentosus	30.6
Lutjanus malabaricus	13.4
Aphareus rutilans	1.2
Epinephelus magniscuttis	3.8
Epinephelus morrhua	1.9
Epinephelus septemfasciatus	1.9
Seriola rivoliana	4.3

Species breakdown

In order to determine the species breakdown of the small-scale sectors, a survey from 1983 (David and Cillaurren 1988) was used to split the catch of both the subsistence and artisanal sectors into larger species groupings. Each sector was initially divided into catches of tuna/tuna-like fish, deep-water fish, shallow-water fish, octopus, lobsters, and marine shellfish (Table 1). The 1983 survey also included a listing for freshwater prawns and these catches were excluded from the calculation as this reconstruction focuses only on marine catches. The survey did not include a tuna/tuna-like fish category; however due to information supplied by a Vanuatu fishery resource profile (Amos 2007), it was known that tuna are caught by the small-scale fleet and thus an assumption was made to include this category in the breakdown. Re-normalized percentages from the 1983 survey (David and Cillaurren 1988) with the tuna category included were used as the first anchor points of the breakdown. As it was known that the deep-water fishery began in the early 1970s (Amos 2007), from 1950-1970 deep-water fish catches were set to zero with the percentages from 1983 of all other categories re-normalized to 100%.

Linear interpolation was done between the 1970 and 1983 values. Given information regarding the current fishing status of the different groups (Amos 2007), assumptions were made to create a percentage breakdown for 2010. Linear interpolation was utilized between the 1983 and 2010 values for each group. Each of these larger taxonomic groups was broken down further with the same breakdown being used for both the artisanal and subsistence sectors (see Tables 2-6). The breakdown for the deep-water fish was based on a three year average of the composition of species recorded as landings at the Fisheries Extension Centres from 1990-1992 (Amos 2007; Table 2). Information regarding the composition of the shallow-water fish catch was obtained from a SPC report (Pratchett *et al.* 2011). The percentage breakdown was given by family. In some cases families were disaggregated into known species (Amos 2007) and the 'others' category was further broken down into three additional families which are known to occur in Vanuatu waters and a miscellaneous marine fish category. These values were used as anchor points in 2010. Based on general knowledge of the species present (Amos 2007), assumptions were made as to how the composition might have differed in 1950. Linear interpolation was done between the estimated anchor points in 1950 and the percentages in 2010 (Table 3). Very little information on octopus catches in Vanuatu was available. All octopus catches were simply labeled as *Octopus* spp. Lobsters were disaggregated into four species, based on information from Amos (2007), whose proportions remained constant over the entire time period (Table 4). The marine shellfish category was also further broken down using information from Pratchett *et al.* (2011). A species composition for invertebrate catches in Vanuatu was available. Sea cucumbers and trochus were excluded from the composition as these are estimated separately in the reconstruction as export items. Octopus, spiny lobsters, and crustaceans were also excluded as these have been calculated separately as well. The relative proportions of giant clams, gastropods, and bivalves were then used to inform an assumed species breakdown of the marine shellfish

Table 3. Taxonomic breakdown of the shallow-water fish category of both the artisanal and subsistence sectors. Linear interpolation done between anchor points.

Taxon name	1950 (%)	2010 (%)
Acanthuridae	3.0	3.0
Naso lituratus	2.5	3.0
Acanthurus lineatus	2.5	3.0
Kyphosidae	3.0	4.4
Serranidae	6.0	0.7
Epinephelus merra	3.0	0.3
Variola louti	3.0	0.3
Scaridae	4.0	12.1
Labridae	2.0	0.0
Cheilinus undulatus	1.0	0.0
Haemuidae	5.0	6.0
Lethrinidae	6.0	8.8
Lethrinus harak	3.0	4.5
Lethrinus miniatus	3.0	4.5
Lutjanidae	6.0	0.5
Lutjanus fulvus	3.0	0.2
Lutjanus gibbus	3.0	0.2
Siganidae	8.0	13.3
Carangidae	8.0	10.0
Mugilidae	5.0	6.0
Holocentridae	1.0	1.2
Mullidae	8.0	7.6
Balistidae	3.0	4.5
Miscellaneous marine fish	8.0	5.9

Table 4. Taxonomic breakdown of the lobster category of both the artisanal and subsistence sectors, 1950-2010.

Species	Percentage
Panulirus penicillatus	60
Panulirus versicolor	15
Panulirus longipes	15
Parribacus caledonicus	10

category for 1950 and 2010 (Table 5). Linear interpolation was done between these two points. Finally, the tuna/tuna-like category was further disaggregated based on the relative proportions of the tuna and tuna-like species present in an account of artisanal production in 2004 (Amos 2007; Table 6).

It should be noted that upon comparison of the reconstructed catch with the FAO data, it was found that within the reconstruction the estimated amount of crustaceans was less than that reported by the FAO in two years (1984 and 1985). It is possible that our reconstruction underestimates the catch of crustaceans in these years. However, as these two years correspond to a spike in crustacean catches, we accepted our reconstructed values.

Table 5. Taxonomic breakdown of the tuna/tuna-like category of both the artisanal and subsistence sectors, 1950-2010.

Common name	Scientific name	Percentage
Yellowfin tuna	*Thunnus albacares*	44.0
Skipjack tuna	*Katsuwonus pelamis*	42.0
Wahoo	*Acanthocybium solandri*	8.0
Dogtooth tuna	*Gymnosarda unicolor*	2.5
Rainbow runner	*Elagatis bipinnulata*	1.5
Marlin	Istiophoridae	1.0
Mahi mahi	*Coryphaena hippurus*	1.0

Recreational

Vanuatu is a well known game fishing location and hosts numerous game fishing tournaments, including the Vanuatu Marlin Classic and the Blue Marlin World Cup (Gentner 2009). Recreational fishing is not only limited to tournaments though. Hotels and resorts also hire boats to take guests out fishing and charter boats are available for hire to take tourists out on the water. Data on total number of boats used for recreational purposes was inconsistent across sources. Also, catch rates for smaller boats operating out of resorts were not available. However, it is known that when charter boats take people out for fishing, the boat retains all fish caught and then sells these to hotels, resorts, or restaurants, thus partially supplying fish for the tourist consumption demand. A catch rate of 48-64 t caught annually by the charter fleet was given for 2008 (Gay 2008). Taking the average gives an anchor point of 56 t in 2008. Chapman (2004) stated that charter fishing vessels began operating out of Port Vila in the late 1980s. We assumed that the very first charter fishing vessels began operating in 1980 and set the catch to zero t in 1979. Interpolation was done between the zero anchor point and the point of 56 t in 2008. The rate of increase in catch was carried forward to 2010.

Table 6. Taxonomic breakdown of the marine shellfish category of both the artisanal and subsistence sectors. Linear interpolation used between anchor points.

Taxon group	1950 (%)	2010 (%)
Giant clams (*Tridacna* spp.)	20	10
Gastropods (Gastropoda)	40	60
Other bivalves (Bivalvia)	40	30

No detailed information regarding species composition of recreational catches was readily available. However, it is known that recreational catches mainly consist of billfishes and tuna-like fishes. Thus an assumed composition of 90% family Istiophoridae and 10% family Scombridae was applied.

Tourist seafood consumption

Tourism is an important part of the Vanuatu economy (Gentner 2009). As an island nation, part of the attraction is the promise of fresh local seafood. In order to calculate the contribution of tourist consumption to the marine fisheries take of Vanuatu, we combined tourist stop-over numbers with tourist seafood consumption rates. The numbers of tourists visiting Vanuatu were available for the periods of 1982-1992[3] and 1995-2010.[4] Interpolation was done between the data points in 1992 and 1995. No information regarding when tourism began in Vanuatu was readily available, but it was known that tourist arrivals reached a peak in 1982/83. Therefore, we made an assumption that the tourist sector built up from a starting point in 1970. Interpolation was done between zero in 1969 and the first anchor point of 32,180 tourist in 1982. The decrease in tourist population from 1984-1987 was due to the disruption of air services, multiple cyclones hitting the islands, and fear of political instability (Figure 2).[2] Tourism had recovered by 1989 and continued to increase from there. The average length of stay of a tourist in 1992 was said to be 9 days, but on average through the years the majority of tourists stay one week or less.[5] Therefore, to be conservative, we set the length of stay of a tourist at 7 days for the whole time period. Information regarding consumption amount and frequency was not readily available for the tourist population of Vanuatu. As a proxy, we used information on tourist consumption in the Caribbean. Adams (1992) estimated 250 grams per serving consumed by tourists in several Caribbean Islands. Combined with an assumed 1 serving per day and a stay of 7 days, this gives an estimated 1.75 $kg{\cdot}tourist^{-1}{\cdot}year^{-1}$. This derived consumption rate combined with the time series of tourist numbers gives the total catch supplying tourist demand.

Due to the fact that charter vessels sell their catch to the restaurants and hotels, the recreational catch counts towards the tourist seafood consumption supply. The total calculated tourist seafood consumption minus the recreational catch equals the remaining tourist demand which is supplied by artisanal catches. Therefore, catches supplying tourist consumption appear in both the recreational and artisanal sector. Information regarding the species composition of catches supplying the tourist demand from the artisanal sector was not available. Therefore, an assumed composition of 10% lobster, 50% serranids, 20% lutjanids and 20% lethrinids was applied. Billfishes and tuna-like fishes are already accounted for in the recreational catch which also supplies the tourist demand.

[3] http://www.unescap.org/ttdw/Publications/TPTS_pubs/Pub_1427/Pub_1427_ch3.pdf [accessed September 25, 2012]
[4] http://data.worldbank.org/country/vanuatu [accessed September 25, 2012]
[5] http://www.unescap.org/ttdw/Publications/TPTS_pubs/Pub_1427/Pub_1427_ch4.pdf [accessed September 25, 2012]

Exports

The export fisheries for trochus and sea cucumber are also considered part of the artisanal sector. These exports combined with the artisanal portions of both the domestically consumed catch and the tourist consumed catch, will equate to the total artisanal catch. Shark fin exports are considered industrial.

Trochus

Trochus shell is an important export of Vanuatu. Due to the fact that the main purpose of collecting trochus shells is to export the shells, and that consumption of the meat is a secondary utilization (van Pel 1956), this fishery is calculated separately of domestic consumption and is considered all artisanal. Trochus is reported in the FAO data starting in 1985. Reported values from the FAO were accepted for the years 1985-2010. Prior to that, export values of trochus were available for 1950-1958 (van Pel 1956; Devambez 1959) and 1969-1982 (Bour and Grandperrin 1985). Reports indicated that the trochus fishery closed near the beginning of the year in 1958 and reopened in 1962 (Anon. 1997). Therefore, exports were set to zero from 1959-1961 and then the catch was interpolated from zero in 1961 to the next anchor point of 2 t in 1969. Interpolation was also performed from 50 t in 1982 to 75 t in 1985.

Sea cucumber

Sea cucumber is exported as bêche-de-mer, a popular food item in Asian markets. Sea cucumbers did not appear in the FAO data until 1983. Although there is qualitative information to suggest that the sea cucumber fishery began earlier than this, additional estimates were not made. Given the unpredictable and boom and bust nature of such a fishery, we accept the FAO data as is in order to be conservative.

Large-scale commercial

Tuna fishery

Tuna and tuna-like catches within the FAO[6] reported data are attributed to the large-scale commercial sector. This large-scale commercial sector is mostly made up of foreign vessels that are flagged as Vanuatu. Whether these vessels are joint ventures or flags of convenience is not quite clear. There are some specific records of joint ventures. Korean purse seiners which were managed under a joint venture were flagged as Vanuatu vessels, and began operating in the mid-1990s (Amos 2007). This is the time when purse seine catches first appear in the Western and Central Pacific Fisheries Commission (WCPFC) data for Vanuatu. There is also a record of Vanuatu-flagged vessels that are chartered to Papua New Guinea (PNG) companies and fish in PNG waters. It has been indicated that these catches have been attributed to both Vanuatu and PNG in terms of accounting. Regardless, the Government of Vanuatu's website clearly states that offshore commercial fishing is dominated by foreign vessels.[7] Furthermore, it is stated that all tuna caught in local waters is delivered to American Samoa, Fiji, or Papua New Guinea.[5] Even if a vessel is owned and operated by Ni-Vanuatu, the catch does not contribute to the Ni-Vanuatu domestic food supply. Therefore, large-scale commercial catches are analyzed separately from the small-scale sectors.

Upon comparison of FAO tuna and other large pelagic data (albacore, bigeye, skipjack, yellowfin, 'tuna-like fishes nei', black marlin, blue marlin, striped marlin, and swordfish), Forum Fisheries Agency (FFA) data, and WCPFC data, it was found that all sources matched. We therefore accepted the FAO tonnage as is. FFA and WCPFC data were used to give greater species, spatial and gear disaggregation to the FAO data. Proportions of tuna spatial disaggregation were also used to spatially assign associated by-catch.

Shark fins

Shark fins have also been an export item in Vanuatu, although exports in the recent time period have decreased substantially. Records of shark fin exports in dry weight were found for the years 1980-1986 and 2001-2004 (Amos 2007). An assumption was made that exports were zero in 1970 and linearly interpolated to the first anchor point of dry fin weight in 1980 of 10.7 t. Note that a complete time series of dry weight of fin exports was calculated first, and then converted into wet round weight. Interpolation was also done between the anchor point of 5 t in 1986 and 12 kg in 2001. The export quantity of 15 kg in 2004 was carried forward unaltered to 2010. The time series of dry fin weight exports was converted to wet fin weight using an average conversion factor of 43% (i.e., dry fins equate to 43% of the mass of wet fins) and then converted to wet round weight using an average conversion factor of wet fin weight equates to 3% of wet round weight (Biery 2012; Biery and Pauly 2012). It was assumed that the carcass weight (difference between wet fin weight and wet round weight) was completely discarded. Although it is known that the Ni-Vanuatu do consume shark meat, the majority of these sharks were caught by the South Pacific Fishing Company (Amos 2007) which is a large-scale commercial fleet as opposed to the small-scale commercial artisanal fleet which

[6] FAO data was extracted using FishStatJ software (http://www.fao.org/fishery/statistics/software/fishstatj/en). When this study was first started, the global dataset on capture production was available from 1950 to 2010 (2010 version). This dataset has since been updated in March 2013; using the 2011 version. Although the catch of some tuna species has been updated since 1994 in the new FAO dataset (2011 version), this report uses the 2010 version. However, the database will be updated in the future to reflect the new dataset.

[7] http://www.governmentofvanuatu.gov.vu/index.php/government/agriculture [accessed November 6, 2012]

would provide Ni-Vanuatu with shark meat for consumption. For the few years were tonnage of shark meat sold at the fish markets is available, the tonnage sold compared to the amount of carcass meat available from the finned sharks is insignificant. Although specific information regarding the taxonomic composition of the shark catches for the shark fin trade were not available, it was found that sharks of the family Carcharhinidae were fairly prominent in the waters of Vanuatu (Fourmanoir and Laboute 1976), and therefore an assumed composition of 70% Carcharhinidae and 30% Squalidae was used. Note that although there are more specific wet fin weight to wet round weight conversion factors for these two shark families (Biery 2012), the average conversion factor was used as it gave a more conservative estimate.

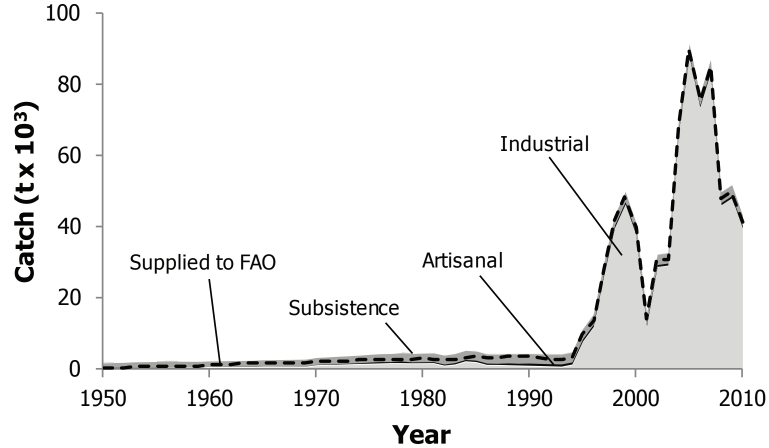

Figure 3. Reconstructed total catches of Vanuatu, 1950-2010, by fisheries sector with data supplied to FAO overlaid as line graph. Note that the recreational sector is too small to be visible on the graph.

Results and Discussion

The reconstructed total catch for Vanuatu was estimated to be 886,750 t over the 1950-2010 time period. This is 9.5% higher than the 810,021 t of landings reported by the FAO on behalf of Vanuatu (Figure 3). Of the total reconstructed catch, the industrial sector constitutes 81.5%, artisanal 2.9%, subsistence 15.5% and recreational 0.1%. The industrial sector increased from 200 t in 1950 to 2,100 t in 1984. After a slight decrease to the mid-1990s, catches increased rapidly to a peak of 46,000 t in 1999. Catches declined after that to a low of 12,000 t in 2001 before rising back up to another peak of almost 88,000 t in 2005. Catches followed a declining trend after that with only 39,500 t caught in 2010. Discards in the industrial shark fishery equated to almost 2% of the total industrial catch (12,000 t). Industrial catches may be taken from within Vanuatu's EEZ, within another countries' EEZ, or from the high seas. It was estimated that only 3.5% of the total industrial catch is taken from within Vanuatu's EEZ. In addition to the fact that the majority of industrial catches are taken from outside the EEZ, these industrial catches do not directly benefit the Ni-Vanuatu and their seafood consumption and the magnitude of these catches over-shadow the results of the small-scale sector.

Thus, if we look only at the small-scale catches, we see that reconstructed total catches are estimated at 164,100 t which is 64% higher than the catches reported to FAO (99,800 t) which are deemed to be the small-scale reported baseline (Figure 4a). Artisanal catches, on average, display an increasing trend. Catches increased from 119 t·year^{-1} in 1950 to 175 t·year^{-1} in 1957, then fell to 109 t·year^{-1} in 1959. From 1959 onwards, artisanal catches generally increased with a slight dip in 1978-1979 where catches fell from 566 t·year^{-1} to 347 t·year^{-1}. After 1980, catches increased to a peak of 752 t·year^{-1} in 1998 then decreased slightly to 640 t·year^{-1} by 2010 (Figure 4a). Artisanal catches were estimated to be 66% domestic consumption, 26% export, and 8% tourist consumption. The subsistence sector has experienced a steady growth, increasing from 1,280 t·year^{-1} in 1950 to 2,890 t·year^{-1} in 2010 (Figure 4a). Recreational catches began in 1980 and increased gradually from zero to 21 t·year^{-1} in 1999. From 1999 to 2010 the rate of recreational catch increased and catch was estimated to be 64 t·year^{-1} by 2010 (Figure 4a).

Skipjack tuna (*Katsuwonus pelamis*) contributed to the majority of the industrial catch, representing 68% of the catch from 1950-2010. This was followed by albacore tuna (*Thunnus alalunga*) and yellowfin tuna (*Thunnus albacares*) which account for approximately

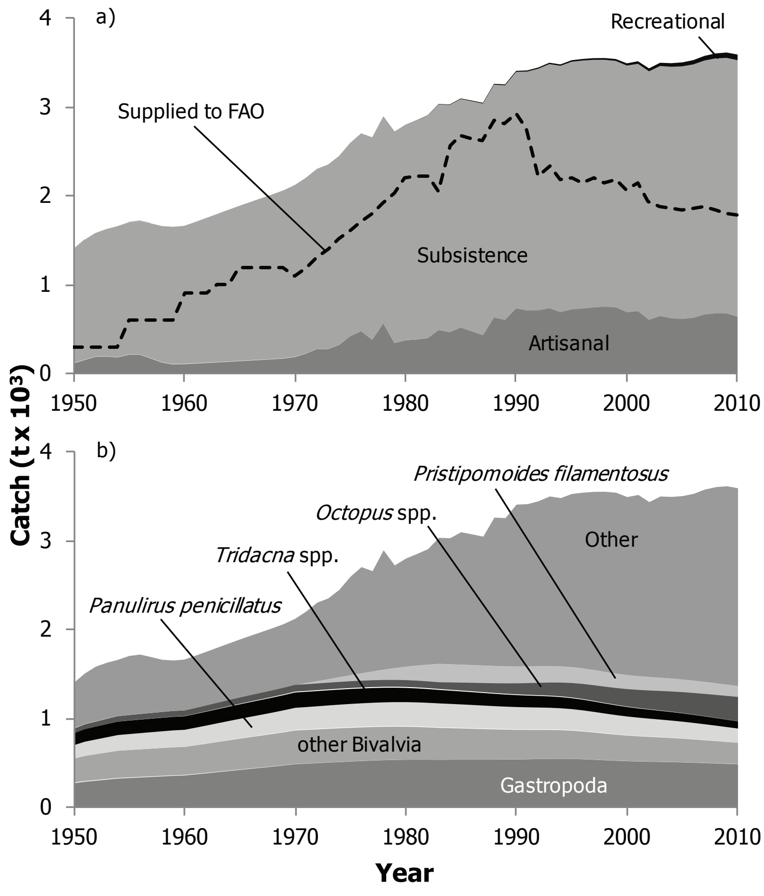

Figure 4. Reconstructed total small-scale catches of Vanuatu, 1950-2010, by a) fisheries sector with adjusted FAO data overlaid as line graph; and b) major taxonomic groups. 'Other' represents 49 additional taxonomic categories.

14% and 12%, respectively. Small-scale catches were dominated by invertebrates, including gastropods (17.6%), pronghorn spiny lobster (*Panulirus penicillatus*; 8.4%), giant clams (*Tridacna* spp.; 5.2%), octopus (4.4%) and other bivalves (12.3%; Figure 4b). The most important fish taxa was crimson jobfish (*Pristipomoides filamentosus*; 3.6%). Trochus was the dominant species caught within the artisanal sector, followed by the pronghorn spiny lobster (*Panulirus penicillatus)*, representing 17% and 16% of the total artisanal catches, respectively. Subsistence catches for the period 1950 to 2010 were composed mainly of gastropods (20%), followed by other bivalves (i.e., excluding *Tridacna* spp.; 14%). For the same period, the recreational catch was assumed to be 90% Istiophoridae and 10% Scombridae.

Vanuatu has one of the lowest seafood consumption rates in the South Pacific. This is due to the fact that unlike most other Pacific islands, Vanuatu has an agricultural sector. Not only do most Ni-Vanuatu maintain personal garden crops but Vanuatu also exports beef with approximately 30% being canned for local consumption.[8] As Ni-Vanuatu have a second source of local animal protein, they are not as reliant on seafood as some of the other Pacific island countries. Although the Ni-Vanuatu are not as reliant on seafood as other Pacific island countries, this does not mean that the marine resources are not valued. Studies showed that seafood was more important to the Ni-Vanuatu diet than was originally believed. Also, although the large-scale fisheries do not directly contribute to domestic food security, the revenue from joint ventures, as well as some access agreements for foreign vessels, are important to the economy of Vanuatu. Although not addressed in this report, it should be mentioned that as Vanuatu is engaged in multiple joint venture agreements and is fishing in other countries' EEZs, it has been reported that these industrial catches may be double counted. Catches by Vanuatu flagged purse seiners fishing in Papua New Guinea waters which are chartered to Papua New Guinea companies have been cited as also being reported by Papua New Guinea (Gillett 2011). As these catches are taken by Vanuatu flagged vessels, we consider them Vanuatu catch and therefore they are included here. However, it is apparently common practice by Pacific island countries for catches by chartered vessels in the waters of the host country to be attributed to the host country and therefore Papua New Guinea also reports these catches. This is just another instance where better communication and cooperation between countries when it comes to international fisheries issues is greatly needed.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Vanuatu, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational	Discards[1]
1950	500	1,600	200	119	1,280	-	-
1951	500	1,710	200	157	1,350	-	-
1952	500	1,780	200	193	1,390	-	-
1953	600	1,930	300	195	1,430	-	-
1954	600	1,960	300	187	1,470	-	-
1955	900	2,000	300	215	1,490	-	-
1956	1,000	2,120	400	217	1,500	-	-
1957	1,000	2,090	400	175	1,520	-	-
1958	1,000	2,060	400	131	1,530	-	-
1959	1,000	2,050	400	109	1,550	-	-
1960	1,400	2,160	500	112	1,550	-	-
1961	1,400	2,210	500	118	1,590	-	-
1962	1,400	2,250	500	125	1,630	-	-
1963	1,500	2,300	500	131	1,670	-	-
1964	1,500	2,340	500	138	1,710	-	-
1965	1,800	2,490	600	145	1,740	-	-
1966	1,800	2,530	600	152	1,780	-	-
1967	1,800	2,580	600	159	1,820	-	-
1968	1,800	2,620	600	166	1,850	-	-
1969	1,800	2,660	600	174	1,890	-	-
1970	2,100	3,120	1,000	191	1,930	-	-
1971	2,200	3,290	1,002	228	1,980	-	80
1972	2,300	3,470	1,005	281	2,020	-	161
1973	2,400	3,600	1,007	279	2,070	-	241
1974	2,510	3,780	1,010	325	2,120	-	322
1975	2,610	4,010	1,012	421	2,180	-	402
1976	2,710	4,200	1,015	479	2,230	-	483
1977	2,816	4,250	1,023	382	2,280	-	563
1978	2,825	4,470	935	566	2,330	-	644
1979	2,819	4,260	811	347	2,380	-	724
1980	2,937	4,360	752	378	2,420	1	805
1981	2,715	4,440	533	386	2,460	2	1,053
1982	2,715	3,800	512	400	2,500	3	376
1983	2,542	4,230	521	490	2,540	4	677
1984	2,956	5,140	451	468	2,560	5	1,654
1985	3,686	4,960	1,038	518	2,570	6	827
1986	3,328	4,150	703	477	2,590	7	376
1987	3,328	4,120	716	435	2,610	8	351
1988	3,506	4,250	660	631	2,620	9	326
1989	3,410	4,170	609	605	2,640	11	301
1990	3,470	4,240	559	733	2,670	12	276
1991	3,260	4,170	508	710	2,690	13	251
1992	2,655	4,120	447	712	2,720	14	226
1993	2,710	4,090	386	735	2,750	15	201
1994	3,187	4,660	1,006	692	2,780	16	176
1995	9,687	11,170	7,492	723	2,790	17	151
1996	13,748	15,270	11,602	733	2,790	18	126
1997	28,462	29,920	26,265	745	2,790	19	101
1998	41,672	43,160	39,525	752	2,780	20	76
1999	48,366	49,770	46,178	745	2,780	21	51
2000	39,623	41,070	37,553	691	2,780	25	26
2001	14,055	15,440	11,919	703	2,790	29	1
2002	30,582	32,080	28,641	605	2,800	33	2
2003	30,871	32,520	28,987	648	2,820	37	36
2004	68,383	70,020	66,520	623	2,830	40	1
2005	89,628	91,290	87,779	616	2,850	44	1
2006	75,416	77,090	73,561	628	2,860	48	1
2007	85,137	86,840	83,262	665	2,860	52	1
2008	47,861	49,620	46,012	679	2,870	56	1
2009	49,784	51,600	47,978	677	2,880	60	1
2010	41,246	43,050	39,459	640	2,890	64	1

[1] Discards are from the industrial shark fishery.

Appendix Table A2. Reconstructed total small-scale catch (in tonnes) by major taxonomic category for Vanuatu, 1950-2010. 'Others' contain 49 additional taxonomic categories.

Year	Gastropoda	Misc. bivalvia	*Panulirus pencillatus*	*Tridacna* spp.	*Octopus* spp.	*Pristipomoides filamentosus*	Others
1950	274	274	151	137	51	-	510
1951	292	288	160	143	54	-	568
1952	304	296	166	147	56	-	615
1953	315	304	172	150	58	-	629
1954	327	311	178	153	59	-	632
1955	333	313	181	153	60	-	663
1956	339	315	184	153	61	-	668
1957	345	317	186	154	61	-	629
1958	351	319	189	154	62	-	587
1959	358	320	192	154	63	-	568
1960	362	320	194	153	63	-	572
1961	374	327	199	155	64	-	587
1962	386	333	205	158	66	-	604
1963	398	340	211	160	68	-	620
1964	411	347	218	163	70	-	637
1965	424	353	224	165	71	-	654
1966	436	359	230	167	73	-	669
1967	448	365	235	168	74	-	685
1968	460	370	241	170	76	-	701
1969	474	376	248	172	77	-	718
1970	488	383	254	174	79	-	745
1971	493	383	257	173	80	12	806
1972	500	383	260	172	80	25	885
1973	506	384	262	172	81	38	911
1974	512	384	265	171	81	52	985
1975	518	384	268	170	82	67	1,110
1976	523	383	270	168	82	82	1,197
1977	528	382	272	167	82	98	1,131
1978	532	381	274	165	82	115	1,345
1979	535	379	275	163	82	133	1,156
1980	537	376	276	161	82	150	1,218
1981	538	372	276	159	82	168	1,257
1982	538	368	276	156	81	187	1,301
1983	537	363	275	153	81	206	1,421
1984	538	360	272	150	87	204	1,420
1985	538	356	270	148	94	201	1,493
1986	538	352	267	145	100	199	1,473
1987	539	348	264	142	107	196	1,453
1988	539	344	261	140	114	194	1,672
1989	539	341	258	137	121	191	1,670
1990	540	338	256	135	128	189	1,824
1991	542	335	253	133	135	187	1,829
1992	545	333	251	131	143	185	1,860
1993	547	330	249	129	151	183	1,913
1994	547	327	246	127	159	181	1,897
1995	546	323	242	124	166	178	1,952
1996	542	317	237	121	173	174	1,980
1997	537	310	231	117	179	170	2,008
1998	531	304	225	114	185	166	2,030
1999	526	297	220	110	191	161	2,039
2000	521	291	214	107	197	158	2,006
2001	518	286	210	104	205	154	2,042
2002	516	282	205	102	212	151	1,971
2003	513	278	201	99	220	148	2,043
2004	511	273	196	97	228	145	2,047
2005	508	269	191	94	235	142	2,067
2006	504	264	186	92	243	138	2,105
2007	500	258	181	89	250	134	2,167
2008	496	253	174	86	257	130	2,210
2009	491	248	167	84	264	126	2,236
2010	487	243	161	81	272	122	2,229

Appendix: Notes on the completion of FAO Form Fishstat NS1 (National Summary)[1]

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These notes are addressed primarily to fisheries statisticians (or those who have drawn the short straw and been given the FAO form to complete) working in countries with a mainly subsistence fishery and with little or no staff to collect data.

It is important to bear in mind that every other statistician is lying, intending to lie, cannot help lying or has been told to lie. If your own statistics are a model of truth or are painfully arrived at estimates, it will be impossible to test their honesty; it will be assumed that you too, are lying (lying means, of course, data management- a scientific administrative technique which may be familiar to readers. The concept of 'creative truth' is, perhaps, preferable).

Avoid ending in zeros, this is clearly the result of glib oversimplification. Figures that end in uneven numbers suggest that care has been taken to achieve the final total.

Check the previous year's figures with this year's 'estimate', there should be no suggestion of any discernable pattern since this indicates that a formula has been used. If you do use a formula, remember to finish off your final 3, 4 or 5 digits (depending on the size of your fishery) with a random number. It is statistically sound to use a random number.

Each year's estimate should be larger than the previous year's estimate. This indicates that the policy pursued by your department and government for the development of the fishery is a success. Do not make your increase too large, or other countries will become interested and ask awkward questions. It is permissible to lower your figures in cases where your country is disputing the fishing policy of a neighbour, a drop in your national catch will indicate a lowered return on the shared stock and will also cast doubt on the validity of your neighbour's own reported figures.

The species catch will offer some problems. FAO are not interested in, or perhaps have not heard of, species that may form the major component of your catch. The form may also ask for details of fish species which you have lost in your 'other species' figures. This problem is best handled by creating an 'FAO species composition Chart'. Go for a species composition that offers an attractive mix; remember that you are selling your fishery; be commercial. Aid agencies are interested in only one or two volume species. Look for fashionable species but also remember that you need certain strength in the artisan fished species, in other words, don't overdo tuna. A small point to note but an important one, your species figures must add up to the total estimate (you will of course have worked backwards), enter any difference into the 'Marine fishes NEI' section, this is its purpose.

If you are newly appointed as Fisheries Statistician, you will be keen to demonstrate the incompetence of your predecessor. Your estimates should reflect this. Other countries catch estimates will also bear signs of this or, in the case of expanding fisheries departments, the appointment of statisticians where there were previously none. As a new statistician you will be interested in how your predecessor attained his figures. He may have left handing over notes- "I always add 25%" or some other suggestions; ignore these. As a scientist you must use scientific method and there are many tools available to you. Geometric progression is always popular and lends itself its creative statistics. Alternatively, you can plan for the future and produce a graph of your fisheries progression in the years ahead; this method, muted by the use of random numbers (see above), produces some very acceptable figures, and also enables you to have several years estimates in reserve, saving a great deal of work.

If you do not have access to a computer, arrange to have your figures printed on one elsewhere. All figures produced as computer printout will be believed where hand-written ones will be rejected. This point in universally true for all statistical applications.

A final note of encouragement, since the information source of your data is yourself, you have control. No one will dispute your figures, especially when they have been printed in a soberly bound volume.

(Editor's note: Sad but true, this is the way that some fisheries statistical returns are produced–but not in Kiribati!)

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