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FISHERIES CATCH RECONSTRUCTIONS: ISLANDS, PART I

Fisheries Centre, University of British Columbia, Canada

FISHERIES CATCH RECONSTRUCTIONS: ISLANDS, PART I

Edited by

Dirk Zeller and Sarah Harper

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DIRECTOR'S FOREWORD

Island countries around the world rely heavily on marine fisheries resources for nutrition (fish are often the primary source of protein for their citizens), revenues and jobs. Indeed, the food security of many coastal communities around the world, particularly in developing countries, depends on the ability to obtain food fish from the sea. Moreover, most fishing by inhabitants of the islands of the Atlantic and Pacific is small-scale, with fish being caught mainly for subsistence or local artisanal purposes. Currently, national fisheries statistics, and the numbers submitted by member countries to the FAO, do not consistently account for the catches of thousands of small-scale fishers. The result of this poor accounting is that official catch records largely underestimate the likely true catch of a country, and hence underestimate the economic and social reliance on marine resources by these countries. By default therefore, small-scale fisheries end up accounting for a substantial component of the Unreported catches as part of global Illegal, Unreported and Unregulated (IUU) fishing.

With improved infrastructure and technology seen over the past half century, our ability to extract greater quantities of fish from the Ocean has increased dramatically. For small island countries, the problem is compounded by foreign fleets operating in their waters, which puts further strain on the resources available for local consumption.

Most developing countries lack the resources to properly monitor their fisheries, yet they are some of the most vulnerable to the effects of overfishing and collapsed fisheries. A more complete estimate of total fisheries extractions is fundamental to more effectively managing fisheries resources in order to mediate potential threats to food security.

This report presents a comprehensive estimate of total marine fisheries extractions in the waters of several island countries in the Atlantic and Pacific Oceans. The reconstruction method used here was developed by researchers at the *Sea Around Us* Project and has been used to estimate total fisheries catches for a wide variety of large and small countries. The aim of these catch reconstructions is to account for catches of marine fish stocks from the 1950s to the present, thus providing a time series baseline from which future changes in fisheries resources can be assessed. While this catch reconstruction effort is still affected by uncertainties, it provides an improvement over the official statistics currently available for fisheries management and policy development.

Ussif Rashid Sumaila, Director

UBC Fisheries Centre

December 2009

CAYMAN ISLAND FISHERIES CATCHES: 1950-2007[1]

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ABSTRACT

Total marine fisheries catches were estimated for the Cayman Islands from 1950-2007. Reports of fisheries catches by the Cayman Islands over this time period were very limited. Fisheries data obtained from the FAO were the only available data for most years and represent only catches taken by Cayman fishers in foreign waters. Supplemental information was obtained for fisheries both inside and outside of Cayman waters, including artisanal, subsistence, recreational and shark catches taken between 1950 and 2007. Our reconstruction of total marine fisheries catches by the Cayman Islands in the Western Central Atlantic (FAO Area 31), which included all fisheries sector estimates, was 3 times larger than that presented by the FAO on behalf of the Cayman Islands. Landings of tuna and decapod species reported to the FAO as being caught by Cayman vessels in the Eastern Central Atlantic (area 34) were also presented but were not included in our reconstruction. These catches are thought to have been taken by 'flag-of-convenience' vessels of non-Caymanian origin. Our investigation of Caymanian fisheries illustrated the need for better reporting of fisheries catches by all fisheries sub-sectors and better taxonomic accounting.

INTRODUCTION

The Cayman Islands, a British overseas territory in the Caribbean Sea, are comprised of three islands: Grand Cayman (19.20°N, 81.15°W), Cayman Brac (19.43°N, 79.49°W), and Little Cayman (19.49°N, 80.02°W). Grand Cayman is the largest and most populated of the three, where the capital city, George Town, is located (Figure 1). The Cayman Islands are located in FAO Statistical area 31, the Western Central Atlantic. The islands were officially settled in the early 1700s, but were first discovered by Columbus on his trip between Porto Bello and Hispaniola in 1503. The islands soon became known as frequent feeding and breeding grounds for green turtles *(Chelonia mydas)* and hawksbill turtles *(Eretmochelys imbricata)*. Shipwrecked sailors, military deserters, and iterant fishers whose occupations centred on selling captured turtles to passing ships comprised the majority of the early Cayman population (Smith, 1985).

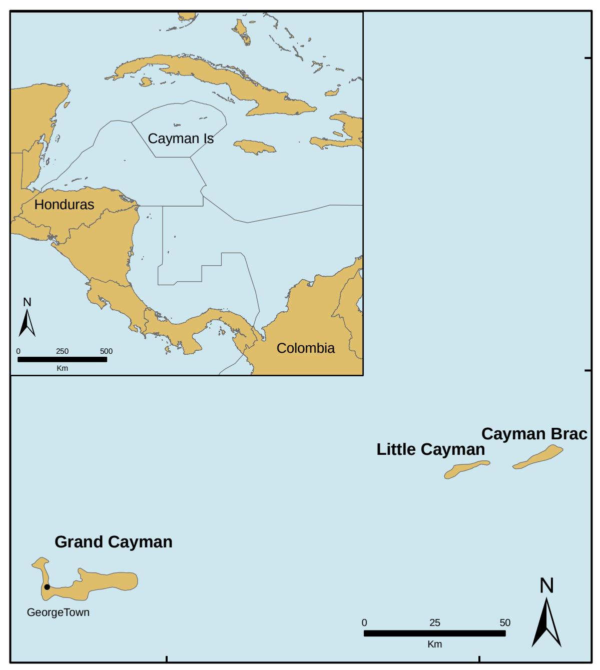

Figure 1. Map of the Cayman Islands showing Grand Cayman, Little Cayman and Cayman Brac. Inset map showing EEZ of Cayman Islands, Honduras and Colombia.

In the 1937 British Colonial Report for the Cayman Islands, fishing is reported to be the mainstay of the islanders (Anon., 1937). In a 1943 census, 63 fishers were reported to be employed in the fishing industry, which is the only year the number of

[1] Cite as: Harper, S., Bothwell, J., Bale, S., Booth, S., and Zeller, D. (2009) Cayman Island fisheries catches: 1950-2007., pp.3-11. *In*: Zeller, D. and Harper, S. (eds.) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia [ISSN 1198-6727]

fishers was officially surveyed or reported. The bulk of the catch consisted of turtles (~3,000 green turtles·year^{-1} and ~2,950 kg·year^{-1} of hawksbill turtle shells), sharks (> 6,000 hides·year^{-1}), and sponges (Anon., 1952). Initially, turtles were caught locally, but by the early 1800s, local catches were so low that fishers moved to waters off the shores of Costa Rica, and in the 1850s to those of Cuba, Nicaragua, and Honduras (Thompson, 1944).

It was in the shallow, sandy-bottomed waters of Cuba, Nicaragua, and Honduras that shark fishing developed as a side-line of turtle fishing. Fishers discovered nurse sharks (*Ginglymostoma cirratum*) and tiger sharks (*Galeocerdo cuvier*), which were harpooned after being baited with lines, and trapped in turtle nets. At this time, the leather industry was keen to use shark skins for their durable and scuff-resistant qualities, but the trade peaked as early as 1937 when more than 11,000 hides were exported (Anon., 2006b; Thompson, 1944). A general lack of knowledge prevented other marketable items such as fins, liver oil or flesh from becoming exportable commodities. Because leather was the only item of interest, the size of a shark was of the utmost importance, and as a result, fishers targeted sexually mature females, which caused shark populations to quickly decline. In addition, turtles were protected by conservation policies in the mid-1960s, and thus the Cayman Islands' primary resource could no longer be targeted (Troëng and Rankin, 2005).

In the early 1900s, fishers began targeting pelagic bony fish, which primarily included kingfish (*Scomberomorus* spp.), queenfish (*Acanthocybium solanderi*), dolphinfish (*Coryphaena hippurus*), and bonito (*Sarda sarda*; Thompson, 1944). Exploitation otherwise focused on bottom fish immediately surrounding the islands (Thompson, 1944); however, catches were generally inadequate to supply the demand for local fish. Some of this was due to poor infrastructure for storage and distribution, as eastern regions experienced surplus catches and small markets, whereas in George Town, demand always exceeded supply. However, overall, the opportunities for fishing in the Cayman Islands were not very plentiful (Thompson, 1944). There were thought to be many sites of unrealized fishing potential outside of local waters, such as Rosaline Bank, the Mosquito Cays, Seranna and Seranilla Banks, and the mass of small cays and islands elsewhere in the region (Thompson, 1944). Despite attempts in 1951 to develop fisheries targeting these areas, the necessary infrastructure, knowledge, and capital were missing, and no industrial fin-fish fishery developed (Anon., 1952; 1954; 1956; 1958; 1960). In the 1960s, however, Nassau grouper (*Epinephelus striatus)* spawning aggregations began to be locally exploited. They were quickly depleted and the species now receives some protection locally (Bush *et al*., 2006). Of the six Nassau grouper aggregations, four were fished out (Semmens *et al*., 2006)

Historically, finfish fisheries were always subsistence or small-scale artisanal. Due to a shortage of fish for local consumption, fresh seafood formed only a small part of the Cayman diet, and practically no fish were available for commercial export. According to Thompson (1944), a significant dependence on tinned fish such as salmon, sardines, tuna and herring from northern origins occurred at this time. He reports the sole commercial-scale attempt by Cayman fishers to market abroad to have been a seasonal surplus of saltfish exported to Jamaica. Some fish were exported to Central America, but faulty handling, a poor choice of markets, and political difficulties made the business unsustainable. Tinned fish were consistently easier and more economical to deal with than locally sourced catches (Thompson, 1944). In the 1980s, Cayman flagged purse seine operations fished for skipjack tuna (*Katsuwonus pelamis)* and yellowfin tuna *(Thunnus albacares)* in the Eastern Central Atlantic (FAO statistical area 34). Nantantian decapods were also targeted in this area and reported to FAO into the early 1990s. However, these vessels had flags of convenience, and were not of Cayman origin.

Today, the Cayman Islands are economically well-off, with an economy dominated by tourism and offshore banking (Shackley, 1998). With an average *per capita* income of U.S. $46,500 (2006 estimate), and the highest standard of living in the Caribbean, the average citizen is not dependent upon locally sourced fish. Over 90% of foods are imported (Anon., 2008), but some artisanal and subsistence fishing persists (J. Bothwell, pers. obs., DoECI). Population growth on the Cayman Islands largely mirrored its development as an offshore banking centre (Brittain-Catlin, 2005). The population rose from approximately 7,500 in 1970, to 25,000 in 1990. During the 1990s, the Cayman Islands experienced an annual growth rate of 4.3%, which was the highest in the Caribbean at that time, and in 2005, the Cayman Islands had a resident population of more than 45,000 (Ellison and Farnsworth, 1996; Anon., 2006a). The developments which went along with population growth threaten important mangrove areas and channels, integral to the health of marine fish populations. Between 1980 and 1990, mangrove area decreased from

114 km² to 72 km² in the Cayman Islands. A general trend was found at this time in the Caribbean between the disappearance of mangrove habitat and decreasing fisheries catches (Ellison and Farnsworth, 1996).

Several marine conservation laws were enacted in 1986 in response to coastal developments in the Cayman Islands and the anecdotal observations by fishermen of reduced catches. These were accompanied by the creation of Marine Protected Areas (MPAs) categorized as: 1) Marine Parks; 2) Environmental Areas; 3) Replenishment Zones; and later 4) Grouper Spawning Sites (www.mpaglobal.org). Fishing for Nassau groupers is closed between 1 November and 31 March each year at 6 known and 2 potential spawning aggregation sites (Bush *et al.*, 2006), which were severely depleted through recreational, artisanal and subsistence fishing. Of the historical spawning aggregations most are in either depleated or in decline and only one is considered comparatively healthy (Bush *et al.*, 2006). Amendments to the laws of 1986 were made in 2002 and 2003 to continue a complete ban on fishing in aggregation sites until 2011 (Bush *et al.*, 2006; C. Semmens, pers comm., Reef Environmental Education Foundation). Lobster (*Panulirus argus*), conch (*Strombus gigas*), whelk (*Cittarium pica*) and several other species are also protected (information available from Cayman Islands Department of Environment [DoECI], http://www.doe.ky). Approximately 34% of coastal waters are presently protected to some extent by MPAs and all local waters fall under these conservation laws (Spalding *et al.*, 2001).

Historically, little attention was paid to the monitoring of marine resources, but there is now a focus on marine conservation. While the FAO present fisheries catch data since the 1950s, these records appear to be the only readily available fisheries data over this past 50+ year period. After reviewing the history of the Cayman Islands, it appears that considerable under-reporting occurred in the early periods. Globally, catches of small-scale fisheries are often not recorded or are under-reported by local fisheries agencies (e.g., Zeller *et al.*, 2007), which appears also to be the case for the Cayman Islands. The purpose of the present study was to reconstruct fisheries catches by the Cayman Islands and present a review of Caymanian fishing operations between 1950 and 2007. These attempts aim to counter the phenomenon known as 'shifting baselines' in managing fish stocks (Pauly, 2000). The assumptions made throughout the methods are justified by the unsatisfactory alternative of accepting the current database, which is quite limited in scope, containing no meaningful data prior to the late 1980s and containing little taxonomic detail throughout.

MATERIALS AND METHODS

Cayman fishing vessels operate both in the waters of the Cayman Islands and in the waters of neighbouring countries. Fisheries catches as presented by the FAO on behalf of the Cayman Islands occur in FAO statistical area 31, which includes the Cayman Islands EEZ and the EEZ of many other Caribbean countries, and in area 34, which lies directly east of Area 31 (Figure 1). We describe the fisheries that take place in each of these areas.

Western Central Atlantic (FAO Area 31)

Fishing in Cayman waters

An inshore (artisanal) fishery takes place within the Cayman EEZ. Catches by this sector are small, estimated at 3-5 t·year^{-1} since the 1950s (Brunt and Davies, 1994; J. Bothwell, pers. obs., DoECI). This fishery includes catches for subsistence purposes (approximately 25%), for commercial purposes (approximately 25%) and for recreation (approximately 50%). The species targeted by this sector are mainly of the Lutjanidae and Serranidae families (Table 1). In the early period (1950s), the catch was dominated equally by lutjanids and serranids, whereas in the later period (1990s/2000s) the catch was mainly lutjanids (J. Bothwell, pers. obs., DoECI). Additional species may have also been caught by this sector.

Table 1. Estimated taxonomic breakdown of fish caught inside and outside Cayman waters between 1950 and 2007 (J. Bothwell, pers. obs., DoECI). This breakdown excludes sharks and turtles, which dominated the catch in the 1950s.

Taxon	Percentage of catch (%)	
	1950s	1990s
Lutjanidae	45	80
Serranidae	45	10
Dolphinfish	2.5	2.5
Small pelagics[a]	2.5	2.5
Misc. marine fishes	5	5

[a] mainly Rainbow runners and Ocean triggerfish.

An offshore recreational fishery for billfishes started in the Cayman Islands in the 1970s and continues today (J. Bothwell, pers. obs., DoECI). This fishery takes place inside the Cayman Islands EEZ. Annual fishing derbies target Blue Marlin (*Makaira nigricans*) and other pelagic sportfish (Brunt and Davies, 1994). Records of catches by this fishery are limited, but Brunt and Davies (1994) present the number of fish caught and retained over the 1983-1991 time period. Thus, fish that were caught and released were ignored here, i.e. assumed to have survived. The numbers of retained fish were converted to wet weight (in tonnes) using average weights for each species presented in FishBase (www.fishbase.org). Catches over 1970-1980 time period averaged half that of the 1983-1991 period, the 1990s were estimated to have the same average catch as reported for 1983-1991 (35.8 t·year^{-1}) and catches in the 2000s were assumed to have decreased by a third (J. Bothwell, pers. obs., DoECI).

Fishing in foreign waters

Reported annual landings for 1950 - 2007 in the Western Central Atlantic (FAO Statistical Area 31) for the Cayman Islands were obtained from the FAO FishStat database. Data supplied to the FAO by the Cayman Islands for FAO statistical area 31 are presented as 'miscellaneous marine fishes'. For the period 1950-1986, <0.5 t·year^{-1} are reported (Figure 2). Between 1987 and 1990, the annual landings increase from 76 t to 110 t, and are then consistently reported as 125 t·year^{-1} until 2007, with the exception of 1996 when 110 t were reported (Figure 2). Aside from the limited information presented by the data supplied to the FAO, very little quantitative information was found in the literature as a basis of comparison for our analysis.

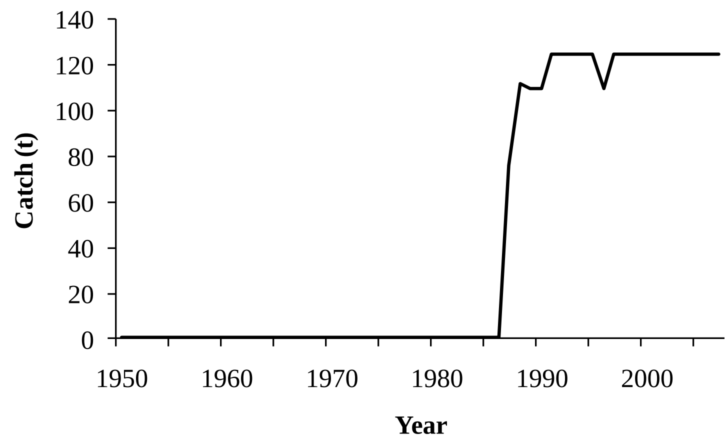

Figure 2. Catches presented by the FAO on behalf of the Cayman Islands, 1950-2007.

In personal correspondence with the Department of the Environment, Cayman Islands (DoECI), it was determined that the data presented by the FAO for statistical area 31 were catches taken in Honduran waters (Misteriosa and Rosario Banks) and Colombian waters (Baja Nuevo). In 2002, the government of the United Kingdom and Honduras entered into an access agreement which allowed a limited number of Cayman vessels to fish for snapper and grouper on select banks within Honduran waters. Prior to this formal agreement, fishing was allowed under historic (informal) access arrangement (J. Bothwell, pers. obs., DoECI). No such agreement exists for Cayman vessels in Colombian waters; however, the location of fishing in Colombian waters (Baja Nuevo) is a disputed zone within Colombia's EEZ which means that it may not be recognized by fishing vessels as being Columbian waters.

Table 2. Shark exports for the Cayman Islands as documented in the Colonial Reports (1937-1960). Also shown are conversions to kilograms and metric tonnes using FishBase life history tool.

Year	Hides	Catch (kg)	Catch (t)
1935	11,962	514,366	518
1936	6,487	278,941	281
1937	6,254	268,922	271
1953	934	40,162	40
1954	568	24,424	25
1955	675	29,025	29
1956	521	22,403	23
1957	1,700	73,100	74
1958	900	38,700	39
1959	485	20,855	21
1960	1,000	43,000	43

In the 1950s, catches by the Cayman Islands' in waters outside the Cayman Islands were thought to have been twice the amount of the current 125 t·year^{-1} estimate; however, catches in the 1950s were almost entirely of sea turtle and shark, the majority of which was exported (J. Bothwell, pers. obs., DoECI). To estimate catches by this fishery from the 1950s through to the 1980s—before data supplied to the FAO report any sizable catches—a linear interpolation was done from the 1950 estimate of 250 t to the 1988 estimate supplied to the FAO of 112 t, excluding the portion of the catch which would have been either turtle or shark catches. We assumed that, as shark and turtles populations declined and turtle protection legislation was introduced, these Cayman vessels would have continued fishing operations but would have begun targeting other species.

Turtle catches in 1950 were estimated to be approximately 200 t·year^{-1} (J. Bothwell, pers. obs., DoECI) and were assumed to be zero in 1965, when legislation was introduced banning turtle harvests (Troëng & Rankin, 2005). To derive a time series of turtle catches from 1950 to 1965, we interpolated linearly between the two anchor points (1950 and 1965). Although these catches were used in our calculations, we did not include turtle catches in our reconstruction of total marine fisheries catches.

Shark catches were estimated based on records kept by the Cayman National Trust (an ecological and historical preservation society, www.nationaltrust.org.ky) and data obtained from British Colonial Reports (Anon., 1937; 1954; 1956; 1958; 1960). Caymanians began shark fishing in the early 1930s off the coast of Costa Rica. Fishers then shifted their efforts to the shores of Nicaragua and Honduras, but by the late 1930s, sharks were already in serious decline (Anon., 2006b). The Colonial Reports present the number of hides exported, which were assumed to each represent one individual. We calculated the live weight equivalent in metric tonnes using the life-history tool from FishBase, which converts fish length to weight based on species specific, empirically derived ratios (Froese and Pauly, 2008; www.fishbase.org; Table 2). We assumed that nurse sharks were the predominant catch, so we used the statistics for this species in our calculations. The average length of a nurse shark at maturity is 194 cm, which converts to an average weight of 44 kg (Compagno, 1984). Because the largest individuals were targeted for hide quality, the average weight at maturity was used to derive relatively conservative annual catches (t). We estimated shark catches in 1950 to be approximately 50 t. This was based on our estimate of catches taken by Cayman vessels outside Cayman waters (250 t), excluding the sea turtle portion of the catch (200 t). An interpolation was then done between the 50 t estimate for 1950 and the 40 t for 1953.

Due to evidence of rapidly depleting shark stocks as early as 1940, a diminishing turtle fishery in the mid-1960s, and a lack of any shark catch or export data post-1960, we chose to linearly interpolate catch values from the last data point available (1960), to zero in 1965. More specifically, the introduction of laws protecting turtles from fishing in the mid-1960s throughout Caribbean waters, and a complete ban of Cayman vessels in Nicaraguan waters decreased the ease and feasibility of fishing where sharks had once been plentiful (Troëng and Rankin, 2005). It also eliminated opportunities for turtle fishing which had historically been the primary catch of fishers who caught sharks, and as a result, shark fishing eventually ceased as a commercial activity.

Catches taken outside the Cayman EEZ were mainly shark and sea turtle in the 1950s. As catches of these declined, fish from the Lutjanidae and Serranidae families were targeted. Catches also included Dolphinfish and small pelagics such as Rainbow runners (*Elagatis bipinnulata*) and Ocean triggerfish (*Canthidermis sufflamen*). The catch composition aside from shark and turtle was the same as what was estimated for the artisanal fishery in Cayman waters (see Table 1). Similar to what was described above for the artisanal sector, serranids were more heavily exploited in earlier time periods than they are today and catches in recent times are dominated by the lutjanids family (J. Bothwell, pers. obs., DoECI; Table 1).

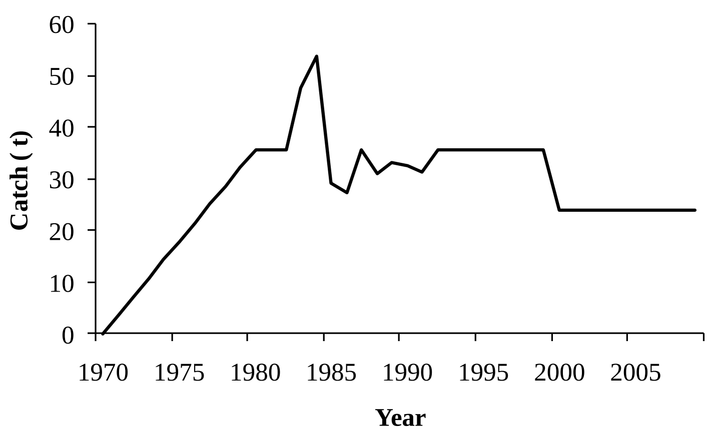

Figure 3. Estimated catches for the Cayman Islands offshore recreational fishery for billfishes, 1970-2007.

Eastern Central Atlantic (FAO Area 34)

FAO FishStat revealed Cayman flagged vessels fishing for both yellowfin and skipjack tuna in the Eastern Central Atlantic (FAO Statistical Area 34) during the years 1980-1982. Nantantian decapods were also reported by the Cayman Islands in this area for the period 1979-1993. The majority of tuna fishing in the

Eastern Atlantic is by purse seine (Joshi, 1993), and the vessels fishing in the Eastern Central Atlantic are likely to be flag of convenience operations, and not Cayman owned vessels (J. Bothwell, pers. obs., DoECI). Very few true distant water fleets are operated from Latin America in general, and the Cayman Islands are a popular choice for registration of foreign vessels. This is due to the presence of a stable government and dependable legal system (Beaudry and Folsom, 1993).

No reconstructive effort was applied to the data from FAO Area 34, as it is quite common for these types of vessels to obtain licenses for short periods of time. In addition, no further evidence of these fishing operations could be found in the literature.

Results

Western Central Atlantic (FAO Area 31)

<u>Fishing in Cayman waters</u>

Catches by the inshore (artisanal) sector totalled 232 t between 1950 and 2007, based on 4 t·year^{-1} (the average of the source data of 3-5 t·year^{-1}). This total included approximately 58 t of subsistence catches, 58 t of commercial catches and 116 t from the inshore recreational fishery.

Catches by the offshore recreational billfish fishery were estimated to be approximately 1068 t over the 1970-2007 time period. Catches peaked during the 1980s and 1990s and then declined to present day catches of approximately 23 t·year^{-1} (Figure 3). The taxonomic breakdown applied throughout the time period was 96% Atlantic blue marlin, 3% Atlantic white marlin, 1% Sailfish and a small number of Longbill spearfish (<0.5%).

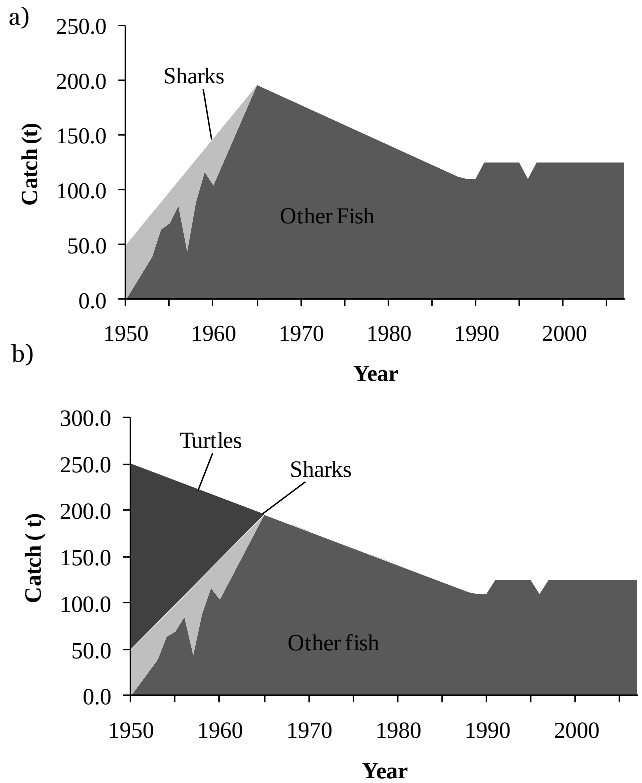

Figure 4. a) Catches included in our reconstruction of marine fisheries catches by the Cayman Islands, 1950-2007. b) Turtle, shark and other fish catches. Turtle catch used only in calculating catches of other fish (see Methods).

<u>Fishing in Foreign waters</u>

Total catches of approximately 7,789 t were estimated to have been taken by Cayman vessels outside of the Cayman EEZ. Included in this total were 520 t of shark caught between 1950 and 1965, and 7,269 t of other fish caught between 1950 and 2007 (Figure 4a). The sharks were mainly caught in the waters of Nicaragua, Costa Rica and Honduras, whereas the majority of other fish catches were from Honduran and Colombian waters.

The shark catch was thought to predominantly consist of nurse sharks with a minor component of tiger sharks. Shark fishing appears to have peaked in 1935, when almost 12,000 hides or 518 t of shark were caught and exported. A secondary peak in catches occurred in 1957 when 1,700 hides or 74 t of shark were exported. The trade collapsed to between 21 and 43 t in the last two years data were recorded (1959 and 1960). In

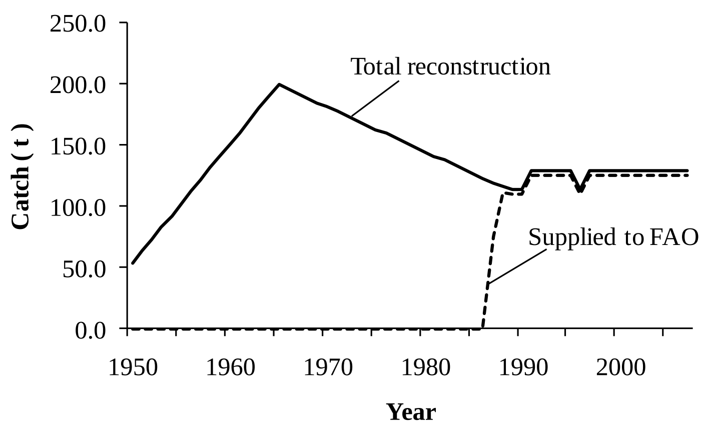

Figure 5. Estimated total marine fisheries catches by the Cayman Islands, inside and outside of the Cayman EEZ, within FAO statistical Area 31 for the 1950-2007 time period as compared to the catch total supplied to the FAO.

these final years of reporting catches were about 4% of the mid-1930s catch.

Catches of other fish were mainly serranids and lutjanids in the early time period, whereas the catch was dominated by lutjanids in later years. Fish catches peaked in the late 1960s, declining until the 1990s when catches levelled off, remaining relatively constant thereafter.

Total Reconstructed Catch

Our reconstruction of marine fisheries catches by the Cayman Islands for the period 1950-2007 was estimated to be approximately 8,200 t (Figure 5). This total is 3.2 times larger than the amount presented by the FAO on behalf of the Cayman Islands for catches taken in FAO Statistical Area 31. Catches supplied to the FAO and presented as Cayman Island catches are for fisheries in non-Cayman Island waters only and appear to under-report actual catches. We estimated that additional catches by Cayman vessels fishing outside of Cayman waters in the early period (1950-1980s) and catches by the inshore (artisanal) sector inside of Cayman waters over the entire time period, added 5,500 t to the total catches presented by the FAO on behalf of the Cayman Islands over the study period (1950-2007).

Eastern Central Atlantic (FAO Area 34)

According to FAO statistics, Cayman registered vessels fishing in Statistical Area 34 landed a total of 8,495 t of nantantian decapods during the period 1979-1993, with a peak catch of 1,021 t·year^{-1} in 1987 (Figure 6). A total of 2,162 t of yellowfin tuna were caught during the 1980-1982 period, with a peak catch of 1,460 t in 1981 and a minimum catch of 100 t in 1982. Between 1980 and 1982, 2,119 t of skipjack tuna were landed, peaking in 1981 at 1,800 t and decreasing to a minimum of 30 t by 1982.

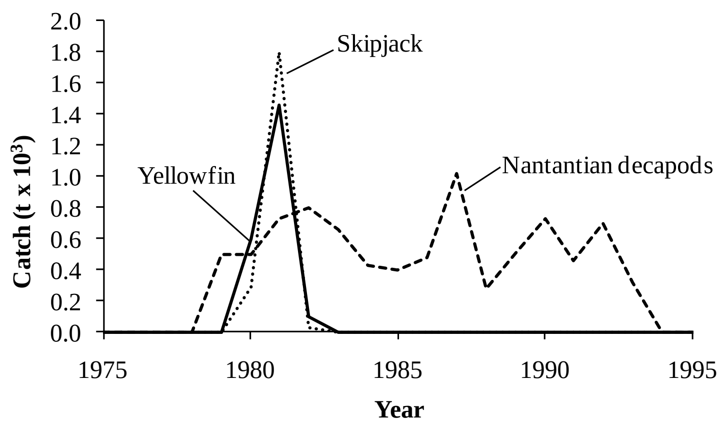

Figure 6. Catches of skipjack tuna, yellowfin tuna and nantantian decapods in the Eastern Central Atlantic (FAO statistical area 34) by Cayman Island registered vessels, 1950-2007.

DISCUSSION

Total marine fisheries catches by the Cayman Islands (excluding catches by Flag of Convenience vessels in Area 34) were over 3 times larger than those presented by the FAO on behalf of the Cayman government. While some Cayman Islands catches were presented in FAO fisheries statistics between 1950 and 2007, these data under-report actual catches. We know from Thompson (1944) that fisheries resources were not plentiful in local waters, even at the beginning of the 20th century, which is likely why the offshore sector developed so early (pre-1950). Despite having limited fishing opportunities in local waters, some catches were taken inside the Cayman Island's EEZ, which have not been represented in fisheries reports. Fisheries catches outside of the Cayman EEZ have, in part, been accounted for in the catch statistics supplied to the FAO; however we estimate that catches were under-reported in the early time period, and those that have been described lack taxonomic detail. Here, we reconstructed marine fisheries catches by identifying additional fisheries sectors, including the inshore (artisanal) fisheries, offshore recreational fishery and shark fishery, which have been neither represented in FAO data nor have they been documented in detail in the literature.

Although early fishing efforts targeting nurse sharks and tiger sharks in the Caribbean Sea were documented in the literature, they have not been included in the catch statistics supplied to the FAO. This industry was rather short-lived due to the exploitative rate at which sexually mature female sharks were targeted for the size and quality of their hides. Catches peaked very early on in the lifespan of this fishery (1930s), and had declined substantially by the 1960s. This fishery occurred-primarily as a by-product of green turtle fishing (Thompson 1944); therefore, the introduction of conservation laws for marine turtles in the mid-1960s, likely also led to the observed decline in shark catches. As turtle and shark fisheries declined, fishers presumably started targeting snapper and grouper, which could be sold or exported, though this did not generate the revenue that was no longer provided by the previously lucrative shark and turtle trade. As the fisheries declined and vessel technology changed most of the fishers switched careers to the merchant marine, crewing mainly on vessels from other countries.

In this report, we included the tuna and decapod catches from the Eastern Central Atlantic, presented by the FAO as Cayman Island catches. These catches were likely to have been taken from vessels that were re-flagged from another country of origin. Historically, the Cayman Islands were a popular choice to register foreign vessels, but in 1989, the Cayman government rendered the registration of such vessels illegal, and the practice appears to have been discontinued. These catches were not included in our reconstruction of marine fisheries catches as these were not catches made by the Cayman Islands.

While Cayman fisheries seem very small and of little economic significance, getting a better understanding of catches, especially with respect to their taxonomic composition, should be considered a relevant and worthwhile pursuit, as the Cayman Islands struggle with growing ecosystem problems due to development and population pressure. Recreational fisheries have potentially greater economic significance as does the revenue from dive tourism. Both of these activities require that a healthy ecosystem be maintained.

In closing, though commercial fisheries are no longer the mainstay of Cayman residents, small-scale fisheries persist, and an increased effort in documenting catches to the level of species is integral to the health of fisheries resources. The current data submitted to FAO do not provide accurate or reliable information to manage Cayman Island fisheries, as these report only catches taken outside of their waters.

Acknowledgements

We acknowledge the support of the *Sea Around Us* Project, a scientific collaboration between the University of British Columbia and the Pew Environment Group. We would like to thank the Cayman Department of Environment for correspondence regarding fisheries management and artisanal fishing, and C. Semmens, a member of the REEF Environmental Education Foundation, for her correspondence regarding Cayman MPAs and the protection of grouper spawning areas.

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RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR GUADELOUPE FROM 1950-2007[1]

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ABSTRACT

A reconstruction of total marine fisheries catches for Guadeloupe was undertaken from 1950-2007. The catch reconstruction combines commercial landings based on data as supplied to the FAO with unreported catches based on estimates of subsistence catches taken from consumption information combined with trade and commercial data and recreational catch estimates. Total reconstructed catches were estimated to be approximately 502,696 t over the 1950-2007 time period, which is 35% larger than the total catches of 372,156 t as reported by the FAO on behalf of Guadeloupe. In the most recent years (2000-2007), total annual catches were on average 21% higher than the reported landings suggested. Reporting only commercial landings gives an incomplete picture of the fisheries of a country on both a local and global scale as it generally does not include small-scale and/or subsistence fisheries and recreational fisheries.

INTRODUCTION

Guadeloupe is an island group located in the eastern Caribbean Sea, between 16° N and 61° W and is made up of two main islands, *La Basse-Terre* and *La Grande-Terre*, and four smaller islands *La Désirade*, *Les Saintes*, *Marie-Galante* and *Petite Terre*, comprising about 1,700 km², with an Exclusive Economic Zone (EEZ) of over 95,000 km² (Figure 1). It is part of the Lesser Antilles group, between Montserrat in the north and Dominica Island in the south (Figure 1). The island is one of the four overseas departments of France, and thus has also been a part of the European Union (EU) since 1957. The territory is divided in two urban districts: Basse-Terre (prefecture of the Guadeloupe department) and Pointe-à-Pitre.

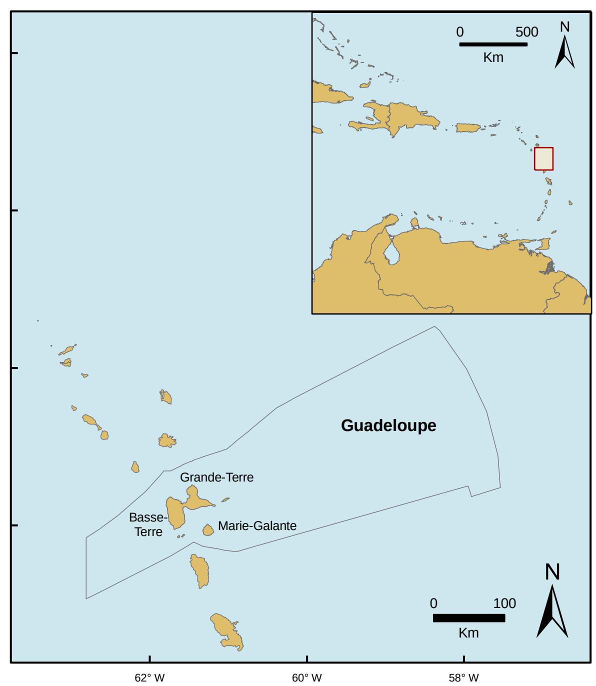

Figure 1. Map of Guadeloupe and its EEZ. Inset map showing its location within the Caribbean.

The FAO FishStat database, which offers time series data on marine fisheries landings from 1950 to the present, is based on national statistical data supplied by its member countries. Therefore, the quality of the FAO data depends on the capacity of statistical collection within these countries. The FAO data have been the basis of many global fisheries studies (e.g., Pauly *et al.*, 1998) but they are, in fact, incomplete (Zeller *et al.*, 2006; 2007). Furthermore, data reported by FAO do not distinguish between fisheries sub-sectors such as commercial vs. subsistence. In addition, Illegal, Unreported and Unregulated (IUU)

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catches are a concern for fisheries worldwide (Bray, 2000) and presumably also add to total marine fisheries removals by Guadeloupe in the Caribbean Sea.

Fishing in Guadeloupe is traditionally concentrated around the island shelf due to the large number of species and the fact that the EEZ of other neighboring island countries are more difficult to reach. The main species caught are tunas, bonitos, king mackerel (*Scomberomorus cavalla*), bigeye scad (*Selar crumenophthalmus*), sea bream (*Archosargus rhomboidalis*), saury (*Scomberesox saurus saurus*), snapper (*Lutjanus* spp.), queen snapper (*Etelis* spp.), deep-sea sharks, crustaceans, mollusks and sea urchins, which can all be sold commercially. Queen conch (*Strombus gigas*) and spiny lobster (*Panulirus argus*) fisheries are significant in some areas of the Caribbean Sea (Agard and Gobin, 2000); however, Guadeloupe mainly imports these to meet their consumption demand.

Guadeloupe's fishing fleet is comprised mainly of small boats less than 12 m in length with powerful motors that enable them to operate over the entire continental shelf, and a few boats greater than 12 m in length that operate offshore (Anon., 2006). In 2005, there were an estimated 1,000 registered fishers, the majority of which were small-scale fishers (Anon., 2009a). The recreational fishing sector was estimated in 2005 to have 106 fishers who mainly targeted fish in the Labridae and Scaridae families, dolphinfish, and shellfish such as Conch (Guyader, 2008).

The expansion of fisheries in the Caribbean has been limited by over-exploitation of inshore fisheries by small-scale fisheries, a reliance on small vessels and a lack of cold storage facilities (Agard and Gobin, 2000). Fishing in Guadeloupe and other nearby islands are also affected by the presence of a naturally occurring but toxic alga (*Ciguatera*) which contaminates fish flesh and renders it inedible (Olsen *et al.*, 1984). The risk of Ciguatera limits the trade of seafood products, particularly with respect to exports from Guadeloupe but also imports from other nearby islands. Efforts in the 1970s were made by the FAO in conjunction with the Canadian International Development Agency (CIDA) to expand the fisheries sector in the Caribbean Islands through fleet upgrades and processing infrastructure (Mohammed, 2003a).

The objective of the present study is to provide an estimate of total marine fisheries catches for Guadeloupe from 1950-2007, which will serve as a scientific baseline for examining issues such as food security and resource depletion in the Caribbean Sea. Although several studies and reports have been published previously, there has been no comprehensive review of potential historical catches that account for subsistence and recreational catches in addition to reported commercial landings, and there has been no expansion to cover Guadeloupe as a whole.

Materials and Methods

Total marine fisheries catches for Guadeloupe were estimated from 1950-2007 using a combination of FAO landings data and global trade statistics assessed by the *Sea Around Us* Project (www.seaaroundus.org). The FAO statistics were taken as representing only commercial landings, to which we added estimates of subsistence catches, being interpreted as non-commercial catches and estimates of recreational catches. Commercial catch data from other reliable sources were used in place of the FAO commercial landings data for years when such data were available. The resulting time series, which includes commercial catches, subsistence catches and recreational catches represents the total reconstructed catch estimates for Guadeloupe from 1950-2007.

Human population

Human population data were taken from the historical population demography website (www.populstat.info). Data are provided for most years. In years without population data, a linear interpolation between neighboring years was done to estimate missing values. The population doubled from 210,000 in 1950 to 421,000 by 2000 (Figure 2). Guadeloupe, like other Caribbean Islands, is a popular holiday destination. Visitors to Guadeloupe totaled 623,134 in 2006 with an average length of stay of 3.5 nights (Anon., 2009b), resulting in 2.2 million visitor days·year^{-1}. Averaged over a full year, this effectively added the equivalent of approximately 6,000 full-time residents to the population of Guadeloupe that year.

Commercial fisheries

Reported commercial landings consist of fishery products that are sold in the domestic market or exported. A review by Desse (1989) of studies describing commercial catches of marine fishes, taken in Guadeloupe, provided four FAO independent anchor points of commercial catches between 1982 and 1985. All other commercial data were taken from the FAO landings statistics database.

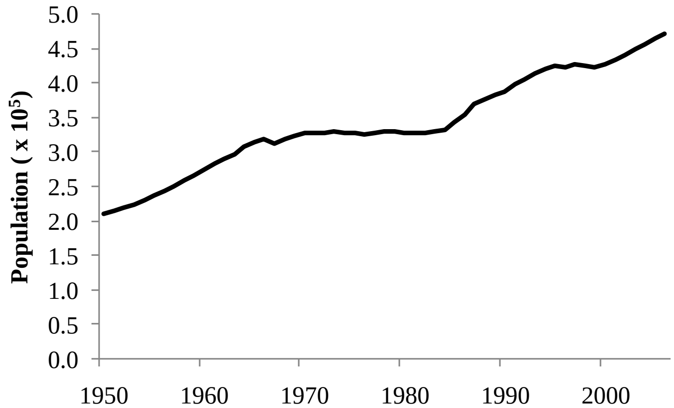

Figure 2. Population estimates for Guadeloupe, 1950-2007.

Trade

While trade data for Guadeloupe were available from the FAO trade database, an alternative source was used here. Trade data were obtained from the *Sea Around Us* Project global trade database and transformed from trade product weight to live weight using FAO conversion factors as well as an independent collection of conversion factors (from EuroStat, Japanese customs, US Census Bureau, and UN ComTrade) integral to the global trade database. Import and export data from 1963-1995 were available for Guadeloupe and estimates for earlier years were derived through linear interpolation from an assumption of zero trade in 1944, i.e. during WWII, to the first good anchor point in 1963. This may result in an underestimate of trade in the early years. To estimate trade in the later period where data were either missing or incomplete, we used the five-year average of live weight from 1991-1995 and carried it forward as a constant value from 1995 to 2007. Estimates of net trade (import – export) were then used in estimating seafood consumption based on Aldrich and Connell's (1992) claim that half of all seafood consumed in Guadeloupe were supplied through imports. The consumption rate in comparison with the reported landings and net trade was then used as the basis for our calculation of subsistence catches.

Subsistence fisheries

Data regarding subsistence or artisanal fishing in Guadeloupe were not readily available. Small-scale fisheries in Guadeloupe likely comprise both artisanal and subsistence sectors. We assumed conservatively that artisanal catches were included in the reported landings as they are part of the commercial sector, while subsistence catches were not accounted for in the reported landings. Subsistence catches were estimated as the portion of the total demand (i.e., consumption) that is neither met through commercial catches nor imports. The US National Marine Fisheries Service (NMFS) released a set of estimates for annual seafood consumption in Guadeloupe, but these appear to be based on the data supplied to the FAO, which are likely underestimates as they are based on the amount of seafood products available from commercial fishing and net trade (imports - exports) only. Aldrich and Connell (1992) state that in Guadeloupe "about half of all fish consumed are imported", which was used here to estimating seafood consumption. Hence, the *per capita* consumption rate was assumed to be twice the *per capita* import rate. To derive subsistence catch rates, we first took our estimated consumption rate, subtracted *per capita* net trade (imports- exports) to get an estimate of the portion of the total consumption demand that is met through local supply (which includes commercial and subsistence sectors) and then removed the *per capita* commercial catches. Thus,

$$C_s = S_t - T_N - L_C$$

where C_s is Subsistence catch, S_t is Total Supply (= total consumption), T_N is Net Trade (imports - exports) and L_C is Commercial landings.

In cases where there was substantial annual variation in the *per capita* subsistence rates due to large variations in net trade, an average was taken from the two years before and after the anomaly. This adjustment was necessary for 10 of the 56 years in the time series. The first few years in the time series likely had higher consumption rates than those calculated here, as trade was just getting started and probably accounted for less than half of consumption in these early years.

Table 1. Estimated species composition (%) of subsistence catches for Guadeloupe based on St. Lucia's species composition for inshore fisheries (Mohammed, 2003a).

Common name	1950-1959	1960-1969	1970-1980[1]	1981-1990	1991-2001
Barracudas	0.0	0.5	4.3	15.8	2.1
Bermuda chub	0.0	0.0	0.0	0.4	0.3
Bonefishes	0.0	0.0	0.0	0.0	0.1
Butterfishes	0.0	0.1	0.0	0.0	0.0
Croakers	0.0	0.0	0.0	0.2	1.5
Demersal sharks	0.0	0.0	0.0	1.3	1.2
Goatfishes	0.0	0.0	0.0	0.0	3.2
Groupers	4.2	3.5	6.4	19.9	3.6
Grunts	0.0	0.0	0.0	13.7	3.2
Halfbeaks	5.5	0.9	0.0	0.0	19.5
Herring and sardines	0.0	0.9	0.0	0.0	5.1
Jacks (reef)	0.8	0.0	0.7	2.6	1.7
Jacks (coastal)	76.0	87.3	34.5	14.4	19.7
Lobsters	2.6	4.0	0.7	0.8	4.7
Marine fish nei	7.6	0.0	45.9	0.0	2.2
Octopus	0.0	0.0	0.0	0.0	0.2
Parrotfish	0.0	0.0	0.0	4.2	4.7
Queen conch	0.0	0.0	0.0	1.9	10.7
Rays	0.0	0.0	0.0	0.1	0.2
Snappers	3.7	2.7	7.4	24.7	16.1

[1] Note change in time period coverage

To determine the species composition of the subsistence catch, we used species composition data from Mohammed *et al.* (2003a) for the nearby island of St. Lucia. The species composition used was from St Lucia's inshore fishery, which is assumed to be essentially artisanal and/or subsistence in nature. From this data set, we excluded turtles and species that were likely caught for sale to the Aquarium trade industry. The resulting species composition was applied to the annual subsistence catch totals for Guadeloupe as time series averages (Table 1). The time series averages were calculated based on breaks in the taxonomic accounting related to reporting changes in the species composition reported by Mohammed *et al.* (2003a), but were approximately decadal. In recent years, more species were reported, which likely reflected better species identification and improved reporting. The decadal averages from the St. Lucia species composition data were then applied to Guadeloupe's annual subsistence catch totals to derive tonnages, disaggregated by taxa.

Recreational Catches

Catches for the recreational fisheries sector were based on a preliminary study by Ifremer (2008), which estimated that the 2005 recreational fisheries catch for Guadeloupe was about 323 t, or 0.74 kg·person^{-1}. Assuming that recreational catches were zero in 1950, we derived a complete time series by linear interpolation from zero in 1950 to 0.74 kg·person^{-1} in 2005. The 2005 value was carried forward unaltered as the *per capita* recreational fishing rate for 2006 and 2007. This is likely an underestimate of recreational catches as this fishery sector is likely to increase alongside the tourism industry. Of the total recreational catch, 90% were fish and 10% were shellfish (O. Guyader, 2008). This ratio was used throughout the time series to estimate annual tonnage for these two categories.

RESULTS

Commercial landings

Commercial landings in 1950, as reported by Guadeloupe to the FAO were 1,500 t·year^{-1} and increased substantially to 9,525 t·year^{-1} by 1977 (Figure 3). From 1978 to 1999, annual landings as reported by the FAO and Desse (1989) were less variable, with an average of 8,786 t·year^{-1} during this period (values ranged from 8,000 t·year^{-1} to 10,480 t·year^{-1}). From 2000 onward estimated landings were about 10,100 t·year^{-1}.

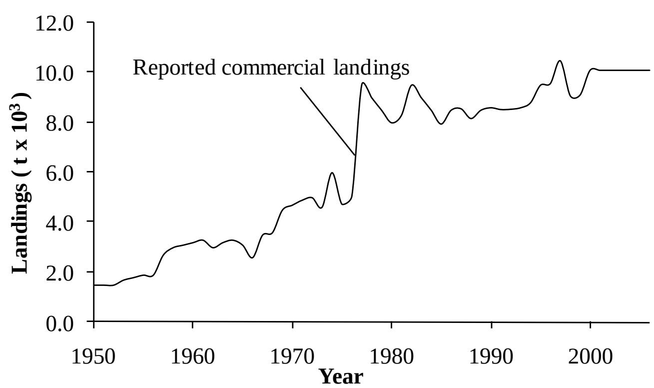

Figure 3. Commercial landings for Guadeloupe, 1950-2007.

Trade

The net trade (imports – exports) data for Guadeloupe was linearly interpolated from 2,569 t·year⁻¹ in 1950 to the first anchor point of 8,135 t·year⁻¹ in 1963 (Figure 4). Net trade, when positive, implied net imports. Net trade (i.e. imports) increased to 9,793 t·year⁻¹ in 1966, then decreased to 5,016 t·year⁻¹ by 1973. Subsequently, imports increased to a peak level of 15,384 t·year⁻¹ in 1995. From 1996 onward data were incomplete, so the 5-year average from 1991-1995 (i.e., 11,898 t·year⁻¹) was used as the estimated value for all remaining years (1996-2007). Again, it is likely that this value was higher due to the increasing trend displayed in the previous period of reported data, but was held constant to remain conservative in our estimate.

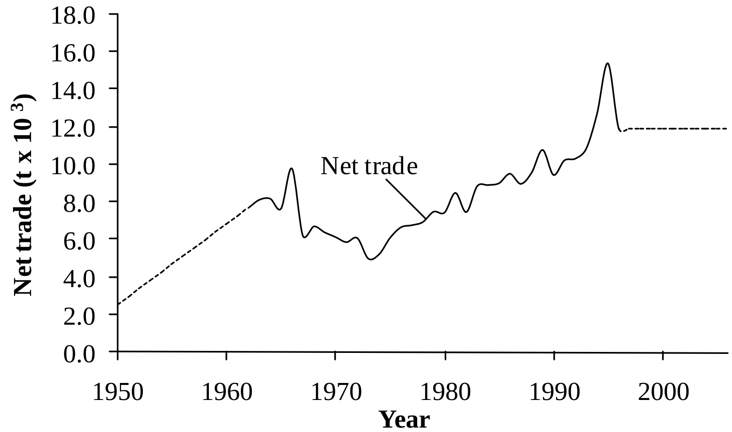

Figure 4. Net trade for Guadeloupe estimated for the period 1950-2007. Dashed lines indicate interpolated periods. Source: (W. Swartz, unpubl. data).

Subsistence catches

Subsistence catch estimates were derived from estimated *per capita* consumption rates, net trade and commercial landings. Subsistence catches make up the portion of the consumption that is neither supplied by the commercial sector nor through trade (Figure 5). Subsistence catch estimates varied greatly, and although it is likely that the population was larger than was reported at the beginning of the time series, a conservative approach was taken (Figure 6). In 1950, the subsistence catch was estimated to be just over 1,000 t·year⁻¹, which increased substantially to 4,935 t·year⁻¹ by 1963. Subsistence catch decreased to 396 t·year⁻¹ in 1973, then averaged 1,183 t·year⁻¹ for the following decade, and decreased again to about 420 t·year⁻¹ in both 1984 and 1987. The catch continued to vary over the following decade with an average catch of 2,168 t·year⁻¹ (values between 861 t·year⁻¹ and 3,911 t·year⁻¹). From 2000 onward, derived catches were stable with an average of approximately 1,800 t·year⁻¹ (in response to the net trade data being carried forward at a constant rate in the absence of complete trade data).

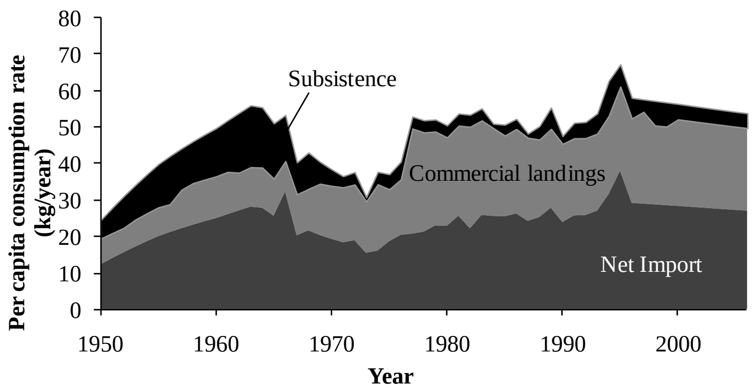

Figure 5. Guadeloupe's *per capita* consumption rate used in combination with commercial landings and trade data to derive subsistence catch rates, 1950-2007.

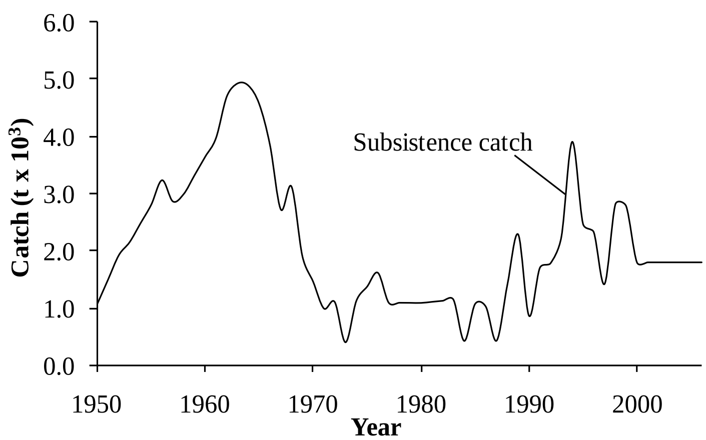

Figure 6. Estimated subsistence catches for Guadeloupe, 1950-2007.

Recreational catches

Recreational catch estimates totaled 8,343 t for the period 1950-2007. Over the time series, we estimated that 7,509 t of fish were caught recreationally and 834 t of shellfish were caught recreationally.

Total catch reconstruction

The reconstructed total catch for Guadeloupe from 1950-2007 was estimated to be 502,696 t (Figure 7). This reconstructed catch was 35% larger than the landings reported by the FAO on behalf of Guadeloupe (372,156 t) over the same time period (Figure 7). The biggest discrepancy occurred in the first two decades of the time period, and in the more recent period. Since the early 1990s, total annual catches seem to be 24% higher than the data reported annually to the FAO (Figure 7).

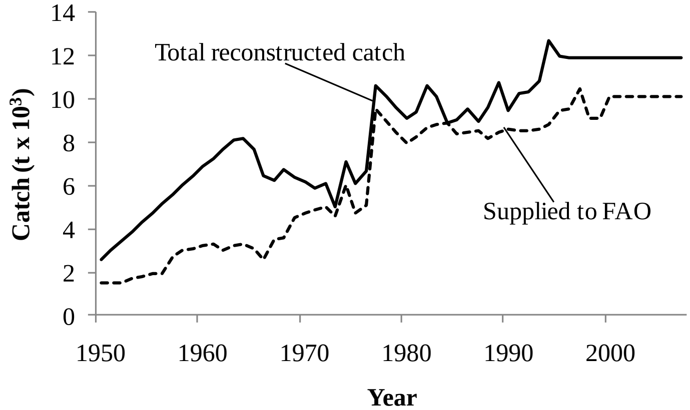

Figure 7. Total reconstructed catch compared to total landings supplied to the FAO by Guadeloupe, 1950-2007.

DISCUSSION

Guadeloupe's total catches from 1950-2007, as estimated in our reconstruction, were approximately 502,696 t. Over the same time period, FAO FishStat reports 372,156 t. The reconstructed catch, which includes estimates of subsistence catches, was 35% higher than the total landings as supplied to the FAO. While Guadeloupe relies heavily on imports from neighboring islands and overseas regions, they continue to source a portion of their seafood supply domestically. Of this, only commercial landings are officially reported. The majority of the fishing fleet is made up of small vessels, which primarily target pelagic fish species for commercial purposes (FAO, 2002). Some vessels operate near shore, targeting smaller reef-fish for commercial and subsistence purposes. Subsistence fisheries catches are often unaccounted for in fisheries statistics (Zeller *et al.*, 2006; 2007), and are therefore not included when estimating the scale and impact of fisheries for a particular region. Fish resource depletion, particularly of inshore fisheries of the Lesser Antilles have been, in part, the result of open-access, small-scale fisheries (Chakalall *et al.*, 1998). If these fisheries sectors continue to be unaccounted for, effective management of these areas will remain a challenge and these marine habitats will continue to be compromised.

Our estimates of subsistence catches for Guadeloupe may be underestimates, as our approach attempted to remain conservative. Given the lack of data on Illegal, Unreported and Unregulated (IUU) catches in this region, we did not estimate other IUU components which may also factor into the equation. It is known that commercial vessels from other countries outside the Caribbean exploit fish stocks within the EEZ of this region, without the consent of the islands' governments (Agard and Gobin, 2000). However, the extent to which this occurs has not been quantified.

The recreational fishing sector is another fisheries component that is currently unaccounted for in most reported landings (e.g., Zeller *et al.*, 2008). Recreational fishing targets large sport fish as a component of the well-developed tourism industry in the Caribbean. Research by the French Research Institute for Exploitation of the Sea (Ifremer) has begun to assess recreational fishing in the region, but the results of this study are only preliminary (O. Guyader, pers. comm., Ifremer). While these preliminary findings were included in our reconstruction, further investigations into recreational fishing may provide a more detailed species breakdown of this fisheries sector.

While the population continues to increase, the numbers of visitors to Guadeloupe also continues to grow, placing an ever increasing demand on the Island's resources. Seafood supplies are limited and tourists often seek highly prized items and local delicacies such as lobster, conch and urchin, which have been over-harvested in many areas of the Caribbean (Agard and Gobin, 2000; Chakalall *et al.*, 1998). Imports are increasingly required to meet both local consumption demands as well as the tourist market. Hotels and resorts often source their seafood directly from fishers (Mohammed *et al.*, 2003b) or import products from elsewhere. Although known to be unreported in many cases, we assumed these catches would be accounted for in the reported landings, as they are technically caught by its commercial sector.

This report shows that the current method of fisheries catch reporting is inadequate, and that more comprehensive reporting is necessary to account for total catches taken by the subsistence and recreational fishing sectors, which can often be considerable.

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RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR MARTINIQUE, 1950-2007[1]

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ABSTRACT

Total marine fisheries catches by Martinique were estimated from 1950-2007, and included both commercial landings and subsistence catches. The commercial landings were obtained from the FAO fisheries statistics database and from other reliable sources. Subsistence catch estimates were based on total fisheries catches recorded over a ten year period that included artisanal fisheries catches. Subsistence catch estimates were then converted to *per capita* rates using Martinique's population data and expanded to cover the whole time series. Total reconstructed catches were estimated to be approximately 319,400 t over the study period (1950-2007), which is 32% larger than the catch total of 241,277 t supplied to the FAO. Fisheries in Martinique are predominantly small-scale, with catches either for commercial and/or subsistence purposes. The landings data supplied to the FAO reports mainly commercial landings, which results in an underestimation of actual fish removals from the marine ecosystem. We believe that greater emphasis should be placed on comprehensive reporting of fisheries catches that includes all fisheries sectors.

INTRODUCTION

Martinique is an island located in the eastern Caribbean Sea, between 14° N and 64° W with an area of about 1,100 km² (Figure 1). It is included in the Lesser Antilles group, between Dominica Island to the north and Saint Lucia to the south. The island is one of four that are overseas departments of France, and thus a part of the French Republic and of the European Union (since 1957). Due to its remote location, Martinique relies heavily on imports and support from France. The territory is divided into four urban districts: Fort-de-France, La Trinité, Le Marin and Saint-Pierre. The Exclusive Economic Zone (EEZ) covers over 47,000 km² and is relatively small owing to its proximity to other island states.

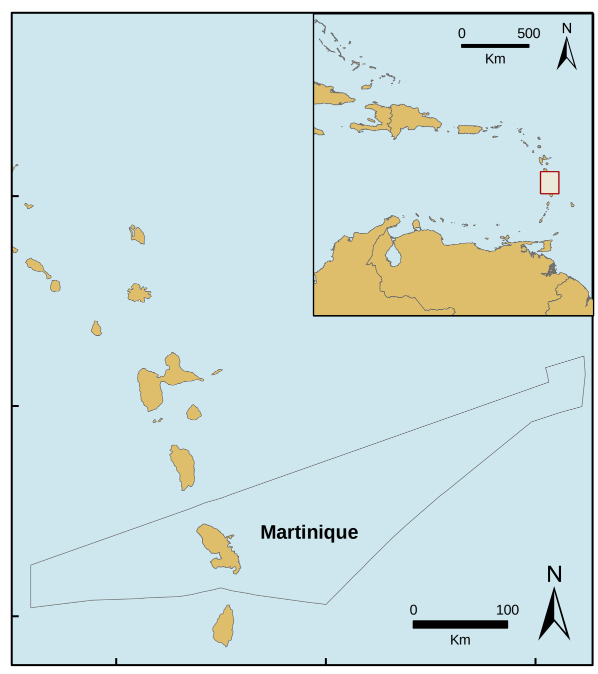

Figure 1. Map of Martinique showing the country's EEZ (solid line) and location within the Caribbean (inset).

The FAO FishStat database, which offers time series data on marine fisheries landings from 1950 to the present, is based on national statistical data supplied by its member countries. Therefore, the quality of the FAO data depends on the capacity of statistical collection within these countries. The FAO data have been the basis of many global fisheries studies (e.g., Pauly *et al.*, 1998) but they

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are, in fact, incomplete (Zeller *et al.*, 2006; 2007). Furthermore, data reported by FAO do not distinguish between fisheries sub-sectors such as commercial vs. subsistence. In addition, Illegal, Unreported and Unregulated (IUU) catches are a concern for fisheries worldwide (Bray, 2000) and presumably also add to total marine fisheries removals by Martinique in the Caribbean Sea

Large pelagic fish account for almost 60% of total reported landings, and often uses fish aggregating devices (FADs) targeting blue marlin (*Makaira nigricans*), yellowfin tuna (*Thunnus albacares*), blackfin tuna (*Thunnus atlanticus*), dolphinfish (*Coryphaena hippurus*) and king mackerel (*Scomberomorus cavalla*). In 2004, the Martinique fishing fleet comprised almost 1,200 registered boats, most of which were less than 12m long with small tonnage and powerful motors. This is largely a non-industrial fleet and operated along the coastline and on FADs (Anon., 2006a). The recreational fishing sector was estimated in 2005 to have 137 fishers who mainly targeted fish in the Labridae and Scaridae families, dolphinfish, crustaceans such as lobster and shellfish such as Conch (Guyader, 2008).

The objective of the present study is to provide an estimate of total marine fisheries catches from 1950 – 2007, to serve as a scientific baseline in the face of climate change and potential threats to food security. Although several studies and reports have been published previously regarding these issues, there has been no comprehensive review of potential historical catches in the region, combining subsistence catches and recreational catches with reported commercial catches, and there has been no specific focus on Martinique.

MATERIALS AND METHODS

Estimates of commercial marine fisheries landings were taken from several reports detailing the weight of fishes caught. While most subsistence catches were not reported, we obtained some data on artisanal fisheries from which we extracted the portion considered to be subsistence catches. Interpolations between anchor points of data were used to estimate fisheries catches via *per capita* catch rates and human population data. Estimates of recreational catches were also added to our reconstruction of marine fisheries catches for Martinique.

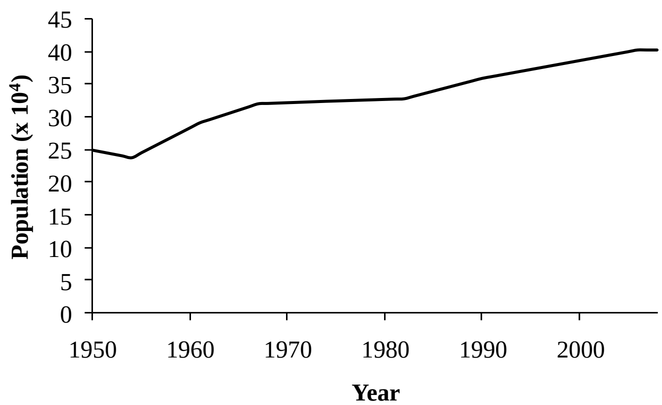

Figure 2. Martinique's human population, 1950-2007.

Human population

Human population data were obtained from the historical population demography website, Populstat (www.populstat.info/). A linear interpolation was done between census years to derive a complete time series of population values from 1950-2007. The population of Martinique in 1950 was estimated to be about 250,000 and in 2007 the population was approximately 403,000 (Figure 2).

Commercial landings

Reported commercial landings consist of fisheries products sold in markets or exported, and these are what the FAO typically reports in their landings statistics on behalf of a particular country. Here, commercial landings data were taken from FAO landings statistics and, when available, from other reputable sources that document fisheries catches (Table 1). For 2007, the FAO commercial catch data from 2007 was carried forward, unaltered.

Table 1. Data sources for Martinique's commercial fisheries catches, 1950-2007.

Date	Source
1950-1969	FAO
1970-1979	Lantz (1988)
1980-1986	Desse (1989)
1987	Lantz (1988)
1988-2007	FAO

Subsistence catches

Estimates of subsistence catches were based on total fisheries catches described by Lantz (1988) for the period 1977-1986, which included both artisanal and commercial fisheries catches. Using the totals presented in Lantz (1988), we subtracted commercial catches, and the remaining amount was taken as the subsistence catch. These were translated into *per capita* subsistence catch rates using the population for the corresponding year. An average *per capita* rate was calculated for the first five years in the series (1977-1981), and this average was carried backwards in time and multiplied by the population to derive subsistence catch estimates for 1950-1976. This same method was used to derive subsistence catch estimates for the period 1987-2007. For this time period, the average *per capita* rate from 1981-1986 was used and applied to the annual population as a constant rate for the remainder of the time series.

The species composition of the subsistence catches were derived from a study by Gobert (1990) that estimated the overall composition by family or taxon group of demersal catches for Martinique in 1987 and 1988. We adjusted the values slightly by removing sea turtles, which were also excluded from our commercial catch totals. The adjusted proportion for each group (Table 2) was then applied to the total subsistence catch to derive subsistence catch amounts, disaggregated by family or taxon group. These proportions were applied to all years in the time series.

Table 2. Subsistence catch composition (%) for Martinique modified from Gobert (1990).

Family or group	Portion of total catch
Scaridae	13.9
Lutjanidae	10.5
Serranidae	10.1
Haemulidae	8.8
Holocentridae	8.5
Carangidae	5.4
Muraenidae + Congridae	4.8
Mullidae	4.3
Acanthuridae	4.1
Mugilidae	2.6
Squalidae	2.2
Priacanthidae	1.9
Sphyraenidae	0.5
Marine fishes nei	7.2
Lobsters	7.3
Crabs	1.7
Urchins	1.6
Cephalopods	2.4
Gastropods	2.0

Trade data

Trade data for Martinique were available for the period 1962 – 1995. Prior to this, we assumed that trade began in earnest with the end of WWII in 1945, although it is likely that some imports were available during the war, as Martinique allied herself with the French Vichy government until 1943, when Martinique was occupied by the Free French Forces. However, to remain conservative, imports were set to zero in 1944, and then linearly interpolated to the first data point in 1962. Commodity types that were not for human consumption (e.g. fish meal for aquaculture) were excluded from the analysis.

Recreational Catches

Recreational catch estimates were based on a preliminary study by Ifremer (2008), which found that the 2005 recreational fisheries catches in Martinique totaled 412 t, or 1.03 kg·person^{-1}. We assumed that recreational catches were zero in 1950 and then derived our time series through linear interpolation from zero in 1950 to 1.03 kg·person^{-1} in 2005. The 2005 *per capita* recreational fishing rate was carried forward unaltered to 2007. This is likely an underestimate of recreational catches as this fishery sector is likely to increase alongside the tourism industry. Of the total recreational catch approximately 62% were fish, 19% were shellfish and the remaining 19% were crustaceans (Guyader, 2008). These percentages were used throughout the time series to estimate annual tonnage of fish, shellfish and crustaceans caught recreationally.

Total Reconstructed catch

Total marine fisheries catches for Martinique from 1950-2007 were calculated as the sum of commercial catches provided by FAO and other reliable sources, and subsistence catches, which were estimated using population data and trade statistics.

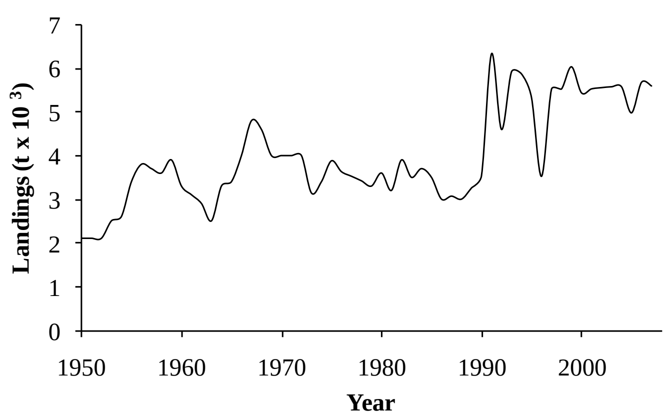

Figure 3. Commercial catches for Martinique, 1950-2007.

RESULTS

Commercial landings

In 1950, the commercial landings as supplied to the FAO were reported to be 2,100 t·year^{-1}, and increased to an average of 3,750 t·year^{-1} in the period from 1956-59 (Figure 3). Landings then decreased to 2,500 t·year^{-1} in 1963. By 1967 landings had almost doubled to 4,800 t·year^{-1}, but then decreased to 3,000 t·year^{-1} by 1988. Landings increased again to its highest level in 1991 at almost 6,300 t·year^{-1}. For the remainder of the study period, landings varied considerably, ranging from 6,000 t·year^{-1} to 3,500 t·year^{-1}, with an annual average of 5,300 t·year^{-1}.

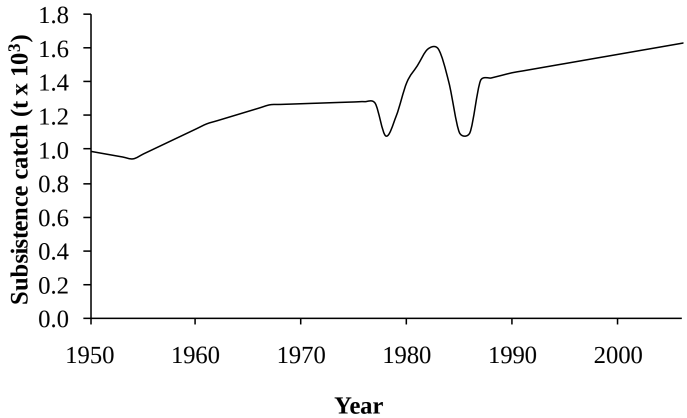

Figure 4. Subsistence catches in Martinique, 1950-2007.

Subsistence catches

At the beginning of the time series the subsistence catch was estimated at around 1,000 t·year^{-1} and by the end of the time series averaged around 1,600 t·year^{-1}. Due to the estimation method used, subsistence catches did not vary much year to year except for the late 1970s to the late 1980s when subsistence catches fluctuated considerably (Figure 4).

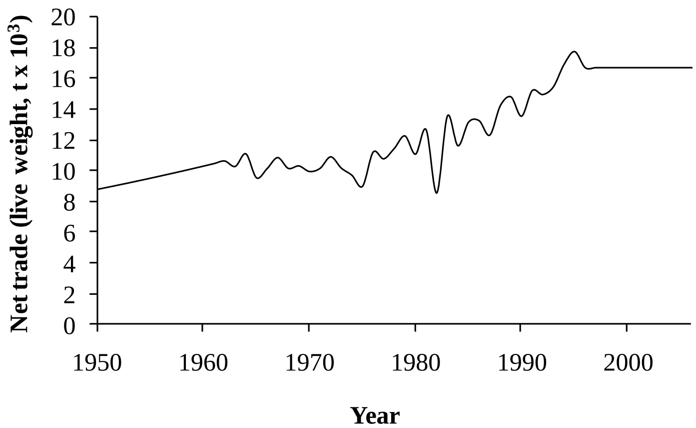

Figure 5. Net trade (imports – exports) in live weight (t) for Martinique, 1950-2007.

Trade data

Martinique imports far more seafood products than it exports, thus it has a large positive net trade balance that supplies some of the seafood consumed by the people of Martinique. The net trade was estimated to be 8,760 t·year^{-1} of imports in 1950, and showed an increasing trend with some variability (Figure 5). The net trade reached a maximum amount of 17,708 t·year^{-1} of imports in 1995.

Recreational Catches

Estimated recreational catches totaled approximately 11,400 t over the period 1950-2007. During this period, we estimated that over 7,000 t of fish were caught recreationally and 2,000 t each of shellfish and crustaceans were taken by the recreational sector.

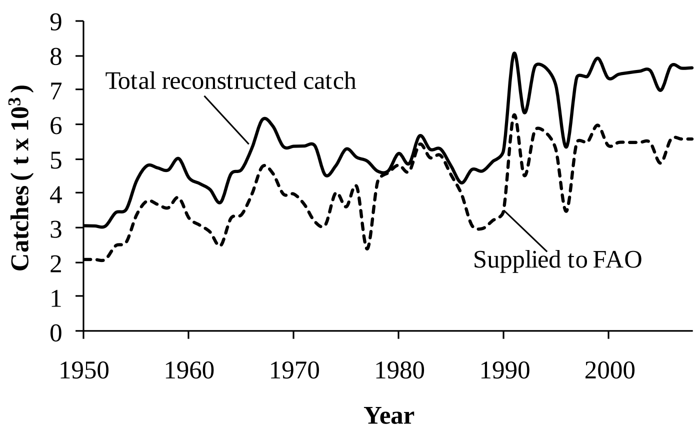

Figure 6. Martinique's total reconstructed catches and total landings as supplied to FAO from 1950-2007.

Total reconstructed catch

The reconstructed catch total was estimated to be 319,400 t for the period 1950-2007 (Figure 6). Total marine fisheries catches were estimated to be approximately 3,088 t·year^{-1} in 1950, and increased to a peak of approximately 8,000 t·year^{-1} in 1991. Throughout the remainder of the time period total fisheries catches were on average about 7,300 t·year^{-1}, with only limited year to year fluctuations. Seafood consumption rates were relatively stable over the time period considered, with an average *per capita* consumption rate of 53.2 kg·cap^{-1}·year^{-1} (a range of 42.7-65.7 kg·cap^{-1}·year^{-1}). The relative contributions from the various fisheries sectors to the seafood supply remained fairly similar over the time period (Figure 7).

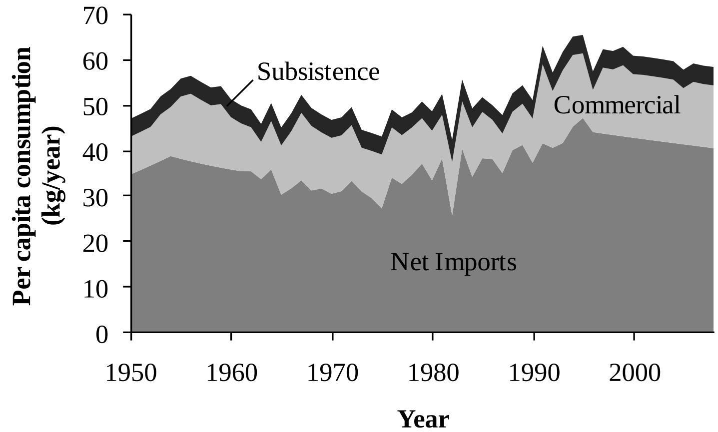

Figure 7. *Per capita* rates for commercial catches, subsistence catches and net trade, which together make up *per capita* consumption for Martinique from 1950-2007.

DISCUSSION

The total reconstructed catch for Martinique for the period 1950-2007 was approximately 319,400 t, compared to the total reported catch as supplied to the FAO of 241,277 t. The reconstructed catch, which included commercial landings and estimates of subsistence and recreational catches, was 34% larger than the total catch reported by the FAO on behalf of Martinique. For the more recent years (2000-2007), the difference was 38%.

Currently, the fisheries statistics that are reported by FAO on behalf of Martinique include only commercial fisheries landings. Our catch reconstruction attempts to account more comprehensively for the total marine fisheries of Martinique by including estimates of subsistence and recreational catches. These estimates are likely underestimates as we used a conservative approach and were only able to account for the additional catches from the subsistence and recreational sectors. Other Illegal, Unreported and Unregulated (IUU) catch components were not estimated but are likely to also add to the total marine fisheries removals by Martinique. A review of the literature presented little information on IUU catch components for the Caribbean Sea region.

Trade data were used in estimating total consumption for Martinique and hence contributed to establishing the total reconstructed catch for Martinique. It illustrates the reliance of Martinique on imports to meet their seafood demand. Martinique and Guadeloupe, both French Overseas Departments, have much higher seafood consumption rates than in other areas of the Caribbean (Anon., 2006b). This may reflect cultural differences and the large number of French tourists that visit Martinique each year (over 503, 000 tourists in 2006, 79% were from France [www.onecaribbean.org/statistics/]). While the high demand for seafood in Martinique is met through substantial imports from elsewhere, they continue to supply a portion of their consumption demand domestically. This report shows that the current method of fisheries reporting for Martinique is incomplete, and that there needs to be more comprehensive reporting which includes subsistence and recreational fishing sectors.

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THE FISHERIES OF ST HELENA AND ITS DEPENDENCIES[1]

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ABSTRACT

The island of St. Helena and its two dependencies (Ascension and Tristan da Cunha Islands) are the most isolated populated islands in the world. As such, the people of these islands have always fished the waters around these islands, yet global fisheries catch statistics do not adequately describe the catch taken in these waters since they are only reliable for the commercial sector, which only began in earnest during the 1970s. Presented here are estimates of total fisheries catches for all three islands for the period from 1950-2006, which include estimates of small-scale catches, commercial catches, and Illegal, Unreported and Unregulated (IUU) catches. From 1950-2006, total fisheries catches for the three islands were estimated to be over 73,000 tonnes, which is 1.8 times larger than data presented in FAO fisheries statistics for the same time period. The largest contributors to the differences were the inclusion of estimates for the small-scale catches taken over the entire time period, and the improved estimate of commercial lobster catches from 1950-1970.

INTRODUCTION

St Helena, a UK overseas territory most famous for being Napoleon's last place of exile, is a small, isolated island in the South Atlantic Ocean that has two dependencies— Tristan da Cunha and Ascension Island (Figure 1). Tristan da Cunha has 5 neighboring islands that comprise the Tristan da Cunha group, two of which, Gough and Inaccessible, are World Heritage Sites. The islands are sparsely populated, with a current population estimate of approximately 5,800 living on the islands of St Helena, Ascension and Tristan da Cunha. Economic activity is limited by several factors, including the reliance on ship transport since there are no airports on St Helena or Tristan da Cunha, and the airfield on Ascension, until very recently, has been primarily for military purposes. The island of St Helena is heavily reliant on financial aid from the UK government (Anon., 2003) and is experiencing a downward trend in population due to emigration from a lack of economic opportunities. The people and government of Tristan da Cunha are economically self-reliant from earnings in the lobster fishery. In the past profits from the lobster fishery have been used to build up reserves, but recently, to maintain government services, these reserves have been drawn on (Anon., 2006). Ascension Island, until 2002, received its main funding sources from the military and the two main commercial organizations (BBC, and Cable and Wireless), but since 2002 personal income taxes have funded government activities (Anon., 2008).

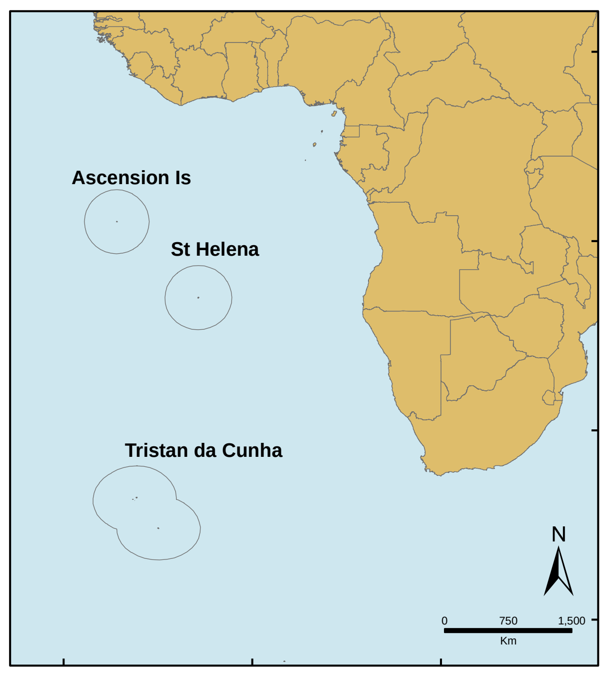

Figure 1. Map of St Helena and its dependencies, Ascension Island and the Tristan da Cunha group. EEZ indicated for each.

[1] Cite as: Booth, S. and Azar, H. (2009) The fisheries of St Helena and its dependencies. pp. 27-34. *In*: Zeller, D. and Harper, S. (eds) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Although the commercial fishery sector is one of the main contributors to the economies of St Helena and Tristan da Cunha, the importance of the non-commercial fishery for all three islands has never been assessed. Edwards (1990) describes the history of fishing around St Helena with anecdotes of fishing from 1589 until the late 20th century. During the days of the British Empire, there were numerous commissions established to look at developing fisheries in St Helena. In 1903, a commission was established to report on "the reason for the present unsatisfactory state of the Fishing Industry" and "the best way of remedying the evil." It reported that 34 men were engaged in hook and line fishing on 11 licensed boats of which only two were really sea-worthy. The other boats were manned by men only partly reliant on fishing for a living and the commissioners thought that that the fishermen were idle and merely indulged in subsistence fishing, catching enough to live on for two or three days and not going out again until they needed more money. The commissioners also thought the fishermen were involved in a conspiracy; by keeping the market supply low they could keep the prices artificially high. It also noted that the leeward grounds and the inshore areas appeared overfished.

After World War II, there were three separate attempts by the government to establish commercial fishing enterprises on St Helena, but the enterprises failed and no significant fishing lasted for more than one fishing season. In 1973, the British Overseas Development Administration implemented another program to develop the commercial fishing industry and from 1976-1978 a group of fisheries specialists worked on St Helena and found that the fishing fleet had developed little since 1910 and fishing methods were as they had been for centuries (Edwards 1990). However, by the late 1970s with the establishment of the St Helena Fisheries Corporation, a continuous commercial fishery was established.

In comparison, the commercial fishery for lobster around the Tristan da Cunha island group has been in continuous operation since 1949. Even when all the islanders were evacuated from 1961-1963 because of a volcanic eruption, the large-scale enterprise continued to fish around the islands. Roscoe (1979) reviews the commercial lobster fishery from its inception to the mid-1970s, and the associated finfish catch, used for bait and for human consumption, was reported for 1989 (Cooper *et al*., 1992).

Here we estimate fisheries catches from 1950 to 2006 for the commercial and small-scale fisheries. Catches of fish species for St Helena are estimated from data presented in Edwards (1990), who notes that small-scale subsistence fishing has been carried out at St Helena since the first settlers arrived. The inclusion of the estimated small-scale fisheries catches will have the greatest effect at the beginning of the time period, both in terms of nominal catches and the diversity of, prior to the establishment of the commercial fisheries sector in the late 1970s. The other benefit of this catch reconstruction is to separate catch estimates between St Helena and its two dependencies.

METHODS

Commercial fisheries catches were estimated separately for St Helena and for Tristan da Cunha; no commercial fisheries catches were estimated for Ascension. Small-scale fisheries data were estimated for all three islands and in the case for Ascension Island the resident population was discounted by the estimated military population. Small-scale fisheries catch data were first transformed into *per capita* rates. The *per capita* rate combined with the yearly population data were treated as the demand for fisheries products. In turn, the demand was met by the small-scale catch, imports and the amount of catch remaining after exports (Equation 1). Given the demand, catch data as supplied to FAO and trade data, the small-scale catch was estimated for each year. From 1950 to 1977, demand is equal to small-scale catch, but afterwards FAO catch data and net trade must be taken into account.

Demand = small-scale catch + imports + (FAO catch data-exports) ...Equation 1)

Human population data

People reside on the islands of St Helena, Tristan da Cunha and Ascension Island; the other islands are uninhabited. Human population statistics for the three inhabited islands were taken from Populstat (www.populstat.info). The population data for census years were used and linear interpolations were done between census years to create a time series of human population for the three islands from 1950 to 2006. The population for Tristan da Cunha was set to zero from 1961-1963 since all people were evacuated to England due to a volcanic eruption on the island.

Trade data

In order to account for the trade of fishery products, reported since 1977, export and import data (Alder *et al.*, 2008) were used to determine the amount of the commercial catch that remained for local use and the amount of demand met by imports. We assume that all imports other than flours, fish-meals and oils were destined for human consumption. Most import data were of relatively small amounts and were treated as imports to the island of St Helena. However, for years when more than 100 tonnes were reported, the import totals were split between the three islands based on the islands' proportion of total population. All catches of lobster from the Tristan da Cunha group were treated as exports and excluded from the mass balance equation (Equation 1).

Commercial fisheries data

St Helena

Prior to the commencement of regularly occurring commercial fisheries in 1978, there were two attempts made (post-1950) to initiate commercial fisheries. The first attempt in 1955 landed 42 tonnes of skipjack (*Katsuwonis pelamis*) and 28 tonnes of albacore (*Thunnus alalunga*) and the second attempt in 1966 landed 7.5 tons of tuna, 2.3 tons of wahoo (*Acanthocybium solandri*), and 1.7 tons of stump lobster (*Scyllarides herklotsii*). Between 1969 and 1974, landings were not consistent and the company ended their contract. Commercial fish catches reported for the island of St Helena from 1978 onwards (Edwards, 1990) are consistent with those reported to FAO. However, the catch of the stump lobster was taken from Edwards (1990) who reports average catches of 1.15 t·year^{-1} (range 0.05 to 4.65 t·year^{-1}) between 1966 and 1989. There are also small catches of the longlegs lobster (*Panulirus echinatus*) taken in an artisanal fishery (see small-scale fisheries data below), that were assessed for their commercial potential in the mid-1970s and again in the 1980s, but the commercial experimental fishery only landed small quantities (Edwards, 1990).

Tristan da Cunha

Tristan da Cunha is dependent upon earnings from its lobster fishery revenues for its economy. The commercial fishery, which targets the Tristan rock lobster (*Jasus tristani*) for the export market, began in 1949 and is comprised of two fleets: a local, small-scale fleet from Tristan and a large-scale commercial enterprise that uses fishing/factory vessels (Roscoe, 1979; Cooper *et al.*, 1992). A review of the lobster's biology and its exploitation for the time period 1949-1976, which covers the annual production of tails, was used to determine catches for 1950-1976. A tail to live weight conversion factor of 3.3 was used to convert tail weights to live weight (Roscoe, 1979). Associated with this fishery are catches of octopus and finfish, which are either used for baiting the lobster traps or for human consumption. 70% of the fish caught (by weight) in 1989 were comprised of St. Paul's fingerfin (*Nemadactylus monodactylus*) and barrelfish (*Hyperoglyphe* sp.; Cooper *et al.*, 1992). Catches of finfish for bait or human consumption by the local fleet amounted to 62 tonnes in 1989 and 15 tonnes for the two licensed fishing vessels (Cooper *et al.*, 1992). The non-tail portion of lobsters (cephalothoraces) are turned into fishmeal, which is exported mostly to Europe. Due to a volcanic eruption, the local fleet and all inhabitants were evacuated from the island from 1961-1963, although the large-scale commercial enterprise continued to fish during this period (Roscoe, 1979). There has been reports of lobster poaching from the waters around Tristan da Cunha with an estimated 75 tonnes of tails

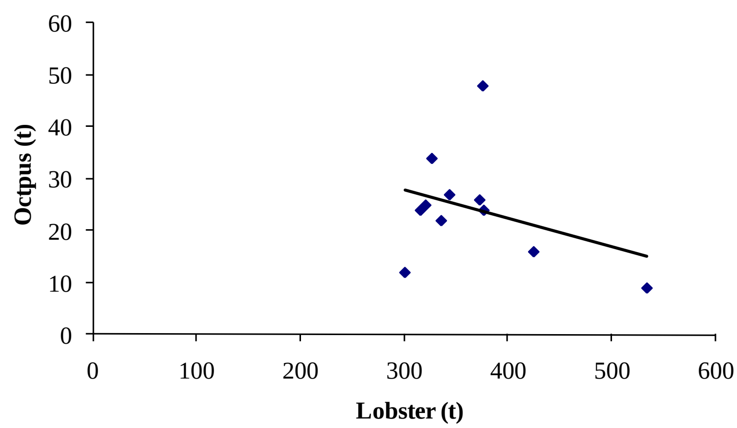

Figure 2. Relationship between reported landings of octopus and lobster (r=0.342).

been taken illegally between 1965 and 1974 (Roscoe, 1979), and there is still concern over illegal fishing (Petit and Prudent, 2008).

Here we replace the earliest time periods of lobster catches as presented by the FAO with those of Roscoe (1979) and also account for octopus catches taken in this fishery by regressing the catch of octopus versus lobster with data as supplied to FAO from 1995 to 2005 and apply this to the earlier time period (Figure 2). We also extend the catches of finfish as a ratio of lobster catches to cover the entire time period. However, the finfish catch taken by the local, small-scale fleet was considered to account for both the amount used for bait and for home consumption (see small-scale fisheries data below). We estimate catches of illegal lobster from 1965 to 2005 using the amount reported for the 1965-1974 period as an average amount per year (Roscoe, 1979).

Small-scale fisheries data

Small-scale fisheries catches were estimated for all three islands using the small-scale estimate for St. Helena. Although there are no recent reports quantifying the amount of catch for this sector, we can estimate the amounts using the assertion that there was little development in the fishing industry from the early 1900s until the commercial enterprises began in the late 1970s (Edwards, 1990), and by assuming that the monthly proportion of catches were the same in 1903 as when the commercial fisheries began in earnest. Further, we assume that the *per capita* consumption rates determined for St Helena can be directly applied to Ascension and Tristan da Cunha.

For Tristan da Cunha, the amount of finfish taken in the small-scale lobster fishery was compared to the estimated *per capita* consumption rates of St Helena to determine whether additional catches should be accounted for. This was done by comparing the *per capita* consumption rates for St Helena to the *per capita* catch rates of finfish from the lobster fishery of Tristan da Cunha.

<u>St Helena's small-scale estimate</u>

For a one month period in March/April 1903, fisheries landings at the Jamestown market were monitored and the numbers or weight of fish were reported; here we assume that the landings reported apply to the month of March and to the whole population (1903 population ~3,340). For the late 1970s and early 1980s, the average totals of catches (by percent or by weight) are available by month (Edwards, 1990). Thus, the proportion of catches taken in March can be determined for the later time period and this proportion is applied to 1903. Using the proportion of yearly catches for the later time period and the actual landings amount for March 1903 the total yearly catch (by species or group) for 1903 was estimated as:

$$\text{Total yearly catch}_{1903} = \text{MarchLandings}_{1903} / \text{MarchProportion}_{1977\text{-}1986} \qquad \text{...Equation 2)}$$

For those species which were reported in 1903 by number rather than by weight, the length-weight relationship was:

$$W = aL^b \qquad \text{...Equation 3)}$$

where W is weight (in grams) and L is length in (cm). The average length for species was determined from the asymptotic length ($L\infty$) reached by the species *Seriola lalandi* and *Scomber colias* (formerly known as *Scomber japonicas*; Froese and Pauly, 2008). These two species were reported in Edwards (1990) as having an average landed weight of 15 kg and 0.2 kg, respectively. These average landed weights correspond to 62.6% and 46.4% of their $L\infty$ values, respectively (Froese and Pauly, 2008). Thus, the average percentage of $L\infty$ for these two species (54.5%) was used to determine the average length for species that did not have weights reported.

Results

Human Population

The human population for the three islands was estimated at 5,100 people in 1950 and peaked in 1988 at an estimated 6,500 people before declining to approximately 5,400 people in 2006 (Figure 3). The change in population has not been the same between islands and the changes in total population are largely driven by population changes for St Helena. Tristan da Cunha's population grew from an estimated 200 persons in 1950 to an estimated 300 persons since the mid-60s, while the non-military population for Ascension was estimated at 240 persons in 1950 and is currently at 700. The population for the island of St Helena grew from approximately 4,600 persons in 1950 to 5,600 in 1988 before declining to a current population of approximately 4,400 persons. Some of the recent population growth in Ascension has been due to immigration from St Helena.

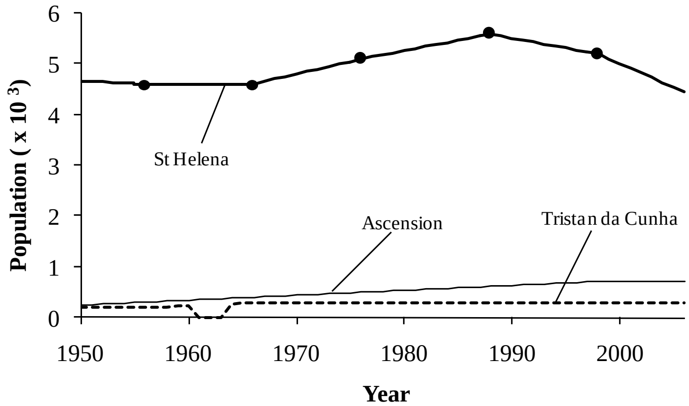

Figure 3. Population of St Helena and its two dependencies. Solid circles represent years of census data and apply to Ascension and Tristan da Cunha).

Trade Data

Trade data for the import and export of fishery products were reported for the 1975 to 2006 period and using appropriate conversion factors the product weights were transformed to live weights (Alder *et al.*, 2008). Data concerning the export of lobster were removed from the trade data and were replaced by the estimated catch of lobster (see commercial fisheries data below). Also, the trade data concerning the categories 'flour, meal and pellets' and 'fats and oils' were excluded from analysis as it was assumed that these categories are not part of the demand in the mass balance Equation (2). It is likely that these categories are used for animal feed (Figure 4).

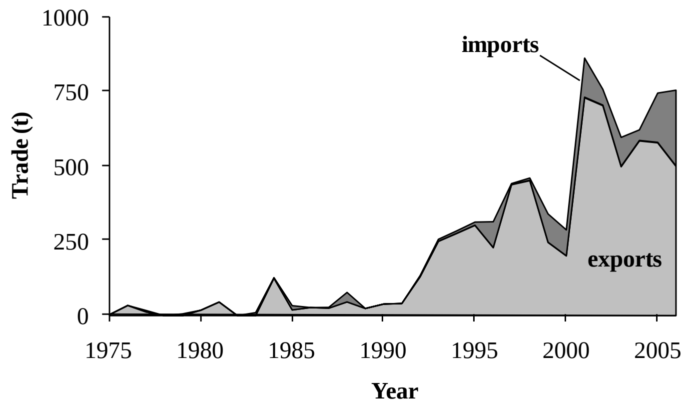

Figure 4. Reported trade data for St Helena. Exports exclude lobster, and the categories 'flours', fishmeals' and 'oils' were excluded from imports.

Commercial fisheries data

St Helena

Commercial fisheries for the island of St. Helena appear to be well described in the data supplied to FAO after 1977 since the data in Edwards (1990) are nearly identical, and this suggests good transfer of commercial fisheries data between the local agency responsible and the global community. The two failed attempts to establish commercial enterprises in 1955 and 1966 landed 70 tonnes and 12 tonnes

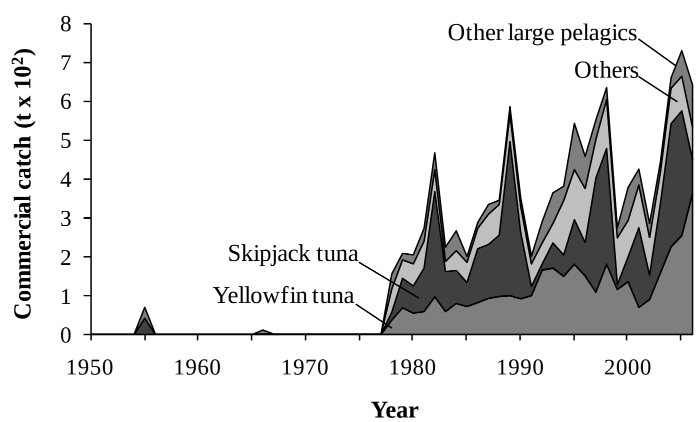

Figure 5. Commercial catches for the island of St Helena.

respectively were included in the estimated commercial catches as exports. During the period from 1966-1978 there were also small amounts of stump lobster (average 1.2 tonnes·yar^{-1}) landed as well. Since the data from Edwards (1990) and data supplied to FAO are nearly identical from 1978 onwards, we rely on the catch totals presented by FAO (Figure 5).

Commercial catches have been increasing since 1978 from an estimated 156 tonnes to 732 tonnes in 2005, with the most important species being skipjack tuna and yellowfin tuna. From 1978 to 1989 commercial catches averaged 297 t·year^{-1}; from 1990-1999 commercial catches averaged 406 t·year^{-1}; and from 2000-2005 they averaged 488 t·year^{-1}. However, there is large intra-annual variation largely due to peaks in catches of skipjack tuna approximately every 7 years.

Tristan da Cunha

Data as supplied to the FAO for the lobster fishery from 1950 to 1975 were replaced with the data from Roscoe (1979) and from 1965 onwards illegal catches of lobster were estimated to be 25 t·year^{-1} . Excluding the first two years of data, which have low catches and reflect the fishery in a start-up phase, catches of lobster averaged 891 t·year^{-1} from 1952 to 1975, with peak catches occurring during the 1960s, before they began to decline after 1969. Data as supplied by FAO for lobster declines from 839 t in 1976 to 373 t in 2005, with average catches of 386 t·year^{-1}.

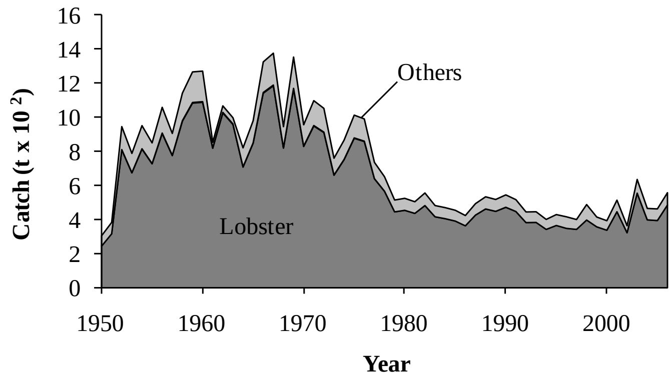

Figure 6. Commercial catches taken from the waters around the Tristan da Cunha island group.

Catches of finfish used for bait by the large, commercial vessels represent 3.5% of the lobster catch; whereas the small-scale, local powerboat fleet catches of finfish for bait and/or home consumption represents 14.5% of the lobster catch, excluding the 1961-1963 time period when the islanders were evacuated due to the volcanic eruption. Average catches of finfish by both sectors were 103 t·year^{-1} for the entire time period. Based on the regression relation between octopus and lobster, octopus catches were estimated to average 6 t·year^{-1} from 1950 to 1977, and from 1978 to 2005 averaged 21 t·year^{-1} (Figure 6).

Small-scale fisheries data

St Helena

Small-scale catches as represented by the one month of landings at the Jamestown market on St Helena in 1903 were estimated to be approximately 14,500 kilograms. The estimated yearly catches for 1903 were approximately 276,600 kilograms resulting in an island-wide *per capita* rate of 82.8 kg·person^{-1}·year^{-1}. This rate was used as the demand for 1950 to 2006 and was also considered to be the demand for the two other populated islands as well.

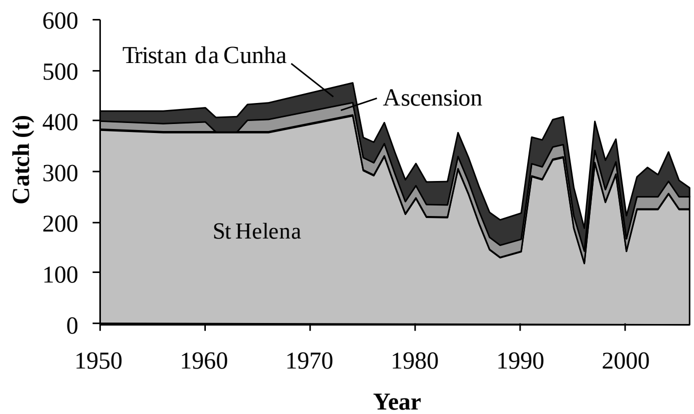

Figure 7. Small-scale fisheries catches destined for subsistence use for the three inhabited islands of St Helena, Ascension and Tristan da Cunha.

Small-scale catches were estimated at approximately 400 t·year^{-1} from 1950 to 1974. After this, small-scale fisheries become more variable as both imports and commercial catches contribute to meeting the demand. Small-scale catches from 1975 to 2006 declined from an estimated 306 t in 1975 to approximately 260 t in 2006 (Figure 7).

Tristan da Cunha

Small-scale fisheries catches for Tristan da Cunha were considered to be reflected in the amount of catch taken by the local lobster fleet. The amount of finfish catch associated with the local lobster fleet, led to a potential average *per capita* supply of 320 kg·person^{-1}·year^{-1} (range: 145-689 kg·person^{-1}·year^{-1}). Because there is no breakdown of what portion is retained for human consumption and what portion is used for bait, and the fact that the potential *per capita* supply was much larger than that for the estimated *per capita* demand, the catches of finfish associated with the lobster catches are the only small-scale fisheries reported here. Catches of finfish by the small-scale lobster were split, assuming that the demand for the population was 82.8 kg·person^{-1}·year^{-1}, and this led to yearly catches rising from an estimated 17 tonnes·year^{-1} in 1950 to 25 tonnes·year^{-1} in 2006 (Figure 7).

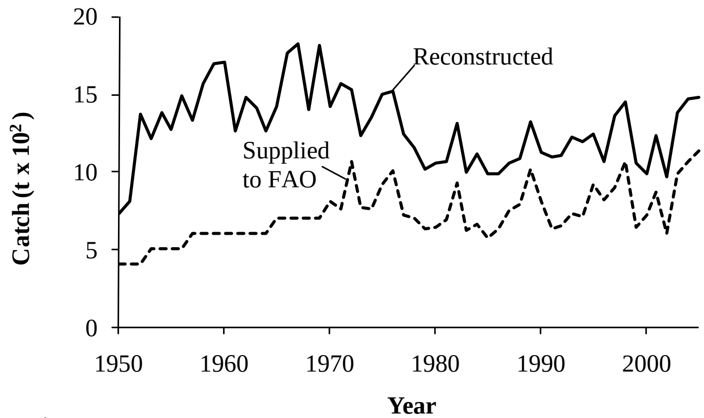

Figure 8. Comparison between catches reported to the FAO and our reconstructed total catches, which include estimates for small-scale catches. The large discrepancy in the early years is largely due to the inclusion of small-scale estimates and differences in lobster (*Jasus tristani*) catches (see text for details).

Ascension

The *per capita* demand rate of 82.8 kg·person^{-1}·year^{-1} led to demand being estimated as 20 tonnes in 1950 to 58 tonnes in 2006. In the late 1990s, some of this demand was assumed to be met by imports of fishery products. Thus, catches in 2006 were estimated at 18 tonnes given imports of 40 tonnes (Figure 7).

DISCUSSION

Estimated fisheries catches for St Helena and its dependencies amount to over 73,500 tonnes from 1950 to 2006. In comparison, data reported to FAO are approximately 41,000 tonnes resulting in estimated catches being 1.8 times larger than those reported (Figure 8). This is largely due to the under-reporting in the early years. Up until 1970, only two species were reported in FAO statistics, yellowfin tuna and Tristan da Cunha rock lobster. Yellowfin tuna catches were reported as 100 tonnes·year^{-1} for this time period and the rock lobster increased from 400 to 600 tonnes·year^{-1}. The rock lobster is only distributed around the Tristan da Cunha island group and was for export and thus, we can conclude that the reported fisheries statistics for St Helena and its dependencies are incomplete. This work hopes to fill in the gaps that are missing in the reported catch statistics.

For the island of St Helena, export data for three years (2001-2003) were greater than the corresponding year's catch as supplied to FAO (by ~ 790 t for the 3 year period) resulting in negative balances in the mass balance Equation (2). However, in four other years (1982, 1989, 2005 and 2006) commercial catches combined with the trade data were slightly larger than demand resulting in positive balances in the mass balance equation implying that no small-scale fisheries occurred in those years. However, here we made the assumption that small-scale fisheries still occurred in these years, and this resulted in the demand over the four years being exceeded by supply by approximately 707 tonnes from 1977-2006. Thus, over the entire time period mass balance was achieved.

This mass balance approach expands on FAO's apparent seafood consumption food balance sheet method by incorporating estimates of small-scale catches, which were excluded in FAO's methodology. In the case of St Helena, a small, isolated island territory that has large costs associated with imports and exports, the FAO method would estimate the apparent seafood consumption rate from 1950 to 1978 as near zero since yellowfin tuna would be the only fish available on the local market. Such a method obviously underscores the reliance of these people on the ocean for their food security.

After over 100 years, the tables have turned and the global community must now ask their fishery scientists and government bodies responsible the reason for the present unsatisfactory state of fisheries statistics. The best way of remedying the evil may be to have transparency in the reporting of all catch statistics that are made available to the public at large. Most countries only report on the commercial quantities landed—not on the total catches, often despite having better catch statistics available.

ACKNOWLEDGMENTS

The authors of this report would like to acknowledge the support of the *Sea Around Us* Project, a scientific collaboration between the University of British Columbia and the Pew Environment Group.

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THE FISHERIES RESOURCES OF THE CLIPPERTON ISLAND EEZ (FRANCE)[1]

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ABSTRACT

Clipperton Island is a French Territory in the Eastern Central Pacific, about 1,300 km southwest of Acapulco, Mexico. The geology and biology of Clipperton Island, including its coral reefs and fish fauna, are well-documented. Although there was an unsuccessful attempt at settlement, the island is presently uninhabited, and surveillance by the French navy is scattered to non-existent. Therefore, there is probably a high degree of illegal fishing in the Clipperton Exclusive Economic Zone; this is increased by the fact that at least one neighboring country contests French sovereignty. Diving for lobsters and shark finning also appears to occur near Clipperton Atoll, but the extent of these activities will likely remain uncertain. For the *Sea Around Us* Project, and its global database of fisheries catches, this means that the catches made by various countries in the Clipperton Island EEZ must be estimated indirectly. This can be done by 'allowing' all countries that report catches of large pelagic fishes from the Eastern Central Pacific (FAO Area 77) to enter the Clipperton Island EEZ, which should account for the catch of tuna and other large pelagics from that area.

INTRODUCTION

Clipperton Island, named after an English privateer, is a French Territory in the Eastern Central Pacific, about 1300 km southwest of Acapulco, Mexico (Figure 1). The area of Clipperton Island is 9 km², its position is 10°18'N and 109°13'W. The EEZ around Clipperton has a surface area of 435,600 km² (www.clipperton.fr/).

Although there was, in the beginning of the 20th century, an unsuccessful attempt at settlement, the island is presently uninhabited, and surveillance by the French navy is scattered to non-existent. Therefore, there is a high, but unknown degree of illegal fishing in the Clipperton Exclusive Economic Zone. Also important is the fact that Mexico, based on historical and geographical arguments, contests French sovereignty (see www.clipperton.fr/ for details).

The geology and biology of Clipperton Island, including its coral reefs and fish fauna, are well-documented, and were last reviewed in Charpy (2009). An extensive bibliography may be found at www.clipperton.fr/incagen.html?biblioaccueil.htm ~main.

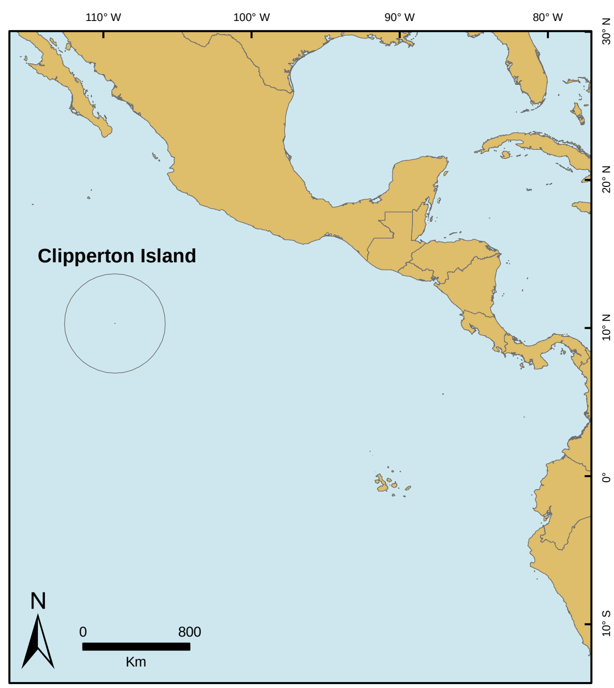

Figure 1. Clipperton Island and its Exclusive Economic Zone (EEZ).

[1] Cite as: Pauly, D. (2009) The fisheries resources of the Clipperton Island EEZ (France), pp. 35-37. *In*: Zeller, D. and Harper, S. (eds.) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Fishing activities in the Clipperton EEZ

The following fisheries-related activities were reported in www.clipperton.fr/: *"The island has been abandoned since World War II; since then it has only been visited by sport fishermen, regularly scheduled patrols by the French Navy, and Mexican tuna and shark fishermen. [...]. In 1988, five Mexican fishermen became lost at sea after a storm that occurred during their trip along the coast of Costa Rica. They drifted within sight of Clipperton, but were unable to reach it. In 1998, two American deckhands, from a fishing boat based out of California were stranded on the island for three weeks"*.

Other sources (e.g., Nieussat 1976; Goujon 1988) also mention events and anecdotes indicative of a high degree of illegal fishing in the Clipperton EEZ (illegal because this fishing does not occur after an access agreement has been concluded with France, and/or fishing licenses acquired). This is summarized in www.clipperton.fr/: "*Tuna fishing is the main activity in Clipperton EEZ, but it is practiced only by foreign vessel operating without permission*".

Estimation of the catch and catch value taken for the Clipperton EEZ

The extent of the illegal fishing mentioned above is difficult to estimate. The FAO, in 1969, estimated the tuna catch around Clipperton to be 25,000 t·year^{-1} (www.clipperton.fr/), which following Nieussat (1976), would have been taken by US, Mexican and Japanese vessels.

On the other hand, Goujon (1988) estimated "*foreign vessels*" to catch between 3,000 and 20,000 t·year^{-1}. It is probably the upper figure which is more realistic, given that Anon. (2009) writes: "*Ten factory ships and a number of catcher boats were observed fishing between December 2004 and March 2005 [...]. During every scientific expedition and visit by a vessel from the French Navy, fishing vessels under the flag of Mexico, Costa-Rica, Guatemala and even the USA were observed and recorded. During an expedition in 2001, three fishing vessels were observed in three days in the waters around Clipperton [...]. Also in 2001, a Costa-Rican longliner was boarded whose fishing map was centered on Clipperton Island*".

As a result, our main source (Christian Jost, n.d.; www.clipperton.fr/) suggests the catch taken from the Clipperton EEZ to be 50,000 t·year^{-1}. However, this catch need not consist exclusively of tuna and associated fish. Thus, bluespiny lobster (*Panulirus penicillatus*) were either absent or extremely rarely observed during dives conducted as part of surveys in November 1997 and February 2001, while "thousands" were observed in the 1960s. Similarly, the scarcity of sharks was noticeable (except for hammerhead sharks), again compared with earlier accounts, which suggest that the waters immediately adjacent to the island are also exploited.

The losses to France that this represents have been roughly estimated, using a value of 0.42 €/kilogram of fish caught, based on Korean-French agreement on Korean fishing in French Polynesia. For an annual catch of 50,000 t, this amounts to 21 million € (=31 million US $), which is much higher than the sum of 1.2 million € actually received, for an annual catch of 3,000 t·year^{-1}, from 60 Korean vessels (www.clipperton.fr/).

Although France is a member of the Inter-American Tropical Tuna Commission (IATTC), French fishing vessels (longliners and purse seiners) have been operating in the Clipperton Island EEZ only since 2006. As the French navy cannot effectively patrol the Clipperton Island EEZ, it is hoped that the presence of French vessels will contribute to deter poaching by boats of other countries (www.clipperton.fr/).

CONCLUSIONS

For the *Sea Around Us* Project, and its global database of fisheries catches, this means that the catches made by various countries in the Clipperton Island EEZ must be estimated indirectly. This can be done by 'allowing' all countries that report catches of large pelagic fishes from the Eastern Central Pacific (FAO Area 77) to enter the Clipperton Island EEZ, which should account for the catch of tuna and other large pelagics from that area. This should be complemented by an assumed catch of lobster and (finned) reef sharks, which also appear to be exploited near Clipperton Atoll.

ACKNOWLEDGMENTS

I would like to acknowledge the support of the *Sea Around Us* Project, a scientific collaboration between the University of British Columbia and the Pew Environment Group.

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www.clipperton.fr (see Jost, C.)

TIMOR-LESTE'S FISHERIES CATCHES (1950-2009): FISHERIES UNDER DIFFERENT REGIMES[1]

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ABSTRACT

Timor-Leste (East Timor) became an independent country at the close of the 20th century, and thus the FAO's fisheries division only presents catch data for Timor-Leste from 1999 onwards. However, as a former colony of Portugal and afterwards, as a province of Indonesia, the fisheries sector was described in various technical reports. Here, we present estimates of Timor-Leste's fisheries catches from 1950 to 2009. During the Portuguese period (1950-1974), total fisheries catches were estimated to be approximately 51,000 tonnes. Commercial fisheries catches were estimated to have averaged 83 t·year^{-1} from 1950-1965, but declined to 37 tonnes in 1973; however, small-scale catches were estimated to have increased from approximately 1,600 t in 1950 to 2,300 t in 1973. During the Indonesian period (1975-1998) fisheries catches were estimated to be approximately 72,000 tonnes. The commercial sector's catch expanded from 60 t in 1974 to 2,800 t in 1998, and the small-scale catches averaged approximately 2,050 t·year^{-1}. However, due to the armed conflict surrounding independence in 1999, the associated destruction of infrastructure, and the exodus of people to refugee camps, commercial catches were estimated to have declined to 400 t in 2000, but have since increased to approximately 2,000 t·year^{-1} by 2009. Small-scale catches during this time increased in importance, increasing from approximately 2,500 t in 1999 to approximately 3,500 t·year^{-1} by 2009. Overall, estimated total catches increased from approximately 1,600 t in 1950 to approximately 5,600 t in 2009.

INTRODUCTION

The Democratic Republic of Timor-Leste (East Timor) is a small country located in Southeast Asia with a current population of approximately one million people. It has been shaped by many conflicts, and it is still dealing with post-colonial reconstruction (Anon., 2006). East Timor is located on the eastern half of the Timor Island, but it also comprises the nearby islands of Atauro and Jaco and an exclave, Oecussi-Ambeno, within the Indonesian part of the Timor Island, known as West Timor (Gertil, 2002). Approximately 80 percent of its population resides in rural areas; and are engaged in subsistence agriculture, and the main population centre is Dili (Da Costa *et al.*, 2003).

East Timor's recent history is best described by considering three distinct time periods over the time period of concern (1950-2009). During the 1950-1974 time period, East Timor was a colony of Portugal, as it had been since the early 1500s. In 1975, East Timor declared its independence, but

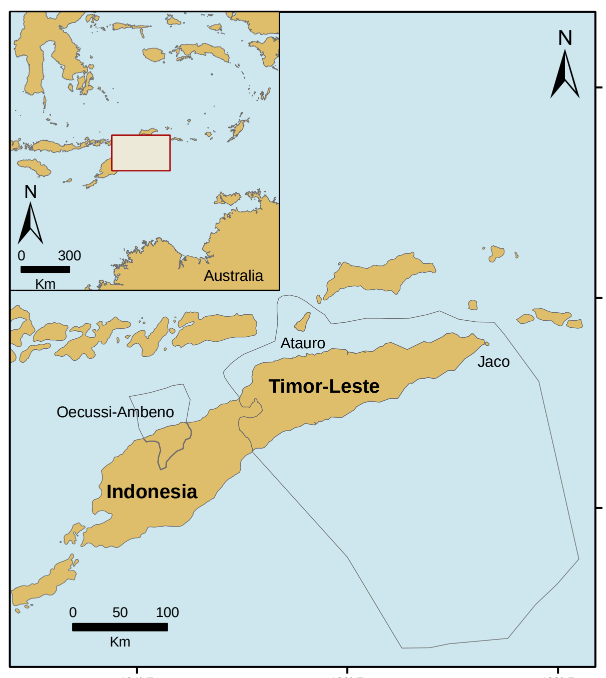

Figure 1. Map of Timor-Leste (East Timor) including islands of Atauro and Jaco, and exclave, Oecussi-Ambeno. Solid line demarcates the country's EEZ.

[1] Cite as: Barbosa, M. and Booth, S. (2009) East Timor's fisheries catch reconstruction (1950-2009): Fisheries under different regimes. pp. 39-51. *In*: Zeller, D. and Harper, S. (eds.) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

was consequently invaded by Indonesia, which occupied the region until 1999. In 2000, the country gained its independence.

East Timor was exploited for its resources during the Portuguese and Indonesian periods. The Portuguese originally were attracted by sandalwood, which was the main product exported until the late 19th century, and they also established the capital, Dili, in 1769 (Anon. 2009a). Although the Japanese occupied the East Timor during the World War II, the Portuguese re-gained control over Timor, and, in 1953 the colony was declared an “Overseas Province” of the Portuguese Republic.

Indonesia invaded the country in 1975 with the help of United States, who feared that the FRETELIN, which had declared independence from Portugal, was communist (CIP, 1978; Burr and Evans, 2001; Povey and Mercer, 2002). Indonesians claimed it as their 27th province and largely controlled the economic resources during its period of occupation. Over the next 24 years (1975-1999) the East Timor’s guerrilla force FRETELIN fought Indonesian forces. The estimated number of Timorese killed or who died from illness and hunger vary from 60,000 to 200,000 (Taylor, 1995).

In 1999, due to international pressure, the Indonesian government entered into an agreement with Portugal and United States to hold a UN-sponsored referendum to determine the fate of East Timor. 78.5% of the East Timor population chose independence instead of being autonomous province of Indonesia. However, just after the referendum, Timorese militias, organized and supported by the Indonesian army, carried out a campaign of violence and destruction against pro-independence factions. In one month, 75 percent of the country's infrastructure was demolished, about 2,000 Timorese were killed and 300,000 people fled westward. The violence came to an end on 20 September 1999 and, in 2002, Timor-Leste was internationally recognized as an independent state and became a member of the UN.

Currently, East Timor is one of the poorest nations in the world and is dependent on foreign funding (Pedersen and Arneberg, 1999). Problems such as a high illiteracy rate, lack of health care and sanitation, and hunger are a reflection that 40% of the population lives on US$0.55 per day (Anon., 2007; Da Costa *et al.*, 2002; FAO/WFP, 2003). Even though Timor has received more donor funds per capita than anywhere else in the world, people are still dying from hunger and deficient health care (Povey and Mercer, 2002).

Although Timor-Leste has a limited coastline, fishing has always been the main source of food and income for people living in coastal communities. Fisheries catches have included large tuna, flying fish, coral reef fish, and deepwater snappers (Felgas, 1952; ADB, 2004). However, the database of the United Nations Food and Agricultural Organization (FAO), lacks most of the catch information for the country. Since 1950, FAO requires that each member country report information concerning food and agriculture production, including fisheries (Pauly and MacLean, 2003). Resources were not directed to collect catch data during its colonial stage, and thus catches were not assessed and reported to FAO prior to 1999.

Table 1. Data sources and methods used for estimating human population for East Timor, 1950 – 2009. Asterix (*) indicates year of linear interpolation. Italicized numbers indicate estimated values.

Period	Year	Population	Source
Portugese	1950	433,000	United Nations[4]
	1951-1969	*	-
	1970	610,300	Populstat[3]
	1971	*619,165*	1950-1970 trend carried forward
	1972	*628,030*	1950-1970 trend carried forward
	1973	*636,895*	1950-1970 trend carried forward
	1974	*645,760*	1950-1970 trend carried forward
Indonesian	1975-1979	*	-
	1980	555,400	Populstat[3]
	1981-1989	*	-
	1990	747,800	Populstat[3]
	1991-1998	-	1980-1990 trend carried forward
Independence	1999-2000	-	2001-2004 trend carried backward
	2001	787,342	Anon. (2003)
	2002-2003	*	-
	2004	923,198	Anon. (2006)
	2005	992,000	United Nations[4]
	2006-2009	992,000	2005 value used

The FAO statistics have been used as baseline for many fishery studies (Pauly *et al.*, 1998), for food security policies, and development strategies. Nevertheless, reconstruction of fisheries catches, undertaken for several countries by the *Sea Around Us* Project have shown the incomplete nature of FAO's fishery statistics (Zeller *et al.*, 2006; Zeller *et al.*, 2007). This is largely due to the exclusion of illegal, unreported and unregulated catches (IUU; Bray, 2000), especially as it concerns to unreported catches. The *Sea Around Us* Project has detailed various cases in which whole fisheries sectors are not presented in FAO statistics, leading to underestimates in global fisheries statistics (e.g. Booth and Watts, 2007; Zeller *et al.*, 2006). Such a lack of data leads not only to underestimation of the total catch, but it may also lead to misinterpretation of the actual trends in marine fishery resources over time. The purpose of this study is to present a time series of fisheries catch data from 1950 to present for East Timor.

Table 2. Data sources and reconstruction methods used for estimating the number of commercial fishers for East Timor's Portuguese period (1950-1974). *Italicized* numbers indicate estimated values.

Year	Commercial fishers	Source
1950	*36*	[a]
1951	*39*	[a]
1952	*41*	[a]
1953	*44*	[a]
1954	*46*	[a]
1955	*49*	[a]
1956	*52*	[a]
1957	*55*	[a]
1958	*59*	[a]
1959	*63*	[a]
1960	*66*	[a]
1961	*70*	[a]
1962	*75*	[a]
1963	*79*	[a]
1964	*84*	[a]
1965	*90*	[a]
1966	*95*	[a]
1967	*101*	[a]
1968	*107*	[a]
1969	*114*	[a]
1970	116	FAO (1999)
1971	136	FAO (1999)
1972	138	FAO (1999)
1973	141	FAO (1999)
1974	*154*	[a]

[a] Reconstructed by exponential model

MATERIAL AND METHODS

East Timor's fisheries catch from 1950 to 2009 were considered to comprise two sectors, according to the end use of the catch. The commercial sector sells its fish in markets, whereas the small-scale catch is used for subsistence, even though there is some trade between communities.

Separate estimates were made for the commercial and small-scale sectors for each year, and thus total catches are estimated by adding the two sector's catches together. In order to take into account the changes that have occurred in East Timor throughout the study period, three different time periods were considered to reflect the political landscape that the fisheries operated in.

Human population data

The human population was reconstructed to serve as a baseline to help to estimate small-scale catches from 1950-1975. The anchor points of data were taken from census information available from *Populstat* (www.populstat.info) for 1970, 1980 and 1990 (Table 1), and from the *National Statistics Directorate* of East Timor for 2001 and 2004 (Anon., 2003; 2006). For 1950 and 2005 data were taken from population estimates provided by United Nations (Anon. 2009b).

For each of the three historical periods, interpolations between points of census data were made. For years when no interpolations could be made, the relative trend was carried forward or backwards to derive estimates of population by extrapolation. In order to

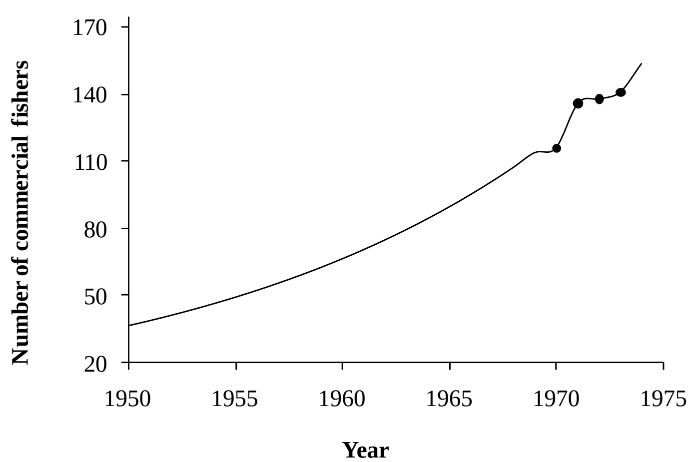

Figure 2. Number of commercial fishers estimated by fitting an exponential growth model ($y = 34.306e^{0.06x}$) to the available data, for East Timor's Portuguese period (1950-1974).

account for the gradual decrease in population after the Indonesian invasion, we used two different methods during the 1970s. For 1971-1974, we carried the 1950-1970 trend forward. From 1975-1979, we linearly interpolated between the 1974 derived population estimate and the 1980 assessed population. This resulted in a gradual decreasing trend after 1975, a reflection of the turmoil caused by Indonesia's annexation of East Timor.

Total number of fishers: The main purpose of reconstructing the number of fishers was to combine the number of commercial fishers with catch rates (i.e., catch·fisher^{-1}) to estimate catches in some years when data were missing.

1950-1974 (Portuguese period): The total number of fishers was estimated by summing commercial and small-scale fishers. Data on the number of commercial fishers were reported by FAO as being 116 in 1970; 136 in 1971; 138 in 1972 and 141 in 1973 (FAO, 1999; Table 2). The number of fishers during years of lacking data were estimated by fitting an exponential growth model to the available data (Figure 2).

Table 3. Data sources and methods used for estimating the total number of fishers for East Timor, 1950 - 2009. Asterix (*) indicates year of linear interpolation. *Italicized* numbers indicate estimated values.

Year	Total Fishers	Source
1950-1974	-	Reconstructed[a]
1975-1986	*	-
1987	5581	BPS (1998a)
1988	5620	BPS (1998a)
1989	6410	BPS (1998a)
1990	6918	BPS (1998a)
1991	7152	BPS (1998a)
1992	7944	BPS (1998a)
1993	8284	BPS (1998b)
1994	8631	BPS (1998b)
1995	8580	BPS (1998b)
1996	8742	BPS (1998b)
1997	9066	BPS (1998b)
1998	*9366*	1974-1987 trend carried forward
1999	*2614*	2000-2001 trend carried backward
2000	4057	FAO[b]
2001	5500	JICA (2002)
2002-2009	*5500*	2001 value used

[a] sum of commercial and small-scale fishers; [b] FAO - www.fao.org [Accessed July 27, 2009].

The number of small-scale fishers were estimated by dividing the small-scale catch by the catch rate (catch·fisher^{-1}), which was assumed to be equivalent to the average amount caught by commercial fishers between 1950 and 1964 (1.53 t·year^{-1}; see 'commercial fisheries' below). During this time there were only non-motorized canoes, and our assumption implies similar efficiency between commercial and small-scale fisheries.

1975-1998 (Indonesian Period): For 1987-1997 from the East Timor's Central Board of Statistics (*Badan pusat statistic* – BPS) had information on the total number of fishers available (BPS, 1998a; 1998b; Table 3), which showed an increase in the number of fishers over time. Linear interpolation was used to fill-in the years from 1975-1986. For 1998, the 1974-1987 trend (an increase of 300 fishers·year^{-1}) was carried forward.

1999-2009 (Independence): Information on the total number of fishers was available for 2000 and 2001. In 2000, it was estimated that there were 4,057 fishers (Anon. 2009c) and in 2001, according to the Japan International Cooperation Agency (JICA), there were 5,500 fishers (JICA, 2002). For 1999, the 2000-2001 trend (an increase of 1,443 fishers·year^{-1}) was carried backward, and for 2002-2009 the 2001 value was used (Table 3). The decline from 9,366 fishers in 1998 to 2,614 in 1999 is a direct consequence of the Indonesian Deliberate destruction of infrastructure.

Commercial Fishery

The commercial catch was estimated by linear interpolation between catch anchor points and, in order to complete the time series during each period, we also applied the trends in years when catch data were lacking.

1950-1974 (Portuguese period): Commercial catch data were gathered from reports of a development plan carried-out by Presidência do Conselho Secretário Técnico of Portugal (PCST) for 1965 and 1968-1973 in Timor (PCST, 1965; 1967; 1968; 1971; Table 4). During this time catches decreased from 80 t·year^{-1} in 1965 to 37 tonne•year^{-1} in 1973, and this may be linked to the agricultural development plan, which led to an expansion of this sector with a consequential decrease in yearly landings of fish as fishers were leaving the fisheries sector to work in the agriculture sector (PCST, 1965; 1967).

Table 4. Data sources and methods used for estimating commercial marine fishery catch (t) for East Timor's during the Portuguese period (1950-1974). Values in *Italics* are estimated.

Year	Commercial catch (t)	Source	Commercial Fishers	Source	Commercial catch (t·fisher $^{-1}$)
1950	*76* [a]	-	*36* [b]	-	[c]
1951	*78* [a]	-	*39* [b]	-	[c]
1952	*79* [a]	-	*41* [b]	-	[c]
1953	*81* [a]	-	*44* [b]	-	[c]
1954	*82* [a]	-	*46* [b]	-	[c]
1955	*83* [a]	-	*49* [b]	-	[c]
1956	*84* [a]	-	*52* [b]	-	[c]
1957	*85* [a]	-	*55* [b]	-	[c]
1958	*86* [a]	-	*59* [b]	-	[c]
1959	*86* [a]	-	*63* [b]	-	[c]
1960	*86* [a]	-	*66* [b]	-	[c]
1961	*86* [a]	-	*70* [b]	-	[c]
1962	*85* [a]	-	*75* [b]	-	[c]
1963	*84* [a]	-	*79* [b]	-	[c]
1964	*82* [a]	-	*84* [b]	-	[c]
1965	80	PCST	*90* [b]	-	0.89 [d]
1966	*77* [a]	-	*95* [b]	-	-
1967	*74* [a]	-	*101* [b]	-	-
1968	70	PCST	*107* [b]	-	0.65 [d]
1969	68	PCST	*114* [b]	-	0.60 [d]
1970	43	PCST	116	FAO (1999)	0.37
1971	32	PCST	136	FAO (1999)	0.24
1972	19	PCST	138	FAO (1999)	0.14
1973	37	PCST	141	FAO (1999)	0.26
1974	*60* [a]	-	*154* [b]	-	[e]

[a]Estimated using commercial fishers and commercial catch rate; [b] Estimated using exponential growth model; [c] 1965-1968 trend carried backward; [d] Estimated using catch anchor point, and estimated number of fishers;[e] 1972-1973 trend carried forward

Years in which commercial catches were missing, had catches estimated by combining the number of commercial fishers with catch rates (i.e., catch·fisher^{-1}). Data on number of commercial fishers were gathered from an FAO report on number of fishers, for 1970-1973 (FAO, 1999, see Table 2), and reconstructed for the rest of the colonial period according to the method described above (see total fishers section). The commercial catch rates (catch·fisher^{-1}) were determined from anchor points of commercial catch, available for 1965 and 1968-1973, and number of fishers. For 1950-1964, the 1965-1968 trend (an increase of 0.08 t·year^{-1}) was carried backward. For 1966-1967 a linear interpolation was made between 1965 and 1968. For 1974, the 1972-1973 trend (an increase of 0.125 t·year^{-1}) was carried forward. The highest rate of 0.89 t·fisher^{-1} was in 1965, and thereafter catches ranged from 0.14 t·fisher^{-1} (1972) to 0.37 t·fisher^{-1} in 1970. In 1965, 1968 and 1969, total catches were reported, but the catch rate was derived from the estimate number of fishers.

1975-1998 (Indonesian Period): Data on commercial catches were reported by the Fisheries Statistics of Indonesia for 1978, 1979, 1982 and 1985 (Anon., 1978; 1979; 1982; 1985; Table 5), and by the Central Board of Statistics of East Timor (BPS, 1998a; 1998b). Catches during this period were reported as 225 t·year^{-1} in 1978 and increased steadily to 2,800 t·year^{-1} in 1998. Information regarding commercial fisheries catches in 1998 was found in a project completion report on the Hera Port rehabilitation, prepared by the Asian Development Bank (ADB) (Anon., 2004), and were 2,800 fishers. For 1975-1977, linear interpolation was made between the derived value for 1974 and the value reported for 1978. For the rest of the years of missing data, simple linear interpolations were used to estimate catches.

1975-1998 (Indonesian Period): Data on commercial catches were reported by the Fisheries Statistics of Indonesia for 1978, 1979, 1982 and 1985 (Anon., 1978; 1979; 1982; 1985; Table 5), and by the Central Board of Statistics of East Timor (BPS, 1998a; 1998b). Catches during this period were reported as 225 t·year^{-1} in 1978 and increased steadily to 2,800 t·year^{-1} in 1998. Information regarding commercial fisheries catches in 1998 was found in a project completion report on the Hera Port rehabilitation, prepared by the Asian Development Bank (ADB) (Anon., 2004), and were 2,800 fishers. For 1975-1977, linear interpolation was made between the derived value for 1974 and the value reported for 1978. For the rest of the years of missing data, simple linear interpolations were used to estimate catches.

1999-2009 (Post-independence): For the post-independence period the data were taken from the Asian Development Bank report on the Hera Port rehabilitation (Anon., 2004). This report detailed fisheries catch data over time, for 2001 (950 t·year^{-1}) and 2004 (2,044 t·year^{-1}) (Table 6). Linear interpolation was done to fill in the years of missing data. The value of 2003 was used as the best estimate for each year after, since data were lacking.

Figure 5. Data sources and methods used for estimating marine fishery catch (t)

Year	Catch (t)	Source
1974	*60* [a]	-
1975 -1977	-	-
1978	225	Anon. (1978)
1979	499	Anon. (1979)
1980 -1981	-	-
1982	397	Anon. (1982)
1983 -1984	-	-
1985	494	Anon. (1985)
1986	-	-
1987	580	Anon. (1987)
1988	637	Anon. (1988)
1989	645	BPS (1998a)
1990	803	BPS (1998a)
1991	944	BPS (1998a)
1992	1,358	BPS (1998a)
1993	1,851	BPS (1998b)
1994	2,002	BPS (1998b)
1995	2,165	BPS (1998b)
1996	2,315	BPS (1998b)
1997	2,423	BPS (1998b)
1998	2,800	Anon. (2004)

[a] Value estimated according to method described for the colonial period

Small-scale Fishery

The estimates of small-scale catches are considered in a different manner than commercial catches. Here, we present the methods of estimating small-scale catches over the entire time period. Small-scale catches are usually not reported in fisheries statistics and thus are very scarce in the literature. Thus, small-scale catches were reconstructed through per capita rates and the human population data.

For 1988, 1997, 2001 and 2003, total catch were reported to be 3,000 (Da Costa *et al.*, 2003), 4,000 (Anon., 2004), 3,800 (JICA, 2002) and 5,206 (Anon., 2004) t·year^{-1}, respectively; and commercial catches were reported as being 637 (Anon, 1988), 2,423 (BPS, 1998b), 950 (Anon, 2004), 2,044 (Anon, 2004) t·year^{-1} respectively (Table 7). Thus, small-scale catches were estimated by difference (i.e., small-scale = total catch - commercial catch). In order to form anchor points of small-scale *per capita* catch rate (i.e., t·person·year^{-1}) for the small-scale sector, the subsistence catch (Table 7) was divided by the population (Table 8). These anchor points of *per capita* catch rates were interpolated to fill in the years with no data (Table 8).

Table 6. Data sources and methods used for estimating commercial marine fishery catch (t) for East Timor's post- independence period (1999- 2009). Asterix (*) indicates year of linear interpolation.

Year	Commercial catch (t)	Source
1998	2,800	Anon. (2004)
1999	*	-
2000	1,602	2001-2003 trend carried backward
2001	950	Anon. (2004)
2002	*	-
2003	2,044	Anon. (2004)
2004-2009	-	2003 value

From 1950-1974 we assumed that the *per capita* rates for the year 2000 (0.0036 t·year^{-1}) would be the most representative of the catch rates, since the fishery infrastructure was destroyed and the catches were made mostly by the artisanal fishers in dugout canoes. This is most likely a conservative assumption considering that the inshore fishery resources must have been available in higher levels in earlier times than in the present, resulting in higher catch rates. The fact that the 1950s is the only period that some marine catch in East Timor is reported as having been exported (53 t

Table 7. Data sources of total catch and commercial catch used for estimating small-scale *per capita* catches rates for East Timor, from 1950 - 2009. Asterix (*) indicates year of linear interpolation.

Year	Total Catch (t)	Source	Small-scale catch (t)	Source
1950-1974	*	-	-	-
1975-1987	*	-	-	-
1988	3,000	Da Costa *et al.* (2003)	2,363	Total Commercial
1989-1996	*	-	-	-
1997	4,000	Anon. (2004)	1,577	Total Commercial
1998	*	-	-	-
1999-2000	*	-	-	-
2001	3,800	JICA (2002)	2,850	Total Commercial
2002	*	-	-	-
2003	5,206	Anon. (2004)	3,162	Total Commercial
2004-2009	*	-	-	-

in 1950; 50 t in 1951; 22 t in 1952 and 25 t in 1953) (Felgas, 1956), adds some validity to this assumption. For 1998, the 1988-1997 trend (a decrease of 0.0002 t·year-1) was carried forward. And for 1999-2000 the 2001-2003 trend (a decrease of 0.00001 t·year-1) was carried backward unaltered. From 2004-2009, the 2003 *per capita* catch rate was used. Multiplying the estimated *per capita* catch rate of each year by the corresponding population produced estimates of the small-scale catch for the whole period of study.

Table 8. Population data and methods used in calculating per capita small-scale catches (t). Asterix (*) indicates year of linear interpolation.

Year	Population	Small-scale catch rate ($t \cdot person^{-1} \cdot year^{-1}$)	Methods
1950-1974	-	0.003	2000 value used
1975-1987	-	*	-
1988	709,320	0.003	Small-scale / Population
1989-1996	-	*	-
1997	882,480	0.0017	Small-scale / Population
1998	-	0.0016	1988-1997 trend carried forward
1999-2000	-	-	2001-2003 trend carried
2001	187,342	0.0036	Small-scale / Population
2002	-	*	-
2003	877,913	0.0036	Small-scale / Population
2004-2009	-	0.0036	2003 value used

Taxonomic breakdown

Data concerning the species composition of catches are very limited. Catches as presented by the FAO on behalf of East Timor are only for the year 2000, and are reported as mainly in the miscellaneous marine fishes category. Therefore, we used two sets of data to better represent the taxonomic breakdown of catches. We used information from Cook (2000) and from Anon. (1985) to derive percentages of catches. Cook (2000) data concerned a market survey in Dili and Anon. (1985) reported catches by taxa. We applied these percentages to the catch totals to estimate catch by taxa.

RESULTS

Human Population

The population of East Timor has grown from approximately 433,000 people in 1950 to a current population of approximately 992,000 people. However, during this time, there were two periods when the population declined (Figure 3). The first population decline was a result of the conflict related to the Indonesian invasion, and occurred gradually in the years following 1974. This decline was then offset by a policy to increase food production (Pedersen and Arnsberg, 1999), which resulted in population growth from 1980 to 1998. The second decline, in 1999, was a result of 175,000 people leaving East Timor for refugee camps, a further 200,000 people displaced within East Timor and about 2,000 being killed by Indonesian militias (Mendonça, 2002).

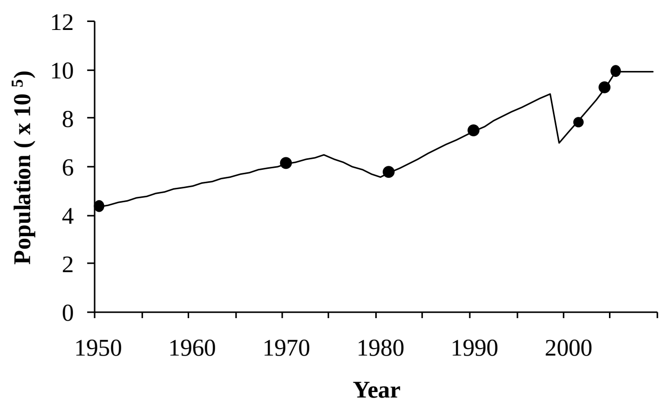

Figure 3. Human population reconstructed for Timor-Leste, 1950-2009. Hard data, found in the literature, are indicated by anchor points (•).

The years following 1999 show rapid population growth due to the return of refugees and a high fertility rate associated with a young age structure of the population. By the first half of 2001 the population was estimated to have risen again, as people returned to East Timor, to around 87% of its estimated pre-crisis level, in 1998 (Anon., 2003).

Total fishers

The number of fishers was estimated to have risen from 1,061 fishers in 1950 to 1,682 in 1974 (Figure 4). The number of fishers then declined from 9,366 in 1998 to 2,614 in 1999. Since 1999 the number of fishers grew to approximately 5,500.

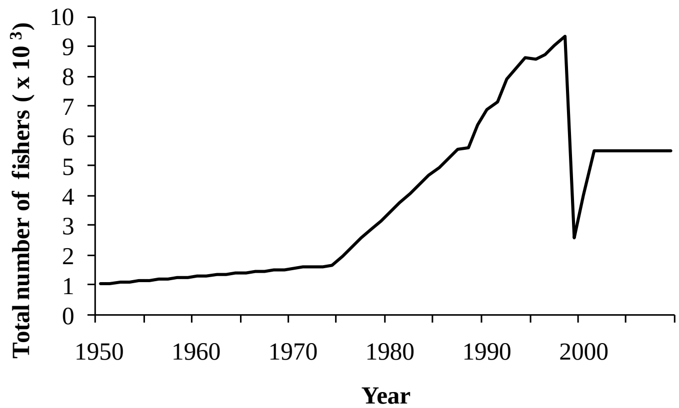

Figure 4. Total number of fishers in East Timor, 1950-2009.

Commercial Fishery

1950-1974 (Portuguese period): The commercial catch during the colonial period is relatively low, averaging 80 t·year^{-1}, and was caught by artisanal fishers. Even after the development plan carried out by Portugal from 1965-1974 in East Timor (PCST, 1965; 1967; 1968; 1971), which included the purchase of powered boats and engines, fishery catches were still decreasing until 1973, from 80 t·year^{-1} in 1965 to 37 t·year^{-1} in 1973 (Figure 5). This is most likely a reflection of the importance placed on agriculture during the years of development (PCST, 1974).

The fishery was limited to the inshore areas, and relied on traditional methods and knowledge. During this period, Atauro Island and Dili were the main fishing spots and the inshore marine resources of these areas supported some export of dried fish and shellfish. Offshore areas were not utilized for fishing (Felgas, 1956).

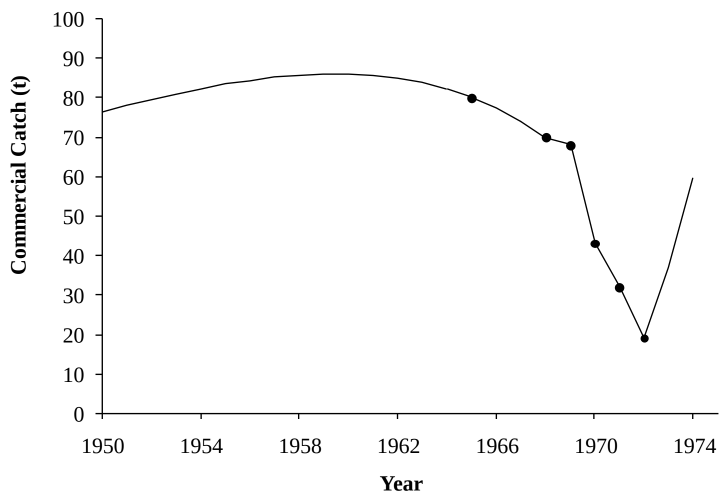

Figure 5. Commercial catch, Portuguese period, 1950-1974.

1975-1998 (Indonesian Period): It was during the Indonesian occupation that East Timor's marine fishery reached its peak, with the 1990s representing the largest of fishery landings. Commercial catches rose from 101 t·year^{-1} in 1975 to 2800 t·year^{-1} in 1998 (Figure 6).

Despite the violence, a complex administrative structure was implemented in East Timor during the Indonesian rule (Pedersen and Arnsberg, 1999). From 1978 to 1982 there was development of the infrastructure, with 14 public markets and 1,264 km of roads being constructed, and also, by the 1980s, there were investments in fishponds, fish markets, hatcheries and the fishing fleet.

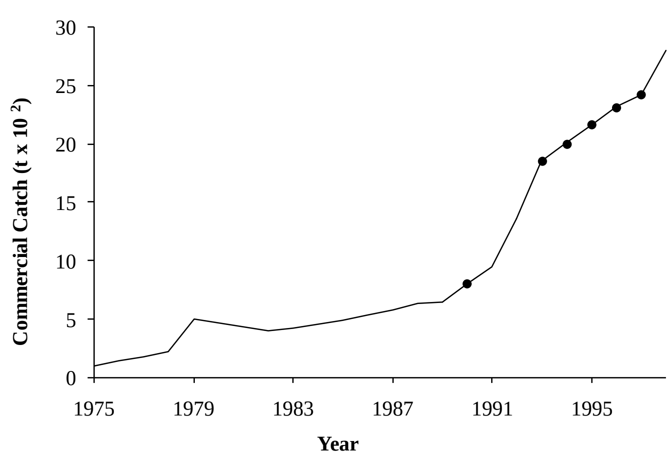

Figure 6. Commercial catch, Indonesian period, 1975-1998.

The construction of the Hera Port, near Dili, in 1990, with a boatyard and fish market, helped to develop the commercial fishery by supporting offshore fishing vessels (ADB, 2003). While, for 1987, the records indicate a commercial catch of about 600 tons of fish (Anon., 1987), in

1997, it had increased to 2,400 tons (BPS, 1998b), with about 60% of fish landings being made in Dili at a rate of about 4 t·days^{-1} (Cook, 2000). At that time, there were 995 dugout canoes, 402 small boats and 630 boats with outboard motors (Pedersen and Arneberg, 1999). However, the commercial fishery was dominated by Indonesians from Sulawesi, who landed all the yellowfin tuna (*Thunnus albacores*) of export quality (Cook, 2000), as the local people were not allowed to fish in deep waters (ADB, 2004; 2003).

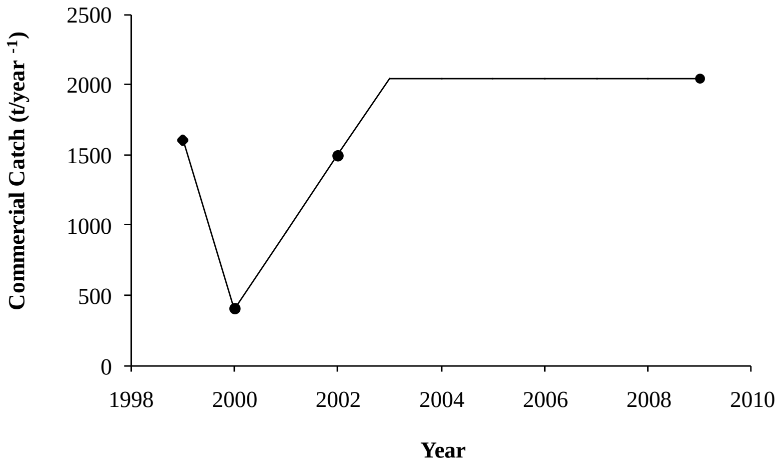

Figure 7. Commercial catch, Post-independence period , 1999-2009.

1999–2009 (Post–independence): After 1999, there was a sharp drop of commercial catch landings as a result of the post-referendum conflicts (Figure 7).The catches declined from the reported value of 2,800 t·year^{-1} in 1998 (Anon., 2004), to the estimated amount of 403 t·year^{-1} in 2000. In retaliation Indonesian militias destroyed nearly 90% of the boats, fishing gear and onshore processing infrastructure (Anon., 2009d). All the commercial fishing boats left East Timor, with about 24 moving to Atauro Island and the rest being destroyed (ADB, 2003). Wooden boats other than dugouts were built outside the country, mostly in Sulawesi. Less than 10% of the number of powered fishing crafts that were present in 1997 were thought to have been operational during a FAO mission in 2000 (Cook, 2000). The broken engines could not be repaired as there were no spare parts available, nor were there qualified personal to do the repairs as many skilled laborers had left the country (Cook, 2000).

The destruction of the Hera Port ice machine, which used to produce up to 17 tonnes of ice per batch, led to a decline in effort. Without any other substantial source of ice supply, the remaining fishers that had larger canoes or boats were unable to travel further or fish for longer periods. Salting fish was not an effective solution since there was also a shortage of salt (Cook, 2000). The three main public markets of Dili, where fish used to be sold, were all burnt, as well as landing sites and markets at Manatutu and Ambeno.

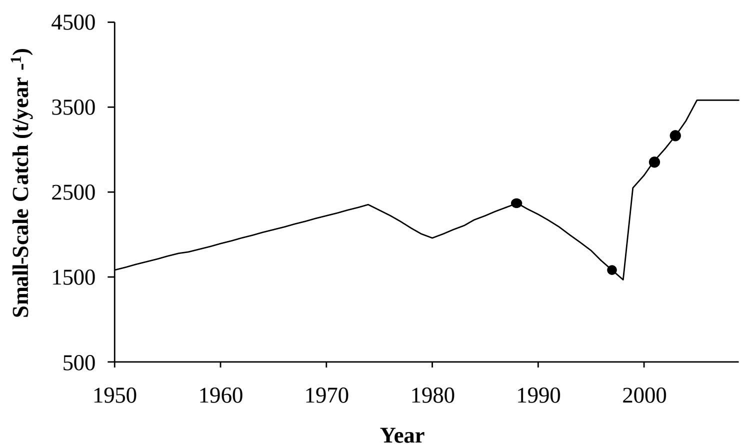

Figure 8. Small-scale catch for the entire study period (1950-2009). Solid circles (•) represent values reconstructed from hard data.

After 2001, with the return of the refugees and rebuilding of infrastructure by various international agencies and volunteers, the industry slowly moved toward recovery (Cook, 2000). The Hera Port was rehabilitated in 2003 (ADB, 2003) and is now being managed by an Australian company. As a result, in 2003 the catches had already largely recovered, having risen to 2,044 tonnes·year^{-1} (Anon., 2004).

Small-scale Fishery

The average catch taken by the small-scale fishery sector, mainly for subsistence use during the colonial period, was approximately 2,000 t·year^{-1} (Figure 8). The slight and constant increase over the years follows the trend in population growth. Between 1975 and 1980, catches decrease from 2,275 t·year^{-1} to 1,945 t·year^{-1}, rising again from 2,000 t·year^{-1} in 1981 to 2,363 t·year^{-1} in 1988. The fluctuation and the years of declining catches are a function of the population changes that occurred as a result of the Indonesian invasion.

From 1989 to 1998, small-scale catches decreased from 2,302 t·year^{-1} to 1,457 t·year^{-1}, which contrasts with the growth in population. This might be a reflection of the construction of public markets by the Indonesians, where people could formally sell part of their catch. In fact, the commercial sector expanded during this time period. However, some decline in small-scale catches might be because of the Indonesian investments in East Timor's agriculture, including wet rice production, irrigation systems, cattle importation and fishponds (Pedersen and Arnsberg, 1999). This may have made the small-scale fishers less dependent on fisheries as a source of nourishment and income, and some may have become involved in agriculture, as it happened before, back in the Portuguese time period.

In 1999, with the destruction of the fisheries infrastructure, fishing fleet and the consequential decline of the commercial sector, the small-scale catch increased abruptly to 2,535 t·year^{-1}. After this time fisheries resources once again became one of the main sources of food for coastal communities. Small-scale catches continued to increase up to approximately 3,600 t·year^{-1} following 2005. In 2002, it was estimated that 50% of the fishermen were involved in fishing as their primary source of food and income (Anon. 2009d).

Total Reconstructed Catch

Overall, the total reconstructed marine fisheries catches in East Timor increased over the period considered in this study, from 1,648 t in 1950 to 5,617 t in 2009. The largest increase occurs after 1990, and reflects a significant increase in the commercial catch. Estimated total catches increased from 3,038 t·year^{-1} in 1990, to 4,136 t·year^{-1} in 1999. By the year 2000, just after the post-referendum conflicts, estimated total catches declined to 3,096 t·year^{-1}, and were caught primarily by the small-scale sector. Total catches exceeded 4,500 t in 2002. Several times, an increase in one of the marine fishery sectors considered (small-scale and commercial) is followed by a decrease in the other. For the period when East Timor's total catch is reported in the FAO records (409 t in 1999; 363 t in 2000; 357 t in 2001; 350t for 2001-2007; Anon. 2009c), our reconstructed total catch indicates an average amount approximately 13 times bigger (4,136 t in 1999; 3,096 t in 2000; 3,800 t in 2001; 4,503 t in 2002; 5,206 t in 2003; 5,369 t in 2004 and 5,617 t for 2005-2007). The fact that records as presented by the FAO on behalf of East Timor report the same amount for the last nine years suggests that it is very likely that no re-assessment has actually been done during this time.

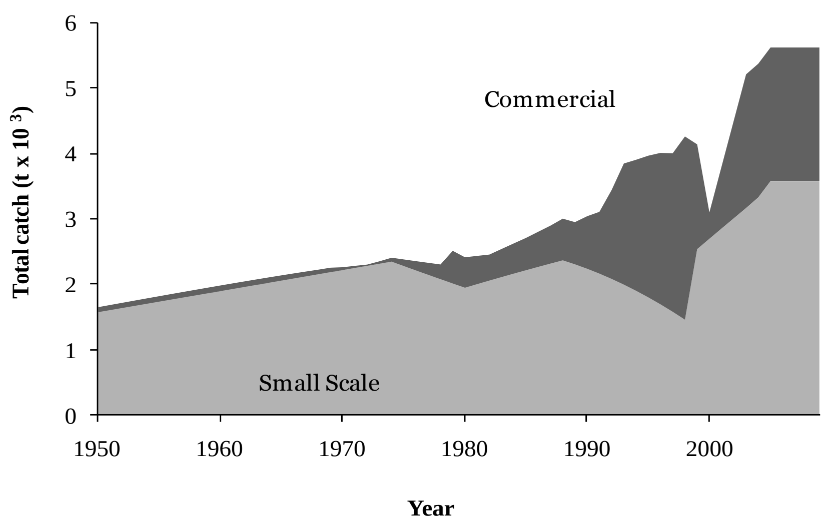

Figure 9. Total reconstructed catch for the period 1950-2009, including commercial and small-scale catches.

Taxonomic details

Fisheries catches of East Timor were dominated by large pelagics, such as tunas and tuna-like species, which represented 33% of the reconstructed total catch. Reef fishes were also important, as can be seen by the importance of Red snapper (Lutjanidae; 10%), Yellow tails and Fusiliers (Caesionidae; 10%) and the yellowfin surgeonfish (*Acanthurus xanthopterus*; 7%). Other important taxa throughout the time period included Sardinellas, Halfbeaks (*Hemiramphus*), Indian Mackerel (*Rastrelliger kanagurta*) and Needle fishes (Belonidae), which together represented 16% of the total reconstructed catch. The remaining 24%

of the reconstructed catch was composed of fish from the following families and genera Leiognathidae, Mugilidae, Serranidae, Elasmobranchii, Rajidae, Scomberoides, Exocoetidae, *Chirocentrus*, Haemulidae, Lethrinidae, Sphyraena, Carangidae, *Siganus*, *Scarus* and *Trachurus*.

Discussion

This is the first time that the East Timor's marine fisheries catches are estimated for the period from 1950 to the 21st century. In face the importance of the fishery resources to the country's food security, the present study may provide some insights and directions for future fisheries management plans and polices for East Timor. Total catches were estimated to be approximately 177,000t over the entire study period, and were 13 times bigger than FAO totals for years when data were supplied to the FAO.

The few years of catch statistics presented by FAO indicates that marine fisheries in East Timor have been scarcely assessed over the years, with minimal data being supplied to the FAO. Contrasting with our estimates, it is very likely that what has been reported to FAO only accounts for commercial sector and strictly for what is formally sold at the markets. However, since FAO statistics report the same value from 2005-2007, it is also possible that no actual assessment has been made, at least lately.

Thus, in association to the improvements made by the international agencies to the country's marine fishery infrastructure, there should also be investments in establishing the means for assessing, monitoring and reporting the catches in order to better understand and predict the real and sustainable potential of the fisheries resources for food security.

In contrast to what many policy makers and aid personnel (Da Costa *et al.*, 2003; FAO/WFP, 2003) suggest, East Timor's fishery potential is not very high, and is not underexploited. Although Timor-Leste lies at the core of the Coral Reef Triangle, the most biodiverse part of the world, it lacks shallow waters. East Timor has a limited continental shelf compared to other countries in the Coral Triangle, with depths of 200m located 1 nautical mile from shore (Anon., 2004; Da Costa *et al.*, 2003). A few reefs and sea grass beds are mainly restricted to Dili's proximities and Atauro Island, which are, essentially, the places where fisheries take place (Pedersen and Arneberg, 1999). Thus, a different viewpoint of East Timor's fisheries may be that the East Timorese have not exploited much of their coastline because there is not much to be exploited (Cook, 2000).

As a result, potential for demersal or seabed fisheries, such as reef fishing or prawn trawling is restricted by its seascape, which could be already over-fished by small-scale fishers.

In April 2000, the FAO's mission (Cook, 2000) assessed the inshore fishery condition in order to identify potential projects for funding by donors. The survey examined the size and amount of catches of the main species on sale at the street market in Dili, and recorded an average amount of 500kg of fish being landed per day into Dili, mostly coming from coral reef shallow seabed areas. Reef emperors (Lethrinidae) smaller than 12 cm and rabbitfish (Siganidae) smaller than 15 cm were often seen, was taken as an indication that reef areas were overfished. Pelagic fishes, usually fished offshore, such as yellowfin, bigeye and albacore tuna, were rarely seen during the three, one-hour survey periods, but small pelagic fishes, such as the Indian mackerel (*Rastrelliger kanagurta),* were regularly present. Also, in a survey undertaken between 2005 and 2006, at Beloi, a village located at Atauro Island, the studied reefs did not present as much fishes as expected. A large number of small fishes was found, but groupers and snappers of larger sizes (>40cm) were rarely seen during dives. Local fishermen confirmed the wide exploitation of the reefs for fishery by the local communities, and the reefs were also noted to be in a poor state (Dutra & Taboada, 2006).

Deep water fishing has never been well developed in East Timor, and this may be partly due to due to East Timor being under a monsoon regime, whose heavy rains and onshore winds make the conditions unfavorable for eexploiting open waters. From November to April, the amount of fish in the north coast declines and Atauro Island, the place where the more active fishers are found, is exposed to both the SE and NW monsoon winds (Cook, 2000; Pedersen and Arneberg, 1999). Therefore, East Timor's marine fishery resource potential should be carefully considered in regards to the differences between inshore and offshore sources, and the factors that affect fisheries catches.

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RECONSTRUCTION OF TOTAL MARINE FISHERIES CATCHES FOR FRENCH POLYNESIA (1950-2007)[1]

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ABSTRACT

French Polynesia's total marine fisheries catches were estimated for the 1950-2007 time period. The 'catch reconstruction' method used to estimate total catches includes all fisheries sectors (i.e., commercial, artisanal and subsistence catches). Separate approaches were used for each of the major island groups, reflecting differences in fishing activities between the islands. Overall, our estimated catch for French Polynesia's fisheries from 1950 to 2007 was approximately 600,000 t. This total was twice the amount reported by the FAO on behalf of French Polynesia. The data supplied to the FAO reflect only commercial landings, while our reconstructed catch estimate was more comprehensive, combining small-scale fisheries catches with commercial sector catches. This method of accounting for all fisheries components is essential to improving the management of fisheries resources and reducing threats to food security in French Polynesia.

INTRODUCTION

Over 100 islands make up the French Pacific Territory of French Polynesia, with an Exclusive Economic Zone (EEZ) of nearly 5 million km² (www.seaaroundus.org), located between 13° and 22° S and 25° and 148° W (Figure 1). The islands are divided into 5 main groups: the Society Islands, the Austral Islands, the Gambier Islands, the Marquesas Islands, and the Tuamotu Islands (Figure 1). The Society Islands are the best known, with the popular tourist destinations of Bora Bora, Moorea and Tahiti (Figure 1). The island of Tahiti is host to the capital city of Papeete, where the main fish market is located. The human population of French Polynesia reached approximately 160,000 in 2007. Since 1992, more than 70% of the total population of French Polynesia has resided on the island of Tahiti, being mostly concentrated around the capital city of Papeete (Walker and Robinson, 2009). In 2004, French Polynesia acquired a status as part of France which made it responsible for all regulation and management regarding fisheries resources within its own EEZ.

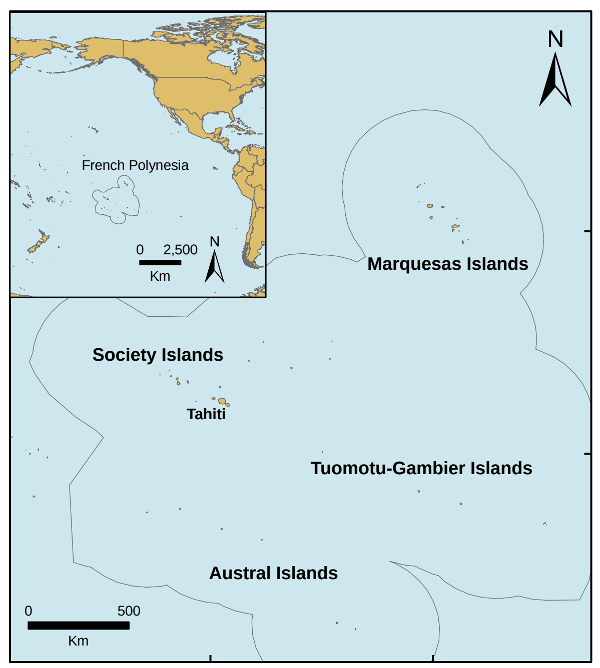

Figure 1. Map of French Polynesia showing the major island groups, the country's EEZ and an inset map showing the location within the Pacific Ocean.

Fishing has always been an important source of protein in French Polynesia, especially for populations living greater distances from the main island of Tahiti (Salvat, n.d.). Many of the islands are host to diverse reef and lagoon systems; the Tuamotu and Society Islands have moderately high coral diversity, with large

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coral reefs and a variety of reef types, and approximately 800 species in 90 families of fish have been recorded. Overall, approximately 84 of the islands of French Polynesia are coral atolls and are considered vulnerable to human pressures (Salvat, n.d.). Because of the rich diversity surrounding the Society and Tuamotu Island groups, and concentration of human populations, these coral reefs have been subjected to varying degrees of exploitation for centuries. Some areas of the Society Islands show signs of extensive overfishing with noticeable declines in mature-sized fish due to the use of destructive gear types including fine meshed nets and spears (Payri and Bourdelin, 1986). However, fishing apparently has never comprised a significant portion of the economy. Prior to the 1960s, exports of copra, vanilla, coffee, and phosphate dominated the economy, while fishing was largely conducted for subsistence purposes. In the early 1960s, France began nuclear testing in French Polynesia. The nuclear testing program had significant impacts on the development of the Polynesian economy, as many military personnel were sent to the islands to work (Anon., 2008). As a result, a major airport and shipping port were built near the capital city of Papeete. These developments greatly facilitated economic activities with other countries (Walker and Robinson, 2009). The nuclear program was conducted mainly between 1966 and 1974 (Danielsson, 1990), but was not completely concluded until 1996. The French government then enacted 'Le Pacte de Progrès', to facilitate growth in tourism, agriculture and fisheries (Walker and Robinson, 2009).

Currently, the economy is dominated by copra, fishing, pearl farming and tourism (Anon., 2002). The majority of domestic fishing in French Polynesia has always been for subsistence and artisanal purposes. Small-scale fishing on the coast is conducted in boats called *'poti marara'* (flyfishing boats), while the *'bonitier'* fleets operate a little further offshore. The catches of the coastal *poti marara* boats consist mainly of albacore (*Thunnus alalunga*), yellowfin (*Thunnus albacores*) and dolphinfish (*Coryphaena hippurus*; Bard *et al.,* 1998). Historically, these fishers used canoes with hand-lines made of vegetable fibers, hooks made of wood and mother-of-pearl, and chunks of live fish for bait. The *bonitier* vessels target mainly skipjack (*Katsuwonus pelamis*) and some yellowfin (Bard *et al*., 1998). Catches from small-scale fisheries are consumed for subsistence, bartered or traded locally, or taken to market.

Fishers also obtain catches from lagoons; consisting mainly of parrotfish (Scaridae), surgeonfish (Acanthuridae) and trevally (Carangidae). The main gears used for lagoon fishing include nets, lines, spearguns, cages, traps, and traditional Polynesian fish ponds (latticed networks of stones built to trap fish; Anon., 2002). While many subsistence fishers fish for themselves and their families, it is also common to give or trade fish with other individuals (Yonger, 2002). There are also a significant number of fish sold at the roadside, including the majority of lagoon fish caught on the island of Moorea (Walker and Robinson, 2009). Fishers who ship their catch to markets in Tahiti do so by plane or boat (Payri and Bourdelin, 1986).

In the early 1990s, financial incentives were given to develop an offshore industrial tuna fishing fleet as part of 'Le Pacte de Progrès' (Walker and Robinson, 2009). The Polynesian long-liner fleet targets deep swimming tunas with bigeye tuna (*Thunnus obesus*) heavily exploited, and some billfish in the north-east portion of the EEZ, north of the Marquesas Island group. This north-eastern portion of the EEZ where Polynesian long-liners have operated since the early 1990s, has traditionally been targeted by international distant-water long-liners. Korea, Japan and Taiwan have operated such fleets historically, while currently, only Korean boats possess licenses (Bard *et al*., 1998). While Bard *et al*. (1998) stated that the majority of long-liner catches were sold locally, with some exports to Japan, Hawaii and France, Walker and Robinson (2009) state the majority of long-liner catches are in fact exported. It is likely that the exported portion of these catches has increased over time. French Polynesia also imports several varieties of fish not available in local waters (e.g., Atlantic salmon), as well as a variety of processed fish products due to the absence of any domestic processing or canning facilities (Anon., 2002).

FAO FishStat (www.fao.org) is the only publically accessible database for global fisheries catches. The catches presented in this database are known to represent primarily commercial landings. In the case of French Polynesia, the data presented by FAO on behalf of French Polynesia are thought to account for all catches landed for the markets in Papeete and possibly Pirae, as well as the commercially exported tunas from offshore long-liners.

The purpose of this study was to estimate the total fisheries catches for French Polynesia from 1950-2007, including all fisheries sectors (i.e., subsistence, artisanal and commercial catches). As described above, the majority of catches in French Polynesia have historically been subsistence in nature. The resources available to provide estimates of subsistence catches are limited, and our approach uses an assumption based approach using information found in the academic and grey literature, with interpolations between anchor points to estimate unknown catches (Zeller *et al.*, 2006, 2007; Zeller and Pauly, 2007).The report herein presents the best estimate of all small-scale catches and commercial landings for French Polynesia from 1950-2007.

MATERIALS AND METHODS

Human population data

Human population data were derived from the Populations Statistics database (www.populstat.info) and the Institut Statistique de Polynésie Française (ISPF; www.ispf.pf). Population data were acquired for each of the 5 island groups between 1950 and 2007 whenever census data were available. The Island of Tahiti (part of the Society Islands) was treated separately due to the large urban population which resides there. Specific population data for the island of Tahiti (total population) and its urban municipal jurisdictions (communes) were used to disaggregate rural and urban populations (see below). The urban population of the capital city of Papeete was taken to include the following 7 communes: Papeete; Faaa; Punaauia; Pirae; Mahina; Paea; and Arue. These urban population data were taken from the Population Statistics database (www.populstat.info). Data for all populations on all islands were typically acquired from the Population Statistics database prior to 2002, and from the ISPF (www.ispf.pf) from 2002-2007. Years between census points were interpolated linearly to estimate population time series (Figure 2).

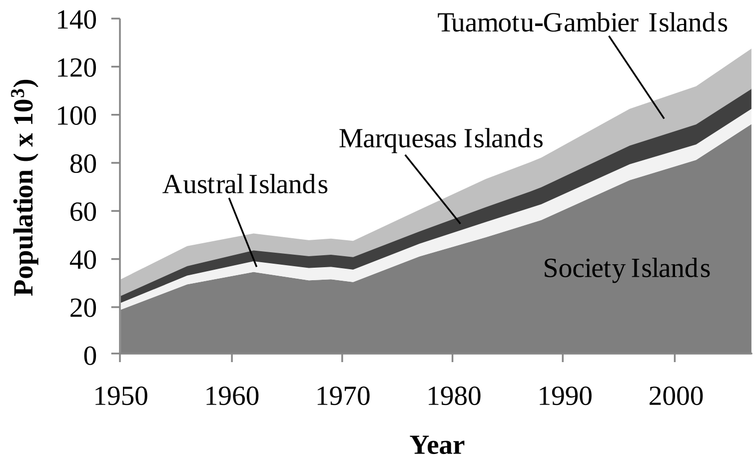

Figure 2. Human population for the major Island groups of French Polynesia, 1950-2007

Subsistence fisheries

Both the academic and grey literature were thoroughly reviewed for data pertaining to subsistence fisheries in each of the five island groups of French Polynesia. *Per capita* catch data referring to subsistence and artisanal fishing were found for the island of Moorea (Society Island), and the Tikehau atoll (Tuamotu Islands). The island of Moorea is adjacent to the island of Tahiti, which is visited frequently by tourists. An estimate of 519 t·year^{-1}, or 43.7 kg·person^{-1}·year^{-1} was reported to be caught and consumed for subsistence by fishers on Moorea (Yonger, 2002).

Subsistence catch data for the Tikehau atoll reflect a more remote population on healthy, productive atolls (Schultz, 1999). Subsistence catches were reported at approximately 150 kg·person^{-1}·year^{-1} (Caillart *et al.*, 1994). Using human population data for each island group, we expanded these *per capita* catch data to represent subsistence catches on all island groups from 1950-2007. Once the total subsistence catch for each island group was derived, we estimated the taxonomic composition with data from Caillart *et al.* (1994), Schultz (1999), Yonger (2002), Aswani and Allen (2009), Suggs (n.d.). Caillart *et al.* (1994) and Yonger (2002) present catches of the most frequently caught species on the Tikehau atoll (Table 1), and the island of Moorea (Table 2), respectively. Aswani and Allen (2009) present counts of individual taxa on the inner, mid, and outer portions of a reef in the Marquesas Island group, Suggs (n.d.) provides general information pertaining to subsistence fishing which aided formulation of our assumptions, and Schultz (1999) provides detailed information on taxa found in and around the Marquesas Islands. These data were used to appropriate the taxonomic composition of reconstructed subsistence catches.

Society Islands (except Tahiti): The Society Islands are frequently visited by tourists. The subsistence catch data found in the literature for the island of Moorea represents fishers who reside within a reasonable distance of the market in Papeete, as well as those who are influenced by the tourist industry (which provides alternative sources of income). We applied the subsistence catch rate found for the island of Moorea in 2001 of 43.7 kg·person^{-1}·year^{-1} (Yonger, 2002), to all island populations found within the Society Island group for 2001 (Table 1), excluding the population of the island of Tahiti (see below). This rate was held constant from 2002-2007 (Table 1). For 1950, we assumed a rate twice that of 2001 (i.e., 87.4 kg·person^{-1}·year^{-1}), and interpolated linearly from 1950-2001 (Table 1). This decreasing trend in *per capita* subsistence consumption since 1950 is assumed to account for the growth of Papeete as an urban centre, the growth of the tourism industry, and increased availability of imported goods. Taxonomic breakdowns of estimated catches were based on data from Table 2.

Table 1. Annual *per capita* catch rates (kg·person^{-1}·year^{-1}), applied to the resident populations of the five island groups of French Polynesia to estimate subsistence catches from 1950-2007, values in *italics* denote anchor points, (-) denotes linear interpolation in years between anchor points. Sources: Caillart *et al.* (1994); Yonger (2002); see text for details.

Year	Society Islands	Rural Tahiti	Austral Islands	Marquesas Islands	Tuamotu-Gambier Islands
1950	*87.4*	*43.7*	*43.7*	*43.7*	150
1951-2000	-	-	-	-	150
2001	*43.7*	*21.9*	*43.7*	*21.9*	150
2002	43.7	21.5	43.7	21.9	150
2003	43.7	21.0	43.7	21.9	150
2004	43.7	20.6	43.7	21.9	150
2005	43.7	20.2	43.7	21.9	150
2006	43.7	19.8	43.7	21.9	150
2007	43.7	19.3	43.7	21.9	150

Society Island (rural Tahiti only): Under the assumption that the urban population of Tahiti does not engage in subsistence fishing, we provide estimates of subsistence catches for the rural population of Tahiti only. The rural population was derived by subtracting the urban population of Papeete from the total population of Tahiti for 1950-2007. In 2001, we applied half the rate found for the island of Moorea from Yonger (2002) to represent subsistence catch rates (i.e. 21.9 kg·person^{-1}·year^{-1}) in rural Tahiti. Thus, we assumed lower due to relative proximity to an urban centre (Table 1). This is supported by Salvat (n.d.) who noted a relatively lesser amount of fishing for subsistence purposes on the island of Tahiti. In 1950 we assigned the original 2001 *per capita* catch rate found for Moorea, representative of the year 2001. We interpolated linearly between 1950 and 2001, then applied the average decrease in *per capita* catch rates from 1950-2001, for the years 2002-2007 (Table 1). This methodology represents a conservative estimate for a population in close proximity to the main Polynesian fish market and largest urban centre.

Table 2. Lagoon and reef fish (kg) taken from the lagoon of Moorea in 2001 (Society Islands), French Polynesia (Yonger, 2002).

Taxon name	Common name	Catch (kg)	%
Selar crumenophthalmus	Bigeye scad	26,762	40.6
Myripristis sp.	Soldierfish	6,056	9.2
Naso unicornis	Bluespine unicornfish	3,700	5.6
Scarus oviceps	Dark capped parrotfish	3,246	4.9
Epinephelus merra	Honeycomb grouper	2,508	3.8
Ctenochaetus striatus	Striated surgeonfish	1,848	2.8
Caranx melampygus	Bluefin trevally	1,613	2.3
Misc. marine fishes	Other	20,115	30.8

Austral Islands: The Austral islands are located in the southwest portion of the French Polynesian EEZ (Figure 1). The northern Austral islands include the rocky Bass Islands, while the southern Austral islands, the Rapa islands, are volcanic in origin. These most southerly islands are surrounded by relatively low sea temperatures, and have no fringing reefs. The Bass islands in the north, however, have well developed fringe, and barrier reefs (Spalding *et al.*, 2001). These aspects of geography contribute significantly to the diversity of species available for inshore fishing.

Very little information pertaining to fishing in the Austral Islands was found. However, Spalding *et al.* (2001) refer to the critical role fishing plays in all Polynesian populations, and particularly those of more remote islands. Larrue (2006) states that the majority of Tubuai's population (one of the more populated northern, Austral Islands) are dual fisher/farmers. The author describes a wild harvest for Giant Clam (*Tridacna maxima)* as being an important subsistence fishery. On land, the dietary stables are taro, breadfruit, coconut, sweet potato, yams, and chestnuts, which are grown on the Island (Larrue, 2006). The population also relies on introduced species of pig and chicken (Bolt, 2008). Given the relative lack of reef and lagoon habitat, we assumed a lower rate of fisheries productivity and thus, lower *per capita* subsistence catch rates. These assumptions were made despite the relative isolation of the Austral Islands, which would normally contribute to increased *per capita* catch rates. This lead to the application of the more conservative rate for the island of Moorea (i.e. 43.7 kg·person^{-1}·year^{-1}; Yonger, 2002), held constant for the 1950-2007 time period (Table 1). Using the population data for the Austral Islands, we applied the *per capita* catch rate reported for the island of Moorea in 2001. Taxonomic breakdowns of catches were estimated using the information presented for Moorea (Table 2), although the more marginal nature of coral reef habitats may cast some doubts on this.

Table 3. Taxonomic composition applied to subsistence catches for the Marquesas Islands from 1950-2007. Percentage data derived through assumption-based consideration of source material.

Taxon name	Common name	Proportion of total subsistence catch (%)
Scombridae	Mackerels, tunas and bonitos	30
Acanthocybium solandri	Wahoo	20
Lutjanidae	Snappers	20
Serranidae	Sea basses: groupers and fairy basslets	10
Misc. marine fishes	Others	20

Marquesas Islands: The Marquesas group is located in the most northerly region of the French Polynesian EEZ. These islands are somewhat similar to the Austral Islands, being steep, rugged, and volcanic in origin. Due to the cool Humboldt currents from Peru, the islands are too cool to support extensive growth of coral reefs (Suggs, n.d.) and lack the enclosed lagoon environments characteristic of the Society and Tuamotu Islands. Anaho Bay has a small inshore reef, but ciguatera has greatly reduced the Marquesan population who traditionally fished in this bay (Aswani and Allen, 2009). In the 1950s, when populations still fished in the bay (before ciguaterabecame widespread), commonly caught taxa included parrot fish, jacks (Carangidae), squirrel fish (Holocentridae), grouper (Serranidae), mullets, triggerfish, wrasse, sharks, manta rays and two species of sardines. However, a lack of reef and lagoon environments forced many Marquesans to focus on pelagic fishing as a source of sustenance. Fishing was done with hook and line as well as with nets and included catches of tuna and bonito (Scombridae), mahi-mahi *(Coryphaena hippurus)* and wahoo (*Acanthocybium solandri*). Today, local crops as well as pigs, cattle and imported foods have an impact on the necessities of fishing for subsistence (R. Suggs, pers. comm.)[2].

Table 4. Lagoon and reef fish taken from Tikehau atoll of the Tuamotu Islands, French Polynesia (Caillart *et al.,* 1994)

		Catch (kg)				
Taxon name	**Common name**	**1983-1984**	**1984-1985**	**1985-1986**	**1986-1987**	**%**
Lethrinus miniatus	trumpet emperor	34,812	29,923	13,961	50,983	19.6
Lutjanus gibbus	humpback red snapper	8,152	11,371	24,374	24,354	10.3
Caranx melampygus	bluefin trevally	24,357	21,332	10,213	11,214	10.1
Selar crumenophthalmus	bigeye scad	8,337	14,201	17,133	16,063	8.4
Epinephelus microdon	camouflage grouper	180	810	5,183	48,902	8.3
Lutjanus fulvus	blacktail snapper	11,226	15,962	13,050	7,694	7.2
Naso brevirostris	spotted unicornfish	3,036	15,299	19,374	2,293	6.0
Mulloides sp.	Goatfish	9,593	8,506	11,066	5,359	5.2
Albula vulpes	Bonefish	12,292	7,889	6,391	5,099	4.8
Upeneus vittatus	yellowstriped goatfish	9,454	882	6,206	1,085	2.7
Sphyraena forsteri	bigeye baracuda	2,835	2,835	5,085	1,954	1.9
Acanthurus xanthopterus	yellowfin surgeonfish	2,085	6,229	307	1,661	1.6
Myripristis sp.	Soldierfish	2,475	1,559	2,931	1,851	1.3
Decapterus pinnulatus	mackerel scad	2,195	1,424	3,580	1,582	1.3
Misc. Marine Fishes	Other	15,848	15,974	16,152	26,348	11.2

As a result of the ciguatera concerns in inshore waters, the subsistence fishing that still occurs is even more focused offshore. Furthermore, high abundances of deeper water snapper on the outer portion of the

[2] R. Suggs, personal communication, archaeologist, author, interpreter and lecturer of the Marquesas Islands and the Pacific, mongonui@msn.com, ph: (208) 429-1619, [*Date of communication*: December 30, 2009].

narrow and steep shelf surrounding the islands are also targeted (Aswani and Allen, 2009). Sport fishers have reported nearshore catches of Pacific little tunny (*Euthynnus affinis*), skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacores*), bigeye tuna (*Thunnus obesus*), blue marlin (*Makaira mazara*), sailfish (*Istiophorus platypterus*), wahoo (*Acanthocybium solandri*), giant trevally (*Caranx ignobilis*), jacks (Carangidae), queenfish (*Scomberoides* sp.), job fish (*Aprion virescens*), red snapper (*Lutjanus bohar*), emperors (Lethrinidae) and groupers (Serranidae), including white-margined groupers (*Gracila albomarginata*) and occasionally Giant groupers (*Epinephelus lanceolatus*; Schultz, 1999).

Thus, we felt a conservative estimate of subsistence catches on the Marquesas Islands would be accomplished by applying the 2001 Morea catch rate of 43.7 kg·person^{-1}·year^{-1} to 1950 Marquesas. For 2001, we assumed half this rate (21.9 kg·person^{-1}·year^{-1}). Linear interpolation was used to estimate catches from 1950-2001, and the 2001 rate was held constant for the period from 2002-2007 (Table 1). Species compositions of catches were broken down for all years in the period from 1950-2007 (Table 3).

<u>Tuamotu-Gambier Islands:</u> The information derived from Caillart *et al.* (1994) for the Tikehau atoll (Tuamotu Island) was used to represent *per capita* subsistence catch rates of 150 kg·person^{-1}·year^{-1} throughout the Tuamotu and Gambier Islands. The rate of 150 kg·person^{-1}·year^{-1} was applied in all years (1950-2007) to the combined population of the Tuamotu-Gambier Islands to estimate subsistence catches (Table 1).

Artisanal and commercial fisheries

Most information from the literature pertaining to commercial or artisanal fisheries catches document those sold at the market in Papeete, or tunas caught by offshore long-liners which are both sold locally and exported. The majority (about 72%) of fish sold in the market in Papeete are from local lagoons and reefs, while the other 28% are caught offshore. Approximately 23% of marketed lagoon and reef fish are caught in waters surrounding the Society Islands, while approximately 64% are from the atolls surrounding the Tuamotu Islands, and 13% are from reefs and lagoons elsewhere in the French Polynesian EEZ (Payri and Bourdelin, 1986). Many artisanal fishers also sell catches by the roadside or directly to restaurants. These catches likely remain unaccounted for in data supplied to the FAO. Chauvet and Galzin (1996) report that approximately 15% of catches of reef and lagoon fish by artisanal fishers in the Tuamotus are represented by 'unauthorized sales'. This value was used in our reconstruction to augment annual catches of lagoon and reef fish in all Islands to fully account for all likely catches from 1950-2007. This rate was not applied to any other species (tunas, or other pelagics) due to a lack of disaggregation between commercial and artisanal origins of these landings in the data presented by the FAO on behalf of French Polynesia.

From 1950-1970, landings, as supplied to FAO, describe only two taxonomic entities, miscellaneous marine fishes and Skipjack tuna. After 1970, FAO presents additional landings of some invertebrates (crustaceans, spiny lobsters, echinoderms) and dolphinfish, and in the late 1980s and early 1990s, landings of bigeye tuna, albacore tuna, and minor quantities of other taxa are documented. It seems that the majority of fish from reefs and lagoons are lumped into the miscellaneous marine fish category. Taxonomic data derived from Caillart *et al.* (1994) and Yonger (2002) provide a breakdown of the most commonly fished taxa from reefs and lagoons (previous section, Tables 2 & 4) around the Society and Tuamotu Islands.

Since the majority (64%) of lagoon and reef fish marketed in Papeete come from the Tuamotus, we applied the taxonomic breakdown from Caillart *et al.* (1994) to 64% of the catch of miscellaneous marine fishes as presented by FAO in each year from 1950-2007. Similarly, since 23% of marketed lagoon and reef fish are caught in the Society Islands, we applied the taxonomic breakdown from Yonger (2002) to 23% of the miscellaneous marine fishes presented by FAO in each year during the period from 1950-2007. We retained the remaining (13%) of miscellaneous catches from FAO as such. Therefore, the new adjusted miscellaneous marine fishes (MMF) category accounts for the cumulative sum of 'others' from Caillart *et al.* (1994), Yonger (2002), and the remaining 13% from MMF category as presented by FAO.

Bard *et al.* (1998) provide data for skipjack and yellowfin tuna sold in the Papeete market, Polynesia-wide catch estimates of skipkack and yellowfin, and Bigeye catches by both domestic and foreign long-liners (Table 5). The authors also provide an estimate of catches of tuna made by coastal *poti marara* boats for all years during the period from 1954-1996 (200-500 t·year^{-1}) consisting mainly of albacore, yellowfin and dolphinfish (Bard *et al.*, 1998; Table 5). Catches by coastal fleets are not required to be reported (Bard *et*

Table 5. Data reported by FAO and Bard *et al.* (1998) for skipjack and yellowfin tuna (1950-2007) as well as catches reported by Bard *et al.* (1998) for catches of albacore, yellowfin and dolphinfish from the coastal *bonitier* fleet for all of French Polynesia for the period 1954-1996, (n/a) denotes years for which no data were reported by a source.

	FAO	Bard *et al.* (1998)	
Year	**Skipjack + Yellowfin**	**Skipjack + Yellowfin**	**Albacore, yellowfin + dolphinfish**
1950	500	n/a	n/a
1951	500	n/a	n/a
1952	500	n/a	n/a
1953	800	n/a	n/a
1954	1,000	n/a	350
1955	800	n/a	350
1956	1,000	n/a	350
1957	700	n/a	350
1958	600	n/a	350
1959	700	n/a	350
1960	1,000	n/a	350
1961	1,000	n/a	350
1962	1,500	n/a	350
1963	1,000	n/a	350
1964	1,000	n/a	350
1965	700	n/a	350
1966	900	n/a	350
1967	700	n/a	350
1968	800	n/a	350
1969	1,000	n/a	350
1970	900	n/a	350
1971	600	n/a	350
1972	700	n/a	350
1973	700	n/a	350
1974	713	n/a	350
1975	721	n/a	350
1976	749	1,711	350
1977	263	1,996	350
1978	1,037	2,981	350
1979	696	n/a	350
1980	936	1,312	350
1981	1,001	1,468	350
1982	1,034	1,557	350
1983	836	1,491	350
1984	1,250	2,344	350
1985	836	1,623	350
1986	961	1,356	350
1987	878	1,536	350
1988	715	1,314	350
1989	754	1,370	350
1990	1,567	1,400	350
1991	1,623	1,472	350
1992	1,520	1,406	350
1993	1,727	n/a	350
1994	1,440	n/a	350
1995	2,220	n/a	350
1996	2,211	n/a	350
1997	1,986	n/a	n/a
1998	2,403	n/a	n/a
1999	2,611	n/a	n/a
2000	2,951	n/a	n/a
2001	3,071	n/a	n/a
2002	2,633	n/a	n/a
2003	2,600	n/a	n/a
2004	2,644	n/a	n/a
2005	2,510	n/a	n/a
2006	2,963	n/a	n/a
2007	1,984	n/a	n/a

al., 1998), so it is unlikely that these catches are included in data supplied to FAO. Though the report by Bard *et al.* (1998) refers to their particular period of study (1954-1996), we augmented landings supplied to FAO with an addition 350 t (the median of the given range) each year by assigning 1/3 of this tonnage to each of the three species cited by the authors (albacore, yellowfin tuna & dolphinfish).

For the years Bard *et al.* (1998) provide total landings of skipjack and yellowfin for all of French Polynesia (1976-1992), totals exceed those of all skipjack and yellowfin landings presented by FAO (often being 1.5-2 times as much) for the years 1976-1978 and 1980-1989 (Table 5). Thus, we replaced FAO landings for these years with the data provided by Bard *et al.* (1998). The skipjack and yellowfin totals given by Bard *et al.* (1998) were split into two taxonomic groupings (skipjack and yellowfin), by using the ratio of reported skipjack to yellowfin landings from FAO statistics in each year.

Bigeye tuna catches from Polynesian long-liners reported by Bard *et al.* (1998) from 1990-1995, match those presented by FAO during this time, and thus, it was assumed that data supplied to FAO after this time (1996-2007) are likely to be correct.

Therefore, we used data presented by the FAO to represent artisanal and commercial fisheries catches in French Polynesia between 1950 and 2007, except for the period 1976-1992 when data from Bard *et al.* (1998) was used in place of data as supplied to FAO.

Thus, our reconstruction of commercial/ artisanal catches entailed: 1) disaggregating the miscellaneous marine fishes category with data from Caillart *et al.* (1994) and Yonger (2002) for all years, 1950-2007; 2) improving the accuracy of commercial skipjack and yellowfin landings in the years listed above, 3) adding additional albacore, yellowfin and dolphinfish catches from the *poti marara* fishery in all years (1950-2007); and 4) augmenting commercial/artisanal catches of lagoon and reef fish by 15% to appropriately represent unauthorized sales for the period from 1950-2007. We also present landings from distant water fleets as reported from Japan, Korea and Taiwan. However, these landings are not included in our reconstruction totals.

RESULTS

Subsistence catches

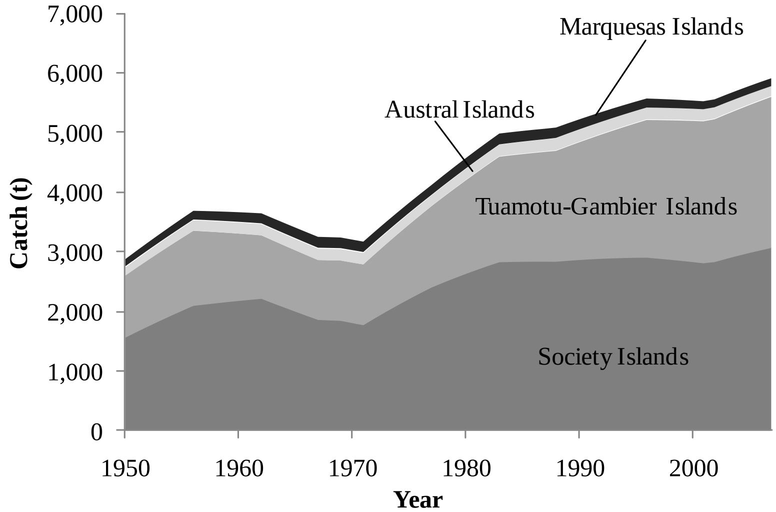

Figure 3. Subsistence catches for French Polynesia, 1950-2007, by island group.

Society Islands: Subsistence catches for the Society Islands including rural Tahiti totaled approximately 146,500 t for the period 1950-2007 (Figure 3). For the most recent years, annual subsistence catches in these islands appeared to account for around 3,000 t·year^{-1}. Overall, subsistence catches for the Society Islands were the greatest of all the island groups considered in this study due to the large proportion of the total population residing in this group. Bigeye scad (*Selar crumenophthalmus*) was the largest individual taxon of the catch, with approximately 57,000 t for the period (1950-2007), and around 1,200 t·year^{-1} for recent years. Soldierfish and Bluespine unicornfish were the next largest individual taxon, with catches of approximately 250 t·year^{-1} in the recent time period (2000-2007).

Tuamotu-Gambier Islands: Our estimate of subsistence catches for the Tuamotu-Gambier Island group for the period 1950-2007 totaled approximately 94,000 t (Figure 3). For recent years, catches were around 2,400 t·year^{-1}.Catches of trumpet emperor (*Lethrinus miniatus*) were the dominant individual taxon component, totalling approximately 18,400 t (480 t·year^{-1} for recent years). Bluefin trevally and Bigeye scad also had substantial catches, with totals of approximately 9,460 t and 7,900 t, respectively over the 1950-2007 time period (250 t·year^{-1} and 205 t·year^{-1}, respectively, for the recent period).

Austral Islands: Our estimate of subsistence catches totaled approximately 13,500 t for the period 1950-2007 for the Austral Island group (Figure 3). In the recent period (2000-2007), catches were estimated to be around 280 t·year^{-1}. Bigeye scad comprised the largest individual taxon component of subsistence catches with totals of approximately 5,500 t for the period 1950-2007. Other major taxa included Soldierfish, Bluespine unicornfish, and Darkcapped parrotfish, each representing between 5-10% of total the Austral Island subsistence catch over the 1950-2007 time period.

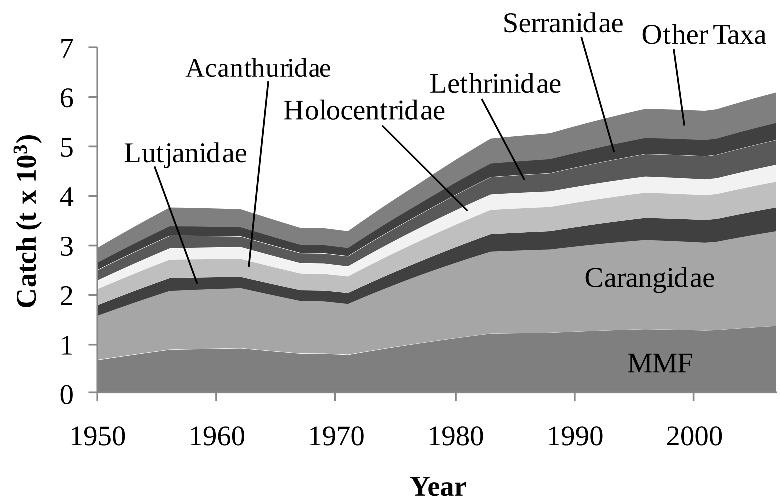

Figure 4. Subsistence catches by taxa for all Island groups combined. The category 'other taxa' includes Albulidae, Mullidae, Scaridae, Scombridae and Sphyraenidae.

Marquesas Islands: Our estimate of subsistence catches for the Marquesas Islands totaled approximately 10,700 t for the period from 1950 to 2007 (Figure 3). Annual catch for the recent period was 180 t·year^{-1}. Family Scombridae (Mackerels, tunas and bonitos) contributed the greatest component of the overall subsistence catches. Catches of fish in the Scombridae family totaled over 5,000 t for the period 1950-2007 (approximately 90 t·year^{-1} ·for the recent period, 2000-2007), while catches of wahoo and snapper (Lutjanidae) were approximately 2,000 t each for the period 1950- 2007 (around 36 t·year^{-1} for the recent period, 2000-2007).

<u>Total subsistence reconstruction:</u> Overall, subsistence catches totaled approximately 259,200 t for the period 1950-2007 (Figure 3). The majority of catches were taken in the Society Islands, followed by the Tuamotu-Gambier Island group, the Austral Islands, and the Marquesas Islands (Figure 3). Subsistence catches increased throughout the 1950s, and initially peaked at approximately 3,686 t·year^{-1} in 1956. During the 1950s the average catch was approximately 3,400 t·year^{-1}. Subsistence catches were estimated to have declined through the 1960s hitting a low of approximately 3,207 t·year^{-1} in 1971. Subsistence catches in French Polynesia have generally increased since this time, averaging 3,800 t·year^{-1} in the 1970s, approximately 5,000 t·year^{-1} in the 1980s, 5,600 t·year^{-1} in the 1990s, and approximately 5,800 t·year^{-1} from 2000-2007. While subsistence catches of some island groups maybe declining (i.e., Austral and Marquesas Islands), it appears that overall subsistence catches in French Polynesia are still increasing (Figure 3). While the taxonomic breakdown of subsistence catches included species level, we grouped the catches by family for the purposes of this report. Subsistence catches were dominated by fish in the Carangidae family (Figure 4). The Acanthuridae, Lutjanidae and Lethrinidae also provided substantial amounts of catch (Figure 4).

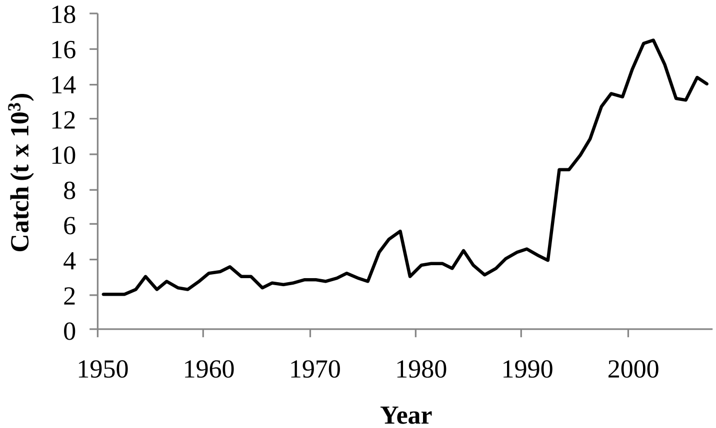

Figure 5. Estimated commercial catch for French Polynesia, 1950-2007.

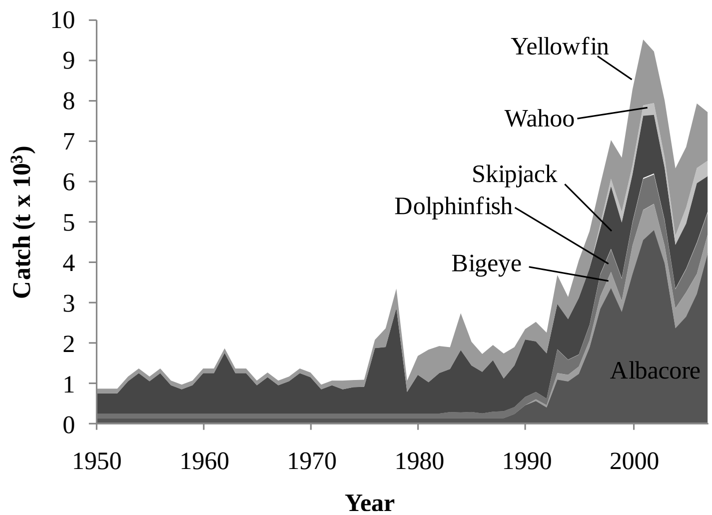

Figure 6. Commercial landings of main pelagic species caught by French Polynesia, 1950-2007.

Artisanal and commercial catches

Our estimates of commercial catches for the period 1950-2007 totaled approximately 336,000 t (Figure 5). Commercial catches initially averaged approximately 2,300 t·year^{-1} in the 1950s, and increased gradually to an average of between 3,000-4,000 t·year^{-1} in the 1980s. Starting in the early 1990s, a dramatic increase from approximately 4,000 t·year^{-1} to a peak of 16,500 t·year^{-1} by 2002 was reported (Figure 5). Since this time, commercial catches appear to have declined slightly to an average annual catch of 14,600 t·year^{-1}.

Our estimates of commercial catches were comprised mostly of data as supplied to FAO, however, some additions of skipjack and yellowfin tuna were made to commercial landings in the 1970-1980s, and to artisanal landings of albacore, yellowfin and dolphinfish throughout the time period (1950-2007). Additions for the artisanal *poti marara* fleet added approximately 7,000 t to the commercial catch totals of each of the respective species (1950-2007), while approximately 8,300 t of skipjack, and 4,000 t of yellowfin tuna landings were added to data presented by FAO (1950-2007).

Of the commercial pelagic catches (excluding reef and lagoon fishes), the main catches were those of skipjack, albacore, yellowfin, and dolphinfish, which comprised approximately 60,800 t (18%); 49,685 t (15%), 30,464 t (9%); and 13,792 t (4%) of the reconstructed total commercial catch, respectively (1950-2007; Figure 6). For the period 1950-1990, the main species appears to have been skipjack (Figure 6). In the 1950s, skipjack catches averaged approximately 700 t·year^{-1}, increasing to 1,050 t·year^{-1} by the 1980s. Only minor quantities of albacore, yellowfin tuna, and dolphinfish appear to have been caught during this period (1950-1990; Figure 6). In the early 1990s, catches of albacore tuna increased dramatically from approximately 400 t·year^{-1}, to more than 4000 t·year^{-1} in 2007, in line with the offshore expansion encouraged by 'Le Paste de Progrès'. Catches of yellowfin tuna increased throughout the time period, from those representative only of the coastal *poti marara* fishery (~120 t·year^{-1}) from 1950-1979, to averages of approximately 1,500 t·year^{-1} from 2000-2007. Catches of other large pelagics and tunas (i.e., dolphinfish, bigeye tuna, and wahoo) increased slightly in the early 1990s, averaging 490 t·year^{-1}, 375 t·year^{-1} and 275 t·year^{-1}, respectively, for the period 1990-2007 (Figure 6).

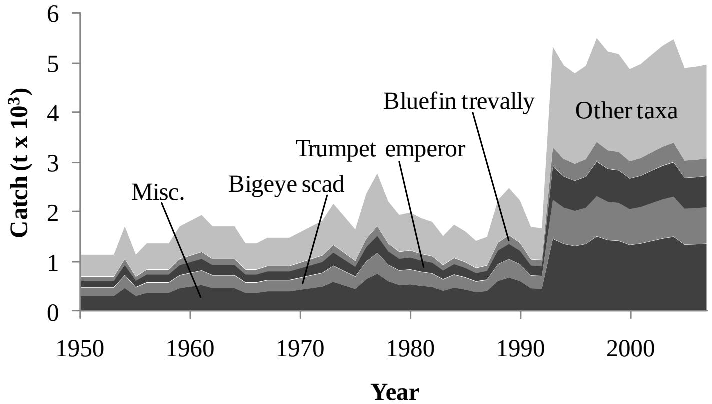

Figure 7. Improved FAO category for miscellaneous marine fishes (MMF) in terms of a) 15% addition of unauthorized sales, b) taxonomic breakdown from Caillart *et al.* (1994) to 64% of MMF category and Yonger (2002) to remaining 23%. The category 'other taxa' includes 15 individual species.

Data from Caillart *et al.* (1994) and Yonger (2002) were used to dissagregate the 'marine fishes nei' or 'miscellaneous marine fishes' category from FAO FishStat, where 18 taxa replaced most of the original miscellaneous marine fishes category. Approximately 35,800 t (10%) of total commercial catches remained as miscellaneous marine fishes. This was a substantial reduction from the original FAO data, in which approximately 40% of the commercial catch was represented as uninformative 'miscellaneous marine fishes'.

Thus, we improved the data taxonomically by about 30%. Bigeye scad (15%), trumpet emperor (13%) and bluefin trevally (7%) comprised the largest components of the disaggregated miscellaneous marine fishes category (Figure 7). Included in these estimates of commercial taxa were the 15% of unauthorized sales of reef and lagoon fish (1950-2007), attributed to artisanal fishers selling catches at the roadside or directly to restaurants. The addition of unauthorized sales added approximately 3% to the overall reconstruction (1950-2007).

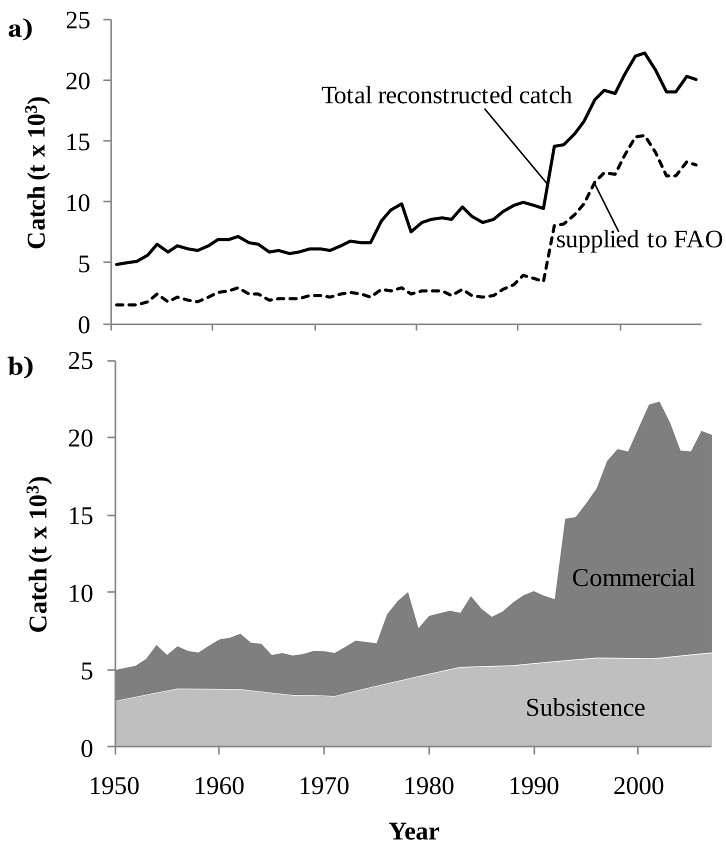

Figure 8. Total reconstructed catch for French Polynesia, 1950-2007, a) comparing reconstructed catches with landings as supplied to FAO; and b) showing reconstructed catch by fisheries sector: commercial and subsistence.

Overall reconstruction of catches for French Polynesia, including subsistence and commercial sector catches totaled approximately 595,500 t for the period 1950-2007 (Figure 8a). This catch total was twice the amount presented by FAO on behalf of French Polynesia for the same time period. Commercial and subsistence components were fairly similar in magnitude overall, representing approximately 56% and 44% (respectively) of the total reconstructed catch from 1950-2007 (Figure 8b). Subsistence catches appear to have been more prevalent than commercial catches between 1950 and the early 1990s, comprising between 44% and 62% of the total reconstructed catch. After this time, subsistence catches comprised approximately 30% of the total reconstructed catch (1992-2007), due to the offshore expansion of commercial fisheries under 'Le Pacte de Progrès'.

Table 6. Landings (t) of various taxa reported by Taiwan from the French Polynesian EEZ.

Year	Yellowfin	Albacore	Bigeye	Other
1972	402	2,192	544	272
1973	263	3,756	634	329
1974	252	2,568	377	236
1975	442	1,751	391	150

Table 7. Landings of various taxa reported by Japan from the French Polynesian EEZ, (n/a) denotes years in which no data were reported.

Year	Albacore tuna	Yellowfin tuna	Bigeye tuna	Marlins	Skipjack	Other
1972	7	154	358	n/a	6	89
1973	12	104	476	n/a	4	79
1974	33	236	1,307	n/a	7	249
1975	26	394	1,221	n/a	8	182
1979	90	807	819	n/a	n/a	229
1980	161	908	1,618	n/a	n/a	635
1981	89	370	763	n/a	n/a	196
1982	140	126	305	1	n/a	94
1984	26	221	464	n/a	n/a	158
1985	22	507	1,105	n/a	n/a	152
1986	32	n/a	n/a	n/a	n/a	n/a
1987	57	n/a	826	3	n/a	189.8
1988	142	n/a	n/a	n/a	n/a	n/a
1989	72	n/a	n/a	n/a	n/a	n/a
1990	49	n/a	n/a	n/a	n/a	n/a
1991	19	n/a	n/a	n/a	n/a	n/a
1992	3	n/a	n/a	n/a	n/a	n/a

Foreign fleets in the Polynesian EEZ:

Several foreign fleets were given access to fish in French Polynesia's EEZ during different time periods. Thus, Taiwan (1972-1975), Japan (1972-1992) and Korea (1975-1996) reported pelagic catches for the EEZ waters (Table 6, 7 and 8). After 1977, no legally permitted access has been granted to any foreign fleet, except for a non-executed access agreement with Korea in 2004 (www.seaaroundus.org).

Table 8. Landings of various taxa reported reported by Korea from the French Polynesian EEZ, (n/a) denotes years in which no data were reported.

Year	Albacore tuna	Yellowfin tuna	Bigeye tuna	Skipjack tuna	Marlins	Other
1975	85	555	1,778	6	n/a	116
1980	n/a	n/a	n/a	320	n/a	n/a
1981	n/a	466	491	n/a	n/a	596
1982	n/a	385	358	n/a	n/a	387
1983	685	314	291	n/a	n/a	338
1984	522	513	358	n/a	n/a	197
1985	1,176	737	826	n/a	n/a	357
1986	739	908	1,089	n/a	33	294
1987	935	n/a	n/a	n/a	n/a	n/a
1988	730	n/a	2,790	n/a	n/a	n/a
1989	627	n/a	1,004	n/a	n/a	n/a
1990	817	n/a	1,825	n/a	n/a	n/a
1991	515	n/a	3,213	n/a	n/a	n/a
1992	227	n/a	1,110	n/a	n/a	n/a
1993	n/a	n/a	750	n/a	n/a	645
1994	n/a	n/a	1,231	n/a	n/a	899
1995	n/a	n/a	1,321	n/a	n/a	702
1996	n/a	n/a	1,842	n/a	n/a	1,190

Discussion

Our catch reconstruction totaled approximately 595,500 t for the period from 1950-2007, which is two times larger than total reported landings of approximately 286,000 t as supplied to FAO. In our reconstruction, approximately 259,000 t of subsistence catches and approximately 51,000 t of commercial catches were added to the commercial landings presented by FAO. Additions of commercial catches were sourced from the literature. Reporting only commercial catches will have consequences for the management of fisheries resources. In the case of French Polynesia, a group of remote and isolated islands, the consequences are significant. The importance of subsistence fishing to remote populations is substantial and presents a likely food security issue. Dependence on such resources for sustenance has obviously decreased throughout the years, with increased transport of goods and pre-processed food between areas, however, subsistence fishing is still evident on the islands immediately surrounding the capital city, Papeete, and thus, must still be quite prevalent on the more remote islands (as was evident in catch rates described by Caillart *et al.* [1994]). As shown by estimates in this study, subsistence fishing can account for at least half of the total fisheries catches for a country, and thus, can comprise significant tonnage. Thus, marine resources are far more important for fundamental food security purposes in French Polynesia than the official data would suggest.

Many places in French Polynesia have already been observed to be showing signs of heavy exploitation (Yonger, 2002), and different environments likely warrant different management strategies. The subsistence catch reconstruction in this report was a first attempt to identify catches from particular island groups in French Polynesia. In addition, factoring in some estimate of unauthorized sales for populations living on remote islands would likely be very appropriate, since only one major fish market exists. Such sales are likely to be occurring on all islands in French Polynesia, and the estimate of 15% by Chauvet and Galzin (1996) may be an underestimate.

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RECONSTRUCTION OF TOTAL MARINE FISHERIES CATCHES FOR NEW CALEDONIA (1950-2007)[1]

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ABSTRACT

Our reconstruction of total marine fisheries catches by New Caledonia for the 1950-2007 time period included estimates of commercial, subsistence and recreational fisheries. Commercial fisheries catches were obtained from the FAO and from government reports to which we added estimates of catches from the subsistence and recreational sectors. Catches of sea cucumber deemed for export as 'bêche-de-mer' were assessed separately but included in our reconstruction. Subsistence catches were, in part, based on per capita consumption rates and estimated separately for each of the three provinces of New Caledonia. Total reconstructed catches were estimated to be approximately 393,673 t, which is 3.5 times larger than the total catches presented by the FAO on behalf of New Caledonia. Almost half of this total was catches by the subsistence sector. This report illustrates the importance of the non-market economy in the fisheries of New Caledonia and highlights the need for more comprehensive accounting of marine fisheries catches that includes all fisheries sectors.

INTRODUCTION

New Caledonia is located in the southwestern Pacific around 21°30'S, 165°30'E (Figure 1). The main island, 'La Grande Terre', and three smaller islands, make up approximately 18,000 km² of land area (Figure 1), with a total population of approximately 244,000 in 2008. The islands are divided into three provinces including the North Province, South Province and the Loyalty Islands Province (Figure 1). The Exclusive Economic Zone (EEZ) is approximately 1.7 million km², and is host to commercial, subsistence and recreational fishing.

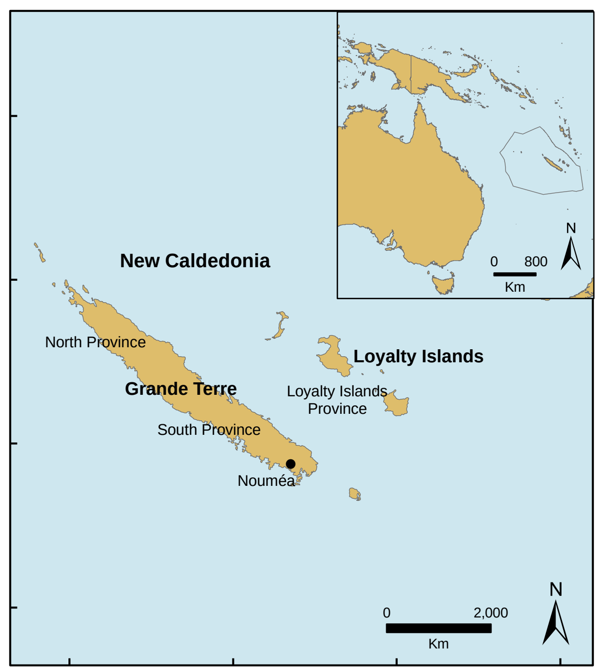

Figure 1. Map of New Caledonia showing the main island of Grande-Terre and smaller, Loyalty Islands. Inset map showing the Country's EEZ and location within the South Pacific.

Commercial fisheries are defined here as those consisting of fish marketed locally or exported abroad. Commercial fisheries in New Caledonia target the Carangidae, Scombridae and Serranidae families. Some of these commercial catches are sold at the local markets (Loubens, 1978); however high-valued species such as tuna and dried sea cucumber ('bêche-de-mer') are exported. Commercial fisheries in New Caledonia, including the bêche-de-mer fishery, could be considered artisanal fisheries as the majority are small-scale (Labrosse *et al.*,

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2000a). The exception to this is the offshore tuna fisheries, which operate on a larger scale.

Offshore fisheries for tuna began in the 1960s with exploitation by foreign fleets from Asia (Anon., 1985; Virly, 1996) and starting in the 1980s by a domestic New Caledonian fleet. Since the establishment of their EEZ in 1979, access agreements have allowed foreign fleets to fish in New Caledonia's waters. Japan was the first to formalize an access agreement with New Caledonia in 1979, followed by Taiwan in 1980 and then the USA and Korea in 1991 (W. Swartz, pers. comm., UBC Fisheries Centre). A small New Caledonian fleet started fishing offshore around 1980 (Virly, 1996).

Subsistence fishing plays an important role in Pacific Island countries, often dominating the coastal fisheries sectors (Bell *et al.*; Labrosse *et al.*, 2006). On average, only about 20% of fishes and invertebrates taken from Pacific Island reef systems enter the market economy (Adams *et al.*, 1996). In New Caledonia, the majority of fishing is small-scale (subsistence and artisanal), and occurs mostly in reef and lagoon waters where a high diversity of fishes, mollusks and crustaceans have sustained thousands of years of exploitation. In these coastal waters, the majority of catches are taken by fishers on foot or in canoes, with spears, hand-lines, nets and a variety of trap types. Here we define subsistence fisheries as those used primarily for home consumption or those which are bartered locally, but never sold on the market or exported.

Recreational fishing in New Caledonia likely started in the mid 1960s at the same time as the artisanal fishery for skipjack started (Anon., 1985). The artisanal fishery uses small Tahitian-style boats targeting skipjack using pole-and-line (Anon., 1985). New Caledonia's recreational fishing fleet has over 11,000 registered vessels and fish using mainly hand-lines and spears (Dalzell *et al.*, 1996).

The purpose of this study was to estimate total marine fisheries catches in New Caledonia between 1950 and 2007, accounting for all fisheries sectors. FAO FishStat (Anon., 2009) offers time series data on marine fisheries landings from 1950 to 2007. FAO data have been the basis of many influential fisheries studies (e.g. Pauly *et al.*, 1998), however FAO do not seek to quantify or distinguish between fisheries sub-sectors (i.e., commercial vs. subsistence). Although several studies and reports relating to the fishing industry in New Caledonia have been published (Loubens, 1978; Hallier and Kulbicki, 1985; Palladin *et al.*, 1988; Blanchet, 1991; Dalzell *et al.*, 1996; Leblic, 1999), there have been no comprehensive reviews of all fisheries sub-sectors. Our aim in this report is to estimate total marine fisheries catches by accounting for fisheries sectors other than simply commercial and thereby provide a more comprehensive assessment of fisheries removals by New Caledonia.

MATERIALS AND METHODS

Fisheries data were obtained from the FAO FishStat database, from Government reports and from independent studies. Anchor points for commercial, subsistence and recreational catches for the 1950-2007 time period were obtained and linear interpolations were made between anchor points to derive a complete time series of catches for each sector. All catches taken by New Caledonian fishers were assumed to have been taken from within New Caledonia's EEZ in FAO Statistical Area 71.

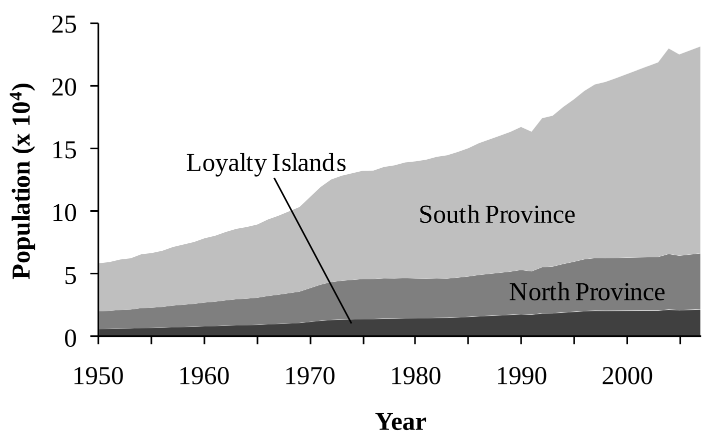

Figure 2. Human population of New Caledonia by province, 1950-2007.

Human population data

Human population data were used to determine per capita rates for recreational catches and for converting per capita subsistence rates into catch amounts. We obtained census data from an online population statistics database (www.populstat.info; Accessed September 2009) for New Caledonia as a whole and for each of the three Provinces of New Caledonia (North Province, South Province and Loyalty Islands Province). In years when census data were not available, a linear interpolation was done to estimate the population for intervening years in order to derive a complete time series of population data from 1950-2007 (Figure 2).

Commercial Fisheries

FAO data were used as the best estimate of commercial fisheries catches throughout the time period except in years when data from independent sources were available and provided a more comprehensive estimate. FAO catch statistics include sea cucumber catches which are almost entirely exported as bêche-de-mer. In this report we have dealt with the bêche-de-mer fishery separately (see 'Bêche-de-mer' section); therefore, sea cucumber catches were excluded here from the commercial fisheries catch estimates but were included in our overall assessment and comparisons.

Table 1. Taxonomic breakdown of commercial catches presented by Loubens (1978) for New Caledonia in 1975.

Common name	Taxon name	Proportion of catch (%)
Barracudas	Sphyraenidae	0.3
Blackbarred halfbeak	*Hemiramphus far*	0.5
Bluespine unicornfish	*Naso unicornis*	3.9
Bluespot mullet & Bluetail mullet	*Valamugil* spp.	9.4
Giant clam	*Tridacna gigas*	0.7
Golden-lined spinefoot	*Siganus lineatus*	2.9
Groupers	Serranidae	11.0
Indian mackerel	*Rastrelliger kanagurta*	3.2
Jacks & Trevallies	Carangidae	1.1
Japanese large-eye bream	*Gymnocranius euanus*	1.7
Leopard coralgrouper	*Plectropomus leopardus*	5.3
Mangrove crab	*Goniopsis cruentata*	3.2
Misc. cephalopods	Cephalopoda	0.6
Mojarras	Gerreidae	0.4
Narrow-barred spanish mackerel	*Scomberomorus commerson*	3.2
Emperors	Lethrinidae	0.8
Other fish species	Misc. marine fishes	5.3
Other mollusc & crustacean spp	Misc. marine invertebrates	1.0
Other mullet species	Mugilidae	1.1
Parrotfishes	Scaridae	1.1
Silver grunt	*Pomadasys hasta*	0.3
Sky emperor	*Lethrinus mahsena*	5.7
Slender emperor	*Lethrinus variegatus*	1.7
Snappers	Lutjanidae	5.4
Spangled emperor	*Lethrinus nebulosus*	24.3
Trumpet emperor	*Lethrinus miniatus*	3.9
Wrasses	Labridae	1.0
Yellowfin tuna	*Thunnus albacares*	0.7

Commercial catch data for the 1976-1986 period were obtained from a report by Palladin *et al.* (1988). The data from Palladin *et al.* (1988) were similar to catches presented by the FAO but were used in place of FAO catches from 1981 to 1986 for all species except tunas. While Palladin *et al.* (1988) present tuna catch totals that are almost identical to FAO tuna totals, the FAO data present these catches by taxa, therefore we used the FAO data. A report by Hallier and Kulbicki (1985) presented Skipjack catches for 1981-1983, which were almost identical to those presented by the FAO. A report by Dalzell *et al.* (1996) presented commercial catches for New Caledonia's coastal, reef and deep-slope, pelagic and invertebrate fisheries for 1993. While this report was detailed in its spatial description of fisheries sectors, the totals presented were thought to include recreational catches. Therefore, we used the data as supplied to FAO to represent commercial catches for 1993.

Offshore fishing for tuna by foreign fleets started in New Caledonia in the 1960s when Japanese fleets began exploiting tuna stocks in and around New Caledonia. New Caledonian longliners began offshore operations two decades later, starting around 1980. A report by the South Pacific Commission (Virly, 1996) describes catches by the New Caledonian longline fleet as occurring almost entirely within the country's EEZ, therefore Tuna catches presented by the FAO were assumed to have been taken within New Caledonia's waters.

To improve the taxonomic breakdown of the commercial sector data, we applied Loubens (1978) detailed taxonomic composition of commercial catches from 1975 to the 'miscellaneous marine fishes' category as well as a species breakdown for the Mackerel and Mullet groupings, in all years when catches were reported for these categories (Table 1). For comparison of pelagic and non-pelagic catches, we grouped Albacore, Barracudas, Bigeye tuna, 'Mackerels, tunas and bonitos', 'Marlins, sailfishes, etc nei', Narrow-barred spanish mackerel, Shortfin mako, Skipjack tuna, 'Tuna-like fishes nei' and Yellowfin tuna as Pelagics and the remaining taxa as non-pelagics.

Bêche-de-mer Fishery

An export industry for bêche-de-mer has existed in New Caledonia since the mid-1800s (Conand, 19861991). The beche-de-mer fishery fluctuated substantially over the years, partly due to political and/or economic events such as the 1920s boom and WWII (Conand, 1991). The industry nearly vanished after WWII and was only re-established in the late 1970s or early 1980s. Reports of sea cucumber catches begin to appear in the FAO fisheries statistics in 1977. The report by Conand (1991) show that exports of bêche-de-mer were minimal between 1950 and 1980, after which large exports of over 1000 t (live weight) were reported. At this time 'bêche-de-mer' was one of the main fisheries export products. The processing of sea cucumber for export involves a smoking and drying process, which reduces the body weight by approximately 90% (Conand, 1991; Dalzell *et al.*, 1996). Using a conversion factor of ten, we converted the Dalzell *et al.*, (1996) estimate of 77 t (dry weight) for 1993 to a live weight. The resulting amount was the same as the amount presented in the FAO catches statistics for that year. The FAO data provided the most complete time series of sea cucumber catches, therefore these data were used for all years from 1977-2007.

Subsistence Fisheries

To estimate subsistence catches for New Caledonia we used separate subsistence catch rates for each of the three Provinces--North Province, South Province and Loyalty Islands Province. These rates were, in part, based on the ethnic composition of the area. Consumption rates were presented by Loubens (1978) for people of Melanesian and Polynesian heritage (50 kg·person^{-1}·year^{-1}) and for people of European heritage (35 kg·person^{-1}·year^{-1}). A study by Labrosse *et al.* (2000b) presented subsistence catch rates for all three provinces for 1991.

Loyalty Islands Province: The consumption rate of 50kg·person^{-1} was used as the 1950 subsistence catch rate for the Loyalty Islands Province as the population was and continues to be predominantly (97% in 1996; Anon., 1996) composed of Melanesians. We also assumed that seafood consumption in the Loyalty Islands at this time would have been almost entirely met through subsistence fishing.

South Province: Residents of the South Province were dominated by Europeans settling in and around the capital city, Noumea. We assumed a subsistence catch rate in 1950 of 35 kg·person^{-1}, which was the catch rate given by Loubens (1978) for people of European heritage. A linear interpolation was done between the 1950 anchor point and the 1991 rate given by Labrosse *et al.* (2000b).

North Province: For the North Province, the 1991 rate given by Labrosse *et al.* (2000b) for the Islands Province was used as the 1950 anchor point as the North province also has a populations of predominantly Melanesians (78% in 1996 (Anon., 2001)) but may have had greater access to commercial catches landed at markets in the South Province.

For all three provinces a linear interpolation was done between the 1950 and 1991 anchor points and the 1991 rate was carried forward unaltered to 2007. The subsistence catch rates by province were then applied to the population of each province and summed to derive an estimate of total subsistence catches for New Caledonia from 1950-2007. The taxonomic breakdown of subsistence catches was derived using the species composition of commercial catches given by Loubens (1978; Table 1), excluding large pelagics (i.e. Yellowfin tuna). We assumed that species caught commercially for the local market would also have been caught by the subsistence sector to meet local consumption demands in areas where there was limited access to the marketplace.

Recreational Fisheries

Catches were presented by Loubens (1978) for 'la pêche plaisancière' in 1975, which included estimates for both subsistence and recreational sectors. Recreational catches were estimated using the number of registered boats that fished occasionally (3000 boats in 1975) and a catch rate of 0.6 t·boat^{-1}·year^{-1}. This was used as the 1975 anchor point. Commercial catches presented in Dalzell *et al.* (1996) assumed to include recreational catches amongst the totals for reef, deep-slope, coastal and/or pelagic fisheries. To derive the recreational catch for 1993, we subtracted the commercial catches (FAO catches) from the total presented by Dalzell *et al.* (1996). We assumed that recreational fishing started in 1965, around the same time as the artisanal fishery for skipjack (Anon., 1985). Recreational catches were, therefore, set at zero in 1964.

The two anchor points for recreational catches (1975 and 1993) were converted to per capita catch rates using population data obtained from Populstat (www.populstat.info/). Linear interpolations were done from zero in 1965 to the first available anchor point in 1975 and between the 1975 and 1993 anchor points. The 1993 rate was carried forward, unaltered, to 2007. The complete time series of per capita recreational catch rates was then applied to the population of New Caledonia to derive recreational catch amounts from 1965-2007.

According to Dalzell *et al.* (1996), a large proportion of nearshore pelagics are taken by recreational fishers. Therefore, we applied the breakdown of nearshore pelagics presented in Dalzell *et al.* (1996) to 70% of our recreational catch estimates across the entire time period considered. Dalzell *et al.* (1996) describes that in New Caledonia 80% of the catches made by trolling along the coastal margins in the early 1990s are from the Scombridae family (Mackerels, bonitos, and tunas) followed by the Sphyraenidae (Barracudas) which make up 10% of the catch (Dalzell *et al.*, 1996). Catches of coastal pelagic species are dominated by Spanish mackerel (*Scomberomorus commerson*), Wahoo (*Acanthocybium solandri*), Kawakawa (*Euthynnus affinis*) and Yellowfin tuna (*Thunnus albacores*). We assumed that the remaining 30% of recreational catches were coral reef and lagoon species. The taxonomic breakdown for this portion of the recreational catch was estimated to be 10% each from the Serranidae, Lutjanidae and Lethrinidae families

RESULTS

Commercial Fisheries

Commercial fisheries sector catches, excluding the bêche-de-mer fishery, were estimated to be 84,760 t over the 1950-2007 time period (Figure 3a). Almost half of the commercial catches were pelagic species from the Serranidae and Scombridae families (Tunas, Mackerels and Groupers). Catches of reef-fish of the Lethrinidae family (Emperors and scavengers) were also substantial, contributing approximately 11,230 t to the commercial catch from 1950-2007. Pelagic and non-pelagic species catches

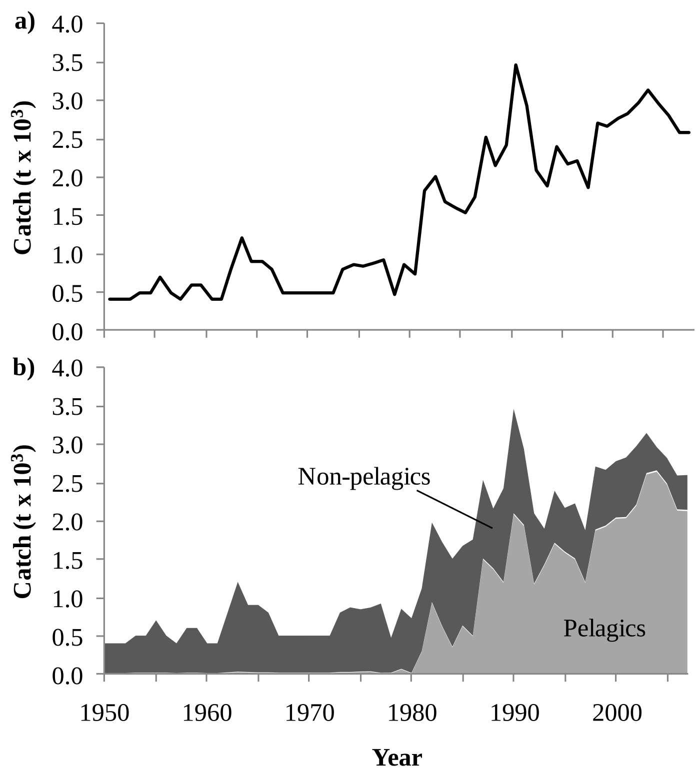

Figure 3. a) Commercial catches, excluding bêche-de-mer, by New Caledonia over the 1950-2007 time period. b) Commercial catches (excluding bêche-de-mer) divided into Pelagic and non-Pelagic species (see text for details).

were roughly equal when summed over the entire study period, however, Pelagic species have dominated the catch in recent decades (Figure 3b).

Bêche-de-mer Fishery

Catches of sea cucumber for export as bêche-de-mer totaled approximately 28,800 t over the period 1977-2007 (Figure 4). Catches fluctuated substantially from year to year, ranging between 42 t·year^{-1} and 2,500 t·year^{-1}. Due to the large annual fluctuations exhibited here, we consider this to be a 'pulse' fishery. Catches were highest during the mid-1980s to mid-1990s, averaging 1,500 t·year^{-1}. Since the mid-1990s catches have been around 600 t·year^{-1}.

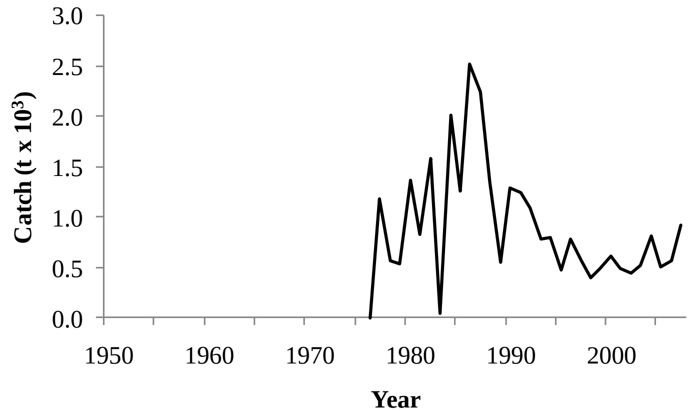

Figure 4. Bêche-de-mer catches (live weight) in New Caledonia, 1950-2007.

Subsistence Fisheries

Subsistence catches were estimated to be over 180, 000 t over the 1950-2007 time period. Subsistence catches were estimated using province-specific subsistence catch rates, which gave catch totals for the North, South and Loyalty Islands provinces (Figure 5). Subsistence catches were approximately 2,000 t·year^{-1} in 1950, increasing to about 3,400 t·year^{-1} by 1975, and then were estimated to be just over 4,000 t·year^{-1} by 2007.

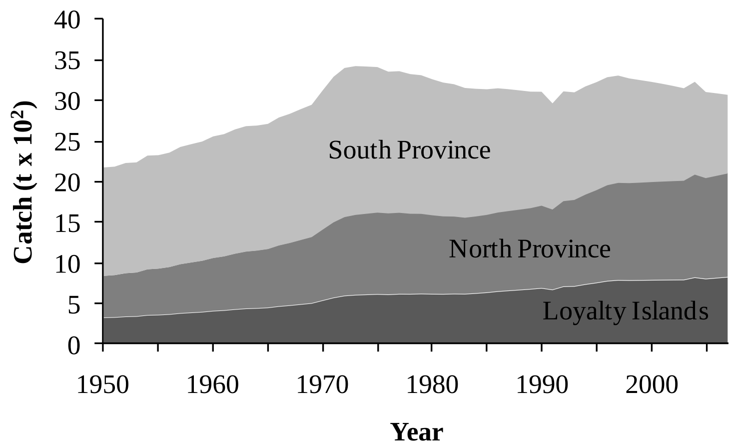

Figure 5. New Caledonia's subsistence catches estimated for the 1950-2007 time period.

Recreational Fisheries

Catches by the recreational sector totaled just over 100,000 t from 1965-2007 (Figure 6). We assumed that the recreational sector started in the mid-1960s, therefore catches were estimated to be zero from 1950-1964. The main species caught in the recreational sector were from the Scombridae family.

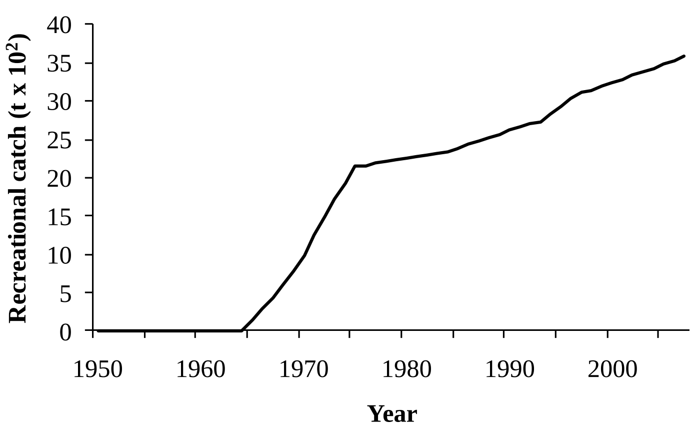

Figure 6. Recreational fishery catches by New Caledonia, 1950-2007.

Total reconstructed catch

Our reconstruction of total marine fisheries catches for New Caledonia from 1950-2007 was estimated to be 393,673 t (Figure 7). This total included estimates of commercial, subsistence and recreational catches, which together were 3.5 times larger than the total presented by the FAO on behalf of New Caledonia (Figure 8). We assumed that catch data supplied to FAO represented only catches from the commercial fisheries sector. The reconstructed catch for 1950 was estimated to be approximately 2,500 t·year^{-1}, increasing steadily to 10,000 t·year^{-1} by the late 1980s and remaining around this level throughout rest of the study period, with only minor year to year fluctuations.

DISCUSSION

Total reconstructed catches of New Caledonia's marine fisheries from 1950-2007 were estimated to be approximately 393,673 t. This catch total is 3.5 times larger than total catches presented by the FAO on behalf of New Caledonia. Total catches, as supplied to FAO, were approximately 110,000 t over the 1950-2007 time period, and represented commercial catches only. Our estimates of subsistence and recreational fisheries sectors together added almost 200,000 t to the total.

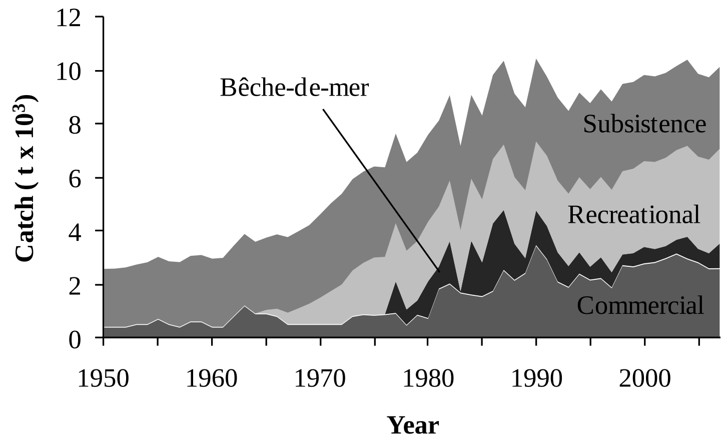

Figure 7. Reconstructed catch (commercial, recreational and subsistence catches) and FAO catch taken in FAO statistical area 71 over the time period 1950-2007.

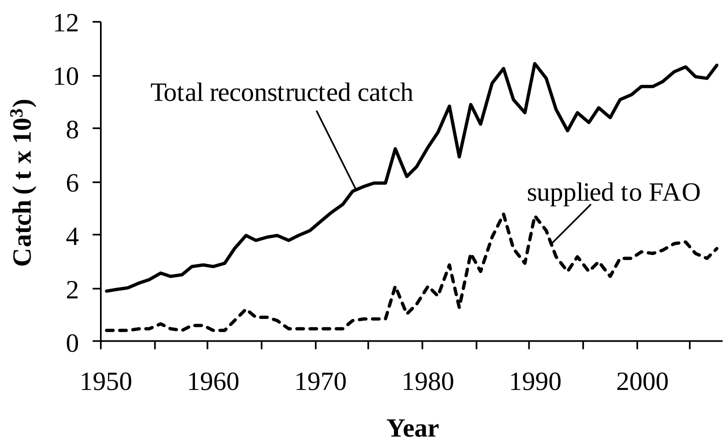

Figure 8. Total reconstructed catch for New Caledonia and total catches presented by the FAO, 1950-2007.

Commercial catches for New Caledonia were well documented between 1976 and 1986 by Palladin *et al.* (1988) and Hallier and Kulbicki (1985) and in 1993 by Dalzell *et al.* (1996). Independent reports of commercial catches prior to 1976 and for the recent period (1990s and 2000s) were not readily available. In years when we had data from both the FAO and from independent reports, catches were found to be similar in magnitude, giving confidence in our use of the data supplied to FAO as the best estimate of commercial catches in years when no other data were available. While independent reports were available for the commercial fisheries sector, there was a considerable deficiency in data for the subsistence and recreational sectors. These sectors were largely unaccounted for in government reports and by independent studies. Subsistence fisheries are a dominant factor in New Caledonia's coastal marine resource exploitation, yet very little data exist documenting yields or landings (Dalzell *et al.*, 1996).

In our estimation of New Caledonia's marine fisheries, subsistence catches were consistently higher than commercial catches, underlining the importance of the non-market economy in the fisheries of this country. The lack of studies concerning subsistence fisheries required us to estimate subsistence catches based on assumptions about consumption rates and the amount of this that was supplied through subsistence fisheries. Subsistence catch amounts for 1975 and 1993 were reported by Loubens (1978) and Dalzell *et al.* (1996), respectively. Catch amounts presented in these studies were also estimated and were similar to our estimates for the same years.

The per capita subsistence catch rate averaged over all three provinces varied from 37 kg·person^{-1}·year^{-1} in 1950 and 17 kg·person^{-1}·year^{-1} in 2007. Based on the data presented by Labrosse *et al.* (2000b), subsistence catch rates varied substantially by province with the Loyalty Islands (Islands Province) having the highest per capita subsistence catch rate. This high per capita rate likely reflects a lower dependence on commercial catches due to limited access to the markets where commercial catches are sold (i.e. the

Noumea market in the South Province. The decrease in subsistence catch rates observed over the study period may reflect the increase in industrialized fishing fleets and improved infrastructure for the distribution and storage of seafood products that occurred over the past forty years (Adams and Dalzell, 1994).

The domestic offshore fishery developed more recently than the coastal fisheries and is much less developed than the distant water fleets (Japanese, American, Korean and Taiwanese) targeting offshore species. The increase in catches of pelagic species by New Caledonia since the late 1980s was due to the development of a domestic fishery for deep-slope and offshore species, encouraged by assistance from the French government (Palladin *et al.*, 1988; Blanchet, 1991; Labrosse *et al.*, 2000a). The majority of tuna caught by this fishery are exported and rarely enter into the local seafood supply (Anon., 1985; Palladin *et al.*, 1988).

Despite the expansion of offshore fisheries, the primary supply of local seafood remains from the lagoon and reef fisheries that operate informally or on a small-scale (i.e. subsistence and artisanal fisheries). The reef and lagoon systems of New Caledonia are still described as intact ecosystems, with healthy populations of large predators and other fish. Many threatened species including turtles, whales and dugongs seek refuge in New Caledonian waters, some of which are protected as a World Heritage Site (UNESCO, 2009). However, coastal development, agriculture and logging are placing increasing pressure on these productive reef and lagoon systems that provide food to much of the population (Adams *et al.*, 1996; Labrosse *et al.*, 2000a). The importance of maintaining these relatively intact ecosystems is inextricably linked to the food security of the people of New Caledonia who depend on local access to seafood as their main source of protein. Better accounting of fisheries removals by the subsistence sector is urgently needed in order to highlight the importance of this fishery sector and in turn sustain food supplies over the long term. The people of New Caledonia are heavily reliant on seafood for their way of life, maintaining the system that provides this valuable commodity is imperative. Proper accounting in fisheries is fundamental to this process and currently New Caledonia documents less than a third of what is being removed from its water's.

Acknowledgments

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HISTORICAL PERSPECTIVE OF SABAH'S MARINE FISHERIES[1]

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ABSTRACT

This study reconstructs the marine fisheries catches for the Malaysian state of Sabah from 1950-2006. Sabah's fisheries are exploited by a commercial and small-scale sector. Although landings statistics of both sectors are recorded annually, it is recognized that small-scale fisheries landings are underestimated due to a large number of unlicensed local and migrant fishers. The presence of unlicensed trawl vessels indicates that reported commercial landings are also likely underestimated. Our reconstruction indicates that from 1950-2006, Sabah's marine catches were 2.5 times higher than landings reported in the official statistics. We find that trawler discards totaled over 970,000 million tonnes from 1965-1990, which was around 95% of the quantity of marine landings recorded for this period. Further, in the past decade, the number of small-scale fishers may have been on average 3 times higher than the number recorded in the annual fisheries statistics, resulting in a level of fishing pressure which far exceeds that which is currently perceived. Finding ways to address this unreported fishing effort is therefore a priority for the government, especially since Sabah's small-scale fisheries focus on coral reefs, which have already been extensively damaged throughout Sabah. Overall, our findings suggest the need for a better understanding about the level of fisheries exploitation in Sabah, and by extension, likely in all of Malaysia.

INTRODUCTION

Marine fisheries play an important role in Malaysia for their contribution to food security, foreign exchange through exports, and job creation (Gopinath and Puvanesuri, 2006). Sabah is the second highest producer of marine fish landings in Malaysia, contributing an average of 15% of the country's annual marine landings from 2000-2006. The Sabah Fisheries Department reports annual statistics of marine landings, number of licensed fishing boats, gears, and fishers. However, it is recognized that marine landings and the number of fishers are underestimated (Mohammad Ariff, 1999; Biusing, 2001). The effect of this is felt particularly in the small-scale traditional sector, due to the widespread and scattered nature of these fisheries. In other countries, failure to account for small-scale fisheries have led to a substantial underestimation of fisheries catches (Zeller *et al.*, 2006). Further, unlicensed commercial fishing effort may be exerting additional pressure on already stressed fisheries resources. Our objective is thus to reconstruct Sabah's total marine catches

Figure 1. Map of Borneo, showing Sabah and Sarawak. Parts of Peninsular Malaysia are shown on the left.

[1] Cite as: Teh, L. S., Teh, L. C., Zeller, D. and Cabanban, A. (2009) Historical perspective of Sabah's marine fisheries. pp. 77-98. *In*: Zeller, D. and Harper, S. (eds.) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports 17 (5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

for the years 1950-2006 to present a more complete estimate of the quantity of fisheries resources taken from Sabah waters.

Sabah's marine fisheries

Sabah is a state of Malaysia, situated on the northeast corner of Borneo (Figure 1). The state polices the territorial waters extending up to twelve nautical miles, while the federal government has jurisdiction over an Exclusive Economic Zone (EEZ), measured as either 200 nautical miles (nm) from shore or the mid-line between neighboring countries' landmasses. Sabah is bordered by the South China Sea in the west, the Sulu Sea to the north-east, and the Sulawesi Sea to the south-east (Figure 1). Mangroves and mudflats fringe the coastal zone, and many outlying islands are scattered offshore. Coral reefs are present in shallow waters throughout the state's coast, and are heavily exploited by Sabah's substantial population of subsistence and artisanal fishers.

Sabah's marine capture fisheries are exploited by the commercial and small-scale sectors, which accounted for approximately 65% and 35% of annual total fisheries landings in 2004, respectively. The term 'traditional' is used by the Sabah Fisheries Department to refer to small-scale fisheries, and we use both terms synonymously in this study. Marine landings consist of pelagic and demersal species. In 2006, recorded landings were approximately split evenly between pelagic and demersal fishes. Demersal landings were made up of finfish (75%), invertebrates (15%), and shrimp (10%). The Sabah Fisheries Department classifies trawlers and purse seines as commercial gears, of which trawlers are the dominant gear. Traditional gears include hook and line, which accounts for the highest traditional fish landings, gillnets, lift nets, bag nets, push scoop nets, traps, and shellfish collection.

The majority of Sabah's capture fisheries occurs within approximately 30 km (16.2 nautical miles) from the coast, as there are few vessels in Sabah larger than 70 GRT that are capable of deep sea fishing (Biusing, 2001). A spatial zoning system defines the boundaries where different types of fishing vessels are allowed to fish. Zone A, the traditional fishing zone, extends from shore out to 5 nautical miles, and is open only to traditional fishing vessels. Commercial vessels less than 40 GRT are allowed in zone B (5-12 nautical miles from shore), while zone C (12-30 nautical miles) is open to all vessels less than 70 GRT.

According to official statistics, there were 20,845 licensed fishers in Sabah in 2006 (Anon., 2006); however, this is considered to be an underestimate due to a large number of unlicensed and migrant fishers (Biusing, 2001). Local small-scale fishers are mainly of Bajau ethnicity, while the large population of migrant fishers, many of whom reside illegally in Sabah, originate from the southern Philippines and Indonesia. Some of this group are of Bajau background and are employed as crew on large commercial fishing vessels or are engaged in traditional fishing. The number of fishers in Sabah increased rapidly in the mid 1970s to 1980s as refugees fleeing political instability in southern Philippines settled along coastal areas or outer islands of Sabah, and turned to fishing for a livelihood. To the present day, illegal entrants continue to filter into Sabah and live in relative poverty in overcrowded water villages, a situation which has given rise to societal discontent as they have been accused of carrying out crime, dynamite fishing, and stressing coastal resources (Pilcher and Cabanban, 2000; Anon., 2008a).

Overall, due to its social and political context, Sabah's traditional fisheries sector faces the marginalization commonly experienced by small-scale fisheries in the region (Pauly, 1997). Nonetheless, these fisheries provide the main source of income and meat protein for a large proportion of Sabah's rural coastal communities (Fisher, 2000; IPMB, 2003; Teh *et al.*, 2005; Foo *et al.*, 2006), and reinforce the critical role small-scale fisheries play in supporting the food and livelihood needs of coastal communities throughout Southeast Asia (McManus, 1997; Burke *et al.*, 2002; Loper *et al.*, 2008). The importance of inshore fisheries to Sabah's coastal populations is even greater considering that Sabah is one of the poorest states in Malaysia (Leete, 2008).

Marine fisheries in Malaysia are regulated by the Fisheries Act of 1985, which makes provision for the management, development, and conservation of fisheries resources. Federal development strategies, including those for fisheries, are announced every five years. Under the 9th Malaysia Plan for 2006-2011, poverty eradication among fishers in Sabah was earmarked as a priority program. Some government program aimed at alleviating poverty include diesel fuel subsidies for fishers, grants for setting up seaweed and aquaculture operations, and agriculture development schemes (Anon., 2008b; 2009; Anon., 2008c).

The Sabah Fisheries Department is the main agency in charge of managing the state's fisheries resources. Its objectives include uplifting the socio-economic status of the fisheries community, managing fishery resources to ensure a reliable supply of fish, increasing capture production, and carrying out fisheries monitoring, research, and development (www.fishdept.sabah.gov.my/deptfunctions.asp).

Commercial fisheries

Following its beginnings in the early 1960s, the prawn trawl fishery quickly became the major commercial fishery in Sabah. Trawling was first encouraged by the British, then the Sabah government, as a means of generating export revenue amid growing international demand (Mohammad Ariff, 1999). From 12 trawlers in 1962, the fleet grew rapidly to reach over 1000 vessels in 1985 and up to 1400 registered vessels in 2006. At the same time, prawn landings in Sabah increased from 209 t in 1962 to 10,209 t in 1990, but thereafter declined significantly from 6,702 t in 1991 to 2,880 t in 1999, indicating that prawn resources had been exploited beyond their sustainable limit (Biusing, 2001).

Uses for bycatch from prawn trawlers were investigated in the late 1970s (Snell, 1978a). However, it was not until the beginning of the 1990s when so-called 'trash' fish and bycatch of juvenile or low-value fish that were previously discarded at sea by trawlers were increasingly landed for use in fishmeal processing plants (Biusing, 2001). With this ready market, some trawlers now even make special fishing trips to target 'trash' fish for fishmeal production. In 2000, there were 8 fishmeal plants in Sabah, each with an average production of about 2,500 t year^{-1} (Biusing, 2001). Several fishmeal plants have reportedly faced raw material shortages and have been turning to other countries such as Indonesia for supply (Biusing, 2001)

Seine nets (e.g., beach seines) have traditionally been used on a small-scale basis by rural fishers. The commercial purse seine fishery developed in the mid 1980s to catch tuna, anchovies, and other pelagic fish (Biusing 2001). The main purse seine fishing grounds are in deeper parts of the EEZ on the west coast of Sabah, and adjacent to Semporna waters in the east coast (Biusing 2001). Some fish processing plants reportedly operated their own purse seiners to obtain raw materials (i.e., 'trash' fish).

Small-Scale fisheries

Sabah's small-scale fisheries are concentrated in the inshore area, targeting mainly reef associated and estuarine species (Wood, 2001; Teh *et al.*, 2005). These multi-species fisheries contribute the main supply of fresh fish for local consumption in coastal villages, with a portion being transported to larger markets in the main urban centers. Certain specialized fisheries, such as those for the live reef food fish trade, bêche-de-mer, and abalone, are carried out by small-scale fishers using hook and line, traps, and diving (both free diving and hookah). The high global demand generated for these specific species has led to the rapid decline in the populations of these reef species (Daw *et al.*, 2002; Choo, 2004; Scales *et al.*, 2007). The use of destructive fishing techniques such as dynamite and cyanide is still common (Oakley *et al.*, 1999; Pilcher and Cabanban, 2000; Teh *et al.*, 2007). This has damaged and destroyed unprotected reefs throughout Sabah (Oakley *et al.*, 1999; Pilcher and Cabanban, 2000; Koh *et al.*, 2002), leading to a low abundance of commercially important fish compared to protected areas (Teh *et al.*, 2008). The magnitude of small-scale fishing is underestimated in the official statistics, as small-scale landings are not recorded in many fishing villages (Teh *et al.*, 2007)

Fisheries Statistics

The first Fisheries Department in present-day Sabah was established in 1948, with the main function of compiling fisheries statistics and performing research. During this time, surveys were carried out at the Sandakan fish market, but these data were not available to us. The Fisheries Department was closed in 1953 and re-organized as a sub-department under the Agricultural Department. Its activities were confined to freshwater fish culture, as providing additional protein to the rural population's diet was seen as a more immediate need than collecting statistical data (Anon., 1953). Following the closure of the Fisheries Department, there was no government authority responsible for marine fishing in North Borneo.

Prior to independence in 1963, British colonial reports provided data only on the quantity of exported fisheries commodities. After independence, statistics on marine fisheries landings, the registered number of vessels, fishers, and fishing gears has been compiled by the Sabah Fisheries Department. Before 1991, marine fish landings statistics were estimated from fish market surveys, trawler logbooks, fish processing plant reports, and export data. An improved system was introduced in 1991, which used a stratified random sampling approach to estimate landings of selected fishing gears in Sabah's 16 coastal districts (Biusing, 2001). Sampling occurs at the largest landing sites in each fishing district (between1 to 3 sites are selected). Landings from these sites are then extrapolated to account for all other landing sites in the district (E. Jinuat pers. comm.)[2]. However, this has resulted in the underestimation of small-scale landings (Teh *et al.*, 2007). The presence of unlicensed trawlers (Snell, 1978b; Manan, 2003) also indicates that commercial landings are likely underestimated. Furthermore, the official figures for the number of licensed fishers and vessels have not been updated since 1998, due to the lack of funding to carry out the necessary surveys (E. Jinuat, pers comm.)[2].

History of marine resource use in Sabah

Maritime culture and trade are an important part of the region's history. Archaeological findings suggest that coastal dwellers were already present and living off the resources of nearshore and ocean environments in the south-eastern district of Semporna some 3,000 years ago (Sather, 1997). By the thirteenth century, there was a thriving maritime trade network that linked China and insular South-East Asia (Tregonning, 1965).

North Borneo was part of the powerful Sulu Sultanate, and marine resources from here were collected and delivered back to Jolo, the seat of the Sulu Empire (Tregonning, 1965; Warren, 1971). The Bajau people were the main collectors of marine resources (Tregonning, 1965; Warren, 1971). These included fresh and dried fish which were traded in markets (Evans, 1915), as well as high value commodities such as bêche-de-mer, shark fins, mother-of-pearl, tortoise shells, and turtle eggs (Tregonning, 1965; Warren, 1971). Being semi-nomadic sea people, the Bajau moved freely and frequently between the waters of Sabah and the southern Philippines in multi-day fishing trips to harvest marine resources, returning to their home moorages to sell or barter their catch (Warren, 1971; Sather, 1984, 1985, 1997). Today, the sea Bajau remain the most marine oriented ethnic group in Sabah.

Present-day Sabah was ceded to the British North Borneo Chartered Company in 1881. The era under Company rule was marked by agricultural land development and expansion, whereas fisheries were viewed only as a source of protein supply for the population, and little was invested in its development (Mohammad Ariff, 1999).

Early British administrators introduced a boat licensing system to monitor the semi-nomadic fishing population (Sather, 1997). They also encouraged fishers to adopt a settled lifestyle as plantation workers. Thus, the British influenced a transition towards an increasingly monetized economy, and drew many traditionally nomadic, sea-oriented people towards a settled lifestyle on land. The emphasis on land development led to the arrival of migrant workers, and the demand for fish as a protein source started to increase.

Gradually, a corresponding shift in the composition of Sabah's marine resource trade occurred. Bêche-de-mer, mother of pearl and turtle shells, although still important, did not have the importance they had under Sulu rule. Instead, attention was now centered on domestic demand for fish to feed a growing local population which was being driven by an influx of plantation laborers. From 1942 to 1945, North Borneo was occupied by Japanese military forces. Economic activity was disrupted as coastal residents retreated inland or, in the case of the Bajau, returned to fishing from the security of small islands in order to avoid Japanese rule along the coast (Mohammad Ariff, 1999). With the defeat of Japan in 1945, North Borneo was placed under British Military Administration, then became a British crown colony in July 1946.

[2] E. Jinuat, Fisheries Officer, Sabah Fisheries Department, Kota Kinabalu, Sabah [date received: December 2008].

Colonial rule

North Borneo's fishing industry was severely disrupted by World War II, during which many vessels and most of the fishing gear were destroyed (Anon., 1947). However, fish still remained the population's staple food after the war (Anon., 1953). The period under colonial rule was marked by technological change, such as the replacement of paddle and sails with engines. Local materials from the jungle and mangroves that were traditionally used to make fishing gear were replaced with imported, factory produced synthetic materials. By the late 1950s, mechanized fishing boats were popular throughout the coastal districts (Anon., 1958). As a result, there was also a change in fishers' spatial movement, as they were able to go further from shore and exploit new fishing grounds. However, fishing was still done primarily in inshore waters (Anon., 1958).

The fishing industry during this period was still not well organized, and the majority of fishing was subsistence based and done by independent fishers using traditional gears. Nevertheless, they were able to catch enough fish to meet local demand, as well as to export surplus to neighboring countries (Anon., 1957; Mohammad Ariff, 1999). While dried or salted fish and bêche-de-mer had been the main exports under Company rule, dried shrimp and fish formed the major export commodities under the British administration (Anon., 1956). During this period, prawn fisheries were carried out by local fishers using tidal prawn nets. Under colonial rule, a small portion of fish was exported fresh for the first time. Domestically, the old system of sea transport was replaced by roads, which along with the emergence of ice production, facilitated the movement of fresh fish to major markets in coastal towns. In urban areas, the fishing industry was primarily run by ethnic Chinese middlemen, who financed fishing gears and boats, as well as controlled fish marketing (Anon., 1955; Mohammad Ariff, 1999). In 1958, the British administration introduced experimental trawling, using a twin beam otter trawl. Widespread trawling started in 1962, marking the beginning of the modern commercial fisheries sector in Sabah (Mohammad Ariff, 1999).

Post colonial rule

In 1963 North Borneo gained independence from Britain and joined the Malaysian federation, in the process changing its name to Sabah. At this time, fishing was still carried out primarily by small-scale fishers. The new Sabah state government became involved in all aspects of the fishing industry, including production, marketing, and addressing the poverty of fishing communities (Mohammad Ariff, 1999). A series of fisheries infrastructure projects, low interest loans, and fishing boat and gear subsidy schemes were implemented (Mohammad Ariff, 1999). Furthermore, a fishers co-operative (Ko-Nelayan) was set up to help with the development of the fishing industry and looking after the interests of fishers (Abdul Mannan, 1982).

From 1963 to 2006 the population of Sabah increased nearly sixfold, increasing from 504,000 to 3 million. A key driver of Sabah's population growth has been the arrival of a large number of migrants, many of whom entered Sabah illegally, starting around the late 1960s. Coastal towns and outer islands were settled by refugees fleeing political instability in the southern Philippines during the late 1970s (Piper, 1984). In fishing villages on some islands off the town of Semporna on Sabah's east coast, up to 90% of households were non-Malaysian citizens (Piper, 1984). Migrants also formed a large portion of the commercial fishery work force (Manan, 2003).

METHODS

In this study, all fisheries statistics unless stated otherwise were extracted from the Malaysian Department of Fisheries Annual Reports (available at www.dof.gov.my/v2/perangkaan.htm). Data were available from 1965 to 2006; however, the reporting of data was not consistent throughout the years, with coarser data available in the earlier years. Note that from 1986 onwards, fisheries statistics for Labuan, an island within Sabah state waters, was reported separately from Sabah. However, in this study, reported statistics are inclusive of Labuan to make it comparable with statistics prior to 1986.

In Sabah, the presence of large numbers of unlicensed vessels and fishers has been a persistent problem for many years (Wong, 1982; Anon., 1991; Mohammad Ariff, 1999; Biusing, 2001). The catch reconstruction takes this issue into account by explicitly incorporating unlicensed vessels and fishers to estimate the catch for Sabah's commercial and traditional fishery, respectively. Due to the more organized nature of the commercial fishery, we assumed that the number of licensed vessels was a good indicator to estimate number of unlicensed vessels for reconstructing total commercial catches. On the other hand, the traditional small-scale sector lacks any formal organization. Therefore, we based the reconstruction of traditional catches on the estimated number of traditional fishers in Sabah, in order to reflect the widespread, scattered nature of the fishery.

Commercial fisheries

Prawn trawlers

Number of trawlers

Trawling was introduced to Sabah in 1958 (Anon., 1958), but only became widespread in the 1960s. The time series of reported trawl landings started in 1962, while the number of unlicensed trawlers was reported for 3 time periods (Table 1). We assumed the ratio of registered to unlicensed trawl vessels changed linearly between the three time periods, starting with zero unlicensed vessels in 1958.

Table 1. Available data sources for estimating the ratio of licensed to unlicensed trawlers in Sabah.

Year	No. registered trawlers	No. unregistered trawlers	Ratio (unregistered/registered)	Source
1976	342	573	1.58	Snell (1978b)
1979	594	206	0.35	Abdul Mannan (1982)
2003	682[a]	550[a]	0.81	Manan (2003)

[a] These numbers are based on observation at Sandakan, the major port for trawlers in Sabah. We applied this ratio to the number of licensed trawlers for the whole of Sabah.

The ratio of licensed to unlicensed trawlers from these three time periods was applied to the number of licensed trawlers reported each year to obtain estimated numbers of unlicensed vessels (Table 2). However, in 1991, a change in the statistical recording system used by the Sabah Fisheries Department led to data on licensed vessels pre- and post-1991 being incompatible (Biusing, 2001). Specifically, data recorded after 1991 showed a substantial increase due to better coverage of landing areas. As a result, the number of trawlers spiked by over 80% in 1991, increasing from 1046 vessels in 1990 to 1834 in 1991. Furthermore, it appears that the number of licensed vessels was not updated between 1998 and 2005, remaining constant at 1422 vessels for this period. To minimize these data effects, we did two sets of interpolations. First, we smoothed the number of vessels between 1985 (1054 vessels) and 1998 (1422 vessels). Then, to account for the lack of updated records, we interpolated between 1999 (1422 vessels) and 2006 (1200 vessels; Table 2). Both these modifications to the number of reported licensed vessels is presented as *v(smoothed)* in Table 2.

Catch rate for trawlers

Total catch rates (i.e., inclusive of prawns and fish) for trawlers in Sabah were available for 1962, 1976, and 1994. In 1962, an average catch rate of 35 katis hr^{-1} (21kg hr^{-1}) was reported by Mohammad Ariff (1999). In 1976, a study on bycatch in the shrimp trawl fishery was undertaken by the Sabah Fisheries Department, in which the catch from commercial trawlers was analyzed. The average catch rates recorded during the survey trips were 121.1 kg hr^{-1} during the peak fishing months, 36 kg hr^{-1} for the low fishing months, and 63 kg hr^{-1} during the medium fishing months (Snell 1978b). We used the medium catch rate for our estimate. A survey on technical efficiency of the trawl fishery in Peninsular Malaysia found that the average catch rate for a commercial trawler was 48 kg hr^{-1} in 1994 (Viswanathan *et al.*, 2000). As we could not find commercial catch rate data for Sabah in this period, we used that rate from Peninsular Malaysia to represent Sabah's catch rate in 1994. From 1962 to 1994, catch rates were assumed to increase or decrease linearly between the anchor years of 1962, 1976, and 1994. We applied a constant catch rate of 48 kg hr^{-1} from 1994 to 2006.

Table 2. Reported licensed [$v_{licensed}$], adjusted licensed [$v_{interpolate}$], and estimated unlicensed number of trawlers, as well as trawl catch rates used to estimate total catch for the trawl fishery for Sabah.

Year	No. of reported trawlers $v_{licensed}$	No. of trawlers with interpolation $v_{interpolate}$	No. of unlicensed trawlers $v_{unlicensed}$	Total estimated no. of trawlers	Catch rate ($kg \cdot hr^{-1}$)
1962	12	12	4	16	21.0[a]
1963	53	53	23	76	24.0
1964	86	86	46	132	27.0
1965	135	135	84	219	30.0
1966	152	152	108	260	33.0
1967	221	221	176	397	36.0
1968	311	311	275	586	39.0
1969	312	312	303	615	42.0
1970	294	294	312	606	45.0
1971	301	301	346	647	48.0
1972	334	334	413	747	51.0
1973	324	324	430	754	54.0
1974	359	359	508	867	57.0
1975	322	322	484	806	60.0
1976	360	360	573	933	63.0[b]
1977	525	525	618	1143	62.2
1978	536	536	408	944	61.3
1979	594	594	206	800	60.5
1980	516	516	189	705	59.7
1981	620	620	240	860	58.8
1982	444	444	181	625	58.0
1983	789	789	337	1126	57.2
1984	908	908	405	1313	56.3
1985	1054	1054	492	1546	55.5
1986	856	1082	526	1609	54.7
1987	1100	1111	562	1673	53.8
1988	972	1139	599	1738	53.0
1989	1036	1167	637	1805	52.2
1990	1046	1196	677	1872	51.3
1991	1834	1224	717	1941	50.5
1992	1578	1252	759	2011	49.7
1993	1560	1280	801	2082	48.8
1994	1419	1309	845	2154	48.0[c]
1995	1419	1337	890	2227	48.0
1996	1414	1365	936	2302	48.0
1997	1414	1394	983	2377	48.0
1998	1422	1422	1032	2454	48.0
1999	1422	1394	1039	2434	48.0
2000	1422	1367	1046	2412	48.0
2001	1422	1339	1051	2390	48.0
2002	1422	1311	1056	2367	48.0
2003	1422	1283	1033	2317	48.0
2004	1422	1256	1011	2267	48.0
2005	1422	1228	989	2216	48.0
2006	1200	1220	966	2166	48.0

Sources: [a] Mohammad Ariff (1999); [b] Snell (1978b); [c] Viswanathan *et al.* (2000)

Trawl fishing effort

An average trawl fishing effort of 1608 hrs $vessel^{-1} \cdot yr^{-1}$ was estimated based on information from Mohammad Ariff (1999) for 1962, while Snell (1978b) reported an annual effort of 1214 $hrs \cdot vessel^{-1} \cdot year^{-1}$ for 1976. The former effort value was applied to 1962, and linearly increased to 1214 $hrs \cdot vessel^{-1} \cdot year^{-1}$ in 1976. A constant effort of 1214 $hrs \cdot vessel^{-1} \cdot year^{-1}$ was applied to all years after, from 1976 to 2006.

Catch for trawl fishery 1962-2006

The total annual catch for trawlers (C_{tr}) was calculated as

$$C_{tr} = v \cdot r \cdot f$$

where v is the total number of trawl vessels (i.e., $v_{interpolate} + v_{unlicensed}$, Table 2), r the annual catch rate, and f the average annual fishing effort per vessel.

Trawler discards and bycatch

Beginning in the 1990s, co-called 'trash' fish and other trawler bycatch was increasingly landed for use in fishmeal processing plants (Biusing, 2001). This was not the case prior to 1990, which implies that from 1962 to 1990, a substantial amount of catch was discarded at sea. A breakdown of a typical trawl catch was provided in Snell's (1978b) study on bycatch in the prawn-trawl fishery (Table 3). To estimate the quantity of discarded fish from 1962-1990, we multiplied the 'unmarketable fish' percentage (64%) by the estimated annual trawl catches. Biusing (2001) reported that there is currently a shortage of 'trash' fish for fishmeal production; thus, it is reasonable to assume that for recent years, no discarding is done by trawlers.

Table 3. Percentage breakdown of a commercial trawl catch in Sabah (Snell 1978b)

Item	% of catch[a]
Prawn	6.0
Marketable fish	24.9
Unmarketable fish	63.9

[a]Averaged from 3 different commercial vessels which operated during different months of the year.

Purse seiners

Number of purse seine vessels

The purse seine fisheries in Sabah started in the late 1980s. We did not find any reports documenting unlicensed purse seine vessels; however, we assumed that unlicensed vessels did exist, since the incentives driving unlicensed vessels in the trawl sector are likely to operate in the purse seine fisheries as well. To estimate the number of unlicensed purse seine vessels, we first calculated the average (across all years) ratio of licensed: unlicensed vessels in the trawl fishery. We then applied this ratio to the yearly number of licensed purse seine vessels to estimate the number of unlicensed purse seine vessels per year.

Catch rate for purse seine vessels

The only catch rate information specific to purse seiners in Sabah was from an experimental fishing survey carried out in 1988, during which a catch rate of 14 t per haul was recorded (Chee, 1995). We chose not to use this catch rate as it might not be representative of normal commercial fishing operations. Instead, we used a catch rate of 180.67 $t \cdot boat^{-1}\ year^{-1}$ that was recorded for purse seine vessels in Peninsular Malaysia in 1983 (Hotta and Low, 1985). This rate was applied to the assumed start year of 1987 for purse seine vessels in Sabah. To account for changes in catch rate over time, we assumed that the catch rate changed in proportion to the annual change in recorded landings per vessel. Since 1998, the number of recorded purse seine vessels has remained the same in the national statistics.

Total Commercial catch

Total commercial catch was calculated by summing total catches (licensed + unlicensed vessels) from the trawl and purse seine fisheries from 1962 to 2006. Note that this is inclusive of discards from 1962 to 1990.

Traditional fisheries

Estimation of traditional catches is based on the number of traditional small-scale fishers. As mentioned earlier, the number of fishers recorded in the official statistics is considered an underestimate. The Fisheries Department does not know how many migrant fishers reside in Sabah, but they could number in the thousands (Biusing, 2001). We therefore estimate the number of traditional fishers who fish for both subsistence and artisanal purposes in two steps. First, we estimate the number of potential fishers (i.e., both commercial and traditional fishers) from the general population. This comprises local fishers and non-Malaysian (migrant) fishers, many of whom entered Sabah illegally from Indonesia and the Philippines. Secondly, we estimate the number of traditional fishers from this larger fisher population as detailed below.

Estimating the population of potential fishers

<u>Locals</u>

To account for local fishers, we assumed that they were all Bajaus. As mentioned earlier, Bajaus traditionally made a living from fishing, and are the primary marine resource users and fishers in present-day Sabah (Tregonning, 1965; Piper, 1984; Sather, 1997). Besides Bajaus, other ethnic groups such as Suluks and Brunei Malays may also engage in fishing (Biusing, 2001). However, their participation is lower than the Bajaus, and by including only Bajaus we make our estimate conservative. The number of Bajaus as a proportion of Sabah's total population has remained relatively constant from 1950 to the present, varying between 11 to 15% (Lee, 1968; Anon., 2001; Leete, 2008). We used an average of 13% for all years to derive the number of Bajaus from Sabah's population from 1950-2006 (p_B, see Estimate 1 below).

<u>Migrants</u>

There is a large migrant population in Sabah (Anon., 1990a; Sam, 2008). Constant arrivals and deportation make it difficult to estimate this population. Our estimate was based on available data in 1990 and 2005, when illegal immigrants were estimated to make up 30% and 25% of Sabah's total population, respectively (Anon., 1990b; Leete, 2008; Sam, 2008). Migration between Sabah and neighboring countries has occurred for centuries. However, for the period of interest to us (1950-2006), the wave of immigrants started to arrive in Sabah in the late 1960s, intensifying during the South Philippine Moro insurgency during the 1970s. Thus, we assumed that arrivals started in 1968, and that the percentage of immigrants as a proportion of Sabah's population increased linearly from 0 in 1967 to 30% in 1990. Thereafter, we also assumed that the proportion decreased linearly to 25% in 2005 and remained constant in 2006.

<u>Estimating number of traditional fishers</u>

Fishers in Sabah were predominantly 'traditional' until commercial fisheries started in the 1960s. Therefore, the estimated number of fishers was assumed to be all traditional fishers for the period 1950-1965. Biusing (2001) reported that from 1991-1999, an average of 78.5% of local fishers were traditional fishers, while 40.7% of non-Malaysian fishers (immigrants) were traditional fishers. This breakdown was applied to the estimated number of local and immigrant fishers for the period 1991-2006. For the period 1966-1990, we linearly decreased the proportion of traditional fishers from 100% in 1965 to 78.5% in 1991. We did likewise for non-Malaysian fishers for the period 1968 to 2006.

We estimated the number of traditional fishers using three different methods detailed below, and used an average of the three estimates as the basis to calculate traditional catch.

Estimate 1

The majority of Bajau and non-Malaysian residents reside in Sabah's coastal districts (Anon., 2001). We assumed that fishing villages were all located in rural coastal areas, so that it was reasonable to base the number of Bajau traditional fishers (F_{TB}) on Sabah's rural population as:

$$F_{TB} = p_B \cdot r \cdot p_{hh} \cdot v_f \cdot f_{hh} \cdot t_B,$$

where p_B is the population of Bajaus in Sabah (see estimation of local fishers above), r is the proportion of population living in rural areas, p_{hh} is the average household size, v_f is the proportion of households that fish in a village, f_{hh} is the number of fishers per household, and t_B is the proportion of Bajau fishers who are traditional fishers.

In 1951, 10% of the population was urban, while in 1960 15% of the population was urban, of which indigenous people comprised 17% (Jones, 1966). In other words, only 2.6% of the indigenous population lived in urban areas in 1960. Thus, we assumed that from 1950-1960 all indigenous people, including the Bajau, were rural residents (i.e., r = 1.0). From 1960 onwards we linearly decreased the rural population to two further anchor points- in 1970, 80% of the population was rural (r = 0.8) and in 2005, 50% (r = 0.5) of the population was rural (Leete, 2008). We left the 2006 rural population the same as that in 2005.

Data on average household sizes (p_{hh}) in Sabah were available for the following periods: 1960 = 5; 1970 = 5.5; 1980= 5.4 (Leete and Kwok, 1986); 2008=5 (Anon., 2008d). These values were applied to the following periods: 1950-1969, p_{hh} = 5; 1970-1979, p_{hh} = 5.4; 1980-1999, p_{hh} = 5.4; and 2000-2006, p_{hh} = 5. The values for the proportion of households that fish in a village (v_f) were based on a study of a Bajau fishing village in Semporna during the 1960s and 1970s (Sather, 1997). In 1965, Sather (1997) found that 98% of village households still depended on fishing for all, or part of their incomes. By 1979, the proportion of fishing dependent households had fallen to 25%. More recent surveys done since the late 1990s found that fishing was still the primary livelihood for the majority of people in coastal villages (Piper, 1984; Fisher, 2000; Wood, 2001; Teh *et al.*, 2005; Teh *et al.*, 2007), with fishing households making up from 20% (Teh, unpublished data) to between 80 to 90% (Almada-Villela, 1997) of village households. Based on this information, we assumed that in 1950 almost all (v_f = 0.98) households in coastal villages fished. This was linearly decreased to 25% in 1979 (v_f = 0.25), and to a conservative value of 20% (v_f = 0.20) in 2004. The proportion was kept constant from 2004-2006.

A socio-economic survey of small-scale fishers in the early 1980s found that there were on average 1.4 fishers per household (Abdul Mannan, 1982). We applied this value (f_{hh} = 1.4) to all years to obtain the number of Bajau fishers. Finally, we multiplied the number of Bajau fishers by t_B, the proportion of Bajau fishers who are traditional fishers (1950-1965: t_B = 1.0; 1966-1990: interpolated t_B = 1.0 -> 0.78; 1991-2006: t_B = 0.78), to obtain the number of traditional Bajau fishers in each year.

The number of non-Malaysian (migrant) traditional fishers (F_{TN}) was calculated as:

$$F_{TN} = p_N \cdot f_N \cdot t_N$$

where p_N is the population of non-Malaysian citizens in Sabah, f_N is the proportion of non-Malaysian citizens who are fishers, and t_N is the proportion of non-Malaysian fishers who are traditional fishers. Hassan (1978) found that 10% of migrants originating from Tawi-Tawi Island in the Philippines, a common origin for many of Sabah's migrants, took up fishing as a livelihood after arriving in Sabah. Therefore, we applied 10% (f_N = 0.1) to the population of non-Malaysians to obtain the number of non-Malaysian fishers. We used the same proportion for all years up to 2006. The proportion of non-Malaysian fishers who are traditional fishers (t_N =0.40, see above) was used to determine the number of non-Malaysian traditional fishers.

Estimate 2

The anchor point for this estimate was 1891, the year in which a population census indicated there were only 910 fishermen (8% of the population) in former British Borneo (Mohammad Ariff, 1999). To carry forward this estimate, we made the assumption that the proportion of fishers to total population remained stable through time. This may be a strong assumption given that new industries and economic opportunities would have attracted fishers to other occupations. However, a detailed study of a fishing community showed that when local fishers turned to more stable and paid employment in other resource sectors starting in the late 1960s and early 1970s, their places were taken by the arrival of migrants (Sather, 1985, 1997). Moreover, fishing was, and still is, a fall back activity which people return to. It is therefore likely that on the whole, the proportion of Sabah's population that is involved in fishing has remained approximately the same. To carry our estimate through time, we simply applied the percentage of fishers (8%) to our defined fisher population: from 1950 to 1968 this percentage was applied to the population of Bajaus. From 1968 onwards, the percentage was applied to the population of Bajaus plus non-Malaysian citizens. This was then multiplied by t_B and t_N to obtain the number of traditional Bajau and non-Malaysian fishers.

Estimate 3

Due to the dispersed and relatively isolated nature of Sabah's small-scale fisheries, many fishers do not register for licenses. According to a fisheries official, the number of unlicensed fishers made up an additional 30% from the number of licensed fishers recorded in the fisheries statistics (E. Jinuat, pers. comm.)[2]. Further, the extra 30% consisted of small-scale fishers, both locals and non-Malaysians. We assume that this under-reporting has been occurring since Malaysian independence, so that from 1963 to 1998, we increased the annual number of licensed traditional fishers by 30% to account for unlicensed fishers. From 1998 to 2006, this approach could not be used because statistics on the number of fishers had not been updated and recorded the same number of fishers (20,845, or 8,091 traditional fishers) each year. However, the number of traditional fishers had in fact been increasing by around 4,000 annually (E. Jinuat, pers. comm.)[2]. Therefore, for 1998-2006, we added 4,000 fishers to each subsequent year to obtain the total number of traditional fishers (inclusive of unlicensed fishers).

Traditional catch rates

We estimated catch rates for 3 periods: 1950-1969, 1970-1999, and 2000-2006. Each period was chosen to roughly coincide with the prevailing economic conditions which affected small-scale fishers.

1950-1969: An annual catch rate of 3.09 t fisher^{-1}year^{-1} was used. This catch rate was based on an anthropological study done in a Semporna Bajau fishing community in 1965 by Sather (1984, 1997). We derived a catch rate based on Sather's qualitative description of the proportion of a catch that was sold after each multi-day fishing trip, the price of fish in the Semporna market, and the frequency and duration of long fishing trips. In addition, we added a subsistence catch of 2 kg·fisher^{-1}·d^{-1} based on Teh *et al.* (2007) for the periods that Bajau fishers did not go on extended fishing trips. It is likely that 2 kg is a conservative estimate of the subsistence catch rate for this period, as sharing fish with family and friends was still a common practice, but not as important during the time of the Teh *et al.* (2007) study. Historically, all Bajau Laut in Semporna lived permanently afloat in small sailing vessels, and fished principally around the Semporna area (Sather, 1984; 1985). However, families frequently went beyond Sabah to the southern Philippine Sibutu island cluster to fish and visit friends or family (Sather, 1984). Thus, a portion of their catch was likely not from within Sabah waters. To account for this, we assumed that 15% of catches in this period originated from outside Sabah. This is reasonable since the coral reefs around Semporna, notably the Ligitan reefs, were described as the major fishing grounds for Semporna Bajau Laut (Sather, 1984; 1985). The majority of boat dwelling Bajau Laut families settled permanently on land by the 1960s (Sather, 1985; 1997), thus were not likely to make extended trips to the Philippines after giving up their boat dwelling lifestyle.

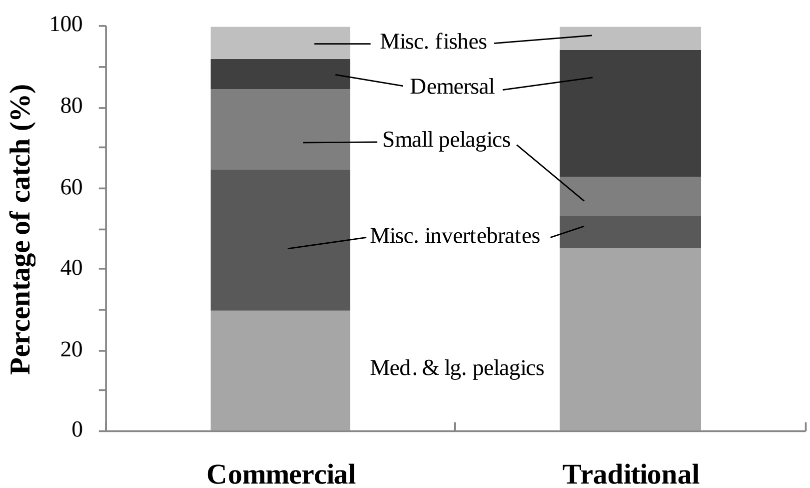

Figure 2. Breakdown of commercial and traditional landings by fish groups, averaged from 1991-1996, and 2002-2006.

Consequently, we used a catch rate of 2.6 t fisher^{-1}·year^{-1} (i.e., 85% of 3.09 calculated above) starting in 1950. This was linearly increased to a catch rate of 5 t·fisher^{-1}·year^{-1} in 1970 (see below).

1970-1999: There were no readily available catch rate data for this period. Demand for fish intensified starting in the 1970s due to the construction of trunk roads, which improved the transportation of fish from rural areas to urban markets. At the same time, an influx of immigrants arrived in Sabah during this period. As Sabah's population, and therefore the fisher population, was still low in the early 1970s, we assumed that fishers' catch rates increased to meet the extra demand. As such, we assumed that the 1970-1989 catch rate was 1.3 t higher (i.e., 5 t·fisher^{-1}·year^{-1}) than the subsequent rate from 1990-2006 (3.68 t·fisher^{-1}·year^{-1}). A catch rate of 5 t·fisher^{-1}·year^{-1} was applied from 1970-1980, then starting in 1981, the catch rate was linearly decreased to 3.68 t·fisher^{-1}·year^{-1} in 2000. Interviews with small-scale fishers in Pulau Banggi, northern Sabah in 2004/2005 indicated that the 1980s were good fishing years, with individual catch rates 3 to 4 times higher compared to the 2000s. Thus, we remained conservative by not doubling the 2000-2006 catch rate of 3.68 t·fisher^{-1}·year^{-1}. Moreover, most of the interviewed fishers indicated that catches started to decline in 2000 (Teh *et al.*, 2007). Again, we made our estimate conservative by starting the decline of the 'good' fishing period in 1981.

2000-2006: A catch rate of 3.68 t·fisher^{-1}·year^{-1} was applied to this period. This catch rate was based on the average catch rate recorded for small-scale reef fisheries in Pulau Banggi, an island group off northern Sabah (Teh *et al.* 2007).

<u>Total traditional catch</u>

Total annual traditional catch (C_{trad}) was calculated as:

$$C_{trad} = x \cdot r_{trad}$$

where x is the number of fishers, and r_{trad} is the individual catch rate.

Catch composition of Sabah's marine fisheries landings

The taxonomic breakdown of annual marine landings was obtained for 1965 to 2006 from annual fisheries reports. A breakdown according to gear was available for 1991 to 1996, and 2002 to 2006. The average composition for commercial (trawl and purse seine) and traditional gears (gillnets, seine nets, hook and line, traps, hand collection, and spears) is presented in Figure 2. The crustaceans group is made up of prawns, lobsters, and crabs, with prawns accounting for the bulk of the reported data.

As the reconstructed catches involved the same gear types as those in recorded landings, it was assumed reasonable to apply the same taxonomic breakdown observed from landings (1965-2006) to the yearly reconstructed catches. Sabah's fisheries were mostly small-scale traditional before 1965; thus, the composition of reconstructed catches from 1950 to 1964 were assumed to resemble the traditional breakdown only (Figure 2). It should be noted that in the north and east coasts of Sabah, subsistence fishing targets mainly reef associated species (Piper, 1984; Wood, 2001; Teh *et al.*, 2005; 2007), while more small pelagics are caught in the west coast. Piper (1984) reported that a spear gun catch consisted of 1 large trigger fish (Balistidae), 1 butterflyfish (Chaetodontidae), 1 sweetlip (Haemulidae), damselfish (Pomacentridae), groupers (Serranidae), angelfish (Pomacanthidae), 1 octopus, tusk fish (Labridae), and rabbit fish (Siganidae). Compared to more recent reports on subsistence fishing (Wood, 2001; Teh *et al.*, 2005; 2007), there appears to have been little change in the type of demersal reef fish caught in the past 20 years.

Table 4. Breakdown of trawl discards from Snell (1978b)

Taxon	% of discards
Ariidae	11.3
Clupeidae	4.4
Engraulidae	1.0
Paralichthyidae	3.5
Gerreidae	1.5
Lagocephalidae	4.2
Leiognathidae	23.2
Mullidae	3.3
Nemipteridae	5.1
Platycephalidae	7.2
Pomadasyidae	7.9
Dasyatidae and Carcharhinidae	6.7
Sciaenidae	8.1
Synodontidae	4.8
Theraponidae	2.3
Trichiuridae	15.4
Others	15.5

Table 5. Estimated number of traditional fishers (1950-2006) compared to reported number of traditional fishers (1987-2006) for Sabah.

Year	Estimated trawl catch	Estimated purse seine catch	Estimated commercial landings	Reported commercial landings
1962	549	-	549	-
1963	2899	-	2899	-
1964	5524	-	5524	-
1965	10032	-	10032	-
1966	12910	-	12910	-
1967	21238	-	21238	-
1968	33527	-	33527	-
1969	37454	-	37454	-
1970	39052	-	39052	26009
1971	43993	-	43993	26721
1972	53449	-	53449	27127
1973	56521	-	56521	31192
1974	68003	-	68003	32309
1975	65995	-	65995	33020
1976	71358	-	71358	30700
1977	86246	-	86246	34900
1978	70311	-	70311	40100
1979	58758	-	58758	40200
1980	51084	-	51084	33300
1981	61405	2195	63601	42008
1982	43974	7155	51129	37592
1983	78113	12114	90227	30116
1984	89821	17073	106895	30258
1985	104137	22033	126170	27873
1986	106760	26992	133752	20672
1987	109329	31951	141281	25496
1988	111841	51220	163061	19123
1989	114292	37623	151915	20742
1990	116679	38172	154851	22361
1991	118998	78577	197575	45321
1992	121247	81950	203197	61856
1993	123421	100963	224383	62613
1994	125517	103363	228880	77504
1995	129784	126867	256651	85278
1996	134118	98171	232289	91014
1997	138518	65420	203938	93018
1998	142983	93471	236454	119804
1999	141812	93851	235663	133434
2000	140577	103725	244301	137694
2001	139277	93041	232319	120877
2002	137913	99040	236953	114404
2003	134994	92374	227368	104703
2004	132075	102182	234256	123210
2005	129155	118447	247602	129730
2006	126236	101648	227884	116165

Prior to 1991, bycatch from trawlers was not landed and thus the taxonomic breakdown of these discards was not recorded. Here, the breakdown of discards is based on a study of trawler bycatch conducted by Snell (1978b) (Table 4). Ninety five percent of bycatch was demersal fish (Snell, 1978b), with the remainder being small pelagics. Discarded fish were either too small for human consumption, poisonous, or had no consumer demand (Snell, 1978b). Trawler bycatch estimated for 1962-1990 was thus allocated to the 'trash fish' and miscellaneous mixed fish category.

The discarded species from Snell's study are consistent with another report, which stated that low value demersal fish which were not landed prior to 1991 included lizard fish (*Saurida* spp.), goat fish (Mullidae), juvenile threadfin bream (*Nemipterus* spp.), slipmouths (Leiognathidae), and flat fish (Plotosidae) (Biusing, 2001). From 1991 to 2006, so-called 'trash' fish comprised the largest proportion (19%) of trawl landings. On the other hand, 'trash' fish only made up a minor (2%) part of purse seine landings.

RESULTS

Commercial sector

<u>Catches</u>

The reconstructed catch for the commercial sector (trawl and purse seine) totaled 5.6 million t for the period 1962 to 2006, with trawl and purse seine catches accounting for 3.8 million and 1.8 million t, respectively. Trawl landings data were available from 1970 to 2006; prior to that, only landings of prawns was reported (1962 to 1970). Purse seine landings data were available from 1987 to 2006. For the period 1970-2006, total reported commercial landings was 2.25 million t, whereas reconstructed catches for the same period totaled 5.52 million t, or 250% higher than reported landings (Table 5).

Incorporating unlicensed vessels and discards resulted in the reconstructed trawl catch trend differing from recorded trawl landings for the 1980-1990

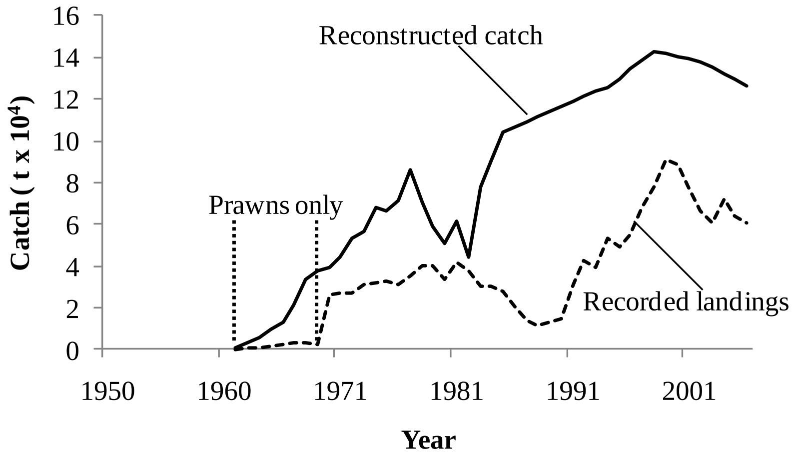

Figure 3. Reconstructed trawl catches and recorded trawl landings 1962-2006. Note that recorded landings from 1962 to 1969 show prawn landings only.

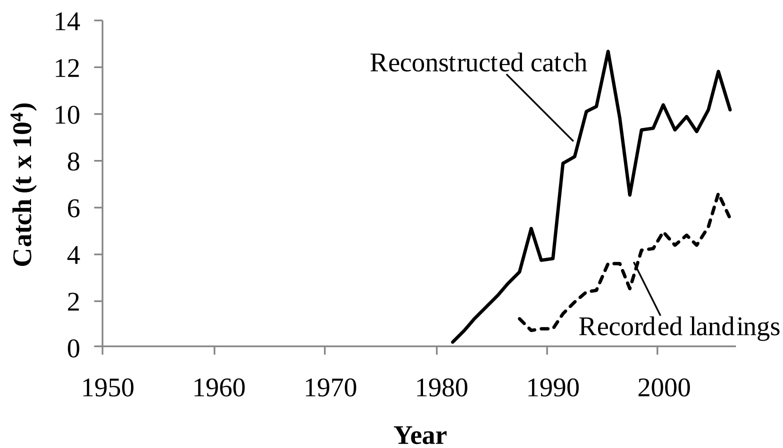

Figure 4. Reconstructed purse seine catches 1981-2006 and recorded landings 1987-2006

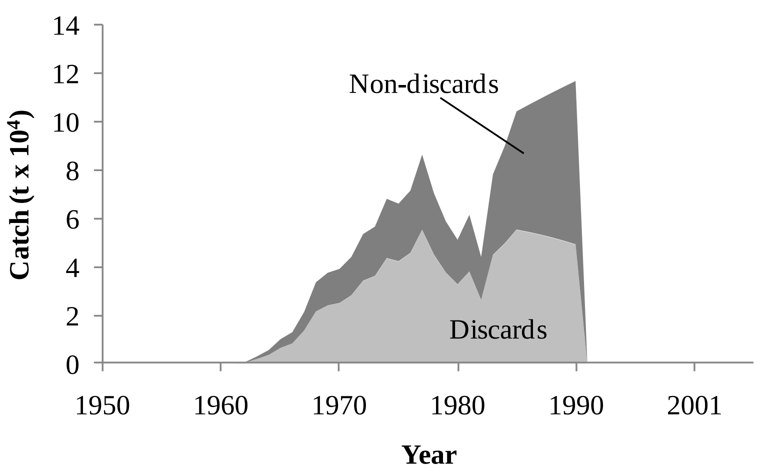

Figure 5. Reconstructed trawl catches showing the amount of discards 1962-2006.

Table 6. Estimated number of traditional fishers (1950-2006) compared to reported number of traditional fishers (1987-2006) for Sabah.

Year	Estimated no. of traditional fishers	Reported no. of total fishers	Reported no. of traditional fishers
1950	9531	-	-
1951	9008	-	-
1952	9088	-	-
1953	9262	-	-
1954	9310	-	-
1955	9377	-	-
1956	9491	-	-
1957	9604	-	-
1958	9780	-	-
1959	9916	-	-
1960	10264	-	-
1961	10328	-	-
1962	10364	-	-
1963	10373	-	-
1964	10451	-	-
1965	10518	-	-
1966	9894	9800	-
1967	9775	9500	-
1968	9717	8950	-
1969	9701	9050	-
1970	9714	9000	-
1971	9842	9000	-
1972	9702	8900	-
1973	9883	11147	-
1974	10535	11182	-
1975	10772	11200	-
1976	11161	11000	-
1977	11491	11180	-
1978	11846	16978	-
1979	12047	17610	-
1980	12524	18000	-
1981	12242	18450	-
1982	12946	19850	-
1983	13627	19900	-
1984	14390	19900	-
1985	15177	20500	-
1986	16012	20500	-
1987	16906	17730	-
1988	17753	17730	9679
1989	18879	18250	9790
1990	19765	16028	9015
1991	20657	16133	9015
1992	23599	17209	10931
1993	24902	18410	11954
1994	27015	19819	13345
1995	27746	19819	13355
1996	29625	20415	14070
1997	30382	20415	14070
1998	31835	20845	9102
1999	35563	20845	9102
2000	32793	20845	9102
2001	35328	20845	9102
2002	35121	20845	9102
2003	36317	20845	9102
2004	37273	20845	9102
2005	40912	20845	9102
2006	41940	20845	9102

period. While both sets of data increased from the 1960s to 1980, the reconstructed catches dipped in the early 1980s, thereafter increasing again until reaching a peak in the late 1990s/early 2000. In contrast, the recorded landings showed the similar dip in the late 1980s, then followed the same path of increase until peaking in the late 1990s (Figure 3).

The reconstructed purse seine catch trend was more consistent with recorded landings. Both showed an increasing trend since data for the fishery started to be reported in 1987. Overall, reconstructed purse seine catches were almost double the recorded landings (Figure 4).

Discards

We estimated that from 1962 to 1990, an average of 33,741 t of fish were discarded by licensed and unlicensed trawlers annually (Figure 5). The sum of estimated discards from 1965 to 1990 was almost equal to the total reported landings for the same period (972,755 t discards vs. 1.03 million t reported landings).

Traditional sector

Number of traditional fishers

We had access to data on the number of reported fishers from 1966 to 2006 (commercial and traditional), and traditional fishers from 1988-2006. We developed estimates for the number of traditional fishers from 1950 to 2006 (Table 6). On average, the estimates presented for 1988 to 2006 were 2.5 times higher than the number of traditional fishermen reported in the fisheries statistics. Note that since 1998, official statistics on the number of fishers have not been updated, and has remained at 8,091 fishers.

Catches

We had reported traditional landings data for 1982 to 2006. The estimated traditional catches showed a generally increasing trend from 1950 to 2006, totaling 4 million t for the period. On the other hand, recorded landings were fluctuating and unstable for the period 1982 to 2006 (Fig.6). The sum of all reconstructed catches from 1982 to 2006 was double that of recorded landings for the same period. Considering the evidence of declining catch rates for the traditional sector, this increasing total catch trend reflects the substantial rise in entrants into Sabah's fisheries.

Total catches

The reconstructed catch time series from 1950 to 2006 summed to 9.7 million t. Compared to landings data reported in the Annual Fisheries Statistics from 1965 to 2006, the reconstructed catch was on average 220% larger (Figure 7a). Since 1991, official statistics reported landings ranging between 115,000 and 218,000 t·year^{-1}, whereas the reconstructed catch totals indicated catches of between 284,000 and 398,000 t·year^{-1}. Overall, the reconstructed traditional catches showed a more stable trend, gradually increasing through time. On the other hand, the commercial catches fluctuated a lot more (Figure 7b).

Catch composition

A taxonomic breakdown for recorded landings was available from 1965 to 2006. In this period, the inclusion of trawler discards in the catch reconstruction resulted in a substantially different breakdown when compared to the fisheries statistics. The reconstructed catch composition for 1950-2006 (inclusive of both traditional and commercial sectors) showed that the 'trash fish' and miscellaneous mixed fish group made up, on average, 27% of the catch, whereas the fisheries statistics recorded an average of 5% (Figure 8).

DISCUSSION

The historical reconstruction presented here spans two periods in Sabah's history. Prior to independence in 1963, the British Colonial Administration recorded only exported fisheries commodities, which consisted primarily of salted fish and dried prawns. Our reconstructed data suggest that the sum of total catches from 1950 to 1962 is around 421,200 t. British Colonial reports recorded a sum of roughly 16,438 t of exported fisheries products for this period (note that no data were recorded in 1953 and 1954). Accounting for the loss in weight of

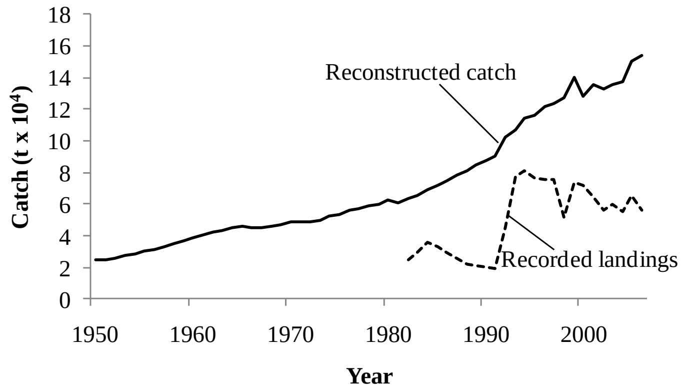

Figure 6. Reconstructed traditional catches for 1950-2006 and reported landings for 1982-2006.

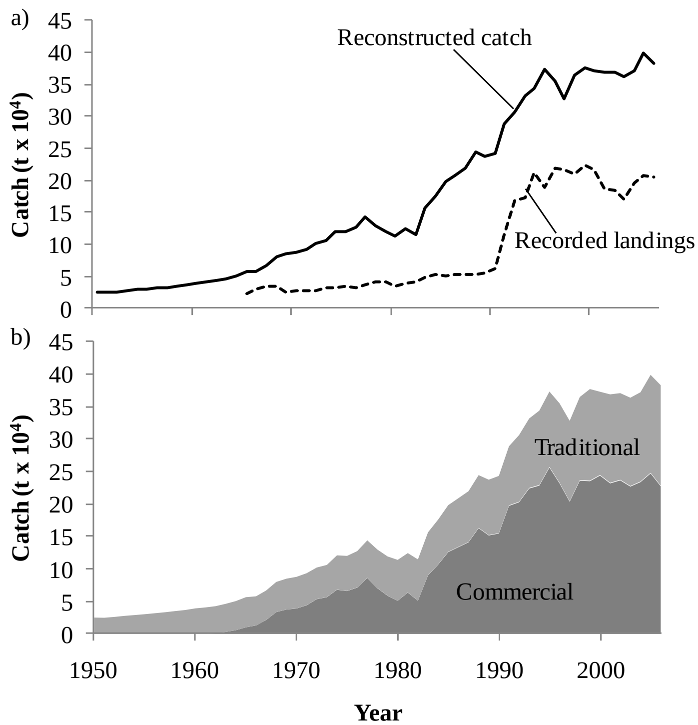

Figure 7. Total reconstructed catch for Sabah, 1950-2006: a) as compared to recorded landings, and b) represented as commercial and traditional components.

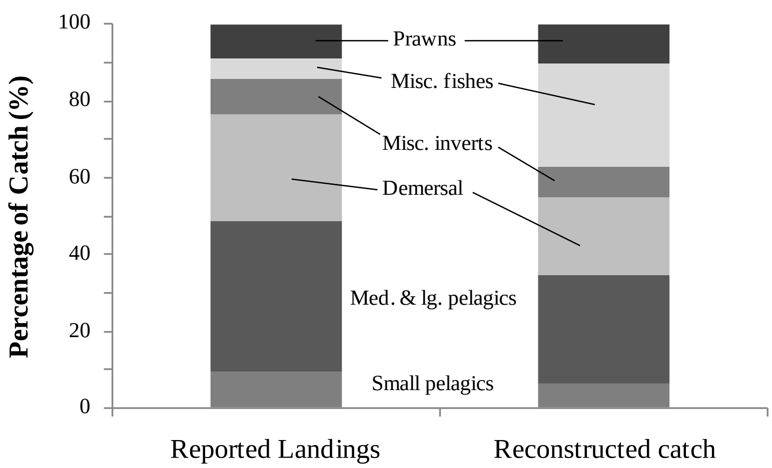

Figure 8. Breakdown of reconstructed catch and reported landings by fish groups.

the dried products, this would be approximately equivalent to 288,000 t of fresh fish. In the post-colonial period, the reconstruction suggests that catches from Sabah's waters are on average 2.2 times higher than those reported in the official Malaysian statistics from 1965 to 2006. This falls in the lower end of findings from other catch reconstruction efforts, where differences of 1.7 fold and up to 17 fold have been found (Zeller *et al.*, 2006; Jacquet and Zeller, 2007; Zeller *et al.*, 2007).

The reconstructed estimates presented here suggest that Sabah's total marine fisheries catches have been on an increasing trend for the 56 year period from 1950 to 2006. This matches the trend from official statistics, although magnitudes differ substantially throughout time. Clearly missing also in the reconstructed data was the steep increases in reported landings in 1990-1991 that were due to the combined effects of: a) a change to an improved methodology used for sampling fisheries landings, and b) the landing of so-called 'trash' fish which were previously discarded prior to finding a market in fishmeal production in the early 1990s (Biusing, 2001). These changes and artifacts are more properly accounted for in the reconstructed estimates. Reconstructed catches from 1965 to 1990 are on average 3.4 times higher than reported landings, compared to an almost two fold difference from 1991 to 2006. This may indicate that Sabah's fisheries monitoring system has improved; nevertheless, the current system still does not account for a substantial amount of small-scale fisheries which take place along Sabah's inshore waters.

The proliferation of small-scale fishing in Sabah's coastal communities, combined with the inadequate coverage of fishing villages by the Fisheries Department, necessitated that we build our estimation of traditional fishers on general demographic statistics, rather than on the reported number of traditional fishers or vessels. Our approach estimated that the number of traditional small-scale fishers was 2.5 times higher than that reported in the fisheries statistics. To our knowledge, our study is the first to explicitly incorporate both local and immigrant fishing effort into an estimate of Sabah's small-scale fisheries catch. Nevertheless, even our estimates may be underestimates, as our local fisher population is based primarily on the population of Bajaus, who have the traditional role of being fishers. We have not included other ethnic groups such as Suluks, who also engage in some fishing, but to a lesser extent than Bajaus. Thus, our estimate presents a lower limit on the number of traditional fishers and fish catch volume. Nonetheless, it reflects the substantial increase in Sabah's population over the past 2 decades. In particular, the difference between registered and estimated fishers starts to widen from the mid-1970s onwards. This period reflects the influx of immigrants fleeing political uprising in Mindanao (southern Philippines) in the late 1970s, many of whom settled in coastal villages or on outer islands where they engaged in fishing.

Sabah's total catches are increasingly becoming more commercialized, with the contribution of traditional to total catches growing at a slower rate than commercial catches in the past two decades. Despite the large number of traditional participants, traditional catch only made up on average 35% of total catch since 1991. Nevertheless, small-scale fisheries are disproportionately important to those who rely on these resources for livelihood and food security (Whittingham *et al.*, 2003; Sadovy, 2005). Indeed, fishing remains the primary, and in many cases, the sole source of income and employment in Sabah's fishing villagers (Wood, 2001; Teh *et al.*, 2005; 2007), which are also among the poorest communities in the country.

On the other hand, a substantial portion of fish landed by the commercial sector is low value or inedible fish destined for fishmeal production or for processing into frozen seafood products for export. From 1992 to 1999, 142,166 t of fishmeal using approximately 531,000 t of raw materials (or on average, approximately 40% of annual marine landings) was produced in Sabah. Of this, slightly over 60% was exported. In fact, several purse seine vessels are operated specifically for capturing the raw materials for fishmeal production (Biusing, 2001). As such, the commercial fishery sector has minimal contribution to sustaining the nutritional needs of Sabah's human population.

The increasing trend in commercial landings actually masks the fact that prawns, the most valuable commercial resource, have been overexploited. Catch per unit of effort has been on a downward trajectory since the early 1970s, and prawns are considered to be exploited beyond the upper limits of sustainable production (Biusing, 2001). The high amount of low value fish in Sabah's trawl catches is similar to neighboring Thailand and the Philippines, where the trawl fleets have led to degradation of coastal marine ecosystems (Christensen and Pauly, 2001). It is highly likely that this is also the case in Sabah.

Importantly, the trawl sector has likely had a larger impact on the marine environment than that suggested by the decline in prawn catches recorded in the official statistics. Our catch reconstruction suggests that discards from the start of the prawn trawl fishery in the early 1960s to 1990 totaled about 973,000 tonnes, an amount almost equal to the reported landings, and 5.6 times higher than the reported prawn catches for that period. Forage fish play an important ecological role in transferring energy from plankton to higher trophic level groups, such as larger fishes and marine mammals (Alder et al. 2008). The removal of forage fish species can therefore have negative consequences for species in the entire ecosystem. While some traditional gears take incidental catches of cetaceans (Jaaman *et al.*, in press) and possibly turtles, there was minimal discarded bycatch observed in small-scale artisanal catches, as fishers tend to keep damaged or low value fish for their own consumption (L. Teh, pers. obs.).

The use of trawler bycatch to make fish balls, fish cakes, and other products developed in the late 1970s (Snell, 1978a), thereby reducing the economic and biological waste to a certain extent. Further, trawler bycatch has reportedly landed since the early 1990s for fishmeal (Biusing, 2001). Nevertheless, the creation of a fishmeal market creates little incentive for trawl operators to decrease the environmental impact of trawling. The efficiency of fishmeal production is such that there have been shortages of raw materials, necessitating the import of trash fish from Indonesia (Biusing 2001). The demand for fishmeal is driven by global growth in aquaculture production, and increasing demand from developed countries for omega 3 rich supplements such as fish oils (Naylor *et al.*, 2009, Jenkins *et al.*, 2009). On the positive side, the Sabah Fisheries Department recognizes the need to decrease trawling effort within inshore coastal waters, and has plans to phase out small trawlers less than 40 GRT in size (Biusing, 2001). However, it remains to be seen whether this effort will be replaced with bigger trawlers diverted to fishing in deeper offshore areas.

The reconstructed traditional catch trend shows that catches at the fishery level have been increasing steadily since the 1990s, even though we based the estimate on an assumed decreasing catch rate for the period. This is being driven by the large number of participants in traditional, small-scale fisheries, and may suggest that fisheries resources may not be able to support the current level of fishing pressure for much longer. This is of concern given that fish is the cheapest animal protein in Sabah, and is still a staple food source, especially for the rural population. For instance, according to a national food and nutrition survey, marine fish is consumed daily, with the frequency of daily intake being significantly higher among rural adults (Norimah *et al.*, 2008).

Sabah's population has increased 6.5 fold since 1960, with an annual population growth rate between 1991 and 2000 of 4.5% (Saw, 2007). Population pressure, combined with the prevailing poverty of fishing villages, suggests that Malthusian overfishing (Pauly *et al.*, 1989) is occurring in Sabah's small-scale fisheries (Teh and Sumaila, 2007). Indeed, unsustainable fishing methods using dynamite and cyanide continue to be persistent problems in Sabah, resulting in extensive damage to coral reef habitat. The continued arrival of migrants from the Philippines and Indonesia will only add to the increasing pressure on fisheries resources, as they increase local fish demand and enter an already crowded traditional fishery. Indeed, in interviews with small-scale artisanal fishers, Teh *et al.* (2007) found that an increase in the number of fishers was the most frequently mentioned reason when fishers were asked about the reason for a decrease in catches.

Over 80% of Sabah's coral reefs are at risk from anthropogenic activities (Burke *et al.*, 2002), thus threatening Sabah's vital reef-based fisheries as well. Overall, coral reef fish catches have been declining (Cabanban and Biusing, 1999). Demand from global seafood markets is a primary driver for the overfishing of several reef resources in Sabah. Catches of fish species targeted for the lucrative live reef food fish trade, such as coral groupers (*Plectropomus* spp. and *Epinephelus* spp.) and humphead wrasse (*Cheilinus undulatus*), have drastically declined since the 1990s (Daw *et al.,* 2002; Scales *et al.,* 2007; Teh and Sumaila, 2007; Teh *et al.,* 2007). Underwater surveys have also shown that the abundance of commercially important fish are very low, and are even locally extinct at some locations (Oakley *et al.*, 1999; Pilcher and Cabanban, 2000; Koh *et al.*, 2002). Landings of sea cucumbers, which are collected by small-scale fishers for the bêche-de-mer trade, have also declined since the 1980s and 1990s (Choo, 2004). Importantly, current bêche-de-mer landings are made of less valuable species compared to before (Choo, 2004).

Other indications that Sabah's reef fisheries are overfished include a decrease in the mean size of fish caught, and the need for fishers to travel further offshore and more distant fishing grounds to catch fish (Teh *et al.*, 2007). At the same time, anecdotal evidence from small-scale fishers indicates that their catches are being adversely affected by purse seine and trawl vessels which intrude into their traditional fishing zones (Biusing, 2001; Teh *et al.*, 2007), leading to harmful effects on the coral reef environment and jeopardizing near shore fish stocks that are targeted by the traditional sector. The interaction between trawl and traditional fisheries already led to conflicts in Peninsular Malaysia (Wong, 1982; Chee, 1995), and steps should be taken to ensure the same does not happen in Sabah.

Government policies aimed at traditional fishers are focused on poverty alleviation and ensuring livelihoods and employment. To date, this has involved programs aimed at providing alternative livelihoods such as seaweed farming or agricultural projects. Simultaneously however, there has been widespread provision of subsidies for fishing gear, boats, fuel, as well as monetary incentives (e.g., RM 0.10 kg^{-1} of fish landed, beginning in the latter half of 2008). These strategies can have adverse effects on fisheries sustainability (Munro and Sumaila, 2002), and should be urgently reconsidered in light of our findings. Better avenues for use of such funds would be in the realm of local, community-based co-management arrangements in relation to the establishment and enforcement of no-take marine reserves that can contribute to more stable yields to traditional fishers as well as ecosystem preservation and hence sustainable production potential (e.g., Russ *et al.*, 2004)

Our results do not include catches by several foreign companies that fished in Sabah for short periods of time during the 1950s and 1960s. For instance, a Japanese company catching offshore tuna operated for 2 years in the 1950s. Similarly, in 1951 the British government allowed a Hong Kong company with a fleet of 3 trawlers to fish, while in 1958 a Filipino company started to catch fish around northern Sabah (Anon., 1958). We do not explicitly account for non-prawn invertebrate catches; instead, these catches, often derived by reef- and shore- gleaning, are encompassed within the overall catch rates used. Subsequently, the invertebrate catches presented here are coarse estimates, and are likely underestimates relative to finfish. As reef gleaning is a common activity (Sather, 1997; Wood, 2001; Teh *et al.*, 2005), this is an area that requires further research.

CONCLUSION

This study shows that the traditional sector is considerably larger than officially recorded in terms of participants, and thus its importance to society is likely to have been underestimated. Importantly, this historical perspective of Sabah's fisheries indicates that even as Sabah's population and the number of fishers grew rapidly, small-scale fishery resources were able to support the growing local fish demand. However, this is now at risk, and maintaining sustainable small-scale inshore fisheries is of utmost importance if these resources are to continue supporting local subsistence and artisanal fishing economies.

In contrast, while commercial fisheries catches are comparatively larger, their contribution to Sabah's food security is minimal, as a substantial proportion of commercial landings are processed into fishmeal, while higher quality fish are frozen and exported. Further, our study indicates that discards from the commercial prawn fishery totaled almost a million tonnes prior to the 1990s, thus likely had a more serious impact on the marine environment than perceived from the official statistics.

Overall, our study points to the need for increased attention on understanding and managing the level of fishing pressure on Sabah's marine resources, especially for small-scale fisheries resources. Government aid to traditional fishers has historically been aimed at poverty alleviation. Unfortunately, many of these programs, in the form of subsidies and grants, may have created perverse incentives to intensify the exploitation fisheries resources. Instead, policies aimed at addressing the unrecorded effort we have estimated here are needed in order to ensure the sustainability of inshore fisheries resources.

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RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR WALLIS AND FUTUNA ISLANDS (1950-2007)[1]

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ABSTRACT

Total marine fisheries catches were estimated for Wallis and Futuna between 1950 and 2007. Our estimate included both commercial and subsistence fisheries sectors. Commercial catches were estimated using data supplied to the FAO by Wallis and Futuna, and the limited independent data that were available in the literature. Subsistence catches were based on an estimate for this sector in the recent time period (1990s) and an assumed *per capita* rate for the early time period (1950s). Together, the subsistence and commercial catches totaled approximately 34,700 t over the 1950-2007 time period, which is 6.4 times larger than the landings presented by FAO. Subsistence catches represented the largest portion (over 80%) of the reconstructed catch, highlighting the importance of this small-scale fisheries sector, and its general neglect in official statistics.

INTRODUCTION

Wallis and Futuna Islands are located between Fiji and Samoa at 176°-178° W and 13°-14° S (Figure 1). This French territory is composed of two island groups, Wallis and Futuna (plus Alofi), that are approximately 200 km apart with an Exclusive Economic Zone (EEZ) of nearly 300,000 km²(www.seaaroundus.org). The Wallis islands contain one main island and several small coral islands. The main island is called Uvea by its inhabitants, covers a land area of about 100 km² and its lagoon is protected by a coral reef. Futuna and Alofi (uninhabited) are south-west of Wallis. Futuna has neither a coral reef nor a lagoon, and the island is regularly hit by earthquakes. The territory's economy is limited to subsistence agriculture and fishing. The territory's revenue is supported heavily by remittances from expatriate workers in New Caledonia, French Polynesia and France, and from licensing distant water fleets (mainly Japanese and South Korean) fishing for tuna.

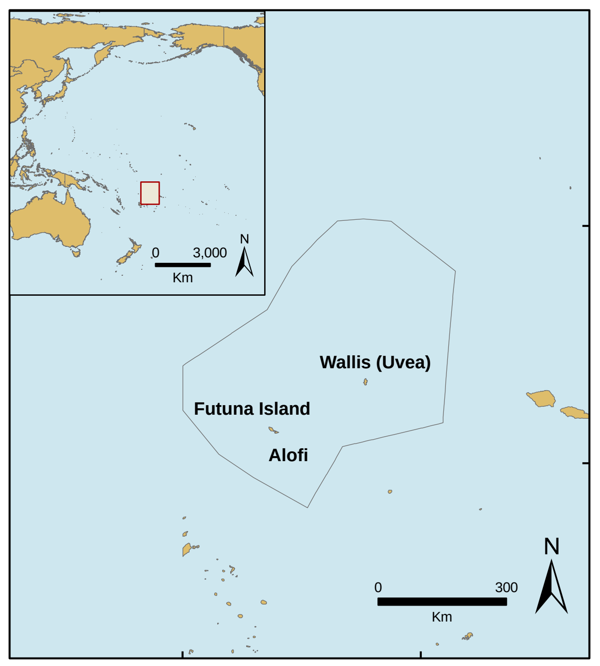

Figure 1. Map of Wallis and Futuna showing the three islands, Wallis, Futuna and Alofi, and their EEZ.

The FAO FishStat database, which offers time series data on marine fisheries landings from 1950 to the present, is based predominantly on national statistical data supplied by its member countries. Therefore,

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the quality of the data depends on the capacity of statistical collection within these countries. The FAO data have been the basis of many influential global fisheries studies (i.e. Pauly *et al.*, 1998) but they are, in fact, incomplete (Zeller *et al.*, 2006; 2007).

The objective of the present study is to provide an estimate of total marine fisheries catches. Although several studies and reports have been published previously, there has been no comprehensive review of potential historical catches, combining both subsistence catches with reported commercial landings.

MATERIALS AND METHODS

Estimates of marine fisheries catches were taken from several reports detailing the weight of fishes taken. While most subsistence catches were not reported, we used a method combining available information on catches and human population to estimate *per capita* subsistence catch rates and consumption rates. Interpolations between data anchor points were done to estimate catch rates over the entire study period (1950-2007). Catch rates were transformed into catch amounts using human population data.

Human population data

Our estimates of subsistence catch required a complete time series of human population data to convert *per capita* subsistence catch rates into catch amounts. Population data for Wallis and Futuna were obtained from several sources: The 'Institut d'Emission d'Outre Mer' (Anon., 2009) and the population statistics historical demography website (www.populstat.info). In years when population data were not available, a linear interpolation was done between neighboring years to derive a complete time series of population data from 1950-2007 (Figure 2).

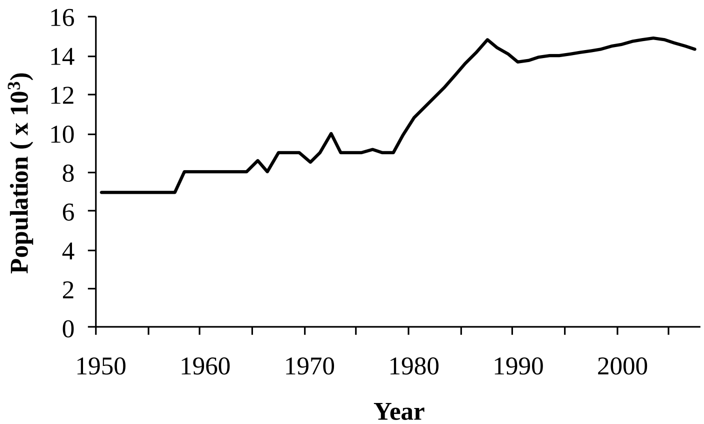

Figure 2. Estimated population of Wallis and Futuna, 1950-2007.

Commercial fisheries

Commercial fisheries data for Wallis and Futuna were taken from the FAO FishStat database for most years. Additional data were obtained from independent reports that reviewed commercial fisheries production in the Pacific region (Angleviel, 1999; Dalzell *et al.*, 1996). Data from these reports were used in years when they provided an apparently more comprehensive assessment of fisheries catches than supplied to the FAO.

From 1950-1969, data supplied to FAO are presented as only 'miscellaneous marine fishes' estimated at <0.5 t·year^{-1}. We assumed that these data were correct as there was a large exodus of the Wallisian and Futunan population in the 1950s to work in the nickel mines of New Caledonia (Anon., 1977; 1984; Taumaia, 1997). This migration included the majority of fishers from Wallis and Futuna that would have been engaged in commercial fishing operations. It was not until the 1970s and 1980s that commercial fisheries were re-established after several government initiatives were brought in to encourage development of the fishery sector (Beverly, 1999).

Commercial catches for the 1989-1994 time period were estimated by Dalzell *et al.* (1996) to be on average 275 t·year^{-1}. This estimate includes reef, deep-slope, pelagic and invertebrate fisheries. We used Dalzell *et al.*'s (1996) estimate for the 1989-1994 period but excluded estimates for trochus shells as these were mainly an export item not for human consumption. Angleviel (1999) estimates commercial catches for 1999 to be 300 t·year^{-1}, which is consistent with data supplied to FAO for that year. For all other years we used FAO catch estimates as presented by FAO.

Subsistence fisheries

Dalzell *et al.* (1996) estimated average annual subsistence catches to be 621 t·year^{-1} over the 1989-1994 time period, which translates into a *per capita* subsistence catch rate of 43.3 kg·person^{-1}·year^{-1}. As for many of the South Pacific Islands, Dalzell *et al.*'s (1996) subsistence data were derived from dietary or *per capita* consumption data, or more commonly, records of frequency of consumption. Bell *et al.* (2009) estimated seafood consumption rates throughout the South Pacific using household surveys. For Wallis and Futuna, Bell *et al.* (2009) estimated a seafood consumption rate of 74.6 kg·person^{-1}·year^{-1} for the early 2000s. Only a portion of this is supplied through commercial catches and the remainder is supplied through subsistence fisheries. We calculated the amount of seafood supplied through subsistence fisheries by subtracting the *per capita* commercial catch from the consumption rate presented by Bell *et al.* (2009). The result was a subsistence catch rate of 55 kg·person^{-1}·year^{-1}, which was higher than Dalzell *et al.*'s (1996) estimate for roughly the same time period. To remain conservative in our estimate, we used the subsistence catch rate given by Dalzell *et al.* (1996) of 43.5 kg·person^{-1}·year^{-1}.

For the early time period (1950s) we assumed that all fish consumed were supplied through subsistence fisheries. As many of the able bodied males left Wallis and Futuna in the 1950s to work in New Caledonia's Nickel industry, the number of fishers engaged in commercial fishing was reduced to almost nothing. Here we assumed that the *per capita* consumption rate for the early 1990s, based on subsistence catch (Dalzell *et al.*, 1996) and commercial catch (FAO), was similar to the rate of seafood consumption in the 1950s. Wallisians and Futunans derive the majority of their protein from the sea and although they import some frozen seafood products today, they eat very little in the way of tinned products and/or meat (Lambeth, 1999). Thus, we estimated the total seafood consumption rate for 1950 to be 63 kg·person^{-1} ·year^{-1}, which we assumed to be the subsistence catch rate for that year. To derive a complete time series for subsistence catch, we interpolated linearly from the 1950s subsistence catch rate to the 1989-1994 subsistence rate given by Dalzell et al. (1996). The 1989-1994 rate was carried forward, unaltered to 2007. To derive total subsistence catch (tonnes) for 1950-2007, we then applied the *per capita* subsistence catch rates to the human population data for Wallis and Futuna.

Catch composition

Commercial and subsistence fisheries of Wallis and Futuna take place mainly on the sheltered coastal reefs and lagoons (Kronen et *al.*, 2008). Only small amounts of fish are taken from outer reef areas and even fewer are caught offshore. At a national level, approximately 37% of catches are from Lagoon fisheries, 27% from barrier reefs, 22% from fringing reefs and 16% from external barrier reefs (Kronen *et al.*, 2008). The catch composition used here was based on work by the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C; Kronen *et al.*, 2008). Fisher surveys were conducted during the early 2000s covering both Wallis and Futuna, the various habitats fished and include commercial and subsistence sectors. The report documents catch amounts for over 60 species caught in the waters of Wallis and Futuna. While catch amounts were reported by species in Kronen *et al.* (2008), for the purposes of this report, they have been summarized by family. The main families caught were Acanthuridae (approximately 20%), Carangidae (14%), Lethrinidae (14%), Lutjanidae (9%) and Mugilidae (7%; Table 1). The other 15 families listed each represented less than 5% of the catch and miscellaneous marine fishes comprised the remaining 14% (Table 1).

Table 1. Estimated catch composition for commercial and subsistence fisheries of Wallis and Futuna (Kronen *et al.*, 2008).

Family	Percentage of catch (%)
Acanthuridae	20.58
Balistidae	0.11
Belonidae	0.04
Carangidae	13.65
Carcharhinidae	0.14
Chanidae	0.05
Coryphaenidae	0.07
Diodontidae	0.34
Holocentridae	3.28
Kyphosidae	2.06
Labridae	0.05
Lethrinidae	14.45
Lutjanidae	9.86
Misc. marine fishes	13.27
Mugilidae	7.35
Mullidae	2.70
Priacanthidae	0.31
Scaridae	4.77
Scombridae	0.08
Serranidae	3.77
Sphyraenidae	3.18

All landings, as supplied to FAO, prior to 1994 were reported as 'miscellaneous marine fishes'. After 1994, catches were also reported for miscellaneous crabs, sea cucumbers and spiny lobsters. Trochus shells, hard corals and turtles were also presented by the FAO but these categories were excluded from our analysis. The estimated catch composition presented by Kronen *et al.* (2008) was used for the taxonomic breakdown of the FAO's 'miscellaneous marine fishes' category in years when the FAO data were used as the best estimate of commercial catches. For commercial catches in years when independent data were used and for subsistence estimates, we applied the taxonomic breakdown from Kronen *et al.* (2008) to the catch totals.

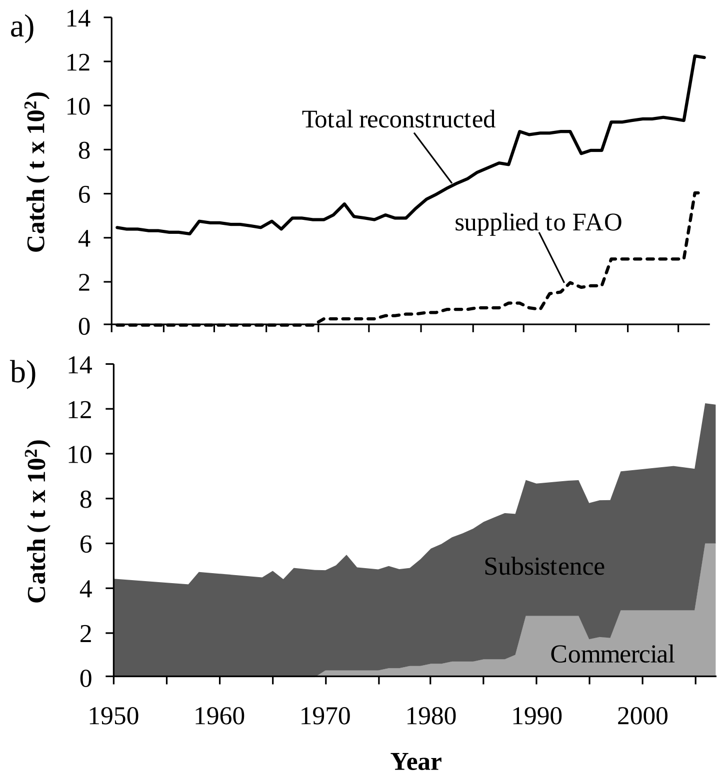

Figure 3. a) Total reconstructed fisheries catches for Wallis and Futuna (commercial and subsistence sectors combined) compared to the FAO's total catches, 1950-2007. b) Estimated catches by the commercial and subsistence sectors of Wallis and Futuna, 1950-2007.

RESULTS

For the period 1950-2007, the reconstructed total catch was estimated to be 37,583 t (Figure 3a). This total is 6.4 times larger than the total catches presented by the FAO on behalf of Wallis and Futuna from 1950-2007. Average annual catches rose from approximately 440 t·year⁻¹ in the 1950s to over 1000 t·year⁻¹ in the 2000s. Total subsistence catches were estimated to be 30,772 t over the 1950-2007 time period (Figure 3b). In the early time period, subsistence catches represented essentially 100% of fisheries catches, while overall they represented 82% of marine fisheries catches. The estimated commercial catch for the 1950-2007 time period was 6,811 t, the majority of which have been taken since 1980.

The taxonomic composition of commercial and subsistence catches was described to the species level; however, here we have grouped species by family. The reconstructed catch, which combined subsistence and commercial, was dominated by surgeonfish species, with an estimated catch of 7,500 t (Figure 4). Species in the Carangidae, Lethrinidae and Lutjanidae families also represented substantial amounts of the total reconstructed catch, with catches of approximately 5,000 t, 5,300 t and 3,600 t, respectively. Catches in the 'miscellaneous marine fishes' (MMF) grouping represented almost 5,000 t or 13% of the total reconstructed catch. The remaining 17 taxa were grouped into the category 'other taxa' as these families represented only minor proportions of the total catch.

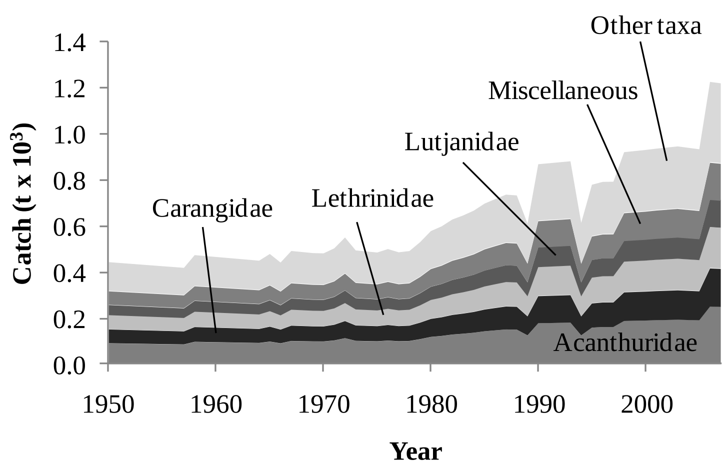

Figure 4. Total reconstructed catch by family for Wallis and Futuna, 1950-2007. The grouping 'other taxa' represents 17 taxa.

DISCUSSION

Our reconstruction of total marine fisheries catches for Wallis and Futuna from 1950-2007 was over six times larger than total catches presented by the FAO on behalf of Wallis and Futuna. This difference was largely driven by the absence of subsistence catches in official data. Commercial catches are not well documented over the 1950-2007 time period; however, we did find independent sources of fisheries data for some years (1989-1994 and 1999). Catches presented in these independent reports were similar in magnitude to the totals reported by FAO, giving confidence to our use of FAO catches in years when these were the only data available.

Subsistence catches were also poorly documented. We obtained a catch estimate for the subsistence sector in the recent time period (Dalzell *et al.*, 1996) and a report of *per capita* seafood consumption for the 2000s (Bell *et al.*, 2009). Both of these reports indicate substantial contributions by the subsistence sector as compared to the commercial sector. Household surveys conducted in the early 2000s revealed that 86% of annual *per capita* fish consumption is derived from the subsistence sector with the remaining 14% being purchased (Bell *et al.*, 2009). Purchased seafood is likely a combination of locally caught and imported products, as local catches are often insufficient to meet local demand (Taumaia, 1997).

The reef and lagoon resources that are the main target of both commercial and subsistence fisheries are considered heavily exploited. Overfishing was reported in both Wallis and Futuna as early as the 1930s (Burrows 1936, 1937 *in:* Kronen *et al.*, 2008). Overfishing has been caused mainly by the use of destructive and unsustainable fishing methods such as dynamite fishing and small-mesh gillnets (Kronen *et al.*, 2008). These methods continue to be used today as they remain largely unregulated.

Although attempts have been made to develop a domestic offshore fishery that would supply fish to the local market and alleviate pressure on inshore resources, this has been slow to take hold (Kronen *et al.*, 2008). Currently, tuna and other pelagics are targeted mainly by foreign fleets fishing in the waters of Wallis and Futuna. In the early 1990s, Fish Aggregating Devices (FADs) were deployed to encourage local fishers to target species further offshore (Kronen *et al.*, 2008). These attempts were only moderately successful, as tuna continue to contribute minimally to the total catch. A study conducted in the 1980s by Dalzell and Preston (1992) found potential for the development of a deep-water snapper fishery, yet catches of snapper have not increased since this discovery (Kronen *et al.*, 2008).

With local seafood supplies unable to meet local demand, imports are increasingly needed to fill this gap. Agricultural opportunities are limited on Wallis and Futuna, therefore, protein from the sea is a necessity. While imports are increasing and efforts to expand the supply of pelagic species continue, subsistence catches remain a substantial contributor to the seafood demands of Wallis and Futuna, yet are not accounted for in official statistics. This study highlights major deficiencies in the assessment and monitoring of Wallisian and Futunan fisheries.

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