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Fisheries Centre, University of British Columbia, Canada

Edited by

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Frédéric Le Manach, Daniel Pauly and Dirk Zeller

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Content

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Director's Foreword

Marine fisheries are exposed to a number of challenges, many deriving from other human activities. However, while they are impacted by coastal pollution, overfishing, habitat modification and climate changes, this is not necessarily reflected in their reported catch levels and/or composition, as catches are often unreported and also taxonomically over-aggregated. Indeed, environmental data quality is a growing problem, as public entities increasingly lack the resources to generate reliable statistics, resulting in important trends not being detected or detected too late.

Fishery resources, moreover, cannot be managed sustainably without correct baseline data. This is particularly important in small island states, where marine resources are often crucial to the food security, as well as financial security, of the islands' inhabitants. The fisheries that residents rely on are mostly the small-scale sectors (subsistence and artisanal), which often remain unmonitored and overlooked, thus representing the majority of unreported catches within global fisheries statistics.

The fishing capacity of developed countries has increased dramatically in the last decades as a result of successive waves of investments and technological innovation. Small island developing states and territories lack the resources to emulate these developments, and therefore must resign themselves to allow foreign vessels to exploit the resources of their Exclusive Economic Zones, usually for modest access fees. The income derived from selling the right to access their EEZs to foreign fleets can be a major source of revenue for these developing countries. Unfortunately, this also puts further stress on the marine resources, and may lead to competition when the species exploited by the foreign fleets are also consumed locally.

The extent of reporting coverage varies from country to country, but in almost every case, there are instances of Illegal, Unreported and Unregulated (IUU) catches. Catches may be missing from official statistics for a variety of reasons, but for most developing countries, lack of resources to properly monitor their fisheries appears to be the main problem. Unfortunately, it is also these developing countries that are most in need of proper monitoring, as the effects of overfishing and collapsed fisheries will have the most impact on them. A more accurate and complete estimate of total fisheries extractions is crucial to the implementation of proper management schemes, which will help to ensure continued food security. In some places, monitoring and reporting have drastically improved in more recent years, which is hopefully a sign of change to come.

As a follow up to *Fisheries catch reconstructions: Islands, Part I* and *Part II*, this report continues to utilize the methodology of reconstructing a historic time series of marine fisheries catches which was developed by researchers at the *Sea Around Us* Project. This edition carries on the assessment of islands in the Pacific, Indian and Atlantic Oceans, with the main focus being on South Pacific and Caribbean island countries and territories. Total marine fisheries extractions are estimated for the period of 1950 to 2010 in an effort to improve the reporting baseline for monitoring and management purposes. Regardless of the uncertainties emanating from having to utilize limited data, these catch reconstructions still provide a more complete and improved picture of the status of the fisheries compared to the official statistics currently used to inform management and policy decisions.

Ussif Rashid Sumaila, Director

UBC Fisheries Centre

November 2012

Cocos (Keeling) Islands and Christmas Island: Brief history of fishing and coastal catches (1950–2010)[1]

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Abstract

The fisheries statistics systems of many countries are performing poorly, often failing to report small-scale catches, particularly from subsistence and recreational fisheries. These deficiencies, which lead to the underestimation of catches, are particularly evident in overseas territories of developed countries. This study is an attempt to remedy this for the years 1950–2010 for the Australia Indian Ocean Territories, an area from which little reporting is done. The results suggest that the Cocos (Keeling) Islands (which Charles Darwin famously visited in 1836) had a catch of approximately 80 $t \cdot year^{-1}$ in the 1950s (subsitence only), which increased, starting in the mid-1980s, to 250 $t \cdot year^{-1}$ in recent years mainly due to the introduction of recreational and later large-scale commercial fishing, with signs of overexploitation since 2000. On the other hand, the coastal catch from Christmas Island was tentatively assessed as being higher (40-70 $t \cdot year^{-1}$) in the 1950s and 1960s than in the 2000s (32 $t \cdot year^{-1}$). Fisheries managers in these areas should focus on determining primary target species and their vulnerability to overfishing as well as developing island-specific recreational fishing management plans.

Introduction

Overexploitation of marine resources continues worldwide despite growing appreciation for the need to maintain marine ecosystem health and biodiversity. Fisheries management has traditionally focused on large-scale commercial operations mainly because of their economic importance and potential for overexploitation. Consequently, fisheries managers have typically ignored a significant portion of the world's catches – those derived from artisanal, subsistence or recreational fishing (e.g., Zeller *et al.* 2006; Zeller *et al.* 2007a; Jacquet *et al.* 2010; Le Manach *et al.* 2012). Historically, the importance of subsistence and artisanal fishing operations occurring along much of the world's coasts has gone unrecognized and subsequently unreported. And in places where reporting has occurred, catch statistics are often too vague to be useful for ecosystem analyses (Watson *et al.* 2004). The high prevalence of unreported subsistence, artisanal and recreational fisheries represents a critical knowledge gap in fisheries management and subsequent data-users often interpret non-reported or missing data as "zero" catches (Zeller *et al.* 2007a). Despite the general notion that they are data-poor, small-scale fisheries have recently been demonstrated to play important roles in economics, food security, culture, society and recreation (e.g., Sadovy 2005; Chuenpagdee *et al.* 2006; Zeller *et al.* 2007b; Boistol *et al.* 2011; Lingard *et al.* 2011; Le Manach *et al.* 2012). It is thus both necessary and justifiable to retroactively estimate catches using subjective inferences and interpolation methods in order to gain insight into historical catch trends based on the premise that the alternative assumption of zero catch is less desirable (Pauly 2007; Zeller *et al.* 2007a; Watson *et al.* 2011).

Many small islands, where substantial subsistence fishing occurs, are associated with larger developed countries, for example, Cocos (Keeling) Islands and Christmas Island, which are both Indian Ocean Territories of Australia (Figure 1). Despite this association, these small islands retain much of their traditional way of life, including being heavily dependent on marine resources (Alder *et al.* 2000). Currently, the small-scale fishing that occurs in these islands is excluded in the reporting of Australian national fisheries statistics. The remote nature of these islands and low urban development often result in them being described as pristine ecosystems (Parks Australia 2005). However, there have been recent reports of local extinctions and significant decreases in the density of highly sought-after marine species, especially in the Cocos (Keeling) Islands (Hender *et al.* 2001). As such, it is the aim of the present study to apply a "reconstruction approach"

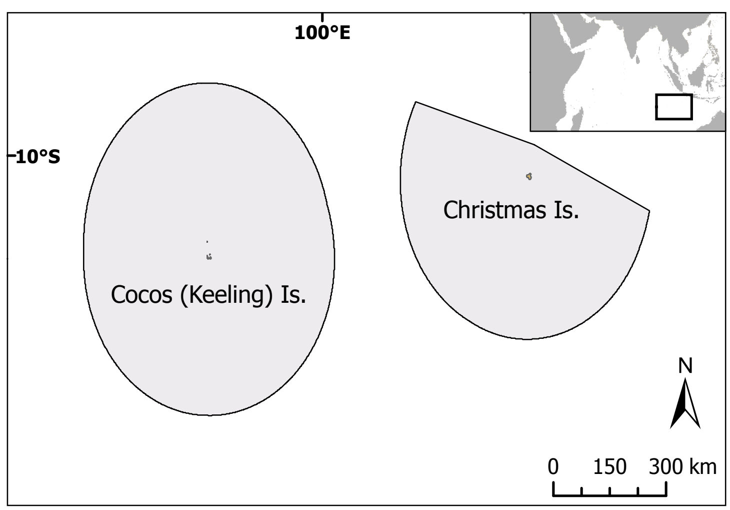

Figure 1. Location of Cocos (Keeling) and Christmas Islands. The gray areas correspond to their respective EEZs.

[1] Cite as: Greer, K., Harper, S., Zeller, D., and Pauly, D. (2012) Cocos (Keeling) Islands and Christmas Islands: Brief history of fishing and coastal catches (1950-2010). pp. 1-13. *In*: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

(Zeller *et al.* 2007a) to derive historic catch time series for the Australian Indian Ocean Territories (AIOT): Cocos (Keeling) Islands (CKI) and Christmas Island (CI). Note that the catch data presented here pertain only to coastal catches, i.e., exclude large pelagic fishes (mainly tuna).

Geographical, environmental and historical review of the island areas

Cocos (Keeling) Islands (12°12' S, 96°54' E) are situated in the eastern Indian Ocean, lying approximately 2,950 km north-west of Perth, Australia, and about 1,000 km south-west of Java, Indonesia (Figure 1). The CKI consist of 27 low-lying islands, which comprise two atolls: North Keeling and South Keeling. The single island of North Keeling remains uninhabited, and in 1995 was established as Pulu Keeling National Park, where access is by permit only. The park boundaries extend from the coastline to 1.5 km into the surrounding sea (Alder *et al.* 2000). South Keeling Atoll is comprised of 26 islands, with a total land area of 14 km² (Armstrong 1992). The islands are remote and are thought to have been completely submerged 4,000 years ago, implying that sea level fluctuations have affected shallow water marine biota (Woodroffe and Berry 1994). Endemism is unexpectedly low given the atoll's isolation.

The South Keeling Islands were first settled in 1827 by John Clunies-Ross and Alexander Hare who brought with them workers from Java and Sumatra (Gibson-Hill 1946). The Clunies-Ross family, which became known as the "King of Cocos," reigned over the island for more than 150 years (Woodroffe and Berry 1994). The family operated a feudal-style government whereby the Malay population (descendants of the original workforce brought in 1827) worked on the family's coconut oil plantation in exchange for housing and food. During this period, the islands were annexed by Britain. However, Queen Victoria granted full control of the islands to the Clunies-Ross family "in perpetuity" (Woodroffe and Berry 1994; Kerr 2009).

The CKI are well known among biologists because Charles Darwin on board HMS *Beagle* visited during the ship's circumnavigation of the world (Pauly 2004). The *Beagle* visited the CKI from April 1 to 12, 1836, and this gave Darwin the opportunity to test his theory of coral reef formation, the basic outline of which was thought out well before he had his first (and only) opportunity to study a coral reef during his visit to the CKI (Stoddart 1962; Woodroffe *et al.* 1990; Armstrong 1991). This theory, which turned out to be correct, was thus developed well before Darwin had all his "facts," in stark contrast to naïve perceptions of how science works. Here is an observation he recorded in his diary:

> I was employed all the day in examining the very interesting yet simple structure & origin of these islands. The water being unusually smooth, I waded in as far as the living mounds of coral on which the swell of the open sea breaks. In some of the gullies & hollows, there were beautiful green & other colored fishes, & the forms & tints of many of the Zoophites were admirable. It is excusable to grow enthusiastic over the infinite numbers of organic beings with which the sea of the tropics, so prodigal of life, teems; yet I must confess I think those naturalists who have described in well-known words the submarine grottoes, decked with a thousand beauties, have indulged in rather extravagant language. (April 4, 1836)

A total of 533 fish species are now reported from the CKI (Allen and Smith-Vaniz 1994), and 11 of those were sampled by Darwin (details in Pauly 2004), who also reported key observations on invertebrates and coral reefs (Armstrong 2004). Referring to "agencies" working against the growth of corals, Darwin also stated that "...some years before our visit unusually heavy rain killed nearly all the fish in the lagoon, and probably the same cause would likewise injure the corals" (*in* Stoddart 1962).

In 1955, the islands became a territory of Australia, and in 1978, unsatisfied with the Clunies-Ross rule of the island, Australia purchased all the lands except for the family home (Woodroffe and Berry 1994). However, it was not until 1984, that the Malay population still residing in CKI became citizens of Australia (Kerr 2009). Since the 1950s, the population of the CKI has fluctuated from 600–700, with a slight decrease in the late 1970s (Figure 2). However, there is an indication that prior to the 1950s, the population was around 1,000, with emigration to Borneo (probably due to decreased opportunities on CKI) accounting for the observed decline. The vast majority of the current population are "Cocos-Malay" people, who have maintained a largely traditional way of life rooted in Islam. They are heavily reliant on local marine resources for protein, although this reliance may

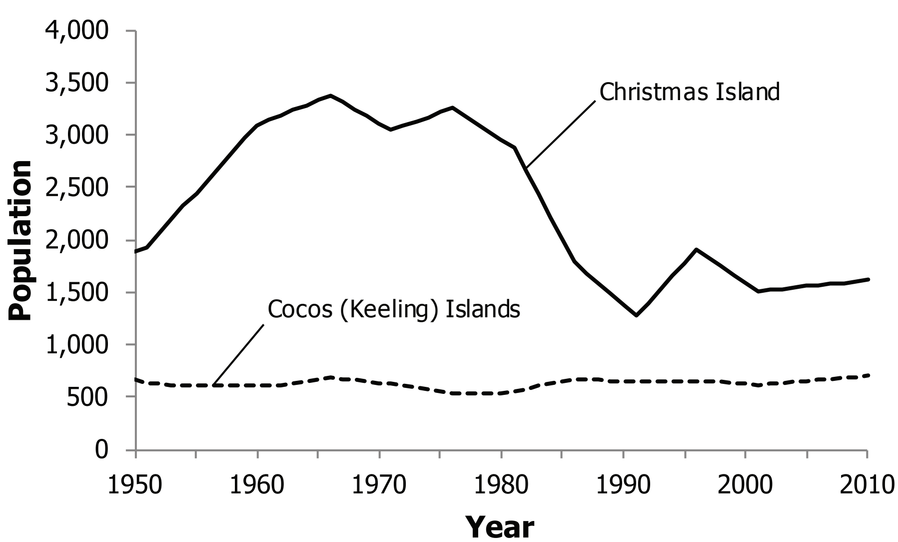

Figure 2. Population estimates for Cocos (Keeling) Islands and Christmas Island, 1950-2010.

have decreased slightly with mainland Australia's increasing presence. However, shipped products are expensive and employment opportunities on the island are few. Thus, many locals remain rooted in traditional cuisine and resource use. Culturally important species are the giant clam (*Tridacna* spp.), spider conch shell (*Lambis lambis*) and coral trout (*Plectropomus leopardus*) (Gibson-Hill 1946; Hender *et al.* 2001). The locals do not consume sharks, but those captured can be sold internationally (Gibson-Hill 1946). Fresh water and land suitable for agriculture are scarce on the islands. A small proportion of the CKI resident population is comprised of Australian expatriates and government workers. It is thought that this portion of the population, relative to the Cocos-Malay people, relies more on resources brought in from mainland Australia, but contributes significantly to a recreational fishing sector. There is a relatively small tourism industry which has been growing, with currently approximately 150 beds available for tourism, and flights occurring 1-2 times a week from Perth, Australia. The main attractions for tourists are fishing and diving.

Christmas Island (10˚30' S, 105˚40' E) is located 2,600 km north-west of Perth and 290 km south of Java, Indonesia (Figure 1). Geographically, although part of the same Vening-Meinesz seamount chain, CI differs drastically from CKI. CI is mountainous, surrounded by a fringing reef, which quickly drops off to deep, oceanic water (Hourston 2010). Although less remote than CKI, CI remained unsettled until the late 1800s when the Clunies-Ross family established a permanent settlement to provide lumber for use on CKI (Hourston 2010). Soon after, the settlement expanded to provide workers for phosphate mining. At this time, the islands were annexed by Britain and were later co-managed with Singapore. In 1957, the island was transferred to Australia. The majority of the island has since been designated a national park (Christmas Island National Park).

The population of CI has fluctuated since the 1950s, likely as a result of its boom and bust economy (Roughan *et al.* 2011), and its current size is approximately 1,600 permanent residents (Figure 2). In addition to phosphate mining, a large casino and resort was opened on the island in 1993, aimed primarily at rich Asian clientele. However, the resort began losing money and was shut down in 1998, causing job losses. The resort has since re-opened without the casino in an attempt to bring jobs and money to the island, but without the potential dire consequences of a casino in a small community. The resort is now one of four, forming the backbone of a small tourism industry. Like the CKI, most tourists come to the island for fishing or diving.

Since the 1970s, boats carrying asylum seekers have come to CI. In 2001, Australia opened the Christmas Island Immigration Detention Centre capable of housing approximately 1,200 asylum seekers (www.immi.gov.au). In 2010, the Australian government reported that there were more than 2,000 asylum seekers residing at the centre (Maley and Taylor 2010). The effect of the detention centre on local resources is unknown.

Much like those of the CKI, the local residents of CI are the descendants of mainly Chinese and Malaysian workers. Resources are brought in from mainland Australia. However, they are expensive and mainly consumed by the small Australian expatriate population. Less is known about the traditional and subsistence needs of the local people on CI than the CKI; however, it is thought that they also rely heavily on local marine resources. The bulk of the research about local biodiversity has focused on the (terrestrial) red crab (*Gecarcoidae natalis*) and the bird populations. There has been little study on local marine resources, and their level of exploitation and vulnerability remains unknown.

For a detailed description of the Australian acquisition of the CKI and CI, see *A Federation of these Seas* by Allan Kerr (2009).

Methods

The coastal catches of the AIOT have gone unreported; therefore they had to be reconstructed entirely. The methods used in this study were based on the methodology of Zeller *et al.* (2007). Estimates of marine catches were based on a literature review and utilized single-year anchor points of catch data in tonnes (t), *per capita* catch rates, human population data, interpolation techniques and anecdotal information. The available coverage in terms of fisheries sectors, targeted species, and culturally important information differed between island areas. Consequently the development of data anchor points also differed between the CKI and CI. The following sections outline, in detail, the methods used for each island territory. It should be noted that this study does not include large-scale commercial catches of high-seas species such as tunas, marlins and sharks.

Cocos (Keeling) Islands

Small-scale fishing

Small-scale fishing on the CKI consists of both subsistence and artisanal fishing. For the purposes of this study, subsistence fishing was defined as any fishing activity that does not generate an income above that needed to live at the most basic subsistence level. In contrast, artisanal fishing is defined as that carried out by individuals or households, involving low investment in technology and gear, whose catch is usually sold locally. A literature search uncovered two anchor points described as subsistence fishing for the years 1992 (Alder *et al.* 2000) and 1993 (Hender *et al.* 2001). In order to derive a complete time series of catch estimates we converted these anchor points to an average *per capita* consumption rate.

In order to estimate an average catch rate *per capita* it was necessary to first estimate the annual human population of the CKI since 1950. The Australian Bureau of Statistics (ABS) has been collecting census data every 5 years since 1986 for the CKI. Prior to 1986, population estimates were found on Populstat (www.populstat.info; accessed: April, 2012) for the following years: 1940, 1951, 1961, 1966, 1971, 1976 and 1981. In order to obtain a complete population time series since 1950, linear interpolation between years of known data was used to estimate the population for unknown years (Figure 2).

The 1992 and 1993 subsistence catch estimates given by Alder *et al.* (2000) and Hender *et al.* (2001) were given as ranges. The median for each range was used to calculate an average between the two years. The average population for those two years was also calculated. Therefore the average catch rate in kilograms *per capita* was calculated by dividing the average catch of 1992 and 1993 by the average population in those years. The average catch rate was found to be 115.11 kg·person^{-1}·year^{-1}. We assume that the *per capita* catch rate in 1950 was the same as for the 1992-1993 period. Thus, we multiplied this average *per capita* catch rate by the total population size for each year since 1950 to estimate the subsistence catch per year. We also assumed the same catch rate per capita going forward to 2010.

In small communities, it is often difficult to distinguish between fish used strictly for subsistence needs and fish that are sold to generate income for the household. In order to account for artisanal catch, we assumed no market economy existed prior to 1985. The arrival of Australian expatriates and government employees in the mid-1980s, together with a budding tourism industry, stimulated the economy, and hence stimulated the growth of an artisanal sector. As such, it was assumed that 10% of the estimated total subsistence catch turned into artisanal fishing from 1985 onwards. The artisanal catch remained constant at 10%, because resources brought in from mainland Australia are expensive, consequently it is likely that Cocos-Malay people continued to fish for themselves as opposed to transitioning over time to purchasing all their food.

Recreational fishing

Recreational catch can be defined as fishing where the main motivation is not consumption, trade or sale of the catch, but rather enjoyment. It is unlikely that prior to 1985 there was much recreational fishing occurring due to the absence of non-Cocos-Malay people in the CKI. As such, it was assumed that prior to 1985, the recreational catch was zero. For the remaining time period, two anchor points were found; one in 1993 and another in 2001 (Hender *et al.* 2001). A linear interpolation between a catch of zero tonnes in 1984 and an average recreational catch of 22.5 t in 1992 (Hender *et al.* 2001) was done to estimate annual recreational catches for the missing years. Similarly, an interpolation was used between the 1992 recreational catch estimate and a 2001 average recreational estimate of 106.2 t (Hender *et al.* 2001). The observed increase in recreational catches between these two anchor points is large. It is likely erroneous to assume that recreational catches continued to increase at such a rate past 2001, especially when tourism trends are considered (see below).

The tourism industry in the CKI remains relatively small, with regular flights initiated in the early 1990s. In addition, there have been no major developments to increase the tourist capacity on the island within the last decade. As a result, the recreational catch from 2002 until 2010 was estimated using a per tourist catch rate. Hotel occupancy rates for each state since 2001 are available on the ABS website. In order to estimate the occupancy rate for hotels in the CKI, the state of Western Australia's statistics were used as they are the governing state body of the AIOT. We were able to estimate the number of beds available for tourists on the island (approximately 150) and use the annual average occupancy rate derived from Western Australia statistics to determine the likely number of tourists on the island per year. It was then possible to take the recreational catch known in 2001, divide it by the number of tourists per year to yield a per tourist catch rate of 25 kg assuming that each tourist stays one week. The recreational catch rate from 2002 to 2010 was calculated by multiplying the number of tourists visiting the CKI per year, based on a one-week stay using an average occupancy rate as collected by the Western Australia government. Although the estimated catch of 25 kg per tourist may be high and not all tourists are going to fish, our estimate of recreational catch was considered conservative as the recreational catch of local residents was not estimated in addition to this.

Large-scale commercial fishing

Currently, there appear to be five large-scale commercial fishing licenses on issue, only one of which is considered active and it is a permit for the capture of live aquarium fish (beginning in 1993). Our study does not include fish taken for the aquarium trade, thus these data were excluded. Two more permits (out of the five) were issued beginning in 2002 by the Australian Fisheries Management Authority (AFMA) for exploratory purposes (AFMA 2002). At this time, the total allowable catch (TAC) was set at 20 t per permit annually. It is unknown to the authors whether or not this exploratory fishing continues to occur; the permits are renewed each year, but the fishery may be inactive. When contacted, the AFMA maintained its policy prohibiting the release of catch data to researchers. Thus, we assumed that since the licenses are issued annually, the fishery remains active and catches its total TAC of 20 t. The final two of the five permits issued allow Australian boats to fish for tuna in the CKI and CI offshore longline fisheries. However, these catches were not included here as large pelagic fishes (i.e., tunas) were not considered in this analysis. The total annual catch from 1950 to 2010 was derived by adding the annual catches from subsistence, artisanal, recreational and large-scale commercial fishing sectors.

Taxonomic breakdown of the catch

The baseline for determining what species comprise the catch came from an anthropological study completed in the mid-1940s, which outlined the catch supplied to European workers of the Cocos Cable Station over a four-month period by local Cocos-Malay fishers (Gibson-Hill 1946). The lowest taxonomic unit that could be distinguished was the family level, with fish from the families Serranidae, Latidae, Lethrinidae, Lutjanidae, Gerreidae, Labridae and Carangidae all contributing to the catch. The average proportion of each family over the four month period was calculated. When comparing the above list of families with other sources describing fisheries targets, it was found that it was a reasonable representation of reef fish, but failed to incorporate some culturally important species that would have likely been kept and consumed by Cocos-Malay fishers and not given to the European workers (i.e., spider conch shell, giant clam and sea cucumbers). Thus, the proportions were adjusted such that 90% of the catch is comprised of the aforementioned seven reef fish families, with the remaining 10% allocated to spider conch (*L. lambis;* 5%), sea cucumber (Holothurians; 2.5%) and *Tridacna* spp. (2.5%).

The above proportions were assumed to be constant from 1950-1992. In 1993 and again in 2001, studies were conducted on the densities of fish on the CKI (Hender *et al.* 2001). In particular, it was noted that the density of groupers (Serranidae), which made up the highest proportion of the catch in the 1940s, had declined from 136 individuals·hectare^{-1} to 36 individuals·hectare^{-1} (a decrease of about 75%). It is thus unlikely that the high proportion of Serranidae observed earlier in the catch continued throughout the 1990s. Therefore, we decreased the proportion of Serranidae in the catch in equal increments between the years 1993 and 2002, and increased the contribution of the other reef fish families accordingly. From 2003 onwards, the proportions of the reef fish families were assumed to remain constant.

Similarly, it was found that the giant clam may now be extinct from the near-shore waters of the CKI. According to a study conducted in 2001, there were only two individuals of *Tridacna gigas* known from the atoll at the time (Hender *et al.* 2001). In order to account for the change in density of *Tridacna* spp.*,* the proportion of the total catch was decreased from 2.5% to 0.005% from 1993 to 2002. In order to account for this change, the proportion of spider conch shells increased to make up the difference. The increase in spider conch is justified because prior to contact with mainland Australia, its collection was largely restricted to exposed reefs during low tide whereby women and children would collect them by hand. However, increased access to equipment such as masks and snorkels has made it possible to now access spider conchs in deeper waters (J. Hender, pers. comm., Australian Department of Climate Change and Energy Efficiency).

Christmas Island

Small-scale fishing

Our literature search yielded no quantitative data on subsistence or artisanal fishing on CI. In order to estimate catches for these sectors, a seafood consumption estimate was used. The first step in this approach was to estimate the annual resident population since 1950. This was done in the same manner as for Cocos (Keeling) Island, first using ABS and Populstat (www.populstat.info; accessed: April, 2012) to provide anchor points, followed by linear interpolations between census population estimates (Figure 2). The next step was to determine an estimate of *per capita* consumption of seafood on CI. The World Health Organization (WHO) suggests that in 1997 the global average was 16 kg of fish *per capita* with island countries having substantially higher dependence on protein derived from fish (www.who.in.en; accessed: April, 2012). A study conducted by Bell *et al.* (2009) found fish consumption in the Pacific Islands and territories to be much higher than what was indicated by the WHO. On average, Pacific Island countries and territories consume 50.7 kg *per capita* per year (Bell *et al.* 2009). It is likely that CI has fishing habits similar to Pacific countries, but to remain conservative, a *per capita* consumption rate of 35.5 kg was used for the 1950-1989 time period. Increasing presence from mainland Australia would likely have decreased fish consumption rates due to increased availability of alternative protein sources. Therefore beginning in 1990, we assumed *per capita* consumption started to decrease so that by the year 2000 it had decreased by 30%. For the remaining years it was assumed that the *per capita* consumption rate remained constant and the rate for 2000 was thus carried forward, unaltered, to 2010. To remain conservative, only 60% of the population was considered to partake in small-scale fishing throughout the entire time period.

For the purpose of this study, it was necessary to allocate proportions of the total small-scale catch to either subsistence or artisanal sectors. CI has had a stronger presence from mainland Australia than the CKI due to phosphate mining, resort development, asylum seekers, and the development of a large immigration detention centre. Consequently, there has been greater potential for market growth over a longer period of time. Subsistence fishing was considered responsible for 75% of the total small-scale catch and artisanal fishing made up the remaining 25%. These proportions remained unchanged from 1950-2010.

Large-scale commercial fishing

There is one large-scale commercial fishery operating out of CI: the Christmas Island Line Fishery (CILF). It is not known exactly when the fishery opened, but there were six large-scale commercial fishing permits issued as early as 1992 (APH 1997). However, by 2007, there were only three large-scale commercial fishing permits available and only one operating in 2008 (DoF 2009). In keeping with Western Australia's privacy policy, reported catches were not available. As such, catch was estimated since 1992, gradually decreasing the number of boats (assumed to be less than 10 m) fishing for 100 days of the year with a starting catch rate of 30 kg·day^{-1}. This catch rate was assumed to remain constant for the remainder of the study period.

Recreational fishing

Information on recreational fishing for CI was unavailable. However, it is likely that some recreational fishing does occur, albeit to a lesser extent than on CKI, due to the substantially more inaccessible coast and coastal waters of Christmas Island. It was assumed that recreational fishing in CI also started in 1985 (as in CKI). However, CI did not experience the changes in the tourism industry that CKI did, and therefore does not exhibit the same increase in catches. Catches were assumed to be zero tonnes in 1984, with a conservative estimate of a constant 1 t·year^{-1} from 1985-2010.

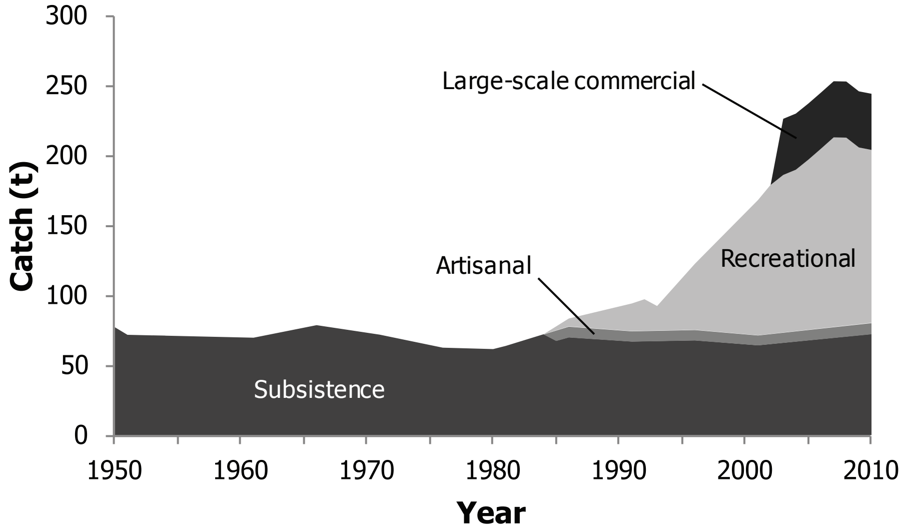

Figure 3. Estimated total catch for Cocos (Keeling) Islands, a remote Australian Indian Ocean territory, indicating individual fishing sector contributions, 1950-2010.

Taxonomic breakdown of catch

No studies have investigated the species caught from either small-scale fisheries or large-scale commercial fishing on CI. Thus, we used the catch composition established for the CKI, due to similarities between the reef species composition on the two islands, with some small adjustments. We assumed again that seven reef fish families (Serranidae, Latidae, Lethrinidae, Lutjanidae, Gerreidae, Labridae, and Carangidae) comprise 60% of the total catch from 1950–2010, with the remaining 40% divided between crustaceans (25%) and an "other invertebrates" category (15%).

Results

Cocos (Keeling) Islands

The total reconstructed estimate of coastal catches for the CKI over the 1950-2010 time period was 6,453 t. Estimated catches have risen from approximately 70 t·year^{-1} in the 1950s to 250 t·year^{-1} in the late 2000s (Figure 3). This has occurred despite the population remaining quite stable (Figure 2). Prior to the early 2000s, the bulk of the catch was taken by local subsistence fishers. However, beginning in the early 1990s, fishing by other sectors (recreational and large-scale commercial) began increasing. Presently, it is estimated that the large-scale commercial and recreational fishing sectors extract more than three times as much as small-scale fishing (subsistence and artisanal) in any given year (Figure 3). The analysis regarding species landed from the CKI revealed that the majority of fish caught are likely to be groupers (family Serranidae) especially prior to the early 1990s (Figure 4). Prior to their decrease in the 1990s, serranids comprised 63% of the total catch and more recently comprise 15% of the total annual catch.

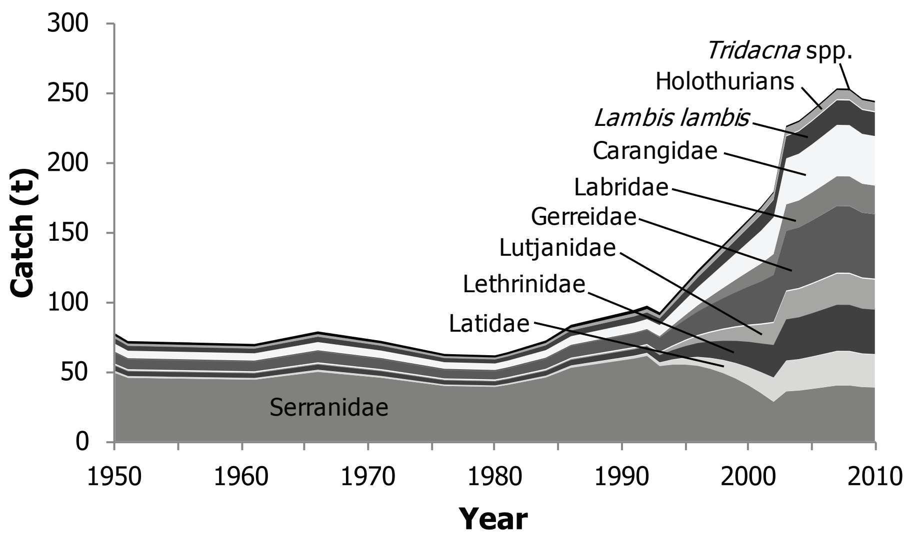

Figure 4. Taxonomic breakdown of Cocos (Keeling) Islands total catch, 1950-2010.

Christmas Island

The total reconstructed estimate for coastal catches of CI over the 1950-2010 time period was 3,115 t. The total catch on CI peaked at 72 t·year^{-1} in 1966 and is presently estimated to be about 31 t·year^{-1}

(Figure 5). The catch almost doubled from 1991 to the mid-1990s (resulting in a secondary peak), which can be explained by the introduction of a large-scale commercial fishing sector in 1992. After a short-lived increase, catches again decreased. This was both a product of decreased consumption and decreased effort in the large-scale commercial sector. This led to a decline in catches to approximately 31 t·year^{-1} by the late 2000s. As a result of our assumptions, the taxonomic breakdown of the catch is dominated by reef fish families, each of which comprise approximately 8% of the total annual catch from 1950-2010 (Figure 6). Crustaceans are likely to contribute a significant proportion of annual catches, estimated to be about 25% in this study. Other invertebrates, such as squid and bivalves, constitute the remaining 15% of the catch.

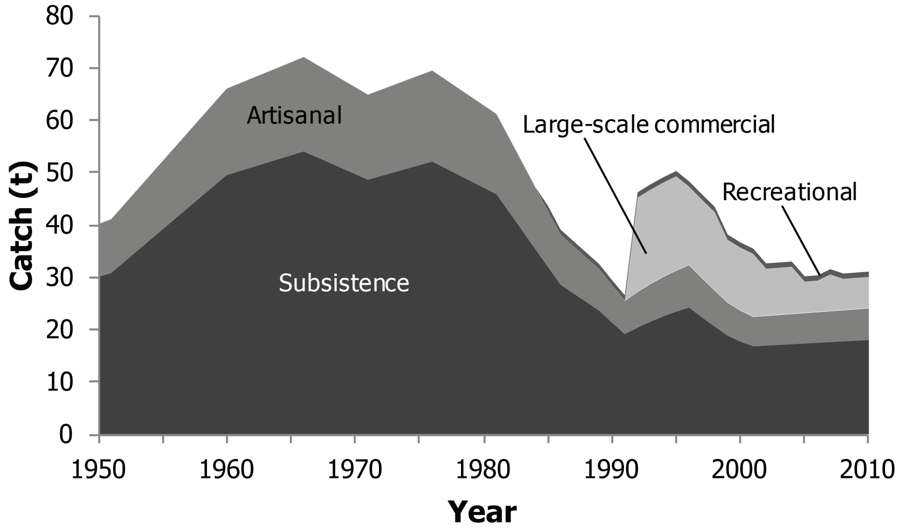

Figure 5. Estimated total catch for Christmas Island, an Australian Indian Ocean Territory, indicating different fishing sector contributions, 1950-2010.

Discussion

The present study used a reconstruction approach (Zeller *et al.* 2007) to retrospectively calculate the total catch, as well as the contributions of individual fishing sectors and the taxonomic breakdown of the catch, for 1950-2010 for the Australian Indian Ocean Territories. There has been no formal collection of data for these territories, therefore this is the first attempt to provide a historical total fisheries catch time series for these islands. The results suggest that fishing is far from negligible, with the CKI landing approximately 250 t and CI landing approximately 31 t in 2010.

What remain to be determined are the levels of fishing that can be sustained. One such estimate was generated in 1999, based on standing stock biomass collected in 1993 by Lincoln-Smith and a sustainable catch rate of 160–320 tonnes per year was estimated (Hender *et al.* 2001). Thus, our results suggest that overfishing may have been occurring in the waters of the CKI for about a decade. These results are further supported by anecdotal evidence describing local depletions of less resilient species such as coral trout (*Plectropomus* spp.) and humphead wrasse (*Cheilinus undulatus*), in addition to the groupers mentioned above (Hender *et al.* 2001; Hourston 2010).

For both islands, recreational fishing presents a problem. The CKI's small-scale fishery, apart from a few culturally important species, likely remains below the estimated sustainable annual stock harvest (Hender *et al.* 2001). The recreational fishing industry has grown substantially in the last two decades, placing unprecedented pressure on marine populations of the atoll. For CI, the impact of recreational fishing remains unknown. The need for management of the marine resources of the CKI is not lost on the Australian Government: "Island specific recreational fisheries management arrangements for the Indian Ocean Territories are currently being progressed to legislation" (DoF 2011).

We have no evidence suggesting any overfishing around CI. However, the lack of information on CI is alarming. The present study was not able to accurately estimate catches for the recreational sector, which for CKI, was a substantial component of the total catch since the mid-1990s. Also, the consumption rate used in this study was a conservative *per capita* estimate of 35.5 kg at the start and 24.85 kg at the end of the study period. Comparable island entities have been found to have much higher *per capita* consumption rates (Bell *et al.* 2009; Gillett 2009; Trujillo *et al.* 2011). Therefore it is important to find out what the habits of Christmas Islanders are. Presently, there is little information regarding their dietary or cultural habits and this represents a critical limiting factor

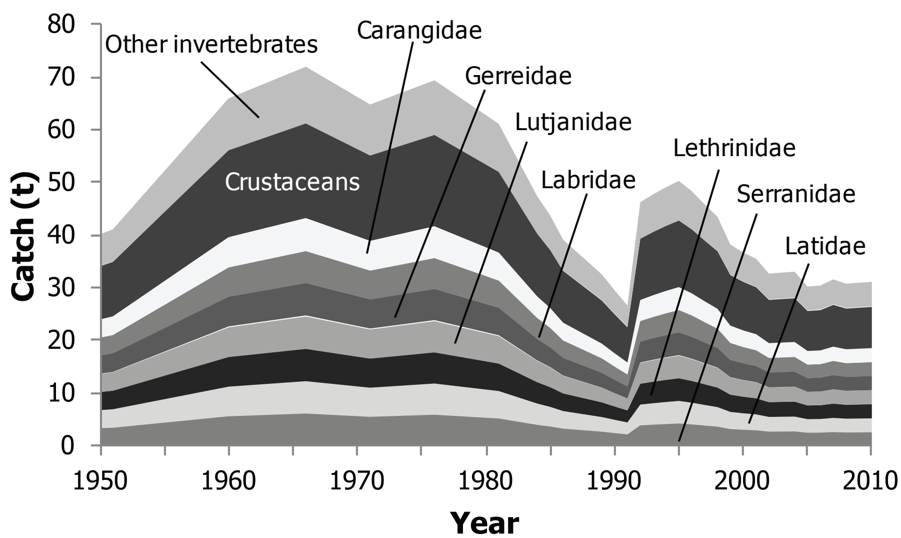

Figure 6. Taxonomic breakdown assumed for Christmas Island catch, 1950-2010.

for the methods used to determine catches in this study. Research tactics such as a household survey every couple of years would provide a greater understanding of the needs of these islanders (Zeller *et al.* 2007).

Large-scale commercial fishing in both territories appears to be minimal. However, the study was hindered by the inaccessibility of catch data. A report for the CKI evaluated the viability of large-scale commercial fishing for some species, such as sea cucumbers and spider conch shell. However, it also found that the majority of "potential" fisheries candidates were not actually viable (Hourston 2010). The large-scale commercial catch for the CKI estimated here, assumed that exploratory fishing continues to occur in the absence of a CKI-specific fisheries management plan. In contrast, the large-scale commercial fishing that takes place at CI does have some form of management in place. It should also be noted that large-scale commercial fishing for large pelagic species such as tuna and billfish does occur in the EEZ of both CKI and CI. These data were not included in this report as the fishery is part of the Western Australia Tuna and Billfish fishery, which also fishes off the west coast of Australia. These data are difficult to disaggregate spatially and are likely accounted for in the statistics of regional fisheries management organizations and by FAO reported landings for Australia. The interaction between this large-scale commercial fishery and the small-scale fishing sector is not well understood and research of this interaction would be crucial to any fisheries management plan.

Another problem in the EEZ of CI is illegal foreign fishing (APH 1997). The EEZ claimed by Australia for CI and by Indonesia for Java overlap, which has created disputes over fishing rights and management of resources. Australia reported that in the 1990s, 40-60 illegal foreign fishing vessels were apprehended per year in the EEZ of CI (APH 1997). Although illegal fishing was not included in this analysis, it should be addressed by resource managers.

Overall, this study found the extraction of fisheries resources from the AIOT to be significant, and thus requires implementation and enforcement of a fisheries management plan specific to each island area. The time series presented here are an attempt to provide managers with an estimation of catches in areas where fishing is occurring, but reporting is not. It is hoped that fishing on what are considered some of the last pristine reefs of the world does not continue to go unnoticed and unmanaged because of the notion that impacts resulting from small-scale fishing are negligible.

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Appendix Table A1. Total reconstructed catch (t) for the Cocos (Keeling) Islands by sector, 1950-2010.

Year	Total reconstructed catch	Subsistence	Artisanal	Large-scale commercial	Recreational
1950	77	77	-	-	-
1951	72	72	-	-	-
1952	72	72	-	-	-
1953	71	71	-	-	-
1954	71	71	-	-	-
1955	71	71	-	-	-
1956	71	71	-	-	-
1957	71	71	-	-	-
1958	70	70	-	-	-
1959	70	70	-	-	-
1960	70	70	-	-	-
1961	70	70	-	-	-
1962	72	72	-	-	-
1963	73	73	-	-	-
1964	75	75	-	-	-
1965	77	77	-	-	-
1966	79	79	-	-	-
1967	77	77	-	-	-
1968	76	76	-	-	-
1969	75	75	-	-	-
1970	73	73	-	-	-
1971	72	72	-	-	-
1972	70	70	-	-	-
1973	68	68	-	-	-
1974	66	66	-	-	-
1975	64	64	-	-	-
1976	63	63	-	-	-
1977	62	62	-	-	-
1978	62	62	-	-	-
1979	62	62	-	-	-
1980	62	62	-	-	-
1981	64	64	-	-	-
1982	67	67	-	-	-
1983	69	69	-	-	-
1984	72	72	-	-	-
1985	78	68	7.5	-	2.8
1986	83	70	7.8	-	5.6
1987	86	69	7.7	-	8.4
1988	88	69	7.6	-	11.3
1989	90	68	7.6	-	14.1
1990	92	68	7.5	-	16.9
1991	94	67	7.4	-	19.7
1992	97	67	7.5	-	22.5
1993	92	67	7.5	-	17.5
1994	102	68	7.5	-	27.4
1995	112	68	7.5	-	37.2
1996	122	68	7.5	-	47.1
1997	132	67	7.5	-	56.9
1998	141	66	7.4	-	66.8
1999	150	66	7.3	-	76.6
2000	159	65	7.2	-	86.5
2001	168	64	7.1	-	96.3
2002	179	65	7.2	-	106.2
2003	226	66	7.3	40	112.3
2004	230	67	7.4	40	115.1
2005	237	68	7.5	40	121.3
2006	245	69	7.6	40	128.1
2007	253	70	7.7	40	135.1
2008	252	71	7.8	40	134.0
2009	245	71	7.9	40	126.0
2010	244	72	8.0	40	123.2

Appendix Table A2. Total reconstructed catch (t) for the Cocos (Keeling) Islands by major taxa, 1950-2010.

Year	Serranidae	Latidae	Lethrinidae	Lutjanidae	Gerreidae	Labridae	Carangidae	*Lambis lambis*	Holothurians	*Tridacna* spp.
1950	49	1.5	4.2	0.70	8.5	0.35	5.3	3.9	1.9	1.9
1951	46	1.4	3.9	0.65	7.9	0.32	4.9	3.6	1.8	1.8
1952	45	1.4	3.9	0.64	7.9	0.32	4.9	3.6	1.8	1.8
1953	45	1.4	3.9	0.64	7.9	0.32	4.9	3.6	1.8	1.8
1954	45	1.4	3.8	0.64	7.9	0.32	4.9	3.6	1.8	1.8
1955	45	1.4	3.8	0.64	7.8	0.32	4.9	3.5	1.8	1.8
1956	45	1.4	3.8	0.64	7.8	0.32	4.9	3.5	1.8	1.8
1957	45	1.3	3.8	0.64	7.8	0.32	4.8	3.5	1.8	1.8
1958	45	1.3	3.8	0.63	7.8	0.32	4.8	3.5	1.8	1.8
1959	45	1.3	3.8	0.63	7.7	0.32	4.8	3.5	1.8	1.8
1960	44	1.3	3.8	0.63	7.7	0.31	4.8	3.5	1.7	1.7
1961	44	1.3	3.8	0.63	7.7	0.31	4.8	3.5	1.7	1.7
1962	45	1.4	3.9	0.64	7.9	0.32	4.9	3.6	1.8	1.8
1963	47	1.4	4.0	0.66	8.1	0.33	5.0	3.7	1.8	1.8
1964	48	1.4	4.1	0.68	8.3	0.34	5.2	3.8	1.9	1.9
1965	49	1.5	4.2	0.69	8.5	0.35	5.3	3.8	1.9	1.9
1966	50	1.5	4.3	0.71	8.7	0.35	5.4	3.9	2.0	2.0
1967	49	1.5	4.2	0.70	8.5	0.35	5.3	3.9	1.9	1.9
1968	48	1.5	4.1	0.68	8.4	0.34	5.2	3.8	1.9	1.9
1969	47	1.4	4.0	0.67	8.2	0.34	5.1	3.7	1.9	1.9
1970	47	1.4	4.0	0.66	8.1	0.33	5.0	3.7	1.8	1.8
1971	46	1.4	3.9	0.65	7.9	0.32	4.9	3.6	1.8	1.8
1972	44	1.3	3.8	0.63	7.7	0.32	4.8	3.5	1.8	1.8
1973	43	1.3	3.7	0.61	7.5	0.31	4.7	3.4	1.7	1.7
1974	42	1.3	3.6	0.60	7.3	0.30	4.6	3.3	1.7	1.7
1975	41	1.2	3.5	0.58	7.1	0.29	4.4	3.2	1.6	1.6
1976	40	1.2	3.4	0.56	6.9	0.28	4.3	3.1	1.6	1.6
1977	40	1.2	3.4	0.56	6.9	0.28	4.3	3.1	1.6	1.6
1978	39	1.2	3.4	0.56	6.8	0.28	4.3	3.1	1.6	1.6
1979	39	1.2	3.3	0.56	6.8	0.28	4.2	3.1	1.5	1.5
1980	39	1.2	3.3	0.55	6.8	0.28	4.2	3.1	1.5	1.5
1981	41	1.2	3.4	0.57	7.0	0.29	4.4	3.2	1.6	1.6
1982	42	1.3	3.6	0.60	7.4	0.30	4.6	3.3	1.7	1.7
1983	44	1.3	3.8	0.63	7.7	0.31	4.8	3.5	1.7	1.7
1984	46	1.4	3.9	0.65	8.0	0.33	5.0	3.6	1.8	1.8
1985	49	1.5	4.2	0.70	8.6	0.35	5.3	3.9	1.9	1.9
1986	53	1.6	4.5	0.75	9.2	0.38	5.7	4.2	2.1	2.1
1987	54	1.6	4.6	0.77	9.4	0.39	5.9	4.3	2.1	2.1
1988	56	1.7	4.7	0.79	9.7	0.39	6.0	4.4	2.2	2.2
1989	57	1.7	4.9	0.81	9.9	0.40	6.2	4.5	2.2	2.2
1990	58	1.8	5.0	0.83	10.1	0.41	6.3	4.6	2.3	2.3
1991	60	1.8	5.1	0.85	10.4	0.42	6.5	4.7	2.4	2.4
1992	62	1.9	5.2	0.87	10.7	0.44	6.7	4.9	2.4	2.4
1993	54	2.5	5.7	1.56	10.9	1.15	7.1	4.8	2.3	2.1
1994	55	3.6	7.2	2.55	12.9	2.09	8.7	5.5	2.6	2.2
1995	55	4.8	8.7	3.69	15.1	3.18	10.4	6.3	2.8	2.1
1996	54	6.2	10.5	4.99	17.4	4.44	12.3	7.1	3.1	2.1
1997	52	7.7	12.3	6.40	19.7	5.81	14.2	7.9	3.3	2.0
1998	49	9.4	14.3	7.96	22.2	7.33	16.3	8.7	3.5	1.8
1999	45	11.2	16.4	9.66	24.8	8.99	18.6	9.6	3.7	1.6
2000	40	13.1	18.7	11.50	27.6	10.79	21.0	10.5	4.0	1.4
2001	35	15.2	21.0	13.49	30.5	12.74	23.5	11.4	4.2	1.2
2002	28	17.6	23.8	15.78	33.9	14.98	26.4	12.5	4.5	0.9
2003	36	22.2	30.1	19.94	42.8	18.93	33.4	15.8	5.6	1.1
2004	36	22.6	30.6	20.27	43.5	19.24	34.0	16.1	5.7	1.1
2005	38	23.3	31.6	20.91	44.9	19.84	35.0	16.6	5.9	1.2
2006	39	24.1	32.6	21.60	46.4	20.50	36.2	17.1	6.1	1.2
2007	40	24.9	33.7	22.31	47.9	21.17	37.4	17.7	6.3	1.3
2008	40	24.8	33.7	22.29	47.8	21.16	37.3	17.7	6.3	1.3
2009	39	24.2	32.7	21.67	46.5	20.57	36.3	17.2	6.1	1.2
2010	39	24.0	32.5	21.52	46.2	20.42	36.0	17.1	6.1	1.2

Appendix Table A3. Total reconstructed catch (t) for Christmas Island by sector, 1950-2010.

Year	Total reconstructed catch	Subsistence	Artisanal	Large-scale commercial	Recreational
1950	40	30	10.0	-	-
1951	41	31	10.3	-	-
1952	44	33	11.0	-	-
1953	47	35	11.7	-	-
1954	49	37	12.3	-	-
1955	52	39	13.0	-	-
1956	55	41	13.7	-	-
1957	58	43	14.4	-	-
1958	60	45	15.1	-	-
1959	63	47	15.8	-	-
1960	66	50	16.5	-	-
1961	67	50	16.8	-	-
1962	68	51	17.0	-	-
1963	69	52	17.3	-	-
1964	70	53	17.5	-	-
1965	71	53	17.8	-	-
1966	72	54	18.0	-	-
1967	71	53	17.6	-	-
1968	69	52	17.3	-	-
1969	68	51	16.9	-	-
1970	66	50	16.6	-	-
1971	65	49	16.2	-	-
1972	66	49	16.4	-	-
1973	67	50	16.7	-	-
1974	68	51	16.9	-	-
1975	69	51	17.1	-	-
1976	69	52	17.4	-	-
1977	68	51	16.9	-	-
1978	66	50	16.5	-	-
1979	64	48	16.1	-	-
1980	63	47	15.7	-	-
1981	61	46	15.3	-	-
1982	57	42	14.1	-	-
1983	52	39	13.0	-	-
1984	47	35	11.8	-	-
1985	44	32	10.7	-	1
1986	39	29	9.5	-	1
1987	37	27	9.0	-	1
1988	35	25	8.4	-	1
1989	33	24	7.9	-	1
1990	29	21	7.1	-	1
1991	27	19	6.4	-	1
1992	46	20	6.8	18	1
1993	48	22	7.2	18	1
1994	49	23	7.5	18	1
1995	50	23	7.8	18	1
1996	48	24	8.1	15	1
1997	46	22	7.5	15	1
1998	43	21	6.9	15	1
1999	38	19	6.3	12	1
2000	37	18	5.9	12	1
2001	35	17	5.6	12	1
2002	33	17	5.7	9	1
2003	33	17	5.7	9	1
2004	33	17	5.8	9	1
2005	30	17	5.8	6	1
2006	30	18	5.8	6	1
2007	32	18	5.9	7	1
2008	31	18	5.9	6	1
2009	31	18	6.0	6	1
2010	31	18	6.0	6	1

Appendix Table A4. Total reconstructed catch (t) for Christmas Island by major taxa, 1950-2010.

Year	Serranidae	Latidae	Lethrinidae	Lutjanidae	Gerreidae	Labridae	Carangidae	Crustaceans	Other invertebrates
1950	3.4	3.4	3.4	3.4	3.4	3.4	3.4	10.0	6.0
1951	3.5	3.5	3.5	3.5	3.5	3.5	3.5	10.3	6.2
1952	3.8	3.8	3.8	3.8	3.8	3.8	3.8	11.0	6.6
1953	4.0	4.0	4.0	4.0	4.0	4.0	4.0	11.7	7.0
1954	4.2	4.2	4.2	4.2	4.2	4.2	4.2	12.3	7.4
1955	4.5	4.5	4.5	4.5	4.5	4.5	4.5	13.0	7.8
1956	4.7	4.7	4.7	4.7	4.7	4.7	4.7	13.7	8.2
1957	4.9	4.9	4.9	4.9	4.9	4.9	4.9	14.4	8.7
1958	5.2	5.2	5.2	5.2	5.2	5.2	5.2	15.1	9.1
1959	5.4	5.4	5.4	5.4	5.4	5.4	5.4	15.8	9.5
1960	5.7	5.7	5.7	5.7	5.7	5.7	5.7	16.5	9.9
1961	5.7	5.7	5.7	5.7	5.7	5.7	5.7	16.8	10.1
1962	5.8	5.8	5.8	5.8	5.8	5.8	5.8	17.0	10.2
1963	5.9	5.9	5.9	5.9	5.9	5.9	5.9	17.3	10.4
1964	6.0	6.0	6.0	6.0	6.0	6.0	6.0	17.5	10.5
1965	6.1	6.1	6.1	6.1	6.1	6.1	6.1	17.8	10.7
1966	6.2	6.2	6.2	6.2	6.2	6.2	6.2	18.0	10.8
1967	6.0	6.0	6.0	6.0	6.0	6.0	6.0	17.6	10.6
1968	5.9	5.9	5.9	5.9	5.9	5.9	5.9	17.3	10.4
1969	5.8	5.8	5.8	5.8	5.8	5.8	5.8	16.9	10.2
1970	5.7	5.7	5.7	5.7	5.7	5.7	5.7	16.6	9.9
1971	5.6	5.6	5.6	5.6	5.6	5.6	5.6	16.2	9.7
1972	5.6	5.6	5.6	5.6	5.6	5.6	5.6	16.4	9.9
1973	5.7	5.7	5.7	5.7	5.7	5.7	5.7	16.7	10.0
1974	5.8	5.8	5.8	5.8	5.8	5.8	5.8	16.9	10.1
1975	5.9	5.9	5.9	5.9	5.9	5.9	5.9	17.1	10.3
1976	6.0	6.0	6.0	6.0	6.0	6.0	6.0	17.4	10.4
1977	5.8	5.8	5.8	5.8	5.8	5.8	5.8	16.9	10.2
1978	5.7	5.7	5.7	5.7	5.7	5.7	5.7	16.5	9.9
1979	5.5	5.5	5.5	5.5	5.5	5.5	5.5	16.1	9.7
1980	5.4	5.4	5.4	5.4	5.4	5.4	5.4	15.7	9.4
1981	5.2	5.2	5.2	5.2	5.2	5.2	5.2	15.3	9.2
1982	4.8	4.8	4.8	4.8	4.8	4.8	4.8	14.1	8.5
1983	4.5	4.5	4.5	4.5	4.5	4.5	4.5	13.0	7.8
1984	4.1	4.1	4.1	4.1	4.1	4.1	4.1	11.8	7.1
1985	3.7	3.7	3.7	3.7	3.7	3.7	3.7	10.9	6.6
1986	3.4	3.4	3.4	3.4	3.4	3.4	3.4	9.8	5.9
1987	3.2	3.2	3.2	3.2	3.2	3.2	3.2	9.2	5.5
1988	3.0	3.0	3.0	3.0	3.0	3.0	3.0	8.7	5.2
1989	2.8	2.8	2.8	2.8	2.8	2.8	2.8	8.1	4.9
1990	2.5	2.5	2.5	2.5	2.5	2.5	2.5	7.4	4.4
1991	2.3	2.3	2.3	2.3	2.3	2.3	2.3	6.6	4.0
1992	4.0	4.0	4.0	4.0	4.0	4.0	4.0	11.6	6.9
1993	4.1	4.1	4.1	4.1	4.1	4.1	4.1	11.9	7.2
1994	4.2	4.2	4.2	4.2	4.2	4.2	4.2	12.3	7.4
1995	4.3	4.3	4.3	4.3	4.3	4.3	4.3	12.6	7.5
1996	4.1	4.1	4.1	4.1	4.1	4.1	4.1	12.1	7.2
1997	3.9	3.9	3.9	3.9	3.9	3.9	3.9	11.5	6.9
1998	3.7	3.7	3.7	3.7	3.7	3.7	3.7	10.9	6.5
1999	3.3	3.3	3.3	3.3	3.3	3.3	3.3	9.5	5.7
2000	3.1	3.1	3.1	3.1	3.1	3.1	3.1	9.2	5.5
2001	3.0	3.0	3.0	3.0	3.0	3.0	3.0	8.9	5.3
2002	2.8	2.8	2.8	2.8	2.8	2.8	2.8	8.2	4.9
2003	2.8	2.8	2.8	2.8	2.8	2.8	2.8	8.2	4.9
2004	2.8	2.8	2.8	2.8	2.8	2.8	2.8	8.3	5.0
2005	2.6	2.6	2.6	2.6	2.6	2.6	2.6	7.5	4.5
2006	2.6	2.6	2.6	2.6	2.6	2.6	2.6	7.6	4.6
2007	2.7	2.7	2.7	2.7	2.7	2.7	2.7	7.9	4.7
2008	2.6	2.6	2.6	2.6	2.6	2.6	2.6	7.7	4.6
2009	2.6	2.6	2.6	2.6	2.6	2.6	2.6	7.7	4.6
2010	2.7	2.7	2.7	2.7	2.7	2.7	2.7	7.8	4.7

Reconstruction of the Cook Islands fisheries catches: 1950–2010[1]

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Abstract

The Cook Islands is a nation comprised of small islands, which lie in the eastern central Pacific Ocean. In this study, we reconstructed the marine fisheries catches for the Cook Islands from 1950-2010, including the subsistence sector, the small-scale artisanal fishery, and the large-scale commercial sector, which is aimed at exports. We found catches from the Cook Islands to be almost 2 times the amount reported by the FAO on behalf of the Cook Islands. The majority of this discrepancy was attributed to the subsistence fishery, which is largely unreported. This study demonstrates the need for improved monitoring and reporting in all fisheries sectors to assist managers in maintaining fisheries resources, which are crucial for domestic livelihoods and food security.

Introduction

The Cook Islands lie in the Pacific Ocean (between latitudes 8° S and 23° S, and longitudes 157° W and 167° W) bordered by French Polynesia to the east, American Samoa and Tonga to the west, and New Zealand to the south-west (Figure 1). The Cook Islands comprise 15 individual islands with a combined land area of 237 km² and an exclusive economic zone (EEZ) of almost 2 million km² (www.seaaroundus.org; accessed: August 16, 2012). The population of the Cook Islands (as of 2011) was approximately 17,800, with the majority of Cook Islanders living on the island of Rarotonga (Cook Islands Statistics Office 2011). The islands are named after the English explorer Captain James Cook who visited them in 1773. They became a British protectorate in 1888, and were later annexed to New Zealand in 1901. Although the Cook Islands chose independent rule in 1965, they maintain a special relationship with New Zealand in terms of aid and citizenship. Its people identify themselves as Cook Island Maori, and are closely related to the Maori of New Zealand.

Cook Islanders have relied heavily on marine resources for hundreds of years, as have most of the inhabitants of the Pacific region (Johannes 1997). They therefore have a strong sense of stewardship for the sea. A traditional land and sea tenure system helped to create enforceable controls, and a form of prohibition known as *ra'ui* could be placed on an area by the traditional chief to protect the resources (Hoffmann 2002). When the Cook Islands Act of 1915 was introduced, it replaced the landowner's ability to enact these controls with English law, leading to less robust management practices (FAO 2010).

Cook Islanders employ a variety of traditional fishing methods, which utilize many locally-sourced materials. *Tītomo* is a type of hook-and-line fishing carried out while diving; young coconut flesh and fish pieces are offered as bait by the diver to catch *kōperu* (*Decapterus macallerus*) and *pātuki marau* (*Epinephalus hexagonatus*) respectively. Once the fish is hooked, it is transferred to the canoe that floats alongside the diver. *Matau tāmoe* is another type of hook-and-line fishing using a line (often secured to a reef structure) that is baited with live freshwater eel or octopus to attract large trevally. Canoes are commonly used for a type of trolling for reef fishes known as *tavere* and for *i'i* (drop-stone fishing) to catch large pelagic fishes, such as tuna. *I'i* is carried

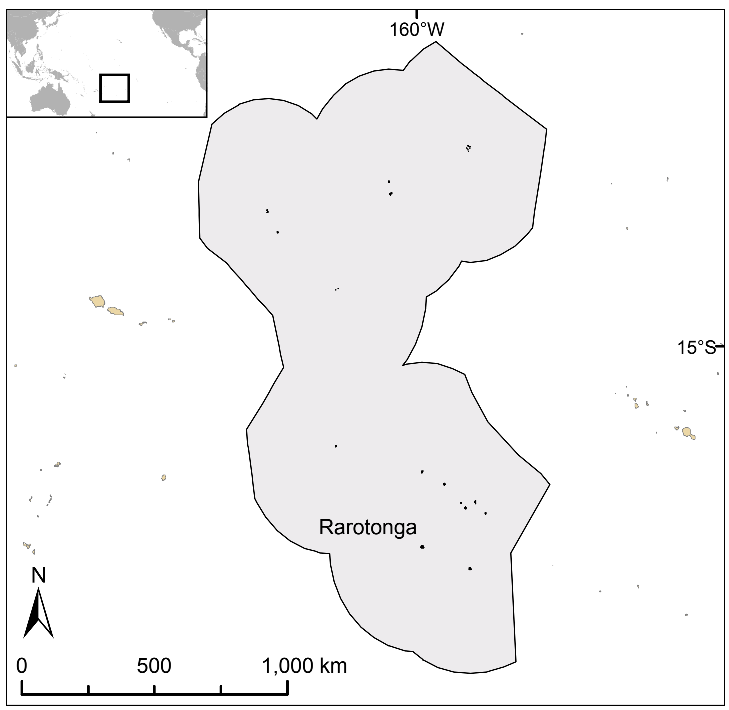

Figure 1. Map of the Cook Islands and its exclusive economic zone (gray area).

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out by placing ground bait and a baited hook inside a leaf, which is then secured by a slip-knot to a weight (typically a rock) that is lowered over the side of the canoe. At the required depth, the line is pulled briskly upward to release the bait and hook from the leaf. Similarly, drop-stone fishing with baited hook (without using ground bait) is also used to catch *mangā* (*Promethichthys prometheus*) at night. Coconut palm fronds have been used in the past for a type of fishing known as *rau*; the fronds were tied together to make a wall held up by men and women and used to surround a shallow school of fish which were then collected. This *rau*, or "leaf sweep," has been replaced by modern fishing gear, such as gillnetting (Anon. 2000). Although these traditional fishing methods (including reef gleaning) are still practiced throughout the islands, traps, gillnets, rod-and-reel, trolling, and longlining are becoming more prevalent (Anon. 2000; FAO 2010). In addition, canoes are being replaced by fiberglass or aluminum boats with outboard motors. However, those canoes that are still in use are typically powered by outboard motors.

The Cook Islands have experienced relatively constant population growth since the 1950s, estimated at 0.4% per year (Cook Islands Statistics Office 2006), except for a decline in the early 1970s, which occurred after the opening of Rarotonga International Airport, and caused migration to New Zealand. Of the total population of the Cook Islands, approximately 7,500 people participate in the labor force. One of the largest sectors of employment in the Cook Islands is trade, restaurants and accommodation (Cook Islands Statistics Office 2006), indicating the importance of tourism on the islands. Indeed, between 2007 and 2011, there was an average of just over 100,000 visitors to the islands annually, with New Zealanders, Australians, and Europeans being the most frequent visitors (Cook Islands Statistics Office 2012). Although the thriving tourism industry has provided many income opportunities and increased purchasing power, approximately half of all households still engage in subsistence activities, such as fishing, for their livelihoods (Cook Islands Statistics Office 2006). Most subsistence fishing occurs in the northern and southern island groups with very little in Rarotonga itself due to its developed marketplace for fish sales (Gillett 2011b).

There are several distinct types of fishing fleets in the Cook Islands. The locally based offshore fleet consists of either Cook Islands-owned and -operated vessels, or joint-venture vessels owned by investors, but operated by Cook Islanders. Landings of both of these fleets are considered domestic irrespective of whether the catch remains in the country, although the majority of catches from these fleets are destined for export. Furthermore, joint-venture vessels likely have the majority of their beneficial ownership residing outside the country. The Cook Islands' locally based offshore fishery has two parts: a fishery in the northern island group that typically offloads its catches to the canneries in American Samoa, and a smaller fishery in the southern island group that typically supplies the demand in Rarotonga (Anon. 2010b). Both these fisheries target tunas and billfishes primarily with longline gear. The foreign-based offshore fleet consists of foreign-owned and operated vessels that fish the EEZ waters of the Cook Islands under foreign-access agreements (Anon. 2008; Gillett 2009). The inshore fishery consists of an artisanal and a subsistence sector. The artisanal fishery describes small-scale fishers who supply domestic markets, while subsistence fishers are those who fish to provide food for themselves and their kin (Gillett 2011b).

The western and central zones of the Pacific Ocean contain the largest tuna fisheries in the world, and generate the largest source of income of any industry in the Pacific Islands (Hunt 2002; Gillett 2011b). The *Multilateral Treaty on Fisheries Between Certain Governments of the Pacific Island States and the Government of the United States of America* ("the US Treaty") was created in 1987 and allows US-flagged purse seine vessels – in exchange for a foreign access fee – to fish the waters of 16 different Pacific Island states including the Cook Islands, mainly for tuna (Anon. 2008).

While fisheries landings data have been collected by the FAO since 1950, much of the subsistence fishing on the islands goes unreported. Often a lack of data is misinterpreted as "zero catches," which is a misleading and potentially dangerous assumption for fisheries managers to make (Pauly 1998). In order to fully understand the changes that are occurring in a dynamic system such as a fishery, catch time series are needed to evaluate trends and assist managers in making sound decisions regarding sustainability and future use of resources (Pauly 1998). Given the importance that the ocean and its resources play in the lives of Cook Islanders, it is critical to account for all fisheries sectors and components.

Methods

Data presented by the FAO on behalf of the Cook Islands were obtained from the FishStat capture production database for FAO areas 77 and 81. Using information presented in Gillett (2009), and following the reconstruction approach described in Zeller *et al.* (2007), we estimated demand of locally sourced seafood and compared this to the portion of FAO landings considered to remain in-country for domestic consumption in order to determine missing (i.e., unreported) catch amounts.

Domestic fisheries in the Cook Islands were primarily small in scale until the establishment of a locally based offshore longline fleet in the late 1990s (Chapman 2001; Gillett 2009). The number of longline vessels increased from one vessel in 2000 (Gillett and Lightfoot 2002) to 35 vessels in 2007 (Gillett 2009). Seafood exports were negligible prior to the mid-1990s, but as the longline fleet expanded, exports of tuna subsequently increased. Current estimates suggest that approximately 10% of the longline catch is retained for domestic consumption (FAO 2010; Gillett 2011b). Prior to the 2000s, the majority, if not all, of the catch was consumed by the domestic market.

Human population and demand

Population data were obtained for the Cook Islands (Cook Islands Statistics Office 2011; www.populstat.info/; accessed: May, 2012), and linear interpolation was used where data were unavailable. Using *per capita* consumption estimates from previous food consumption studies in Rarotonga in combination with human population data, we estimated local seafood demand. The *per capita* seafood consumption estimates were 116.0 kg·person^{-1}·year^{-1} in 1989 (Solomona *et al.* 2009) and 64.2 kg·person^{-1}·year^{-1} in 2006 (Moore 2006; Table 1). The same rate of decrease as calculated between these points was carried forward to estimate consumption rates from 2007 to 2010. For 1950, we assumed a consumption rate that was 20% higher than in 1989 (i.e., 139.2 kg·person^{-1}·year^{-1}) due to reduced availability of protein alternatives (e.g., imports) at this time. To derive a complete time series of consumption rates, we interpolated linearly between anchor points. To adjust for import-derived consumption, we used the *per capita* canned fish consumption rates summarized in Rongo and van Woesik (2012) for 1989 to 2007, and the anchor point for 2008 summarized by Gillett (2009; Table 2), and assumed that the Cook Islanders were eating negligible amounts of canned proteins immediately following WWII (i.e., assumed zero consumption in 1945) and interpolated linearly between these estimates. Although some sources have found higher consumption rates of tinned proteins at the time (Fry 1957), these estimates are only from the island of Rarotonga, where most exports arrive. Outer islands are not likely to have had access to these imports as easily and have been shown to rely more heavily on locally sourced foods (Faine and Hercus 1951; Gillett 2011b). Furthermore, they have higher fish consumption rates in comparison to Rarotongans (Passfield 1997 in Gillett 2009). The time series of canned protein consumption was then subtracted from the seafood consumption rates estimated earlier to derive an approximate demand of domestically sourced fresh fish. This demand was then compared to the domestically available supply in order to determine whether there were any unreported or "missing" catches. The difference between the reported supply (i.e., landings as presented by the FAO minus exports; discussed below) and our estimated demand was considered unreported catch. The catches of all invertebrates, reef-associated and demersal fishes, and 10% of the tunas (*Thunnus alalunga*, *T. obesus*, *T. albacares*, and *Katsuwonus pelamis*), which were attributed to the small-scale sector, were assumed to be consumed domestically. The catches of the remaining 90% of tunas and 100% of the billfishes (family Istiophoridae) and Pacific bluefin tuna (*T. orientalis*) were attributed to the large-scale sector, which was for export.

Table 1. Anchor points used to determine local consumption rates employed in this study.

Year	Per capita consumption rate (kg/person/year)	Source
1950	139.2	Estimate
1951-1988	-	Linear interpolation
1989	116.0	Solomona *et al.* (2009)
1990-2005	-	Linear interpolation
2006	64.2	Moore (2006)
2007-2010	-	Interpolation carried forward

Small-scale sector

The Cook Islands communities are largely subsistence based, relying heavily on the ocean for their wellbeing, livelihood, culture and food (Gillett 2011b). Because of this dependence, we assumed that in 1950, 90% of the small-scale catch was from the non-commercial (i.e., subsistence) sector and that the remaining 10% was from the commercial (i.e., artisanal) sector. Gillett (2009) estimated artisanal (133 t) and subsistence (267 t) catches in 2007. Using this, we determined a breakdown of 33% artisanal and 67% subsistence fishing. To derive a breakdown from 1950 to 2010, we linearly interpolated between the 1950 and 2007 percentages for the subsistence sector (i.e., from 90% to 67%) and artisanal sector (i.e., from 10% to 33%) catches, and continued to apply the same interpolation rates up to 2010. This breakdown was then applied to the reconstructed small-scale catches, which included both reported and unreported components.

Large-scale sector

As the large-scale commercial sector of the Cook Islands fishery only became established in the mid-1990s, we assumed that reporting had improved by this time and therefore accepted the FAO data for large pelagic species. We assumed that 90% of the catches reported for FAO area 77 of albacore (*T. alalunga*), bigeye (*T. obesus*), yellowfin (*T. albacares*), and skipjack (*K. pelamis*) tunas were taken by the large-scale sector, while the remaining 10% were from small-scale operations. Futhermore, we assumed 100% of the other large pelagic species catches, such as the billfishes and the Pacific bluefin tuna (*T. orientalis*), were also from the large-scale sector. All catches taken within FAO area 81 were considered to be part of the large-scale sector as this area of the EEZ does not overlap with the inshore area where small-scale fishing is taking place. As the large-scale sector was

Table 2. Anchor points used to determine import-derived (canned-fish) consumption rates employed in this study.

Year	Per capita consumption rate (kg/person/year)	Source
1945	0.0	Estimate
1946-1988	-	Linear interpolation
1989	6.7	Solomona *et al.* (2009)
1990-2000	-	Linear interpolation
2001	6.5	Solomona *et al.* (2009)
2002-2005	-	Linear interpolation
2006	11.2	Moore (2006)
2007	10.9	Pinca *et al.* (2007)
2008	10.8	Gillett (2009)
2009-2010	10.8	Gillett (2009)

assumed to be primarily for export, it was not considered part of the domestic supply. The majority of tuna catches from the Cook Islands go to overseas markets, with more than half being exported to the US, and the remainder destined for Japan, Australia and New Zealand.

The locally based offshore fishing sector in the Cook Islands uses longline vessels exclusively (Anon. 2010b; FAO 2010). Trolling vessels were used in the past, but since 2008 they have not been licensed for offshore fishing (Gillett 2011b). The longline fishery in the Cook Islands targets primarily large tuna species with albacore (*T. alalunga*) making up approximately 75% of this catch (FAO 2010; Gillett 2011b).

Large-scale operations of tuna fishing can include fishing grounds outside of the EEZ. Therefore, data from the Forum Fisheries Agency (FFA) for albacore, bigeye, skipjack and yellowfin tuna, were used to determine the spatial allocation of the tuna catch. Upon comparison with the FAO data, it was determined that the FFA data covered catches from FAO area 77 only. We therefore made an assumption that all catches from FAO area 81 were taken within the EEZ as these catches were relatively small. In regards to the catches taken from within FAO area 77, for the years 2002-2010, the FFA data were directly utilized to allocate tuna catches within and outside the EEZ with relative proportions being utilized when necessary. The reported small-scale tuna catches are included in the portion assigned to within the EEZ. For the years 1997-2001, the FFA data suggest that all catches come from outside the EEZ. As we know that the small-scale catches must have been taken from within the EEZ boundaries, we assume that the 10% of tuna catches that were assigned to the small-scale sector come from within the EEZ and the rest of the catch (which is industrial) is taken outside the EEZ. For the years prior to the start of the FFA data we also assume that the 10% small-scale tuna is caught within the EEZ and all of the industrial catch is taken outside. The FFA data were also used to differentiate the catches taken outside of the EEZ into high seas catches and catch taken from another country's EEZ for the years 1997-2010. The other large pelagic species associated with the large-scale fleet were spatially distributed in proportion to the overall tuna allocation of the large-scale fleet.

Foreign fishing

The US is the primary foreign entity with access to Cook Islands waters (Gillett 2009), although other nations such as the Republic of Korea have had access at times (Gillett and Lightfoot 2002). The revenue from this access doubled between 1999 and 2008 (Gillett and Lightfoot 2002; Maoate 2008 in Gillett 2009). Gillett and Lightfoot (2002) estimated the annual catch of offshore foreign fishing in the Cook Islands during the late 1990s as 300 t. Since 2000, foreign access has been suspended (except through charter arrangements with local companies), as the focus of government policy shifted towards promoting the development of the domestic longline fishing industry (CSIRO 2003). In 2011, however, China began negotiating fishing agreements for access to Cook Islands' waters (Manins 2011). Under foreign access agreements, vessels are allowed to fish in the Cook Islands' EEZ. However these catches were not landed in the Cook Islands and are in theory accounted for in the catches reported by the foreign fishing nation for that FAO area, and were therefore not included in this reconstruction.

By-catch and discards

By-catch and discarded catches are common to many fishing sectors and locations. While by-catch may occur to some extent in the Cook Islands, little of it is discarded because all of the catch is seen as economically valuable (Gillett 2011a) and sold in local markets (FAO 2010). However, this also means that there is little incentive to avoid by-catch (Davies *et al.* 2009; Gillett 2011a). Some reports of by-catch in the Cook Islands estimate it as being very small, approximately 2-3% (Anon. 2010b). And because by-catch is retained and sold, it is considered as being consumed locally and therefore assumed to be accounted for in the artisanal and subsistence catches estimated here. However, both the Western and Central Pacific Fisheries Commission (WCPFC) Third Session report (Anon. 2007) and the Seventh Session report (Anon. 2010b) noted that the by-catch of sharks was under-reported and not well documented.

Taxonomic catch composition

From 1950-1969, almost all catches in the Cook Islands were reported to the FAO as "marine fish nei," and to a much lesser extent "marine molluscs nei." From 1970 to the mid-1990s, taxonomic detail improved, but tuna catches remain taxonomically unreported until 1994, with the exception of some skipjack tuna (*Katsuwonus pelamis*) in the 1970s. To assign the unreported catches to taxa and improve the resolution of the FAO miscellaneous marine fishes category prior to the mid-1990s, we used the taxonomic breakdown of the fish taxa commonly caught in the Cook Islands presented

Table 3. Taxonomic breakdown of demersal and reef-associated fishes (adapted from Pratchett *et al.* 2011). Also applied to the 'marine fishes nei' category of the FAO reported data.

Taxonomic family	Common name	Catch (%)
Scaridae	Parrotfishes	36.8
Kyphosidae	Sea chubs	14.5
Acanthuridae	Surgeonfishes, tangs, unicornfishes	10.4
Serranidae	Groupers and fairy basslets	9.7
Holocentridae	Squirrelfishes and soldierfishes	4.9
Siganidae	Rabbitfishes	4.6
Mullidae	Goatfishes	4.1
Lethrinidae	Emperors or scavengers	2.6
Labridae	Wrasses	2.3
Lutjanidae	Snappers	2.3
Others	-	7.9

by Pratchett *et al.* (2011). The unreported catch was broken down into near-shore pelagics, demersal fishes and invertebrates. According to Pratchett *et al.* (2011), near-shore pelagics (dominated by tuna) compose 60% of the catches, demersal fishes represent 36.5%, and the remaining 3.5% comprises invertebrates. The demersal fishes were broken down into the 11 families outlined by Pratchett *et al.* (2011; Table 3). Unreported invertebrates were further broken down into the groups outlined by Pratchett *et al.* (2011; Table 4). As sea urchins were not included in this breakdown, but were represented in the FAO landings, we assigned the "Others" category as urchins to account for this discrepancy. Where reported catches were assigned to taxa in the FAO reports, they were accepted as reported. Therefore the taxonomic breakdowns were applied only to unreported catches and the FAO "marine fish nei" category.

Table 4. Taxonomic breakdown of invertebrates.

Taxa	Catch (%)
Giant clam	30.8
Sea cucumber	24.4
Gastropods	15.4
Spiny lobster	15.3
Crustaceans	4.3
Bivalve	2.7
Octopus	2.3
Trochus niloticus	0.8
Others (sea urchins)	4.0

Results

Total reconstructed catches for the Cook Islands for the period 1950-2010 were estimated to be 144,842 t. This estimate includes catches for the subsistence, artisanal and large-scale sectors, and is 1.88 times the FAO reported landings of 77,031 t for the same time period (Figure 2a). Of this reconstructed catch, the majority came from the subsistence fishery, which totalled approximately 96,000 t for the 1950-2010 period, much of which was unreported. The catches of the artisanal fishery were estimated to be almost 25,000 t over the same time period, and catches from the large-scale sector (despite its recent introduction) totalled around 24,000 t for the 1950-2010 period. Overall, small-scale catches (i.e., artisanal and subsistence) increased from 2,077 t in 1950 to a peak of 2,687 t in 1964, before declining steadily to 929 t by 2010 (Figure 2a). Starting in the early 2000s, total catches increased rapidly due to the large-scale sector's catches of tuna and billfish, which dominate total catches (Figures 2a, 2b).

Four species (*T. alalunga, T. obesus, T. albacares,* and *K. pelamis*) accounted for more than 87,000 t of the total reconstructed catches (Figure 2b). The parrotfishes (family Scaridae) also accounted for a noteworthy amount of the early subsistence catches (nearly 13,000 t). Other taxa that made important contributions to the reconstruction were chubs (family Kyphosidae) with 5,000 t, groupers (family Serranidae) with 7,400 t, and invertebrates, accounting for almost 10,500 t. The diversity of the catches is demonstrated by the "Others" category, which contributed over 16,000 t.

As part of the allocation process, it was estimated that approximately 28% of the large-scale catches were taken from outside of the EEZ. These catches represent 4.6% of the total reconstructed catch.

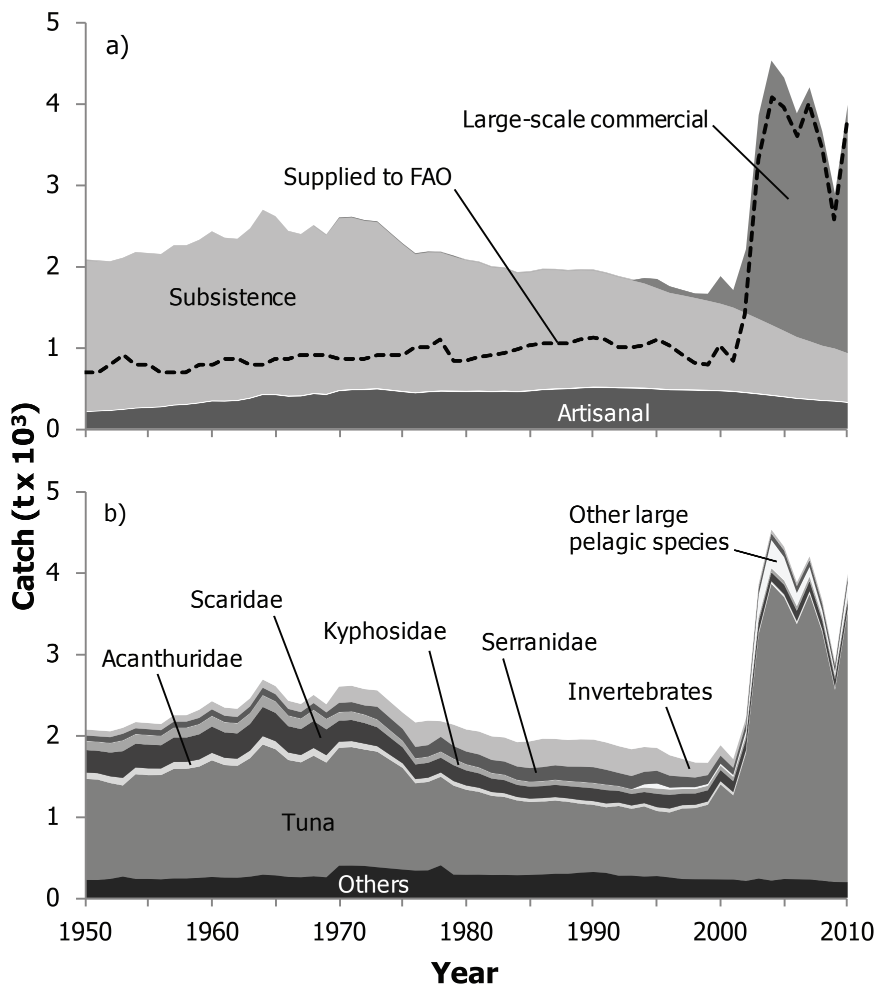

Figure 2. Total reconstructed catches for the Cook Islands for the time period 1950-2010, by (a) sector and (b) major taxa. "Tuna" includes *T. alalunga*, *T. obesus*, *T. albacares*, and *K. pelamis*. "Others" includes 10 different taxa and a "miscellaneous" category. "Other large pelagic species" includes the family Istiophoridae and *T. orientalis*.

Discussion

Our reconstructed catch for the time period 1950-2010 shows that total estimated catches in the Cook Islands were almost 2 times that reported by the FAO on behalf of the Cook Islands, with a large portion attributed to unreported subsistence catches. This confirms a recent report from the World Bank (2012), which demonstrates that the contribution of subsistence fisheries to overall catches is more important than previously thought. Our estimation was based on demand for locally sourced fresh fish using the anchor points listed in Tables 1 and 2, and the assumption that the demand was 20% higher in 1950 than in 1989. This was a conservative assumption based on a lower availability of imported proteins in the 1950s as compared with the more recent periods, when diet is known to have changed (World Health Organization 2003).

Ciguatera poisoning, a type of seafood intoxication that renders reef fishes dangerous to eat, has been problematic for almost 20 years in most of the southern Cook Islands (Rongo *et al.* 2009; Rongo and van Woesik 2011). This has caused a shift in fresh fish consumption towards pelagic species that are unaffected by ciguatera poisoning (Rongo and van Woesik 2012). In addition, ciguatera poisoning has caused a reduction in the frequency of subsistence fishing in Rarotonga, where the majority of Cook Islanders reside (Rongo and van Woesik 2012), and likely explains the decline in subsistence fishing catches in the 2000s (Figure 2a). The impact of ciguatera poisoning also halved the *per capita* seafood consumption in Rarotonga from 1989-2006, while meat consumption doubled during this period (Rongo and van Woesik 2012).

While finfish comprise the majority of the catch, several types of invertebrates such as molluscs, crustaceans, and urchins are also harvested. Zoutendyk (1989, in Dalzell *et al.* 1996) found that several species of sea cucumbers are important subsistence items that do not appear in the FAO reported data. Exports from the Pacific islands region in the 1990s were estimated at 15,000-20,000 t of fresh (wet) weight per year (Dalzell *et al.* 1996), although specific estimates for the Cook Islands were unavailable. Our reconstructed catch estimates that 140 t of sea cucumber were harvested from 1950-2010, and this may be an underestimate. Pratchett *et al.* (2011) notes that a wide range of invertebrates, which goes beyond the major groups listed (Table 3), are collected, and therefore the reconstructed catch of invertebrates should be considered a conservative estimate.

In this study, by-catch and discards were considered as being accounted for by the small-scale fisheries, because much of the non-target catch is consumed locally (FAO 2010; Gillett 2011a). However, it should be noted that in the case of the northern longline fleet, which operates out of American Samoa and delivers its catches to the canneries in Pago Pago, there is no domestic market to utilize the non-target catches, and by-catch from these fleets is likely discarded at sea (Gillett 2011b). Another cause for concern in relation to by-catch is juvenile bigeye tuna (*T. obesus*), which are often caught around fish aggregating devices (FADs) targeting skipjack tunas (*K. pelamis*). The small-scale tuna fishery in the Cook Islands has developed around the use of FADs, and local fishers are heavily reliant upon them to increase their catches while simultaneously reducing their costs (Chapman 2001). However, a decline in the stock of bigeye (Gillett 2011b) is being attributed to the increased use of FADs (Hunt 2002; Chapman 2004; World Bank 2012).

Monitoring, control and surveillance is arguably one of the best ways to obtain accurate reporting in fisheries. A WCPFC report (Anon. 2007) noted that in 2006, less than 5% of all vessels were sampled at ports in the Cook Islands and only one trip in 2007 had a fisheries observer on board. Our estimates demonstrate the need for improved monitoring of subsistence fisheries, given that this sector made significant contributions to overall reconstructed catches. The WCPFC Seventh Session report (Anon. 2010b) noted that a workshop was held in 2011 to help tackle this challenge.

Illegal fishing is known to occur in the Cook Islands, and the country is vigilant about prosecuting these crimes when the vessels are caught (Anon. 2010a). However, given the size of the Cook Islands' EEZ, patrolling and enforcing this vast expanse of ocean is a major challenge, and it is reasonable to assume that many cases of illegal fishing go unseen.

The capture of reef fish from the Cook Islands for the home aquarium trade is considerable. The value of the aquarium fish trade in 2000 was estimated at NZ$252,000 (approximately US$130,990; Gillett and Lightfoot 2002). Although this value does not translate easily into tonnage, due to different fishes having different values, it should still be thought of as a noteworthy contribution to the marine harvests of the Cook Islands. Fish are not the only items to be exported for the aquarium trade; invertebrates are taken as well. In 2008, approximately 1,800 live clams (*Tridacna derasa*) were exported for this purpose (Gillette 2009). Aquarium trade fishes and invertebrates were not included in this reconstruction. However, these catches should be included in future plans for marine resource management.

Recreational fisheries data for the Cook Islands were not readily available. However, Chapman (2004) reported only 14 recreational sport-fishing boats in the Cook Islands. These boats typically target large pelagic species for game-fishing tournaments. Other information related to recreational fisheries in the Cook Islands (i.e., number of recreational fishers, amount of catch per fisher, and number of fishing trips per fisher) were not found. For the purposes of this reconstruction, we assume the contribution of recreational fisheries to be negligible; however recreational fishing is an issue that needs to be addressed in the future given the expanding tourism industry in the country.

This study has demonstrated the importance of comprehensive accounting for all sectors of fisheries in the Cook Islands, as improper accounting can lead to unintentional mismanagement of resources. Although the country appears to be improving its marine resources monitoring, the previously unaccounted subsistence sector has large implications for long-term trends and potentially impacts sustainable management of these resources.

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

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal	Large-scale commercial
1950	700	2,080	1,869	208	0
1951	700	2,070	1,851	215	0
1952	800	2,050	1,833	221	0
1953	900	2,100	1,863	234	0
1954	800	2,170	1,917	250	0
1955	800	2,160	1,898	257	0
1956	700	2,140	1,879	264	0
1957	700	2,250	1,963	288	0
1958	700	2,250	1,955	297	0
1959	800	2,320	2,002	316	0
1960	800	2,420	2,083	340	0
1961	850	2,340	2,005	338	0
1962	850	2,330	1,985	346	0
1963	800	2,460	2,084	375	0
1964	800	2,690	2,267	421	0
1965	850	2,610	2,189	419	0
1966	850	2,430	2,029	400	0
1967	900	2,390	1,986	403	0
1968	900	2,500	2,068	432	0
1969	900	2,390	1,964	421	0
1970	850	2,600	2,129	464	9
1971	850	2,610	2,126	476	9
1972	850	2,570	2,084	478	9
1973	900	2,560	2,061	485	9
1974	900	2,420	1,941	469	9
1975	900	2,280	1,824	451	9
1976	1,000	2,160	1,719	435	9
1977	1,000	2,180	1,728	448	9
1978	1,091	2,180	1,713	461	5
1979	830	2,140	1,671	454	11
1980	840	2,080	1,625	452	0
1981	880	2,050	1,598	454	0
1982	910	1,990	1,545	448	0
1983	940	1,980	1,527	452	0
1984	970	1,920	1,476	446	0
1985	1,017	1,930	1,480	452	0
1986	1,055	1,960	1,499	464	0
1987	1,058	1,960	1,486	474	0
1988	1,060	1,950	1,469	478	0
1989	1,106	1,960	1,470	486	0
1990	1,125	1,950	1,461	493	0
1991	1,108	1,920	1,426	492	0
1992	993	1,870	1,384	488	0
1993	1,010	1,830	1,350	485	0
1994	1,025	1,860	1,315	482	66
1995	1,107	1,850	1,265	473	112
1996	1,025	1,760	1,217	464	80
1997	897	1,720	1,187	464	66
1998	805	1,670	1,156	463	54
1999	795	1,670	1,124	461	85
2000	1,025	1,880	1,092	456	336
2001	827	1,710	1,054	447	213
2002	1,412	2,210	997	435	782
2003	3,306	3,860	942	419	2,496
2004	4,070	4,520	887	403	3,234
2005	3,962	4,310	831	385	3,098
2006	3,594	3,880	774	364	2,740
2007	4,000	4,200	733	351	3,112
2008	3,424	3,660	695	338	2,625
2009	2,578	2,890	668	331	1,894
2010	3,835	3,980	618	311	3,053

Appendix Table A2. Total reconstructed catch (in tonnes) by major taxonomic group for the Cook Islands, 1950-2010.

Year	Acanthuridae	Scaridae	Kyphosidae	Serranidae	Tunas[1]	*T. orientalis* and Istiophoridae	Invertebrates	Others[2]
1950	79	279	110	73	1,246	0	73	217
1951	78	277	109	73	1,239	0	72	216
1952	83	294	116	78	1,182	0	72	229
1953	94	331	130	87	1,124	0	73	258
1954	83	294	116	78	1,291	0	76	229
1955	83	294	116	78	1,280	0	75	229
1956	81	288	113	76	1,286	0	75	224
1957	85	302	119	80	1,351	0	79	236
1958	85	302	119	80	1,351	0	79	236
1959	88	311	123	82	1,372	0	100	243
1960	92	325	128	86	1,438	0	100	254
1961	89	315	124	83	1,388	0	100	245
1962	88	313	123	82	1,380	0	100	244
1963	93	330	130	87	1,461	0	100	257
1964	102	361	142	95	1,607	0	100	281
1965	99	350	138	92	1,556	0	100	273
1966	92	326	128	86	1,442	0	100	254
1967	91	321	126	84	1,417	0	100	250
1968	95	335	132	88	1,487	0	100	262
1969	90	320	126	84	1,415	0	100	250
1970	73	260	102	118	1,456	0	200	393
1971	74	261	103	119	1,461	0	200	393
1972	72	256	101	117	1,436	0	200	389
1973	66	235	93	162	1,426	0	200	373
1974	61	217	85	157	1,339	0	200	359
1975	56	199	78	152	1,254	0	200	345
1976	52	182	72	148	1,077	0	300	332
1977	52	185	73	149	1,091	0	300	335
1978	52	185	73	188	1,092	0	192	397
1979	56	198	78	162	1,098	0	262	282
1980	53	187	74	163	1,049	0	270	280
1981	51	180	71	166	1,022	0	281	281
1982	48	168	66	167	976	0	289	277
1983	46	163	64	170	962	0	295	278
1984	43	152	60	172	922	0	298	275
1985	42	150	59	175	899	0	327	279
1986	43	151	59	180	899	0	347	284
1987	43	153	60	185	903	0	323	293
1988	43	153	60	185	888	0	325	293
1989	46	161	63	194	850	0	335	307
1990	46	161	64	202	828	0	338	315
1991	47	167	66	190	810	0	335	303
1992	41	147	58	169	861	0	328	268
1993	41	144	57	170	825	0	328	270
1994	40	140	55	162	866	37	304	258
1995	47	167	66	164	803	59	280	264
1996	48	170	67	155	802	21	250	248
1997	41	145	57	138	871	20	217	228
1998	40	142	56	127	878	20	184	226
1999	40	141	56	117	920	20	151	225
2000	39	140	55	107	1,171	20	128	224
2001	39	137	54	96	1,039	20	107	222
2002	38	133	52	95	1,574	49	68	205
2003	34	120	47	82	3,015	278	48	233
2004	31	110	43	79	3,660	346	45	209
2005	33	118	47	81	3,477	285	44	228
2006	36	129	51	84	3,146	161	46	225
2007	35	125	49	83	3,518	117	46	223
2008	31	110	43	79	3,065	76	46	207
2009	29	103	41	72	2,369	46	42	191
2010	29	103	41	72	3,338	168	42	189

[1] Tunas category includes *Thunnus alalunga*, *T. obesus*, *T. albacares*, and *Katsuwonus pelamis*.
[2] Others category includes five taxa and a "miscellaneous" group.

Reconstruction of marine fisheries catches for the Republic of Fiji (1950–2009)[1]

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Abstract

Fiji's fisheries have undergone many changes over the past 50+ years. Urbanization, technological innovations, and increased incentives from the government (subsidies, loans, etc.) have all shaped the landscape of Fiji's marine fisheries. In this study, the total reconstructed catch for Fiji's marine fisheries (1950-2009) is estimated to be approximately 2,760,000 tonnes.[2] This total includes subsistence, artisanal, and large-scale commercial fisheries (plus discards). This estimate is 2.8 times the total landings presented by the FAO on behalf of Fiji. This discrepancy is much lower in the recent time period, with the reconstructed estimate being only 18% larger than the data reported to the FAO in the last decade. The main reporting issue in Fiji appears to be under-reporting of subsistence catches due to incomplete estimates made in the past. This study highlights the need for improved fisheries catch monitoring, including non-commercial catches, in light of concerns over sustainable management of fisheries resources and the associated food security issue.

Introduction

The Republic of Fiji is an archipelago in the south-west Pacific Ocean, which consists of 322 volcanic or limestone islands (Vunivalu 1957; USDS 2010), as well as numerous other cays and islets (Teh *et al.* 2009). Fiji is located at 15-23°S and 177°E-178°W with a land area of 18,500 km² (Teh *et al.* 2009), and an Exclusive Economic Zone (EEZ) of 1.28 million km² (www.seaaroundus.org; Figure 1). There is a mixture of fringing and barrier reefs surrounding almost all of the islands (Vunivalu 1957). The climate is tropical but relatively mild due to the position of the islands, which puts them in the path of easterly instead of south-easterly trade winds (Vunivalu 1957). Fiji also experiences heavier rainfall than most tropical countries and in the wet season monsoonal winds accompany the rain (Horne 1881; Vunivalu 1957). Suva, the capital of Fiji, is located on the largest and most populous island, Viti Levu. Although 70% of Fiji's population resides in Viti Levu, the majority are located in coastal areas due to the rough terrain of the interior (USDS 2010). The second largest island is Vanua Levu (Teh *et al.* 2009).

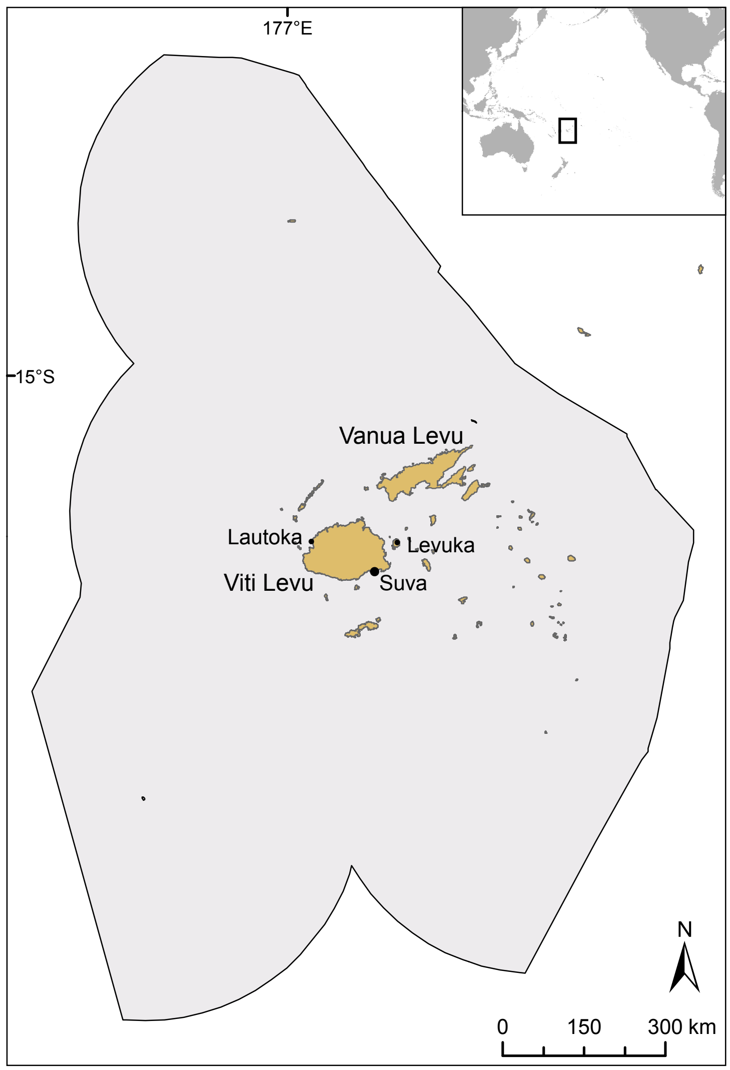

Figure 1. Map of the Republic of Fiji and its EEZ, showing the major cities of Suva, Lautoka, and Levuka, as well as the two largest islands, Viti Levu and Vanua Levu.

Fijians are of Polynesian and Melanesian descent (Deane 1921). The current population of Fiji consists of mostly Fijians and Indians, but also includes Europeans, Chinese, and other Pacific Islanders. Fiji was proclaimed a British dependency in 1874, and in 1879, was opened to immigration by Indians who were essentially brought in to work as labourers in the sugar mills, as well as cotton, coconut, and coffee

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[2] See addendum for updating dataset to 2010.

plantations (Vunivalu 1957). In 1970, Fiji gained its independence, after which native Fijians spent the next 17 years struggling to accept Indo-Fijian rule (USDS 2010). In 1987, two consecutive military coups overthrew the government and the country officially became the Republic of Fiji (USDS 2010). Despite these tensions, there has been very little ethnic violence within the country (Norton 1990).

Important sectors of Fiji's economy are sugar, fisheries, and tourism (Gillett 2011). Marine resources have always been important to the Fijian diet, although market-based economic utilization has occurred relatively recently (DeMers and Kahui 2012). There has recently been a strong trend of urbanization in Fiji (Norton 1990) and this has been one of the contributing factors to the changes in Fiji's fisheries (Jennings and Polunin 1996).

Early fishing by the Fijians was almost exclusively subsistence based, with effort focused on reef and coastal areas (DeMers and Kahui 2012). Fisheries were controlled through long standing customs and administered by chiefs, when necessary. Fishing areas, known as *qoliqoli*, were controlled by individual families with well recognized boundaries (DeMers and Kahui 2012). Around the 1950s, the nature of Fiji's fisheries began to change. The open ocean was relatively untapped and traditional methods were still in use; however, newly acquired equipment and technology started to be incorporated (Roth 1953; DeMers and Kahui 2012). Furthermore, local fish trade increased, which gave way to the commercialization of Fijian fisheries (DeMers and Kahui 2012). At the time (1950s), three ports existed. Suva was the most active, receiving cargo ships from North America, Australia, New Zealand, the United Kingdom, and other Pacific Island countries (Vunivalu 1957). The other two ports were located in Lautoka and Levuka (Vunivalu 1957; Figure 1). Thanks to infrastructure left over from World War II, an international airport became operational in Nadi in the late 1940s, with local air service to Nausori, Labasa, and Lautoka on Viti Levu as well as Vanua Levu and Taveuni (Vunivalu, 1957). In the late 1940s, a small cannery opened in Pago Pago (American Samoa), as a result of efforts by a Fiji fishing company, which had been developing a pole-and-line fleet (Gillett 2007). Having a cannery in American Samoa would give access to the foreign tuna market, predominantly the United States (Gillett 2007). Unfortunately, catches were not consistent enough for the cannery to be profitable, forcing it to close (Gillett 2007). The US opened their own cannery in Pago Pago in the early 1950s, which was instrumental in the success of fishing endeavours by the US and others in the Pacific, including in Fijian waters (DeMers and Kahui 2012). In 1964, the Pacific Fishing Company (PAFCO), a fish-processing facility which supports local fisheries and prepares fish for re-export, was opened (DeMers and Kahui 2012). PAFCO also built a cannery in Levuka, Ovalau in 1970, and employed a large proportion of the villagers from all over the island (Barclay 2010). The IKA Corporation, a domestic fishing company, was founded in the mid-1970s to supply PAFCO with tuna (DeMers and Kahui 2012). Unfortunately, IKA collapsed in the 1990s, due to the introduction of cheaper purse seine fleets (Barclay 2010). In the mid 1980s, a deep-slope fishery in Fiji was active and would export the catches to more demanding overseas markets (Dalzell *et al.* 1996). In 1987, the fishery declined due to disruption in air service, and the vessels from the fleet were utilized for pelagic longlining, which saw much better returns (Dalzell *et al.* 1996). Unfortunately, encouragement from the government and other organizations to increase fishing efforts (through subsidies, loans, and instructional programs), has lead to problems of overcapacity in Fiji's fisheries sector (DeMers and Kahui 2012). Legislation and management is more geared toward commercialization than sustainability.

The domestic, and especially the small scale, fisheries of Fiji have been largely overlooked in monitoring and management considerations. Much of the recent research highlighting the importance of these fisheries only appears in reports which are less widely accessible (DeMers and Kahui 2012). The purpose of this study is to provide a comprehensive overview of all Fiji's fisheries and to reconstruct the total catch history over time for all sectors, from 1950 to 2009.

Methods

Total marine fisheries catches were estimated using information obtained from national reports, independent studies, local experts, and grey literature. Fisheries catches were estimated based on household surveys and consumption data presented in the literature. The Fiji Department of Fisheries reports catches for subsistence, artisanal, and large-scale commercial sectors. Most of the literature differed in their definition of these sectors. For example, Rawlinson *et al.* (1995) and Gillett (2009) differed slightly in their definition of subsistence and artisanal sectors, although combined, both refer to small-scale similarly. Although this may have resulted in categorizing of catch amounts into different sectors, the total catch is not affected. Here, we follow the general definition of subsistence and artisanal catches as being primarily for non-commercial (direct consumption) and commercial (sale) purposes, respectively.

Human population data

Human population data were acquired in order to estimate subsistence and artisanal fishery catches. Population data were used to convert *per capita* seafood consumption rates into estimates of total demand. Population data for Fiji were obtained from a population statistics historical demography website[3] for 1950-1959, and from The World Bank databank[4] for the years 1960-2009 (Figure 2).

[3] www.populstat.info, accessed June 16, 2011

[4] http://databank.worldbank.org/ddp/home.do, accessed June 16, 2011

Subsistence fisheries

Anchor points of either *per capita* subsistence catch or consumption rates were extracted from the literature in order to estimate subsistence catches from 1950-2009. For the recent time period, Gillett (2009) estimated subsistence catch in 2007 to be 17,400 tonnes. Using the 2007 population, a *per capita* subsistence catch rate of 20.75 kg·person^{-1}·year^{-1} was calculated. This anchor point was carried forward and used as the subsistence catch rate estimate for 2008 and 2009. Gillett (2003) gave an estimate for 1999 of 21,600 tonnes total annual subsistence catch. This equated to a subsistence catch rate of 27.14 kg·person^{-1}·year^{-1} for 1999. A linear interpolation was done between the 1999 and 2007 subsistence catch rate anchor points. Finally, it was necessary to obtain an estimate for the early time period (1950s). Jennings and Polunin (1996) completed a study on three islands in the Lau Islands group of Fiji, which are some of the most remote islands of the country. They found that the Fijians on these islands maintained a traditional diet high in marine derived protein (Jennings and Polunin 1996). Therefore, we assumed remote island seafood consumption rates were similar to consumption rates in the early time period for the entire country. Three different estimates of remote island *per capita* subsistence consumption were obtained (Kuster *et al.* 2005; Bell *et al.* 2009). When averaged, they yielded an estimate of 128.31 kg·person^{-1}·year^{-1}. This estimate was used as the anchor point for 1950. Catch rates were linearly interpolated from the 1950 anchor point to the 1999 anchor point, giving us a complete time series of subsistence catch rates for 1950-2009 (Table 1). Using the subsistence catch rates along with the population data gathered, total annual subsistence catches were estimated for the 1950-2009 time period.

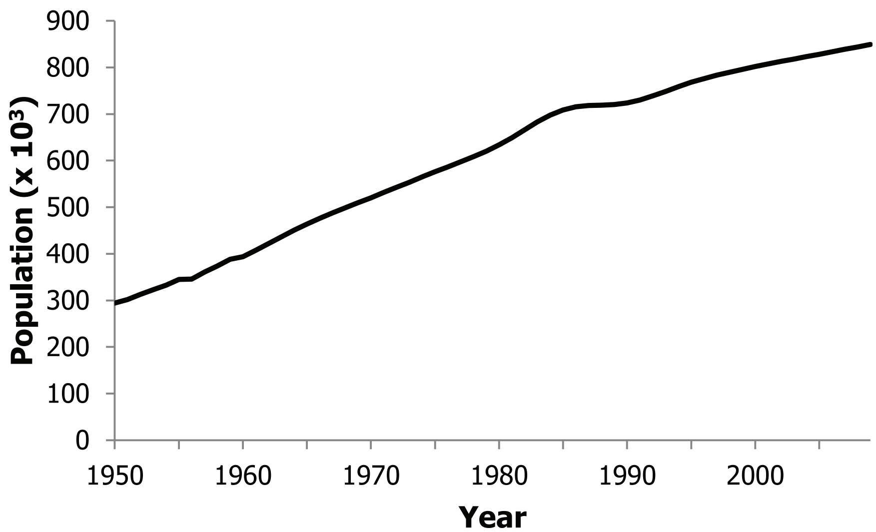

Figure 2. Estimated human population of Fiji, 1950-2009.

Artisanal fisheries

Artisanal (i.e., small-scale commercial) fisheries catches were estimated using anchor points of artisanal *per capita* consumption catch rates from the literature. Rawlinson *et al.* (1995) estimated the total annual artisanal catch in 1993 to be 6,206 tonnes. Using the human population data, the estimated artisanal *per capita* catch rate for 1993 was therefore 11.6 kg·person^{-1}·year^{-1}. Gillett (2009) estimated the 2007 total artisanal catch to be 9,500 tonnes, which translates to a *per capita* rate of 11.3 kg·person^{-1}·year^{-1}. A linear interpolation was performed between the *per capita* rates based on Rawlinson *et al.*'s (1995) estimate and Gillett's (2009) estimate. The 2007 estimate was carried forward unaltered to 2009. An assumption-based starting point of zero artisanal catch in 1945 was chosen due to the end of WWII and thus the presence of a minimal cash-economy at the time. A linear interpolation was performed between the anchor points of zero kilograms *per capita* in 1945 and the Rawlinson *et al.* (1995) estimate of 11.6 kg·person^{-1}·year^{-1} in 1993 (Table 2). The derived artisanal catch rates for 1950-2009 were then combined with human population data to establish a complete time series (1950-2009) of catch data for the artisanal fishery.

Table 1. *Per capita* catch rates used to estimate total subsistence catch in Fiji.

Years	Catch rate (kg/person/year)	Source
1950	128.31	Average of Kuster *et al.* (2005) and Bell *et al.* (2009)
1951-1998	-	Linear interpolation
1999	27.14	Gillett (2003)
2000-2006	-	Linear interpolation
2007	20.75	Gillett (2009)
2008-2009	20.75	Carried forward from 2007

When assigning the FAO data to sectors (see "Reported catch" in Methods section) the artisanal sector was assigned last, as national reports mainly provided detailed information on subsistence and large-scale commercial sectors. Therefore, when comparing our reconstructed estimate to the reported data, the artisanal sector catches had the most variation. In the period of 2006-2008 there was an apparent spike in FAO catches for the artisanal sector. We assumed that the FAO had access to additional information we were

Table 2. *Per capita* catch rates used to estimate total artisanal catch in Fiji.

Years	Catch rate (kg/person/year)	Source
1945	0	Assumption
1946-1992	-	Linear interpolation
1993	11.63	Rawlinson *et al.* (1995)
1994-2006	-	Linear interpolation
2007	11.33	Gillett (2009)
2008-2009	11.33	Carried forward from 2007

not aware of and we accept the FAO data as the best representation of artisanal catches for the years in which our estimates were below FAO totals. The large increase followed by an immediate decrease seen in the 2006-2008 FAO data could be due to changes in trade, unusual weather patterns, or a combination of factors.

Large-scale commercial fisheries

The large-scale commercial fishery targets large pelagic fish such as tunas and billfish. When comparing the FAO reported catches for tuna and billfish species to national and independent reports, the various reports were all close to each other. Thus, the FAO reported catches for tuna and billfishes (*Thunnus alalunga*, *T. obesus*, *Katsuwonus pelamis*, *T. albacares*, *Makaira indica*, *M. mazara*, *Tetrapturus audax*, and *Xiphias gladius*) were accepted and taken to be the best representation of large-scale commercial fisheries catches. However, by-catch associated with the longline fishery does not seem to be accounted for by FAO data. These catches consist largely of sharks, rays, skates, mantas, and other fishes. There is a high market demand for shark fins and therefore when there is shark by-catch, the fins are usually retained while the rest of the shark body is discarded.

To estimate shark by-catch from domestic longline vessels, it was assumed that Fiji's shark fin exports equalled the total amount of foreign and domestically caught shark fins. To separate out the domestic portion, we used the percentage of exported domestic shark fins reported by Swamy (1999) for 1996 and 1997, to estimate the percent contribution of domestic to total shark fin exports (in dry fin weight) for the entire time period. Domestic shark fin exports were zero prior to 1988 (Swamy 1999). We linearly interpolated between 0% domestic shark fin exports in 1987 and 46% (calculated from Swamy 1999) in 1996. Swamy's (1999) reported value of 57% for the proportion of domestic shark fin exports in 1997 was carried forward, unaltered, to 2009. We assumed that the catch profile documented by the SPC observer programme for domestic longline vessels in Fiji, and reported by Swamy (1999), was representative of the species caught by the entire domestic longline fleet. Swamy's (1999) data provided us with the number and average length of each species caught.

A species breakdown was achieved by using the data from Swamy (1999) and conversion factors to determine the percentage that each species contributed to wet fin weight. However, before determining the species composition it needs to be noted that shark fin export totals are in dry fin weight and thus need to be converted into wet fin weight in order to be utilized in the species breakdown. A conversion factor of 0.43 was used (i.e., dry fin weight equates to 43% of the wet fin weight; Biery *et al.* 2011). Also note that only after completing the species breakdown were the wet fin weights converted to wet round weight. In order to determine the percentage contribution of each species to the total wet fin weight the average length of each species was first converted to average weight using the Fishbase life-history tool (www.fishbase.org). Round (i.e., whole) weight to fin weight conversion factors were then used to calculate average wet fin weight for each species (Biery *et al.* 2011). Average wet fin weight and numbers of each shark species caught were used to calculate the percent contribution of each species to domestic exports. Using this breakdown, total domestic shark fin exports for each year were separated into the different species and then converted back to round weight. "Unidentified sharks" reported in observer data (Swamy 1999) had the smallest average length (93.0 cm) and were likely composed of small pelagic sharks (Williams 1997). To determine the relative contribution of "unidentified sharks", fin to round weight conversion factors and average weights of three small pelagic sharks (*Carcharhinus plumbeus, C. sorrah,* and *C. albimarginatus*) occurring in the Pacific were used as proxies. In addition, 10-23% of sharks (by weight) were additionally discarded without being finned (Gilman *et al.* 2007) and hence not accounted for in the fin export data. To remain conservative, 10% (round weight) was added to the domestic shark catch derived from the fin data under the assumption that this discarded catch was composed of unwanted species such as pelagic stingrays and other rays, skates, and mantas not appropriate for finning (Swamy 1999). By-catch was further broken down into discards and unreported commercial landings. Wet weight of the landed fins equalled the unreported commercial component and the discarded shark carcasses, pelagic stingrays, and other rays, skates, and mantas equalled the discards of the commercial sector.

Table 3. Taxonomic breakdown applied to the unreported subsistence catch of Fiji, 1950-2009. Also applied to the "marine fishes nei" category within the reported subsistence catch for the years 2002-2009. Derived from Kuster *et al.* (2005).

Taxa	Catch (%)	
	1950-1981[a]	2002-2009
Lethrinidae	16.1	19.7
Mullidae	10.9	9.8
Miscellaneous pelagic fish	9.7	1.9
Bivalves	9.6	17.9
Scaridae	9.5	5.8
Acanthuridae	8.6	6.6
Miscellaneous marine crustaceans	6.9	1.4
Siganidae	5.6	6.8
Gastropoda	4.7	4.4
Mugilidae	4.0	1.0
Serranidae	3.9	5.7
Carangidae	3.9	0.0
Lutjanidae	2.5	0.3
Miscellaneous aquatic invertebrates	2.1	1.8
Holocentridae	2.0	3.1
Balistidae	0.0	10.6
Kyphosidae	0.0	1.9
Labridae	0.0	1.3

[a] For the 1982-2001 period, the breakdown was interpolated.

Spatial allocation

Large-scale operations of tuna fishing can include fishing grounds outside of the EEZ. Therefore, data from the Forum Fisheries Agency (FFA) for albacore, bigeye, skipjack and yellowfin tuna, were used to determine the spatial allocation of the tuna catch. The data only cover the years from 1997-2010. For the years 1997-2008, the FFA data were used directly to allocate catches to either within the EEZ, into another country's EEZ or to the high seas. For 2009, proportions from the data were utilized as there were slight discrepancies in the totals from the FAO and the FFA. The proportions of the catch inside and outside of the EEZ from 1997 were also used to spatially disaggregate the catch from 1970-1996. The other large pelagic species associated with the large-scale fleet (black marlin, blue marlin, striped marlin, swordfish, and sharks) were allocated in proportion to the overall tuna allocation of the large-scale fleet.

Catch Composition

Reported catch

The reported subsistence and artisanal catches were broken down by taxa based on the FAO taxonomic breakdown (excluding the large-scale pelagic species: *Thunnus alalunga*, *T. obesus*, *Katsuwonus pelamis*, *T. albacares*, *Makaira indica*, *M. mazara*, *Tetrapturus audax*, and *Xiphias gladius*). First, we calculated what the proportion of subsistence and artisanal catches were of total small-scale catches for each year. These percentages were then multiplied by the amount of the catch in each FAO category per year to estimate how much of each individually reported taxon (i.e., FAO category) was caught by the subsistence and artisanal sectors. Thus, we assumed equal representation of each reported taxa in both small-scale sectors. After completing this breakdown, it was observed that the "marine fishes nei" category in the FAO data increased substantially, from an average of 1,000 t·year^{-1} over the 1950-2001 time span to 8,000 t in 2002 and then over 19,000 t in 2003, after which it began to level out. Therefore, from 2002-2009, an additional breakdown was applied to the "marine fishes nei" category for both the reported subsistence and artisanal sectors. For the subsistence sector, a species breakdown derived from Kuster *et al.* (2005) (see "Unreported catch" below for details) was applied to the "marine fishes nei" category for the time period of 2002-2009 only (Table 3). The same method was used for the artisanal sector, except that a breakdown from a Fiji Fisheries Division annual report (see "Unreported catch" below for details) was used instead (Table 4).

Table 4. Taxonomic breakdown for the unreported artisanal catch of Fiji, 1950-2009. Also applied to the "marine fishes nei" category within the reported artisanal catch for the years 2002-2009.

Taxa	Catch (%)
Miscellaneous aquatic invertebrates	28.2
Scombridae	22.9
Lethrinidae	14.7
Carangidae	9.6
Sphyraena spp.	9.4
Serranidae	8.4
Mugilidae	6.9

Source: Anon. (1991).

Unreported catch

Unreported small-scale catches were also assigned taxonomically. Unreported subsistence catches were broken down into taxa based on the Kuster *et al.* (2005) remote island consumption survey that reported total subsistence catches for finfish and invertebrates for the years 1982 and 2002 (Table 3). For the 1950-1982 time period, the 1982 species composition was used. From 1983-2001, a linear interpolation between the 1982 and 2002 anchor points was done. For 2002-2009, the 2002 species breakdown was used. These percentages were then multiplied by the unreported subsistence catch to obtain an estimated annual catch in tonnes by taxa from 1950 to 2009.

The unreported artisanal catch was broken down using artisanal catches reported in the 1990 Fiji Fisheries Division annual report (Anon. 1991). The species composition was applied to the unreported artisanal catches for each year to obtain an estimate, in tonnes, for individual taxa (Table 4).

Unreported large-scale commercial fishery catches included shark by-catch (landed and discarded). The taxonomic breakdown of the by-catch was completed during the process of estimating total by-catch (see "*Large-scale commercial fisheries*" in the Methods section). By-catch included mostly shark species, with *Prionace glauca*, *Carcharhinus falciformis*, *Isurus oxyrinchus*, and *C. longimanus* representing the largest proportions of the catch (Table 5). There were also small percentages of pelagic stingrays and rays, skates, and mantas.

Table 5. Taxonomic breakdown of unreported longline fishery by-catch (landed and discarded), 1950-2009. Adapted from Swamy (1999) with conversion factors provided by Biery *et al.* (2011).

Taxa	Catch (%)
Prionace glauca	50.9
Carcharhinus longimanus	13.6
Isurus oxyrinchus	9.6
Carcharhinus falciformis	9.6
Dasyatidae	9.0
Carcharhinus amblyrhynchos	2.5
Isurus paucus	1.2
Other Carcharhinidae	1.1
Rajiformes	1.0
Alopias vulpinus	0.8
Galeocerdo cuvier	0.4
Sphyrna lewini	0.2
Alopias pelagicus	0.1

Results

The reconstructed total catch estimate over the 1950-2009 time period (2,759,723 t) is 2.8 times the catch reported by the FAO on behalf of the Republic of Fiji (991,024 t; Figure 3a, Appendix Table A1). Of the total reconstructed catch, 77.7% is from the subsistence fishery (Figure 3a) with 72.9% of the subsistence catches being unreported. Subsistence catches in the 1950s were on average 40,040 t·year^{-1}, increasing to a peak in 1967 of 45,470 t·year^{-1}, after which catches decrease to an average of 18,950 t·year^{-1} in the 2000s. Artisanal catches accounted for 11.9% of the total catch (Figure 3a). Artisanal catches increased throughout the time period from 800 t·year^{-1} in the 1950s to 8,740 t·year^{-1} in the 1990s, and peaked in 2007 with 15,960 t. Large-scale commercial catches (including estimated shark and associated species by-catch) amounted to 10.4% of the total catch (discards contributed 2.0% to the total reconstructed catch) (Figure 3a). Large-scale commercial fishing did not begin until the early 1970s. Catches follow a general increasing trend until 2004 when catches peak and then decline. Average annual catches for the 1970s were approximately 870 t·year^{-1} and then increased to an average of 17,090 t·year^{-1} in the 2000s. For the most recent decade (2000-2009) the total reconstructed catch (all sectors) was estimated at an average of 46,390 t·year^{-1}. Catches were highest in the 1980s with an average annual catch of 50,070 t·year^{-1}.

The total reconstructed catch was dominated by the family Lethrinidae, which represented 14.6% of the catch (over 401,500 t) over the 1950-2009 time period (Figure 3b, Appendix Table A2). The second largest contribution was the family Scombridae, accounting for 12.4% of the total catch. Molluscs (7.5%), Mullidae (6.7%), Scaridae (5.5%), Acanthuridae (5.4%), "miscellaneous pelagic fishes nei" (5.3%), and Mugilidae (5.1%) also represented substantial portions of the catch. Scombridae catches exhibit an increase over the time period, which is to be expected with the development of the large-scale commercial sector.

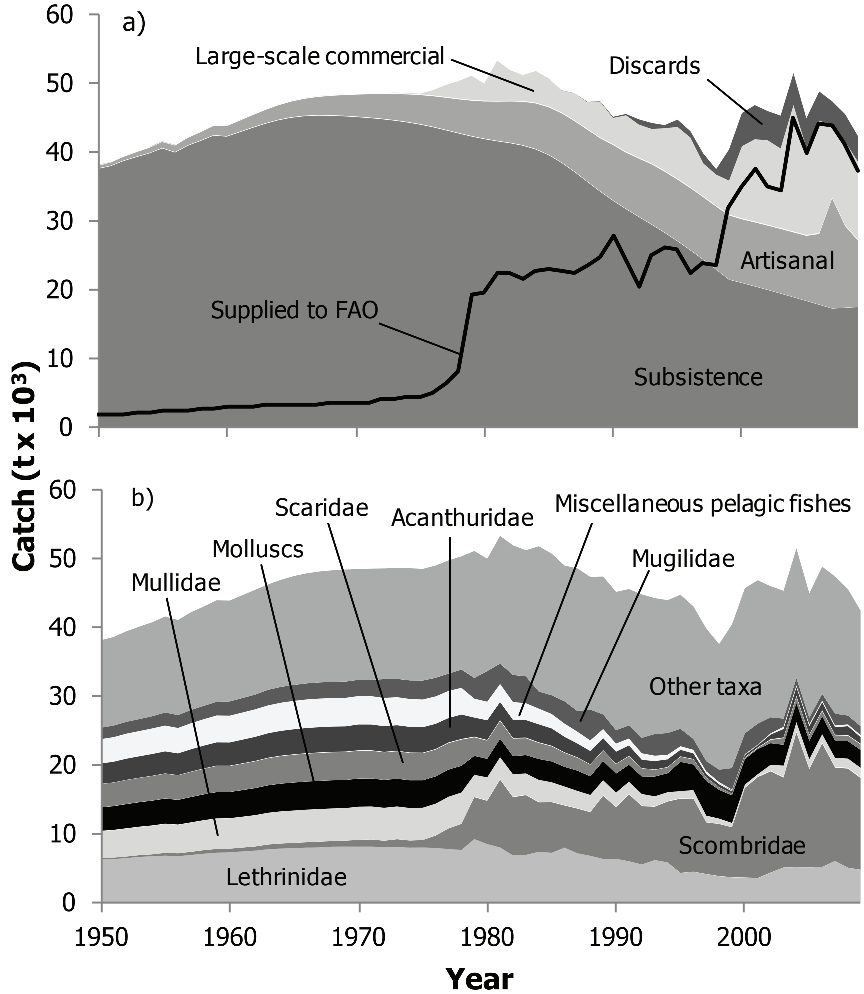

Figure 3. Total reconstructed fisheries catches for Fiji, 1950-2009, (a) by sector, with comparison to the total catch data supplied to the FAO; and (b) by major taxa. The grouping 'other taxa' represents 47 individual taxonomic categories.

The large-scale commercial catch was dominated by albacore tuna (*T. alalunga*) with 93,114 tonnes caught over the study period (1950-2009) and an annual average of 4430 t·year^{-1} since 1989 when Fiji began catching it commercially. Skipjack tuna (*K. pelamis*) and yellowfin tuna (*T. albacares*) fishing both began in 1970 and have had annual averages since then of approximately 1,910 t·year^{-1} and 1,040 t·year^{-1}, respectively. Bigeye tuna (*T. obesus*) had the smallest catches which were on average 390 t·year^{-1} since 1982. By-catch from the Fiji longline fishery consists of both a landed shark fin portion and a discarded, unused, whole shark body portion. The landed shark fins only represent 4.8% of the shark (and related species) by-catch. The other 95.2% represents the discards, which equates to 54,000 t. This consists of discarded, finned shark bodies and unfinned pelagic stingrays, rays, skates, and mantas which are thrown overboard. Discards were dominated by oceanic blue shark (*Prionace glauca*) which represented 50% of the total discards. Discards started at only 54 t in 1988 and peaked at over 4,900 t in 2001. The annual average in the last 5 years (2005-2009) was 3,900 t·year^{-1}.

As part of the allocation process, it was estimated that approximately 21% of the large-scale catches were taken from outside of the EEZ. These catches represent 2.2% of the total reconstructed catch.

Discussion

The total reconstructed catch for the Republic of Fiji for the 1950-2009 period totalled over 2.7 million t which was 2.8 times the total catch reported by Fiji to the FAO. The discrepancy between the reported and reconstructed total is mainly due to a large amount of unreported subsistence catch, especially for earlier time periods.

Subsistence catches not only represented the largest proportion of the total catch, but it was also estimated that 72.9% of subsistence catches were unreported. While the subsistence fishery is undoubtedly a very important fishery to the Fijian people, its importance has been underestimated in the past. Throughout the time span considered here, subsistence catches decreased despite the population of Fiji increasing steadily over time. This decrease in subsistence catch is due to a decrease in subsistence consumption, most likely the product of a shift to an increasingly cash based economy (Veitayaki 1995).

Accordingly, there has been an increase in artisanal catch. This has been accompanied by a shift in the diet of the women (and their families) who sell artisanal catches at the market. The women are in need of money and tend to sell off all of their catch, and therefore end up buying cheap canned meats for themselves and their families to eat (Vunisea 2005). This may have contributed to the decrease in consumption of subsistence catch and an increase in health issues (Anon. 2003). This same effect can be attributed to other types of working individuals as well. More Fijians are moving to urban areas and accepting full-time jobs, leaving them little time to fish to feed themselves (Jennings and Polunin 1996). Therefore, they either buy fresh fish from the market or buy imported alternatives (Jennings and Polunin 1996; Sadovy 2005).

Most significantly, however, is that after accounting for all catches, the overall time trend in catches changes, from a generally increasing trend based on the data supplied to the FAO, to a slowly declining trend (peak in 1981) in total catches in Fiji (Figure 3a). It is important to note that although subsistence catch has declined and there has been a shift towards commercialization, the subsistence fishery still remains the largest contributing sector of Fiji's fishing industry (accounting for 42% of the total catches in 2009) and will continue to be an important component (DeMers and Kahui 2012), particularly in rural and remote areas. Despite advances in technology, subsistence fishing remains largely traditional (DeMers and Kahui 2012).

Although Fiji is one of the few Pacific Island countries to estimate subsistence catch, there is justified criticism in these estimates (Gillett 2009). National subsistence catches prior to the 1979 survey were based on an estimate made by a fisheries official of 2,500 tonnes per year, which is low considering the results of a 1979 survey estimating subsistence catches of almost 14,000 tonnes. Gillett (2009) also questions the accuracy of the 1979 survey. Further estimates of subsistence catch by national authorities were then made by simply adding 200 tonnes to the previous year's catch as a way of accounting for population growth (Sharma 1988; Rawlinson *et al.* 1995). Our reconstructed catch estimate suggests a very different trend. The two estimates generally agree for the recent time period, with the difference in annual averages being approximately 10%, but for the early time period, the reconstructed annual average is just over 17 times the national estimate. The total reconstructed time series estimate of the subsistence fishery is 3.7 times the reported subsistence estimate. Given that the total reconstructed estimate is only 2.8 times the total reported by the FAO, we can see that subsistence catches are extremely important to the Republic of Fiji.

It should be noted that within the Republic of Fiji, catch rates and fishing patterns can fluctuate greatly. Rawlinson *et al.* (1995) has shown that there are significant differences between the fishing practices of native Fijians and Indo-Fijians. Indo-Fijians are more likely to buy seafood than fish for their own, whereas native Fijians tend to catch their own fish (Rawlinson *et al.* 1995). As Jennings and Polunin (1996) have shown, there are large differences between those living on more remote islands or in rural areas and those who live in urban centres. People in urban centres tend to have public sector jobs which keep them busy and unable to fish for their own food. There is also a greater sense of commercialization in urban centres due to more extensive communication and transportation networks. These allow more cost effective imports and trade, as well as form better environments for markets to be profitable. These wide variations in consumption have also been discussed in a nutrition study conducted in Fiji (Jansen *et al.* 1990). The study assesses almost all aspects of the Fijian diet, including nutritional composition, preparation, preservation, intake, feeding in children, technology, and fish consumption. The study is very thorough and is the type of research which is important and useful for assessing the utilization and demand of marine resources. The study presented estimates of seafood consumption rates which did fall within our range throughout the time period. However, the estimates were not used directly to calculate our own estimates. The study states that precise consumption estimates are not available (Jansen *et al.* 1990) and thus the subsistence consumption estimate may, in this case, be based on national estimates. Another estimate which was not used was that of Starkhouse (2009) because when his estimate of the subsistence catch is divided by population, the resulting consumption rate is slightly smaller than that of Gillett (2009), who's estimate we utilized in our reconstruction. This is just another example of how varied these estimates can be, based on what information is utilized. Although great variations exist within Fiji's borders, here we focused on overall national trends and averages. However, such variability should be taken into account in the development of policies and frameworks that address issues such as food security and livelihood maintenance.

Sharks need better protection in Fijian waters. In the last five years, the tuna longline fleet has averaged 3,700 tonnes of shark by-catch per year (which equates to an average of 22.4% of total large-scale commercial catch annually). Since 1988, shark by-catch has ranged anywhere from 1% to almost 45% of the total large-scale commercial catch. All species discarded have an IUCN Red List designation of Threatened or Near Threatened (IUCN 2011) and 66% of all shark species found in Fijian waters fall into these categories as well (Anon. 2011c). Although there has not been much research on the shark fisheries of Fiji, it is known that they are a significant exporter of shark fins and are mostly exporting to the largest importer of shark fins, Hong Kong (Juncker *et al.* 2006). The Fijian government is aware of this issue, which is why they are working with the Coral Reef Alliance and the Pew Environment Group to create the Fiji National Shark Sanctuary (Anon. 2011a). The proposed sanctuary would cover Fiji's entire EEZ. This would prohibit the commercial fishing of sharks as well as the import, export, and sale of shark products in Fiji; this is welcome because not only are the sharks themselves endangered, but their demise also threatens the marine environment, as sharks are important to the health of marine ecosystems (Anon. 2011a).

Traditional management of Fiji's marine resources was characterized by restricted access to inshore resources and a detailed understanding of the marine flora and fauna within their waters, which created a perfect environment for sustainable exploitation (DeMers and Kahui 2012). However, recent efforts to capitalize on and commercialize Fiji's resources threaten to upset the balance. Although our estimates do show a decline in catches within Fiji's EEZ, this may largely be due to a shift in preference from subsistence supplied protein to market-based, non-marine protein sources. However, overexploitation is possible if fisheries management does not evolve to be more sustainable. Depletion of the inshore marine environment could cause declines in tourism, as a large part of Fiji's appeal is its natural beauty (DeMers and Kahui 2012). Introduction of Locally Managed Marine Areas has had some positive effects but more is needed (DeMers and Kahui 2012). Fiji's marine resources can be a great asset to their economy, if managed wisely. Fiji is a perfect example of how modern technology and policy do not always equal more sustainable catches and better management, and that tradition should not be disregarded. DeMers and Kahui (2012) conclude that it is traditional management which can help put Fiji back on track towards economically valuable and sustainable inshore fisheries.

Large-scale pelagic fisheries may require a broader management approach which involves regional management authorities and transboundary considerations. Fishing of large pelagics within a country's EEZ does not only occur by the host country. Foreign fleets pay access fees for rights to fish those waters. Host countries may also engage in joint venture operations, in which they combine forces with another country to permit easy access of large-scale fleets to local waters. This usually occurs when the host country has the marine resources but lacks the equipment to take advantage of their own resources. Therefore, tuna management is not exclusively a domestic issue. There can also be issues of illegal, unregulated, and unreported fishing within large-scale operations. In fact, there have been recent coordinated efforts to try and identify and eradicate these types of fishing. The Pacific Island Forum Fisheries Agency (FFA) and the Regional Fisheries Surveillance Centre (RFSC) coordinated Operation Kurukuru 2011, which covered approximately 30 million square kilometres of ocean in the South Pacific, encompassing the majority of Pacific Island EEZs, including Fiji's (Anon. 2011b). Individual countries surveyed their own EEZs, as well as adjacent high seas areas, and were supported by aerial surveillance provided by Australia, New Zealand, the United States, and France (Anon. 2011b). This highly coordinated and cooperative venture successfully identified, apprehended, and fined a number of vessels which were operating illegally or violating regulations (Anon. 2011b). Sustainable tuna management is a global issue which will require international cooperation (DeMers and Kahui 2012), as shown in Operation Kurukuru. Although it is easier to convince governments and organizations to change when there is dramatic evidence of trouble, Fiji is an example of how future problems can be predicted before irreversible damage is done and while there is still time to adjust policies and practices so that the fishery can remain sustainable and profitable.

Women in fisheries

Fijian women provide a large contribution to fishing. When surveying the village of Tailevu, both men and women stated that women's work was limited to household tasks, but observations indicated that women also participated in fishing activities (Schoeffel 1985). The women of Fiji transfer their knowledge of the intricacies of fishing the reef flats (i.e., reef gleaning) to young girls, thus creating a long line of women fishers (Chapman 1987). The women of Fiji are also known to be more knowledgeable than the men when it comes to certain aspects of fisheries (Chapman 1987; Vunisea 2005). For example, reef gleaning, the major fishing activity that women take part in, requires detailed knowledge of the habitat and range of tools used (Vunisea 2005). Some of the gear used by women includes nylon hand lines to fish on the reef. In the past, women used scoop nets and hand nets, usually in conjunction with poison to fish in the inshore areas and tidal pools. This no longer occurs due to a national ban on the use of poisons, starting in 1996 (Cumming *et al.* 2004), and the introduction of large gillnets which have resulted in men taking over netting activities (Vunisea 2005). Other techniques employed by fisherwomen in the past include certain barrier techniques to trap fish (Vunisea 2005). Both men and women fish at night for a variety of finfish and invertebrates using either a benzene pressure lamp or waterproof flashlight, both of which have replaced the more traditionally used torch (Vunisea 2005). Technological innovations have had little impact on women in fisheries, as rudimentary methods and tools are actually better suited to the nature of the fishery and the species targeted (Vunisea 2005).

Change has occurred in conjunction with the change in market demand. Previously, the focus of fishing was for food, whereas the focus has shifted toward catches to sell at the market (Vunisea 2005). Women who live on more remote islands continue to fish the way they always have, but women who live in or near urban centres have their effort determined by the market demand (Vunisea 2005).

Within the subsistence and artisanal sectors, women are also the primary processors of fish and are skilled in not only smoking and drying, but also in techniques to keep the catch fresh until market day in order to sell fresh fish (Vunisea 2005). Fijian women mostly sell their own catch (and occasionally those of male relatives) at local markets and this can include shellfish, prawns, shrimps, and octopus, as well as cooked or smoked fish (Schoeffel 1985). Many women will make long trips to the Suva market because they are "guaranteed better sales" (Vunisea 2005).

The life of catching and selling fish is not an easy one for the women of Fiji. They involve long trips on unsafe transportation and result in little sleep and poor nutrition, with little reward (Vunisea 2005). Although there is a lot of focus on the fact that women's fisheries are often dismissed as being relatively unimportant, what is often most overlooked is the social importance of women's fishing (Vunisea 2005). Despite the sometimes gruelling conditions, for the women themselves it is an opportunity to spend time with the other women of the village, get out of the house, and to prove their fishing abilities (Vunisea 2005). This social aspect has also allowed women to network with one another and share resources.

Although women mostly contribute to the subsistence and artisanal fisheries, when it comes to larger-scale commercial endeavours, women play a key role in the processing sector. For instance, a joint venture fishing operation (PAFCO), has over 100 women employed (out of 150 workers) at its cannery (Schoeffel 1985). Although there has been recognition that women's participation in and contributions to fisheries have been overlooked, most researchers who undertake the task of describing the importance of women fishers, do it in a qualitative manner. Mostly researchers discuss women's role as an "immense contribution" with no quantitative measure or any indication of the contribution towards the economy or household (Vunisea 2005).

Addendum

Since completing this reconstruction, FAO data became available to 2010. To update the above reconstruction, the 2010 FAO data were accepted as the reported component. In the recent time period, it was determined that almost all catches were reported, thus leaving large-scale commercial by-catch (landings and discards) as the only unreported component for 2010. Landed by-catch and discards for 2010 were calculated based on the proportion of 2009 landed by-catch and discards to the FAO total of 2009, respectively. The sectoral breakdown (artisanal, subsistence, large-scale etc.) for 2010 for the reported component was based on taxa for the large-scale commercial component, whereas for the artisanal and subsistence sectors, the 2009 proportions (of the reported component only) were used. Spatial allocation for the large-scale catches of 2010 was completed using the proportions present in the FFA data, as was also done for 2009. Please note that the values and comparisons for the years 1950-2009 were based on the 2009 FAO dataset, and changes were not made to account for small differences within the 2010 dataset regarding previous years.

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Appendix Table A1. FAO landings vs. total reconstructed catch (in tonnes), and catch by sector, for Fiji, 1950-2009.

Year	FAO Landings	Total reconstructed catch	Subsistence	Artisanal	Large-scale commercial	Discards
1950	2000	38,100	37,700	356	-	-
1951	2000	38,600	38,100	439	-	-
1952	2000	39,400	38,900	531	-	-
1953	2200	40,100	39,400	626	-	-
1954	2200	40,700	40,000	726	-	-
1955	2500	41,500	40,700	836	-	-
1956	2500	41,000	40,100	922	-	-
1957	2500	42,200	41,100	1,049	-	-
1958	2800	43,000	41,800	1,178	-	-
1959	2800	43,900	42,600	1,316	-	-
1960	3000	43,900	42,400	1,431	-	-
1961	3000	44,600	43,000	1,580	-	-
1962	3000	45,400	43,700	1,737	-	-
1963	3200	46,200	44,300	1,903	-	-
1964	3200	46,900	44,800	2,074	-	-
1965	3300	47,400	45,200	2,247	-	-
1966	3300	47,800	45,400	2,423	-	-
1967	3300	48,100	45,500	2,600	-	-
1968	3500	48,200	45,500	2,778	-	-
1969	3500	48,300	45,400	2,962	-	-
1970	3610	48,400	45,300	3,151	0.5	-
1971	3610	48,500	45,100	3,346	0.5	-
1972	4200	48,500	45,000	3,548	0.5	-
1973	4100	48,600	44,800	3,755	100.3	-
1974	4410	48,500	44,500	3,968	83.0	-
1975	4610	48,500	44,200	4,185	91.0	-
1976	5020	48,900	43,800	4,406	742.0	-
1977	6380	49,700	43,300	4,630	1,711.0	-
1978	8220	50,300	42,900	4,861	2,524.0	-
1979	19300	51,000	42,400	5,107	3,494.0	-
1980	19640	49,900	42,100	5,372	2,496.0	-
1981	22460	53,200	41,700	5,660	5,836.0	-
1982	22570	51,900	41,500	5,970	4,436.0	-
1983	21630	51,100	41,100	6,287	3,755.0	-
1984	22670	51,700	40,500	6,591	4,588.0	-
1985	23080	50,700	39,700	6,866	4,079.0	-
1986	22650	48,900	38,600	7,103	3,219.0	-
1987	22340	48,500	37,300	7,304	3,938.0	-
1988	23730	47,300	35,800	7,486	3,911.7	54
1989	24770	47,300	34,400	7,673	5,192.1	61
1990	27880	45,100	33,100	8,022	3,843.9	156
1991	24510	45,500	31,900	8,133	5,330.2	182
1992	20590	44,700	30,700	8,408	4,859.7	746
1993	25060	44,200	29,600	8,704	5,058.1	852
1994	26320	43,900	28,400	8,805	6,220.2	454
1995	25850	44,700	27,200	8,895	7,569.8	1,044
1996	22460	43,000	25,900	8,971	7,262.6	922
1997	23940	39,800	24,500	9,038	4,842.0	1,424
1998	23680	37,500	23,100	9,096	4,584.0	791
1999	31870	40,400	21,600	9,282	4,993.1	4,509
2000	35020	45,700	21,100	9,200	10,535.7	4,800
2001	37600	46,800	20,600	9,248	11,993.4	4,931
2002	35000	45,900	20,100	9,292	12,312.4	4,219
2003	34510	45,300	19,600	9,333	11,609.1	4,747
2004	45080	51,400	19,000	9,374	18,386.4	4,615
2005	40000	44,900	18,500	9,415	12,756.4	4,219
2006	44340	48,800	18,000	10,237	16,361.4	4,219
2007	43780	47,400	17,400	15,955	10,591.1	3,403
2008	41360	45,500	17,500	11,855	12,188.9	3,952
2009	37400	42,300	17,600	9,619	11,382.1	3,700

Appendix Table A2. Total reconstructed catch (in tonnes) for Fiji by major taxa, 1950-2009.

Year	Lethrinidae	Scombridae	Mullidae	Molluscs	Scaridae	Acanthuridae	Miscellaneous pelagic fishes	Mugilidae	Others[1]
1950	6,310	181	3,893	3,420	3,399	3,071	3,454	1,650	12,700
1951	6,390	200	3,937	3,460	3,438	3,105	3,493	1,672	12,900
1952	6,520	221	4,018	3,530	3,508	3,169	3,565	1,708	13,200
1953	6,690	243	4,059	3,570	3,544	3,201	3,601	1,729	13,400
1954	6,790	266	4,117	3,620	3,595	3,247	3,653	1,758	13,700
1955	6,880	391	4,163	3,660	3,636	3,284	3,694	1,882	13,900
1956	6,800	411	4,098	3,600	3,579	3,233	3,637	1,864	13,800
1957	6,980	440	4,207	3,700	3,674	3,318	3,733	1,913	14,200
1958	7,160	501	4,284	3,770	3,741	3,379	3,801	1,929	14,400
1959	7,310	532	4,367	3,840	3,814	3,445	3,875	1,969	14,700
1960	7,370	513	4,350	3,820	3,799	3,431	3,860	2,057	14,600
1961	7,490	547	4,419	3,890	3,859	3,485	3,921	2,092	14,900
1962	7,620	583	4,488	3,950	3,919	3,540	3,983	2,129	15,200
1963	7,810	675	4,554	4,000	3,977	3,592	4,041	2,250	15,300
1964	7,920	714	4,609	4,050	4,025	3,635	4,090	2,282	15,500
1965	7,990	731	4,649	4,090	4,060	3,667	4,125	2,302	15,800
1966	8,050	771	4,673	4,110	4,081	3,686	4,147	2,323	16,000
1967	8,090	811	4,683	4,120	4,089	3,694	4,155	2,339	16,100
1968	8,180	806	4,682	4,120	4,088	3,693	4,154	2,337	16,200
1969	8,200	848	4,674	4,110	4,081	3,686	4,147	2,347	16,300
1970	8,190	968	4,762	4,100	4,071	3,777	4,136	2,348	16,100
1971	8,200	1,013	4,746	4,090	4,057	3,765	4,123	2,356	16,100
1972	8,110	922	4,728	4,070	4,041	3,750	4,106	2,722	16,100
1973	8,140	1,115	4,705	4,050	4,021	3,732	4,086	2,641	16,100
1974	8,050	1,019	4,664	4,050	3,996	3,741	4,060	2,689	16,300
1975	8,070	1,066	4,636	4,010	3,966	3,723	4,030	2,742	16,200
1976	8,000	1,785	4,587	3,980	3,929	3,680	3,993	2,689	16,300
1977	7,840	2,985	4,566	3,960	3,887	3,565	3,950	2,506	16,400
1978	7,720	3,780	4,517	3,890	3,843	3,551	3,905	2,638	16,400
1979	9,300	6,085	3,220	2,760	2,723	2,774	2,767	2,987	18,400
1980	8,570	6,280	3,378	2,700	2,668	2,876	2,711	4,440	16,300
1981	8,080	9,852	3,268	2,670	2,619	2,629	2,661	2,941	18,500
1982	6,920	8,454	3,302	2,640	2,573	2,632	2,614	3,920	18,800
1983	6,990	8,695	3,127	2,670	2,471	2,556	2,457	3,902	18,300
1984	7,440	7,192	3,234	3,040	2,352	2,632	2,286	2,474	21,100
1985	7,300	7,361	2,858	3,030	2,213	2,541	2,099	2,703	20,600
1986	8,050	6,122	2,722	2,860	2,052	2,294	1,896	3,230	19,700
1987	7,220	6,497	2,522	2,950	1,877	2,061	1,687	2,993	20,700
1988	6,860	6,342	2,456	2,710	1,698	2,000	1,481	4,475	19,300
1989	6,400	9,191	2,210	2,790	1,527	1,785	1,289	2,113	20,000
1990	6,420	7,510	2,064	2,770	1,370	1,831	1,117	1,942	20,100
1991	6,060	9,748	1,779	2,470	1,228	1,572	963	1,898	19,800
1992	5,590	8,481	1,722	2,560	1,146	1,314	863	2,239	20,800
1993	6,230	7,764	1,454	2,880	970	1,320	697	3,148	19,700
1994	5,900	8,848	1,309	2,760	846	1,213	578	3,162	19,300
1995	4,370	10,798	1,046	4,280	722	1,021	467	2,523	19,500
1996	4,550	10,630	1,186	3,740	735	892	447	1,576	19,300
1997	4,200	7,504	903	5,080	476	608	269	1,484	19,300
1998	3,900	7,574	701	4,200	356	562	186	1,803	18,300
1999	3,740	7,252	537	4,040	240	467	114	3,121	20,900
2000	3,700	13,032	447	3,720	191	391	82	3,012	21,100
2001	3,620	14,689	394	3,670	144	357	54	3,054	20,800
2002	4,420	14,718	932	3,160	480	718	154	2,322	19,000
2003	5,160	13,093	1,709	3,030	972	1,255	311	1,174	18,600
2004	5,200	19,622	1,520	2,800	876	1,255	281	1,011	18,900
2005	5,170	14,299	1,438	2,680	832	1,209	267	948	18,100
2006	5,250	17,973	1,358	2,560	790	1,169	253	939	18,500
2007	6,110	13,583	1,399	2,500	780	1,102	250	1,700	19,900
2008	5,130	14,416	1,448	2,530	796	1,309	255	1,272	18,400
2009	4,820	13,317	1,472	2,590	820	1,005	263	1,282	16,700

[1] Others category includes 47 additional taxonomic groups.

Reconstruction of total marine fisheries catches for Haiti and Navassa Island (1950–2010)[1]

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Abstract

A reconstruction of total marine fisheries catches for Haiti and Navassa from 1950 to 2010 was undertaken. The catch reconstruction combines estimates of artisanal catches with subsistence catches estimated from seafood consumption data combined with trade and aquaculture data. The reconstructed total catch for Haiti and Navassa was estimated at 846,900 t for the study period (1950-2010), which is approximately three times the reported catch of 280,272 t. A large part of this discrepancy was due to the inclusion of unreported subsistence catch estimates and the improved accounting of conch, lobster, crab and shrimp artisanal fisheries catches in the early time period.

Introduction

Famous for its practice of the voodoo religion, a tumultuous history of successive dictatorship and, recently, a catastrophic earthquake in 2010, the rugged tropical Republic of Haiti shares the island of Hispaniola with the Dominican Republic. Hispaniola, "discovered" by Christopher Columbus in 1492, lies in the north central Caribbean, between 18° and 20° north latitudes, and 71° 30' and 74° 30' west longitudes (Figure 1). The island was the first Spanish settlement in the New World (Smucker 2001) and the world's first black republic. Haiti is a mountainous country characterized by steep slopes and a narrow shelf (Appledoorn and Meyers 1993). It is associated with 5 small islands: Tortuga Island, Gonaive Island, Vache, Les Arcadins, and Navassa Island, located between Haiti and Jamaica. Note that while Haiti claimed Navassa in 1804, it has been under the jurisdiction of the USA as part of the Caribbean Islands National Wildlife Refuge since 1856 (Wiener 2006). However, we at the *Sea Around Us* Project have allocated Navassa Island's EEZ to Haiti as it is Haitians who fish in Navassa's waters and not the US.

Haiti has a land area of approximately 27,750 km^2, occupying the western third of the island of Hispaniola. It is bounded to the north by the Atlantic Ocean and to the south by the Caribbean Sea. Haiti and its associated islands experience a tropical climate with temperatures between 25.5°C and 28°C depending on altitude and exposure to the prevailing north-east trade winds. Rainfall is irregular, giving Haiti a semi-arid climate, with little to no rainfall from December through February. A considerable portion of the Haitian coast is fringed with coral and rocky reefs, with large areas of sand and gravel beach and low-lying mangrove swamps (Fiedler *et al.* 1943), while Navassa Island is comprised of a raised plateau surrounded by limestone cliffs. In terms of ecosystem productivity, the waters off Haiti are largely regarded as rather poor producers of fish, since there are no large fluxes of nutrients available to support plankton production. However, to the north, a branch of the North Equatorial Current passes approximately 20 miles offshore. This current is one of the major migration routes of tuna, marlin, swordfish and other large migratory species (Fiedler *et al.* 1943). Also, due to its isolation and uninhabited status, Navassa had been described as having a relatively pristine reef community (Miller *et al.* 2002).

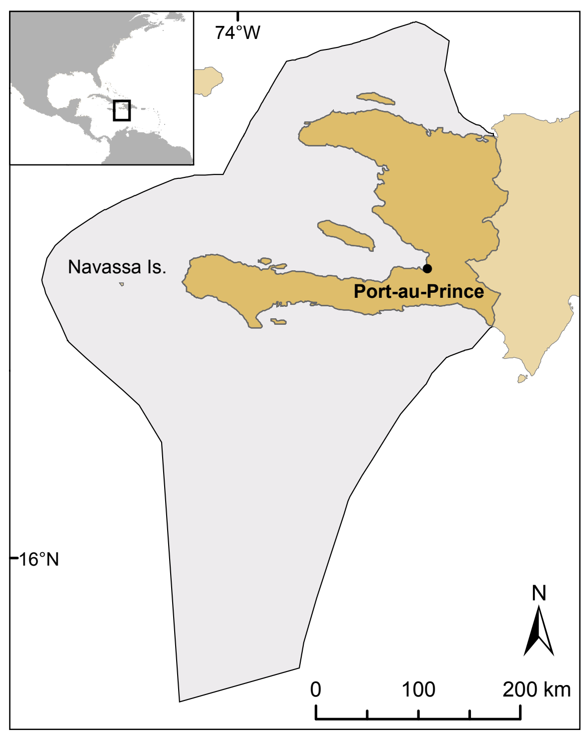

Figure 1. Map of Haiti and associated islands including Navassa. The black line corresponds to the demarcation of the Exclusive Economic Zone.

Haiti is one of the poorest and most densely populated countries in the Western Hemisphere. Current *per capita* GDP stands at $500 (UNEP 2010). Haiti is a country with enormous environmental problems, a direct consequence of the poverty which plagues a large fraction of the population. The diet of the average Haitian includes meals in which beans and occasionally meat (goat, beef, or pork) or fish serve as the main source of protein (Sebrell *et al.* 1959). However, such proteins are not consumed every day. Haiti has a continental shelf area of approximately

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435 km² and an Exclusive Economic Zone (EEZ) of approximately 112,000 km² (www.seaaroundus.org), which was declared in 1977. This is the smallest EEZ of all the Greater Antillean Islands, which also include Cuba, Jamaica, Puerto Rico, and the Dominican Republic. The main marine resources exploited within the EEZ are demersal (reef) fish and a limited quantity of pelagic fish, both over the continental shelf and offshore (Romain 2005). The continental shelf around Haiti is relatively narrow and easily accessible to fishers, and as a result, the coastal and demersal fish stocks are heavily over-exploited (FAO 1981). In contrast, offshore pelagic fisheries and deep-water demersal fisheries are said to be under-exploited due to technological limitations (Mateo and Haughton 2003). Marine species are also exploited in the mangrove forests, where people mainly catch crabs as well as shrimp, fish and shellfish (Aube and Caron 2001).

Small-scale fishing has a long history along Haiti's coast (Fiedler *et al.* 1943), and it absorbed many underemployed and unemployed Haitians (Zacks 1998). Marine resource exploitation in Haiti has always been open-access. Thus the fisheries resources of Navassa are extremely important to Haitian fishers, and appear to have been exploited since at least the 1970s (Wiener 2006). The fishing sector is primarily artisanal, multi-gear, multi-species and marketed mainly for local sale and personal consumption (FAO 1981). Small-scale fishers operate from small wooden boats (Zacks 1998), canoes and pirogues, which are propelled by oars or sails (Brethes and Rioux 1986 in Appledoorn and Meyers 1993). Presently, the sector comprises about 52,000 fishers from 400 villages, operating a total of 26,400 vessels (Damais *et al.* 2007). Despite technological advances elsewhere in the Caribbean, the Haitian fisheries sector remains predominantly unmechanized. Only 1,400 motorized vessels were enumerated by the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR) in a 2007 fisheries sector study.

Traditionally, fishing is done by men, while women, often called *Madam Sara*, do the marketing of the catch (Zacks 1998). Overall, fishing is multi-species and multi-gear. Fish pots, nets, lines and spearguns are the primary gears used. Occasionally, those who can afford them may use lights attached to a battery for night fishing called *pêch batri* (Wiener 2006). Pieces of fish, lobster, marine turtle, sea star, bird, sea cucumber, crab, orange, and corn-based animal feed made into a ball are used as bait. Anything which may have value either for consumption or sale, or use as bait is taken (M. Karnauskaus, pers. comm., National Marine Fisheries Service, NOAA).

Marine organisms exploited in Haiti are consumed by the fishers and their families or marketed locally or, in the case of conch and spiny lobster, internationally (Zacks 1998). After basic processing, fish catches are classified into three groups: red or pink *pwason rose*, white *pwason blanch* and black *pwason noir*. The least desired black fish include butterfly fish and puffer fishes, white fish is mid-range and includes dolphin fish (*Coryphaena hippurus*) and barracuda (*Sphyraena barracuda*) while "red" or "pink" fish such as snapper (Lutjanidae) and grouper (Serranidae) are the most desired (Wiener 2006). About 30% of the fish caught in Haiti is salted and dried before being marketed, the rest is consumed fresh (Damais *et al.* 2007). Post-harvest losses are reported to be common in Haiti's fishing villages, since ice and refrigeration are scarce or completely lacking. Poor sanitation standards have also affected Haiti's ability to trade internationally. Haitian seafood is banned from European and North American markets (Anon. 2003). However, some species are exported such as lobsters (*Panulirus argus*), conch (*Strombus* spp.), shrimp (*Penaeus* spp.), octopus (Octopodidae) and crabs (*Menippe mercenaria*) with a significant proportion of these catches informally entering the Dominican Republic (Anon. 2003). Overall, Haiti's demand for seafood is higher than local catches can satisfy, and thus Haiti is a net importer of fish (MARNDR 2009).

As in many Caribbean Islands, the fisheries sector has been neglected by the governments of Haiti. According to Mateo and Haughton (2003), the Haitian Fisheries Service initiated in 1952 has limited institutional capability and insufficient finances to operate satisfactorily. Fisheries legislations are outdated. The Fisheries Law of 1977 is still the main legal instrument by which fisheries activities are regulated (Mateo and Haughton 2003). Management regulations are generally neither respected by fishers nor enforced by the fisheries management authorities. Though data collection is one of the key functions of the Fisheries Service, limited human resources mean that statistical data for the sector are very poor.

It is widely recognised that catch statistics are crucial to fisheries management (Pauly 1998). Fisheries data of any kind, including catch data, are virtually impossible to find for Haiti. For instance, when reviewing tables documenting fisheries data for the various islands of the Caribbean region (in FAO, Caribbean Regional Fisheries Mechanism [CRFM], Gulf and Caribbean Fisheries Institute [GCFI] documents), Haiti's input is almost always left blank. This study aims to gather available information on fisheries catches and fishing practices to reconstruct Haiti and Navassa Island's total fisheries catches for the period 1950-2010. The catch reconstruction method used here is based on the approach developed by Zeller *et al.* (2007). We aim to improve the catch data both quantitatively and taxonomically.

Methods

Baseline catch, trade and aquaculture data were extracted from the FAO FishStat database. A review of accessible Haitian historical, dietary and fisheries literature was undertaken to identify anchor points required for inferences on seafood demand, total artisanal catches, number of fishers and species caught. Commercial fisheries landings consist of fish marketed locally or exported abroad. Due to the small-scale nature of all commerce in Haiti, all commercial landings in Haiti are attributed to artisanal catches. Here we define subsistence catches as those used primarily for home consumption or those which are bartered locally. Though we realise that the boundary between artisanal and subsistence is less than clear cut.

Human population and fisher population

People reside on Haiti and adjacent islands, except Navassa Island, which is uninhabited, but visited by Haitians fishers. Human population statistics for Haiti were taken from Populstat (www.populstat.info) for 1950 and from World Bank from 1960–2010. A linear interpolation was used to derive population values for years with missing data. The overall population of Haiti has increased steadily from 3 million in 1950 to nearly 10 million in 2010 (Figure 2a). Population data were used in the calculation of total seafood demand from 1950 to 2010 (which was utilised in reconstructing subsistence catches) and also in the estimation of the proportion of fishers in the total population.

Table 1. Data sources of fishers, artisanal catches and calculated CPUEs.

Year	No. of fishers	Artisanal Catches (t)	Source	Artisanal CPUE (kg/fisher/year)
1942	3,017	938	Fiedler *et al.* 1943	311
1957	8,000	4,035	Beghin *et al.* 1970	504
1976	-	7,650	France (1977)	762[1]
1985	11,000	-	Laserre *et al.* (1985) in Mateo and Haughton (2003)	-
1989	12,000	-	UNDP/FAO (1989) in Mateo and Haughton (2003)	-
2000	30,000	-	Breuil (2000) in Mateo and Haughton 2003)	-
2006	52,000	15,850	MARDNR (2007)	305

[1]This CPUE was calculated using our estimate of number of fishers for 1976 (10,036) as derived through linear interpolation.

Data on the number of fishers in Haiti were available for six years from 1942 to 2006, from various sources (Table 1). We used a direct linear interpolation between anchor points to derive data for all years during the period 1942-2006. From the final anchor point (2006) we determined the proportion of fishers in the population and use this fixed figure to estimate number of fishers for 2007-2010. Using this approach suggests that nearly 55,000 fishers existed in Haiti in 2010 (Figure 2b).

Artisanal landings of Haiti

Annually, national organizations such as the MARNDR in Haiti submit catch data and other fishery statistics to FAO. Ideally, catch statistics should be collected for all fisheries sectors: industrial, artisanal, subsistence and recreational. Unfortunately, only a limited number of countries collect this information (Garibaldi 2012). Thus commercial landings are typically what the FAO reports in their landings statistics on behalf of a country. Estimates of Haiti's artisanal fisheries catches, used here as anchor points, are represented in Table 1. Dividing reported catches by the number of fishers reported for the corresponding year gave the catch per unit effort (CPUE) for artisanal fishers. We estimated four values of CPUE for 1942, 1957, 1976 and 2006. Linear interpolations were applied between these 4 anchor points to derive the CPUEs for 1950-2010. Multiplying CPUE by the number of fishers estimated for each year (Figure 2b.) we reconstructed an estimate of Haiti's artisanal fisheries catches from 1950 to 2010.

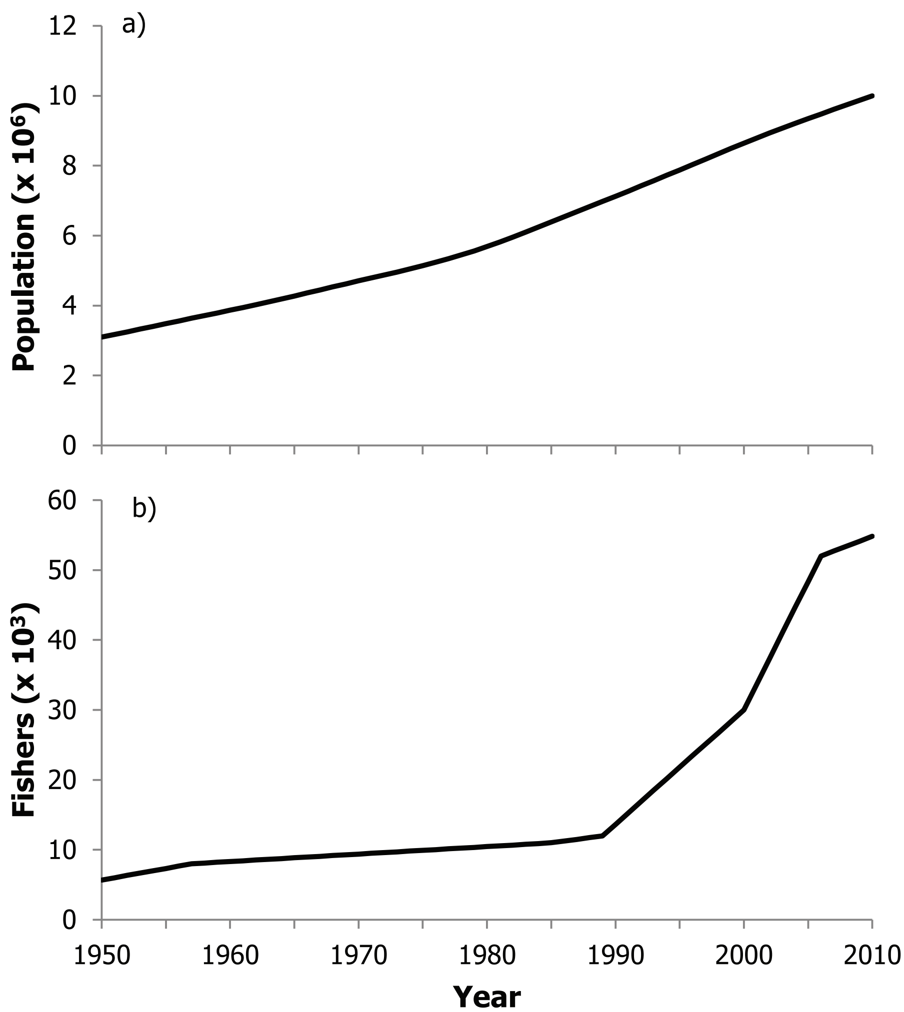

Figure 2. Basic statistics on Haiti: a) Total Haitian population and b) trend in the number of fishers.

Subsistence catches

It is reported that Haitian fisheries are primarily subsistence based (Moal 1977; FAO 1981). However, data regarding subsistence fisheries in Haiti were not readily available. To independently estimate the subsistence catches in Haiti, we relied on a national nutrition study by

Sebrell *et al.* (1959), which cited an average fish intake of 2.92 kg·person^{-1}·year^{-1}. To derive subsistence catch rates, we assumed the consumption reported in Sebrell *et al.* (1959) remained constant over time. Hence we estimated total seafood demand by multiplying annual population numbers by 2.92 kg·person^{-1}·year^{-1}. This generated total demand for seafood, from which available import and aquaculture data were subtracted to arrive at estimated domestic marine catch demand. As import data were highly variable and unreliable, we used this derived marine catch demand as a guide only. From this, we derived an assumed average *per capita* seafood subsistence rate of approximately 1.0 kg·person^{-1}·year^{-1}. However, we also assumed subsistence catch rates were 25% higher in the earlier time period and 25% lower in the later time period. Thus we applied a seafood subsistence rate of 1.25 kg·person^{-1}·year^{-1} in 1950 and 0.75 kg·person^{-1}·year^{-1} in 2010. Interpolating linearly between these two *per capita* domestic marine subsistence rates, and subsequently multiplying by annual population figures, we estimated subsistence catches for Haiti from 1950-2010.

Composition of Haiti's catch

Catches as reported by the FAO on behalf of Haiti are highly aggregated, with just five groups being presented: "Natantian decapods nei", "Stromboid conchs nei", "Caribbean spiny lobster", "Marine crabs nei" and "Marine fishes nei". As detailed quantitative catch data for Haiti and Navassa were not readily available, we used the FAO breakdown in years with the most taxonomic categories as a starting point. Thus we calculated the proportion of total catch by group from 1995 to 2010 (1995 is the first year when all groups have a non-zero value recorded) and applied these proportions throughout the period 1950 to 1995 to the total reconstructed catch. The proportions were as follows: "Natantian decapods nei" (6.5%), "Stromboid conch nei" (5.2%), "Caribbean spiny lobster" (9.3%), "Marine crabs nei" (2.5%) and "Marine fishes nei" (76.5%). For 1995 onwards, we used annual proportions from the FAO dataset and applied these to total reconstructed catches.

For the artisanal sector we assumed 80% reef-demersal taxa, 10% pelagic taxa and 10% miscellaneous marine fishes in 1950. In 2010 we assumed 60% reef-demersal taxa, 30% pelagic taxa and 10% miscellaneous marine fishes, using direct linear interpolation in between. The reef-demersal component was further subdivided using Zacks (1998) while the pelagic taxa component was further subdivided using qualitative information from Prado *et al.* (1991, in Reynal *et al.* 2000) and Zacks (1998). For the subsistence sector, we assumed 20% miscellaneous marine fishes and 80% reef-demersal taxa for the period 1950-2010. Given the preference of Haitian people for delicate fish over "thick or greasy meat" (Zacks 1998) pelagic species are assumed not to form part of these catches. The reef-demersal component was further subdivided using Zacks (1998).

Table 2. Taxonomic breakdown for artisanal sector in Haiti.

Taxa	% in 1950	% in 2010
Ablennes hians	0.32	0.24
Acanthocybium solandri	1.25	3.75
Acanthurus bahianus	0.20	0.15
Caranx ruber	9.49	7.12
Chaetodon capistratus	0.52	0.39
Chaetodon sedentarius	0.20	0.15
Clepticus parrae	27.17	20.38
Conger triporiceps	0.28	0.21
Coryphaena hippurus	1.67	5.00
Decapterus macarellus	1.07	0.80
Epinephelus cruentatus	0.64	0.48
Gymnothorax moringa	0.32	0.24
Haemulon aurolineatum	1.67	1.25
Haemulon flavolineatum	0.52	0.39
Haemulon plumieri	1.47	1.10
Hemiramphus brasiliensis	0.48	0.36
Holocentrus adscensionis	1.55	1.16
Holocentrus rufus	1.51	1.13
Inermia vittata	0.44	0.33
Lactophrys spp.	0.20	0.15
Lutjanus apodus	0.20	0.15
Lutjanus campechanus	2.03	1.52
Lutjanus griseus	0.36	0.27
Makiara nigricans	1.67	5.00
Mulloidichthys martinicus	2.98	2.23
Myripristis jacobus	0.64	0.48
Ocyurus chrysurus	0.52	0.39
Priacanthus cruentatus	1.11	0.83
Pseudopeneus maculatus	1.83	1.37
Rhomboplites aurorubens	0.99	0.74
Scombridae	1.25	3.75
Selar crumenophthalmus	5.56	4.17
Sparisoma aurofrenatum	6.95	5.21
Sparisoma chrysopterum	0.52	0.39
Sparisoma rubripinne	0.24	0.18
Sparisoma viride	2.11	1.58
Sphyraena barracuda	1.25	3.75
Sphyraena picudilla	5.2	3.90
Thunnus spp.	1.25	3.75
Tylosurus crocodilus	0.75	0.57
Xiphias gladius	1.67	5.00
Misc. marine fishes	10.00	10.00

To further disaggregate the "Marine fishes nei" category, we relied on quantitative and qualitative catch data from Zacks (1998) and Prado *et al.* (1991, in Reynal *et al.* 2000). Zacks' (1998) study included an examination of three separate catches from each of ten fishers using multiple traditional gears (bamboo traps, gill nets, hook and line, and spearguns) from June to August 1995 in Luly, Haiti. Prado *et al.* (1991, in Reynal *et al.* 2000) provided details of a pelagic fish aggregating device (FAD) fishery being established in Haiti in the early 1990s, allowing fishers with the means (i.e., motors) to exploit larger coastal pelagic species such as dolphinfish (*Coryphaena hippurus*), blue marlin (*Makaira nigricans*) and sailfish (*Xiphias gladius*). Zacks (1998) also described that fishers targeting sailfish incidentally capture wahoo (*Acanthocybium solandri*), dolphinfish, mackerel (*Scomberemous* spp.), barracuda (*Sphyraena barracuda*) and tunas (*Thunnus* spp.). Hence, the following species breakdown was applied to the pelagic category: blue marlin (16.7%), sailfish (16.7%), dolphinfish (16.7%), wahoo (12.5%), mackerels (12.6), barracuda (12.5%) and tunas (12.5%). The complete species breakdowns for the artisanal and subsistence sectors are shown in Tables 2 and 3, respectively.

Navassa catch levels and composition

Three scenarios of annual landings for fish, lobster and queen conch at Navassa were estimated by Miller *et al.* (2008). Methods included extrapolations of landings observed in on-site visits and stated by fishers working in Navassa in semi-directed group and individual interviews in 2004 and 2005. Their extrapolations were based on number of boat trips to Navassa per year, mean daily boats observed in November 2004 and mean daily boats observed in 2002. Since fish caught in Navassa and landed in Haiti is already processed (head and guts removed), Miller *et al.* (2008) applied FAO conversion factors (2.0 and 2.5) to arrive at a max-min range of fresh whole catches landed annually under the following fishing scenarios: 150 trips, 99 trips and 45 trips. We took the minimum total catch landed and assumed a discard rate of zero (M. Karnauskaus, pers. comm., National Marine Fisheries Service, NOAA), which provided a conservative mean estimate of 31 t·year^{-1}, which we applied each year, beginning in 1970 to reconstruct the minimum fish catches from Navassa Island.

To disaggregate Navassan catches, we utilized Miller *et al.* (2002) enumeration of species caught in fishing boats observed at Navassa Island from October to November 2002 (Table 4). These were converted to weights using the species common weights in Fishbase (www.fishbase.org; accessed January, 2012) and a trap fishing survey of Pedro Bank (Hartsuijker 1982).

Table 3. Taxonomic breakdown for the subsistence sector in Haiti.

Taxa	%
Ablennes hians	0.32
Acanthurus bahianus	0.20
Caranx ruber	9.49
Chaetodon capistratus	0.52
Chaetodon sedentarius	0.20
Clepticus parrae	27.17
Conger triporiceps	0.28
Decapterus macarellus	1.07
Epinephelus cruentatus	0.64
Gymnothorax moringa	0.32
Haemulon aurolineatum	1.67
Haemulon flavolineatum	0.52
Haemulon plumieri	1.47
Hemiramphus brasiliensis	0.48
Holocentrus adscensionis	1.55
Holocentrus rufus	1.51
Inermia vittata	0.44
Lactophrys spp.	0.20
Lutjanus apodus	0.20
Lutjanus campechanus	2.03
Lutjanus griseus	0.36
Mulloidichthys martinicus	2.98
Myripristis jacobus	0.64
Ocyurus chrysurus	0.52
Priacanthus cruentatus	1.11
Pseudopeneus maculatus	1.83
Rhomboplites aurorubens	0.99
Selar crumenophthalmus	5.56
Sparisoma aurofrenatum	6.95
Sparisoma chrysopterum	0.52
Sparisoma rubripinne	0.24
Sparisoma viride	2.11
Sphyraena picudilla	5.20
Tylosurus crocodilus	0.75
Misc. marine fishes	20.00

Results

Haiti artisanal catches

Reconstructed artisanal catches for Haiti totalled 492,273 t, which accounts for 58.1% of the total reconstructed catches for Haiti and Navassa Island (Figure 3a). In 1950, artisanal catches amounted to 2,350 t·year^{-1}, increasing to 7,650 t·year^{-1} in 1976 before stabilizing until 1989. From 1990 onwards, catches increase substantially to a peak of 16,710 t·year^{-1} in 2010. Catches of large pelagic species prior to FAD fishery development (1950-1989) averaged approximately 370 t·year^{-1}, and increased to an average of 1,758 t·year^{-1} from 1990 to 2010 due to FADs.

Haiti subsistence catches

Reconstructed subsistence catches for Haiti increased steadily from 3,871 t·year^{-1} in 1950 to 7,495 t·year^{-1} in 2010 (Figure 3a). Total reconstructed catches from this sector amounted to 353,355 t, which accounts for 41.7% of the total reconstructed catches for Haiti and Navassa Island.

Catch composition

Fisheries catches of Haiti were dominated by reef and demersal species (Figure 3b) such as wrasses (Labridae; 20%) and parrotfish (Scaridae; 7%). Also important were small coastal pelagics, such as jacks (Carangidae; 12%) and southern sennet (*S. picudilla;* 4%). Invertebrate species were also dominant, as is demonstrated by the importance of lobster (Panuliridae; 9%), miscellaneous decapods (6.5%), conch (Strombidae; 5%) and miscellaneous crabs (3%). Large pelagics account for approximately 7% of total catches but are increasing in significance. Pelagic species dominant in FAD catches were blue marlin, dolphinfish, swordfish, wahoo, barracuda and tunas. "Others" comprised 22 families of reef and demersal species including surgeonfish (Acanthuridae), butterflyfish (Chaetodontidae), squirrelfish (Holocentridae), trunkfish (Ostraciidae), eels (Congridae), stingrays (Dasyatidae and Urotrygonidae), sharks (Carcharhinidae), octopus, and sea cucumbers (Holothuroidea), as well as "Marine fishes nei". Reconstructed catches from Navassa Island totalled 1,271 t for the 1970–2010 time period and are included in Figure 3. These catches were dominated by *Sphyraena barracuda* (32%).

Table 4. Taxonomic breakdown for Navassa Island catches. The breakdown was based on Miller *et al.* (2002).

Taxa	%
Balistidae	6.73
Urotrygonidae	3.05
Monacanthidae	6.75
Lutjanidae	5.60
Malacanthidae	0.77
Sphyraenidae	35.15
Holocentridae	0.53
Ostraciidae	25.99
Acanthuridae	4.28
Carangidae	9.00
Scaridae	0.15
Dasyatidae	0.31
Carcharhinidae	1.43
Serranidae	0.26

Total reconstructed catch

Total annual reconstructed landings linearly increased from an average of 6,800 t·year^{-1} in the early 1950s to 12,000 t·year^{-1} in the early 1970s, and then stabilized at an average of 13,100 t·year^{-1} from the mid-1970s to 1990 (Figure 3a). From there catches increased again up to their peak in 2010 of 24,236 t·year^{-1}. This trend differs from the data presented by FAO on behalf of Haiti. Landings increased to a peak in the mid-1980s, where they then decreased in to the mid-1990s and increased again to a new high in 2004 and stayed constant until 2010 (Figure 3a). The reconstructed total catch for Haiti and Navassa for the period 1950-2010 was estimated at 846,900 t, which is approximately 3 times the catch supplied to the FAO by Haiti (Figure 3a).

Discussion

Haiti and Navassa Island's total catches from 1950-2010, as estimated in our reconstruction, were approximately 846,900 t. Over the same period, FAO reported landings of 280,272 t on behalf of Haiti. The reconstructed catch is 3 times the total landings as supplied to the FAO. Our reconstruction does three things: it assesses fisheries sectors that have been overlooked, including Navassa Island fisheries and a sizeable subsistence fishery, it improves on what has been reported for the artisanal sector by filling in catches of invertebrates for a time period when catches were wrongly recorded as zero, and it improves the taxonomic resolution of the catch.

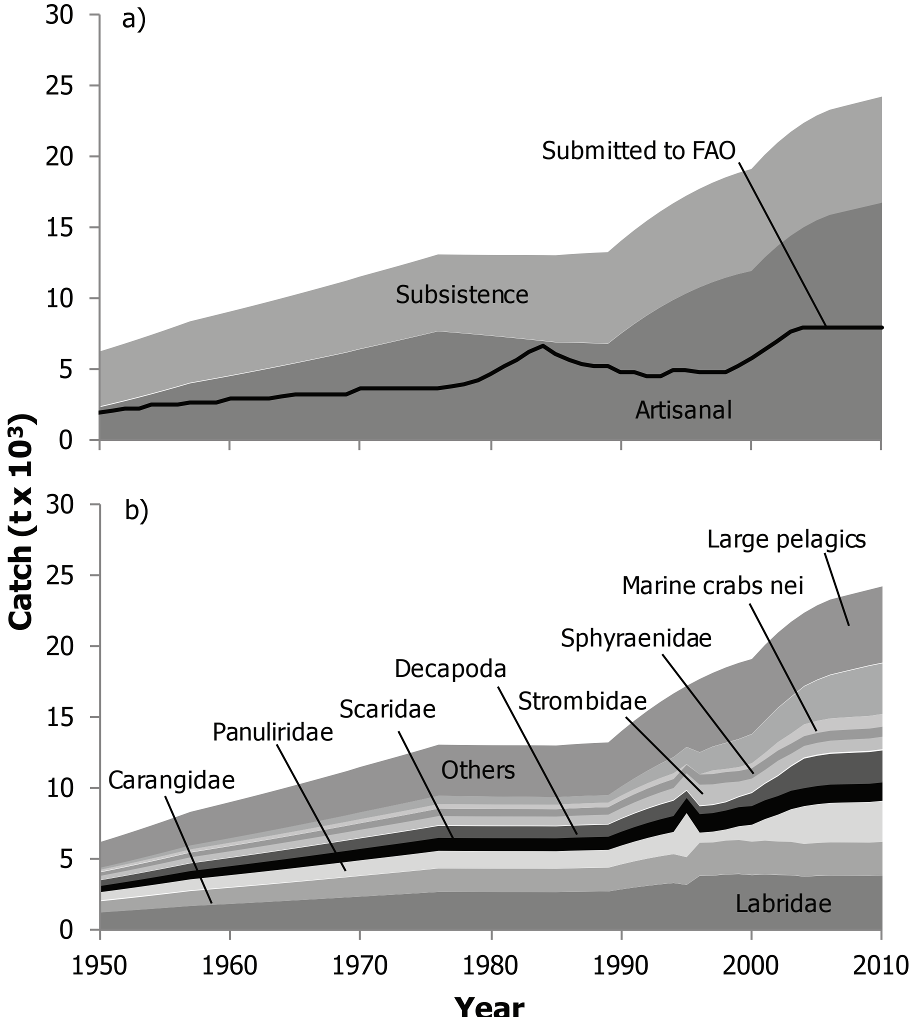

Figure 3. a) Total reconstructed catches for Haiti and Navassa Island by sector, compared to data reported to the FAO from 1950 to 2010. b) Total reconstructed catches for Haiti and Navassa Island by main taxa caught. 'Others' category comprised 20 taxa of reef and demersal fish.

Catches from the subsistence sector, contributing 41.7% to the overall fisheries reconstruction for Haiti, were the largest contributor to the difference in reported catches and reconstructed catches. Haitian fisheries are demonstrating some of the symptoms of Malthusian overfishing (Pauly 1994): the population of fishers increased by a factor of 2.5 in the decade 1990 to 2000, and CPUEs fell by 60% from 1976 to 2005. Uncontrolled population growth has placed considerable pressure on Haiti's resources, and this pressure is rapidly being transferred to the sea. With several recommendations pointing to further investment in exploiting offshore FAD fisheries (Mateo and Haughton 2003; MARNDR 2009; Damais *et al.* 2007), the likely response will be larger and more powerful boats fishing further offshore as described by Pauly and Froese (2001). Due to high demand, Haiti relies heavily on imported seafood. However, a significant portion of seafood demand is still being satisfied by domestic catches. Of these catches, only those from the artisanal sector are partially being recorded and hence reported to the FAO. This is demonstrated by the similarity of FAO landings data in 1950 to our reconstructed catches from the artisanal sector. Given the high likelihood that Haiti, at least in recent times, is one the countries that fails to report their catches to FAO (Garibaldi 2012), it is likely that FAO utilises an expert estimate only. This is also reflected in the very limited taxonomic accounts in official data.

While our approach requires assumption-based inferences and interpolations, we believe that our estimate reflects more correctly the likely scale of actual catches than does reported data (Zeller *et al.* 2007). The people of Haiti depend on fisheries, both as a vital source of protein and as a livelihood. As it stands, they are degrading the very system which supports them. Haiti reports about a third of what is being removed from its waters. Better accounting of fisheries extractions by the subsistence sector is urgently needed to better understand total resource use. Given the difficulties in fisheries monitoring, especially subsistence fisheries, this can be best achieved through regular, albeit non-annual, surveys (Zeller *et al.* 2007).

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

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal
1950	2,000	6,220	3,870	2,350
1951	2,100	6,510	3,940	2,560
1952	2,200	6,800	4,010	2,790
1953	2,200	7,100	4,080	3,020
1954	2,500	7,400	4,140	3,260
1955	2,500	7,720	4,210	3,510
1956	2,500	8,040	4,270	3,770
1957	2,700	8,370	4,330	4,040
1958	2,700	8,590	4,390	4,200
1959	2,700	8,820	4,450	4,370
1960	2,900	9,050	4,510	4,540
1961	2,900	9,280	4,570	4,710
1962	2,900	9,510	4,630	4,880
1963	3,000	9,750	4,690	5,060
1964	3,100	9,990	4,750	5,240
1965	3,200	10,240	4,810	5,430
1966	3,200	10,480	4,870	5,620
1967	3,300	10,740	4,930	5,810
1968	3,300	10,990	4,990	6,000
1969	3,300	11,240	5,050	6,200
1970	3,700	11,530	5,100	6,430
1971	3,700	11,780	5,150	6,630
1972	3,700	12,040	5,200	6,830
1973	3,700	12,290	5,250	7,040
1974	3,700	12,550	5,300	7,250
1975	3,700	12,820	5,360	7,460
1976	3,700	13,090	5,410	7,680
1977	3,850	13,080	5,470	7,610
1978	4,000	13,070	5,540	7,530
1979	4,200	13,060	5,610	7,450
1980	4,700	13,060	5,690	7,370
1981	5,200	13,050	5,770	7,280
1982	5,700	13,050	5,860	7,190
1983	6,200	13,050	5,950	7,100
1984	6,600	13,050	6,040	7,010
1985	6,100	13,040	6,130	6,910
1986	5,700	13,100	6,210	6,890
1987	5,450	13,160	6,300	6,870
1988	5,200	13,210	6,380	6,840
1989	5,200	13,250	6,450	6,800
1990	4,800	14,050	6,530	7,510
1991	4,800	14,790	6,610	8,180
1992	4,500	15,480	6,680	8,790
1993	4,550	16,110	6,750	9,360
1994	5,000	16,700	6,820	9,880
1995	5,017	17,230	6,890	10,340
1996	4,745	17,720	6,960	10,760
1997	4,801	18,150	7,030	11,120
1998	4,759	18,530	7,090	11,440
1999	5,300	18,850	7,150	11,700
2000	5,800	19,120	7,200	11,920
2001	6,400	20,110	7,250	12,860
2002	7,000	20,980	7,300	13,690
2003	7,600	21,740	7,340	14,400
2004	8,000	22,380	7,370	15,010
2005	8,000	22,900	7,400	15,500
2006	8,000	23,310	7,430	15,880
2007	8,000	23,540	7,450	16,100
2008	8,000	23,780	7,460	16,310
2009	8,000	24,010	7,480	16,520
2010	8,000	24,240	7,490	16,740

Appendix Table A2. Total reconstructed catch (in tonnes) for Haiti and Navassa Island by major taxa, 1950-2010.

Year	Labridae	Carangidae	Panuliridae	Scaridae	Decapods	Strombidae	Sphyraenidae	Brachyura	Large Pelagics	Others[1]
1950	1,290	767	580	467	405	322	248	156	180	1,800
1951	1,350	802	607	488	424	337	259	163	196	1,880
1952	1,410	839	634	510	443	352	271	170	213	1,950
1953	1,470	875	662	533	462	367	282	178	231	2,030
1954	1,540	913	691	556	482	383	295	185	249	2,110
1955	1,600	952	720	579	503	400	307	193	269	2,190
1956	1,670	992	750	603	523	416	320	201	288	2,280
1957	1,740	1,032	780	628	545	433	333	210	309	2,360
1958	1,790	1,060	801	645	560	445	342	215	321	2,420
1959	1,830	1,088	823	662	574	457	351	221	334	2,480
1960	1,880	1,116	844	679	589	468	360	227	347	2,540
1961	1,930	1,144	865	696	604	480	369	232	360	2,600
1962	1,980	1,173	887	714	619	492	379	238	374	2,660
1963	2,030	1,203	909	732	635	505	388	244	387	2,720
1964	2,080	1,232	932	750	651	517	398	250	401	2,780
1965	2,130	1,263	955	768	666	530	407	256	415	2,850
1966	2,180	1,293	978	787	683	543	417	263	430	2,910
1967	2,230	1,324	1,001	806	699	556	427	269	444	2,980
1968	2,280	1,355	1,025	825	716	569	437	275	459	3,040
1969	2,340	1,387	1,049	844	732	582	447	282	474	3,110
1970	2,390	1,421	1,074	863	749	596	458	288	499	3,190
1971	2,440	1,452	1,097	882	765	610	468	294	514	3,260
1972	2,490	1,483	1,121	901	782	623	478	301	530	3,320
1973	2,550	1,515	1,145	920	798	636	488	307	546	3,390
1974	2,600	1,547	1,169	940	815	649	498	314	562	3,460
1975	2,660	1,580	1,194	960	833	663	509	320	578	3,520
1976	2,710	1,614	1,220	980	851	678	520	327	595	3,600
1977	2,710	1,612	1,219	979	850	677	519	327	589	3,600
1978	2,710	1,611	1,218	979	849	676	519	327	584	3,600
1979	2,710	1,610	1,217	978	849	676	519	326	578	3,600
1980	2,710	1,609	1,216	978	848	676	518	326	571	3,610
1981	2,710	1,609	1,216	977	848	675	518	326	565	3,610
1982	2,710	1,609	1,216	977	848	675	518	326	558	3,620
1983	2,710	1,608	1,216	977	848	675	518	326	551	3,630
1984	2,700	1,608	1,215	977	847	675	518	326	543	3,630
1985	2,700	1,607	1,214	976	847	674	518	326	536	3,640
1986	2,720	1,615	1,221	981	851	678	520	327	535	3,660
1987	2,730	1,622	1,226	986	855	681	523	329	533	3,680
1988	2,740	1,629	1,231	989	858	684	525	330	531	3,700
1989	2,750	1,633	1,235	992	861	686	526	331	528	3,710
1990	2,890	1,720	1,308	1,045	913	727	554	351	640	3,900
1991	3,020	1,797	1,377	1,092	961	765	579	369	758	4,060
1992	3,140	1,867	1,442	1,134	1,006	801	602	387	881	4,220
1993	3,240	1,929	1,501	1,172	1,047	834	621	403	1,009	4,350
1994	3,340	1,983	1,556	1,205	1,085	864	639	417	1,139	4,480
1995	3,200	1,904	3,087	1,157	514	1,201	613	58	1,194	4,300
1996	3,840	2,279	710	1,385	559	1,492	735	19	1,547	5,160
1997	3,850	2,288	756	1,390	566	1,435	737	268	1,673	5,180
1998	3,930	2,336	779	1,420	583	1,362	753	229	1,832	5,300
1999	3,960	2,354	960	1,430	710	1,067	759	284	1,970	5,360
2000	3,880	2,308	1,187	1,403	922	989	744	362	2,055	5,270
2001	3,930	2,336	1,508	1,420	1,161	943	753	471	2,259	5,330
2002	3,890	2,312	1,887	1,405	1,407	1,049	745	599	2,411	5,280
2003	3,880	2,304	2,287	1,400	1,714	858	742	714	2,574	5,270
2004	3,780	2,248	2,655	1,366	2,095	839	724	838	2,678	5,150
2005	3,830	2,275	2,717	1,382	2,144	859	733	858	2,876	5,230
2006	3,850	2,290	2,765	1,392	2,182	874	738	873	3,059	5,280
2007	3,850	2,289	2,794	1,391	2,204	883	738	882	3,215	5,300
2008	3,850	2,287	2,821	1,390	2,226	892	737	890	3,374	5,310
2009	3,840	2,284	2,848	1,388	2,248	900	736	899	3,536	5,320
2010	3,880	2,304	2,876	1,400	2,269	909	743	908	3,582	5,370

[1] Others category includes 22 additional families.

Marine fisheries of Jamaica: total reconstructed catch 1950-2010[1]

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Abstract

Jamaica, a single island country in the eastern Caribbean, has a long history of human settlement and overfishing. The country is considered one of the most overfished in the Caribbean region. Despite fish featuring heavily in the cuisine and culture of the island, non-commercial (subsistence and recreational sectors) catches have not previously been estimated comprehensively. These non-commercial catches, as well as discards, are missing from the data presented by the FAO on behalf of Jamaica. This study estimates total catches for all marine fisheries sectors for 1950-2010, including non-commercial catches and discards. Our total reconstructed catch equated to almost 3 million tonnes during the 1950-2010 time period. Our estimate is 4.3 times the data reported by the FAO on behalf of Jamaica. The discrepancy between our estimate and the reported data is attributable to large unmonitored non-commercial catches. Improved monitoring and public outreach to subsistence and recreational fishers is imperative if recent management initiatives to create marine protected areas are to succeed.

Introduction

Jamaica, a lush tropical island country in the Caribbean Sea, lies at 18° 15' N and 77° 30' W (Figure 1). The island has a land area of 10,991 km² and an exclusive economic zone (EEZ) of 263,283 km² (www.seaaroundus.org; accessed: August 16, 2012; Figure 1). Jamaica's southern continental shelf extends 25 km from shore, while the northern coast has only a narrow shelf of 1.6 km before dropping to a depth of more than 300 m (Munro 1983). Seven off-shore banks (Pedro, Walton, Morant, Albatros, Henry Holmes, Grappler, and Formigas) are separated from the coastal shelf by deep oceanic waters (Figure 1). Coastal marine areas are characterised by sand or limestone bedrock overlaid with seagrass beds and coral reefs. Large rivers, which flow into the ocean in both the north and south, have for the past few decades brought increasing sediment and nutrients to the coastal environment. These additional inputs are having a negative impact on the health of Jamaica's coral reefs (Goreau and Thacker 1994).

Jamaica has endured a long history of political and social hardship including two colonisations (Spain [1517-1655] and the United Kingdom [1656-1960]), and played a major role in the slave trade (Beckwith 1929). The now-independent country continues to face immense economic challenges that hinder development; presently it is rated as the world's fourth most severely indebted country (Hurley *et al.* 2010). In 2009/2010, more than half of the annual budget was committed to debt servicing (Planning Institute of Jamaica 2009). The economy of this small island is heavily reliant on bauxite, tourism and remittances which contribute over 85% of foreign exchange (Planning Institute of Jamaica 2009). The slow-growing economy of the country was negatively affected by the recent global recession (Planning Institute of Jamaica 2009). Additionally, Jamaica is annually threatened by hurricanes, as the country lies in the hurricane belt of the central Atlantic. Despite these hardships, Jamaica has made positive achievements towards the United Nations Millennium Development Goals with significant reductions in poverty, malnutrition, and hunger, as well as increased enrolment in primary education

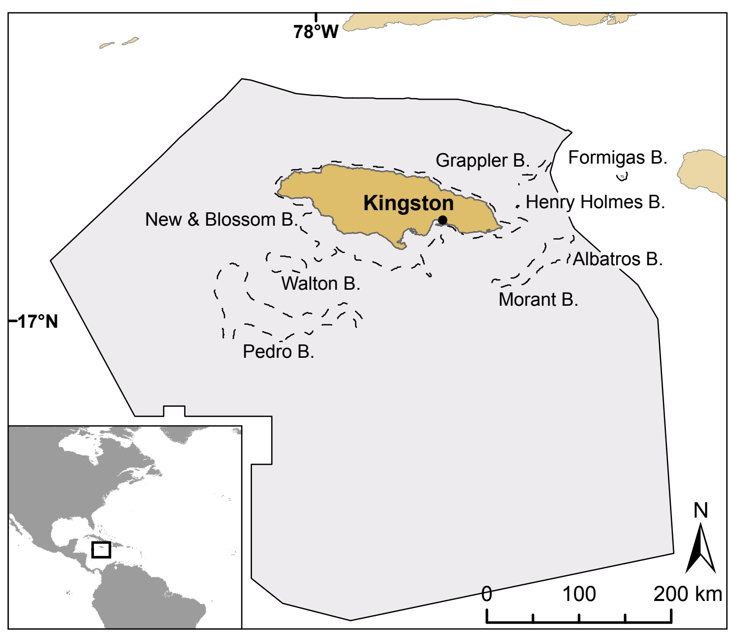

Figure 1. Map of Jamaica and its exclusive economic zone. Outer fishing banks are shown with dashed lines.

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(Planning Institute of Jamaica 2009). Tourism remains an important industry with 2.9 million visitors attracted to the stunning and culturally unique island in 2009 alone (Planning Institute of Jamaica 2009).

Jamaica has a vibrant culture, which includes a spicy and flavourful cuisine. Local produce, fish, chicken, goat, and pork feature heavily in the island's gastronomy. In addition to imported salt fish, a long time dietary staple in Caribbean nations dating back to the slave trade (Kurlansky 1997), local fresh fish is integral to the Jamaican diet and culture. Reef fish also feature in social gatherings, and holiday meals. Despite the importance of fish in the nation's culture, and the popularity of beaches for recreation and social gatherings, Jamaicans are typically not seafaring people and marine environments beyond the high-water line receive little attention (S. Lingard, pers. obs.).

This contrasts with Pacific island countries, such as Palau, which have traditionally focused heavily on managing the sea and its associated resources, which are integral to the local way of life and sense of self identity (Ota 2006). In Jamaica, marine resources have been undervalued by both the government and the public, leading to the marginalization of Jamaica's small-scale fishers. For example, the joint Ministry of Agriculture and Fisheries received 0.9% of the annual budget in 2008/2009 (Hurley *et al.* 2010). Marginalization of small-scale fisheries by governments, which contributes to the degradation of fisheries resources, is common in developing countries (Pauly 1997). In addition to marginalization of the fisheries sector, Jamaica has degraded the habitats necessary for the maintenance of fisheries resources on a large scale. Beginning in the 1960s, the majority of mangrove and wetland habitats were altered for construction of large resorts (Bacon 1987). Information available at the time suggested wetlands were important to fisheries, serving as nurseries to many species of Caribbean reef fish (Austin 1971). Despite a history of marginalization of fisheries and marine resources in Jamaica, recent attempts have been made to alter this misconception by highlighting the value of marine resources to tourism, and the total value of the artisanal fishery (Gustavson 2002; Sary *et al.* 2003; Kushner *et al.* 2011; Waite *et al.* 2011).

In the past, Jamaica's marine resources were overfished by indigenous Arawak communities (Hardt 2009). Recovery from early exploitation was possible due to reduced fishing pressure during colonization events (Hardt 2009). Prior to independence in 1960, the main activities fuelling Jamaica's economy were agricultural exports of produce, such as banana and sugar cane (Dunn 1972). As a result of the restrictive nature of plantation life, which did not allow residents to capture fish, colonization activities reduced fishing pressure. Therefore, fisheries are thought to have been minor prior to emancipation in 1832 (Hardt 2009). In the post-emancipation period, there was rapid development of open-access, multi-gear fisheries in near-shore areas (Thompson 1945; Munro and Thompson 1973; Hardt 2009). By 1945, Jamaica's near-shore areas had already been declared overfished (Thompson 1945). However, it was not until 1950 that a management body, the Fisheries Division, was established (Oswald 1963).

Fishing activities have remained small in scale, even in recent times. The majority of fishing activities are multi-species and multi-gear, but the fisheries for Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*) are monitored separately (Munro and Thompson 1973; Aiken 1985a, 1998; Aiken *et al.* 1999; Aiken and Kong 2000; Aiken *et al.* 2002; Aiken *et al.* 2006; Murray and Aiken 2006). The conch fishery operates solely on Pedro Bank with mother ships (typically 24 m in length) collecting the catch taken by divers (Aiken *et al.* 1999). Lobster is caught both by industrial[2] fishers on Pedro Bank (there is a limit of 12 industrial licences per annum; Kong 2003), and by small-scale trap fishers on both Pedro Bank and in near-shore waters. Lobsters are often caught as valuable by-catch (i.e., catch of non-target species) in the Antillean Z trap (the most common gear type used in the Jamaican artisanal fishery; Aiken 1982). Industrial lobster fishers, which operate on Pedro Bank, use steel hull vessels 25-30 m in length (Kong 2003). The majority of conch and lobster captured by fishers with designated licences are destined for export (Aiken and Kong 2000).

Jamaican fishing canoes range from a minimum of 4 m to more than 18 m in length (Aiken and Kong 2000). The larger canoes are used by fishers traveling to Pedro and other outer banks. While some smaller canoes are still wooden dugouts, the majority of fishing vessels are constructed of fibreglass (S. Lingard, pers. obs.). Prior to 1960, the majority of fishing canoes were powered by oar or sail (Oswald 1963). In 1956, however, government subsidies were offered to aid fishers in the mechanization of their vessels (Oswald 1963). During this period a marginal increase in production was seen as fishers were capable of exploiting new offshore banks; however, offshore resources were quickly exhausted (Koslow *et al.* 1988). The subsequent increase in landings in the early 1990s was due to the establishment of the Pedro Bank queen conch fishery (Aiken *et al.* 1999).

While the Fisheries Division has traditionally been the sole governing body responsible for the management of Jamaica's marine fisheries, several NGOs have been awarded funding to manage the newly designated fish sanctuaries.[3] The most recently enacted legislation regarding fisheries management is the Fisheries Industry Act of 1976,[4] with a new draft policy having been in the final stages of arbitration for almost 10 years. Enforcement of existing regulations has been insufficient due to limited financial and human resources within the department. In addition to overfishing, several environmental factors have combined to amplify degradation of fisheries resources, such as hurricanes, herbivore population crashes, marine pollution, coral diseases and bleaching events (Woodley *et al.* 1981; Liddell and Ohlhorst 1986; Hughes 1994; Lapointe 1997). There has been little development of the pelagic fishery due to the absence of a market for large fish (Aiken 1985b; Harvey *et al.* 1989; Aiken and Kong 2000).

[2] Industrial is used here as it is by defined by Kong (2003). However, we consider industrial lobster fishing activities in Jamaica to be small-scale commercial (artisanal) due to the use of traditional gear.

[3] Caribbean Coastal Area Management Foundation, Blue Fields Bay Fishermen's Friendly Society, St Mary Fishermen's Cooperative, Oracabessa Foundation, Negril Coral Reef Preservation Society, Montego Bay Marine Park Trust, Fisheries Division, Alloa Fisherman's Group and Business Community

[4] http://www.moa.gov.jm/fisheries.php; accessed June 13, 2011

To date, Jamaica's official record-keeping has made no attempt to account for recreational catches, subsistence catches, or discarded by-catch. In other countries, these sectors have been shown to contribute significantly to the total catch (Zeller *et al.* 2006; Wieglus *et al.* 2010). Previous attempts to account for missing data include an assessment of the economic contribution of Jamaica's artisanal fisheries (Gustavson 2002; Sary *et al.* 2003; Waite *et al.* 2011); however, these studies do not attempt to estimate all sectors. This report seeks to establish a comprehensive time series of Jamaican fisheries catches (1950-2010) including all fisheries catch components.

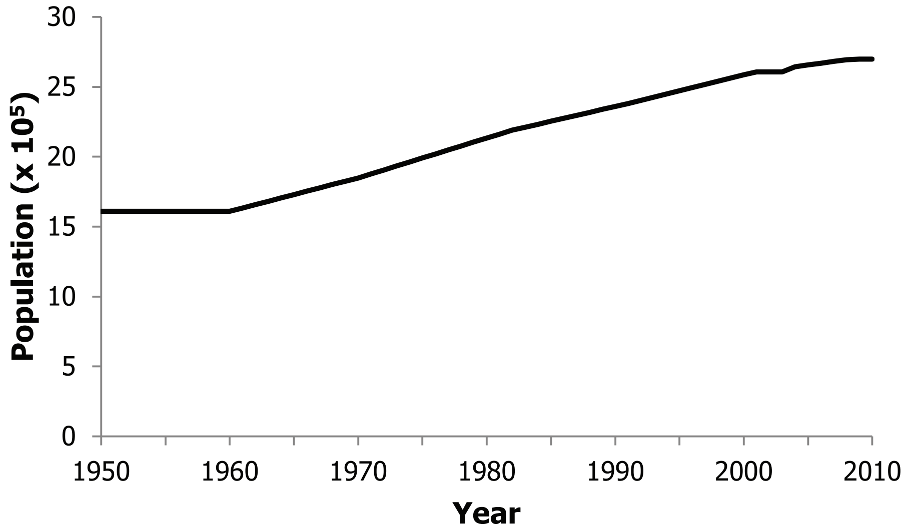

Figure 2. Population of Jamaica, 1950-2010.

Methods

Population

Population data were obtained in order to calculate subsistence catch rates for the 1950-2010 time period. Census data were only available for the years 1960, 1970, 1982, 1991, and 2001.[5] We carried the 1960 estimate back to 1950 and the 2001 estimate forward to 2010. Linear interpolations were done between estimates to create a complete time series of population data (Figure 2).

Artisanal

Landings presented by the FAO on behalf of Jamaica were found to be similar to those reported by the Fisheries Division, and were therefore assumed to be representative of the artisanal catches for the time period considered. Admittedly, there are problems with accurately estimating catches in many Caribbean artisanal fisheries due to highly dispersed landing sites, the large range of species caught, multiple gear types, and irregular fishing patterns as a result of socio-economic conditions within fishing communities (Munro 1980). Therefore a portion of the below described subsistence catch may be considered unreported artisanal catch, but was here referred to as subsistence catch as we were unable to further disaggregate the data.

Total demand

To estimate subsistence catch, total seafood demand was calculated using population data combined with estimates of *per capita* fish consumption. Few sources of *per capita* fish consumption estimated independently of fisheries landings were available for the Caribbean region. Cole (1976 in Olsen *et al.* 1984) estimated a *per capita* consumption rate of 30 $kg \cdot person^{-1} \cdot year^{-1}$. We assumed this estimate referred to only fresh fish. Although other seafood products are consumed in Jamaica, we focused here on fresh fish consumption as it comprises the majority of the Jamaican seafood diet. We carried this estimate of 30 $kg \cdot person^{-1} \cdot year^{-1}$ back unaltered to 1950 and forward to 1980. Adams (1992) estimated that consumption of fresh fish averaged 1.7 times per week, or 20 $kg \cdot person^{-1} \cdot year^{-1}$, for the Caribbean region. We applied Adams (1992) estimate from 1990-2008. Between 1980 and 1990 linear interpolation was used to derive a complete time series of *per capita* fish consumption. We then combined the consumption estimates with population data to estimate total demand for fresh fish.

To estimate imports of fresh fish, we used import data from Thompson (1945) to calculate the proportion of total imports that fresh fish products represented during the 1940s. From Thompson (1945) we calculated that 0.07% of fisheries imports were fresh fish. We applied this 0.07% figure to Thorne's (1965) fisheries import figures for 1950-1959 to estimate imports of fresh fish. From the amount of fresh fish imported we also calculated *per capita* fresh fish import rates. Using FAO reported imports of fresh fish (1976-2010) and population data, we calculated *per capita* imports of fresh fish for 1976. Linear interpolation of *per capita* fresh fish imports was done for 1960-1975 using the calculated *per capita* import rates from Thorne (1965) for 1959 and the FAO for 1976. We combined these estimates of *per capita* imports with population estimates to calculate total imports of fresh fish. For the period of 1976-2008 we used the summed FAO fresh fish imports. We then multiplied our population by the *per capita* import rates to deduce total fresh fish imports. By combining demand for fresh fish with total fish imports, we were able to calculate total demand for fishery products from 1950-2010.

[5] http://statinja.gov.jm/Popcensus.aspx; accessed: August, 2011

Subsistence catch

To convert our estimated total demand for fresh fish to an estimate of subsistence production we subtracted FAO reported aquaculture production, reconstructed estimates of fresh fish imports, and FAO reported landings (adjusted for fresh fish exports) from the total demand for fresh fish.

Discards

Several fishing techniques employed in Jamaica are non-selective and therefore likely to incur by-catch and result in discards. For example, trap and net fishing gears, which utilize fine mesh and wire, can cause substantial catch of non-target species. There is also an unmonitored bait fishery for penaeid shrimp (S. Lingard. pers. obs.), which are caught in fine nets that result in the capture of juvenile reef fish. Thus far, no attempts have been made to estimate bait shrimp and reef fish by-catch in Jamaica. To account for these missing catch components, we needed to disaggregate the FAO reported landings by gear type using the available literature. For the period 1950-1981, we applied Sahney's (1983) breakdown of catch by gear type: 53% trap, 23% net, 17% line, and 7% other gears. For the period from 2000 to 2008 we applied estimates of catch by gear type from Sary *et al.* (2003): 49% trap, 10% line, 3% net, and 38% spear. For the period 1982-1999, we interpolated linearly between the two sets of percentages of catch by gear type. To calculate discards in the trap fishery, we applied the discard rate of 29% from Nicholson and Hartsuijker (1982) for the 1950-1981 period. For this early time period, when larger, more valuable species were more abundant, we assumed that the market was more selective and that a discard rate of 29% would be a conservative estimate. However, catches of large, valuable species such as large jacks, groupers, and snappers declined from 1950 to 1982 (Aiken and Haughton 1987). Therefore, these species have disappeared from catches during the recent time period (Murray and Aiken 2006), and species that were previously considered trash species and discarded, have become targeted catch (Aiken and Haughton 1987). Due to this shift in target catch, discard rates from 1990 to 2010 were much lower (estimated to be 2-5%; K. Aiken, University of the West Indies, pers. obs.). Thus, for the time period 1990-2010 we applied a conservative discard rate estimate of 2% for trap gears. Although a higher discard rate of 18% was reported for the Morant Cays trap fishery in 1996 (Pears and Sary 1996), this estimate was only for a single bank. We considered the estimated discard rate of 2% to be more representative of all trap fisheries for the recent time period, given the overfished state of the southern shelf and the increasing retention of non-targeted catch. For the years from 1981-1989, a complete time series of fisheries discards for trap catches was created using linear interpolation between 29% and 2%.

Table 1. Species composition (% of catch) of sport fishery catches, 2002-2010.

Taxon name	Common name	Catch (%)
Makaira nigricans	Blue marlin	48.0
Acanthocybium solandri	Wahoo	23.0
Coryphaenidae	Dolphin fish	14.0
Scombridae	Tunas and mackerels	7.6
Others	All other species	7.6

Adapted from Quinn (2005).

To estimate discards from net gears, we applied the 4.4% discard rate estimated by Kelleher (2005) to the landings from nets over the entire time period. Discard rates were only applied to the artisanal catches from nets and traps as they are non-selective. Whereas discard rates were not applied to artisanal catches from hook-and-line, and spear gear types, due to their more selective nature. We also did not apply discard rates to subsistence catches due to the types of gears used in this sector. The gear most commonly used by non-commercial fishers (i.e., subsistence and recreational) in Jamaica is line and spear,[6] which we assumed to have negligible discards.

Table 2. Anchor points (% of catch) used in the taxonomic breakdown of Jamaica's south coast artisanal fisheries catches. Linear interpolations were used between data points to establish a complete time series, 1950-2010.

Family	1950-1971	1980	2001-2010
Acanthuridae	6	7	6
Balistidae	3	1	1
Carangidae	9	5	1
Clupeidae	15	16	13
Coryphaenidae	0	0	0
Haemulidae	8	8	5
Holocentridae	1	3	6
Lutjanidae	7	15	3
Mugilidae	1	1	1
Mullidae	1	4	12
Palinuridae	6	4	0
Scaridae	9	12	28
Scombridae	0	3	2
Serranidae	9	1	6
Sparidae	0	1	1
Sphyraenidae	1	1	1
Others	23	17	13

Sources: Munro (1974a, 1974b), Sahney (1983), Murray and Aiken (2006).

Shrimp

The FAO presents landings for penaeid shrimps, but only for some years. To obtain a complete time series estimate of shrimp catches, we combined information available from FAO with national data presented in Waite *et al.* (2011). Shrimp catches were set at zero for 1950 as no shrimp fishery is discussed in the early literature (Thompson 1945) and shrimp does not seem to feature heavily in the Jamaican diet (S. Lingard, pers. obs.). We then interpolated linearly between the 1950 anchor point and the first year of shrimp landings presented by the FAO (277 t in 1994). For the period 1994-2003, we used the FAO shrimp landings, and from 2004-2008, we used national data presented by Waite *et al.* (2011). Discard rates were not applied to catches for this fishery due to the small-scale, low-impact hand nets used by these fishers (Galbraith and Ehrhardt 2000).

[6] S. Lingard, 2011 unpublished data submitted in report to Fisheries Division

Sport fishery (recreational)

A sport tournament fishery has been in operation in Jamaica since 1959 (Harvey *et al.* 1989). In its early years, the fishery targeted blue marlin (*Makaira nigricans*; Harvey *et al.* 1989). However, in recent years the catch has included a diversity of scombrids and other oceanic pelagic species (Quinn 2005). Tournament catches for the period of 1976-1986 were calculated using the number of fish caught and average weights taken from Ortiz and Farber (2001). Average weight per fish was calculated for the Ortiz and Farber (2001) length data using the FishBase Life History Tool (www.fishbase.org). The average weights were then multiplied by the total number of *M. nigricans* landed in each year of the tournament fishery as quoted by Harvey *et al.* (1989). This resulted in estimated landings (in tonnes) for the sport fishery from 1976-1986. We carried the 1976 estimate back unaltered to 1959 as a small tournament fishery has been in operation since this date (Harvey *et al.* 1989). Quinn (2005) estimated sport fishery landings from tournament records in 2002. Utilizing the taxonomic information from Quinn (2005), we have assigned catches from this sector to four taxa (*M. nigricans, Acanthocybium solandri, Coryphaena* spp., and Scombridae) plus an "Others" category of 7.6% (Table 1). We interpolated from a catch composed of 100% *M. nigricans* in 1986 (Harvey *et al.* 1989) to the taxonomic composition of tournament catches in Quinn (2005) in order to create a complete time series of tournament catches.

Table 3. Anchor points used (% of catch) in the taxonomic breakdown of Jamaica's north coast artisanal fisheries catches. Linear interpolations were used between data points to establish a complete time series, 1950-2010.

Family	1950-1968	1980	2001-2010
Balistidae	1.4	1.5	1.4
Carangidae	16.8	17.9	8.5
Clupeidae	0.1	1.1	1.1
Coryphaenidae	1.4	1.4	1.4
Haemulidae	2.4	2.5	2.4
Lutjanidae	12.4	19.6	10.9
Mullidae	5.0	3.5	3.0
Mugilidae	4.1	1.9	0.0
Palinuridae	1.3	1.4	0.0
Scaridae	18.9	11.1	17.0
Serranidae	11.4	1.1	4.4
Scombridae	1.9	9.4	1.0
Others	23.1	27.5	49.0

Sources: Sahney (1983) and Sary (2003).

Taxonomic breakdown

Three geographically distinct areas are fished in Jamaica: the north coast (narrow shelf), south coast (wide shelf), and outer banks. The majority of the banks have been exposed to significant fishing pressure since the mechanization of boats began in 1956 (Koslow *et al.* 1988). Due to the different gear types, shelf widths, and historical fishing pressure in each area, we separated artisanal catches by area and applied separate taxonomic breakdowns. The only comprehensive species-level breakdowns available for trap and line fisheries were from Munro (1974a, 1974b). We weighted these two gear types according to estimates of catch by gear type in Sahney (1983) and created a single catch composition. Catch composition for other gear types were unavailable, except for Sahney (1981); therefore we recalibrated the estimated catch by gear type in Sahney (1983) to include only trap and line. Munro's (1974a, 1974b) estimates of the taxonomic composition of catches were presented as the contribution to total catch. To make the breakdown applicable to all sources, we grouped the species by family. We combined the aggregated species data from Munro (1974a, 1974b) with the family composition data from the studies outlined below for each of the three fishing grounds. Although family composition varies by fishing ground, we assumed the species composition within families to be similar across fishing grounds.

<u>South coast</u>

For catches from the south coast, we compared several sources of taxonomic information for different years: 1971 (1974a, 1974b), 1980 (Sahney 1983), and 2001 (Murray and Aiken 2006; Table 2). Using Sahney's (1983) breakdown of south coast landings by gear type (66.6% trap and 33.4% line), we weighted the trap and line landings from Munro (1974a, 1974b) to create a comprehensive estimate of south coast catches by taxa. Munro (1974a, 1974b) assigned catches by species; therefore, we aggregated species into families to allow comparison with the other two sources. Families present in Munro (1974a, 1974b) but not present in other sources were grouped into an "Others" category. The combined estimate from Munro (1974a, 1974b) was carried back unaltered to 1950. Sahney's (1983) catch composition was used as a mid-point between Munro (1974a, 1974b) and Murray and Aiken (2006). Several families were not estimated in Murray and Aiken (2006) and in Sahney (1983), but are known to be caught regularly. These families include Balistidae, Clupeidae, Coryphaenidae, Mugilidae, Scombridae and Sphyraenidae. To accommodate these additional taxa, catch compositions for Murray and Aiken (2006) and Sahney (1981) were adjusted by carrying forward estimates of these missing taxa. Also Murray and Aiken (2006) had no "Others" category in their estimates, so the "Others" estimate from Munro (1974a, 1974b) was also carried forward. Linear interpolation between estimates was then used to complete the times series. Murray and Aiken's (2006) estimate, adjusted for missing taxa, was carried forward to 2010.

Table 4. Anchor points (% of catch) used in the taxonomic breakdown of Jamaica's outer banks artisanal fisheries catches. Linear interpolations were used between data points to establish a complete time series, 1950-2010.

Family	1956-1980	2001-2010
Acanthuridae	0	6
Balistidae	7	0
Carangidae	10	1
Clupeidae	1	0
Coryphaenidae	4	3
Haemulidae	9	5
Holocentridae	0	7
Lutjanidae	6	4
Mugilidae	0	0
Mullidae	4	13
Palinuridae	3	0
Scaridae	10	30
Scombridae	4	3
Serranidae	14	6
Sparidae	0	1
Others	28	20

Sources: Sahney (1983), Murray and Aiken (2006).

North coast

For the north coast, taxonomic information was available for 1968 (Sary *et al*. 2003), 1980 (Sahney 1983), and 2001 (Sary *et al*. 2003; Table 3). We applied linear interpolation between estimates for these three years. Picou-Gill *et al*. (1996) also provided disaggregated Discovery Bay catches for 1990-1991 to the family level; however, as these estimates concerned a single bay, we consider them to be unrepresentative of the entire north coast area and chose not to incorporate them. Several important taxa (families Balistidae, Clupeidae, Coryphaenidae, and Haemulidae) were absent from the estimates put forth by Sary *et al*. (2003). To avoid recording the catch of these important taxa as zero, we have carried Sahney's (1983) estimates for these taxa back to 1950 and forward to 2010. The taxonomic compositions for 1968 and 2001 in Sary *et al*. (2003) were then recalibrated to accommodate these additional taxa. The recalibrated estimate for 1968 was carried back to 1950, and the recalibrated estimate for 2001 carried forward to 2010. Linear interpolation of percentage breakdowns between years of known data was done to establish a complete time series of catch composition from 1950-2010.

Table 5. Anchor points (%) used in the taxonomic breakdown of Jamaica's subsistence fisheries catches. Linear interpolations were used between data points to establish a complete time series, 1950-2010.

Family	1950-1968	2001-2010
Carangidae	0.28	0.06
Carcharhinidae	0.08	0.05
Haemulidae	0.11	0.03
Holocentridae	0.01	0.03
Lutjanidae	0.20	0.05
Muraenidae	0.00	0.01
Scaridae	0.17	0.25
Scombridae	0.00	0.01
Serranidae	0.17	0.09
Sphyraenidae	0.04	0.27
Others	0.10	0.20

Source: Sary (2003).

Outer banks

The only comprehensive study detailing taxonomic composition for Pedro Banks and the other outer banks was for 1980 (Sahney 1983). However, Murray and Aiken (2006) completed an extensive study in 2001-2002 of Whitehouse – one of the largest fishing villages on Jamaica's south coast. A large portion of the fishers on the south coast target the outer banks (Pears and Sary 1996; Grant 1999; Murray and Aiken 2006). The absence of large predatory species is reported on the outer banks as well as the southern shelf (Koslow *et al*. 1988; Pears and Sary 1996; Murray and Aiken 2006). In light of these observations, we assumed landings from south coast fishing beaches were representative of those on the outer banks for the recent time period. We applied the breakdown from Sahney (1983) for the years 1956-1980, and interpolated linearly to the 2001 estimate from Murray and Aiken (2006; Table 4). We recalibrated Murray and Aiken's (2006) estimate for 2001 to accommodate the addition of targeted taxa that were not included, but we know to contribute to catches (Coryphaenidae, Scombridae, and "Others;" described previously).

Subsistence

Subsistence catches were assigned taxonomically to the family level. Recent data suggest the majority of subsistence fishers use lines and spears as their primary gear types.[7] We have applied the taxonomic compositions for 1968 and 2001 from Sary (2003), with linear interpolation between intervening years, to subsistence catches, as they were most representative of observed catches by subsistence fishers in Jamaica (S. Lingard, pers. obs.; Table 5).

Results

Reported landings

Landings reported by the FAO on behalf of Jamaica for the period 1950-2010 amounted to just over 683,000 t (Figure 3a). Reported landings were presented for six taxonomic categories: miscellaneous marine fishes (505,527 t), spiny lobster (7,689 t), stromboid conch (168,916 t), penaeus shrimps (889 t), marine crabs (106 t), and tuna-like fishes (726 t). All reported landings are from the artisanal sector.

South coast

Total estimated catches on the south coast amounted to approximately 284,000 t over the 1950-2010 time period. Reef fish catches totalled 283,100 t, and reported penaeus shrimp catches totalled 889 t. The most abundant families caught on the south coast were Clupeidae, Scaridae, Lutjanidae, and Haemulidae with total catches of approximately 44,700 t, 43,000, 21,500 t and 20,800 t respectively.

North coast

Total catches from the north coast between 1950 and 2010 were approximately 93,200 t. The most abundant families were Scaridae (14,700 t), Carangidae (13,100 t), Lutjanidae (12,400 t), and Serranidae (6,000 t).

[7] S. Lingard, 2011 unpublished data submitted in report to the Fisheries Division

Outer banks

Catches from the outer banks totalled 304,900 t from 1950-2010. The most abundant catches on the outer banks were for the taxa *Lobatus gigas* (168,900 t), Scaridae (31,700 t), Serranidae (15,400 t), and Mullidae (13,700 t).

Reconstructed catch

Subsistence

Total subsistence catches over the 1950-2010 time period were estimated to be 2,186,633 t (Figure 3a). The most important families in the subsistence sector were Carangidae (380,700 t), Sphyraenidae (296,300 t), Scaridae (296,300 t) and Serranidae (279,000 t). In 1950, catches consisted mainly of Carangidae (11,700 t·year^{-1}), Lutjanidae (8,300 t·year^{-1}), and Serranidae (7,000 t·year^{-1}). In 2010, catches were dominated by Sphyraenidae (6,100 t·year^{-1}), Scaridae (5,700 t·year^{-1}), and Serranidae (2,000 t·year^{-1}).

Discards

Discarded catches, which include shrimp caught as bait, and discarded fish from trap and net fisheries, were estimated to be 81,425 t from 1950-2010 (Figure 3a). Discards in 1950 amounted to 1,160 t·year^{-1} and declined to 400 t·year^{-1} in 2010. Peak discards occurred in 1962 with 2,800 t of discarded fish.

Shrimp

The total reconstructed catch for penaeid shrimp was 8,725 t from 1950-2010, which included 889 t of reported landings. Shrimp landings started in 1951 and grew from 6 t·year^{-1} to 277 t·year^{-1} in 1994. Catches then proceeded to follow an oscillating trend of decrease followed by increase followed by decrease with a peak in 2005 of 875 t.

Sport fishery

Tournament landings were estimated to be 470 t over the 1950-2010 period. Total catches of *M. nigricans* and *A. solandri* (wahoo) were estimated to be 379 t and 40 t respectively over the entire time period (Figure 4).

Total reconstructed catch

Total reconstructed catches of Jamaica for the 1950-2010 time period were estimated to be 2,960,000 t (Figure 3a). The total catches were 4.3 times larger than the FAO reported landings, which were considered to represent only artisanal landings.

Catches of Carangidae, the most important taxon caught throughout the study period, decreased by 86% from 12,200 t·year^{-1} in 1950 to 1,700 t·year^{-1} in 2010 (Figure 3b, Table 6). Similar trends were visible in Serranidae, Lutjanidae, and Haemulidae (Figure 3b, Table 6). Total catches of Carcharhinidae (requiem sharks) were 139,400 t over the 1950-2010 time period. The most abundant species of finfish in the artisanal sector

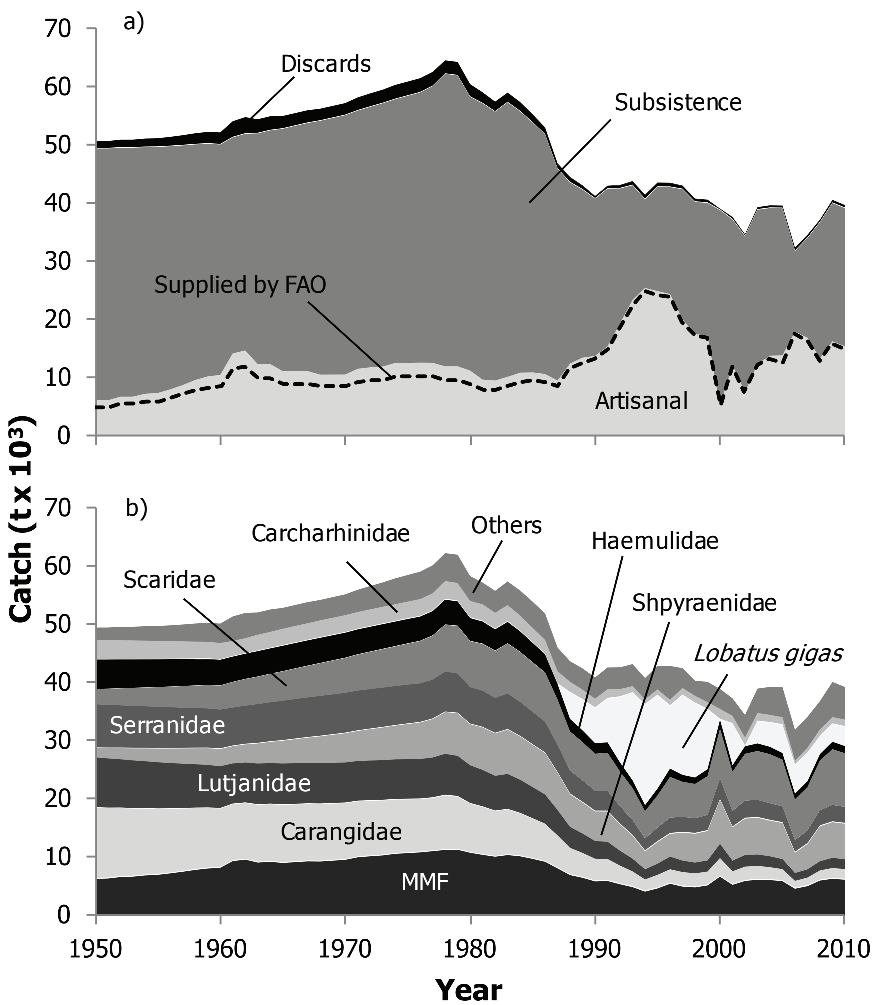

Figure 3. Total reconstructed catch of Jamaica, 1950-2010, a) by sector (recreational fishery not visible), with comparison to the FAO reported landings, and b) by major taxa. "MMF" equals miscellaneous marine fishes and the "others" category includes 29 additional taxonomic groups.

were *Opisthonema oglinum*, *Sparisoma viride*, *Ocyurus chrysurus* (yellowtail snapper), and *Epinephelus guttatus* (red hind) totalling 43,400 t, 27,700 t, 15,100t, and 13,200 t respectively. Catches from the targeted Caribbean spiny lobster (*P. argus*) and queen conch (*L. gigas*) fisheries equated to 19,500 t and 168,900 t, respectively. Significant is the shift over time from top predators (Serranidae, Carangidae, and Lutjanidae) to taxa lower in the food chain (e.g. Scaridae; Figure 3b).

Appendix tables (A1 and A2) present total reconstructed catches by year, sector and taxa.

Table 6. Change in catch of Jamaica's most valuable fish taxa between 1950 and 2010.

Taxon	Catch (t)		Decrease (%)
	1950	2010	
Carangidae	12,180	1,703	86
Lutjanidae	8,688	1,713	80
Serranidae	7,470	2,749	63
Haemulidae	5,093	1,337	74

Discussion

The total reconstructed catch for Jamaica was estimated to be approximately 3 million tonnes over the 1950-2010 time period. This is 4.3 times the landings reported by the FAO on behalf of Jamaica (683,855 t). This considerable difference between the total reconstructed catch and landings presented by the FAO is attributable to the absence of subsistence catches, discards, and tournament landings from officially reported data. Detailed studies exist for various aspects of Jamaica's fisheries for the period 1945-2010 (Thompson 1945; Oswald 1963; Munro and Thompson 1973; Munro 1983; Aiken 1985a, 1985b; Aiken and Haughton 1987; Koslow *et al.* 1988; Pears and Sary 1996; Picou-Gill *et al.* 1996; Aiken *et al.* 1999; Grant 1999; Aiken and Kong 2000; Aiken *et al.* 2002; Sary *et al.* 2003; Quinn 2005; Aiken *et al.* 2006; Murray and Aiken 2006; Passley *et al.* 2009); however, this is the first study to estimate all fisheries catch components as a complete time series from 1950 to present. Total catch, as estimated using the reconstruction approach (Zeller *et al.*, 2007), increased from 49,400 t in 1950 to a peak of 62,300 t in 1978 where catches then declined and have only recently appeared to start to level out. In contrast, data reported to the FAO suggest that catches have been relatively stable over the entire time period considered (excluding the marked increase during the 1990s as a result of the Pedro Bank conch fishery).

This study highlights the importance of fresh fish in the Jamaican diet. A substantial portion of this fresh fish demand is met through subsistence fisheries, a sector that has been largely ignored in the collection of Jamaican fisheries data. Similar contributions by the non-commercial sector have been seen in other regions of the world, such as Pacific island nations (Zeller *et al.* 2006; Zeller *et al.* 2007; Lingard *et al.* 2011), where the importance of this sector to the economy has also gone unrecognized.

Catches from the growing spear fishing sector make up a considerable portion of the reconstructed subsistence catch. Trap, net and line fishing have traditionally been the most common gear types used in Jamaica (Munro and Thompson 1973; Sahney 1983), but the use of spears is increasing (Sary *et al.* 2003; Passley *et al.* 2009). Catch from spear fishers in 2009 was estimated to be 3,000 t per year (Passley *et al.* 2009). The landing sites used by these fishers are often outside the normally surveyed locations (N. Hado, pers. obs., Food for the Poor). Thus it is likely that a large portion of catches by this sector are not reported as they are consumed directly by fishers (i.e., for subsistence purposes).

The use of non-selective gear types, such as traps and nets (e.g., seine nets, sprat nets, trawl nets, shove/push nets, trammel nets, lobster traps, china traps), can result in high levels of by-catch. In many cases this by-catch is discarded. To reduce by-catch, attempts have been made to encourage the use of larger mesh in traps (Sary *et al.* 1996). Additionally, a recent initiative has involved retraining fishers to use more selective fishing techniques, such as deep-water hand lining, instead of traps and nets (S. Lingard, pers. obs.).

Fisheries in Jamaica provide a substantial source of employment. An estimated 20,000 licensed fishers are presently operating in Jamaica (CFRAMP 2000) out of an employable population of 1,255,000.[8] Women are heavily employed in Jamaican fisheries, typically as vendors, although some women also go to sea as fishers (Gustavson 2002). The ratio of vendors to fishers in Jamaica is estimated at 3:1 (Gustavson 2002). Women control the income of fishers through the sale of fish and

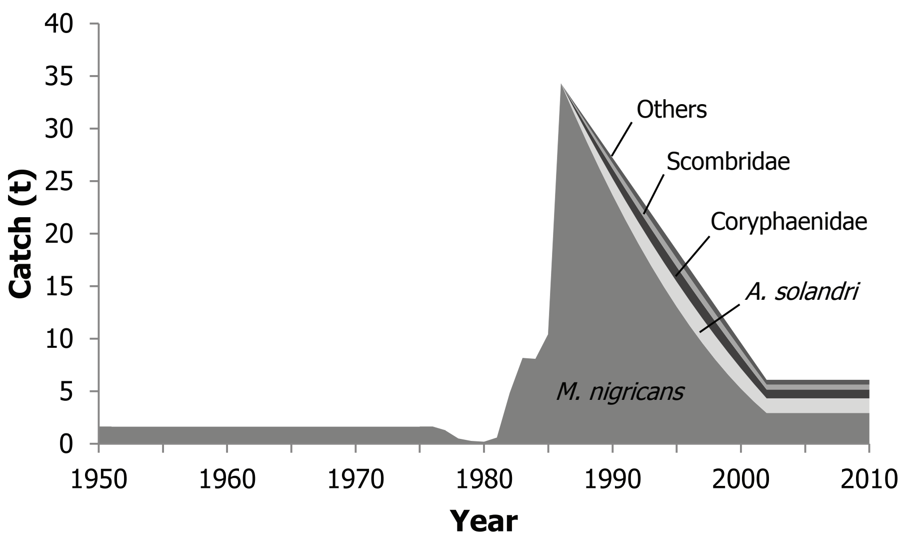

Figure 4. Catch composition of Jamaican tournament sport fishery catches, 1950-2010.

[8] http://statinja.gov.jm/labourforceAgeGroup.aspx; accessed October, 2011

therefore also indirectly control fishing activities, as well as cooperation with management plans and government officials (Grant 2004).

Potential profits for fishers in Jamaica are limited by a lack of adequate processing and marketing facilities (Bélisle 1984a). The majority of fisheries products, with the exception of those from the conch and lobster industries (the majority of products go to export markets; Aiken *et al.* 1999; Aiken and Kong 2000), are sold domestically, beach-side, and unprocessed (Bélisle 1984a; Grant 1998; Aiken *et al.* 1999; Waite *et al.* 2011). Improved distribution and marketing of fresh fish to hotels would be beneficial in reducing waste and improving revenues from dwindling fish resources (Bélisle 1984b), but must also be properly accounted for in official statistics.

Fisheries development projects and government subsidies have traditionally focused on capacity-enhancing subsidies, which increase fishing effort (Sumaila *et al.* 2010). These include building rural market facilities, mechanization of boats, fuel, and gear exchange. In Jamaica, infrastructure such as gear sheds (built by international donors) sit empty and unused, due to lack of local management capabilities, while fishers continue to suffer great economic hardships (S. Lingard, pers. obs.). International donors and local government should instead focus on beneficial subsidies (enforcement of marine protected areas and alternate livelihood development), which work to increase natural capital and decrease fishing effort (Sumaila *et al.* 2010). Joint efforts by The Nature Conservancy, local NGOs and the Fisheries Division are currently under way to establish and enforce fish sanctuaries (i.e., no-take areas).

Despite management efforts, Jamaica has long been considered overfished (Thompson 1945; Aiken and Haughton 1987; Haughton 1988; Koslow *et al.* 1989), and at present, Jamaica's marine resources, appear to be in a state of Malthusian overfishing (Pauly *et al.* 1989). Few alternatives exist for employment, and fishers rarely make enough to recover operational costs, including subsidized fuel (Aiken and Haughton 1991; S. Lingard, pers. obs.). Schemes that aim to reduce fishing pressure, but provide no alternative employment, would further contribute to economic hardships for fishers and their families in the short term. These socio-economic challenges, as well as distrust of the government by members of fishing communities (Grant 2004), make management decisions difficult in Jamaica. Co-management was suggested in the 1980s as a possible solution to these management challenges (Aiken and Haughton 1987). Recently, the Improving Jamaica's Agricultural Productivity Project has been launched to develop co-management within six south coast fishing villages (S. Lingard, pers. obs.).

The magnitude of unreported catches estimated here suggests that improvements to Jamaica's fisheries data collection system are urgently needed. More importantly, this study suggests that many people in Jamaica, previously overlooked in fisheries management and policy, are reliant on marine resources. From a policy perspective, in a country that has long been reliant on seafood, the destruction of natural marine capital (i.e., fish resources) has serious implications for national food security and livelihoods.

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Appendix Table A1. Total reconstructed catch (by sector) vs. FAO reported landings (in tonnes) for Jamaica, 1950-2010.

Year	FAO landings	Total reconstructed catch	Artisanal	Subsistence	Discards	Recreational
1950	5,000	49,400	6,160	43,300	1,160	1.62
1951	5,000	49,500	6,170	43,300	1,160	1.62
1952	5,500	49,600	6,790	42,800	1,276	1.62
1953	5,500	49,600	6,800	42,800	1,276	1.62
1954	5,900	49,700	7,290	42,400	1,369	1.62
1955	6,000	49,700	7,420	42,300	1,392	1.62
1956	6,500	49,800	8,050	41,800	1,508	1.62
1957	7,100	50,000	8,790	41,200	1,648	1.62
1958	7,800	50,100	9,660	40,500	1,810	1.62
1959	8,300	50,300	10,280	40,000	1,926	1.62
1960	8,500	50,100	10,540	39,600	1,973	1.62
1961	11,500	51,400	14,240	37,100	2,669	1.62
1962	11,900	52,000	14,740	37,200	2,762	1.62
1963	10,000	52,100	12,400	39,600	2,321	1.62
1964	10,000	52,600	12,410	40,200	2,321	1.62
1965	9,000	52,800	11,180	41,700	2,089	1.62
1966	9,000	53,300	11,190	42,200	2,089	1.62
1967	9,000	53,800	11,200	42,600	2,089	1.62
1968	8,500	54,200	10,590	43,600	1,973	1.62
1969	8,500	54,700	10,590	44,100	1,973	1.62
1970	8,500	55,200	10,600	44,600	1,973	1.62
1971	9,300	56,000	11,590	44,400	2,158	1.62
1972	9,500	56,600	11,840	44,800	2,205	1.62
1973	9,600	57,200	11,970	45,300	2,228	1.62
1974	10,100	57,900	12,600	45,300	2,344	1.62
1975	10,100	58,500	12,600	45,900	2,344	1.62
1976	10,130	59,100	12,640	46,400	2,351	1.62
1977	10,110	60,200	12,620	47,600	2,346	1.27
1978	9,600	62,300	12,010	50,300	2,228	0.50
1979	9,600	62,000	12,010	50,000	2,228	0.27
1980	9,000	58,300	11,280	47,000	2,089	0.20
1981	7,740	57,200	9,730	47,500	1,796	0.59
1982	7,750	55,800	9,570	46,200	1,621	4.84
1983	8,440	57,400	10,220	47,200	1,573	8.17
1984	9,200	55,800	10,920	44,900	1,505	8.09
1985	9,430	53,900	10,970	42,900	1,327	10.46
1986	9,360	51,900	10,690	41,200	1,105	34.28
1987	8,520	46,000	9,560	36,400	811	32.51
1988	11,430	43,600	12,500	31,100	827	30.75
1989	12,640	42,400	13,510	28,900	626	28.99
1990	13,200	40,900	13,800	27,000	353	27.23
1991	14,800	42,600	15,450	27,100	395	25.47
1992	18,650	42,600	19,410	23,200	498	23.71
1993	22,550	43,100	23,420	19,700	602	21.94
1994	24,830	40,700	25,490	15,200	663	20.18
1995	24,300	42,800	24,950	17,900	649	18.42
1996	23,810	42,800	24,440	18,400	636	16.66
1997	19,590	42,400	20,110	22,300	523	14.90
1998	17,100	40,300	17,550	22,700	457	13.14
1999	16,860	40,100	17,310	22,800	451	11.37
2000	5,140	38,900	5,280	33,600	137	9.61
2001	11,890	37,300	12,210	25,000	318	7.85
2002	7,400	34,400	7,590	26,800	198	6.09
2003	12,080	38,900	12,400	26,500	323	6.09
2004	13,070	39,200	13,840	25,400	349	6.09
2005	12,700	39,200	13,910	25,300	339	6.09
2006	17,510	31,800	17,970	13,800	468	6.09
2007	16,150	34,100	16,930	17,100	431	6.09
2008	12,780	36,800	13,350	23,400	341	6.09
2009	15,890	40,100	16,320	23,800	337	6.09
2010	15,040	39,200	15,440	23,800	5,326	6.09

Appendix Table A2. Total reconstructed catch (in tonnes) for Jamaica by major taxa, 1950-2010.

Year	Miscellaneous marine fish	Carangidae	Lutjanidae	Sphyraenidae	Serranidae	Scaridae	Haemulidae	*Lobatus gigas*	Carcharhinidae	Others[1]
1950	6,350	12,180	8,690	1,600	7,470	2,620	5,090	0	3,336	2,120
1951	6,420	12,020	8,580	1,760	7,410	2,770	5,040	0	3,314	2,140
1952	6,670	11,780	8,420	1,910	7,320	2,940	4,960	0	3,254	2,320
1953	6,740	11,630	8,320	2,070	7,270	3,080	4,900	0	3,233	2,340
1954	6,950	11,410	8,170	2,220	7,180	3,250	4,830	0	3,181	2,490
1955	7,060	11,240	8,050	2,370	7,120	3,390	4,770	0	3,152	2,540
1956	7,310	11,020	7,900	2,510	7,040	3,560	4,700	0	3,093	2,710
1957	7,590	10,780	7,740	2,630	6,950	3,720	4,630	0	3,028	2,900
1958	7,900	10,540	7,580	2,750	6,860	3,890	4,560	0	2,956	3,120
1959	8,150	10,320	7,430	2,870	6,790	4,040	4,490	0	2,899	3,270
1960	8,270	10,110	7,280	3,000	6,700	4,170	4,410	0	2,851	3,340
1961	9,420	9,710	7,030	2,980	6,580	4,430	4,350	0	2,654	4,220
1962	9,690	9,640	6,980	3,130	6,590	4,610	4,340	0	2,643	4,350
1963	9,170	9,850	7,120	3,460	6,720	4,740	4,370	0	2,794	3,830
1964	9,310	9,820	7,100	3,650	6,750	4,920	4,360	0	2,810	3,850
1965	9,110	9,890	7,140	3,940	6,820	5,090	4,370	0	2,893	3,590
1966	9,240	9,850	7,110	4,140	6,840	5,280	4,360	0	2,906	3,610
1967	9,380	9,800	7,080	4,350	6,860	5,480	4,340	0	2,918	3,630
1968	9,350	9,790	7,080	4,610	6,900	5,670	4,330	0	2,964	3,510
1969	9,500	9,730	7,040	4,830	6,900	5,860	4,320	0	2,974	3,540
1970	9,650	9,660	7,010	5,050	6,900	6,050	4,300	0	2,983	3,580
1971	10,080	9,550	6,940	5,200	6,890	6,250	4,280	0	2,947	3,830
1972	10,260	9,460	6,940	5,410	6,850	6,460	4,260	0	2,950	4,020
1973	10,410	9,370	6,950	5,640	6,810	6,680	4,240	0	2,959	4,180
1974	10,680	9,250	6,930	5,820	6,750	6,890	4,220	0	2,941	4,450
1975	10,810	9,160	6,930	6,070	6,720	7,110	4,190	0	2,955	4,570
1976	10,930	9,070	6,910	6,310	6,680	7,330	4,170	0	2,966	4,710
1977	11,140	9,070	6,970	6,640	6,720	7,630	4,180	0	3,013	4,810
1978	11,360	9,300	7,150	7,210	6,930	8,120	4,270	0	3,160	4,790
1979	11,380	9,050	7,020	7,350	6,800	8,240	4,180	0	3,117	4,870
1980	10,870	8,370	6,600	7,100	6,310	7,980	3,920	0	2,909	4,270
1981	10,500	8,150	6,370	7,340	6,250	8,130	3,800	0	2,912	3,750
1982	10,180	7,750	6,080	7,320	6,040	8,180	3,640	0	2,811	3,780
1983	10,470	7,760	6,110	7,660	6,140	8,670	3,680	0	2,845	4,060
1984	10,250	7,290	5,800	7,470	5,860	8,670	3,520	0	2,686	4,300
1985	9,810	6,820	5,450	7,300	5,580	8,600	3,320	0	2,546	4,500
1986	9,310	6,370	5,110	7,160	5,310	8,520	3,130	0	2,419	4,550
1987	8,170	5,500	4,430	6,470	4,670	7,810	2,740	0	2,122	4,090
1988	7,010	4,540	3,650	5,650	3,930	6,780	2,260	4,500	1,798	3,530
1989	6,540	4,140	3,370	5,350	3,670	6,650	2,120	5,250	1,653	3,660
1990	5,920	3,770	3,080	5,110	3,410	6,420	1,950	6,000	1,534	3,660
1991	5,990	3,660	3,000	5,230	3,390	6,610	1,910	7,500	1,524	3,750
1992	5,420	3,090	2,580	4,570	2,940	6,060	1,660	11,250	1,291	3,740
1993	4,930	2,590	2,210	3,960	2,550	5,570	1,450	15,000	1,088	3,800
1994	4,150	1,990	1,750	3,130	2,030	4,760	1,180	17,250	834	3,670
1995	4,710	2,230	1,940	3,740	2,330	5,580	1,320	16,000	970	4,040
1996	5,510	2,370	2,210	3,930	2,640	7,060	1,560	10,740	987	5,820
1997	5,020	2,390	1,990	4,820	2,570	6,080	1,320	13,660	1,188	3,410
1998	4,890	2,290	1,880	4,980	2,510	5,950	1,240	12,750	1,197	2,590
1999	5,230	2,270	1,930	5,090	2,620	6,720	1,320	10,250	1,188	3,490
2000	6,740	3,060	2,480	7,610	3,520	8,630	1,650	0	1,736	3,450
2001	5,320	2,220	1,840	5,770	2,650	6,810	1,240	7,100	1,281	3,020
2002	6,000	2,340	2,020	6,290	2,940	8,110	1,420	0	1,357	3,910
2003	6,210	2,250	1,990	6,330	2,950	8,450	1,420	3,780	1,330	4,210
2004	6,150	2,090	1,900	6,160	2,850	8,490	1,380	4,130	1,260	4,810
2005	5,960	1,950	1,750	6,220	2,710	8,090	1,260	4,800	1,242	5,190
2006	4,650	1,250	1,370	3,500	1,990	7,090	1,110	4,880	673	5,310
2007	5,100	1,370	1,430	4,370	2,180	7,520	1,130	4,800	824	5,330
2008	6,060	1,630	1,600	6,050	2,600	8,610	1,230	3,000	1,115	4,880
2009	6,370	1,730	1,770	6,150	2,820	9,650	1,400	3,000	1,131	6,050
2010	6,210	1,700	1,710	6,140	2,750	9,290	1,340	3,300	1,131	5,630

[1] Others category represents 29 additional taxonomic groups.

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

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Abstract

The Kermadec Islands are an isolated and uninhabited cluster of islands which have been the site of relatively little fishing. The total domestic (New Zealand) catch from the Kermadec Islands' Exclusive Economic Zone (EEZ) waters for the 1950-2010 time period was approximately 971 t. Foreign fishing was also estimated, as these fisheries had a greater impact on the area. The foreign fishery catch was estimated at 14,475 t over the time period. Approximately 80% of this was caught by South Korean vessels, with the other 20% caught by Japanese vessels. At present, there is very little fishing occurring in the Kermadec Region (only 28 t domestic and zero foreign catch in 2010).

Introduction

The Kermadec Islands are the northernmost point of New Zealand (Figure 1). The group consists of four island groups which are (with the major islands listed) as follows: 1) Raoul Island, Meyer Island, and the Herald Islets; 2) Macauley Island and Haszard Islet; 3) Curtis and Cheeseman Islands; and 4) L'Esperance and Havre Rocks (Francis *et al.* 1987). The Kermadec Islands are peaks of volcanic formations rising from the Kermadec Ridge (Francis *et al.* 1987). Although the Kermadecs are part of New Zealand, the EEZ surrounding the islands is nearly separated from the EEZ of the main New Zealand EEZ (surrounding North and South Island), and thus we can refer specifically to the Kermadec Islands' EEZ (612,047 km^2; A. Connell, pers. comm., New Zealand Ministry of Fisheries). The Kermadec region is formed by the subduction of the Pacific Plate under the Australian Plate. This not only creates an area of frequent earthquakes and active volcanoes but also forms the Kermadec trench which is over 10,000 m deep (Wright 2010). The Kermadec Islands are an important locale of unique and diverse terrestrial flora and fauna, and marine life due to their isolation and subtropical location which features a mixture of tropical, subtropical, and temperate species (Gardner *et al.* 2006). In 1934, the islands were declared a Flora and Fauna Reserve and then a Nature Reserve in 1977.[2] Starting in 1987, the New Zealand Department of Conservation has managed the islands and now have permanent staff and volunteers on Raoul Island who are responsible for monitoring meteorological and volcanic activity, weed and pest control, and enforcing regulations of the nature and marine reserves.[2] The islands are uninhabited except for the conservation staff on Raoul Island.[3] The territorial seas (12-mile limit surrounding the coastal edge) around each island and rock were declared marine reserves in 1990 (Eddy 2011). This reserve protects 748,000 ha (7,480 km^2) of ocean (Gardner *et al.* 2006).

Due to the fact that the Kermadec Islands are part of New Zealand, they are not typically evaluated on their own. The purpose of this report is to assess how much fishing actually occurs in the isolated region of New Zealand's EEZ which surrounds the Kermadec Islands.

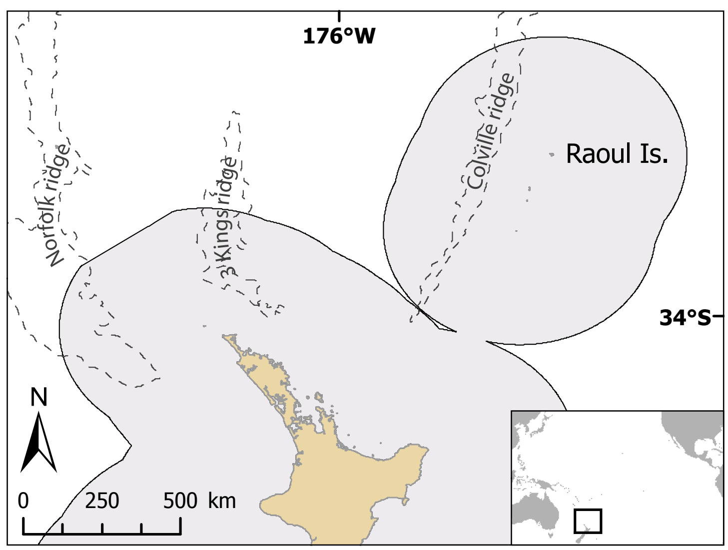

Figure 1. Map of the Kermadec Islands and its EEZ. Raoul Island is shown as well as the connection of the Kermadec Islands EEZ to the New Zealand EEZ surrounding North and South Island.

Methods

To estimate the total fisheries catch within the Kermadec Island EEZ, both domestic and foreign fleets were assessed. For the Kermadecs, only large-scale commercial fleets need to be considered. The islands are uninhabited and thus there is no localized small-scale fishing occurring. New Zealand's EEZ is divided into ten Fisheries Management Areas

[1] Cite as: Zylich, K., Harper, S., and Zeller, D. (2012) Reconstruction of marine fisheries catches for the Kermadec Islands (1950-2010). pp. 61-67. *In*: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] http://www.thekermadecs.org/islands [accessed January 10, 2012]

[3] http://www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/kermadec/facts/ [accessed January 10, 2012]

(FMAs). The Kermadec Island's EEZ is categorized as its own management area, FMA10, and therefore, the New Zealand Ministry of Fisheries (known hereafter as the Ministry of Fisheries) collects data which are specific to the Kermadec Region. However, these data are only available starting in 1990. Prior to this, data relating to foreign fishing were available through various South Pacific Commission[4] (SPC) reports. As for domestic fishing, New Zealand did not have a deep-water fleet prior to 1990, and thus did not fish Kermadec waters at that time (G. Simmons, pers. comm., New Zealand Asia Institute). The Ministry of Fisheries website was also consulted to fit scientific names to the common names presented in the reported data.[5]

Domestic fisheries

Domestic large-scale commercial catches for the 1990-2010 time period were obtained from the Ministry of Fisheries and were accepted as reported data. There were only a few changes made to the data; this affected taxonomic classification of the data, but not the tonnage value. Three categories provided combined data for two species. In these cases the catch was divided between the species. The alfonsino and long-finned beryx (*Beryx slendens* and *B. decadactylus*, respectively) formed a combined category and were each assigned 50% of the combined catch. The same rule was applied to black and yellowfoot paua (*Haliotis iris* and *H. australis,* respectively). Hapuku and bass (*Polyprion oxygeneois* and *P. americanus*, respectively) were treated slightly differently, as they were also present in the data as individual categories. Therefore, the proportion of hapuku to bass in the individual categories was used to divide up the combined category. The only amendment to the actual value of the data was to the "shark fins (unspecified)" category which needed to be converted to the equivalent whole shark weight. After contacting the Ministry of Fisheries, it was found that a conversion factor of 30 was used (C. Loveridge, pers. comm., Ministry of Forestry and Agriculture). This conversion factor was used to calculate the whole wet weight of shark from (what is assumed to be) the wet fin weight. The amount reported as fins was kept separate, labelled as shark ("Selachimorpha"), and was treated as landed catch which was added on to the other miscellaneous shark category. The difference between the whole weight and the fin weight was also labelled as shark ("Selachimorpha"), but was treated as discarded catch (i.e., discarded carcasses). Annual catches were set to zero prior to 1990, as there were no domestic vessels fishing in the Kermadec region of the EEZ at that time.

Foreign fisheries

Foreign large-scale commercial catches for the 1990-2010 time period were obtained from the Ministry of Fisheries. This included catch by foreign licensed and foreign chartered vessel fleets. Foreign licensed vessels stopped fishing in New Zealand at the end of the 1994-95 fishing year (Francis *et al.* 2001). Records of foreign licensed vessels only appear for 1991 and 1992 in the Kermadec region. The official data only list five years in which foreign chartered vessels were present in Kermadec waters, the first year being 1997. Foreign licensed and foreign charter are different ways of managing foreign fleets, and therefore this gap in foreign fishing is assumed to be due to the changes in the management of foreign vessels. In this report, foreign licensed and foreign chartered vessels are treated the same. The official data for foreign vessels (licensed and chartered) were assumed to be representative of foreign catches and were not altered apart from proportioning the catches to the different foreign fleets.

Prior to 1990, there are many references to foreign vessels fishing in New Zealand's EEZ. Taiwanese, Chinese, and Soviet vessels have been identified as fishing in New Zealand's waters. However, these references referred to squid (*Nototodarus sloanii*), hoki (*Macruronus novaezelandiae*), or southern blue whiting (*Micromesistius australis*) fisheries which did not take place in the geographic location of Kermadec (Smith *et al.* 1981; Clark 1985; Chen *et al.* 2008). Only South Korean and Japanese vessels were able to be clearly identified as fishing in the Kermadec EEZ. In the 1980s, there were two foreign licensed longline tuna fisheries operating in New Zealand's EEZ. The southern fishery which was mainly comprised of Japanese vessels was restricted to the waters surrounding North and South Island and targeted southern bluefin tuna (*Thunnus maccoyii*; Murray *et al.* 1984). The northern fishery, which consisted mainly of Korean vessels (with a few Japanese vessels), was much smaller than the southern fishery and operated north of 34°S latitude targeting albacore tuna (*Thunnus alalunga*; Murray *et al.* 1984). This northern fishery was known to focus its effort around Kermadec as well as the Colville Ridge, Norfolk Ridge and the Three Kings Rise system (Figure 1; Murray *et al.* 1984).

SPC Country Statement reports on tuna fishing and resources in New Zealand, provided grids of 1° longitude by 1° latitude cells, showing catch data around New Zealand, which confirmed that the northern fishery did fish inside the Kermadec EEZ (Murray *et al.* 1984; Murray and Ross 1985). Bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) were also present in the catch, along with swordfish (*Xiphias gladius*), known to be a by-catch item (Murray *et al.* 1984). The grids provided spatially allocated catch information in the form of number of sets and fish caught per set for albacore, bigeye tuna, and yellowfin tuna. Grids for the northern and southern fisheries were provided, and showed that both fleets obtained catches within the Kermadec EEZ. As the grids were labelled as "northern fishery" and "Japanese fishery", and were not explicit in differentiating the northern Japanese vessels, it was assumed that the northern fishery represented South Korean catches, and the Japanese fishery catches which fell into the Kermadec EEZ were part of the northern Japanese fisheries catches. These grids provided data from 1981-1984 for the South Korean fleet and 1980-1984 for the Japanese fleet. Additional reports provided average weights of fish for each fishing year (Murray *et al.* 1989).

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[4] Now the Secretariat of the Pacific Community.

[5] http://www.fish.govt.nz/en-nz/International/High+Seas+Fishing/MFish+Approved+Species+Codes/MFish+Approved+Species+Codes+01.htm, [accessed January 5, 2012]

Information regarding the fleets' total catch (without spatial distribution graphs) was available from 1980 to 1988 (Murray *et al.* 1989). Unfortunately, these data included catches made outside of the Kermadec EEZ. Proportions and averages were used to extrapolate the data from the known catches in order to estimate catches from 1985 to 1988. Catches for the years 1989-1990 were estimated by interpolating between the 1988 estimates and the 1991 catches from the Ministry of Fisheries data. The target tuna (albacore, bigeye, and yellowfin) data for 1991-1992, 1997, 1999-2000, 2003, and 2007 for foreign vessels (from the Ministry of Fisheries data) were divided proportionally into South Korean and Japanese catches based on proportions from the 1988 tuna estimates (Table 1). Non-target data were divided using the average proportion of South Korean to Japanese catches in 1988 (Table 1). The Ministry of Fisheries data were assumed to be accurate and thus in years of zero data (excluding 1990), it was assumed that there were no foreign vessels fishing in Kermadec waters.

According to Francis *et al.* (1987), foreign vessels (Japanese, Korean, and Taiwanese) started longline fisheries in New Zealand in the early 1950s. It was assumed that these countries began re-building their fleets after World War II. Therefore, a starting point of zero in 1945 was used as an anchor point. Estimates were interpolated between zero in 1945 and the first data points in either 1980 or 1981, to give a complete time series of target tuna data. The data on non-target species from the Ministry of Fisheries for the foreign licensed vessels only, were used to estimate the non-target catch for the foreign fishery from 1950-1990. Foreign licensed catch data from 1991 and 1992 were averaged to obtain the proportion of target tuna to the non-target species (Table 2).

Finally, there has been one documented case of illegal fishing by a foreign vessel in the Kermadec Islands' EEZ. In late 2009, a Vanuatu flagged longline vessel (Taiwanese owned), as well as a Taiwanese flagged longline vessel, were spotted (12 miles apart) on the same day, just north of the Kermadec Islands.[6] The owners of these vessels have acknowledged that they were fishing illegally and have both paid fines to the New Zealand Government. Although this is the only documented case of illegal fishing, it is assumed that other instances of illegal fishing have also taken place within the Kermadec EEZ, due to the remoteness of the area. However, without further evidence we cannot estimate the impact that illegal fishing has on the marine resources within the Kermadec Islands' EEZ.

Table 1. Percentage of tuna catch within the Kermadec EEZ, by fishing country, in 1988.

Species	Percentage (%)	
	South Korea	Japan
Thunnus alalunga	86.33	13.67
Thunnus obesus	8.96	91.04
Thunnus albacares	83.01	16.99
Average	59.43	40.57

Table 2. Species composition of foreign vessel catches, within the Kermadec EEZ, for 1950-1990.

Taxa	Catch (%)
Target Tuna[a]	69.07
Xiphias gladius	7.73
Isurus oxyrinchus	6.36
Alopias vulpinus	2.91
Tetrapturus audax	2.79
Thunnus maccoyii	1.54
Gasterochisma melampus	0.53
Prionace glauca	0.13
Thunnus thynnus	0.11
Miscellaneous marine fish	5.88
Miscellaneous sharks	2.95

[a] Target tuna consists of *Thunnus alalunga*, *Thunnus obesus*, and *Thunnus albacares*.

Results

The total domestic catch for Kermadec, for the time period of 1950-2010, was 971 t (Figure 2). This catch only spans the time period of 1990-2010 as there was no domestic fishing in the Kermadec EEZ prior to this time period. The average annual catch over the 1990-2010 time period equalled approximately 46 t·year^{-1}. The species composition for the domestic catch was extremely diverse. The data obtained from the Ministry of Fisheries contained 100 taxonomic groups, with only a few miscellaneous categories. Out of this large mix of species, it was seen that the domestic catch was dominated by swordfish (*Xiphias gladius*) which represented 26.9% of the total catch (261 t). Bass (*Polyprion americanus*), bigeye tuna (*Thunnus obesus*), and bluenose (*Hyperoglyphe antarctica*) were the other major species present in the catch, with approximately 95 t (9.8%), 91 t (9.4%), and 85 t (8.7%), respectively, of the total

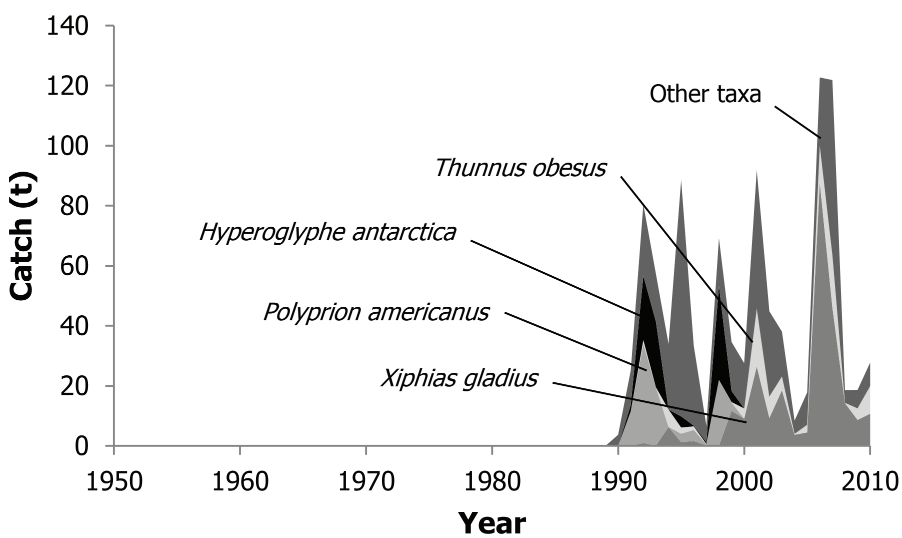

Figure 2. Domestic fisheries catch in the Kermadec Islands EEZ, separated by species. The grouping "other taxa" contains 98 taxonomic groups, and includes both marine fish and invertebrates.

[6] http://www.fish.govt.nz/en-nz/Press/Press+Releases+2010/November10/Foreign+vessel+admits+fishing+illegally+in+New+Zealand+waters.htm [accessed April 13, 2012]

domestic catch (Figure 2). There was a small amount of discarded shark (Selachimorpha) calculated from the shark fin catch, totalling 22 t over the time period and representing 2.3% of the total domestic catch.

The total foreign catch for 1950-2010 is estimated at 14,475 t (Figure 3). The average annual catches peaked in the 1980s with approximately 580 t·year^{-1} and have declined dramatically since. From the information available, it is assumed that only Japanese and South Korean vessels were fishing in the Kermadec EEZ. South Korean vessels represented approximately 80% (11,600 t) of the total foreign catch, with Japanese vessels catching the remaining 20% (2,900 t; Figure 3a). Within the Kermadec EEZ, foreign vessels were mainly targeting tuna and billfish. The overall foreign catch was dominated by albacore with 45.4% (6,576 t) of the catch. Other major species included bigeye tuna, swordfish, shortfin mako shark, and yellowfin tuna, with 2,657 t (18.4%), 1,113 t (7.7%), 909 t (6.3%), and 810 t (5.6%), respectively, of the total foreign catch (Figure 3b). In terms of individual fleets, the only major difference was that South Korea's major species was albacore with 53% (6,149 t) of the total catch, whereas Japan's largest contributor was bigeye tuna with 47% (1,369 t) of the total catch.

Overall, foreign catches far outweighed domestic catches (Figure 4).

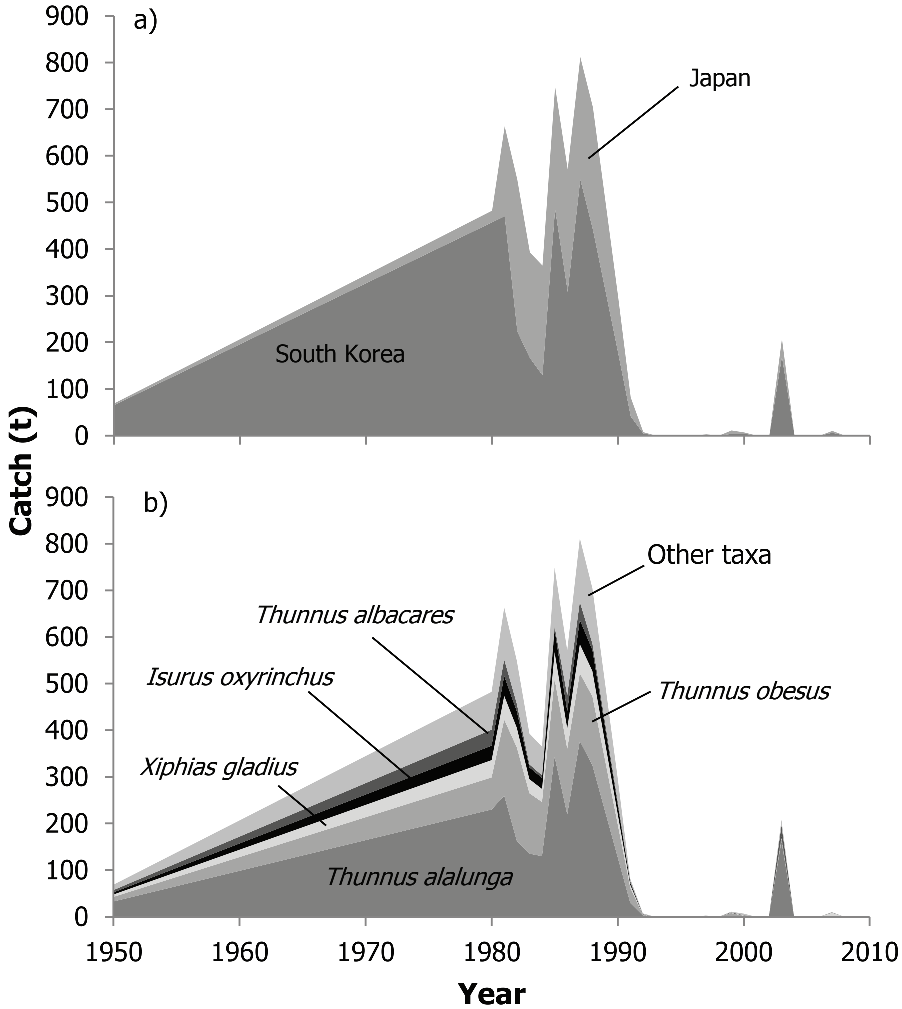

Figure 3. Total estimated foreign catch for the Kermadec Islands' EEZ, 1950-2010, (a) divided by country; and (b) by species. The grouping "other taxa" contains 24 taxonomic groups, including both marine fish and invertebrates.

Discussion

The total reconstructed domestic catch for the Kermadec Islands equalled 971 t, with an additional 14,475 t of foreign vessel catch, for the time period of 1950-2010. Catch data from 1990 onward was provided by the New Zealand Ministry of Fisheries upon request. It should be noted that there appears to be some discrepancy in the Ministry of Fisheries reporting. There is catch data, by region, for the last six years available on the Ministry of Fisheries website. For Kermadec (FMA10), the website reports that there is no customary or recreational fishing as the islands are uninhabited, and also states that the Kermadecs are not open to commercial fishing, except for research purposes. The website reports only 52 kg of commercial catch in 2007 and zero catch in 2008-2010.[7] This is not the same

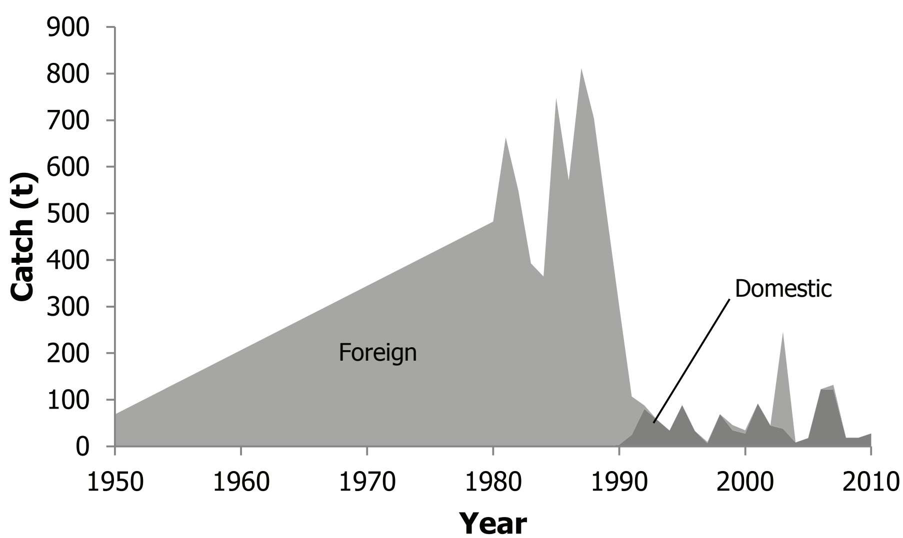

Figure 4. Total estimated catch within the waters of the Kermadec Islands' EEZ, divided by foreign and domestic (New Zealand) catch, 1950-2010.

[7] http://fs.fish.govt.nz/Page.aspx?pk=41&tk=99&ey=2007, accessed February 3, 2012

as the data which were provided by the Ministry of Fisheries upon request, which stated that the domestic catch for 2007 was 122 t. Catches provided by the Ministry of Fisheries for the years 2008-2010 averaged 22 t·year^{-1} which does not equal the zero reported catch value on the Ministry's website either. Currently, only the 12-mile territorial seas around Kermadec are protected/designated as marine reserves. The Kermadec EEZ is named as a Benthic Protection Area which protects the area from bottom trawling. This makes it illegal to trawl within 100 meters of the bottom. With these protection measures in mind, as well as the consideration by conservation organizations to create an ocean sanctuary around the Kermadecs, accurate and transparent reporting of fishing activities in the region is crucial. Consistent and effective patrols are also required to deter and capture illegal fishing vessels which threaten the area.

Acknowledgements

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Appendix Table A1. Total reconstructed catch (t) for the Kermadec Islands, 1950-2010, by fishing country (domestic vs. foreign catches).

Year	Reconstructed domestic catch	Reconstructed foreign catch	
	New Zealand	Japan	South Korea
1950	-	3.6	65.3
1951	-	4.3	78.4
1952	-	5.0	91.4
1953	-	5.7	104.5
1954	-	6.5	117.6
1955	-	7.2	130.6
1956	-	7.9	143.7
1957	-	8.6	156.8
1958	-	9.3	169.8
1959	-	10.0	182.9
1960	-	10.8	196.0
1961	-	11.5	209.0
1962	-	12.2	222.1
1963	-	12.9	235.1
1964	-	13.6	248.2
1965	-	14.3	261.3
1966	-	15.1	274.3
1967	-	15.8	287.4
1968	-	16.5	300.5
1969	-	17.2	313.5
1970	-	17.9	326.6
1971	-	18.6	339.6
1972	-	19.4	352.7
1973	-	20.1	365.8
1974	-	20.8	378.8
1975	-	21.5	391.9
1976	-	22.2	405.0
1977	-	22.9	418.0
1978	-	23.7	431.1
1979	-	24.4	444.2
1980	-	25.1	457.2
1981	-	192.8	470.3
1982	-	325.6	223.3
1983	-	226.4	166.4
1984	-	235.3	129.3
1985	-	262.5	485.8
1986	-	262.5	308.2
1987	-	262.5	549.0
1988	-	262.5	441.4
1989	-	191.5	309.5
1990	3.7	120.6	177.6
1991	25.1	40.9	41.1
1992	80.4	3.1	4.5
1993	57.2	-	-
1994	33.9	-	-
1995	88.6	-	-
1996	33.4	-	-
1997	6.7	1.2	1.7
1998	69.2	-	-
1999	34.6	7.5	3.7
2000	27.6	3.0	4.0
2001	91.9	-	-
2002	44.8	-	-
2003	38.1	38.6	169.2
2004	8.4	-	-
2005	17.8	-	-
2006	122.7	-	-
2007	121.9	4.2	6.0
2008	18.6	-	-
2009	18.6	-	-
2010	27.8	-	-

Appendix Table A2. Total reconstructed domestic catches (t) for the Kermadec Islands, 1950-2010, by taxonomic category.

Year	*Xiphias gladius*	*Polyprion americanus*	*Thunnus obesus*	*Hyperoglyphe antarctica*	Other taxa[1]
1950	-	-	-	-	-
1951	-	-	-	-	-
1952	-	-	-	-	-
1953	-	-	-	-	-
1954	-	-	-	-	-
1955	-	-	-	-	-
1956	-	-	-	-	-
1957	-	-	-	-	-
1958	-	-	-	-	-
1959	-	-	-	-	-
1960	-	-	-	-	-
1961	-	-	-	-	-
1962	-	-	-	-	-
1963	-	-	-	-	-
1964	-	-	-	-	-
1965	-	-	-	-	-
1966	-	-	-	-	-
1967	-	-	-	-	-
1968	-	-	-	-	-
1969	-	-	-	-	-
1970	-	-	-	-	-
1971	-	-	-	-	-
1972	-	-	-	-	-
1973	-	-	-	-	-
1974	-	-	-	-	-
1975	-	-	-	-	-
1976	-	-	-	-	-
1977	-	-	-	-	-
1978	-	-	-	-	-
1979	-	-	-	-	-
1980	-	-	-	-	-
1981	-	-	-	-	-
1982	-	-	-	-	-
1983	-	-	-	-	-
1984	-	-	-	-	-
1985	-	-	-	-	-
1986	-	-	-	-	-
1987	-	-	-	-	-
1988	-	-	-	-	-
1989	-	-	-	-	-
1990	-	-	-	0.005	3.7
1991	0.03	11.447	0.008	2.068	11.5
1992	0.93	33.026	1.300	21.414	23.8
1993	0.10	19.358	0.035	21.789	15.9
1994	6.29	-	5.812	-	21.8
1995	1.24	2.819	2.051	3.706	78.7
1996	1.61	3.677	1.198	0.235	26.7
1997	0.10	0.430	0.110	0.610	5.5
1998	0.06	21.854	0.050	31.280	15.9
1999	11.68	2.772	0.130	3.654	16.4
2000	9.05	-	3.416	-	15.1
2001	26.42	0.002	19.532	-	45.9
2002	9.28	-	7.141	-	28.4
2003	18.50	-	4.581	0.035	14.9
2004	3.69	-	0.350	-	4.4
2005	4.48	-	2.600	-	10.7
2006	87.69	-	12.277	0.010	22.7
2007	46.15	0.012	17.364	0.030	58.3
2008	14.22	-	0.134	-	4.2
2009	8.63	-	3.863	-	6.2
2010	10.69	0.078	9.145	0.070	7.8

[1] Other taxa category includes 97 additional taxonomic groups.

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

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Abstract

Consistent and reliable island-wide fisheries data collection is a challenge for many Caribbean countries. This report presents the reconstruction of total marine fisheries catches by Montserrat for the 1950-2010 time period, which includes officially reported landings and an estimate for unreported catch from the small-scale fisheries sector. Total domestic fisheries catches for the period 1950-2010, were estimated to be approximately 13,300 tonnes, which is 3 times the official landings of 4,288 t reported to FAO on behalf of Montserrat. Small-scale fisheries play an important role in meeting the dietary demands of locals and visitors alike. More complete time series data on total marine landings will enable fisheries managers to make critical evaluations of fisheries and their supporting resources.

Introduction

Montserrat is a little known island in the Lesser Antilles group in the eastern Caribbean, located between Antigua and Guadeloupe at 16° 45' N 62° 12' W (Figure 1). Montserrat has a land area of 138 km² and an Exclusive Economic Zone (EEZ) of nearly 7,600 km² (www.seaaroundus.org). Montserrat was originally populated by Carib Indians, but by the time Christopher Columbus visited in 1493, the island was uninhabited (Kozleski 2004). Over a century later, in 1632, Montserrat came under British control, when anti-Catholic violence in neighbouring Nevis forced a group of Irish slaves to seek refuge (Kravtchenko and Fergus 2005). African slaves were then shipped in to work the sugar plantations from around the mid 1600s. The island was fought over by the French and the British during the 1700s, but today Montserrat remains a British Overseas Territory in the Caribbean and has a rare mix of Anglo-Irish and African cultures (Kravtchenko and Fergus 2005).

On September 17, 1989, Hurricane Hugo struck, damaging most of the island and its infrastructure (Berke and Wenger 1991). Hurricanes are not the only major environmental disaster impacting the island. Due to volcanic eruptions at the Soufriere Hills Volcano from 1995 until 2010, Montserrat's environment and population have undergone profound transformations (Blouet 2007; Ponteen 2010). In 1995, the Soufriere Hills volcano erupted, causing widespread damage. Half of the residents had to be evacuated to either England, USA, or a neighbouring island such as Antigua and Barbados. The coastline has been re-shaped by the volcano's path and several pyroclastic flows have extended the eastern coastline by approximately 1.6 km (Ponteen 2010). About two-thirds of the island, including the former capital of Plymouth, is uninhabitable. A 2011 census (www.gov.ms) revealed that 4,922 people reside on Montserrat in the remaining habitable land space.

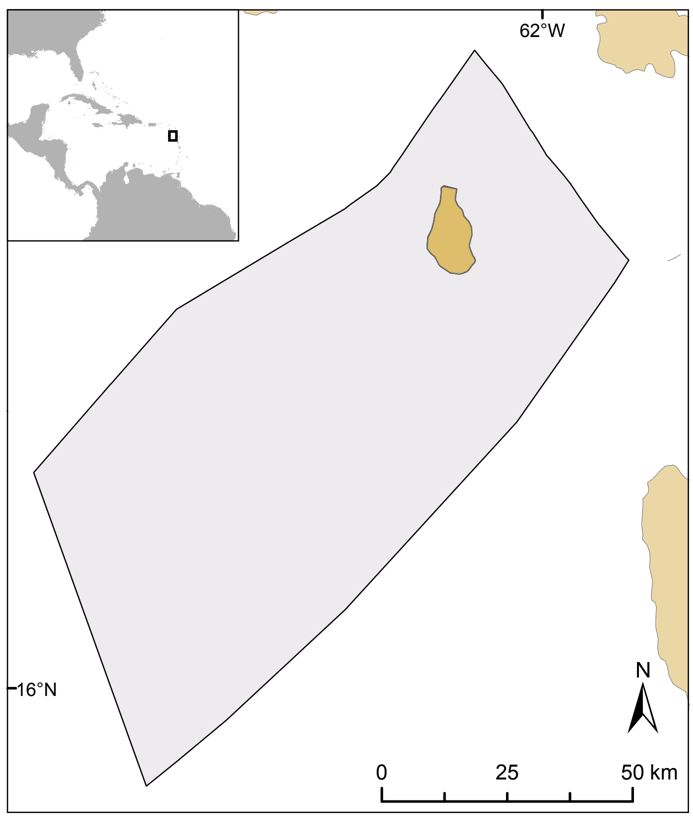

Figure 1. Map of Montserrat and its Exclusive Economic Zone.

Montserrat has a small economy that is based mainly on agriculture, construction and tourism (Vidaeus 1970). Fisheries (often administered under the Department of Agriculture) are essential to island communities of the Caribbean, and Montserrat is no exception. Montserrat's small-scale, open-access fisheries target primarily reef and pelagic species. The sector is mainly artisanal, with some subsistence practices and a small sports-fishing sector. In the mid-1980s, a total of 200 artisanal fishers

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(Goodwin *et al.* 1985) were operating 80 fishing boats (motorised, wooden dories 4-8 m in length; Jeffers 1984). Today, there are 150 fishers operating 38 motorised fishing boats. None of these vessels are registered, although efforts are presently underway to establish a boat registry for the island (Ponteen 2010). Furthermore, foreign fishers, from Guadeloupe and Martinique, are known to be active in the waters of Montserrat (Mahon *et al.* 1988).

Montserrat fishers typically operate on a part-time basis and have alternative livelihoods in sectors such as tourism, agriculture and construction (Vidaeus 1970). Fishers target demersal, reef and pelagic species using a variety of gears including fish pots, beach seines, lines and gillnets (Ponteen 2010). Red hind (*Epinephelus guttatus*) and queen triggerfish (*Balistes vetula*) are two commercially important species landed in Montserrat (CRFM 2010). Needlefish (Belonidae), known locally as "gar", are also important coastal pelagics targeted, along with wahoo (*Acanthocybium solandri*), dolphin fish (*Coryphaena hippurus*), bonito (*Sarda sarda*) and various tunas such as albacore (*Thunnus alalunga*; Ponteen 2010).

As is the case in many Caribbean islands, demand for seafood often exceeds supply on the island, thus Montserrat is heavily reliant on imported seafood products (Vidaeus 1970; Jeffers 1984; Ponteen 2010). Dried salted smoked fish, in particular cod, make up the bulk of historical imports with around 61 t·year^{-1} imported in 1967 and 1968 (Vidaeus 1970). At present, imported frozen fish, crustaceans (i.e., shrimp) and molluscs (i.e., conch), average 46 t·year^{-1} (product weight; Ponteen 2010). Still, despite a heavy reliance on imported seafood, catches from Montserrat's EEZ are an important food source for the island's population of locals and visiting tourists.

Local catches are processed and sold directly by the fishers themselves either on the beach, in the villages (Jeffers 1984), or direct to the hotels and restaurants (Alwyn Ponteen, pers. obs.). There is no middleman and there is no formal fishmarket in Montserrat (the 1995 volcanic eruption destroyed several landing sites and the market in Plymouth). Fishers presently have an informal arrangement with the Port Authority to use their commercial jetty in Carr's Bay for landing their catches (Ponteen 2010). There is no export market for fish caught in Montserrat.

Fisheries data collection in Montserrat began sometime before 1976 (Jeffers 1984). More recently, Montserrat joined the Caribbean Regional Fisheries Mechanism (CRFM) and has been submitting catch and effort data to the CRFM's electronic database, Carafis, since 1997. Collectors monitor the main landing site on weekdays until 4 PM (Alwyn Ponteen, pers. obs.). Due to the inconsistencies in data collection, catch statistics in Montserrat are deficient. These discrepancies have been acknowledged by the Fisheries Division of Montserrat, which is working with CRFM to make improvements to their data collection system. Montserrat did not report any fishery statistics to the FAO for the years between 2003 and 2009 (Luca Garibaldi, pers. comm., FAO), which highlights the need for improved capacity and communication.

A review of all available fisheries literature on Montserrat was undertaken, along with data accessed from the Fisheries Division in order to (1) provide an improved estimate of total marine fisheries catches for Montserrat for the time period 1950-2010, and (2) improve the taxonomic breakdown of the catch.

Methods

The fishing activities in the Montserratian EEZ have been reported by Vidaeus (1970), Giudicelli (1978), Jeffers (1984), Goodwin *et al.* (1985), Mahon *et al.* (1988), Luckhurst and Marshalleck (1995) and Ponteen (2010). Using details on data collection methods from these sources, we estimated unreported catches from the small-scale sector by applying a raising factor to the FAO reported landings data from 1950-2010. Carafis data allowed us to improve on the taxonomic resolution of the reconstructed catches. We also reconstructed the tourist seafood demand, using data on stop-over arrivals combined with seafood consumption rates. Due to a lack of data, no estimate of sport-fishing or foreign fishing was undertaken at the time of this study.

Table 1. Fisheries data collection methods in Montserrat.

Source	Data collection methods
Vidaeus (1970)	Landings recorded daily at 9 sites: Isles Bay, Carr's Bay, Little Bay, Bunkum Bay, Wapping Bay, Plymouth, Kinsale, North Bay, Trant's Bay, South Bay and Old Road
Mahon *et al.* (1988)	Information on catch per trip by species or group is collected at Plymouth
Ponteen (2010)	Data collection is only carried out at the main fishing area (Carr's Bay) and only on weekdays until 4 PM

Local and tourist population

Local population data were taken from Populstat (www.populstat.info), which were available for the majority of the 1950-2010 time period of the study. Linear interpolation was used in years where population data were missing (Figure 2a). Data on the number of stop-over tourists (i.e., travelers who stay on island for more than a day) were available from the Caribbean Tourism Organisation (www.onecaribbean.org/). Data were available from 1980-2008, although it was assumed that tourism began in 1950. Using linear interpolation we derived an entire time series of the number of stop-over tourists visiting Montserrat from 1950-2010 (Figure 2b).

Small-scale catches

Fisheries data collection in Montserrat has fluctuated over the study period 1950-2010 (Table 1). Prior to 1995, Plymouth was the main landing site. However, this area was destroyed by the volcanic eruptions and presently Carr's Bay-Little Bay is the main landing site and the only one monitored routinely (Ponteen 2010). Thus, unreported fisheries catches are expected throughout the time period of the study. Using information on the number of boats at landing sites in Montserrat as surveyed by Mahon *et al.* (1988; Table 2), we derived a ratio of total boats to monitored boats (i.e., 67/24). As the data utilized were collected prior to 1995, Plymouth was still the main landing site at that time and we took it to be the only monitored site. We assumed that the ratio of total boats to monitored boats would be an appropriate representation of the ratio of total catches to reported catches prior to 1989.

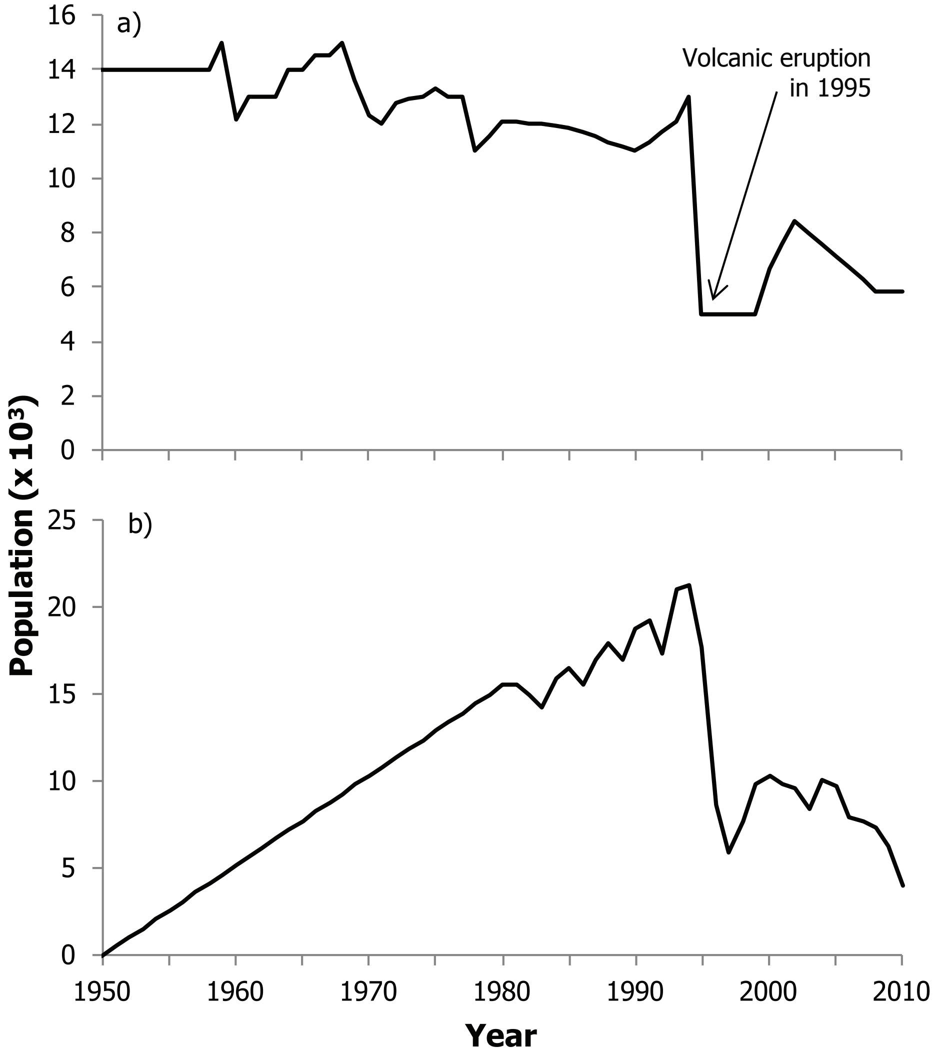

Figure 2. Population statistics of Montserrat, 1950-2010, for (a) total local Montserratian population and (b) stop-over tourist population.

Reported landings for Montserrat were obtained for 1950-2010 from the FAO FishStatJ database (FAO 2012) and for 1997-2011 from the national fisheries division. The two sources of catch data were not comparable in any years, with national data being significantly lower than the FAO reported landings. We had to assume that the FAO had additional information about catches and thus we used the FAO data as our baseline. FAO catch data for Montserrat are essentially flat-lining from 1950-1972 (Figure 3). Thus we considered the more variable data from 1974-1982 as more reliable; and we applied a raising factor of 2.8 (or 67/24, Table 2) to the FAO reported catches for 1974-1982. Combining catch estimates with annual population figures from the corresponding period, we obtained an average *per capita* catch rate of 21 kg·person^{-1}·year^{-1}. Applying this rate constantly to local population data, we derived a complete time series of small-scale catches destined for local consumption in Montserrat for the period 1950-1989.

According to the Montserrat Fisheries Division, catches submitted to CRFM by Montserrat refer only to those landed in Carr's Bay-Little Bay. Meanwhile, two other well-established landing sites exist on the west coast of the island, namely Old Road and Bunkum Bay. It is estimated that around 25% of catches are not recorded since data collectors do not work on the weekends or on weekdays after 4 PM and collectors do not visit Old Road Bay or Bunkum Bay (A. Ponteen, pers. obs.). Thus, for the time period of 1990-2010, we added 25% to FAO reported catches, and estimated total small-scale catches.

We assumed that catches consist of a combination of artisanal and subsistence catches. To assign catches to artisanal and subsistence sectors, it was assumed that in 1950, 80% of catches were from the subsistence sector and 20% were from the artisanal sector. In 2010, 20% of catches were attributed to the subsistence sector and 80% to the artisanal sector. A linear interpolation was done between these two years to derive a complete time-series for the period 1950-2010.

Table 2. Number of boats at landing points in Montserrat, based on Mahon *et al.* (1988).

Landing Area	Total boats
Plymouth	24
Old Road Bay	13
Bunkum Bay	6
Carr's Bay	12
Little Bay	3
German Bay	2
Kinsale	7
Sugar Bay	0
Total	67

Catches satisfying tourist demand

In many parts of the world fishers have regular customers, such as hoteliers and restaurateurs, whom they supply directly with fresh seafood catches. In Montserrat, these catches are often taken directly to the customer without ever passing through a monitored landing site (Alwyn Ponteen, pers. obs.). Therefore, seafood supplying the tourist market was reconstructed separately. Annual tourist population data were combined with data on the average length of stay, which was approximately 7 days according to the Ministry of Tourism. This was taken together with inferences about the frequency of seafood consumption (i.e., one serving of seafood *per* day), and typical serving proportion size (250 g). It was thus determined that tourist seafood demand equals the number of tourists weeks, times the average serving size, times the number of servings per week. In this way, we were able to reconstruct small-scale catches provided directly to the tourist market from 1950 to 2010.

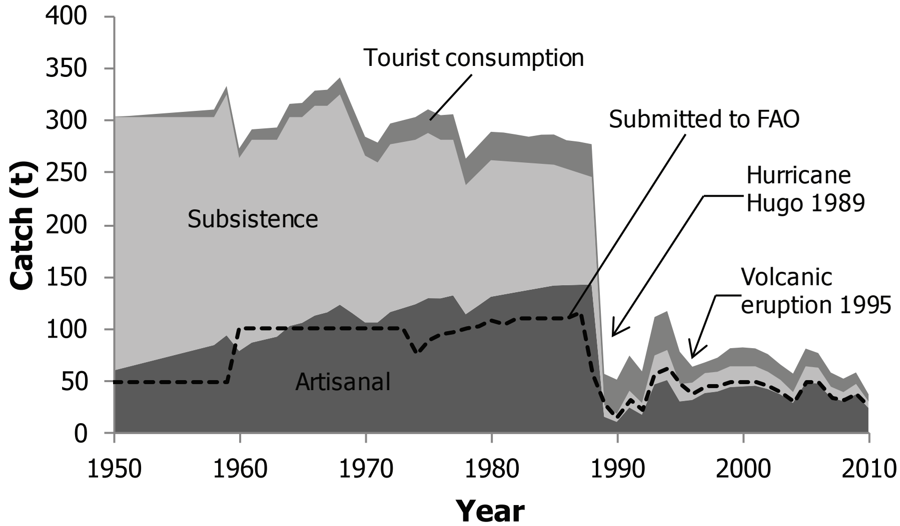

Figure 3. Reconstructed total fisheries catches for Montserrat, 1950-2010, delineating catches for tourist and domestic markets, compared to reported landings submitted to FAO.

Taxonomic composition of catches

Electronic Carafis catch data for Montserrat from 1997-2011 were retrieved and analyzed. Data submitted by Montserrat to the FAO were presented in one taxonomic category, "marine fishes nei", whereas national catch data submitted to CRFM from 1997-2011 provided a breakdown for 160 species from 45 different families. Taking the average proportion of each species from the total catch over the period 1997-2000, we applied this breakdown to the reconstructed catches from 1950-1996. For the 1997-2010 time period, we accepted the annual breakdowns as presented in the Carafis dataset.

Results

Reconstructed catch estimates suggest that landing data submitted to the FAO on behalf of Montserrat are incomplete and lack taxonomic detail. Overall, the 1950-2010 total catch for Montserrat was estimated at 13,263 t, which is 3 times the reported landings supplied to the FAO for the same time period of 4,288 t (Figure 3). Total unreported catches from 1950-2010 were 8,975 t and were on average 147 t·year^{-1}. The drastic decline in catches in 1989 was due to the damage caused by Hurricane Hugo, and again in 1995, when a violent volcanic eruption occurred at Mt. Soufriere Hills. Thus, no obvious unreported catches occurred during these disasters and FAO landings data were accepted for these two years. Catches supplying tourists were estimated at 1,092 t for the period 1950-2010. Average annual catch of 18 t·year^{-1} have supplied this "foreign" sector for the past 6 decades.

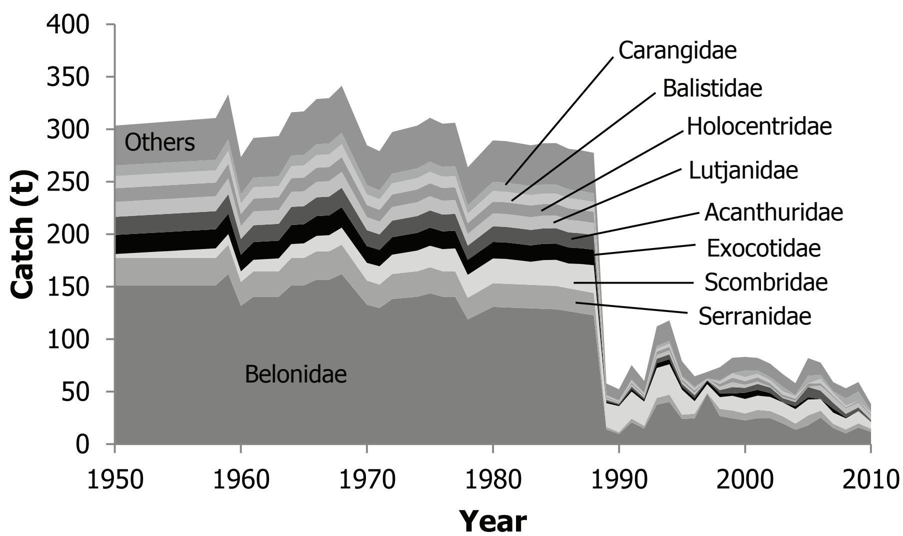

Figure 4. Taxonomic composition of catches for Montserrat, 1950-2010. "Others" contains 36 families of marine species including sharks, lobsters, conch and a miscellaneous marine fishes category.

Montserrat's catches were dominated by pelagic species (Figure 4). Needlefishes (Belonidae; 45%), various scombrids (Scombridae; 7%) as well as flyingfish (Exocotidae; 5%) were important. Reef fish and demersal species targeted included groupers and hinds (Serranidae; 8%), as well as surgeonfish (Acanthuridae; 5%), such as blue tang (*Acanthurus coeruleus*) and doctorfish (*Acanthurus chirurgus*). Other reef families targeted include snappers (Lutjanidae; 4%), squirrelfishes (Holocentridae; 4%), triggerfishes (Balistidae; 4%) and jacks (Carangidae; 3%). The 'others' category, presented here for simplicity, made up the remaining 14% of catches and consisted of 36 families of marine species, including grunts (Haemulidae), parrotfish (Scaridae), sharks (Carcharhinidae), as well as a miscellaneous marine fish category.

Discussion

National catch data reported by the Montserrat fisheries division (1997-2011) were significantly lower than the data submitted to the FAO on behalf of Montserrat. Given that national catch data are collected only at 1 of 3 main landing sites on the island and that Montserrat had not reported landings to the FAO for the majority of the last decade (2003-2009), we used FAO catch data as a baseline for this study.

Fishing is essential to island communities of the Caribbean, and Montserrat is no exception. Like many Caribbean islands, Montserrat is heavily reliant on imported fish, predominantly salted cod from Canada. Even so, the importance of locally caught marine species has been understated (Vidaeus 1970). Local catches are substantially higher than what is being reported to international agencies, and contribute significantly to the food security of local Montserratians. Our total reconstructed catch for Montserrat's marine fisheries for the period 1950-2010 was estimated to be approximately 15,307 tonnes, which is 3.6 times the official reported landings of 4,288 t as presented by FAO on behalf of Montserrat. The difference can be attributed to underreporting of small-scale fisheries, from the subsistence and artisanal fishing sectors, which is due to the method of data collection that presently only monitors one out of three major landing sites. Island-wide data collection is necessary, and historical data are important for fisheries managers to have a complete picture of the status of fisheries and their supporting resources, and to evaluate whether increases in effort will be counterproductive (Pauly 1998).

Furthermore, the tourism sector generates considerable demand for fresh seafood at hotels and restaurants. This is evident as small-scale catches supplying stop-over tourists totaled 1,092 t for the period 1950-2010. This may seem insignificant; however, it represents 8% of the total reconstructed small-scale catches for the island. Thus, the impact of tourists on small islands with limited local food sources should be something that resource managers consider carefully.

Catches submitted to the FAO on behalf of Montserrat were presented in one highly aggregated category, "marine fishes nei". Reconstructed catches were disaggregated into 45 families, which is a major improvement over the reported data. Whilst Montserrat did submit annual catch data to the FAO in 2010, no taxonomic detail was provided. This may be due to the lack of incentive fisheries managers have to change the method in which they fill out the FAO questionnaires annually.

Both Vidaeus (1970) and Mahon *et al.* (1988) have made reference to some un-quantified element of foreign fishing. However, data on their effort and landings were not available. Therefore, this study focused on domestic catches within the waters of Montserrat. Due to limited catch and effort data, a reconstruction of the sports fishing sector was also not undertaken here. Therefore, total marine extractions from Montserrat waters, are likely higher than the total reconstructed estimates suggested in this study.

Acknowledgements

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

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal[1]
1950	50	303	242.8	61
1951	50	304	239.7	65
1952	50	305	236.7	69
1953	50	306	233.7	73
1954	50	307	230.6	76
1955	50	308	227.6	80
1956	50	309	224.6	84
1957	50	310	221.5	88
1958	50	311	218.5	92
1959	50	333	230.8	102
1960	100	273	185.1	88
1961	100	292	194.4	97
1962	100	293	191.6	101
1963	100	294	188.8	105
1964	100	316	200.3	116
1965	100	317	197.2	120
1966	100	329	201.1	128
1967	100	330	198.0	132
1968	100	341	201.6	140
1969	100	313	180.5	133
1970	100	285	160.0	125
1971	100	279	153.5	126
1972	100	297	160.9	136
1973	100	300	159.4	141
1974	77	303	157.8	146
1975	89	311	158.6	152
1976	95	305	152.2	153
1977	98	306	149.3	157
1978	100	264	124.0	140
1979	102	277	127.7	149
1980	109	289	131.1	158
1981	104	289	128.1	161
1982	111	287	125.1	162
1983	110	285	122.0	163
1984	110	287	119.0	168
1985	110	287	116.1	171
1986	110	281	111.8	170
1987	117	280	107.6	172
1988	58	278	103.4	174
1989	28	58	11.5	46
1990	15	52	7.8	44
1991	32	75	16.2	59
1992	23	60	11.4	49
1993	58	112	27.9	84
1994	62	118	29.0	89
1995	48	79	16.8	62
1996	38	65	16.8	48
1997	45	69	19.3	49
1998	46	73	19.1	54
1999	50	82	20.2	62
2000	50	83	19.5	64
2001	50	82	18.9	63
2002	46	77	16.7	60
2003	40	67	14.0	53
2004	31	58	10.5	48
2005	50	82	16.3	66
2006	49	78	15.3	62
2007	35	59	10.5	49
2008	31	53	8.9	44
2009	37	59	10.1	49
2010	24	38	6.2	32

[1] Artisanal includes those catches caught artisanally for local consumption as well as tourist consumption.

Appendix Table A2. Total reconstructed catch (in tonnes) for Montserrat by major taxa, 1950-2010.

Year	Belonidae	Serranidae	Scombridae	Exocotidae	Acanthuridae	Lutjanidae	Holocentridae	Balistidae	Carangidae	Others[1]
1950	151	26.13	3.7	18.21	17.22	14.22	13.05	11.56	10.05	38.0
1951	151	26.13	4.4	18.21	17.22	14.22	13.05	11.56	10.05	38.3
1952	151	26.13	5.1	18.21	17.22	14.22	13.05	11.56	10.05	38.5
1953	151	26.13	5.8	18.21	17.22	14.22	13.05	11.56	10.05	38.7
1954	151	26.13	6.5	18.21	17.22	14.22	13.05	11.56	10.05	39.0
1955	151	26.13	7.1	18.21	17.22	14.22	13.05	11.56	10.05	39.2
1956	151	26.13	7.8	18.21	17.22	14.22	13.05	11.56	10.05	39.4
1957	151	26.13	8.5	18.21	17.22	14.22	13.05	11.56	10.05	39.6
1958	151	26.13	9.2	18.21	17.22	14.22	13.05	11.56	10.05	39.9
1959	162	27.99	10.1	19.51	18.45	15.24	13.98	12.39	10.77	42.8
1960	132	22.77	10.0	15.87	15.01	12.39	11.37	10.07	8.76	35.4
1961	140	24.26	10.9	16.91	15.99	13.20	12.12	10.73	9.34	37.8
1962	140	24.26	11.6	16.91	15.99	13.20	12.12	10.73	9.34	38.0
1963	140	24.26	12.3	16.91	15.99	13.20	12.12	10.73	9.34	38.3
1964	151	26.13	13.2	18.21	17.22	14.22	13.05	11.56	10.05	41.2
1965	151	26.13	13.9	18.21	17.22	14.22	13.05	11.56	10.05	41.4
1966	157	27.06	14.7	18.86	17.83	14.73	13.51	11.97	10.41	43.0
1967	157	27.06	15.4	18.86	17.83	14.73	13.51	11.97	10.41	43.2
1968	162	27.99	16.2	19.51	18.45	15.24	13.98	12.39	10.77	44.8
1969	147	25.47	16.5	17.76	16.79	13.86	12.72	11.27	9.80	41.4
1970	133	22.95	16.8	16.00	15.13	12.49	11.46	10.16	8.83	37.9
1971	130	22.39	17.4	15.61	14.76	12.19	11.18	9.91	8.62	37.4
1972	138	23.89	18.3	16.65	15.74	13.00	11.93	10.57	9.19	39.8
1973	139	24.07	19.0	16.78	15.87	13.10	12.02	10.65	9.26	40.3
1974	140	24.26	19.7	16.91	15.99	13.20	12.12	10.73	9.34	40.8
1975	144	24.82	20.5	17.30	16.36	13.51	12.40	10.98	9.55	41.8
1976	140	24.26	21.1	16.91	15.99	13.20	12.12	10.73	9.34	41.2
1977	140	24.26	21.8	16.91	15.99	13.20	12.12	10.73	9.34	41.4
1978	119	20.53	21.9	14.31	13.53	11.17	10.25	9.08	7.90	36.2
1979	125	21.55	22.7	15.03	14.21	11.73	10.77	9.54	8.29	37.9
1980	131	22.58	23.6	15.74	14.88	12.29	11.28	9.99	8.69	39.7
1981	130	22.51	23.7	15.69	14.83	12.25	11.24	9.96	8.66	39.6
1982	130	22.43	22.9	15.64	14.78	12.21	11.20	9.93	8.63	39.2
1983	129	22.36	22.0	15.59	14.73	12.17	11.17	9.89	8.60	38.8
1984	129	22.28	24.1	15.53	14.69	12.13	11.13	9.86	8.57	39.4
1985	129	22.21	24.8	15.48	14.64	12.09	11.09	9.83	8.55	39.6
1986	127	21.87	23.6	15.25	14.42	11.90	10.92	9.68	8.42	38.7
1987	125	21.54	25.4	15.01	14.19	11.72	10.76	9.53	8.29	38.8
1988	123	21.20	26.5	14.78	13.97	11.54	10.59	9.38	8.16	38.7
1989	14	2.41	22.7	1.68	1.59	1.31	1.20	1.07	0.93	10.9
1990	10	1.68	24.8	1.17	1.11	0.91	0.84	0.74	0.65	10.6
1991	21	3.58	25.8	2.50	2.36	1.95	1.79	1.58	1.38	13.6
1992	15	2.57	23.1	1.79	1.70	1.40	1.29	1.14	0.99	11.3
1993	38	6.49	28.5	4.53	4.28	3.53	3.24	2.87	2.50	18.6
1994	40	6.94	28.9	4.84	4.57	3.78	3.47	3.07	2.67	19.4
1995	24	4.13	23.8	2.88	2.72	2.25	2.06	1.83	1.59	13.8
1996	25	4.25	12.0	2.97	2.80	2.31	2.12	1.88	1.64	10.0
1997	48	0.82	8.4	3.14	0.71	1.09	0.16	0.00	0.28	6.2
1998	27	6.88	11.2	3.67	2.99	3.16	2.83	1.93	1.58	12.4
1999	25	7.44	14.0	2.17	6.12	4.62	4.41	3.94	0.47	14.5
2000	23	6.55	13.8	5.95	4.60	2.92	3.52	3.87	6.11	13.1
2001	25	7.87	13.6	5.47	5.67	2.17	4.08	3.34	3.22	12.0
2002	25	6.73	13.4	3.72	5.22	0.96	3.17	2.94	2.96	12.7
2003	20	6.81	13.3	0.14	3.90	1.12	2.18	3.08	4.53	11.9
2004	14	5.87	13.8	2.77	3.89	1.26	1.96	2.55	1.01	11.2
2005	18	9.46	15.2	2.19	9.80	0.19	3.00	0.22	7.28	16.8
2006	25	6.53	11.0	0.10	7.87	4.93	2.31	4.09	3.78	11.7
2007	15	4.00	10.7	3.77	5.53	5.47	1.46	2.55	1.68	8.6
2008	10	3.67	10.6	0.93	3.32	5.30	0.97	1.69	6.79	9.6
2009	16	3.92	11.8	0.31	3.12	4.70	1.53	0.05	8.96	8.9
2010	12	2.88	6.5	0.09	1.80	3.94	1.34	1.70	1.42	6.7

[1] Others category includes 36 other taxa.

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

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Abstract

Estimates for the subsistence, artisanal, and large-scale commercial sectors of Niue's fishery were obtained for the time period of 1950-2010. Throughout this time period we found that subsistence catches, as well as the large-scale commercial catches, were underestimated in the data reported to the FAO. Our reconstruction of Niue's total marine fisheries catches for 1950-2010 equalled 24,158 t, which was 4.9 times the FAO total catches. This translates to 19,231 tonnes of unreported catches. Subsistence estimates were obtained using *per capita* consumption rates and commercial fisheries estimates were based on catch information from independent reports. The combination of environmental pressures such as severe cyclones and anthropogenic pressures such as fishing, threaten the sustainable use of resources from the marine environment. This report illustrates the importance of collecting catch time series data for sustainable management of Niue's marine fisheries resources.

Introduction

Niue is a single, uplifted atoll island which, in 1974, became a self-governing nation in free association with New Zealand (Quentin-Baxter 2008). Being in free association means that Niue has the power to make its own laws and enter into agreements with other nations as if it was an independent nation, and New Zealand cannot interfere without Niue's consent (Quentin-Baxter 2008). However, Niue still receives essential financial aid, when needed, from New Zealand, and Niueans retain their New Zealand citizenship (Quentin-Baxter 2008). The island is located at 19°S and 169°W, with a land area of 259 km^2 (Figure 1). It has an Exclusive Economic Zone (EEZ) of 316,629 km^2 (www.seaaroundus.org), which borders the waters of American Samoa, Tonga, and the Cook Islands, while international waters lie directly south. Niue is surrounded by a narrow, wave-cut, shelf platform covered in coral, which drops off quickly to extreme depths within 3-5 km of shore (Dalzell *et al.* 1993; Kronen *et al.* 2008). Coral cliffs surround the island, which rise between 20 and 30 m above sea level (Kronen *et al.* 2008). Niue only possesses one wharf, located at Alofi Bay (Alofi being the capital). The wharf is only partially sheltered and is vulnerable to sea conditions, which requires that fishing boats be lifted in and out of the water each day (Gillett 2011). Although government agencies realize that a lack of marine infrastructure has severely hindered Niue's fishing opportunities, there is hesitation to invest due to the frequency of severe weather patterns (Gillett 2011). Over the years, Niue has suffered extensive reef damage, particularly from Cyclone Ofa (February 1990) and Cyclone Heta (January 2004; Kronen *et al.* 2008). Niue's economy is heavily dependent on aid it receives from New Zealand. The majority of Niueans work in the public sector, with their wages also provided by New Zealand (Kronen *et al.* 2008). Although local agricultural crops have failed to produce any profitable export opportunities (Bertram and Watters 1984) they are successful enough for subsistence purposes. Taro, tapioca, yams, kumara, bananas, breadfruit, papaya, watermelon, and citrus fruits are sold at the market twice a week along with coconut crabs, seafood, and imported products (Tuara 2000).

Fishing in Niue has very traditional roots, which are still present today. Niueans continue to use the one- or three-person wooden dug-out canoes that their ancestors have perfected, although these are used less frequently (Powell 1968; Kronen *et al.* 2008). In the late 1970s and early 1980s, several government funded programs were implemented to help increase fishing effort and productivity in Niue. Nick Dryden from the New Zealand Ministry of Agriculture and Fisheries, as well as South Pacific Commission[2] (SPC) "Master Fishermen" Tevita Fusimalohi and Paul Mead made visits to Niue and worked with local fishers to teach them more effective

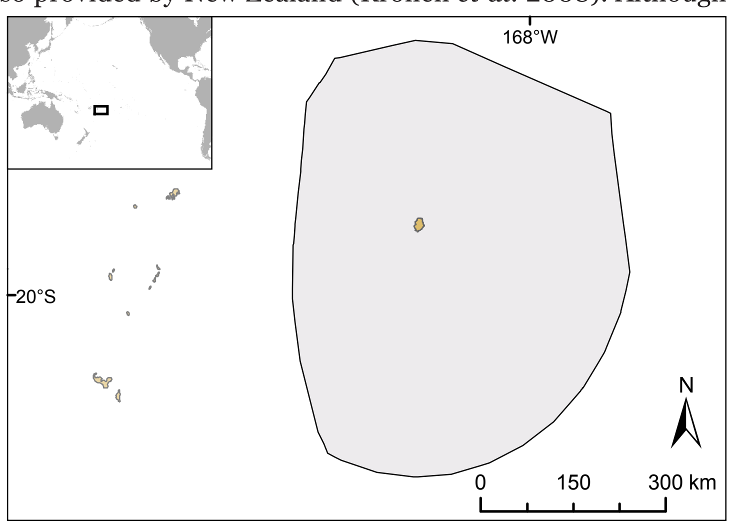

Figure 1. Map of Niue and its EEZ. Niue's closest neighbouring country, Tonga, which lies to the west of Niue, is also shown.

[1] Cite as: Zylich, K., Harper, S., Winkler, N., and Zeller, D. (2012) Reconstruction of marine figheries catches for Niue (1950-2010). pp. 77-86. *In*: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] Now the Secretariat of the Pacific Community.

fishing techniques (Crossland 1979; Mead 1980). In 1977, Nick Dryden brought with him new fishing gear as well as an 8.3 m diesel powered boat, *Nukulafalafa* (Crossland 1979). After surveying the area and finding that trolling was the most effective technique, he trained four local fishers in all aspects of trolling (including operation and maintenance of the vessel; Crossland 1979). In 1978, SPC "Master Fisherman", Tevita Fusimalohi of the SPC Deep Sea Fisheries Development Project (DSFDP) came to train the fishers in bottom fishing techniques as an alternative to trolling (Fusimalohi 1978; Crossland 1979). In 1979, SPC "Master Fisherman" Paul Mead took over operation of the DSFDP and continued working with the Niueans. Unfortunately, Niue was hit by a cyclone at the end of 1979 resulting in the loss of the boat and much of the fishing equipment (Mead 1980; Anon. 1981). However, fishing operations did resume in February 1980 with the arrival of an *alia* catamaran (Anon. 1981). In 1982, the SPC provided Niue with its first two fish aggregating devices (FADs; Farman and Dashwood 1989). That same year, "Master Fisherman" Paul Mead performed vertical longline trials in the vicinity of the FADs (Mead 1989). In the late 1980s, many organizations, including the United Nations Development Programme (UNDP), the Forum Fisheries Agency (FFA), and the U.S. Agency for International Development (USAID), provided the Niue fisheries sector with some support (Anon. 1990). This aid was used for improving infrastructure and obtaining equipment. Unfortunately, in January 2004, Niue was hit by Cyclone Heta, one of the most damaging cyclones to date. Although repaired, Niue's only wharf, as well as the infrastructure and machinery needed for fishing boats to access the water, remain vulnerable (Barnett and Ellemor 2007). The marine environment itself is vulnerable to the severe weather conditions it endures and proper analysis and management is needed to ensure the survival and sustainability of Niue's marine resources (Fisk 2007).

Currently, the FAO FishStatJ database, which provides time series data on marine fisheries landings from 1950 to present, is the only publicly available source of national fisheries catch data over time. FAO data are provided by its member countries. Therefore, the FAO relies on countries to report their figures accurately. The FAO data have been the basis of many influential global fisheries studies (i.e. Pauly *et al.* 1998) but they are known to be incomplete (Zeller *et al.* 2006; 2007).

The objective of this study is to provide a complete time series of estimated total marine fisheries catch of Niue from 1950-2010. Although there have been many studies which have estimated the impact of Niue's fisheries, there has been no comprehensive study showing catch trends over time.

Methods

Estimates of marine catches were made for three sectors: subsistence, artisanal, and large-scale commercial. The subsistence sector was estimated by combining available information on catches and human population data to estimate *per capita* consumption rates. For the artisanal and large-scale commercial sectors, several reports containing yearly catch data were used to make estimates. For the artisanal and subsistence sectors, interpolations between data anchor points were performed in order to obtain catch data for the entire study period of 1950-2010.

Large-scale commercial fisheries

Niue only recently developed a domestic, large-scale fishing operation. In 2005, Niue entered into a joint venture fishing agreement with a New Zealand company, Reef Group, to start a longline fishing sector in their EEZ (Tafatu 2006; Gillett 2011). Under this agreement, all fish caught in the Niue EEZ would be processed at the newly built fish processing facility, Niue Fish Processors Ltd. (Gillett 2011). Prior to 2005, there was no domestic large-scale commercial fishing in Niue's EEZ and therefore catches for this sector were set to zero from 1950-2004. Data from the FAO, Forum Fisheries Agency (FFA), and the Western and Central Pacific Fisheries Commission (WCPFC) all match in tonnage for the large-scale commercial species. FAO reported catches for albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*), skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), black marlin (*Makaira indica*), blue marlin (*Makaira mazara*), striped marlin (*Tetrapturus audax*), and swordfish (*Xiphias gladius*) are accepted as the reported data for the longline fishery with one exception. The FFA data reports small amounts of skipjack and yellowfin tuna as being caught by an "other gear type" in 2004-2006. The large-scale tuna fishery did not begin until 2005 and so these amounts are allocated as reported small-scale tuna catch. It was determined that a small amount of by-catch from wahoo (*Acanthocybium solandri*) and dolphinfish (*Coryphaena hippurus*) was missing from the data in some years. Tafatu (2006) gives a complete breakdown of the 2005 longline catch which includes tonnages for these two species. The ratio of the tonnages of wahoo and dolphinfish to the total reported longline catch was found for 2005 and then applied to 2006-2008 and 2010. For 2009, there was 6 t of reported "tuna-like fishes nei" and this was assigned proportionally to wahoo and dolphinfish. Although all reports provide consistent accounts of the tonnages caught by the longline fishery, Gillett (2009) notes that there may be some under-reporting occurring. Tafatu (2007) reported 320.3 tonnes of tuna and tuna-like fish caught in 2006 by the longline fleet in Niue's EEZ. However, Gillett (2009) points out that this was only the catch for six vessels, while Tafatu (2007) had stated that there were actually 12 vessels licensed to fish in Niue's EEZ. This led Gillett to double the figure resulting in an estimate of 640 t. Gillett (2009) backs up his assumption by stating that unpublished fishery export figures for 2007 equated to 602.2 t, and if local tuna consumption was added this would be close to 640 t. However, since we have estimated local consumption separately, we accept the export value of 600 t as the total catch (tuna plus by-catch) in the years 2006 and 2007. The FAO data for 2005 and 2008-2010 were accepted as correct. At the end of 2007, Niue Fish Processors Ltd. closed (Kronen *et al.* 2008), leaving Niue with fewer vessels fishing their waters in 2008 and resulting in decreased catches (Anon. 2010). This explains why catches drop down to 18.75 t in 2008. In 2009, Niue resumed its joint venture agreement causing catches to start rising again (Anon. 2010).

Large-scale tuna fishing operations can occur outside of a country's EEZ as tuna and other large pelagics are migratory species. The FFA data contained information on catches which could be utilized to determine how much of the catch is taken from inside the country's EEZ, in other countries' EEZs, and in the high seas. Therefore, these data were utilized directly to spatially allocate tonnages of tuna, and proportions were used to also allocate all of the associated by-catch species.

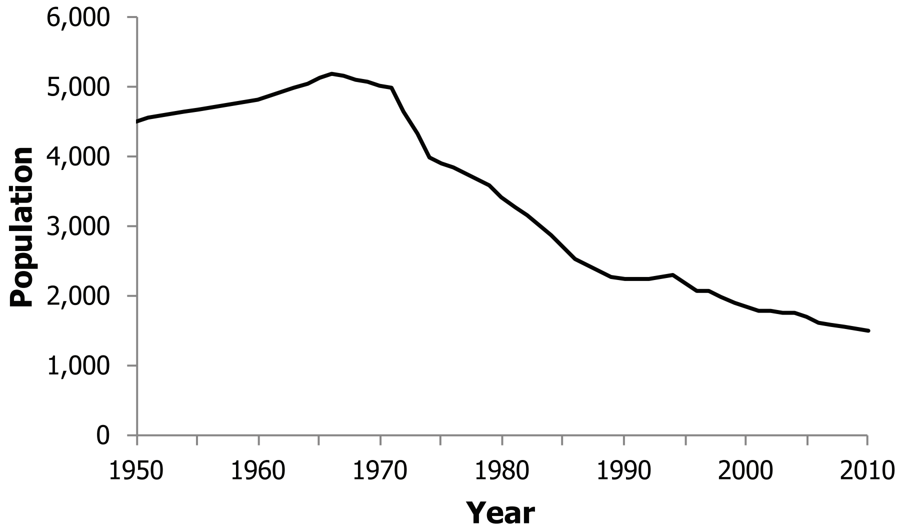

Figure 2. Estimated human population of Niue, 1950-2010.

Artisanal fisheries

Niue's artisanal sector is made up of 4-5 full-time and 2-3 part-time commercial fishers who sell their catch at the market (Dalzell *et al.* 1993). In the literature, this sector is referred to as either artisanal, small-scale commercial, or coastal commercial. Gillett (2009) estimated this sector at 10 tonnes per year and Dalzell (1993) also estimated 10-14 tonnes per year. To remain conservative, we accepted the estimate of 10 tonnes per year and assigned this as the artisanal catch starting in 1993 (as Dalzell was the first to report this estimate) and carried it forward until 2010. The earliest mention of the sale of fish in Niue is in a SPC report (Devambez 1962) and therefore we set artisanal catches at zero from 1950-1960. We then linearly interpolated from zero in 1960 to 10 tonnes in 1993.

Subsistence fisheries

Estimating subsistence catches required a complete time series of Niue human population data for 1950-2010. This was needed to convert *per capita* seafood consumption rates into an estimate of total demand, which was then used in calculating missing catch amounts. Population data for Niue were obtained from the Pacific Regional Information System (PRISM) website.[3] PRISM is a website produced by the Secretariat of the Pacific Community (SPC) to compile statistical data on all countries within the Pacific Community. Linear interpolations between known data points were employed to produce population data for the entire 1950-2010 time period (Figure 2).

Table 1. *Per capita* seafood consumption rates used to estimate total subsistence demand.

Years	Consumption rate (kg/person/year)	Source
1950	118.9	Gillett and Lightfoot (2001)[a]
1951-2006	-	Linear interpolation
2007	89.7	Gillett (2009)
2008-2010	89.7	Carried forward from 2007

[a] Gillett and Lightfoot's (2001) estimate of consumption was assumed to be representative for 1950.

Gillett (2009) estimated the total subsistence catch in 2007 to be 140 tonnes. This estimate was based on the compilation of several different sources, containing both consumption and catch data (Gillett 2009). Using this figure and the 2007 population estimate, a catch-derived subsistence consumption rate of 87.9 kg·person^{-1}·year^{-1} was obtained. This was used as the 2007 anchor point and was carried forward, unaltered, to 2010 (Table 1).

For the early time period, it was assumed that Niue was receiving less imported canned meats and fish than it is today. With fewer canned alternatives available, it was assumed that more fresh seafood was eaten. This trend can be observed by direct comparison of villages on the island in current times. Kronen *et al.* (2008) found that the amount of canned fish consumed is inversely related to the amount of fresh fish consumed. Therefore, in order to account for this increased consumption, Gillett and Lightfoot's (2001) estimate of 118.9 kg·person^{-1}·year^{-1} was used as an approximation for the consumption rate in 1950 (Table 1). We then linearly interpolated between the 1950 and 2007 consumption rates. These consumption rates, in combination with the population data gave a total subsistence demand for the 1950-2010 time period.

In Niue, subsistence fishing also consists of collecting fish to take overseas to friends and relatives living in New Zealand (Dalzell *et al.* 1993). These informal exports, estimated by Dalzell *et al.* (1993), depend on frequent and direct air service. There was direct air service between Auckland and Niue between 1982 and 1988, limited service for 1989 and 1990 (Dalzell *et al.* 1993), and an increase again in 1992 (Eur. 2002). Therefore, informal exports were set to zero from 1950 to 1981. We then linearly interpolated from zero in 1981 to 4.9 tonnes (Dalzell *et al.* 1993) in 1987 and carried this amount forward to 1988. In 1989 and 1990, exports decreased to 95 kg·year^{-1} (Dalzell *et al.* 1993). With air service increasing again in 1992, we assumed that exports reached their previous height by 1995 and thus set informal exports to 4.9 t·year^{-1} from 1995 onwards. A linear interpolation was performed between the

[3] http://www.spc.int/prism/country/nu/stats/Social/Population/Popstats.htm

anchor points of 95 kg in 1990 and 4.9 tonnes in 1995. Adding the informal exports to the calculated subsistence demand gave the total subsistence catch.

For the years 1999 to 2004, our estimated total reconstructed catch was slightly lower than the FAO data. It was therefore assumed that the FAO had additional information and we accepted their reported total catch for those years. In order to account for this discrepancy, we increased our estimated subsistence catch for those years, thus resulting in our total catch being equal to that of the FAO.

Table 2. Estimated catch composition for the large-scale commercial fisheries of Niue.

Species	Catch (%)					
	2005	2006	2007	2008	2009	2010
Acanthocybium solandri	3.13	3.13	3.13	3.13	2.23	3.13
Coryphaena hippurus	1.30	1.30	1.30	1.30	0.93	1.30
Katsuwonus pelamis	1.74	1.28	1.35	5.10	0.13	0.21
Makaira indica	2.61	0.96	2.70	1.27	0.13	0.21
Makaira mazara	3.48	2.56	3.16	5.10	3.16	0.85
Tetrapturus audax	0.87	1.60	4.06	1.27	0.13	0.85
Thunnus alalunga	47.78	68.08	61.76	35.68	77.37	82.40
Thunnus albacares	29.54	13.42	13.52	40.78	10.53	6.80
Thunnus obesus	8.69	7.03	8.11	5.10	5.26	3.40
Xiphias gladius	0.87	0.64	0.90	1.27	0.13	0.85

Source: FAO FishStatJ [accessed November 1, 2012] and Tafatu (2006).

Foreign vessels

Due to the development of the local joint venture fleet, no foreign vessels (with one exception) had authorized access to Niue's EEZ after 2002 (Tafatu 2006). US purse seiners have access under a multilateral treaty, however they have not fished Niue's EEZ for years (Gillett 2009). Japanese and Taiwanese longliners operated in Niue waters in the 1960s and 1970s (Dalzell *et al.* 1993). Dalzell (1993) and Klawe (1978) provide some limited data for these years. There are several reports (e.g. Pasisi 2003; Kronen *et al.* 2008) indicating that from about the mid-1990s to the early 2000s, there were Taiwanese and American Samoan vessels fishing in the Niue EEZ, operating under access agreements. However, these reports do not have enough information to determine the exact dates of these agreements or how much fish was caught.

Catch composition

The joint venture commercial longline fishery occurs offshore and targets large pelagic fish (i.e. tunas and tuna-like fish). The FAO data present landings for the four main species of tuna (albacore, bigeye, skipjack, and yellowfin tuna) and associated by-catch (black marlin, blue marlin, striped marlin, and swordfish). These reported values are accepted for 2005 and 2008-2010 with the aforementioned exemption of small amounts of skipjack and yellowfin tuna in 2005. An unreported component of wahoo amounting to 3.3% of the total reported large-scale catch and 1.4% of the catch for unreported dolphinfish were also added on in 2005-2008 and 2010. In 2009, the 6 t of reported "tuna-like fishes nei" was broken down into wahoo (71%) and dolphinfish (29%; Tafatu 2006). In 2006 and 2007, the proportions of the reported catches plus the unreported wahoo and dolphinfish, were used to determine the composition of the 600 t of longline catch. The complete percentage breakdown for the longline fishery is shown in Table 2.

The species compositions for both the subsistence and artisanal sectors were assumed to be the same. Kronen *et al.* (2008) assessed the status of Niue's fisheries using several different methods, which included a household survey (to gather information about seafood consumption), as well as a survey of fishers to collect data concerning the actual catch. At the broader level, these data provided total annual estimates by weight of catches from trolling and mid-water fishing (tuna and tuna-like species), reef and canoe fishery (reef finfish), and the invertebrate fishery. These data were

Table 3. Estimated species composition of both the subsistence and artisanal sector in Niue.

Taxa	Catch (%)	Taxa	Catch (%)
Acanthocybium solandri	27.90	*Parupeneus multifasciatus*	0.39
Turbo setosus	13.93	*Priacanthus hamrur*	0.31
Thunnus albacares	7.77	Bivalvia	0.28
Decapterus macarellus	4.49	*Chlorurus microrhinos*	0.28
Katsuwonus pelamis	3.75	*Octopus* spp.	0.26
Myripristis berndti	3.45	*Acanthurus guttatus*	0.25
Myripristis violacea	3.45	*Aphareus rutilans*	0.24
Other large pelagics	3.29	*Lutjanus bohar*	0.24
Kyphosus bigibbus	2.72	*Sargocentron cornutum*	0.23
Kyphosus cinerascens	2.72	*Epinephelus fasciatus*	0.23
Kyphosus vaigiensis	2.72	*Parribacus caledonicus*	0.19
Gastropoda	1.98	*Polymixia japonica*	0.18
Panulirus spp.	1.63	*Xiphias gladius*	0.14
Paracirrhites hemistictus	1.50	*Holothuria atra*	0.13
Cirrhitus pinnulatus	1.41	*Acanthurus achilles*	0.13
Istiophoridae	1.22	*Monotaxis grandoculis*	0.10
Thalassoma quinquevittatum	1.20	Misc. marine fishes	0.09
Seriola rivoliana	1.11	*Cephalopholis urodeta*	0.09
Caranx melampygus	1.10	*Variola louti*	0.07
Coryphaena hippurus	1.00	*Scomberoides lysan*	0.05
Epinephelus merra	0.95	*Cephalopholis aurantia*	0.05
Cephalopholis miniata	0.87	*Cephalopholis sonnerati*	0.05
Caranx lugubris	0.80	*Sphyraena barracuda*	0.04
Scylla serrata	0.76	Echinoidea	0.04
Crenimugil crenilabis	0.66	*Mulloidichthys flavolineatus*	0.03
Tridacna maxima	0.56	Misc. aquatic invertebrates	0.03
Tridacna squamosa	0.56	Belonidae	0.02
Decapoda	0.51	*Acanthurus triostegus*	0.02
Scarus spp.	0.51	*Sargocentron spiniferum*	0.01
Acanthurus xanthopterus	0.45	*Sphyraena forsteri*	0.01
Rhinecanthus rectangulus	0.43	*Sphyraena qenie*	0.01
Thalassoma purpureum	0.40	Exocoetidae	0.01

Source: Kronen *et al.* (2008).

used to calculate the proportions of the different sectors within the small-scale fishery. Each sector could then be broken down to individual species. Kronen *et al.* (2008) used the catch data to provide a complete species breakdown of reef finfish and invertebrates caught annually by weight. This was used as the basis for the reef fish and invertebrate species catch composition. As the survey did not include species information on the large pelagic fish caught by trolling and mid-water fishing, Dalzell's (1993) estimates were used for that sector. Dalzell (1993) provides catch data by weight for vessels targeting tuna and tuna-like species. The complete species breakdown for both the subsistence and artisanal sectors is provided in Table 3.

Women in fisheries

Fishing participation in Niue appears to be almost evenly split between men and women. According to the survey by Kronen *et al.* (2008), almost even numbers of males and females participate in both finfish and invertebrate fishing. In terms of fishers who only fish in one sector, there are more males who exclusively fish for finfish, and more females who are exclusive to invertebrate fishing (Kronen *et al.* 2008). Kronen *et al.* (2008) found that female fishers were responsible for 53% of the annual invertebrate catch. On average, per person, female fishers catch 75 kg·person^{-1}·year^{-1}, compared to the 133 kg·person^{-1}·year^{-1} that men catch on average (Kronen *et al.* 2008). Using the number of male and female fishers quoted by Kronen *et al.* (2008) who fish for finfish (either exclusive or in addition to invertebrates) and the annual catch rates, it can be estimated that female fishers are responsible for 24% of the finfish catch. This difference in contribution can be attributed to the types of fishing women generally participate in. One of the main fishing activities which women participate in is reef gleaning. They harvest invertebrates, using their hands and small tools, from the reef flat when the tide is low and collect octopus, sea urchins, sea cucumbers, shellfish, tube worms, snails, and clams (Tuara 2000). This is done during the day, and at night they go out with knives or long spears and hunt crabs, lobsters, and reef fish. They also use a simple wooden or bamboo rod and line with a small piece of bait to catch reef fish from rock pools and over cliff edges in both the day and night (Tuara 2000). While fishing out on a boat is no longer exclusive to men, there are still not many women found fishing on boats (Tuara 2000; Lambeth *et al.* 2002). Post-harvest duties of fish processing are completed by both men and women (Tuara 2000).

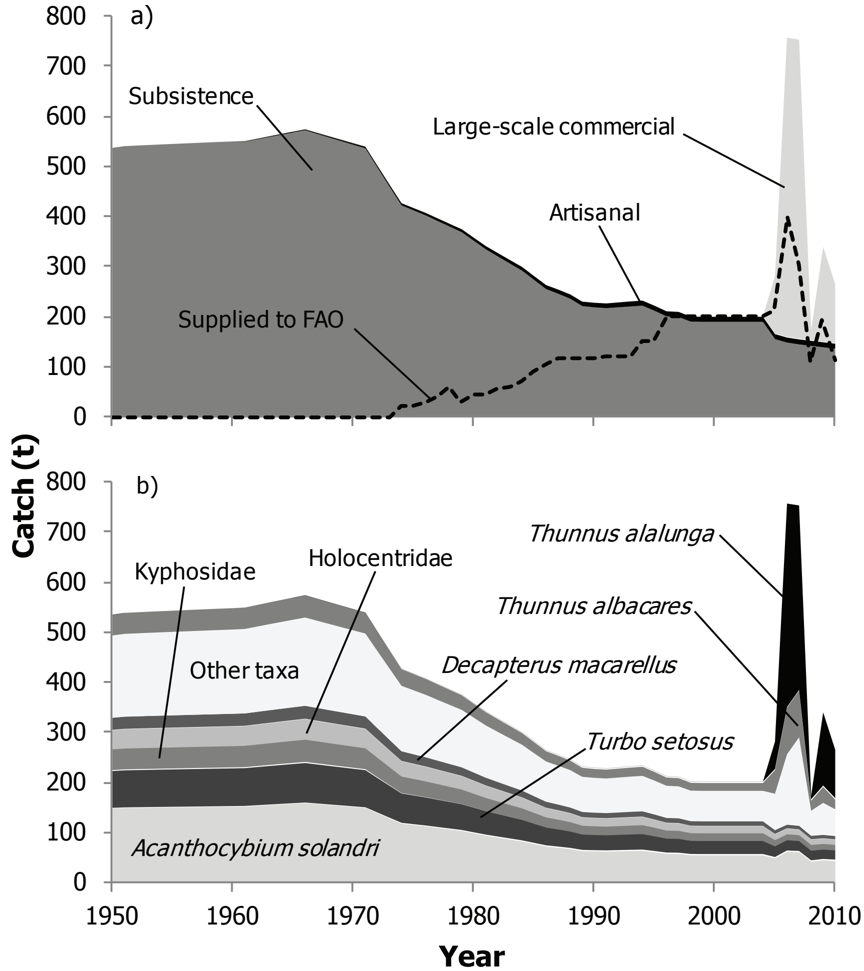

Figure 3. a) Total reconstructed fisheries catches for Niue, by sector, compared to the total catch data supplied to the FAO, 1950-2010; b) total reconstructed catch for Niue by major taxa. The grouping "other taxa" represents 52 taxa (as listed in Appendix Table A2). The families Kyphosidae and Holocentridae represent 3 and 4 species, respectively.

Results

For the period 1950-2010, the reconstructed total catch for Niue was estimated to be 24,158 t. This estimate is 4.9 times the total catch reported by the FAO on behalf of Niue over the same time period (Figure 3a). Overall, large-scale commercial catches represented 6.8% of the total catch, artisanal catches represented 1.4%, and subsistence catches made up the largest portion with 91.8% of the total catch (Figure 3a). Informal exports (which are included in the subsistence catch) are estimated at a total of 111 t, representing only 0.46% of the total catch but are unaccounted for in both the official catch and trade data. Annual catches have peaked in the last five years due to the joint venture agreement that Niue signed with Reef Group. The average annual catch for the recent time period (2005-2010) is estimated at 628 t·year^{-1}. However, there was an earlier peak in catch totals in the 1960s with average annual catches of 560 t·year^{-1}, which only consisted of small-scale catches. Small-scale catches then proceeded to decreased to a low of 175 t·year^{-1} in the 2000s.

The total reconstructed catch was dominated by wahoo (*Acanthocybium solandri*) with 6,329 t caught from 1950-2010. Other species representing large portions of the catch include *Turbo setosus*, *Thunnus albacares*, *T. alalunga*, and *Decapterus macarellus* with 3,436 t, 1,982 t, 1,085 t, and 1,011 t, respectively (Figure 3b). Two families also worth mentioning (which are not already represented) are Kyphosidae (three species) and Holocentridae (four species), with catches of 1,837 t and 1,609 t, respectively, over the 1950-2010 time period (Figure 3b). The remaining 52 taxa, which individually represent minor portions of the total catch, were grouped for presentation into the category "other taxa" (Figure 3b).

The large-scale commercial longline catch was dominated by albacore tuna (*Thunnus alalunga*) with an average of 180 t·year^{-1} caught from 2005-2010. The other species caught by the longliners were *Thunnus albacares*, *T. obesus*, *Acanthocybium solandri, Katsuwonus pelamis, Makaira mazara*, *Tetrapturus audax*, *Coryphaena hippurus, M. indica*, and *Xiphias gladius* with approximately 38.6 t·year^{-1}, 19.3 t·year^{-1}, 8.3 t·year^{-1}, 7.7 t·year^{-1}, 6.1 t·year^{-1}, 4.3 t·year^{-1}, 3.4 t·year^{-1}, 3.2 t·year^{-1}, and 2.0 t·year^{-1}, respectively, in the 2005-2010 time period.

The subsistence and artisanal sectors are dominated by almost the same species and families as the total catch with the exception of albacore tuna (*Thunnus alalunga*), not present in the small-scale sector catches. In the subsistence sector, *Acanthocybium solandri*, *Turbo setosus*, Kyphosidae, *Thunnus albacares*, Holocentridae, and *Decapterus macarellus* have average annual catches of approximately 101 t·year^{-1}, 51 t·year^{-1}, 30 t·year^{-1}, 28 t·year^{-1}, 26 t·year^{-1}, and 16 t·year^{-1}, respectively. Since the assumed start of the artisanal sector in 1961, the average annual catches for *A. solandri*, *T. setosus*, Kyphosidae, *T. albacares*, Holocentridae, and *D. macarellus* have been approximately 1.90 t·year^{-1}, 0.95 t·year^{-1}, 0.55 t·year^{-1}, 0.53 t·year^{-1}, 0.49 t·year^{-1}, and 0.31 t·year^{-1}, respectively.

As part of the allocation process, it was estimated that approximately 14% of the large-scale catches were taken from outside of the EEZ. These catches represent only 0.9% of the total reconstructed catch.

Discussion

The reconstructed total catch for Niue for 1950-2010 was estimated to be approximately five times the landings presented by the FAO on behalf of Niue. This discrepancy is the result of two main issues: a lack of documentation of subsistence catches and an underestimation of the longline catches of Niue's recent commercial joint venture operation. The subsistence sector was estimated to be over 90% of the entire reconstructed catch. Not only was there poor subsistence reporting in the early part of the time period, but it continues to be neglected in the recent period. Since 2005, the data reported to FAO have a greater species disaggregation. However, this disaggregation is a product of the start of the joint venture operation and the species only correspond to those caught by the industrial sector. Prior to 2005, only broad categories of "marine fishes not elsewhere included (nei)" and "tuna-like fishes nei" were used. Once the large-scale commercial longline tuna species began to be reported all other categories declined rapidly in amount, suggesting that large-scale commercial catches are the only catches being recorded. Although it is apparent that there has been an effort to report large-scale commercial catches, they are largely underestimated in some years (Gillett 2009). The total reconstructed large-scale commercial catch is almost 75% larger than the total industrial landings reported from 2005-2010.

From 1950-2004, the reconstructed catch is almost entirely dependent on the population size since the subsistence portion greatly overwhelms the very small artisanal and informal export portions. Therefore, the peak in this section of the timeline corresponds to the peak population in the 1960s (average population of 5,034). The Niuean population then decreases rapidly, with a large number of people migrating to New Zealand. Total fisheries catches decreased as demand declined. This is followed by a dramatic spike in 2006, which corresponds to the rapid increase in catch of the joint venture longline operation. There is another drop in 2008 which corresponds to the closure of the fish processing plant (Kronen *et al.* 2008). Catches begin to increase again in 2009 as Niue negotiated alternative arrangements for their joint venture agreement (Anon. 2010).

Overharvesting is a concern on the island of Niue. Invertebrates are particularly at risk, including lobsters, giant clams, turban shell molluscs, urchins, sea cucumbers, octopus, and some crabs (Tuara 2000). The stocks of giant clams have been decimated and Kronen *et al.* (2008) recommend a total ban. There has been some recognition of this decline by the Niueans. Nets were widely used in the past but are (for the most part) no longer used due to their effectiveness, and the subsequent depletion of associated resources (Tuara 2000). Past areas of concern include use of poisons and use of spear guns with the aid of scuba. In 1965, regulations were put in place to ban the use of poisons or stupefying agents (Wilson 1967). Unfortunately, due to the rugged topography of the coastline it is difficult to police the area (Wilson 1967). Poisons of known use have been the root of a New Guinea creeper *(Derris elliptica)*, the seeds of *kieto (Diospyrus samoenis)*, and the root of *Tephrosia purpurea*, locally known as *kohuhu* (Wilson 1967). Information was not available on whether the use of poisons has ceased or is at least less common. It is clear though, that there have been detrimental effects on the marine environment from the use of these poisons (Fisk 2007).

Niue's exposed coastline has been repeatedly damaged by cyclones, which have negatively affected the marine life. The added effects of a large subsistence sector, continued use of FADs, and increasing large-scale commercial longline effort, further threaten an already vulnerable resource. In an attempt to mitigate these pressures, the Government of Niue, in 1998, created the Namoui Fisheries Reserve (Labrosse *et al.* 1999). However, stronger measures are needed to manage the increasing strain of the more recently established large-scale commercial venture to ensure the sustainability of this fishery. This study highlights the need for and importance of comprehensive fisheries catch records, to monitor changes in fisheries resources caused by natural and anthropogenic stresses.

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

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal	Large-scale commercial
1950	0.25	535	535	-	-
1951	0.25	539	539	-	-
1952	0.25	540	540	-	-
1953	0.25	541	541	-	-
1954	0.25	542	542	-	-
1955	0.25	543	543	-	-
1956	0.25	544	544	-	-
1957	0.25	545	545	-	-
1958	0.25	546	546	-	-
1959	0.25	547	547	-	-
1960	0.25	548	548	-	-
1961	0.25	550	549	0.30	-
1962	0.25	555	554	0.61	-
1963	0.25	560	559	0.91	-
1964	0.25	565	563	1.21	-
1965	0.25	569	568	1.52	-
1966	0.25	574	572	1.82	-
1967	0.25	567	565	2.12	-
1968	0.25	560	558	2.42	-
1969	0.25	553	551	2.73	-
1970	0.25	546	543	3.03	-
1971	0.25	540	536	3.33	-
1972	0.25	502	498	3.64	-
1973	0.25	464	460	3.94	-
1974	20.00	427	423	4.24	-
1975	20.00	417	413	4.55	-
1976	30.00	407	403	4.85	-
1977	40.00	396	391	5.15	-
1978	60.00	386	380	5.45	-
1979	30.00	375	369	5.76	-
1980	45.00	358	352	6.06	-
1981	45.00	341	335	6.36	-
1982	54.00	327	320	6.67	-
1983	60.00	313	306	6.97	-
1984	72.00	300	292	7.27	-
1985	90.00	281	274	7.58	-
1986	105.00	263	255	7.88	-
1987	115.00	254	246	8.18	-
1988	115.00	245	236	8.48	-
1989	115.00	230	222	8.79	-
1990	115.00	228	219	9.09	-
1991	120.00	227	217	9.39	-
1992	120.00	229	219	9.70	-
1993	120.00	231	221	10.00	-
1994	150.00	232	222	10.00	-
1995	150.00	222	212	10.00	-
1996	200.00	211	201	10.00	-
1997	200.00	210	200	10.00	-
1998	200.00	201	191	10.00	-
1999	200.00	200	190	10.00	-
2000	200.00	200	190	10.00	-
2001	200.00	200	190	10.00	-
2002	200.00	200	190	10.00	-
2003	200.00	200	190	10.00	-
2004	200.00	200	190	10.00	-
2005	212.00	281	156	10.00	115
2006	400.00	759	149	10.00	600
2007	302.00	755	145	10.00	600
2008	108.75	172	142	10.00	20
2009	193.00	339	139	10.00	190
2010	113.50	264	136	10.00	118

Appendix Table A2. Total reconstructed catch (in tonnes) for Niue by major taxa, 1950-2010.

Year	*Acanthocybium solandri*	*Turbo setosus*	*Thunnus albacares*	Kyphosidae	Holocentridae	*Thunnus alalunga*	*Decapterus macarellus*	Others[1]
1950	149	75	42	44	38	0	24.0	164
1951	150	75	42	44	39	0	24.2	165
1952	151	75	42	44	39	0	24.2	165
1953	151	75	42	44	39	0	24.3	166
1954	151	76	42	44	39	0	24.3	166
1955	152	76	42	44	39	0	24.4	166
1956	152	76	42	44	39	0	24.4	167
1957	152	76	42	44	39	0	24.5	167
1958	152	76	42	45	39	0	24.5	167
1959	153	76	43	45	39	0	24.6	168
1960	153	76	43	45	39	0	24.6	168
1961	153	77	43	45	39	0	24.7	168
1962	155	77	43	45	40	0	24.9	170
1963	156	78	43	46	40	0	25.1	171
1964	157	79	44	46	40	0	25.3	173
1965	159	79	44	46	41	0	25.6	174
1966	160	80	45	47	41	0	25.8	176
1967	158	79	44	46	41	0	25.5	174
1968	156	78	44	46	40	0	25.2	172
1969	154	77	43	45	40	0	24.8	169
1970	152	76	42	45	39	0	24.5	167
1971	151	75	42	44	39	0	24.2	165
1972	140	70	39	41	36	0	22.5	154
1973	129	65	36	38	33	0	20.8	142
1974	119	59	33	35	31	0	19.2	131
1975	116	58	32	34	30	0	18.7	128
1976	114	57	32	33	29	0	18.3	125
1977	111	55	31	32	28	0	17.8	121
1978	108	54	30	31	28	0	17.3	118
1979	105	52	29	31	27	0	16.8	115
1980	100	50	28	29	26	0	16.1	110
1981	95	48	27	28	24	0	15.3	104
1982	91	46	25	27	23	0	14.7	100
1983	87	44	24	26	22	0	14.1	96
1984	84	42	23	24	21	0	13.5	92
1985	78	39	22	23	20	0	12.6	86
1986	73	37	20	21	19	0	11.8	81
1987	71	35	20	21	18	0	11.4	78
1988	68	34	19	20	17	0	11.0	75
1989	64	32	18	19	16	0	10.3	71
1990	64	32	18	19	16	0	10.2	70
1991	63	32	18	18	16	0	10.2	69
1992	64	32	18	19	16	0	10.3	70
1993	64	32	18	19	16	0	10.4	71
1994	65	32	18	19	17	0	10.4	71
1995	62	31	17	18	16	0	10.0	68
1996	59	29	16	17	15	0	9.5	65
1997	59	29	16	17	15	0	9.4	64
1998	56	28	16	16	14	0	9.0	61
1999	56	28	16	16	14	0	9.0	61
2000	56	28	16	16	14	0	9.0	61
2001	56	28	16	16	14	0	9.0	61
2002	56	28	16	16	14	0	9.0	61
2003	56	28	16	16	14	0	9.0	61
2004	56	28	16	16	14	0	9.0	61
2005	50	23	47	14	12	55	7.4	73
2006	63	22	93	13	11	408	7.1	141
2007	62	22	93	13	11	371	7.0	177
2008	43	21	20	12	11	7	6.8	51
2009	46	21	32	12	11	147	6.7	64
2010	45	20	19	12	10	97	6.6	54

[1] Others category includes 52 additional taxonomic groups.

Reconstruction of total marine fisheries catches for the Pitcairn Islands (1950–2009)[1]

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Abstract

Total marine catches were estimated for the Pitcairn Islands for 1950-2009. A catch reconstruction method was used to estimate both subsistence (non-commercial) and artisanal (commercial) catches. Our reconstruction indicates that from 1950-2009,[2] Pitcairn Islands' marine catches were more than six times greater than the data reported by the FAO on behalf of the Pitcairn Islands would suggest. This is likely due to artisanal catches and changes in human population levels that were not accounted for by the data provided to the FAO. Overall, our results determined that the reconstructed catches for the Pitcairn Islands, which include subsistence and artisanal sector catches, totalled 1,016 tonnes for the period 1950-2009, with 28 t·year^{-1} in 1950, declining to 13 t·year^{-1} by 2009.

Introduction

Pitcairn, Henderson, Ducie and Oeno are the four small islands which comprise the Pitcairn Island group (Figure 1). The islands are located in the central South Pacific roughly 5,300 km from New Zealand and 6,400 km from Chile (Steinberg and McDowell 2003). The closest country to the Pitcairn Island group is French Polynesia, which is approximately 2,000 km to the north-west (Adams and Langley 2005). Due to remoteness and erratic weather conditions, the most accessible route to the Pitcairn's is from the nearest inhabited island of Mangareva (over 483 km away) in French Polynesia. Pitcairn Island is only accessible by boat though there is no good harbor or beach, and steep cliffs and tumultuous waters make landings difficult (Johnson 2007). There is no air strip on the island and air transportation is not possible due to the island's position at the intersection of two major wind fronts (Steinberg and McDowell 2003). The Pitcairn Island group is the last remaining British Overseas Territory in the Pacific. Pitcairn Island became a British dependency on November 29, 1838 (Nicolson 1965). Henderson Island, Oeno Atoll, and Ducie Atoll were included in the dependency in 1938 (Chapman 2004) but are uninhabited. Presently, the Pitcairn Island group is administered by the British High Commissioner to New Zealand with the assistance of an Island Council which is locally elected on Pitcairn Island (Steinberg and McDowell 2003).

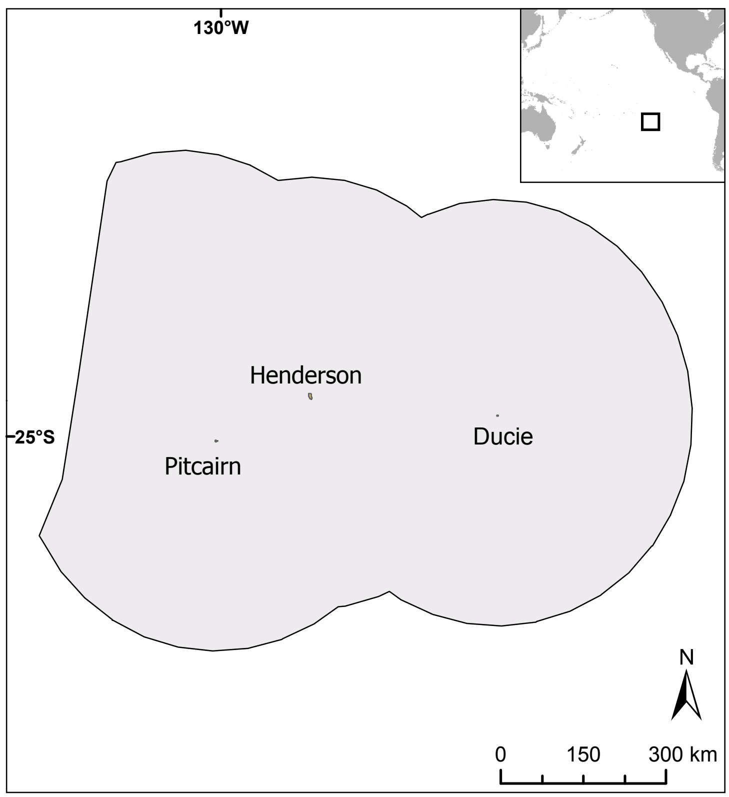

Figure 1. Location of Pitcairn Islands. The solid line represents the EEZ.

The Pitcairn Islands are located between 23° and 26° S and 124° and 131° W. The four islands combined have a total land area of about 47 km^2 and a total EEZ area of approximately 836,000 km^2 of subtropical ocean.[3,4] International waters encircle most of the Pitcairn Islands EEZ with the exception of a shared western EEZ border with French Polynesia (Adams and Langley 2005).

Topographically, Pitcairn is the only volcanic island of the island group, rising approximately 300 m above sea level (Sharples 1994). The island experiences a subtropical climate with mean monthly temperatures ranging from 24°C in January

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[2] See addendum for updating dataset to 2010.

[3] https://www.cia.gov/library/publications/the-world-factbook/geos/pc.html; accessed August, 2011

[4] http://www.seaaroundus.org/eez/612.aspx; accessed August, 2011

to 19°C in July, and an average annual rainfall of about 2,000 mm (Sharples 1994). Natural hazards such as cyclones generally occur between November and March.[3]

Henderson is a raised coralline limestone atoll situated approximately 169 km from Pitcairn (Sharples 1994). In 1989, Henderson Island was declared a UNESCO World Heritage Site as a bird sanctuary. Four species of birds are unique to the Island, namely, the Henderson fruit dove (*Ptilinopus insularis*), Henderson rail (*Porzana atra*), Henderson warbler (*Acrocephalus taiti*), and Henderson lorikeet (*Vini stepheni*).[5] Henderson Island is uninhabited, arid, only has one known freshwater source and is considered the only pristine, forested atoll in the world. Brooke *et al.* (2004) note that the island has been estimated to have existed for about 380,000 years and it is presumed that the caves on the island were occupied by ancient Polynesian inhabitants of Henderson. Presently, Henderson serves the people of Pitcairn as an economic resource supply centre for the harvesting of *miro* and *tou* trees. These *miro* and *tou* trees are mainly used for the carving of curios, which are eventually sold to visitors and cruise ship passengers. The curios are considered essential to the economic well-being of the islanders (Brooke *et al.* 2004). Oeno and Ducie are the other two uninhabited atolls that are seldom visited and they generally remain undisturbed.

Of the four islands, only Pitcairn is presently inhabited. Historically, archaeological evidence indicates the occupation of the island by Polynesian people from about 1000–1300 A.D. (Johnson 2007). Currently, the island is inhabited by mostly seventh generation descendants of Fletcher Christian, eight other *HMS Bounty* mutineers, twelve Tahitian women and six Tahitian men.[6] The population of Pitcairn is almost entirely concentrated in the capital of Adamstown, named after the iconic leader John Adams, the sole male survivor of the original 1790 settlement. The Island itself is named after Major Pitcairn of the British Marines.[6]

Historically, Pitcairn's economy was based on subsistence agriculture (including crops such as coffee, bananas, sweet potatoes, taro, oranges and sugar cane), philately, and sale of handicrafts and fish.[5] Most products were sold to passing ships traveling between New Zealand and Panama (Adams and Langley 2005). For decades, Pitcairn's economic strategy has emphasized the marketable image of Pitcairn being a "postage stamp republic", or a market for stamp collectors (Steinberg and McDowell 2003). The sale of stamps has been and still is a major source of the country's revenue. However, with the advent of the digital revolution and the development of internet and email, the Pitcairn philately based economy has proven to be no longer sufficient to sustain the economic independence of the tiny island of forty-eight people.[5] The use of postage stamps has died out mainly due to email services (Pitcairn Miscellany, 2006). Leslie Jaques, the former New Zealand based Commissioner of Pitcairn Island has reported that the financial situation on Pitcairn Island is severe. He states that, "Pitcairn is now officially under Budgetary Aid to maintain the island [which has] lost approximately NZ$1.6 million over the last four years" (Maple 2004). With an annual budget of approximately NZ$1 million, Pitcairn continues to generate revenue from the sale of postage stamps and a recent phenomenon has been the sale of internet domain addresses particularly the issuing of its ccTLD (country code Top Level Domain) .PN. However, lack of easy accessibility, entrepreneurship, infrastructure, distance from foreign markets, small domestic market, and inadequate policies towards business make Pitcairn's economic outlook less encouraging (Hannesson 2008). Moreover, a perceived lack of facilities, activities and attractions on the island, in addition to tumultuous waters and unpredictable weather stigmatize and hinder Pitcairn's tourism image (Amoamo 2011). Therefore, the island council has taken action and initiated Keynesian economic projects on the island, which address infrastructure issues for the purposes of stimulating the tourism sector. Upgrades of Bounty Bay (the only landing site for visitors), reconstruction of the Hill of Difficulty, the jetty and the slipway are examples of such projects (Maple 2004). Moreover, recent free trade and tourism agreements between Pitcairn and French Polynesia are expected to stimulate the economy (Maple 2004). In addition, news of a Japanese company interested in purchasing an order of 1,000 units of Pitcairn Island honey as well as other Pitcairn produce may encourage the agricultural sector to consider increasing commercial production for purposes of increasing revenue (Maple 2004). Overall, Pitcairners are expecting that future projects including fishing, honey production and eco-tourism will improve the island's current fiscal condition to a state of "self-sufficiency" (Maple 2004).

Pitcairn's economic potential is great. For example, minerals including manganese, iron, copper, gold, silver and zinc, have been discovered within the exclusive economic zone. However, the labor force to exploit this ocean region is insufficient and the monetary resources required to produce a domestic mining industry are far greater than the Pitcairn budget. Contracting foreign companies and charging access fees may be a possible avenue for revenue generation and industrial development of ocean resources.

In this paper, we focus on Pitcairn's fisheries sector. Pitcairn, like many of the other Pacific Island countries, has a tradition of eating fish. As a result of remoteness and limited opportunities for earning income this has led to almost all fishing to be subsistence fishing (Gillett 2009). More importantly, Pitcairn still depends on fresh fish to provide the majority of the animal protein required for good nutrition (Bell *et al.* 2009). The expansion of Pitcairn's fisheries sector for economic development is a topic of great interest, especially since future forecasts do not expect food security issues for the island (Gillett 2009).

In a region defined by an abundance of tuna, a pelagic fishery would seem to be the most applicable industry for economic stimulation. However, Adams and Langley (2005) argue that tuna fisheries or coastal fisheries in general will not be sufficient for Pitcairn Island to sustain economic independence. Moreover, it is not a sustainable approach to economic independence (Adams and Langley 2005). Due to subtropical waters, weather, and ocean hydrology, pelagic fish catches are not common, specifically because of markets being difficult to access, and the fact that Pitcairn "has a small area of fishable shelf" (Adams and Langley 2005). Moreover, the likelihood of a substantial

[5] http://www.thecommonwealth.org/YearbookInternal/140416/140428/pitcairn_islands__pitcairn__henderson__ducie_and_o/; accessed August, 2011

[6] http://library.puc.edu/pitcairn/pitcairn/index.shtml; accessed August, 2011

catch of skipjack and yellowfin is low (Adams and Langley 2005). Therefore, Adams and Langley (2005) conclude that the Pitcairn zone cannot support any significant pole-and-line or purse-seine fisheries. In addition, they state that it will not be profitable for the Pitcairn government to invest in commercial fisheries since it entails large investment and maintenance costs that will more likely harm than stimulate the economy. Moreover, Hannesson (2008) argues that fishing is only a part of a fishery's processes. The other major part is the transformation of the fish into a "saleable product," in addition to the careful handling and transportation of the product to foreign markets (Hannesson 2008).

Overall, the general purpose of this study is for the identification of information gaps in the FAO reported fisheries catches for the Pitcairn Islands. The specific purpose of this study is to estimate the total fisheries catches for Pitcairn Islands from 1950-2009, including all fisheries sectors (i.e., subsistence and artisanal catches). As previously mentioned, almost all catches on Pitcairn Island are subsistence catches (Gillett 2009). The resources available to provide estimates of subsistence catches are limited, and our approach is an assumption based approach using information found in the academic and grey literature. This report presents the best estimate of all small-scale catches and artisanal landings for the Pitcairn Islands from 1950-2009.

Methods

Human population data

Human population data were derived from the Pitcairn Study Centre census database. Years between census points were interpolated linearly to estimate population time series (Figure 2). Pitcairn Island is the only inhabited island in the Pitcairn Island Group,[6] and fluctuations in the population are explained through historical analysis. The main driver of island population fluctuations is determined by environmental factors including: unsustainable resource exploitation, limited land area, resource depletion, insufficient governance practices, and inability to sustain subsistence level of food security.[5] Demographics, including an aging population base, declining population, and emigration also play a substantial role in population fluctuations (Amoamo 2011).

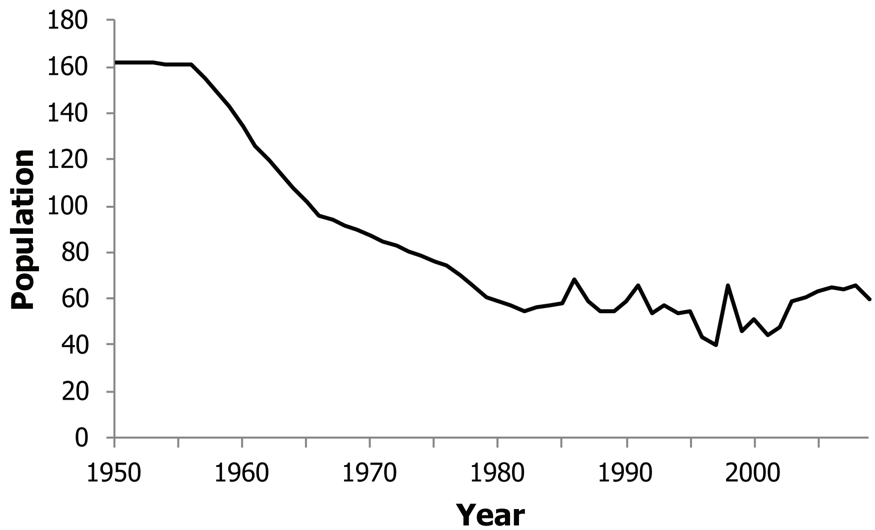

Figure 2. Population estimates for the Pitcairn Islands, 1950-2009.

Presently, 29% of the island population is over 60 years of age with Mr. Len Carlyle Brown being the oldest Pitcairn resident at age 85.[6] The aging population base has resulted in the Pitcairn Island labour force being limited to "8 or 9 hard core fishers" in addition to 3 or 4 regular fishers (Gillett 2009). Moreover, "women and men fished regularly from the rocks, mainly for a fish locally called *nanwi* [*Kyphosus bigibbus*], for the evening meal" (Gillett 2009). As of 2011, only 48 inhabitants reside on Pitcairn Island, mostly seventh generation descendants of the Bounty mutineers.[3] Depopulation as a result of outmigration, predominantly to New Zealand, has led to the population declining from a peak of 233 in 1937 to 60 residents in 2009, to its present population of 48 (Figure 2).

Subsistence Fisheries

Both the academic and grey literature was thoroughly reviewed for data pertaining to subsistence fisheries in Pitcairn Island. *Per capita* catch data referring to subsistence and artisanal fishing were found for Pitcairn Island. Most information on fisheries and subsistence and artisanal catches, was derived from Gillett (2009), Sharples (1994), Adams and Langley (2005) and Dalzell *et al.* (1996). According to Gillett (2009), subsistence fishing produces the majority of all the fish consumed. Consumption is estimated at 140 kg·person^{-1}·year^{-1} (Gillett 2009). Gillett (2009) estimates that if the population of Pitcairn was 50 inhabitants, the 140 kg per capita annual consumption would result in a subsistence catch of seven tonnes per year. Dalzell *et al.* (1996) notes that Pitcairn's annual subsistence fisheries production was 8 metric tonnes in the early 1990s.

Our methodology, consisting of using the consumption information derived from Gillett (2009) for Pitcairn Island, was used to estimate the total subsistence catch for the island. The consumption rate of 140 kg·person^{-1}·year^{-1} was held fixed back to 1950. Once the total subsistence catch for the island was derived, we estimated the taxonomic composition with information from Gillett (2009), Sharples (1994), Adams and Langley (2005) and Dalzell *et al.* (1996).

Adams and Langley (2005), Dalzell *et al.* (1996) and Sharples (1994) present counts of individual taxa on the Pitcairn Islands, which provides general information pertaining to subsistence fishing. This aided the formulation of our assumptions and provided detailed information on taxa found in and around the Pitcairn Islands. These data were used to create an assumed taxonomic composition of reconstructed subsistence catches (Table 1).

Table 1. Taxonomic composition of subsistence and artisanal catches on Pitcairn Island as informed by Adams and Langley (2005), Dalzell *et al.* (1996) and Sharples (1994).

Taxon name	Percentage of total subsistence catch (%)	Percentage of total artisanal catch (%)
Etelis carbunculus	-	20
Pristipomoides spp.	-	20
other Lutjanidae	10	10
Kyphosus bigibbus	20	-
other Kyphosidae	10	-
Epinephelus fasciatus	20	-
Variola louti	-	20
other Serranidae	10	10
Panulirus penicillatus	5	5
Scyllarides spp.	5	5
Miscellaneous invertebrates	10	-
Miscellaneous marine fishes	10	10

Artisanal Fisheries

Most information from the literature pertaining to artisanal fisheries catches is derived from Gillett (2009) who estimates that the catch taken for commercial purposes is approximately five tonnes. Many artisanal fishers sell catches to the occasional passing cruise ships and private yachts. Sharples (1994) reports that the standard price of all fish was NZ$5/kg. According to Gillett (2009), in the year 2007, the commercial catch of five tonnes was worth NZ$51,000. We assumed this catch volume was constant over the time period. An assumed taxonomic composition was also created for the artisanal setor (Table 1).

Results

Subsistence catches

Overall subsistence catches totalled 716 tonnes for the period of 1950-2009 (Figure 3a). Subsistence catches declined throughout this period due to a declining population. Fluctuations in estimated catches over this time period are entirely due to population fluctuations, with average catch declining from 22 t·year^{-1} to approximately 8 t·year^{-1} by 2009 (Figure 3a). Subsistence catches were dominated by the fish species *Epinephelus fasciatus* and *Kyphosus bigibbus*. Lutjanidae, other Serranidae, Miscellaneous marine fishes (MMF), other Kyphosidae, and Miscellaneous Invertebrates (MI) also provided substantial amounts of catch (Figure 3b). Other species caught include *Scyllarides* spp., and *Panulirus penicillatus* (Figure 3b).

Artisanal catches

Artisanal catches totalled 300 tonnes over the 1950-2009 period (Figure 3a). Transportation issues, erratic weather patterns, rough seas and a lack of tourist accessibility to the island have contributed to the absence of substantial artisanal catches over this period; however, such inter-annual variability are not represented in our data. Amoamo (2011) estimates that about 40 cruise ships pass the Pitcairn Islands, however, only eight to ten ships stop at Pitcairn. Consequently, this produces a total of 2,500 to 3,000 visitors during the October to March cruise season

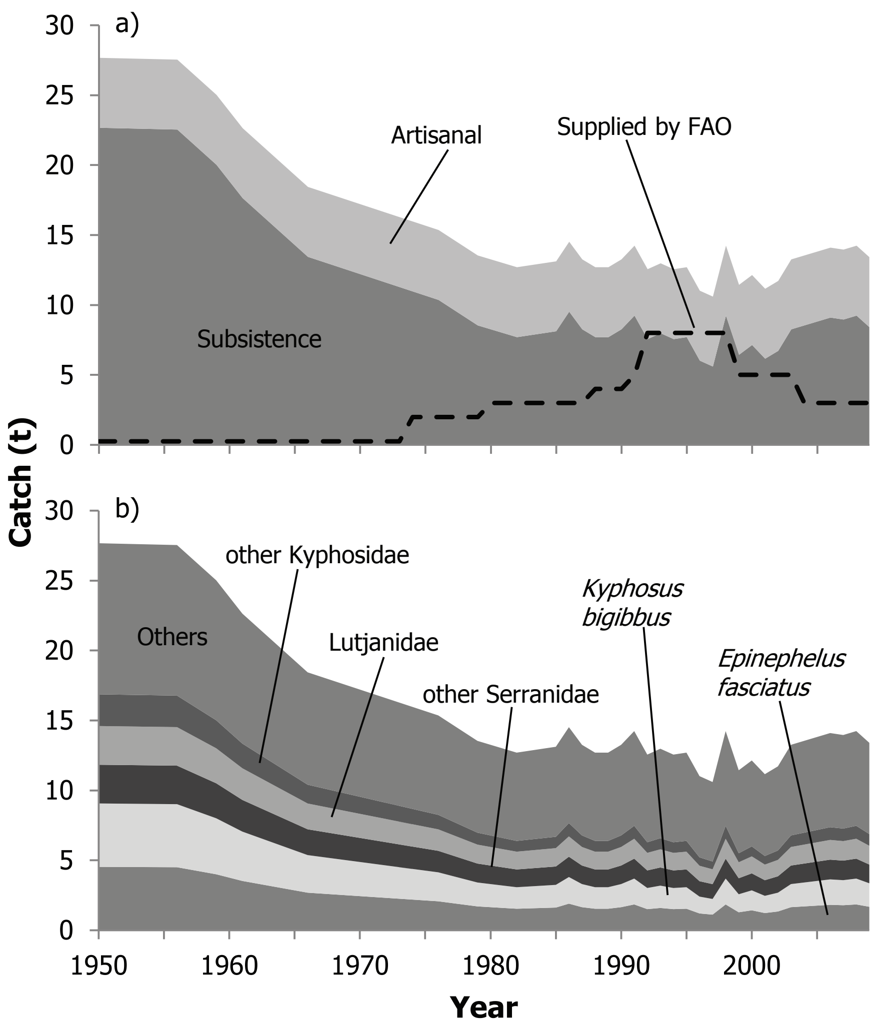

Figure 3. a) Total reconstructed catch by sector for the Pitcairn Islands compared to landings as presented by the FAO, 1950-2009, and b) Total reconstructed catch by major taxa.

(Amoamo 2011). The immediate result of this lack of transportation infrastructure is its negative impact on tourism, which has further restrained the development of Pitcairn Island artisanal fisheries (Amoamo 2011). Artisanal catches were dominated taxonomically by *Variola louti, Etelis carbunculus,* and *Pristipomoides* spp. Other Serranidae, other Lutjanidae, *Panulirus penicillatus,* and *Scyllarides* spp. also contributed to catch (Figure 3b).

Total reconstructed catches

Overall reconstructed catches for Pitcairn Island, which included subsistence and artisanal sector catches, totalled 1,016 tonnes for the period 1950-2009 (Figure 3a). This catch total was more than six times the 158 t reported to FAO on behalf of Pitcairn Island for the same time period. Subsistence catches dominated with approximately 70% of total catches being subsistence and 30% being commercial over the 1950-2009 time period. Subsistence catches dominated during the 1950s when the population was around 160 people, representing approximately 82% of the total reconstructed catch compared to 18% commercial catch for that decade.

Foreign fleets in the Pitcairn Islands EEZ

Adams and Langley (2005) note that Taiwan, China, Japan, Republic of Korea and French Polynesia have been long-line fishing in the area of the Pitcairn Islands EEZ. Gillett (2009) informs us that there is only one accessible document noting the allowance of foreign vessels in the Pitcairn Islands EEZ. The agreement identifies 20 Japanese tuna long-line vessels as legal foreign based fleets within the Pitcairn Islands EEZ (Gillett 2009). Presently, according to Gillett (2009) based on personal communication with a Mr. D. Evans, a contract between Pitcairn Island and an unspecified agent led to the issuing of a license for a long-liner to fish in Pitcairn waters for a fee of NZ$1000 (Gillett 2009).

Discussion

Our estimate of total catches for Pitcairn Island was 1,016 tonnes for the period 1950-2009. This reconstructed catch total was more than six times the amount presented by FAO on behalf of Pitcairn Island for the same time period. In our reconstruction, approximately 300 tonnes of commercial catches and approximately 558 tonnes of subsistence catches were added to the FAO data.

Overall, Pitcairn faces as its major challenges the fundamental survival of its population. With a continuing ageing of the population base and associated out-migration of young people, the likelihood of long-term habitation of Pitcairn is put into question. Thus, it is likely that total catches may continue to remain low or further decline.

Addendum

Since completing this reconstruction, the data has been carried-forward to 2010. We assumed the same total in 2010 as in 2009 and that both the sectoral and taxonomic breakdowns were the same.

Acknowledgements

We thank the *Sea Around Us* Project, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts.

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Appendix Table A1. FAO landings vs. total reconstructed catch (in tonnes), and catch by sector, for the Pitcairn Islands, 1950-2009.

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal
1950	0.25	28	22.7	5
1951	0.25	28	22.6	5
1952	0.25	28	22.6	5
1953	0.25	28	22.6	5
1954	0.25	28	22.6	5
1955	0.25	28	22.6	5
1956	0.25	28	22.5	5
1957	0.25	27	21.7	5
1958	0.25	26	20.9	5
1959	0.25	25	20.0	5
1960	0.25	24	18.8	5
1961	0.25	23	17.6	5
1962	0.25	22	16.8	5
1963	0.25	21	16.0	5
1964	0.25	20	15.1	5
1965	0.25	19	14.3	5
1966	0.25	18	13.4	5
1967	0.25	18	13.1	5
1968	0.25	18	12.8	5
1969	0.25	18	12.5	5
1970	0.25	17	12.2	5
1971	0.25	17	11.9	5
1972	0.25	17	11.6	5
1973	0.25	16	11.3	5
1974	2.00	16	11.0	5
1975	2.00	16	10.7	5
1976	2.00	15	10.4	5
1977	2.00	15	9.8	5
1978	2.00	14	9.1	5
1979	2.00	14	8.5	5
1980	3.00	13	8.3	5
1981	3.00	13	8.0	5
1982	3.00	13	7.7	5
1983	3.00	13	7.8	5
1984	3.00	13	8.0	5
1985	3.00	13	8.1	5
1986	3.00	15	9.5	5
1987	3.00	13	8.3	5
1988	4.00	13	7.7	5
1989	4.00	13	7.7	5
1990	4.00	13	8.3	5
1991	5.00	14	9.2	5
1992	8.00	13	7.6	5
1993	8.00	13	8.0	5
1994	8.00	13	7.6	5
1995	8.00	13	7.7	5
1996	8.00	11	6.0	5
1997	8.00	11	5.6	5
1998	8.00	14	9.2	5
1999	5.00	11	6.4	5
2000	5.00	12	7.1	5
2001	5.00	11	6.2	5
2002	5.00	12	6.7	5
2003	5.00	13	8.3	5
2004	3.00	14	8.5	5
2005	3.00	14	8.8	5
2006	3.00	14	9.1	5
2007	3.00	14	9.0	5
2008	3.00	14	9.2	5
2009	3.00	13	8.4	5

Appendix Table A2. Total reconstructed catch (in tonnes) by major taxa for the Pitcairn Islands, 1950-2009.

Year	*Epinephelus fasciatus*	*Kyphosus bigibbus*	Other Serranidae	Lutjanidae	Other Kyphosidae	Others[1]
1950	4.5	4.5	2.8	2.8	2.3	10.8
1951	4.5	4.5	2.8	2.8	2.3	10.8
1952	4.5	4.5	2.8	2.8	2.3	10.8
1953	4.5	4.5	2.8	2.8	2.3	10.8
1954	4.5	4.5	2.8	2.8	2.3	10.8
1955	4.5	4.5	2.8	2.8	2.3	10.8
1956	4.5	4.5	2.8	2.8	2.3	10.8
1957	4.3	4.3	2.7	2.7	2.2	10.5
1958	4.2	4.2	2.6	2.6	2.1	10.3
1959	4.0	4.0	2.5	2.5	2.0	10.0
1960	3.8	3.8	2.4	2.4	1.9	9.6
1961	3.5	3.5	2.3	2.3	1.8	9.3
1962	3.4	3.4	2.2	2.2	1.7	9.0
1963	3.2	3.2	2.1	2.1	1.6	8.8
1964	3.0	3.0	2.0	2.0	1.5	8.5
1965	2.9	2.9	1.9	1.9	1.4	8.3
1966	2.7	2.7	1.8	1.8	1.3	8.0
1967	2.6	2.6	1.8	1.8	1.3	7.9
1968	2.6	2.6	1.8	1.8	1.3	7.8
1969	2.5	2.5	1.8	1.8	1.3	7.8
1970	2.4	2.4	1.7	1.7	1.2	7.7
1971	2.4	2.4	1.7	1.7	1.2	7.6
1972	2.3	2.3	1.7	1.7	1.2	7.5
1973	2.3	2.3	1.6	1.6	1.1	7.4
1974	2.2	2.2	1.6	1.6	1.1	7.3
1975	2.1	2.1	1.6	1.6	1.1	7.2
1976	2.1	2.1	1.5	1.5	1.0	7.1
1977	2.0	2.0	1.5	1.5	1.0	6.9
1978	1.8	1.8	1.4	1.4	0.9	6.7
1979	1.7	1.7	1.4	1.4	0.9	6.6
1980	1.7	1.7	1.3	1.3	0.8	6.5
1981	1.6	1.6	1.3	1.3	0.8	6.4
1982	1.5	1.5	1.3	1.3	0.8	6.3
1983	1.6	1.6	1.3	1.3	0.8	6.4
1984	1.6	1.6	1.3	1.3	0.8	6.4
1985	1.6	1.6	1.3	1.3	0.8	6.4
1986	1.9	1.9	1.5	1.5	1.0	6.9
1987	1.7	1.7	1.3	1.3	0.8	6.5
1988	1.5	1.5	1.3	1.3	0.8	6.3
1989	1.5	1.5	1.3	1.3	0.8	6.3
1990	1.7	1.7	1.3	1.3	0.8	6.5
1991	1.8	1.8	1.4	1.4	0.9	6.8
1992	1.5	1.5	1.3	1.3	0.8	6.3
1993	1.6	1.6	1.3	1.3	0.8	6.4
1994	1.5	1.5	1.3	1.3	0.8	6.3
1995	1.5	1.5	1.3	1.3	0.8	6.3
1996	1.2	1.2	1.1	1.1	0.6	5.8
1997	1.1	1.1	1.1	1.1	0.6	5.7
1998	1.8	1.8	1.4	1.4	0.9	6.8
1999	1.3	1.3	1.1	1.1	0.6	5.9
2000	1.4	1.4	1.2	1.2	0.7	6.1
2001	1.2	1.2	1.1	1.1	0.6	5.8
2002	1.3	1.3	1.2	1.2	0.7	6.0
2003	1.7	1.7	1.3	1.3	0.8	6.5
2004	1.7	1.7	1.4	1.4	0.9	6.6
2005	1.8	1.8	1.4	1.4	0.9	6.6
2006	1.8	1.8	1.4	1.4	0.9	6.7
2007	1.8	1.8	1.4	1.4	0.9	6.7
2008	1.8	1.8	1.4	1.4	0.9	6.8
2009	1.7	1.7	1.3	1.3	0.8	6.5

[1] Others category includes *Variola louti, Etelis carbunculus, Pristipomoides* spp., *Panulirus penicillatus, Scyllarides* spp., 'miscellaneous marine fishes', and 'miscellaneous invertebrates'.

A brief history of fishing in the Prince Edward Islands, South Africa, 1950–2010[1]

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Abstract

To reconstruct the catch history in the waters of the Prince Edward Islands (South Africa) from 1950 to 2010, catch data were obtained from the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) *Statistical Bulletin* (subareas 58.6 and 58.7), CCAMLR stock assessment reports, as well as South African national commercial and observer datasets. These were used to estimate removals (both landed and discarded) in each of the statistical areas 51, 58.6 and 58.7. Catches of Patagonian toothfish (*Dissostichus eleginoides*), the only target species around the islands, show a sharp increase from 1994, peaking at 22,949 tonnes in 1997, most of which (93%) was taken by vessels operating illegally in the area. These large removals during the first years of the fishery had the effect of unsustainable "mining" of the stock, and thereafter catches fell sharply. At present, a small legal fishery remains operational in the area.

Introduction

The Prince Edward Islands

Located in the south-western Indian Ocean, the Prince Edward archipelago (46°45' S, 37°45' E) comprises two volcanic islands, Marion and Prince Edward (Figure 1). Covering 270 km², Marion Island is the larger of the two, while Prince Edward, lying 22 km northeast, is 45 km² in extent. The archipelago and its 473,380 km² Exclusive Economic Zone (EEZ; www.seaaroundus.org; accessed: July, 2012) are part of the sovereign territory of South Africa, some 2,000 km to the north-west. The oceanographic position of the islands is within the main path of the eastward-flowing Antarctic Circumpolar Current. The islands are managed as a Special Nature Reserve and are not occupied permanently, although there is a scientific base on Marion Island.

Most of the Prince Edward Islands' EEZ falls within subareas 58.7 and 58.6 of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), of which South Africa is a signatory (Figure 1). A small portion of the EEZ extends into CCAMLR subarea 58.4.4 to the south. In the north, part of the EEZ lies beyond CCAMLR's jurisdiction in an area designated as the Western Indian Ocean (area 51; Figure 1) by the Food and Agriculture Organization of the United Nations (FAO).

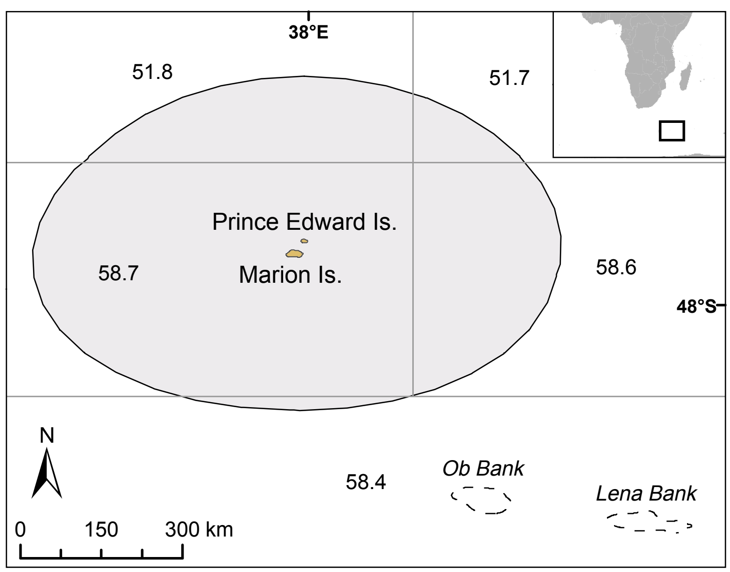

Figure 1. Map of the Prince Edward Islands, its EEZ, and the boundaries of CCAMLR statistical subareas 58.6, 58.7 and 58.4. FAO statistical area 51 lies to the north. Dashed lines, representing ~100 m isobaths, indicate the position of Ob and Lena banks.

Fisheries and their resource species

Kock (1992) provides a detailed description of the historical development of fishing in the Southern Ocean and is the basis for the brief outline presented here. Exploratory fishing in other parts of the southern Indian Ocean began in the late 1960s after several fish surveys by Soviet Union vessels around Kerguelen Islands between 1958 and 1961. French, Japanese, Polish and Soviet vessels investigated and exploited fish populations in the shelf waters of the region, including around the Kerguelen-Heard Ridge, Crozet Islands, and Ob and Lena Banks. Commercial fishing, however, proved largely unprofitable and was subsequently abandoned by most vessels. It is likely that similar exploratory fishing occurred in Prince Edward Islands' waters at this time (M. Purves, pers. comm., Marine Stewardship

[1] Cite as: Boonzaier, L., Harper, S., Zeller, D., and Pauly, D. (2012) A brief history of fishing in the Prince Edward Islands, South Africa, 1950-2010. pp. 95-101. *In*: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Council, Southern Africa Office) and there are reports of catches from exploratory Soviet Union vessels operating around the Prince Edward Islands during the 1970s and 1980s; however these catches would have been very small – no more than 5-10 tonnes per year (E. Pakhomov, pers. comm., University of British Columbia). Kock (1994) estimates that of the 924,000 tonnes of finfish that had been taken from the Indian Ocean sector of the Southern Ocean by the 1992/93 season, 94.4% was fished from around Kerguelen Islands.

Early in 1996, reports that large catches of Patagonian toothfish (*Dissostichus eleginoides*) were being taken in the vicinity of the Prince Edward Islands began surfacing, and unregulated vessels flocked to the area (Purves 1997). Motivated by declining toothfish catches around South America during the mid-1990s, vessels were moving eastward in search of new fishing grounds (Agnew 2000). From as early as 1995, and possibly 1994, there are unconfirmed reports of toothfish vessels operating around the Prince Edward Islands (Appendix R in CCAMLR 2010). In October 1996, a licensed longline fishery for Patagonian toothfish was initiated (Appendix R in CCAMLR 2010). This was the first commercially viable finfish fishery around the archipelago (Japp *et al.* 2008) and it has been the only legal target species. All fishing vessels were equipped with scientific observers, in accordance with the CCAMLR Scheme of International Scientific Observation, which requires observers on all member-countries' vessels operating in CCAMLR waters (Tilney and Purves 1999). However, South Africa lacked the capacity to manage a distant water fishery and protect the islands' resources. As a result, the legal fishery developed in parallel with high levels of illegal fishing in the EEZ, as well as unregulated fishing in the adjacent high seas (Brandão *et al.* 2002). Within three years, the Patagonian toothfish stocks had been decimated (Nel 2008). Improved enforcement of neighboring EEZs, such as those around Crozet and Keurguelen Islands (France) and Heard and McDonald Islands (Australia), exacerbated the situation for South Africa by displacing illegal activity into the unprotected waters of the Prince Edward Islands (Japp *et al.* 2008). Inter-governmental cooperation between Australia, France and South Africa has since improved and led to arrests of illegal vessels (Japp *et al.* 2008). There has been no evidence of illegal fishing for toothfish in the Prince Edward Islands since 2006 (Appendix L in CCAMLR 2011).

Catch per unit effort (CPUE) data showed a steep decline from 0.35-0.50 kg/hook in 1995/96 and 1996/97 to less than 0.1 kg/hook in the early 2000s (Appendix R in CCAMLR 2010). Stock assessment results derived from CPUE and catch-at-length data are inconsistent, however (Brandão and Butterworth 2009). Recently, toothfish catches have been lost to depredation by cetaceans, mainly killer whales (*Orcinus orca*), but also sperm whales (*Physeter catodon*). On some lines, observers have estimated losses as high as 80-90% (Kock *et al.* 2006). Pot fishing was introduced in the 2003/2004 season to alleviate the problem (Watkins 2006; Brandão and Butterworth 2007), but with limited success. The method has not been employed since April 2005 (Brandão and Butterworth 2009).

Up to seven operators have been licensed by South Africa to fish around the islands in any one year, but since the 2001/02 season, only two vessels have fished each season. One vessel has been active since the 2005/06 season, although a second vessel entered the fishery in late 2010 (Appendix R in CCAMLR 2010).

Incidental mortality in both legal and illegal toothfish fishing operations has resulted in the deaths of between 8,500 and 18,500 seabirds, mainly white-chinned petrel (*Procellaria aequinoctialis*; 6,500 to 14,000 individuals), breeding on the Prince Edward Islands during the period from 1996-2000 (Nel *et al.* 2002). In order to reduce this mortality, fishing activities have been prohibited within 12 nm of the islands since December 2004 (Lombard *et al.* 2008). South Africa has also declared its intention to establish a zoned marine protected area around the islands. The proposal is currently under review by the South African Department of Environmental Affairs (CCAMLR 2011).

Methods

CCAMLR catch statistics for statistical subareas 58.7 and 58.6 were used as the basis of this catch reconstruction. These data were extracted from the database version of the CCAMLR 2011 *Statistical Bulletin*, Vol. 23 (available at www.ccamlr.org). Comparison of CCAMLR data with national commercial data and observer data acquired from South Africa's Department of Agriculture, Forestry and Fisheries (both of which are reported to CCAMLR), revealed that the information from CCAMLR's *Statistical Bulletin* was more comprehensive. While trips are likely not all monitored by observers, and commercial reporting has tailed off over time, we assume that CCAMLR has accounted for this in its reporting of catch data in the *Statistical Bulletin*. According to Tilney and Purves (1999), observers monitored 28 of 30 fishing trips in the EEZ from October 1996 to January 1999.

Subarea 58.6 includes part of both the Prince Edward Islands EEZ and the Crozet Islands (France) EEZ. Three countries have reported catches in this area: France, South Africa and Japan. For the purposes of this reconstruction, only catches taken by South Africa were considered, as South Africa has not issued any access agreements allowing foreign vessels to fish in the Prince Edward Island EEZ specifically (R. Leslie, pers. comm., Department of Agriculture, Forestry and Fisheries, South Africa), whereas Japan has had agreements with France. The CCAMLR *Statistical Bulletin* reports catches only from South Africa in subarea 58.7, most of which (65%) lies within the Prince Edward Islands EEZ, therefore all these catches were considered as taken within the EEZ.

Catches presented by CCAMLR according to "season," which runs from December 1st of a given year to November 30th of the next year, were converted to calendar years by assigning catch entirely to the second year of the season. For example, catches in the 2002/03 season were considered as taken in 2003. This was done to facilitate catch mapping (Watson *et al.* 2004) and does not affect cumulative catches.

As part of the Prince Edward Islands EEZ lies beyond CCAMLR's jurisdiction (in FAO area 51), catches taken in this region are not reported in the *Statistical Bulletin*. However, catches of Patagonian toothfish (only) taken in the area 51 portion of the EEZ are reported in CCAMLR's Fishery Report: *Dissostichus eleginoides* Prince Edward

Islands South African EEZ (Subareas 58.6 and 58.7, CCAMLR 2011). Given the three datasets available for area 51 (CCAMLR Fishery Report and the two national datasets), we chose to amalgamate the three and work with the highest catches reported for each taxon group for a given year. Careful considerations were given to ensure there was no double counting of taxa as a result of the amalgamation. Where reported species were found not to occur at the Prince Edward Islands according to distributions on FishBase (www.fishbase.org; accessed: June, 2012) and in Fischer and Hureau (1985), the catches were included in the next highest taxon grouping. This applied generally to very small catches (1 t) and usually for a single year only.

Although a small portion of the Prince Edward Islands EEZ extends into subarea 58.4.4, the CCAMLR *Statistical Bulletin* does not report catches for South Africa in this region. This was confirmed by mapping of effort data contained in the national datasets, which revealed that no gear has been set in this part of the EEZ.

While a pot fishery was conducted from one vessel from 2003 to 2005 (Brandão and Butterworth 2009), there are no records of this gear in the CCAMLR *Statistical Bulletin*. Catches for this gear were taken from Brandão and Butterworth (2007): 73 tonnes in 2004 and 104 tonnes in 2005. To apportion the catch by statistical area, estimates of the spread of the pot fishing catch were made based on information contained in Lombard (2008). The proportions were estimated to be 80% within area 58.7, and 10% each within area 58.6 and area 51.

Illegal catches

Estimates of the illegal catch of Patagonian toothfish from 1997 to 2010 were taken from a stock assessment report of the CCAMLR Working Group on Fish Stock Assessment (Brandão and Butterworth 2007). It is assumed that vessels operating illegally were using longline gear. Linear interpolation was used to estimate catches for 1994, 1995 and 1996, as there are records of illegal vessels likely operating in the area starting from 1994. This catch was then allocated to the subareas 58.6 and 58.7, and area 51 based on the proportion of legal catch taken each year from each statistical area. Thus, we assumed proportionality between the spatial distribution of legal and illegal fishing. During the years for which there was no legal catch (1994 and 1995) the proportions as calculated for the first year of the legal fishery (1996) were applied.

By-catch

Catches of non-target species (anything other than Patagonian toothfish) as reported in the CCAMLR *Statistical Bulletin* were considered by-catch. By calculating the proportion of by-catch as a fraction of the total catch for each taxon per year in each area, this ratio could be applied to the illegal catch in order to estimate the likely by-catch of non-target species. Thus, it is assumed that illegal fishing resulted in similar removals of by-catch as the legal fishery. No by-catch information was available for the first years of the legal fishery (1996 in areas 51, 58.6 and 58.7, and 1997 in areas 51 and 58.6). We assume that by-catch was taken at this time, therefore by-catch (and discard, see below) ratios calculated in each statistical area for the first year for which such information is available were applied to the earlier years.

For the two years that pots were in use (2004 and 2005), it was assumed that by-catch rates were the same as those reported by Watkins (2006), which resulted from a detailed analysis of two fishing trips where by-catch constituted 19% of total catch, with crab species (family Lithodidae) accounting for 58% of this.

Discards

Discarding is monitored by observers and included in national statistics, however the CCAMLR *Statistical Bulletin* includes only aggregated catch information. Records of catches for which there was information on discarding in the two national datasets supplied by South Africa's Department of Agriculture, Forestry and Fisheries were used to calculate a discard rate for each taxon group per year in areas 51, 58.6 and 58.7. For the years in which there was no discard information, linear interpolation was employed to estimate discarding. When there was no information for a particular taxon in one area, the average discard rate calculated for the same taxon in the other area was used.

It is assumed that discarding is as prevalent (or more prevalent) in the illegal fishery as it is in the legal fishery. Therefore, to calculate conservative estimates of discarding in the illegal fishery, discard rates per taxon per year per statistical area derived from the legal fishery were applied to estimates of illegal catch.

To quantify discarding in the pot fishery, a discard rate of 60% was applied, a figure reported by Kelleher (2005) for a Chilean experimental pot fishery for toothfish.

There are no recreational or artisanal fisheries operating in the Antarctic Ocean, and unreported catches in the legal fishery are not a problem due to the high level of observer coverage (Pramod *et al.* 2008).

Results and Discussion

The results of this work are intended to provide a comprehensive reconstruction of historic catches from the Prince Edward Islands of South Africa from 1950 to 2010. This information will contribute to refining the global catch mapping procedure developed by Watson *et al.* (2004).

In the Southern Ocean, Antarctic krill (*Euphausia superba*) makes up the majority of fisheries catches with around 200,000 tonnes taken from the CCAMLR area during 2010 (CCAMLR 2010). While krill is not caught around the Prince Edward Islands, removals of Patagonian toothfish, the only legal target species in the islands, are comparatively small with catches peaking around 23,000 tonnes in 1997 (Figure 2a). These removals were dominated by illegal catches, which are estimated to have exceeded the legal catch during every year prior to 2000 – by as much as 14 times in 1996. Despite the significant levels of illegal catch presented here, it is possible that these estimates are conservative as they are based on CCAMLR estimates of illegal fishing, which reports of trade-based assessments of the illegal, unreported and unregulated (IUU) toothfish catch suggest are underestimates (Lack and Sant 2001; Lack 2008). In its 1997 Report of the Working Group on Fish Stock Assessment, CCAMLR also notes the discrepancy between illegal catches estimated using catch and effort data, and those estimated using landings (CCAMLR 1997).

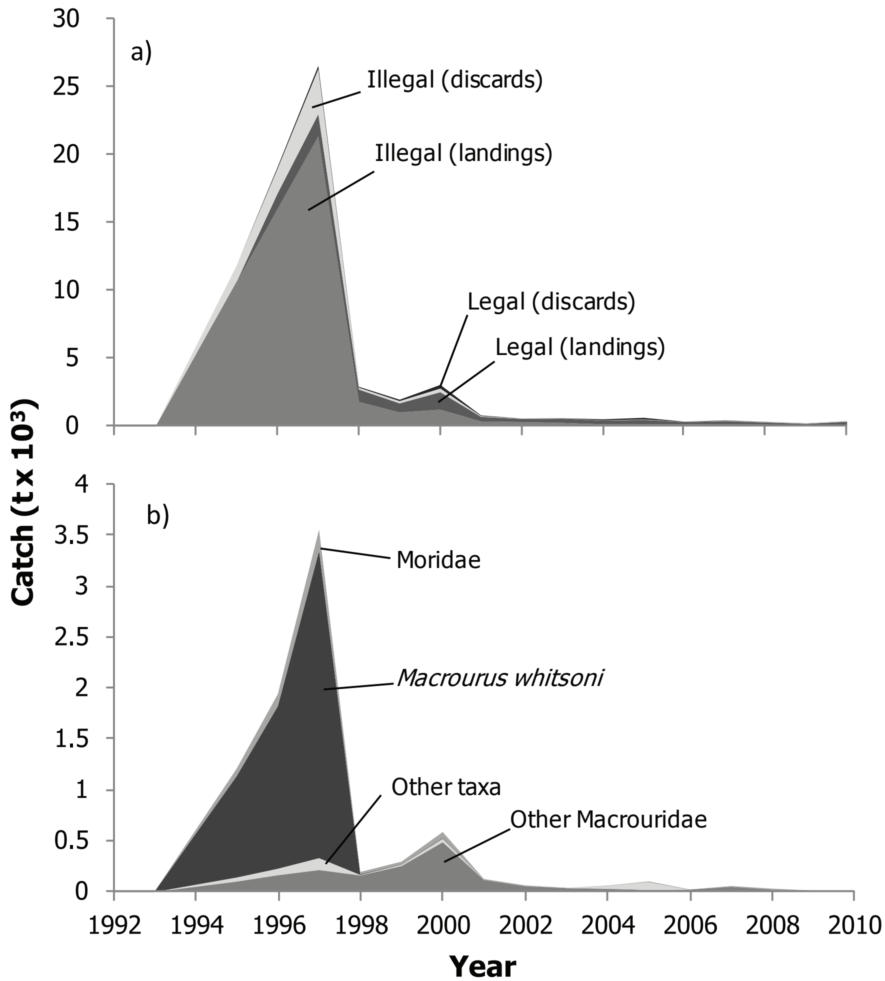

Figure 2. Fisheries catches (in metric tonnes) for the Prince Edward Islands (South Africa) drawn from the CCAMLR 2011 Statistical Bulletin, Vol. 23 (subareas 58.6 and 58.7), supplemented with information from the South African Department of Agriculture, Forestry and Fisheries, and SC-CCAMLR (2011), as well as illegal catch information acquired from Brandão and Butterworth (2007) presented for (a) total catch disaggregated according to catch type and (b) by-catch species only.

Catches of Patagonian toothfish – a long-lived, unproductive species with low fecundity – declined sharply after 1997 as a result of the unsustainable illegal catch taken during the preceding years, which had the effect of "mining" the species (Agnew 2000). The decrease in CPUE resulted in most illegal vessels abandoning the area (Agnew 2000) as well as an expansion of legal fishing effort from an initial concentration around the islands' shelf area and the closest seamounts to dispersed exploitation of the plateau and all seamounts in the northern portion of the EEZ (Lombard *et al.* 2008). A small legal fishery remains operational in the area despite the depleted state of the Patagonian toothfish stock.

CCAMLR was the first international convention to adopt an ecosystem approach to fisheries management (Constable *et al.* 2000; Miller 2011), an approach that aims to take into account the relationship between species and oceanographic processes that together form the marine Antarctic ecosystem (Miller 2011). Information on fishery activity and catches, including by-catch and discards, are reported to CCAMLR by both observers and member countries. This information is then aggregated and reported in the CCAMLR *Statistical Bulletins*. Therefore, although information on by-catch and discarding are collected and included in catch statistics, these removals are not identified as such.

Using information on catches of non-target species and averaging the yearly proportions, by-catch was calculated to account for 11% of the total catch. Rattails (family Macrouridae), mostly Whitson's grenadier (*Macrourus whitsoni*), made up the largest part of the by-catch (79%), with the morid cod family (Moridae) making up the second highest proportion (11%; Figure 2b). These proportions are in line with those reported by Tilney and Purves (1999): macrourids contributing 86% of the by-catch and morids 9%. However, our results show that by-catch contributed a larger proportion of the total catch (11% rather than 5.3%).

While most of the by-catch is discarded (85%, yearly average), the absolute volume of discards in the Antarctic generally (Pramod *et al.* 2008), and around the Prince Edward Islands specifically, is small, with an estimated maximum of 270 tonnes discarded during 2000 by the legal fishery (17% of the total legal catch for that year). When one considers discarding by vessels operating illegally around the islands, this maximum jumps to 3,238 tonnes in 1997. This equates to 9.4% (yearly average) of the total catch of both fisheries. Only small proportions of Patagonian toothfish were discarded, with an average yearly discard rate of 3% since the illegal fishery commenced in 1994.

Although we acknowledge that there are uncertainties associated with this approach for estimating catch histories (for example, using linear interpolation to approximate illegal catches and discard rates) and that the results are not statistically rigorous, they offer a more useful estimation than the alternative – that a lack of data should be interpreted as zero catch (Pauly 1998; Zeller *et al.* 2007).

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Appendix Table A1. Prince Edward Islands' (South Africa) fisheries catch statistics (in tonnes) by catch type, drawn from the CCAMLR 2011 *Statistical Bulletin*, Vol. 23 (subareas 58.6 and 58.7), supplemented with information from the South African Department of Agriculture, Forestry and Fisheries, and SC-CCAMLR (2011), as well as illegal catch information acquired from Brandão and Butterworth (2007). (See text and Figure 2a.)

Year	Legal		Illegal	
	Discards	Landings	Discards	Landings
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	588	5,355
1995	-	-	1,176	10,709
1996	122	1,121	1,764	16,064
1997	241	1,605	3,238	21,420
1998	66	907	132	1,808
1999	103	665	161	1,035
2000	270	1,284	261	1,239
2001	48	341	52	367
2002	11	227	16	329
2003	11	316	10	265
2004	74	276	16	158
2005	122	325	30	156
2006	14	172	12	156
2007	28	239	26	154
2008	17	144	26	148
2009	4	73	42	124
2010	9	224	41	122

Reconstructed catches of Samoa 1950–2010[1]

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Abstract

Samoa has a long history of marine resource use, and today maintains a strong connection to the marine environment. Despite the acknowledged importance of marine resources for food security, Samoan fisheries landings have been under-reported since the FAO started reporting fisheries catch data on behalf of Samoa in 1950. Catches are particularly under-represented in the early years, but reporting has improved somewhat since the 1990s. Using a consumption-based approach, we linked historical information with current patterns of marine resource use to create a complete time series of total marine fisheries catches over the 1950 to 2010 time period. Estimated total marine fisheries catches were 627,700 t for the 1950-2010 period, which is 2.8 times the reported landings submitted to the FAO of almost 220,900 t. In recent years, total reconstructed catches included estimates of under-reported subsistence and artisanal catches, by-catch and discards. This study illustrates the importance of small-scale fishing in Samoa, as well as a need for better monitoring of all fisheries sub-sectors to prevent further declines in fisheries resources vital to food security.

Introduction

Samoa, a small Pacific island country, is comprised of two large islands (Savai'i and Upolu), and seven small islets (two of which, Manono and Apolima, are inhabited). Geographically, Samoa lies between 13° and 15° S, and 168° and 173° W, and is situated in the Western South Pacific. Samoa has a land area of 2,935 km² and an oceanic shelf of 4,500 km² (www.seaaroundus.org; Figure 1). Due to the close proximity of neighbouring countries (American Samoa, Tonga, and Wallis and Futuna), Samoa's Exclusive Economic Zone (EEZ) does not extend 200 nautical miles offshore, which results in Samoa having the smallest EEZ (131,812 km²) in the Pacific region. Barrier reefs encircle most of the islands except on the north coast of Upolu, the main inhabited island, where the shelf extends 14 miles offshore (Gillett 2002).

Samoa is thought to have first been settled by Polynesians 3,000 years ago (Meleisea 1987). In 1830, missionaries from the United Kingdom, the first in a series of three colonial powers, landed in Samoa (Thornton *et al.* 2010). The country was then turned over to Germany from 1914 to 1943 (Meleisea 1987). New Zealand took over as colonial ruler from 1944 until 1962, when Samoa, then known as Western Samoa, gained independence (Meleisea 1987). Western Samoa changed its name to Samoa in 1997. Today the country is one of the poorest in the Pacific region with a *per capita* GDP in 2009 of $2,926 USD.[2] For decades the economy of Samoa has relied on agricultural exports such as coconuts, cocoa and bananas (Beaglehole 1947; Zann *et al.* 1985). More recently, since the establishment of a locally based tuna fishery, marine exports have become a major commodity valued at 10.4 million USD, or 63% of the country's total exports in 2002 (Read 2006). Tourism has also become a major industry, and has expanded substantially since its infancy in the 1980s to over 100,000 visitors annually in 2009 (Tagomoa-Isara 2010).

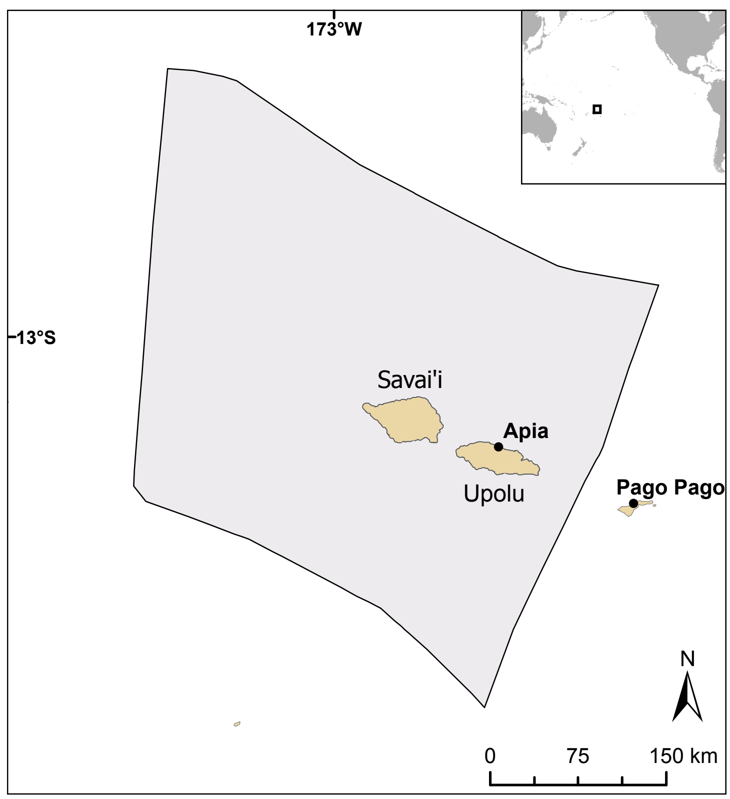

Figure 1. Map of the Samoan EEZ, showing the islands of Savai'i and Upolu as well as the capital city Apia. American Samoa with its capital, Pago Pago, is also shown.

[1] Cite as: Lingard, S., Harper, S., and Zeller, D. (2012) Reconstructed catches of Samoa 1950-2010. pp. 103-118. *In*: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] http://data.un.org/CountryProfile.aspx?crName=Samoa [accessed January 2012]

Samoa has maintained a strong link to its traditional way of life (termed *fa'asamoa*). *Fa'asamoa* encompasses the entire fabric of Samoan life, which has had major impacts on the economic and political development of the country (Lati 2000). Organizational aspects of *fa'asamoa* (which have resulted in sustainable marine resource use over millennia) include extended kinship groups (*agia*), as well as a chieftain system termed *fa'amatai*. Rather than an individual or nuclear family being the unit of social organization, the *agia* encompasses a large extended family group amongst which resources are shared. Land has customarily been distributed based on a tenure system given to *agias* rather than individuals. Similar to the tenured distribution of land, marine resources are tenured and under the jurisdiction of the village chiefs (Faasili and Kelekolio 1999; King and Faasili 1999; Mollica 1999; Zann 1999). The marine tenure system includes many management strategies to prevent overfishing. These strategies include restrictions or specifications on species and/or sizes of fish taken, gear types, harvest seasons, and fishing grounds (Johannes 1978; Mollica 1999). Any excess harvested resources are distributed within the wider community to prevent waste. Each *agia* is headed by a chief (*matai*) who grants permission for the harvesting of marine resources, and whose responsibility it is to distribute resources fairly amongst the community. The details of this system are described in Cahn (2006), Lati (2000), Macpherson (1999), and Meleisea (1987).

Although Samoa has retained a strong link to the *matai* system and other aspects of *fa'asamoa*, (Fitzgerald and Howard 1990), the *fa'amatai* system lost some of its power to sustainably manage marine resources due to pressures from western political systems (Macpherson 1999; Cahn 2006). Additionally, shifts in social organization and an increasing population have resulted in overfishing on Samoa's reefs since the 1960s (Van Pel 1960; Horsman and Mulipola 1995; Mulipola 1998; Faasili and Kelekolio 1999). An example of how the move to a westernized political system impacted the *fa'amatai* system's ability to manage marine resources is that although the *fa'amatai* system contained many village bylaws and customs to combat overfishing, federal legislation and regulations often made enforcement of village bylaws and penalties illegal (Faasili and Kelekolio 1999). Recognizing the opportunity for successful management at the village level, the Fisheries Division added provisions to the 1988 Fisheries Act giving village *fonos* (council of *matais*) the power to enact village by-laws that were legally binding (Faasili and Kelekolio 1999; Johannes 2002).

Traditionally, fish supplied the majority of protein to the Samoan diet (Van Pel 1960; Horsman and Mulipola 1995; Mulipola 1998; Zann 1999; Passfield 2001). Marine resources continue to be important to domestic food security, supplying approximately 74% of the animal protein to the Samoan diet (Bell *et al.* 2009). Two separate types of fishing activities occur in Samoa: fishing for the domestic market and tuna fishing for export markets. The export fishery targets tuna species almost exclusively, while the domestic fishery is for domestic consumption and includes inshore and offshore species (Horsman and Mulipola 1995; Passfield 2001). Although lagoon species provide the majority of food requirements (Horsman and Mulipola 1995; Passfield 2001), pelagic species are also targeted and consumed locally (Van Pel 1960; Anon. 1984). Lagoon fisheries employ a wide variety of gear types. While diving and spear fishing are most common, gillnets, hook and line, and gleaning activities are also important (Zann 1991, 1999; Passfield 2001). Women and children contribute significantly to the household protein supply through the gleaning of invertebrates and seaweeds, and the collection of nearshore fish (Horsman and Mulipola 1995; Passfield 2001; Lambeth *et al.* 2002).

Fisheries are important for both subsistence and economic purposes. Subsistence and artisanal catches were estimated to be 13,800 t with a value of 34.2 million USD over the 2006/2007 financial year (Samuelu and Sapatu 2007). An additional 6.6 million USD was generated from tuna exports for the same year (Hang 2008). Fisheries also employ a substantial portion of the Samoan population, often in an informal manner. Gillett (2009) estimated only 900 people (out of an employable population of nearly 200,000)[3] would be considered commercial fishers, which sell at least 50% of their catch, while 9,200 engage in fishing primarily for subsistence purposes.

The Fisheries Division, originally part of the Department of Economic Development and now part of the Ministry of Agriculture and Fisheries, was established in 1970 (Anon. 1984). In the late 1960s, prior to the establishment of the Fisheries Division, a fishery subsidy program began providing assistance for the mechanization of canoes (Philipp 1977). Mechanization of the fleet was rapid and by 1977 the majority of fishers were using outboard motors (Philipp 1977). In the late 1970s, shortly after mechanization and the development of the Fisheries Division, a formal offshore tuna fishery was established (Philipp 1977).

Fishing by foreign fleets (Japan, Taiwan and Korea) for tuna occurred in Samoan waters from the late 1940s to 1979 (Anon. 1984). Catches by these fleets, mainly longliners, were estimated to be 159.8 t in 1976 (Anon. 1984). While foreign access fishing for tuna is common in many Pacific Island countries, foreign catches in Samoan waters have remained minimal (25 $t{\cdot}year^{-1}$) in the 2000s (Gillett 2009).

Development of a locally based offshore tuna fishery in Samoa commenced in 1975, using modified traditional catamarans called *alias* (Mulipola 1998). However, prior to the development of the formal offshore fishery, customary pole and line fishing for tuna and shark species had occurred for centuries, just outside the barrier reef when weather permitted (Anon. 1984). Reported tuna catches from the locally based offshore fishery in the early period were dominated by skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*; Mulipola 1998). Development of a small-scale longline fishery began in 1991 (Mulipola 1998); however, the commercial offshore longline fishery for tuna officially commenced in 1996 (Su'a *et al.* 2002). Since the start of the fishery in 1996, catches have grown from 2,092 t to 6,200 t in 2002 (Su'a *et al.* 2002), with the majority of fish caught by this sector being exported (Anon. 2007a). As there is no cannery in Samoa, a large portion of catches are exported to American Samoa for processing (Chapman 1998). *Alias* were the dominant fishing craft used by fishers of this sector (Faasili and Time 2006) until 2002, when large commercial vessels (greater than 15 m) came into service.

[3] http://www.sbs.gov.ws/Statistics/Social/DemographicIndicators/tabid/3345/language/en-US/Default.aspx [accessed January 2012]

Under-reporting of fisheries catches is a problem globally, which undermines the importance of fisheries in economics and food security (Zeller *et al.* 2007; Jacquet *et al.* 2010; Garibaldi 2012). Additionally, fisheries have not been acknowledged for their contributions to informal employment (Teh and Sumaila 2011), as well as indirect economic benefits (such as boat building, gear purchases, processing, shipping; Dyck and Sumaila 2010). In Samoa, fisheries are important for domestic food security, livelihoods, and export earnings. However, reporting of national fisheries landings to the Food and Agriculture Organization of the United Nation (FAO) does not adequately reflect their importance. The present study aims to improve the accounting of marine resource use by estimating all fisheries catch components and improving the taxonomic resolution of catches for the period 1950-2010.

Methods

For the 1950-2010 period, FAO landings data were obtained in addition to annual reports by the Fisheries Division of the Ministry of Agriculture, Fisheries and Forests for comparison. National reports divide fisheries into two sectors: inshore and pelagic resources destined for domestic sale, and tuna destined for export (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2000b, 2001, 2002, 2003). In the early period, FAO landings were approximately 300 t·year^{-1}. Fisheries Division data for the same period were not available to make a comparison. However, in recent years national reporting has included better estimates of subsistence and artisanal catches (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2000a, 2001, 2002). Due to a long history of reliance on marine resources in Samoa, we assumed *per capita* subsistence catch rates in the early period would be greater than those experienced today. To estimate unreported catch components, we used seafood consumption rates to estimate total domestic demand for seafood. We considered total domestic demand to represent the total domestic catch, only a portion of which is represented in the reported landings data. Additionally, a comparison between FAO tuna landings and national export records indicated that the majority of tuna were exported. However, some tuna is consumed domestically and this was accounted for in our domestic consumption estimate. The export oriented tuna were treated as a distinct category in our reconstruction, separate from the subsistence and artisanal catches for domestic consumption.

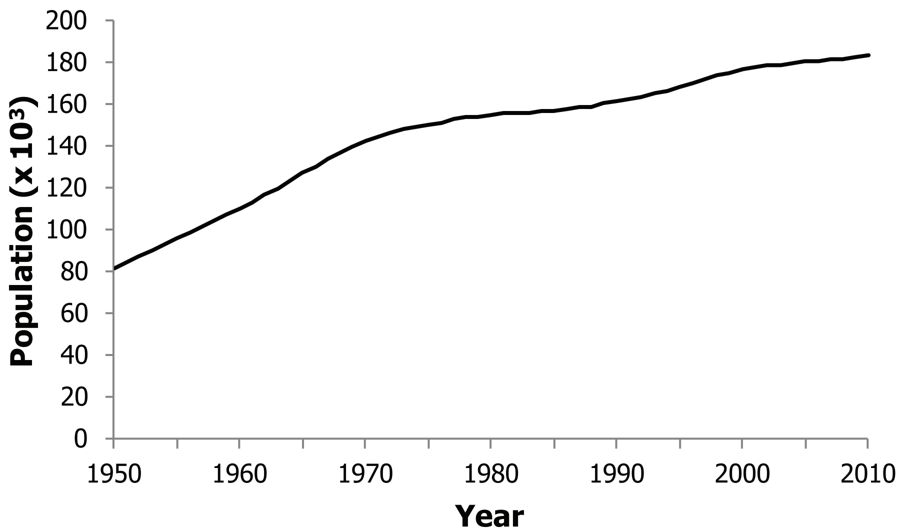

Figure 2. Population of Samoa 1950-2010.

Total domestic catch

Population

Human population data were obtained from the statistic division of the government of Samoa (www.sbs.gov.ws), the World Bank (data.worldbank.org) and The World Resource Institute.[4] World Bank data were available from 1960-2010, and national census data were available for 2001 and 2006 from the government of Samoa. World Bank data for both 2001 and 2006 were similar to national census estimates; therefore, we used the World Bank data for this study. The World Resource Institute estimated a population of 82,000 for the islands of Samoa in 1950. We interpolated between the 1950 estimate and the first year of World Bank data (1960), to derive a complete time series of population for Samoa from 1950 to 2010 (Figure 2).

Seafood consumption

In recent years, attempts have been made to estimate the magnitude of Samoan subsistence catches (Zann 1991; Passfield 2001; Samuelu and Sapatu 2007; Bell *et al.* 2009). Prior to the 1990s, there is little recorded information on subsistence consumption. Some recent information does exist on seafood consumption rates, which includes consumption of seafood derived from subsistence and artisanal fisheries as well as imported products. Passfield (2001) used village surveys on both Savai'i and Upolu to calculate *per capita* consumption rates of 57 kg·person^{-1}·year^{-1} for local seafood, and 14 kg·person^{-1}·year^{-1} for imported seafood (71 kg total).

Prior to 1975, estimates of *per capita* consumption, as well as import data were not available. Although there were reports of imports of milk, butter, and tinned meat into Samoa in the 1950s, these commodities were

[4] http://earthtrends.wri.org/pdf_library/country_profiles/pop_cou_882.pdf

mostly consumed by the small urban population of Apia, while rural areas had minimal access to imported goods (Johnston 1953). Additionally, the subsistence economies of Samoa in the late 1940s were reported to have met the dietary needs of the Samoan people (Beaglehole 1947), which suggests there was no need for imported fish in 1950. With negligible fish imports in the early period, we assumed a fish consumption rate in 1950 of 71 kg·person^{-1}·year^{-1} based on Passfield (2001), consisting entirely of domestically sourced fish. Between 1990 and 1991, two major cyclones (Ofa and Val) hit Samoa, reducing coral cover to nearly zero in many places, and causing major damage to the offshore *alia* fleet (Zann, 1991). Due to these events, fishing capacity was greatly reduced (Zann 1991; Anon. 2000b), thereby reducing consumption in these two years. A household survey between 1990 and 1991 revealed a national average consumption rate of 36 kg·person^{-1}·year^{-1} (Zann 1991). We interpolated linearly from the 71 kg·person^{-1}·year^{-1} in 1950 to 57 kg·person^{-1}·year^{-1} in 2000 (Passfield 2001); however, to reflect the decrease in consumption due to the cyclones, we replaced the interpolated rate in 1990 and 1991 with a rate of 36 kg·person^{-1}·year^{-1} (Zann 1991). From 1992 to 2000, we interpolated linearly between the 36 kg·person^{-1}·year^{-1} estimate and the 57 kg·person^{-1}·year^{-1}. In 2006, a survey undertaken by the fisheries division provided a consumption rate of 59.4 kg·person^{-1}·year^{-1}. We interpolated linearly from the 57 kg·person^{-1}·year^{-1} in 2000 to 59.4 kg·person^{-1}·year^{-1} in 2006 (Samuelu and Sapatu 2007), and carried the 2006 consumption rate forward, unaltered to 2010 (Table 1).

Table 1. Consumption rates used to estimate total domestic demand for seafood in Samoa.

Years	Consumption rate (kg/person/year)	Source
1950	71.0	Passfield (2001)
1951-1988	-	Interpolated[a]
1989	60.1	Interpolated[a]
1990-1991	36.0	Zann (1991)
1992-1999	-	Interpolated[b]
2000	57.0	Passfield (2001)
2000-2005	-	Interpolated[c]
2006	59.4	Samuelu & Sapatu (2007)
2007-2010	59.4	Carried forward[d]

[a] 1951-1989 consumption rate estimated using a linear interpolation from 71 kg·person^{-1}·year^{-1} in 1950 to 57 kg·person^{-1}·year^{-1} in 2000
[b] 1992-1999 consumption rates estimated using linear interpolation from 36 kg·person^{-1}·year^{-1} in 1991 to 57 kg·person^{-1}·year^{-1} in 2000
[c] 2000-2005 consumption rates estimated using linear interpolation from 57 kg·person^{-1}·year^{-1} in 2000 to 59.4 kg·person^{-1}·year^{-1} in 2006
[d] 2007-2010 consumption rates estimated by carrying forward the 2006 estimate unaltered

Total demand for seafood

The time series of *per capita* consumption rates was combined with annual population estimates to give total domestic demand for seafood from 1950 to 2010. Previous studies in other Pacific island countries have, in the absence of catch data, utilized seafood consumption as a proxy for estimating annual catches (Leopold *et al.* 2004). This total domestic demand is considered to be the total domestically retained catch (hereafter referred to as domestic catch) from the artisanal and subsistence sectors. This estimate includes both reported and unreported components.

Artisanal vs. subsistence sectors

Our estimated total domestic demand was used to determine the magnitude of Samoa's domestic catch. This was disaggregated into catches taken by the subsistence and artisanal sectors. In the early period, officially reported landings were considered an under-representation of the true catch and no information was available to disaggregate non-export catches into subsistence and artisanal components. Utilizing national data for the mid to late 1990s (Faasili *et al.* 1997; Faasili *et al.* 1999), we estimated 93% of domestic catches were from the subsistence sector, and 7% from the artisanal sector. We used this breakdown to assign sectors for the reported and unreported components of the domestic catch for the entire time period (Figure 3). In 2008, reported domestic landings were higher than our estimated domestic catch by 260 t. We assumed the FAO estimate was correct and set unreported catches to zero in that year.

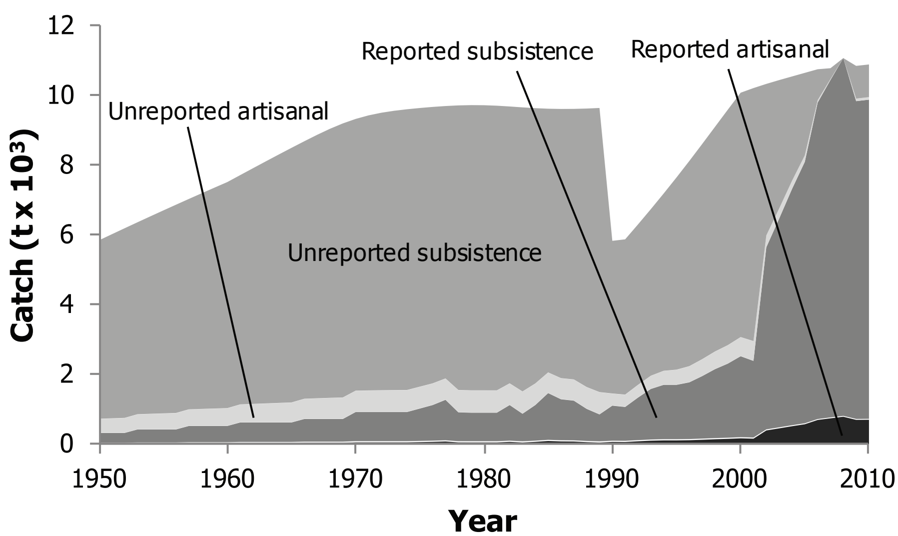

Figure 3. Total domestic demand (tuna and pelagics excluded) for Samoa, 1950-2010, divided into reported and unreported components of the subsistence and artisanal sectors. The catch decline in 1990/91 was due to cyclones (see text).

Export Fishery

Tuna landings

We compared national tuna data (Su'a *et al.* 2002; Imo *et al.* 2005; Faasili and Time 2006; Anon. 2010a) with FAO landings for targeted tuna export species and found these data to be similar. Therefore, we accepted FAO landings data as the best representation of the tuna species (albacore [*Thunnus alalunga*], yellowfin [*T. albacares*], skipjack [*Katsuwonus pelamis*] and bigeye tuna [*T. obesus*]) caught for the export market. Tunas appear in the FAO data beginning in 1978, and in the national data in 1994. From 2002-2010 Samoa's tuna fishery has been well documented, but the data reported to FAO have had poor taxonomic resolution, and were considered slightly underestimated for several years. FAO landings of billfish (black marlin, blue marlin, striped marlin, and swordfish) and the non-specific categories, "tuna-like fishes nei" and "sharks, rays, skates, etc. nei", only appear in some years. National reports (Imo *et al.* 2005; Faasili and Time 2006; Anon. 2007a, 2010a) present landings of billfish, sharks and other pelagic species as by-catch. We assumed the FAO categories "tuna-like fishes nei" and "sharks, rays, skates, etc. nei" also represented by-catch for Samoa. Additionally, due to the use of longliners and the export nature of the fishery, which requires high quality products, the discarding of undersized or low-quality tuna is likely (Kelleher 2005). Using detailed data from national reports, we have improved/estimated by-catch and discards associated with the tuna fishery.

<u>By-catch</u>

The Samoan tuna fishery, between 1975 and 1996, utilized small-scale trolling gear, which incurs minimal by-catch (Bailey *et al.* 1996). However, we assumed that some by-catch occurred during this time and was reported as "tuna like nei" or "sharks, rays, skates, etc. nei" in the FAO data. Longliners came into widespread use in 1996 in Samoa (Su'a *et al.* 2002), and are reported to have significant by-catch rates (13.05% of total catch in the Western South Pacific; Bailey *et al.* 1996). However, Samoa's average by-catch of non-target species from 2002-2009 was 7% (Anon. 2009). Species specific information on longline by-catch was available for the period of 2002-2009 from Western and Central Pacific Fisheries Commission (WCPFC) reports (Anon. 2007a, 2010a). These data were compared to FAO data and it was determined that only part of the data from the WCFPC report was reported in the FAO data. Therefore, unreported by-catch amounts were calculated for the period of 2002-2009. Average proportions from the data were also used to disaggregate the "tuna-like fishes nei" and "sharks, rays, skates, etc. nei" categories in the FAO data. No additional unreported amount of by-catch was calculated for 1978-2001. However, the ratio of unreported by-catch to reported landings of the export fishery for 2009 was used to estimate an unreported amount of by-catch in 2010, with the 2009 species composition being applied as well.

<u>Discards</u>

Longline fishing for tuna and highly migratory species is non-selective and known to incur by-catch of non-targeted species and discards both of targeted and non-targeted species (Bailey *et al.* 1996; Kelleher 2005). Targeted species of inferior quality or individuals caught once quotas have been filled are frequently discarded (Alverson *et al.* 1994; Kelleher 2005). Early on, Samoan tuna fishing was carried out by the domestic *alias* fleet using pole and line, which incurred minimal by-catch and discards (Kelleher 2005). Prior to 1996, we did not apply a discard rate to the pole and line fishery catches. From 1996 onwards, when use of longlines became the dominant gear type, we applied distinct discard rates for catches of bigeye tuna (9.8%), yellowfin tuna (3.6%) and albacore tuna (4.6%) (Anon. 2007b). Globally, (Kelleher 2005) advises a discard rate of 15% for longliners, but Samoa has been reputed to have negligible discard rates (Kelleher 2005; Gillett 2011). Therefore, we applied the lower individual discard rates to estimate discards of the three main target species from 1996-2010.

<u>Baitfish</u>

Baitfish is required to catch tuna using pole and line, however due to limited baitfish supplies in Samoa's EEZ (Anon. 1984), baitfish is imported (Trade and Investment Promotion Unit 2000, in Fitzgerald 2004). Therefore, estimates of baitfish were excluded from this reconstruction.

<u>Spatial allocation</u>

Although it is reported that all catches by the Samoan fishing fleet are taking within the EEZ boundaries (Anon. 2009), data from the Forum Fisheries Agency (FFA) report a small amount of catch in the years 2002 and 2010 being taken from outside of Samoa's EEZ. In 2002 these catches were reported as being taken from another country's EEZ and in 2010 part of the catches come from another EEZ and part from the high seas. The catches within another country's EEZ were assigned as being taken from within American Samoa's EEZ due to the close proximity, the historical relationship between the two countries, and the fact that American Samoa is home to a processing facility which Samoa frequently exports to. Associated by-catch and discards were also proportionally assigned to American Samoa's EEZ and the high seas according to the average proportion of the tuna species in these areas for the years 2002 and 2010. Catches for all other years are taken completely within Samoa's EEZ.

Taxonomic breakdown

Reported domestic catch

Taxonomic detail in the FAO landings is limited, especially for the early period. FAO data are presented in highly aggregated categories such as "marine fishes nei", "echinoderms", "aquatic invertebrates nei", "marine molluscs nei", and "marine crustaceans nei".

To improve the taxonomic resolution of the "marine fishes nei" category, we utilized species compositions of inshore, deepwater, and pelagic catches available from market surveys (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 1995, 2000a, 2001, 2002). For inshore species, we combined market survey information from 1986-2002 (Anon. 1995; Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2001, 2002). We used an average of the first and last 3 years of data and carried these estimates backward to 1950, and forward to 2010, respectively. For deepwater species, we used a four year average from the time period 1996-2001 (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2001). These averages were then carried back unaltered to 1950 and forward to 2010. For pelagic species there was a clear declining trend in some species of tuna from 1996-2002. To capture this trend, we have carried the species composition of market landings in 1996 back to 1950, and the estimates for 2002 forward to 2010. To combine these categories into a single species composition, we calculated the contribution each of the three sectors made to total domestic finfish catches. Market data from 1978 (Anon. 1995) and 1996-2001 (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2001), which provide total market landings by category (inshore, deepwater, and pelagic), were used to weight each category. Although pelagic species only occur until 2001, these species are known to be consumed domestically (Passfield 2001). To account for pelagic species caught for domestic consumption, we set pelagic catches to 10% of total finfish catches in 2010 and interpolated back to the last pelagic species estimate in 2001. The ratio of deepwater species to inshore species was kept constant from 2001 to 2010. The estimate for all categories from 1978 was carried back to 1950 unaltered. The species in each category were then weighted by the contribution of each category in total domestic finfish catches and combined into a single species composition (Appendix Table A1). This breakdown was applied to both the subsistence and artisanal components of the "marine fishes nei" category.

Market survey data also included information regarding invertebrate catches. Three categories (shellfish, crustaceans, and molluscs) are presented in the market data from 1996-2000 (Faasili *et al.* 1997; Faasili *et al.* 1999; Anon. 2000a). As there was no visible trend, we applied a 3 year average to the "crustacean" category, which was applied to the "marine crustaceans nei" of FAO data for the time series of 1995-2010 (Appendix Table A2).

The shellfish and mollusc categories in national market surveys are both in the phylum Mollusca, therefore, they had to be combined for application to the FAO category "marine molluscs nei". "Molluscs" showed no trend in the national market surveys from 1996 to 1998, therefore we used a 3 year average species composition for this category. "Shellfish" data suggested a decrease in *Tridacna squamosa* and *T. maxima* consistent with reports of overfishing of these resources in Samoa (Helm 1988; Mulipola 1993; Zann 1999). Catches of *T. squamosa* have always been small, but decreased to zero in 2000 as the resource has become functionally extinct (Anon. 2001). Reporting of giant clams ceased in national reports in the early 2000s, but collecting of *T. maxima* continues (Passfield 2001); therefore, it was necessary to allocate a small portion of our reconstructed catch to *T. maxima*. Catches of *T. maxima* were set to 10% of total shellfish catches in 2010. Between 2001 and 2010, a linear interpolation was done. Proportions of the remaining species in this family were adjusted accordingly. Estimates for all species were carried back from 1995 to 1950 unaltered. We used ratios of the categories of "molluscs" and "shellfish" in national survey data to weight the species in these two categories and combine them into a single "mollusc" category. The time series of species estimates from this single "mollusc" category was then applied to the FAO category 'marine molluscs nei' 1950 to 2010 (Appendix Table A2).

Similarly to the "mollusc" category, all three categories "crustaceans", "molluscs" and "shellfish" in national data needed to be combined into a single estimate for application to the FAO category "aquatic invertebrates nei", and unreported invertebrate catches. Using the ratio of landings of these three categories in national market data (Faasili *et al.* 1997; Faasili *et al.* 1999) we derived a single species composition by weighting individual taxa (Appendix Table A2).

Unreported catches

Passfield (2001) separated seafood consumption into two components, seaweed and invertebrates (23%), and finfish (77%). Unreported subsistence and artisanal catches were disaggregated into these two categories for the entire time period assuming the ratio of these two components have remained stable in the Samoan diet over the time period considered. We assumed invertebrates represented the majority of the non-finfish consumption and considered the entire 23% to be invertebrates. For the finfish component, we modified the inshore species composition used to disaggregate the "marine fishes nei" category of the reported landings by excluding the pelagic species and applied this new breakdown to the unreported finfish catches (Appendix Table A3). We assumed unreported catches would consist predominately of species from the inshore regions as pelagic species are often better accounted for in the reported data, and Samoans mainly target inshore species for domestic consumption (Zann *et al.* 1985; Passfield 2001). To the invertebrate portion of unreported catches we applied the same taxonomic composition that was applied to the "aquatic invertebrate nei" category of the reported landings (Appendix Table A2).

By-catch

Reported amounts of by-catch (black marlin, blue marlin, striped marlin, and swordfish) were accepted as is. The "tuna-like fishes nei" category for 1978-1992 and 2001 was disaggregated using the 3-year average (2002-2004) of the proportions all non-shark species within the WCPFC by-catch data. The "tuna-like fishes nei" category in 2006 and 2007 was broken down using the same proportions of the 2006 and 2007 unreported tuna-like by-catch in those respective years. The species breakdown of the unreported tuna-like by-catch from 2002-2009 was determined directly from catch amounts of the determined unreported by-catch. Proportions from 2009 were utilized for 2010. The "sharks, rays, skates, etc. nei" category was disaggregated using the average proportions of shark species from the 2002-2009 WCPFC data. Note, however, that due to the large percentage of a miscellaneous shark category in this breakdown, half of the amount of miscellaneous shark was redistributed proportionally to the other categories. For 2002-2007, the respective yearly proportions from the WCPFC data were applied. In 2008-2009, unreported amounts were used directly and the 2009 proportions were used for 2010.

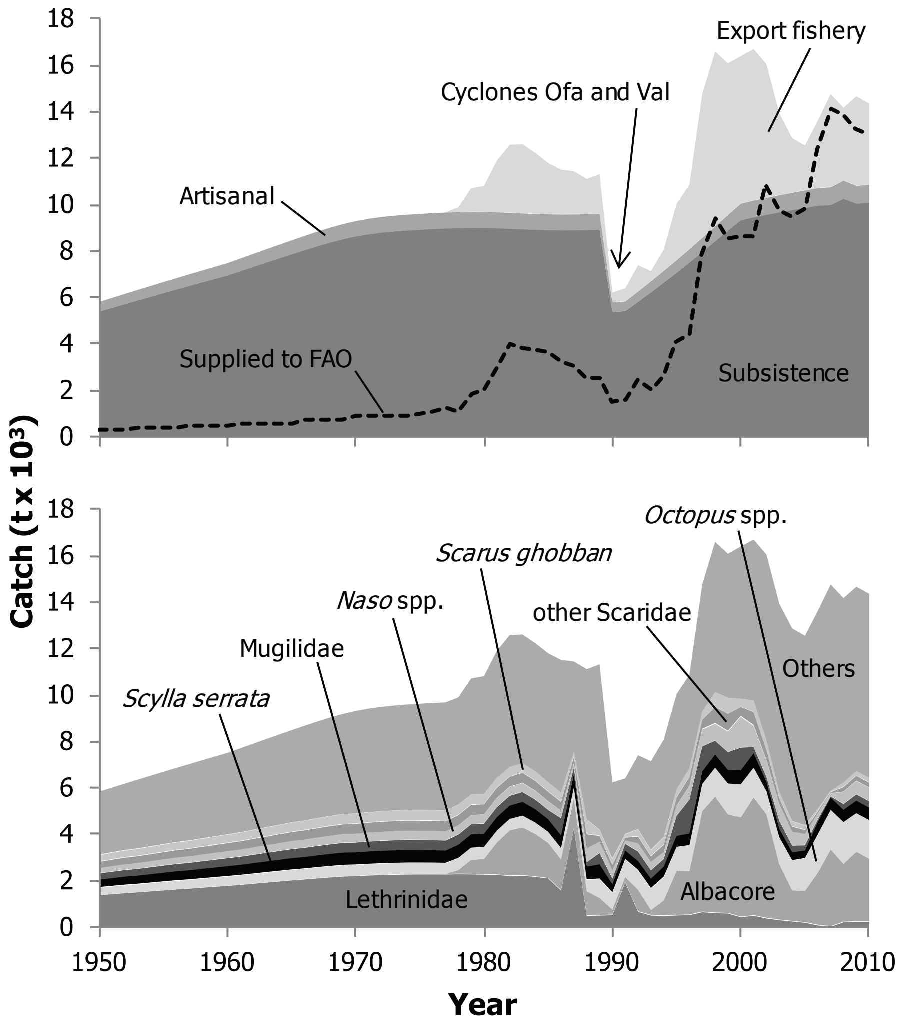

Figure 4. a) Total reconstructed catches for Samoa (by sector), 1950-2010, compared to the total reported landings. Export fishery refers to the tuna and other large pelagic catch that is destined for export and includes by-catch and discard estimates as well. This is part of the artisanal sector but has been separated to distinguish it from domestic catches. The sudden decrease in catches in 1990 was due to two successive cyclones. b) Total reconstructed catches for Samoa, 1950-2010, by major taxa.

Results

Total reconstructed catches were estimated to be 627,694 t over the 1950-2010 time period, which was 2.8 times the total reported landings (220,896 t) presented by the FAO on behalf of Samoa (Figure 4a, Appendix Table A4). The most important taxa in terms of overall tonnage were: Lethrinidae, *Thunnus alalunga*, *Octopus* spp., *Scylla serrata* (mud crab), Mugilidae (mullets), *Naso* spp., *Scarus ghobban* (blue-barred parrotfish), and other Scaridae (parrotfishes), with respective tonnages of: 89,800 t; 66,600 t; 43,700 t; 32,200 t; 24,900 t; 24,900 t; 21,300 t; and 21,300 t (Figure 4b). Between 1950 and 2010, *Thunnus alalunga* contributions increased from 0.03% of the total catch to 18.6% of total catch, while Lethrinidae decreased substantially from 24.2% to 1.9% (Figure 4b, Table A5).

The total small-scale catch for the domestic market was estimated to be 533,000 t over the 1950 to 2010 time period (Figure 3). This consisted of 402,600 t of unreported catches and 130,200 t of reported catches. Artisanal and subsistence sectors contributed 7% and 93%, respectively. Total domestic artisanal catches were estimated to be 38,100 t (Figure 4a). The domestic artisanal fishery catch was dominated taxonomically by Lethrinidae (6,400 t), *Octopus* spp. (3,100 t), *Scylla serrata* (2,300 t), Mugilidae (1,800 t), *Naso* spp. (1,800 t), *Scarus ghobban* (1,500 t) and other Scaridae (1,500 t). Total subsistence catches, over the 1950 to 2010 time period, were approximately 494,750 t (Figure 4a). Lethrinidae represented the largest individual contribution with catches of 83,300 t (Figure 4b). Other important taxa in this sector were *Octopus* spp. (40,600 t), *Scylla serrata* (29,900 t), Mugilidae (23,200 t), *Naso* spp. (23,200 t), *Scarus ghobban* (19,800 t), other Scaridae (19,800 t), *Tridacna maxima* (giant clam; 18,600 t), Labridae (sweetlips; 17,000 t), Carangidae (jacks and trevallies; 14,400 t), and Holocentridae (soildierfishes and squirrelfishes; 13,800 t; Figure 4b). Lethrinid catches decreased from 24.0% of total subsistence catches in 1950 to 2.5% in 2010. A decreasing trend was also seen in Holocentridae (from 4.0% in 1950 to 0.4% in 2010) and Labridae (from 5.3% in 1950 to 0.7% in 2010). In contrast, there was an increasing trend in the catches of *Octopus* spp. from 5% in 1950 to 15% in 2010.

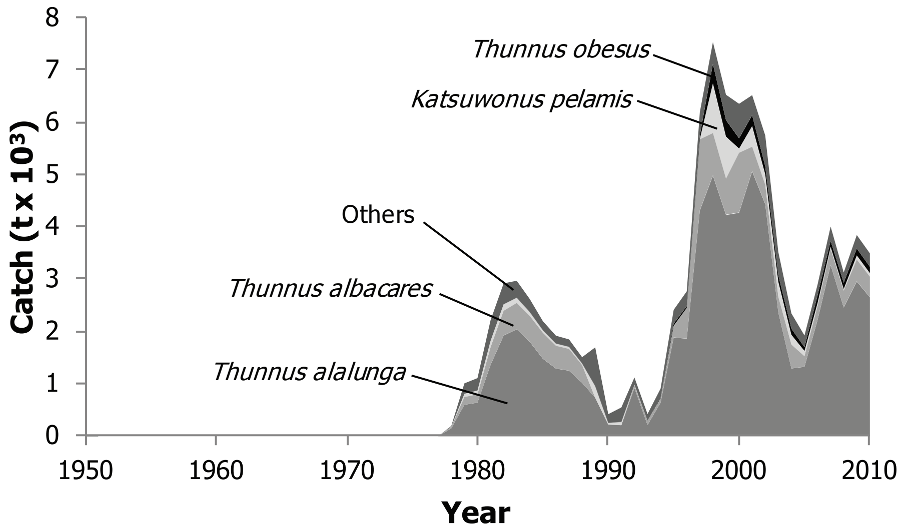

Figure 5. Total reconstructed catches of the export fishery in Samoa, 1950-2010. By-catch and discards are included.

Total reconstructed catch of the tuna and other large pelagic export fishery, from 1978–2010, was estimated to be 94,800 t (Figure 5). Catches were dominated by *Thunnus alalunga* (66,000 t). *Thunnus albacares*, *Katsuwonus pelamis,* and *T. obesus* were also substantial contributors to the catch, contributing 12,600 t, 4,300 t, and 2,300 t, respectively (Figure 5). Total catches of the export fishery included 90,700 t of reported landings. Total by-catch was estimated to be 10,750 t over the 1978–2010 period. This included 9,280 t reported by-catch which consisted of billfishes and miscellaneous tuna-like and shark categories which were further disaggregated in this study. Unreported by-catch in Samoa's tuna fishery was estimated at 1,470 t. The most abundant species caught as by-catch were unidentified sharks (1,730 t), *Acanthocybium solandri* (wahoo; 1,550 t), *Coryphaena hippurus* (dolphinfish; 1,360 t), *Katsuwonus pelamis* (1,100 t), and *Makaira mazara* (blue marlin; 840 t). Total discards of target species by the longline fishery from 1996-2010 were estimated at 2,700 t. This included 2,190 t of *Thunnus alalunga,* 300 t of *T. albacares* and 220 t of *T. obesus*.

As part of the allocation process, it was estimated that approximately 0.3% of the large-scale catches were taken from outside of the EEZ. These catches represent less than 0.05% of the total reconstructed catch.

Discussion

Our reconstructed total catch (1950–2010) for Samoa was 627,700 t, which is 2.8 times the reported landings of 220,900 t presented by the FAO on behalf of Samoa for the same time period. Reconstructed catches in 1950 were 20 times the reported amount, whereas in 2010, reconstructed catches are only 10% higher than the reported data. Importantly, while reported data suggest that Samoa's landings have been increasing since 2001, when we consider total catches (subsistence, artisanal, by-catch and discards) there is an overall declining trend since the peak of 16,700 t in 2001.

Although Samoa's reported landings showed an increasing trend in the early 2000s, reported landings of tuna species have been decreasing since 2001. Reported tuna landings decreased substantially in 2002, likely due to localized excessive effort by *alia* craft in areas of Samoa's EEZ accessible to these vessels (Imo *et al.* 2004; Barclay 2010). Since the mid 2000s, larger vessels have been in operation (Imo *et al.* 2004; Barclay 2010), and although small increases in catches have been achieved, catches have not again reached 2001 levels (Imo *et al.* 2004). The declines in tuna catches are concurrent with reports of declining CPUE, overall tuna catches (Mulipola 1998), and overfishing of bigeye and yellowfin stocks in the Western South Pacific area (Anon. 2010a). In response to these issues, Samoa has adopted the FFA policies for the conservation of tuna stocks, which includes a reduction in longline fishing by 10%, and temporal closures of FAD fishing in member country EEZs (Anon. 2010b). Samoa has also limited foreign participation in tuna fisheries which has resulted in the fishery remaining small in scale due to limited local capital (Read 2006).

In contrast to declining tuna resources, reported landings for the domestic market have been increasing since 2001, suggesting increasing pressure on these resources. During the 1990s, in response to the depletion of inshore resources from natural and anthropogenic disturbances, Samoa turned to small-scale aquaculture of nile tilapia (*Oreochromis niloticus*) as a way to increase domestic seafood production (Ponia 2004). Other conservation efforts have included giant clam nurseries in many villages (Anon. 2010b) and the translocation of other bivalve species to areas where they have been locally depleted (Anon. 2001). An additional factor which has helped to reduce pressure on species targeted for domestic consumption, was the sale of by-catch from the longline fishery at local markets in the mid 1990s (Chapman 1998; Passfield 2001).

Samoa's vulnerability to severe weather events and natural disasters is illustrated by the 1990 and 1991 cyclones which significantly damaged inshore reefs and incapacitated the offshore tuna fleet (Zann 1991). Samoa's islands were again affected by cyclone Heta in 2004, which severely damaged reefs in several villages (Samuelu and Sapatu 2007), and a major tsunami in 2010, which reduced catches in the short term (McAdoo *et al.* 2011). Following the tsunami, acute reductions (as much as 30%) in fish consumption was observed as affected villages were forced to find alternative food sources (McAdoo *et al.* 2011).

In addition to natural disruptions in resource use, human caused depletion of marine resources is a major concern to Samoa's food security. Compounding the effects of overfishing is pollution from sewage and other land-based activities which have caused the degradation of marine resources, particularly in the Apia area (Zann 1991; Samuelu and Sapatu 2007). Due to the volcanic geological origins of Samoa, there is limited arable land on either Savai'i or Upolu (Zann 1999). As a consequence, marine resources are the primary source of protein. Bell (2009) estimated that Samoa's marine resources are inadequate to ensure good health for the population into the future. Imports, if the population can afford to purchase them, could supplement the fish shortages forecasted by Bell (2009). However, the combination of Samoa's low *per capita* GDP and rising oil prices, suggests that the purchase of imports may not be a feasible long-term solution for Samoans. Furthermore, many of the countries in the Pacific region have experienced increased health problems associated with an increasingly westernized diet (Hawkes *et al.* 2010). In response to this and as a means of preserving the *fa'asamoa* culture, Samoa has deterred imports of unhealthy foods by imposing taxes on these items (Hawkes *et al.* 2010).

In recent years, there has been a renewed interest in community-based marine resources management in the Pacific region (Johannes 2002). Samoa, in particular, has moved to re-instate the *fa'amatai* system (King and Faasili 1999) for the management of inshore resources. In the 2009/2010 financial year, a total of 87 villages were implementing community-based management plans through village *fonos* and *matais* (Anon. 2010b). Strong local governance and recognition of community leadership by higher levels of government have been acknowledged as factors in the success of community-based management programs in other marine settings (Bueno-Cudney and Basurto 2009). In Samoa, the retained link to the *fa'asamoa* culture and *fa'amatai* system as well as the recognition of the *fa'amatai*, system by higher levels of government (King and Faasili 1999), likely contributed to the success of these programs in Samoa.

In this study of Samoan fisheries, we have linked historical and cultural aspects of Samoan fishing activities to reconstruct total marine fisheries catches over the last 60 years. Our reconstructed catches suggested a declining trend in overall tuna catches, and an increase in catches for domestic consumption. Despite an increasing trend in inshore catches, overall total fisheries catches show a declining trend, and are forecasted to be inadequate in meeting the future needs of the country in terms of food supply (Bell *et al.* 2009). Ensuring sustainable use of all marine resources, inshore and offshore, is imperative to both domestic food security and the economy of Samoa into the future.

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Appendix Table A1. Taxonomic composition (%) applied to the "marine fishes nei" FAO category for reported subsistence and artisanal catches.

Taxon	1950-1978	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001-2010
Acanthocybium solandri	0.14	0.45	0.49	0.53	0.57	0.58	0.59	0.60	0.61	0.62	0.56	0.49	0.46	0.41	0.47	0.15	0.31
Acanthurus lineatus	1.99	0.96	0.46	0.73	0.42	1.12	0.25	0.42	0.35	0.30	0.44	0.47	0.65	0.69	0.70	0.94	0.83
Ctenochaetus striatus	1.99	0.96	0.46	0.73	0.42	1.12	0.25	0.42	0.35	0.30	0.44	0.47	0.65	0.69	0.70	0.94	0.83
Naso unicornis	1.00	0.38	0.19	0.48	0.30	0.38	0.13	0.29	0.25	0.17	0.42	0.76	0.85	0.76	1.05	1.78	1.38
Naso spp.	3.01	1.14	0.56	1.43	0.91	1.14	0.38	0.86	0.76	0.51	1.26	2.29	2.55	2.28	3.16	5.33	4.13
other Acanthuridae	1.70	0.82	0.40	0.62	0.36	0.96	0.21	0.36	0.30	0.25	0.38	0.41	0.56	0.59	0.60	0.81	0.72
Coryphaena hippurus	0.35	1.16	1.26	1.36	1.46	1.49	1.51	1.54	1.56	1.59	1.43	1.27	0.98	0.67	1.15	0.41	0.69
Gymnosarda unicolor	0.12	0.41	0.45	0.49	0.52	0.53	0.54	0.55	0.56	0.57	0.51	0.45	0.23	0.00	0.06	0.03	0.11
Holocentridae	3.05	0.28	0.31	2.24	0.12	<0.01	<0.01	0.32	0.39	0.37	0.45	0.31	0.29	0.58	0.89	0.07	0.42
Istiophoridae	0.02	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.07	0.06	0.63	1.22	4.14	1.63	0.45
Katsuwonus pelamis	14.41	47.85	52.03	56.21	60.39	61.43	62.48	63.53	64.58	65.63	59.02	52.40	53.67	54.95	25.46	4.33	4.23
Kyphosus cinerascens	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.08	0.24	0.13	0.12	0.17	0.00	3.53
Labridae	3.96	0.20	0.07	3.29	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.14	0.13	0.21	0.10	1.65	0.44
Elagatis bipinulatus	0.03	0.11	0.12	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.12	0.11	0.09	0.06	0.01	0.00
Selar crumenophthalmus	0.99	1.26	0.03	0.00	0.09	0.00	0.32	0.05	0.01	0.63	0.65	0.18	0.32	0.19	0.23	0.49	0.12
other Carangidae	3.34	2.54	0.67	0.62	2.20	0.53	0.45	0.65	0.49	0.43	0.80	1.15	1.20	0.88	2.52	3.67	4.93
Lethrinus olivaceus	4.13	1.72	1.41	1.11	0.81	0.74	0.68	0.61	0.54	0.47	0.95	1.42	1.36	1.29	6.62	11.94	11.58
other Lethrinidae	18.21	5.96	13.27	1.29	1.00	1.75	5.57	1.72	1.14	0.90	1.61	2.27	2.46	2.04	2.27	1.90	2.11
Aphareus rutilans	1.04	0.43	0.35	0.28	0.20	0.19	0.17	0.15	0.14	0.12	0.24	0.36	0.34	0.32	1.66	2.99	2.91
Aprion virescens	1.02	0.42	0.35	0.27	0.20	0.18	0.17	0.15	0.13	0.12	0.23	0.35	0.34	0.32	1.63	2.95	2.86
Etelis spp.	3.38	1.41	1.16	0.91	0.66	0.61	0.55	0.50	0.44	0.39	0.78	1.16	1.11	1.06	5.42	9.78	9.49
Lutjanus gibbus	5.45	2.26	1.87	1.47	1.07	0.98	0.89	0.80	0.72	0.63	1.25	1.87	1.79	1.71	8.73	15.75	15.29
Lutjanus kasmira	0.31	0.13	0.11	0.08	0.06	0.06	0.05	0.05	0.04	0.04	0.07	0.11	0.10	0.10	0.50	0.90	0.87
Pristipomoides spp.	3.38	1.41	1.16	0.91	0.66	0.61	0.55	0.50	0.44	0.39	0.78	1.16	1.11	1.06	5.42	9.78	9.49
other Lutjanidae	0.55	0.53	0.16	0.00	0.37	0.00	0.00	0.39	0.47	0.29	0.40	0.36	0.28	0.24	0.27	0.09	0.68
Mugilidae	3.43	2.74	0.87	0.46	0.90	0.76	0.82	1.01	0.76	0.57	2.56	5.95	3.88	1.88	2.80	3.98	1.79
Mullidae	2.27	1.82	0.78	0.14	0.83	0.00	0.15	0.69	0.67	0.47	0.62	0.53	0.45	0.50	0.32	0.40	0.42
Gymnothorax spp.	1.13	0.42	0.11	0.62	0.17	0.20	0.04	0.11	0.16	0.19	0.37	0.57	0.48	0.35	0.34	0.53	0.76
other Muraenidae	1.13	0.42	0.11	0.62	0.17	0.20	0.04	0.11	0.16	0.19	0.37	0.57	0.48	0.35	0.34	0.53	0.76
Scarus ghobban	3.41	1.37	0.73	1.48	0.44	0.72	0.35	0.70	0.50	0.52	1.00	1.52	1.39	2.14	2.62	1.55	1.75
other Scaridae	3.41	1.37	0.73	1.48	0.44	0.72	0.35	0.70	0.50	0.52	1.00	1.52	1.39	2.14	2.62	1.55	1.75
Variola louti	0.15	0.06	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.04	0.05	0.05	0.05	0.25	0.44	0.43
other Serranidae	1.87	0.91	0.73	0.42	0.40	0.27	0.24	0.49	0.57	0.36	0.57	0.66	0.66	0.82	1.56	2.26	2.62
Sharks	1.47	0.61	0.50	0.39	0.29	0.26	0.24	0.22	0.19	0.17	0.34	0.50	0.48	0.46	2.59	4.34	4.32
Siganidae	0.28	0.25	0.10	0.00	1.19	0.00	0.00	0.16	0.22	0.19	0.25	0.20	0.23	0.17	0.27	0.82	0.47
Sphyraena fosteri	0.76	0.32	0.26	0.20	0.15	0.14	0.12	0.11	0.10	0.09	0.17	0.26	0.25	0.24	1.75	2.42	2.46
Thunnus alalunga	0.61	2.02	2.20	2.38	2.56	2.60	2.64	2.69	2.73	2.78	2.50	2.22	1.95	1.68	1.30	0.36	0.45
Thunnus albacares	3.36	11.17	12.15	13.12	14.10	14.34	14.59	14.83	15.08	15.32	13.78	12.23	14.12	16.08	8.29	1.63	1.54
Thunnus obesus	0.50	1.65	1.79	1.93	2.08	2.11	2.15	2.18	2.22	2.26	2.03	1.80	0.99	0.14	0.29	0.11	0.22
Xiphias gladius	0.17	0.55	0.60	0.65	0.70	0.71	0.72	0.73	0.75	0.76	0.68	0.61	0.31	0.00	0.02	0.01	0.36
Miscellaneous marine fish	2.49	1.49	0.92	0.81	2.51	2.29	1.57	0.56	0.87	0.66	0.73	0.50	0.61	0.53	0.63	0.73	1.51

Sources: Anon. (1995); Faasili et al. (1997); Faasili et al. (1999); Anon. (2000a); Anon. (2001); Anon. (2003). 1979-1985 was estimated from linear interpolation between 1978 and 1986 catch compositions. Data for 2001-2010 is displayed as the average composition of each species in that time period, as values did not change significantly.

Appendix Table A2. Species compositions of Samoa's invertebrate catches 1950-2010. Derived from Faasili *et al.* (1997, 1999) and Anon. (2001).

Crustaceans[a]				
Common name	**Samoan name**	**Scientific name**	**1950-2010**	
Lobster	–	*Panilurus penicillatus*	21.21	
Lobster	–	*Panilurus versicolor*	21.21	
Mud crabs	Paalimago	*Scylla serrata*	53.01	
Reef crabs	Paa aau	*Etisus spendidus*	2.72	
Slipper lobster	Papata,	*Parribacus calendonicus*	1.70	
other crabs	Isi paa	Other crabs	0.14	
Molluscs[b]				
Common name	**Samoan name**	**Scientific name**	**1950-1996**[c]	**2010**
Octopus	Fee	*Octopus* spp.	62.43	62.43
Topshells	Pu, alili	*Turbo mammorata*	2.34	2.34
Other molluscs	–	–	0.30	0.30
Giant clam	Faisua	*Tridacna maxima*	32.13	3.49
Giant clam	–	*Tridacna squamosa*	2.79	0.00
Cockle	–	–	0.00	30.79
Other bivalves	–	–	0.00	0.64
All invertebrates[d]				
Common name	**Samoan name**	**Scientific name**	**1996**[e]	**1997**[f]
Octopus	Fee	*Octopus* spp.	23.77	23.77
Topshells	Pu, Alili	*Turbo mammorata*	0.89	0.89
Other molluscs	–	–	0.12	0.12
Giant clam	Faisua	*Tridacna maxima*	16.80	18.23
Giant clam	–	*Tridacna squamosa*	1.46	0.00
Cockle	–	–	0.25	0.26
Other bivalves	–	–	0.29	0.30
Lobster	–	*Panilurus penicillatus*	11.97	11.97
Lobster	–	*Panilurus versicolor*	11.97	11.97
Mud crabs	Paalimago	*Scylla serrata*	29.91	29.91
Reef crabs	Pa aau	*Etisus spendidus*	1.54	1.54
Slipper lobster	Papata	*Parribacus calendonicus*	0.96	0.96
Other crabs	Isi paa	–	0.08	0.08

[a] Applied to the "marine crustacean nei" category of FAO data
[b] Applied to the "marine molluscs nei' category of FAO data
[c] Between 1996 and 2010 linear interpolation was applied
[d] Applied to "aquatic invertebrates nei" category of FAO data, as well as unreported invertebrate catches
[e] From 1950 to 1996 the proportions of *Tridacna maxima*, *Tridacna squamosa*, cockle and other bivalves changed relative to each other as linear interpolation was done to account for the appearance of cockle and other bivalves in 1997 market survey data
[f] From 1997 to 2010 the proportions of *Tridacna maxima*, *Tridacna squamosa,* cockle and other bivalves changed relative to each other as linear interpolation was done to account for the disappearance of *T. squamosa* after 1997, and decrease of *T. maxima* to 10% of mollusc landings in 2010

Appendix Table A3. Taxonomic composition (%) applied to the finfish component of unreported subsistence and artisanal catches.

Taxon name	1950-1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003-2010
Acanthurus lineatus	3.47	3.85	2.22	4.33	3.30	9.62	2.32	4.39	4.19	4.01	3.18	2.34	3.46	3.98	3.35	3.86	3.62	3.62	2.98
Ctenochaetus striatus	3.47	3.85	2.22	4.33	3.30	9.62	2.32	4.39	4.19	4.01	3.18	2.34	3.46	3.98	3.35	3.86	3.62	3.62	2.98
Naso unicornis	1.75	1.52	0.89	2.85	2.39	3.27	1.18	3.01	2.99	2.32	3.04	3.77	4.52	4.39	5.06	7.28	4.76	4.76	5.40
Naso spp.	5.26	4.57	2.67	8.54	7.17	9.80	3.54	9.04	8.97	6.95	9.13	11.31	13.55	13.17	15.17	21.85	14.27	14.27	16.20
other Acanthuridae	2.97	3.30	1.91	3.71	2.83	8.25	1.99	3.76	3.59	3.44	2.72	2.01	2.96	3.41	2.87	3.31	3.10	3.10	2.55
Selar crumenophthalmus	1.74	5.08	0.13	0.00	0.69	0.00	3.05	0.48	0.08	8.48	4.69	0.90	1.70	1.10	1.12	2.03	0.00	0.00	0.62
other Carangidae	3.61	8.08	1.11	1.63	15.37	2.60	2.27	4.82	3.84	3.85	3.68	3.50	4.19	2.79	2.34	0.00	7.63	7.63	4.19
Chanos chanos	0.00	0.00	0.00	0.00	10.79	0.00	0.00	0.00	1.52	0.73	0.36	0.00	0.30	0.20	0.00	0.00	0.00	0.00	0.00
Gerridae	1.51	0.81	0.09	3.62	0.00	0.00	0.23	0.48	2.71	2.55	1.27	0.00	0.30	0.20	0.00	0.00	0.00	0.00	0.00
Holocentridae	5.28	1.10	1.44	13.31	0.90	0.00	0.00	3.37	4.55	4.97	3.23	1.50	1.50	3.29	4.08	0.00	1.48	1.48	1.28
Kyphosus cinerascens	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.60	1.20	0.70	0.70	0.84	0.00	1.96	1.96	17.89
Labridae	6.92	0.81	0.33	19.60	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.70	0.70	1.20	0.47	6.76	0.00	0.00	2.32
Leiognathidae	0.00	0.00	0.00	0.00	7.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lethrinidae	31.81	23.96	63.77	7.68	7.88	15.04	52.62	18.07	13.43	12.14	11.67	11.19	13.07	11.78	10.88	7.76	8.36	8.36	7.83
Lutjanidae	0.96	2.11	0.76	0.00	2.91	0.00	0.00	4.10	5.53	3.94	2.87	1.80	1.50	1.40	1.28	0.35	4.66	4.66	1.77
Mugilidae	5.99	11.01	4.20	2.77	7.07	6.49	7.78	10.60	8.99	7.66	18.52	29.37	20.66	10.88	13.42	16.30	4.15	4.15	7.82
Mullidae	3.96	7.31	3.73	0.84	6.52	0.00	1.38	7.23	7.88	6.31	4.46	2.60	2.40	2.89	1.55	1.62	2.11	2.11	1.37
Gymnothorax spp.	1.98	1.71	0.51	3.71	1.33	1.76	0.36	1.20	1.84	2.60	2.70	2.80	2.54	2.00	1.63	2.18	4.09	4.09	2.38
other Muraenidae	1.98	1.71	0.51	3.71	1.33	1.76	0.36	1.20	1.84	2.60	2.70	2.80	2.54	2.00	1.63	2.18	4.09	4.09	2.38
Scarus ghobban	5.95	5.50	3.50	8.85	3.46	6.21	3.27	7.35	5.87	7.02	7.26	7.49	7.39	12.38	12.58	6.34	8.58	8.58	5.88
other Scaridae	5.95	5.50	3.50	8.85	3.46	6.21	3.27	7.35	5.87	7.02	7.26	7.49	7.39	12.38	12.58	6.34	8.58	8.58	5.88
Serranidae	2.38	2.80	2.67	1.66	2.32	1.51	1.47	4.34	5.95	4.09	3.24	2.40	2.59	3.79	3.53	3.19	6.82	6.82	3.57
Siganidae	0.49	1.02	0.47	0.00	9.39	0.00	0.00	1.69	2.66	2.60	1.80	1.00	1.20	1.00	1.29	3.35	1.80	1.80	1.80
Miscellaneous marine fish	2.58	4.39	3.36	0.00	0.27	17.86	12.59	3.13	3.50	2.70	2.10	1.50	1.40	1.10	0.98	1.45	6.32	6.32	2.92

Sources: 1986-1994 (Anon., 1995); 1996 (Faasili et al., 1997); 1998 (Faasili et al., 1999); 1999 (Anon., 2000a); 2000 and 2001 (Anon., 2001); 2002 (Anon., 2003). In intervening years linear interpolation was used. For years 1950-1985 the average of 1986-1988 was used, and for 2003-2010 the average of 2000-2002 was used.

Appendix Table A4. FAO landings vs. total reconstructed catch, as well as catch by sector, for Samoa, 1950-2010, in tonnes.

Year	FAO Landings	Total reconstructed catch	Subsistence	Artisanal	Export fishery
1950	300	5,822	5,406	416	0
1951	300	5,996	5,568	429	0
1952	300	6,169	5,728	441	0
1953	400	6,341	5,887	453	0
1954	400	6,510	6,045	466	0
1955	400	6,679	6,201	478	0
1956	400	6,845	6,356	489	0
1957	500	7,010	6,509	501	0
1958	500	7,174	6,661	513	0
1959	500	7,336	6,811	525	0
1960	500	7,496	6,960	536	0
1961	600	7,695	7,145	550	0
1962	600	7,894	7,329	564	0
1963	600	8,091	7,512	579	0
1964	600	8,286	7,694	592	0
1965	600	8,479	7,873	606	0
1966	700	8,669	8,049	620	0
1967	700	8,854	8,221	633	0
1968	700	9,027	8,382	645	0
1969	700	9,181	8,525	656	0
1970	900	9,310	8,644	666	0
1971	900	9,412	8,739	673	0
1972	900	9,488	8,810	678	0
1973	900	9,544	8,862	682	0
1974	900	9,588	8,902	686	0
1975	1,000	9,624	8,936	688	0
1976	1,100	9,655	8,965	690	0
1977	1,250	9,680	8,988	692	0
1978	1,090	9,897	9,005	693	198
1979	1,890	10,717	9,013	694	1,010
1980	1,990	10,814	9,010	694	1,110
1981	3,095	11,905	8,997	693	2,215
1982	4,020	12,588	8,977	691	2,920
1983	3,820	12,612	8,953	689	2,970
1984	3,720	12,239	8,931	688	2,620
1985	3,641	11,801	8,917	687	2,198
1986	3,186	11,517	8,911	686	1,920
1987	3,076	11,449	8,912	686	1,850
1988	2,500	11,119	8,922	687	1,510
1989	2,530	11,323	8,937	688	1,698
1990	1,505	6,229	5,392	415	422
1991	1,595	6,400	5,432	418	550
1992	2,436	7,401	5,830	449	1,122
1993	1,986	7,141	6,237	480	424
1994	2,591	8,077	6,654	512	911
1995	4,094	10,042	7,082	545	2,414
1996	4,410	10,870	7,523	579	2,768
1997	7,867	14,780	7,974	614	6,192
1998	9,364	16,611	8,433	649	7,529
1999	8,562	16,099	8,891	685	6,523
2000	8,594	16,413	9,344	720	6,350
2001	8,612	16,712	9,468	729	6,515
2002	10,880	16,062	9,579	738	5,746
2003	9,702	13,945	9,681	745	3,519
2004	9,455	12,877	9,777	753	2,347
2005	9,835	12,558	9,874	760	1,924
2006	12,434	13,635	9,970	768	2,897
2007	14,090	14,773	9,998	770	4,005
2008	13,898	14,186	10,267	791	3,128
2009	13,278	14,678	10,060	775	3,843
2010	12,999	14,368	10,097	778	3,493

Appendix Table A5. Total reconstructed catch (in tonnes) by major taxa for Samoa, 1950-2010.

Year	Lethrinidae	*Thunnus alalunga*	*Octopus* spp.	*Scylla serrata*	Mugilidae	*Naso* spp.	Other Scaridae	*Scarus ghobban*	Others
1950	1,410	2	299	377	266	233	264	264	2,707
1951	1,453	2	309	389	274	240	272	272	2,786
1952	1,496	2	318	400	282	247	280	280	2,864
1953	1,531	2	322	405	289	253	287	287	2,965
1954	1,573	2	331	417	296	260	294	294	3,042
1955	1,614	2	340	428	304	267	302	302	3,118
1956	1,655	2	349	440	312	274	310	310	3,193
1957	1,690	3	353	444	318	279	316	316	3,291
1958	1,730	3	362	455	326	286	324	324	3,365
1959	1,769	3	371	466	333	293	331	331	3,438
1960	1,809	3	379	477	341	299	338	338	3,511
1961	1,851	4	385	484	349	306	346	346	3,624
1962	1,900	4	395	498	358	314	355	355	3,714
1963	1,948	4	406	511	367	322	365	365	3,803
1964	1,996	4	417	524	376	330	374	374	3,892
1965	2,044	4	427	538	385	338	382	382	3,979
1966	2,084	4	432	544	393	345	390	390	4,088
1967	2,129	4	442	556	401	352	398	398	4,172
1968	2,172	4	451	568	409	359	406	406	4,250
1969	2,210	4	460	579	416	365	413	413	4,320
1970	2,229	5	456	574	420	369	417	417	4,424
1971	2,254	5	461	581	425	373	422	422	4,470
1972	2,272	5	466	586	428	376	425	425	4,504
1973	2,286	5	469	590	431	378	428	428	4,530
1974	2,297	5	471	593	433	380	430	430	4,549
1975	2,299	6	468	588	433	380	430	430	4,588
1976	2,301	7	464	584	433	380	430	430	4,625
1977	2,297	8	457	575	433	380	430	430	4,671
1978	2,310	155	509	616	435	382	432	432	4,625
1979	2,303	606	510	618	434	381	431	431	5,004
1980	2,292	648	510	618	432	379	429	429	5,079
1981	2,278	1,369	509	617	429	377	426	426	5,474
1982	2,234	1,933	496	611	421	369	418	418	5,687
1983	2,247	2,051	508	626	423	372	420	420	5,544
1984	2,196	1,817	493	608	414	363	411	411	5,526
1985	2,127	1,503	472	582	401	352	398	398	5,568
1986	1,612	1,314	477	590	740	307	370	370	5,737
1987	4,274	1,275	479	592	281	179	235	235	3,899
1988	523	1,042	486	604	189	581	603	603	6,488
1989	537	740	804	666	482	488	236	236	7,135
1990	552	228	705	406	238	360	228	228	3,283
1991	1,957	213	762	408	289	132	122	122	2,396
1992	697	928	833	429	409	348	283	283	3,190
1993	538	222	910	461	360	360	235	235	3,819
1994	517	651	997	486	326	296	299	299	4,206
1995	541	1,892	1,022	517	859	424	337	337	4,114
1996	556	1,868	1,106	545	1,459	562	372	372	4,031
1997	682	4,314	1,185	566	1,077	707	385	385	5,480
1998	642	4,979	1,263	586	593	718	675	675	6,480
1999	624	4,228	1,344	608	771	871	722	722	6,207
2000	465	4,265	1,436	626	977	1,310	380	380	6,572
2001	528	5,056	1,305	642	262	902	542	542	6,934
2002	413	4,445	1,008	428	205	705	423	423	8,012
2003	337	2,383	1,152	404	337	697	253	253	8,129
2004	282	1,316	1,279	394	282	584	212	212	8,315
2005	228	1,349	1,393	367	228	471	171	171	8,180
2006	114	2,243	1,641	566	114	237	86	86	8,548
2007	55	3,293	1,710	557	55	114	41	41	8,908
2008	247	2,486	1,794	566	247	511	186	186	7,963
2009	271	2,980	1,661	572	271	561	204	204	7,954
2010	272	2,679	1,659	576	272	563	204	204	7,938

Reconstructing marine fisheries catches in the Solomon Islands: 1950–2009[1]

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Abstract

The Solomon Islands are a large archipelago in the western Pacific Ocean with rich marine resources. The socioeconomic welfare and food security of the country relies heavily on its fisheries. Global markets, localized population growth, increased migration to urban centres, and growing fishing technology and pressure threaten to undermine many of the Solomon Islands' small-scale fisheries, while the presence of joint venture and foreign access commercial tuna fishing fleets is likely to expand due to international demand and foreign exchange income opportunities. The ability to meet domestic seafood demands may be undermined by declining local stocks, and the extent of domestic fishing pressure is underappreciated due to incomplete national fisheries statistics. National reports are concerned with the large-scale commercial fishing sector, and greatly underestimate the contribution of domestic small-scale fisheries. This study provides a reconstruction of the national fisheries data, as reported by the Solomon Islands to the FAO, but inclusive of the domestic commercial tuna industry, and artisanal and subsistence fisheries estimates. Total reconstructed fisheries removals of the Solomon Islands were estimated to be approximately 1.87 million tonnes over the 1950-2009[2] time period. While this estimate is only slightly higher than total landings reported by the FAO on behalf of the Solomon Islands (1.81 million t), it includes 211,000 t of unreported subsistence catch, 29,000 t of unreported artisanal shark catches and 18,000 t of unreported by-catch associated with the commercial tuna fishery.

Introduction

The Solomon Islands are situated between 5°–13°S and 155°–158°E in the south-western Pacific Ocean (Figure 1). The Main Group Archipelago (MGA) consists of a double chain of 6 large islands: Choiseul, Santa Isabel, New Georgia, Malaita, Guadalcanal and San Cristobal (Richards *et al.* 1994). The Solomon Islands includes the MGA in addition to hundreds of other small islands. The capital, Honiara, is located on the island of Guadalcanal.

The total land area of the Solomon Islands is over 27,500 km², with a 2009 population estimate of 523,000. The Exclusive Economic Zone (EEZ), declared in 1978, is 1.5 million km² (www.seaaroundus.org; accessed July 2011). These islands support some of the world's largest lagoons, and fringing and barrier coral reefs along an extensive coastline (Skewes 1990). Formerly a British Protectorate, the Solomon Islands achieved independence in 1977. The islands are high and volcanic, densely forested (though heavily logged), with large mangrove forests, coral reefs and lagoons. The fertile soil supports a growing agricultural sector. The majority of the population lives in small to medium sized coastal villages, although there are considerable inland populations on some major islands (Hviding 1998), and a growing migration to urban centers. Previously lucrative export commodities such as copra, palm oil, timber and minerals have declined in recent years, leaving fishery products as the remaining prospective export.

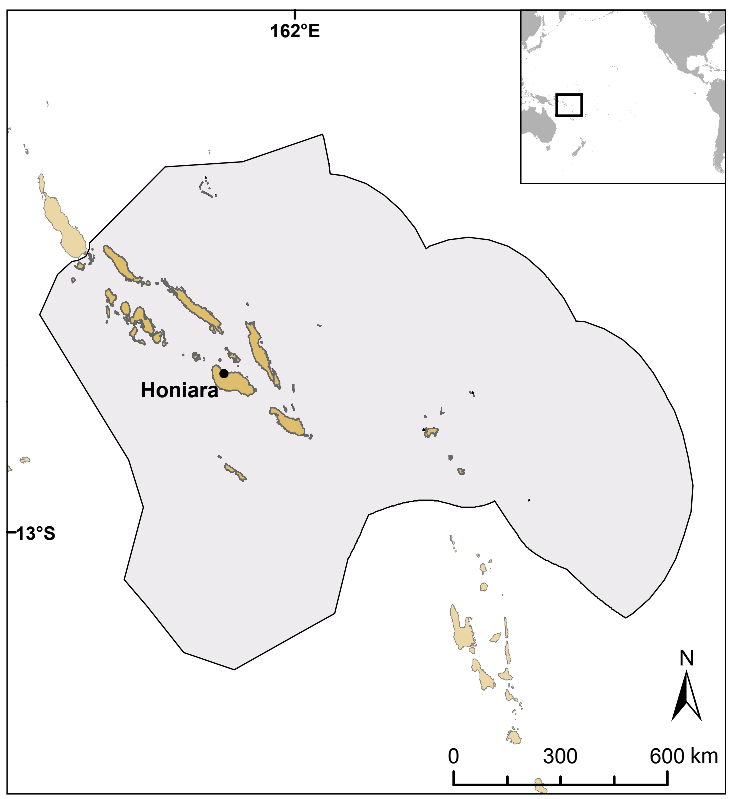

Figure 1. Location of the Solomon Islands and its capital, Honiara. The solid line represents the EEZ.

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[2] See addendum for updating dataset to 2010.

Small-scale fisheries

Traditionally, the Solomon Islands have been largely a non-market economy until at least the 1970s (Barclay and Cartwright 2007), and unsurprisingly, local subsistence fisheries play an important role. The importance of this sector in fisheries is generally poorly reflected globally in catch statistics (Zeller *et al.* 2007), as the available data are thought to be highly unreliable (Gillett 2005). National food security relies heavily on these fisheries, as the local diet is largely based on marine-derived protein coupled with carbohydrates from root crops (Hviding 1998). Fishing gears employed by subsistence fishers include handline (most common) and dropline, troll, spear, gill nets (seasonally), and *buna* – a poison derived from a local vine plant used on coral reefs (Richards *et al.* 1994). In some areas of the Solomon Islands, religious groups (e.g., the Seventh Day Adventist Church) prohibit the consumption of shellfish or fish without scales.

A large portion of the artisanal fishery is carried out using dugout canoes. The finfish catch is primarily comprised of lutjanids (snappers), serranids (groupers), lethrinids (emperors), scombrids (mackerels), and carangids (trevallies; Richards *et al.* 1994). Small-scale tuna fishing does occur in the Solomon Islands, as tuna remains a culturally significant food source for coastal villages (Barclay and Cartwright 2007). Reporting of small-scale tuna fisheries is negligible, suggesting that tuna caught by this sector involves only a select number of villagers who possess the capacity to do so. Estimates of tuna catches by subsistence or artisanal fishers were unavailable, but are thought to be small relative to the large-scale commercial sector, and are not specifically considered in this reconstruction. There have been complaints from the islanders, however, that local tuna catches are declining as a result of the commercial fishing fleets and baitfish fishery.

Other commercially valuable marine exports (e.g., *bêche-de-mer* and trochus) are produced in a manner that resembles artisanal rather than large-scale commercial fisheries (Gillett 2005). Sea cucumbers are not part of the local subsistence diet and are largely exported to China and Southeast Asia in the form of dried *bêche-de-mer*. Trochus meat, however, is consumed by villagers before the shells are sold to foreign markets (Japan and Southeast Asia) or domestic button factories (Richards *et al.* 1994). Aquaculture is a growing practice in the Solomon Islands to farm oysters, prawns, clams, and seaweed; however, this study considers only marine wild capture fisheries.

Subsistence fisheries have existed in the Solomon Islands for centuries. Though managed according to customary traditions, subsistence fishing pressure is high enough to threaten local species, such as giant clams (*Tridacna* spp.) which have been extirpated from some areas (Richards *et al.* 1994). Coastal fisheries are increasingly under threat from a number of factors, such as agricultural development, mining and logging, which are jeopardizing the health of coastal reefs and lagoons. Coupled with the harvesting of mangrove trees and corals, this has a substantial impact on the coastal fisheries. The harvesting of mangrove wood to fuel the fires used in drying *bêche-de-mer* greatly increased in the late 1980s and early 1990s (Adams and Dalzell 1994).

More recently, changes in social structure are also having an influence on fisheries. The shift from community-cooperation to cash markets threatens the status of village chiefs, although traditional authority remains strong today (Gillett 2007). Women's role in reef fishing is increasing, both in subsistence and artisanal sectors, further adding to fishing effort and pressure (Agassi 2005). Although growing urban consumption demands will be supplemented with alternative sources (e.g., imports), the increasing national population will inevitably maintain pressure on artisanal and subsistence fisheries.

Commercial tuna fishery

The only large-scale commercial fishery in the Solomon Islands is for tuna. The large-scale commercial tuna fishery was virtually non-existent before a Japanese survey documented a large supply of tuna and associated baitfish in 1970. This survey marked the establishment of the Solomon Islands Fisheries Department. The Solomon Islands Government signed a joint venture agreement with the Japanese Taiyo Gyogyo Fishing Company in 1972. This venture produced the first domestic pole-and-line and purse seine fleet, Solomon Taiyo Ltd. (STL; Anon. 1988). STL was to progressively develop and expand the commercial fishery, and was granted the exclusive right, other than by fully local companies, to fish within the territorial waters (Evans and Nichols 1985).

In 1977, a joint venture was formed between the government and STL, establishing the second domestic commercial pole-and-line fishing company, National Fisheries Development Limited (NFD). The purpose of this venture was to develop a national fishing fleet employing Solomon Islanders as a way to stimulate local involvement in the commercial tuna industry and supply additional fish to STL. The initial joint venture agreement deemed STL responsible for receiving, processing and marketing all commercial tuna catches in the country (Anon. 1988), from both STL and NFD. Domestic purse seine operations began in 1980. NFD was later sold to the Canadian company, BC Packers (Lewis 2005), and again to Trimarine Corporation (FAO 2002) based in Singapore.

There is little mention of a third joint venture agreement with the Philippines leading to the formation of the company Markirabelle. Both Trimarine (BC Packers) and Markirabelle catch and export tuna with no land-based processing (Anon. 1993). This type of agreement is referred to as transshipment, and is a widespread problem which complicates fisheries management and global catch estimates, as catches are landed in countries other than where or by whom they were caught. The Solomon Islands Government allotted Markirabelle an annual allowable tuna catch of 35,000 t. In 1991, Markirabelle was reportedly under producing at 1,000 t (Anon. 1993) per year. As cited in Gillett (2009), a total of 121 transshipments by foreign purse seine vessels occurred at the Honiara Port during 2005, with 65,616 t of skipjack tuna (*Katsuwonus pelamis*) and 13,012 t of yellowfin tuna (*Thunnus albacares*) being transshipped. Substantive revenues amounting to millions of SI dollars were collected by the government from these transshipments. No further information on transshipments was available at the time of the reconstruction, but this practice is likely continuing.

Japanese fleets were present in the Solomon Islands' waters as early as the 1930s, with no available quantitative records. Between 1980 and 2006, several foreign access agreements were negotiated with Japan, Republic of China, Republic of Korea, USA, Vanuatu, Fiji, the Federated States of Micronesia, Spain, France, and Portugal (Access Agreement Database, unpublished data, *Sea Around Us* project). Access fees account for 0.1% (US$1,707,000; Gillett 2007) of the SI gross domestic product (GDP), based on a 2001 estimate by Gillett and Lightfoot (2001). Fishing contributes 12.8%, or approximately US$36 million to the SI GDP (Gillett 2007). Japanese longline and pole-and-line vessels, and US Multilateral Fishing Treaty vessels, appear to be the only fleets actively exercising foreign access in Solomon Islands' waters as documented in national reports.

The catch of the commercial tuna industry is largely composed of skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*). Associated with the tuna fishery is the capture of valuable non-target species including marlin, sailfish and shark (Gillett 2005). Tuna accounts for 90% of the marine exports of Solomon Islands, primarily frozen or canned. In 1999, 65% of STL's catch was canned, 20% exported frozen, 13% smoked, and 2% made into fish meal (Government of Solomon Islands 1999, in Barclay and Cartwright, 2007). The vast majority of tuna exports are destined for Japan, the UK, and Thailand. In 2001, there was far less fishing, most of the production was for local processing (canning and smoking) and much less frozen tuna was exported (FAO 2002), presumably due to ongoing domestic conflicts.

Civil war broke out in the late 1990s, culminating in the overthrow of the government in June of 2000 (Barclay and Cartwright 2007) and the subsequent closure of all major industries, including fishing enterprises (FAO 2002). The country remained dysfunctional until 2003, when the Australian police and military led the Regional Assistance Mission to Solomon Islands (RAMSI) to re-establish order (Barclay and Cartwright 2007). Tuna canneries were closed but have since re-opened under local management, though exports remain low.

The coastal areas were struck by a major earthquake and tsunami in 2007, further hindering the coastal commercial and subsistence fisheries. A decline is evident in reported commercial tuna landings after 2007, likely as a result of damaged boats and/or lack of fishery statistical collection following the tsunami. Commercial tuna catches remain well below those recorded before the year 2000.

In terms of governance, the Solomon Islands have been recognized as being corrupt in fisheries management and other governance issues in the Pacific Islands region (Hanich and Tsamenyi 2009). The Fisheries Department suffers from a lack of human and financial resources, in addition to problems of transparency and accountability. There are no published annual fisheries reports for the 1994-2004 time period, although Solomon Islands continued to collect data for the Secretariat of the Pacific Community (SPC) and Forum Fisheries Agency (FFA; Barclay and Cartwright 2007). A domestic audit of the Fisheries Department in 2003 revealed that millions of US dollars from distant water access fees had "disappeared into someone's pocket" (Islands Business 2005, as cited by Barclay and Cartwright 2007). Steps are being taken to improve accountability and build the capacity of the Fisheries Department.

Marine tenure

Adding to the governance situation for commercial, subsistence and artisanal fisheries in the Solomon Islands is the presence of customary marine tenure. Most rural land and virtually all reefs are managed by a complex and dynamic system, whereby kinship-based groups exert control over designated areas and associated resources (Skewes 1990). The leaders of such kin groups are referred to as chiefs. Based on traditional knowledge, chiefs monitor the state of their resources and enforce necessary harvest restrictions on reef areas or specific species. In Morovo Lagoon, for instance, tenure rights include limited entry to the fishing grounds, the complete prohibition of dynamite, and partial bans on gillnets, spearfishing, and fish poisons. There were also temporary closures of fishing grounds to allow for fish populations to rebuild (Hviding and Baines 1994).

All coastal resource development initiatives are assessed by local chiefs. Commercial fishing companies respect customary marine tenures by paying royalties to the chiefs who "own" the baitfish fishing grounds. Fisheries managers also work to integrate traditional values with fisheries development aspirations (Skewes 1990). The Provincial Government Act of 1981 specifies that provincial jurisdiction cannot override customary law (Hviding 1998).

The purpose of this study was to provide a more accurate depiction of total marine fisheries extractions by the Solomon Islands than is currently available from data presented by the FAO on behalf of the Solomon Islands. The FAO FishStat database offers time series data on marine fisheries landings from 1950 to 2009. This study estimates unreported catches as well as reviewing reported landings and export data.

Methods

Small- and large-scale domestic fisheries catches were estimated using reported and unreported data for the period 1950-2009. Reported landings were obtained from the FAO FishStat database and government reports, whereas unreported estimates were based on independent studies. Domestic commercial tuna landings from national reports were compared to FAO data, supplemented by data from independent studies. Artisanal and subsistence estimates were based on subsistence catch estimates converted to *per capita* catch rates using human population data.

Demographics

Census data were obtained from two online population statistic databases to complete a time series from 1950-2009. Census information for 1950-1960 was derived from Populstat (Figure 2; www.populstat.info; accessed April, 2011) and data from the World Bank (data.worldbank.org; accessed April, 2011) was used from 1960-2009. The majority of the population of Solomon Islands in the recent period lives in rural areas (80% rural and 20% urban: www.indexmundi.com; accessed April, 2011). Cash markets and lucrative urban employment continue to drive the migration from rural to urban areas.

Tuna fishery

FAO tuna landings were compared to those reported in Annual Government reports from 1987, 1988, and 1993 (Anon. 1987, 1988, 1993), and independent studies conducted by Gillett (2007, 2009) and Barclay and Cartwright (2007). This comparison revealed relatively good transfer of commercial tuna data between the Solomon Islands government and the FAO. Therefore, FAO tuna data were accepted as the best available depiction of Solomon Islands large-scale tuna fishery catches. The notable decline in year 2000 tuna catches is thought to be the result of the civil tensions and resulting fisheries closures.

This section pertains to tuna production by the domestic and joint venture fleets, Solomon Taiyo Ltd. (STL) and National Fisheries Development Ltd. (NFD). Foreign access fisheries are described separately (see *Foreign Fisheries*).

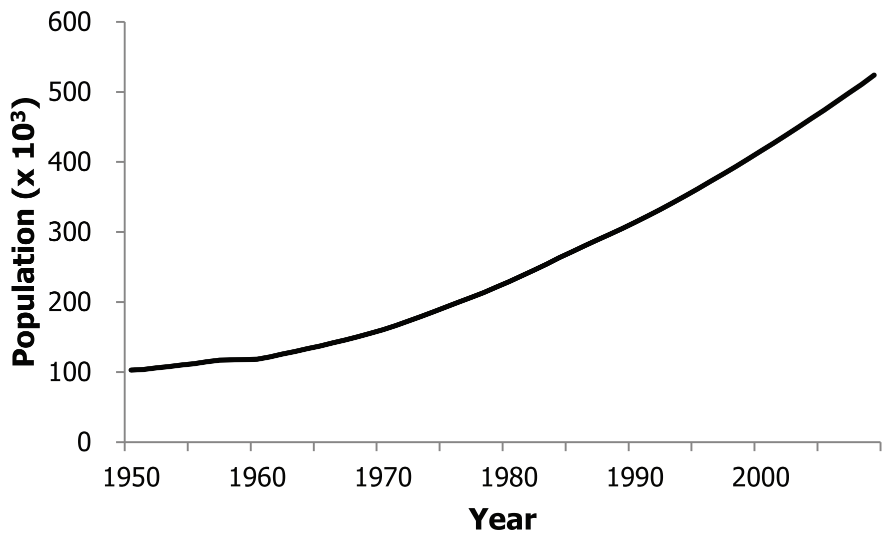

Figure 2. Human population of Solomon Islands, 1950-2009.

Comparing tuna production with tuna exports was indicative of the amount of tuna available for domestic consumption. The data suggest that between 2-20% (240 – 4,800 t·year^{-1}) of tuna production remains in the country each year. When exports collapsed in 2000, 94% (12,000 t) of tuna catches remained within the Solomon Islands.

Large-scale operations of tuna fishing can include fishing grounds outside of the EEZ. Therefore, data from the Forum Fisheries Agency (FFA) for albacore, bigeye, skipjack and yellowfin tuna, were used to determine the spatial allocation of the tuna catch. The FFA data were directly utilized to determine the proportions of the four tuna species inside the EEZ, in another country's EEZ and in the high seas, for the years 1997-2009. The ratio of catches inside to outside the EEZ in 1997 was used to allocate the catches for all previous years.

By-catch

Large, non-tuna pelagic species are often caught alongside the tuna fishery as non-targeted by-catch. Gillett (2009) adjusted reported tuna catches by 30% for longliners and 5% for seiners to account for by-catch. Using the same catch rates, pelagic by-catch was calculated based on reported tuna catches by gear-type.

Prior to 1980, tuna were mainly targeted using pole-and-line. This relatively selective gear-type is associated with low levels of by-catch. The low catches of non-tuna pelagic species seen in national reports during the 1970s (Anon. 1987), and subsequent increase in the following years, likely reflects the change in gear-type from predominantly pole-and-line to less selective gears such as longline.

National and FAO categories for pelagic species other than tuna were assumed to represent landed by-catch from the large-scale commercial tuna industry. These landings were used in combination with calculated by-catch estimates, based on Gillett (2009), to account for the removal of non-tuna pelagic species from Solomon Islands' waters.

National tuna reports present an "others" category, assumed to be non-tuna pelagic species, which were the only available data source for the 1971-1979 time period. From 1980 to 1991, by-catch estimates from Gillett

Table 1. Species composition of shark catches in the Solomon Islands, based on Nichols (1992).

Taxon name	% of catch
Carcharhinus amblyrhynchos	15
Carcharhinus sorrah	15
Carcharhinus melanopterus	15
Triaenodon obesus[a]	15
Carcharhinus albimarginatus	10
Sphyrna lewini	10
Galeocerdo cuvieri	10
Other sharks	10

[a]Included only in the breakdown for the artisanal shark catches as it is a reef associated species. This species was excluded and the composition re-scaled for the breakdown of shark by-catch.

and Lightfoot (2001) were used. FAO landings for non-tuna pelagic species (black marlin, blue marlin, striped marlin, "marlins, sailfishes, etc. nei", "sharks, rays, skates, etc. nei", and swordfish) were used for 1995–1999. By-catch estimates based on Gillett and Lightfoot (2001) were used for 1999 to 2007, since these values seemed most accurate and consistent. A linear interpolation was used to complete the time series between the 1991 (by-catch estimate) and 1995 (FAO Landing) anchor points. Tuna catches by gear-type were unavailable for 2008 and 2009. Landings by gear-type were estimated for these years using an average percentage for the 2000–2007 time period. The Gillett and Lightfoot (2001) adjustments were then applied to estimate by-catch for 2008 and 2009.

FAO FishStat presents landings data for black marlin, blue marlin, stripped marlin, swordfish, a "sharks, rays, skates, etc. nei" category and a "marlins, sailfish, etc. nei" category. We applied the taxonomic composition of non-tuna pelagic species presented in the FAO data to estimates of unreported by-catch. The shark category was further disaggregated using species data presented in Nichols (1992; Table 1).

By-catch associated with the large-scale tuna fishery was also spatially allocated using the proportions of the spatial distribution for total tuna catches each year.

Baitfish

The baitfish fishery operated in parallel to the pole-and-line fishery for skipjack tuna (Evans and Nichols 1985) and was carried out through negotiations under local marine tenure. Baitfish does not appear to be exported from the Solomon Islands, as baitfish exports are prohibited under joint venture agreements. Baitfish catch has been systematically under-reported in the past (Evans and Nichols 1985) and records are assumed unreliable prior to 1981. Baitfish landings were reported in annual government reports (Anon. 1987, 1988, 1993). As we were unable to confirm otherwise, we assumed baitfish production was included in the FAO category "marine fishes nei" (MMF). Therefore, using national reports, we disaggregated baitfish catches from the MMF data. This portion of the MMF catch was then assigned to baitfish taxa, which included anchovies (Engraulidae), sprat and herring (Clupeidae) based on information presented in Evans and Nichols (1985; Table 2).

Table 2. Baitfish fishery taxonomic breakdown, based on Evans and Nichols (1985).

Common name	Taxon name	Catch (%)
Devis' anchovy	*Encrasicholina devisi*	40.0
Shorthead anchovy	*E. heteroloba*	40.0
Buccaneer anchovy	*E. punctifer*	5.0
Spotty-face anchovy	*Stolephorus waitei*	5.0
Indian anchovy	*S. indicus*	5.0
Sprat	*Spratelloides* spp.	2.5
Bluestripe herring	*Herklotsichthys quadrimaculatus*	2.5

Small-scale sector

Small-scale fisheries of the Solomon Islands were predominantly non-commercial (i.e., subsistence) in the early time period. The increasing migration of people to urban centers starting in the 1970s saw a shift from a mainly subsistence to an increasingly market-based economy. Exports of marine invertebrates existed as early as the 1950s; however, the export of marine products caught by small-scale commercial fishers became more prevalent in later decades. Small-scale catches destined for export consisted mainly of marine molluscs. These catches appear to be relatively well reflected in the official landings data. This sub-sector of the artisanal fishery is considered further in the *Export fisheries* section.

Table 3. Anchor points used in calculating subsistence and artisanal catch for Solomon Islands, 1950-2009.

Year	Population	Catch (t)		Catch rate (kg/person/year)		Source
		Subsistence	Artisanal[a]	Subsistence	Artisanal	
1945	-	-	-	-	0.0	Assumption[b]
1950	103,000	-	-	60.0	-	Assumption[c]
1960	118,294	-	-	56.0	-	Assumption[d]
1970	160,668	-	-	52.0	-	Assumption[e]
1999	404,415	13,000	3,200	32.0	5.5	Gillett and Lightfoot (2001)
2002	438,317	13,000	3,100	30.0	5.2	Gillett (2005)
2007	498,240	15,000	3,250	30.1	5.6	Gillett (2007)

[a]Artisanal catches were adjusted using baitfish catch estimates to reflect only domestic consumption sales; [b]Artisanal catch rate was assumed to be zero in 1945; [c]1950 subsistence catch rate assumed to be 60% higher than 1999 combined subsistence and artisanal catch rates; [d]1960 subsistence catch rate assumed to be 50% higher than the 1999 combined subsistence and artisanal catch rates; [e]1970 subsistence catch rate assumed to be 40% higher than 1999 combined subsistence and artisanal catch rates.

While no system existed in the early time period for the collection of small-scale catch data (aside from exports), rough estimates were likely made based on consumption data (Cook 1988). The FAO "marine fishes nei" category was therefore assumed to include some portion of the small-scale finfish catches.

Subsistence and artisanal catches were estimated by Gillett and Lightfoot (2001) to be 13,000 t in the late 1990s. Gillett (2005) provides subsistence and artisanal catch estimates of 13,000 t and 3,100 t, respectively for 2002, while Gillett (2007) provides subsistence and artisanal catch estimates of 15,000 t and 3,250 t, respectively for 2007. Coastal commercial catches estimated by Gillett and Lightfoot (2001) include catches from the industrial baitfish fishery. Baitfish catches were therefore subtracted from the artisanal catch estimates to derive the portion of the catch for domestic consumption. Subsistence and artisanal catch estimates for 1999, 2002 and 2007 (adjusted to reflect only the domestic consumption portion) were used in combination with population data to calculate *per capita* subsistence and artisanal catch rates (Table 3). The *per capita* catch rates of 1999, 2002, and 2007 were used as anchor points to calculate catch rates and landings for the remainder of the time period, with catch rates being interpolated between these years.

In 1950, we assumed a subsistence catch rate of 60 kg·person^{-1}·year^{-1}, based on the assumption that the catch rate was 60% higher than the 1999 small-scale catch rate (subsistence and artisanal combined). For 1960, the subsistence catch rate was assumed to be 50% higher (i.e., 56 kg·person^{-1}·year^{-1}) than the 1999 combined subsistence and artisanal small-scale rates. The subsistence catch rate in 1970 was assumed to be 40% higher (i.e., 52 kg·person^{-1}·year^{-1}) than the combined 1999 rates (Table 3). For the artisanal (i.e., commercial) catch rate, we assumed zero catches in 1945, increasing gradually after WWII. Linear interpolations between anchor points (Table 3) were made to derive a complete time series of subsistence and artisanal catch rates from 1950-2009. These catch rates were applied to the total population to derive total subsistence and artisanal catches.

Table 4. Taxonomic composition % of the artisanal and subsistence sector based on Dalzell and Preston (1992), Gillett (2007) and Richards *et al.* (1994).

Taxon name	Artisanal (%)	Subsistence (%)
Etelinae	30.50	0.0
Apsilinae	30.50	0.0
Lutjanidae	14.30	26.6
Lethrinidae	0.40	0.7
Serranidae	10.80	19.4
Carangidae	0.95	1.7
Scombridae	0.95	1.7
Gempylidae	0.03	0.1
Sphyraenidae	7.80	14.0
other Teleosts	3.80	6.8
Birgus latro	n/a	10.0
Panulirus spp.	n/a	10.0
Tridacna spp.	n/a	10.0

The taxonomic composition of artisanal and subsistence catches was derived from Dalzell and Preston (1992) and Gillett (2007; Table 4). For the artisanal fishery, we applied only a taxonomic breakdown for fish species as we assumed the invertebrates reported by the FAO comprised the majority of commercial invertebrate catches. The taxonomic composition of the subsistence fishery included 30% invertebrates, which were assigned to taxa based on species presented in Richards *et al.* (1994; Table 4). The subsistence breakdown also excluded deepwater snappers of the Etelinae and Apsilinae sub-families, as these were assumed to be taken only by the commercial sector.

Live reef fish and other species

Live reef fish trade, aquarium collectors, tourism-related seafood consumption and sport fishing all contribute to additional marine removals; however, data on these were either unavailable and/or these sectors are not covered in this catch reconstruction (e.g., aquarium collectors). While there are reports of live export of coral trout, snappers and other groupers (FAO 2002), these have not been quantitatively accounted for. The Solomon Islands supply the Chinese Live Reef Food Fish (LRFF) trade to a lesser extent than other Indo-Pacific or Southeast Asian countries. Fishing trials for the LRFF began in the Solomon Islands in 1994 at spawning aggregation sites in Marovo Lagoon, followed by operations in Roviana Lagoon and Ontong Java (ADB 2004). A moratorium was placed on the LRFF in the Solomon Islands after trials were complete, and no LRFF fishing activities have commenced since it was lifted in 2000 (ADB 2004). After adverse social, economic and ecological repercussions of the LRFF, several marine tenures have created no-take zones.

There is an indigenous dolphin fishery that kills hundreds of dolphins each year (Barclay and Cartwright 2007), and which facilitated the live export of 28 dolphins to Mexico in 2003 and 30 to Dubai in 2007. This reconstruction excludes the aquarium trade and cetacean catches. Sport fishing and tourism-derived marine catches were unavailable at the time of the reconstruction but are thought to have low tonnage.

Foreign fisheries

Foreign tuna fisheries catch data are available in national reports from 1987, 1988 and 1993, as well as independent studies by Gillett (2005, 2007) and Barclay and Cartwright (2007). Foreign fisheries statistics have been included separately in this report to portray the additional fishing pressure present in the area (Appendix Table A3). These data are not included in the reconstruction of total fisheries removals by Solomon Islands' fisheries from Solomon Islands' waters.

Another issue of concern surrounding the foreign access fishery is the occurrence of non-tuna pelagic catches, considered by-catch in this report. Non-tuna pelagic catches were recorded in national reports (Anon. 1987, 1988, 1993) as either "other" or "billfish" caught by Japanese foreign based fleets (Appendix Table A4). Taxonomic breakdowns were not available, but were assumed to include the same species as domestic by-catch. No data were available for US purse seine tuna catches regarding non-tuna pelagics. Non-tuna pelagics caught by foreign based fleets are not included in the total reconstructed fish removals from the Solomon Islands.

Table 5. Trochus shell landings as compared to national export data.

Year	FAO trochus landings	National trochus data
1985	500	500
1986	662	662
1987	"44502"	445
1988	"46001"	460
1989	"37107"	371
1990	"30606"	300
1991	"8705"	87

[a]Data in quotation marks considered erroneous, see text.

Export fisheries

Triggered by the decline of the copra industry, an export market for marine products developed with trochus (*Trochus niloticus*), *bêche-de-mer*, shell, blacklip (*Pinctada margaritifera*) and goldlip (*P. maxima*) pearl oysters, green snail (*Turbo marmoratus*) and shark fins as the most valued products (Skewes 1990). In 1993, an export ban was placed on blacklip and goldlip oysters (Richards *et al.* 1994).

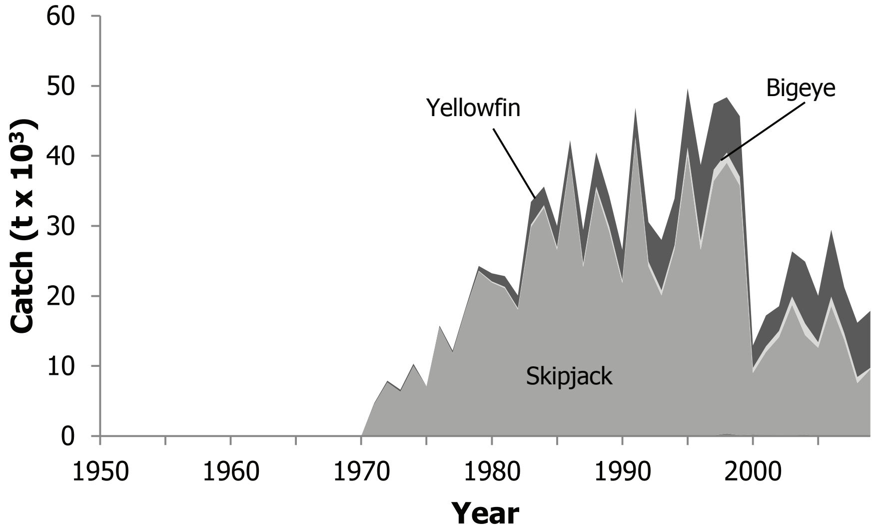

Figure 3. Domestic tuna landings as presented by the FAO on behalf of the Solomon Islands, 1950-2009. Note: Pacific bluefin tuna and albacore catches, although included in this graph, do not appear as catches are small.

<u>Sharks</u>

FAO trade data present quantities of exported shark fins (dried, salted, etc.) from 1987-2008. FAO shark fin exports were converted to whole (wet) weight equivalents using a conversion factor of 2.44% for the genus *Carcharhinus* (Biery 2012; Biery and Pauly 2012). Richard *et al.*'s (1994) estimate of 2 t of exported shark fins in 1985 was also converted to whole wet weight. Exported fins as presented by FAO trade data in 1995 were substantially higher than any other year of reported fin exports. Assuming that this was a data error, we used a five-year average (1993-1997) to represent fin exports for 1995. FAO exports in whole wet weight were then compared to FAO landings (assumed to be the reported by-catch from the industrial tuna fisheries) and estimates of unreported industrial shark by-catch. Export amounts in excess of the estimated shark by-catch, were assumed to be unreported artisanal sector catches of *Carcharhinus*. Sharks caught as by-catch in the artisanal fisheries are sold to the shark-fin export market, while subsistence fishers will consume the meat (Richards *et al.* 1994). Unreported artisanal shark catches for the early time period were estimated based on the first three years of available data (1985-1987) converted to a *per capita* rate and applied to the population from 1950-1984. From 2000 onward, we used the 1997-1999 average unreported artisanal shark estimate, carried forward unaltered to 2009.

<u>Invertebrates</u>

Bêche-de-mer: exports of non-fish marine species include substantial amounts of dried sea cucumber. These are among the most economically valuable resources that can be obtained immediately at the village level (Anderson *et al.* 2010). Among the 20 harvested sea cucumber species in the Solomon Islands, the three most valuable species for *bêche-de-mer* exports are Sandfish (*Holothuria scabra*), White teatfish (*H. fuscogilva*), and Prickly redfish (*Thelenota ananas*; Richards *et al.* 1994). The available FAO *bêche-de-mer* (catch and export) data are assumed to have been recorded as dry weight. *Bêche-de-mer* exports published by Richards *et al.* (1994) were "processed" specimens, meaning they were boiled, cleaned, dried and smoked, and matched reported FAO landings and export data. Thus, FAO landings data, which are supposed to be wet weight, were misreported as dry weight. Based on Conand (1991), a conversion factor of ten was used to derive wet weight equivalents.

Trochus: An export market for trochus shells has long existed in the Solomon Islands. Colonial reports dating back to the 1950s, present export quantities of trochus shells, which are processed into buttons. While the shells are almost entirely exported, the meat is consumed by locals. FAO provides landings of trochus shells starting in 1964. Independent sources present almost identical estimates between 1973 and 1986. However, FAO landings from 1987-1991 are exactly 100 times larger than those presented in national trade reports (Anon. 1988; Table 5). From 1992 onward, FAO trochus shell landings fluctuate considerably from year to year and were, in some years, much higher than estimates from independent studies. These major discrepancies in the data since 1986 suggest a problem in the validation of the data. The large quantities reported by the FAO on behalf of the Solomon Islands (e.g., 44,502 t in 1987; Table 5) are greater than the estimated total allowable catch for the country by a factor of 100. Therefore, we did not accept the FAO data from 1987 onward. The reconstructed time series of trochus catches was thus derived as follows:

- 1951-1963: export data presented in British colonial reports (Anon. 1953, 1955, 1957, 1959, 1961, 1963, 1966).
- 1964-1986: FAO landings were accepted as the best available representation of trochus catches.
- 1987-1990: exports presented in Annual Reports of the Fisheries Department (Anon. 1988).
- 1991: exports presented by Richards *et al.* (1994).
- 1992-1998 and 2000-2005: linear interpolation between 1991 and 1999 anchor points and 1999 and 2006 anchor points, respectfully.
- 1999 and 2006: annual production estimates given by Lasi (2010).
- 2007-2009: estimate for 2006 carried forward.

Results

Large-scale fisheries (tuna landings, by-catch and baitfish)

The tuna fishery, as reported by FAO, shows strong cyclical variation with peaks every three or four years, coinciding with El Niño events (FAO 2002; Figure 3). Large-scale tuna catches were estimated to be greater than one million tonnes over the 1950-2009 time period (20,500 t·year^{-1} since 2000). As reported to FAO, the main species caught were skipjack tuna (81%), yellowfin tuna (17%), bigeye tuna (2.2%) and albacore tuna (0.2%).

Commercial tuna industry by-catch was estimated to be approximately 24,860 t over the 1950-2009 study period (Figure 4). Unreported by-catch constituted 18,400 t (74% of total by-catch) over the study period. This amounts to a 187% increase of non-tuna pelagics (6,400 t reported by FAO for 1950-2009). Estimated by-catch included a total of 4,300 t of reported and 5,800 t of unreported shark by-catch (Figure 5) over the 1950-2000 time period.

The baitfish fishery supporting the commercial pole and line tuna fishery accounts for an estimated 9% (47,465 t from 1972-2009; 467 t·year^{-1} since 2000) of the FAO MMF category (Figure 6). Baitfish catches account for 3% of the overall catch. Baitfish catches were dominated by anchovy of the family Engraulidae and the genus Encrasicholina, specifically, accounting for 85%.

As part of the allocation process, it was estimated that approximately 2.4% of the large-scale commercial catches were taken from outside of the EEZ. These catches represent 1.4% of the total reconstructed catch.

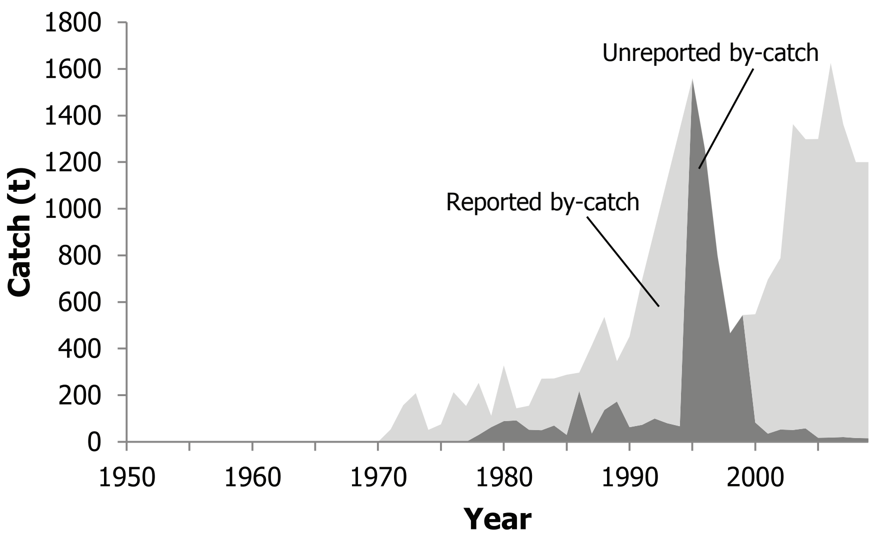

Figure 4. By-catch associated with the Solomon Islands commercial tuna fishery, including a reported component (FAO non-tuna pelagic) and an unreported component, 1950-2009.

Small-scale fisheries

Artisanal finfish catches for the study period (1950-2009) were estimated to be approximately 63,700 t (2,500 t·year^{-1} in the 2000s), and accounted for 13% of the FAO MMF category. The reported component of the subsistence catch for 1950 to 2009 was estimated to be almost 400,000 t. Over 210,000 t of subsistence catches were deemed unreported for the Solomon Islands for 1950-2009 (Figure 6). Unreported artisanal shark catches were estimated to be 29,217 t over the 1950-2009 time period, which is 74% of the total shark catches (Figure 5). This estimate was derived using trade data.

Export fisheries

Invertebrate catches by the commercial sector (primarily export) amounted to over 71,000 t (Figure 7). *Bêche-de-mer* catches represented the majority of artisanal invertebrate catches and amounted to 52,400 t over the 1950–2009 study period. Reconstructed trochus shell catches represented the second largest individual component with an estimated 18,000 t between 1950 and 2009. The remaining catches (abalone, banana prawn, clams, and gastropods) were grouped as ‘other artisanal invertebrates’, which amounted to 1,200 t between 1950 and 2009 (Figure 7).

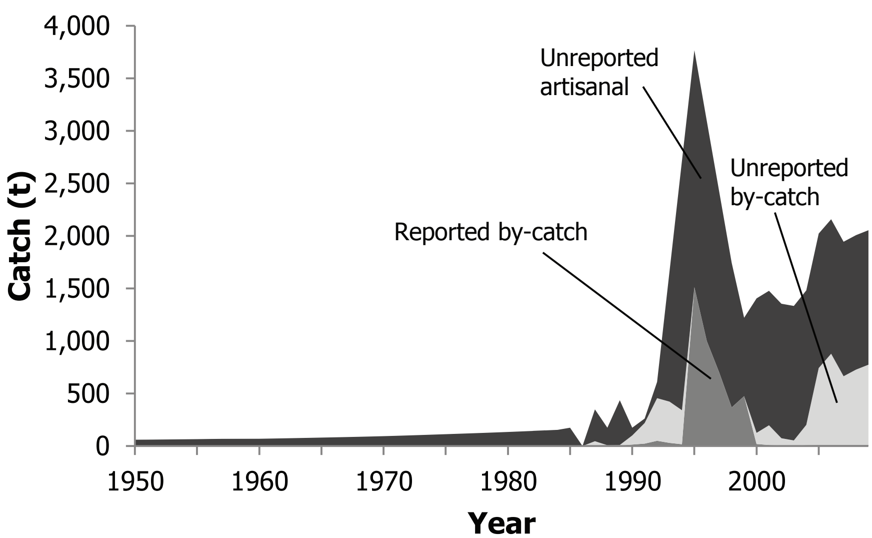

Figure 5. Shark catches for the Solomon islands including by-catch associated with the commercial tuna fishery (reported and unreported), and unreported artisanal catch, 1950-2009.

Foreign fisheries

Combined tuna landings of the Japanese and US foreign based fleets totalled approximately 407,000 t from 1972 to 2007, and another 99,000 t of catch from unnamed foreign countries (Appendix Table A3). Fisheries data were unavailable for 1991-1999. National reports suggest that Japan had a monopoly over the Solomon Islands foreign access allowances until 1988, when US purse seine operations began. The US purse seine fleets immediately started producing higher tuna catches than the Japanese. In 2004, Japan reportedly caught 620 t, whereas the US landed 70,184 t.

The total reported non-tuna pelagic by-catch by Japanese foreign based fleets was approximately 2,770 t from 1974 to 1991. Non-tuna pelagic removal statistics were not available for the US purse seine or other foreign access fleets. The foreign based tuna and non-tuna pelagic catches are presented here but not included in the total catch reconstruction for Solomon Islands fisheries.

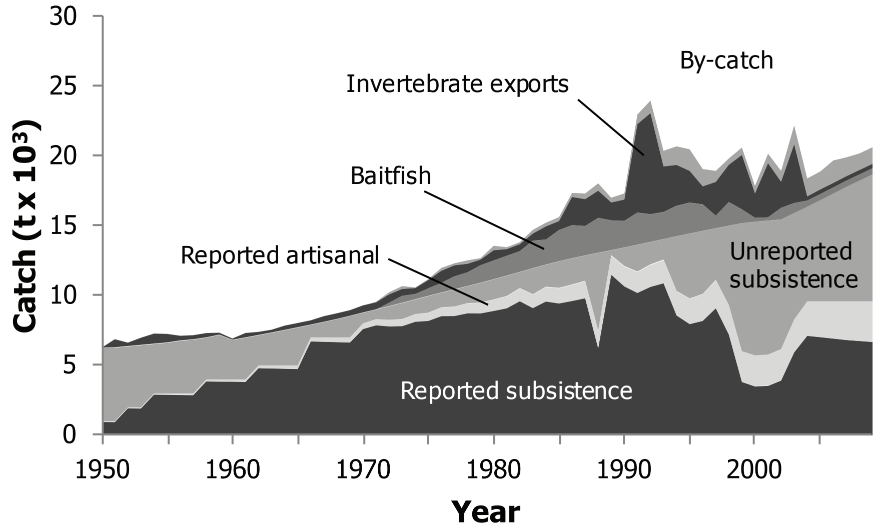

Figure 6. Total fisheries catches for the Solomon Islands by sector and/or fisheries component, excluding tunas and trochus, 1950-2009.

Total reconstructed catch

Total reconstructed catches for the Solomon Islands were estimated to be approximately 1.87 million t from 1950-2009 (41,400 t·year^{-1} since 2000; Figure 8). The FAO on behalf of the Solomon Islands reports landings of 1.81 million tonnes (33,000 t·year^{-1} since 2000). A relatively large adjustment was made to the trochus shell landings, which were considered to be over-reported for some years in the FAO landings data. The main sources of under-reporting were shark and other non-tuna pelagic by-catch and subsistence catches. Subsistence sector catches represented 90% of small scale catches for domestic consumption. Commercial invertebrate catches (exports) represented 4% of the total reconstructed catch and consisted mainly of sea cucumber, trochus shell and other molluscs. Baitfish catches, assumed to be included in the official data, represent 3% of the total reconstructed catch. The reconstructed subsistence fishery represents 33% of the total reconstructed catch. Artisanal catches, including unreported shark landings, comprised 11% of the total reconstructed fisheries removals with the remaining 56% accounting for large-scale, industrial fisheries.

Discussion

Total marine fisheries catches by the Solomon Islands between 1950 and 2009 were estimated to be 1.87 million tonnes, which is only slightly higher than the 1.81 million tonnes reported by the FAO on behalf of the Solomon Islands. Our estimates likely continue to underestimate the total fisheries removals from Solomon Islands' waters, given the exclusion of tourism-derived consumption, the live reef fish sector, and recreational fisheries. Our estimate accounts for substantial small-scale fisheries catches, which were unaccounted for in the official data. Additional Illegal, Unregulated and Unreported (IUU) catches are likely to occur in Solomon Islands' waters; however, our estimates were limited here to unreported small-scale

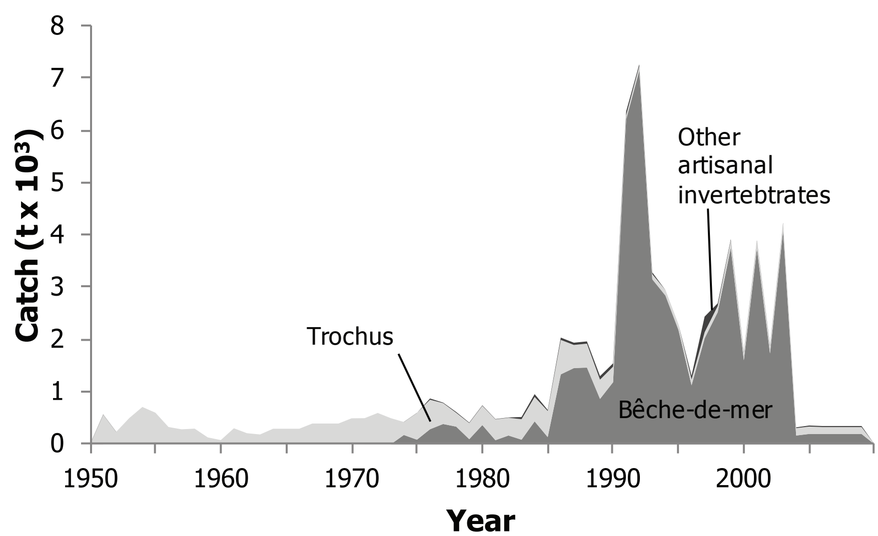

Figure 7. Total invertebrate catches by the commercial sector for the Solomon Islands, 1950-2009.

catches. While we were unable to determine under-reporting of tuna catches in this study, IUU catches of tuna are a problem globally and more attention is urgently needed to estimate the true catches by this fishery in the Solomon Islands and all countries where tuna fishing occurs.

Currently in the Solomon Islands there are no government quotas on the level of catch for any species other than tuna (Skewes 1990) and most invertebrate species caught in the artisanal fishery have been fully- or over-exploited in recent years (Richards *et al*. 1994).

This reconstruction highlights a need for improved monitoring and reporting of small-scale fisheries in the Solomon Islands. In the capital Honiara, 75% of marketed fresh fish is provided by small-scale fishers (FAO 2002). In response to increasing prices of domestic and imported foods, the growth of the subsistence and artisanal fisheries will likely continue. The under-representation of subsistence fisheries in the reported data may have significant implications on the state of local reef fisheries and food security for rural villages and urban centers.

Stock assessments for exploited species other than tuna are lacking in the Solomon Islands due to limited financial and technical resources. There are currently no published stock assessments of finfish associated with the small scale fisheries.

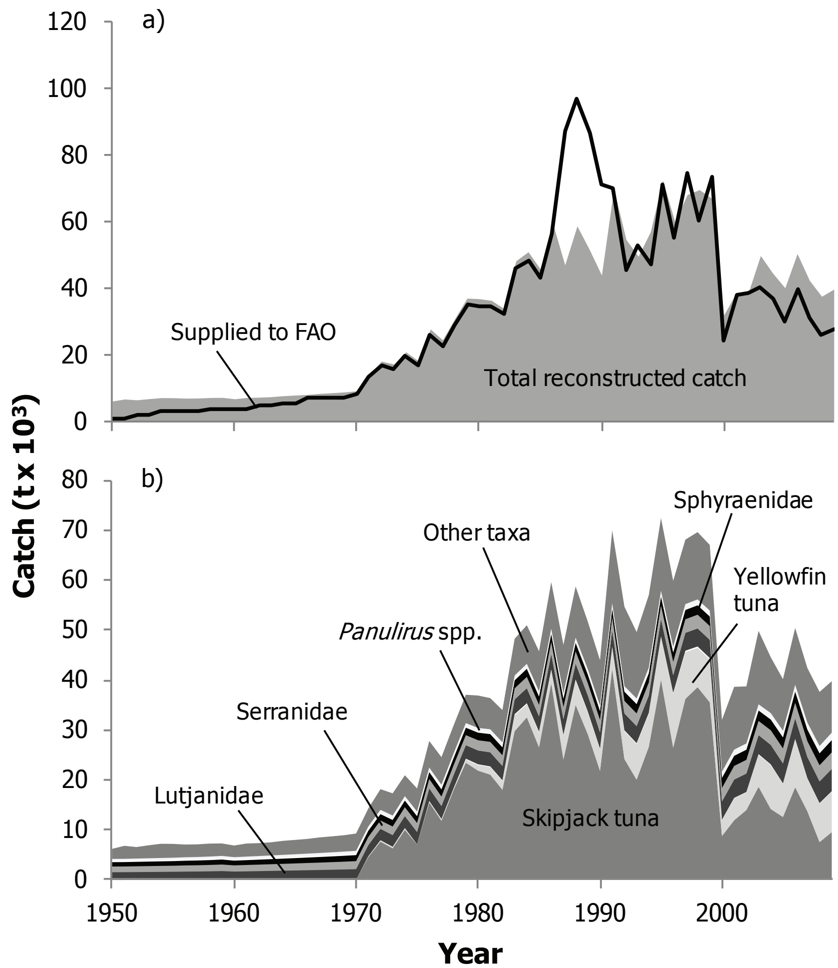

Figure 8. a) Total reconstructed catch compared to total landings supplied to FAO by the Solomon Islands, 1950-2009, and b) total reconstructed catch by major taxa. Others includes 36 taxa and a miscellaneous marine fish category.

The Solomon Islands' sea cucumber fishery exemplifies a boom-and-bust pattern similar to that described by Anderson *et al*. (2010) which typically follows a rapid increase, short peak and a substantial downward trend. A declining sea cucumber fishery could result in social and economic consequences for the coastal villages of the Solomon Islands from a lack of alternative income sources (Anderson *et al*. 2010). In response to declining stocks of sea cucumbers, several marine tenures have restricted *bêche-de-mer* harvesting to every second year (Richards *et al*. 1994). Even with harvesting closures, sea cucumber stocks are slow to recover due to their physical vulnerability to harvesters, slow growth, maturity and recruitment rates, and Allee effects at low densities (Anderson *et al*. 2010). Landings of lower value species are increasing in the Solomon Islands (Richards *et al*. 1994), which is a sign of over exploitation (Anderson *et al*. 2010). The dramatic decrease in *bêche-de-mer* production may be the result of domestic tensions, tsunami impacts, and decline in species abundance.

Solomon Islands' trochus (*Trochus niloticus*) catches are the largest in the Pacific Islands region (www.spc.com; accessed April, 2011). Exports of trochus shell decreased substantially in 1991 as a result of a depressed overseas market coupled with declining catch per unit effort (Richards *et al*. 1994). Increased sales to domestic button factories maintained harvesting pressure, and the stock began showing signs of over-exploitation. Trochus stock assessments have not been conducted in the Solomon Islands (Richards *et al*. 1994).

The commercial tuna fishery is well below the total quota allocation of 120,000 t (Richards *et al*. 1994); however, the unknown extent of transshipments and village level catches occurring in the Solomon Islands could result in significantly higher tuna removals than accounted for in official records, as would other IUU tuna fishing activities. The systemic corruption, particularly by locally based foreign fishing companies (Hanich and Tsamenyi 2009), is an ongoing concern that could threaten the status of commercial tuna and other fisheries in the Pacific Islands region.

Available foreign access fisheries data suggest that Japanese longline and pole and line vessels, and US purse seine fleets were the only foreign fisheries operating in Solomon Islands' waters. In reality, given the number of countries permitted access, these data are likely misrepresentative of the foreign fisheries presence and contribution to total fish removals. Although foreign access catches are not included in the total reconstruction, the tuna and non-tuna pelagic removals of these countries is a concern that poses challenges for fisheries management in the Solomon Islands.

Increased demand for seafood is projected for the Solomon Islands. Forecasts of seafood requirements to meet future *per capita* consumption rates have been estimated by Bell *et al.* (2009) at 18,000 t in 2010, 25,500 t in 2020 and 30,000 t in 2030. *Per capita* seafood demands will likely be partially met by subsistence fisheries, which are currently severely under-represented in the official data. Based on our reconstructed estimate, nearly 16,000 t of subsistence finfish and invertebrate catches were consumed domestically in 2009.

To sustainably secure diverse marine resources, the Solomon Islands government should employ a co-management strategy and work collaboratively with marine tenure chiefs to improve data collection, monitoring, regulation, and enforcement in their waters.

Addendum

Since completing this reconstruction, FAO data became available to 2010. In the 1950-2010 FAO dataset, the erroneous "Trochus" landings identified in the present reconstruction have been corrected. A "Tuna-like fishes nei" category has also been added with catch values for 2008 and 2010 only. The majority of these catches have been disaggregated into albacore, bigeye, skipjack and yellowfin tuna, based on information in the FFA dataset, with the exception of 350 t in 2008 remaining as "Tuna-like fishes nei". To update this reconstruction to 2010, FAO data were added for all reported categories. Unreported catch components for 2010 were then estimated based on the 2009 total reconstructed catch (i.e., the difference between the reported FAO 2010 total and the 2009 total reconstructed catch). The sectoral breakdown (artisanal, subsistence, large-scale etc.) for 2010 for the reported component was based on taxa for the industrial component and for the subsistence and artisanal sectors, the 2009 proportions were used. For the unreported data, the artisanal catch amount was carried forward unaltered and the remaining sectors were estimated accordingly, using proportions. Spatial allocation of the large-scale commercial catches was determined based on the proportions of the 2010 FFA data.

Acknowledgements

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Appendix Table A1. FAO landings vs. total reconstructed catch (in tonnes) for the Solomon Islands, 1950-2009.

Year	FAO landings	Total reconstructed catch
1950	1,000	6,290
1951	1,000	6,900
1952	2,000	6,650
1953	2,000	7,010
1954	3,000	7,310
1955	3,000	7,280
1956	3,000	7,150
1957	3,000	7,190
1958	4,000	7,350
1959	4,000	7,370
1960	4,000	6,960
1961	4,000	7,350
1962	5,000	7,440
1963	5,000	7,590
1964	5,300	7,890
1965	5,300	8,080
1966	7,300	8,270
1967	7,400	8,570
1968	7,400	8,780
1969	7,400	9,010
1970	8,500	9,360
1971	13,510	14,340
1972	17,010	18,220
1973	15,920	17,390
1974	19,640	21,000
1975	16,920	18,370
1976	26,220	27,850
1977	22,780	24,620
1978	29,130	30,990
1979	35,420	37,090
1980	34,800	36,930
1981	34,710	36,420
1982	32,490	34,030
1983	45,980	48,280
1984	48,660	50,980
1985	43,340	45,780
1986	56,450	59,600
1987	87,310	47,050
1988	96,840	58,720
1989	86,700	51,700
1990	71,460	44,010
1991	70,360	69,920
1992	45,720	54,700
1993	52,740	49,620
1994	46,980	57,000
1995	71,450	72,410
1996	55,140	59,860
1997	74,650	68,100
1998	60,210	69,590
1999	73,710	67,020
2000	24,590	32,070
2001	38,250	38,670
2002	38,380	38,750
2003	40,140	49,850
2004	36,700	44,580
2005	30,100	40,210
2006	39,540	50,430
2007	31,320	42,430
2008	26,260	37,660
2009	27,960	39,800

Appendix Table A2. Total reconstructed catch (in tonnes) for the Solomon Islands by major taxa, 1950-2009.

Year	*Katsuwonus pelamis*	*Thunnus alalunga*	Lutjanidae	Serranidae	Sphyraenidae	*Panulirus* spp.	Others[1]
1950	-	-	1,590	1,200	869	618	2,010
1951	-	-	1,600	1,210	872	620	2,600
1952	-	-	1,620	1,220	884	628	2,300
1953	-	-	1,640	1,240	895	635	2,600
1954	-	-	1,660	1,260	907	642	2,840
1955	-	-	1,680	1,270	918	650	2,760
1956	-	-	1,720	1,300	937	662	2,540
1957	-	-	1,740	1,310	947	669	2,530
1958	-	-	1,770	1,340	966	682	2,590
1959	-	-	1,820	1,370	992	699	2,490
1960	-	-	1,720	1,300	941	662	2,330
1961	-	-	1,770	1,330	963	678	2,610
1962	-	-	1,810	1,370	986	693	2,580
1963	-	-	1,850	1,400	1,010	709	2,620
1964	-	-	1,900	1,430	1,035	725	2,800
1965	-	-	1,940	1,470	1,060	742	2,870
1966	-	-	1,990	1,500	1,085	759	2,940
1967	-	-	2,040	1,540	1,111	776	3,110
1968	-	-	2,090	1,580	1,139	794	3,190
1969	-	-	2,140	1,620	1,168	814	3,270
1970	-	0.3	2,200	1,660	1,201	835	3,460
1971	4,570	141.0	2,250	1,700	1,229	854	3,600
1972	7,670	237.0	2,310	1,740	1,260	874	4,130
1973	6,320	286.0	2,370	1,790	1,291	895	4,440
1974	10,020	310.0	2,430	1,830	1,324	916	4,170
1975	7,080	18.0	2,480	1,880	1,355	936	4,620
1976	15,520	209.0	2,540	1,920	1,386	956	5,310
1977	11,850	312.0	2,600	1,960	1,416	975	5,520
1978	18,050	259.0	2,650	2,000	1,446	993	5,590
1979	23,500	685.0	2,710	2,040	1,476	1,013	5,670
1980	21,910	1,154.0	2,760	2,090	1,508	1,033	6,480
1981	21,110	1,531.0	2,820	2,130	1,541	1,053	6,230
1982	18,060	1,796.0	2,890	2,180	1,575	1,074	6,460
1983	29,830	3,234.0	2,950	2,230	1,609	1,095	7,340
1984	32,590	2,647.0	3,010	2,270	1,641	1,115	7,710
1985	26,570	3,011.0	3,060	2,310	1,670	1,132	8,030
1986	39,430	2,555.0	3,110	2,350	1,697	1,148	9,320
1987	24,140	4,806.0	3,150	2,380	1,721	1,162	9,680
1988	35,080	4,894.0	3,200	2,410	1,743	1,174	10,220
1989	29,190	4,383.0	3,240	2,440	1,765	1,186	9,490
1990	21,840	4,342.0	3,280	2,480	1,788	1,198	9,080
1991	42,300	4,224.0	3,320	2,510	1,811	1,211	14,550
1992	24,220	5,630.0	3,360	2,540	1,834	1,223	15,890
1993	20,080	7,193.0	3,410	2,570	1,858	1,235	13,280
1994	26,660	6,671.0	3,450	2,600	1,881	1,247	14,490
1995	40,140	8,433.0	3,490	2,630	1,903	1,258	14,550
1996	26,490	10,820.0	3,530	2,660	1,924	1,268	13,170
1997	36,310	9,411.0	3,570	2,690	1,945	1,278	12,890
1998	38,660	7,902.0	3,600	2,720	1,964	1,286	13,450
1999	35,610	8,643.0	3,640	2,750	1,983	1,294	13,110
2000	8,790	3,208.0	3,660	2,760	1,996	1,302	10,350
2001	11,940	4,410.0	3,680	2,780	2,007	1,309	12,550
2002	14,000	3,529.0	3,700	2,790	2,017	1,315	11,400
2003	18,650	6,431.0	3,800	2,870	2,074	1,351	14,670
2004	14,200	8,840.0	3,910	2,950	2,132	1,387	11,160
2005	12,610	6,630.0	4,020	3,030	2,192	1,424	10,300
2006	18,560	9,550.0	4,130	3,120	2,252	1,462	11,360
2007	13,740	6,546.0	4,240	3,200	2,313	1,500	10,890
2008	7,560	7,749.0	4,350	3,280	2,371	1,537	10,800
2009	9,560	8,133.0	4,450	3,360	2,429	1,575	10,290

[1] Others category includes 36 additional taxa and a miscellaneous marine fish category.

Appendix Table A3. Nationally reported foreign tuna catches.

Year	Tuna Catch (t)	Country	Source
1972	55	Japan	Anon. (1987)
1973	267	Japan	Anon. (1987)
1974	6,828	Japan	Anon. (1987)
1975	8,176	Japan	Anon. (1987)
1976	191,714	Japan	Anon. (1987)
1977	8,090	Japan	Anon. (1987)
1978	462	Japan	Anon. (1987)
1979	2,956	Japan	Anon. (1987)
1980	3,165	Japan	Anon. (1987)
1981	6,000	Japan	Anon. (1987)
1982	3,267	Japan	Anon. (1987)
1983	2,933	Japan	Anon. (1987)
1984	1,288	Japan	Anon. (1987)
1985	7,572	Japan	Anon. (1987)
1986	2,752	Japan	Anon. (1987)
1987	833	Japan	Anon. (1987)
1988	7,715	Japan	Anon. (1988)
	160	USA	
1989	4,589	Japan	Anon. (1993)
	30	USA	
1990	10,200	Japan	Anon. (1993)
	57	USA	
1991	4,155	Japan	Anon. (1993)
	1,774	USA	
1999	948	Foreign	Gillett (2007)
2000	835	Japan	Barclay and Cartwright (2007)
	3,885	USA	
2001	500	Japan	Barclay and Cartwright (2007)
	10,883	USA	
2002	1,267	Japan	Barclay and Cartwright (2007)
	10,883	USA	
2003	1,474	Japan	Barclay and Cartwright (2007)
	31,751	USA	
2004	619	Japan	Barclay and Cartwright (2007)
	70,184	USA	
2007	98,023	Misc. countries	Gillett (2009)

Appendix Table A4. Japanese catches of non-tuna pelagic species.

Year	Catch (t)	Source
1974	3	Anon (1987)
1975	79	Anon (1987)
1976	151	Anon (1987)
1977	48	Anon (1987)
1978	16	Anon (1987)
1979	214	Anon (1987)
1980	207	Anon (1987)
1981	419	Anon (1987)
1982	260	Anon (1987)
1983	174	Anon (1987)
1984	146	Anon (1987)
1985	290	Anon (1987)
1986	227	Anon (1987)
1987	40	Anon (1987)
1988	136	Anon (1988)
1989	182	Anon (1993)
1990	49	Anon (1993)
1991	127	Anon (1993)