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

Andrea Haas[1], Teina Rongo[2], Nicole Hefferman[1], Sarah Harper[1], and Dirk Zeller[1]

[1]*Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, V6T 1Z4, Canada*
[2]*PO Box 881, Avarua, Rarotonga, Cook Islands*
a.haas@fisheries.ubc.ca; eturere@yahoo.com; nheffern@mail.ubc.ca; s.harper@fisheries.ubc.ca; d.zeller@fisheries.ubc.ca

## 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 km$^2$ and an exclusive economic zone (EEZ) of almost 2 million km$^2$ (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).

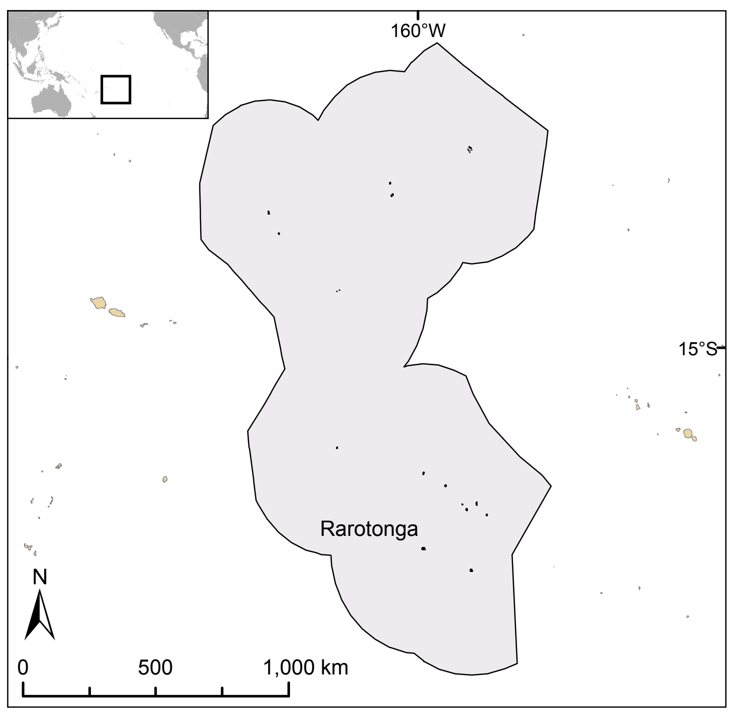


**Figure 1.** Map of the Cook Islands and its exclusive economic zone (gray area).

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

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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*

**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 |

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.

## *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*

**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) |

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 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.

## 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,

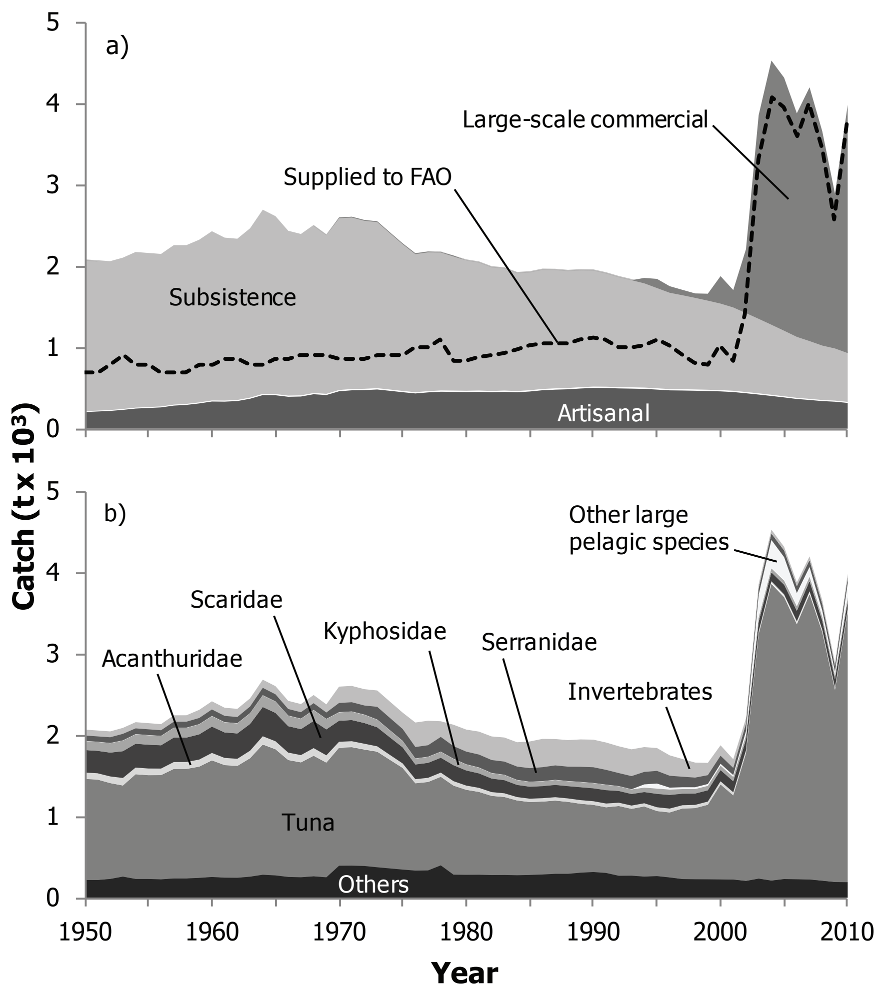


**Figure 2.** Total reconstructed catches for the Cook Islands for the time period 1950-2010, by (a) sector and (b) major taxa. "Tuna" includes *T. alalunga*, *T. obesus*, *T. albacares*, and *K. pelamis*. "Others" includes 10 different taxa and a "miscellaneous" category. "Other large pelagic species"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

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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## References

Anon. (2000) Basic information on the marine resources of the Cook Islands. Ministry of Marine Resources, Government of the Cook Islands and the Secretariat of the Pacific Community. 66 p.

Anon. (2007) Scientific Committee Third Regular Session. Western and Central Pacific Fisheries Commission, Honolulu, United States of America. 3 p.

Anon. (2008) US Treaty. Pacific Islands Forum Fisheries Agency. Available at: http://www.ffa.int/usa_pi_treaty#attachments [Accessed: August 16, 2012].

Anon. (2010a) $2.1 m for illegal fishing in Cook Islands. Islands Business, edition of July 8, 2010. Available at: http://www.islandsbusiness.com/news/index_dynamic/containerNameToReplace=MiddleMiddle/focusModuleID=130/focusContentID=20105/tableName=mediaRelease/overideSkinName=newsArticle-full.tpl [Accessed: May 29, 2012].

Anon. (2010b) Scientific Committee Seventh Regular Session. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia. 4 p.

Chapman L (2001) Tuna fishery development strategy for the Cook Islands. Secretariat of the Pacific Community, Noumea, New Caledonia. X+23 p.

Chapman L (2004) Nearshore domestic fisheries development in Pacific Island countries and territories. Secretariat of the Pacific Community, Noumea, New Caledonia. 255 p.

Cook Islands Statistics Office (2006) Cook Islands 2006 census of population and housing, final report. 214 p.

Cook Islands Statistics Office (2011) Census and surveys. Available at: http://www.stats.gov.ck/Statistics/CensusSurveys/censurvnav.htm [Accessed: August 16, 2012].

Cook Islands Statistics Office (2012) Visitor arrivals by country of usual residence. Available at: http://www.stats.gov.ck/Statistics/Tourism/tourismQ_country.pdf [Accessed: August 16, 2012].

CSIRO (2003) Report of the sixteenth meeting of the standing committee on tuna and billfish. Mooloolaba, Australia. V+210 p.

Dalzell P, Adams TJH and Polunin NVC (1996) Coastal fisheries in the Pacific islands. Oceanography and Marine Biology 34: 395-531.

Davies RWD, Cripps SJ, Nickson A and Porter G (2009) Defining and estimating global marine fisheries bycatch. Marine Policy 33: 661-672.

Faine S and Hercus CE (1951) The nutritional status of Cook Islanders. British Journal of Nutrition 5(3-4): 327-343.

FAO (2010) Fisheries and aquaculture country profile. National Fishery Sector Overview–Cook Islands. 25 p.

Fry PC (1957) Dietary survey on Rarotonga, Cook Islands. The American Journal of Clinical Nutrition 5(1): 42-50.

Gillett R (2009) Fisheries in the economies of Pacific island countries. Asian Development Bank, Mandaluyong City, Philippines. 521 p.

Gillett R (2011a) Bycatch in small-scale tuna fisheries: a global study. FAO, Rome. 132 p.

Gillett R (2011b) Fisheries of the Pacific islands. Regional and national Information, FAO, Bangkok, Thailand. 290 p.

Gillett R and Lightfoot C (2002) The contribution of fisheries to the economies of Pacific island countries. Asian Development Bank, Manila, Philippines. 242 p.

Hoffmann TC (2002) The reimplementation of the Ra'ui: coral reef management in Rarotonga, Cook Islands. Coastal Management 30: 401-418.

Hunt C (2002) Economic globalisation impacts on Pacific marine resources. Marine Policy 27: 79-85.

Johannes RE (1997) Traditional coral-reef fisheries management. pp. 380-385 *In* Birkeland C (ed.) Life and death of coral reefs. Chapman and Hall, New York, United States of America.

Manins R (2011) CI finalises fisheries deal with China. Cook Islands News, edition of November 2, 2011. Available at: http://www3.cookislandsnews.com/2011/November/Wed02/local.htm#1111020106 [Accessed: July 9, 2012].

Moore J (2006) Seafood consumption survey, Rarotonga. Windmere Campus, Bay of Plenty Polytechnic, Tauranga. 36 p.

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

Pinca S, Awira R, Kronen M, Chapman L, Lasi F, Pakoa K, Boblin P, K F, Magron F and Tardy E (2007) Cook Islands country report: profiles and results from survey work at Aitutaki, Palmerston, Mangaia and Rarotonga. Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C/CoFish), Secretariat of the Pacific Community, Noumea Cedex, New Caledonia. 373 p.

Pratchett MS, Munday PL, Graham NAJ, Kronen M, Pinca S, Friedman K, Brewer TD, Bell JD, Wilson SK, Cinner JE, Kinch JP, Lawton RJ, Williams AJ, Chapman L, Magron F and Webb A (2011) Vulnerability of coastal fisheries in the tropical Pacific to climate change. pp. 493-576 *In* Bell JD, Johnson JE and Hobday AJ (eds.), Vulnerability of tropical Pacific fisheries and aquaculture to climate change. Secretariat of the Pacific Community, Noumea, New Caledonia.

Rongo T, Bush M and van Woesik R (2009) Did ciguatera prompt the late Holocene Polynesian voyages of discovery? Journal of Biogeography 36: 1423-1432.
Rongo T and van Woesik R (2011) Ciguatera poisoning in Rarotonga, southern Cook Islands. Harmful Algae 10: 345-355.
Rongo T and van Woesik R (2012) Socioeconomic consequences of ciguatera poisoning in Rarotonga, southern Cook Islands. Harmful Algae. dx.doi.ay/10.106/j.haL.2012.08.003
Solomona DM, Tuatai T, Vuki V and Koroa M (2009) Decadal changes in subsistence fishing and seafood consumption patterns on Rarotonga, Cook Islands. SPC Women in Fisheries Information Bulletin 19: 19-27.
World Bank (2012) Hidden harvest: the global contribution of capture fisheries. The World Bank. XX+69 p.
World Health Organization (2003) Diet, food supply and obesity in the Pacific. World Health Organization, Geneva, Switzerland. 63 p.
Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266-277.

**Appendix Table A1.** 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]

Kyrstn Zylich, Devon O'Meara, Jennifer Jacquet, Sarah Harper, and Dirk Zeller

*Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada*
k.zylich@fisheries.ubc.ca; devonomeara@gmail.com; j.jacquet@fisheries.ubc.ca; s.harper@fisheries.ubc.ca; d.zeller@fisheries.ubc.ca

## 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 km$^2$ (Teh *et al.* 2009), and an Exclusive Economic Zone (EEZ) of 1.28 million km$^2$ (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).

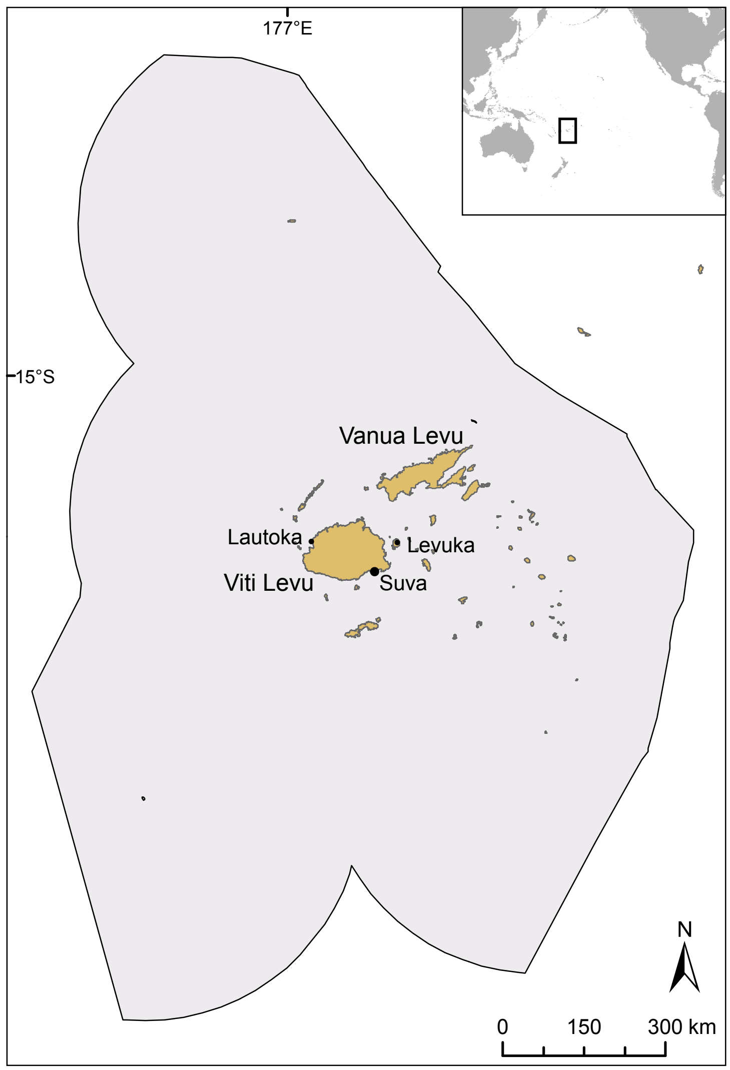


**Figure 1.** Map of the Republic of Fiji and its EEZ, showing the major cities of Suva, Lautoka, and Levuka, as well as the two largest islands, Viti Levu and Vanua Levu.

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

[1] Cite as: Zylich, K., O'Meara, D., Jacquet J., Harper, S., and Zeller, D. (2012) Reconstruction of marine fisheries catches for the Republic of Fiji (1950-2009). pp. 25-36. *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] 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*

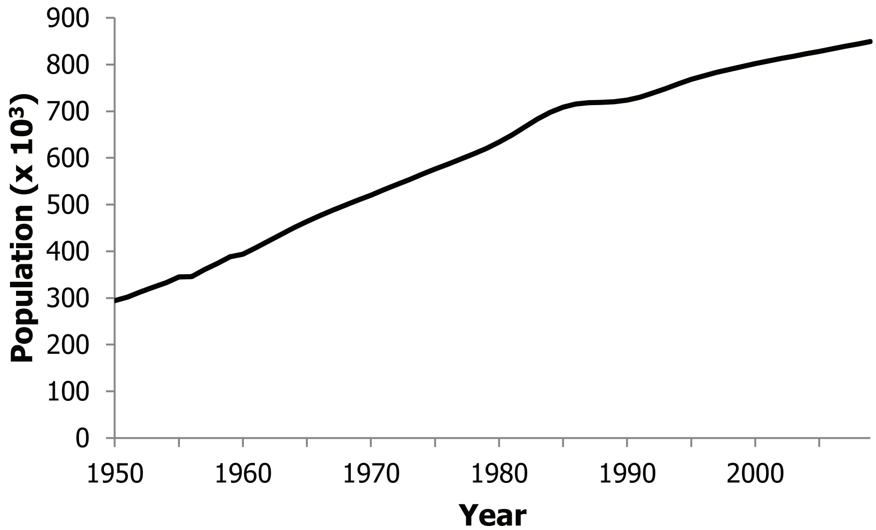


**Figure 2.** Estimated human population of Fiji, 1950-2009.

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.

## *Artisanal fisheries*

**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 |

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 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 |

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 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.

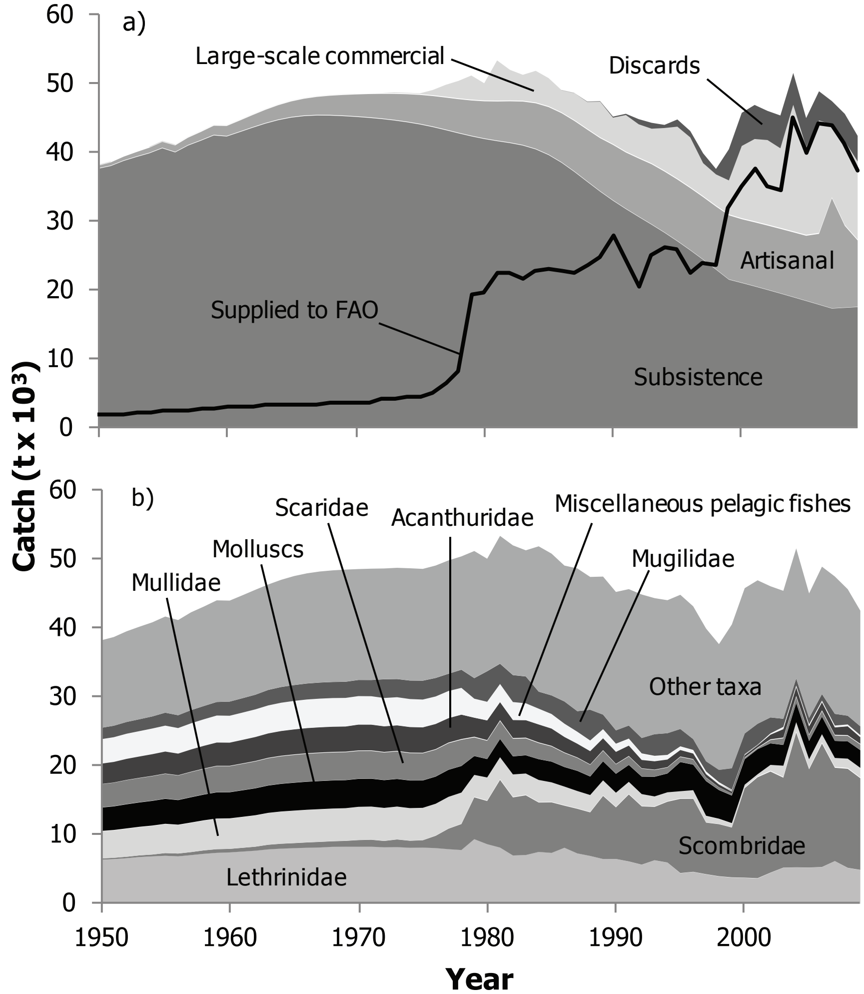


**Figure 3.** Total reconstructed fisheries catches for Fiji, 1950-2009, (a) by sector, with comparison to the total catch data supplied to the FAO; and (b) by major taxa. The grouping 'other taxa' represents 47 individual taxonomic categories.

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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## References

Anon. (1991) Fiji Fisheries Division: Annual Report 1990. Ministry of Primary Industries, Suva (Fiji). 48 p.

Anon. (2003) Diet, food supply and obesity in the pacific. World Health Organization Regional Office for the Western Pacific. 63 p.

Anon. (2011a) Groups to kick off shark awareness campaign in Suva. PEW Environment Group. Available at: http://www.pewenvironment.org/news-room/press-releases/groups-to-kick-off-shark-awareness-campaign-in-suva-85899365465 [Accessed: November 29, 2011].

Anon. (2011b) Region's biggest maritime surveillance operation acts to stop illegal fishing. Forum Fisheries Agency, Honiara (Solomon Islands). Available at: http://www.ffa.int/node/565 [Accessed: November 24, 2011].

Anon. (2011c) Shark conservation in Fiji. PEW Environment Group. Available at: http://www.pewenvironment.org/news-room/compilations/shark-conservation-in-fiji-85899365631 [Accessed: November 29, 2011].

Barclay K (2010) Impacts of tuna industries on coastal communities in Pacific Island countries. Marine Policy 34: 406-413.

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

Biery L, Palomares MLD, Morissette L, Cheung W, Watson R, Harper S, Jacquet J, Zeller D and Pauly D (2011) Sharks in the seas around us: how the *Sea Around Us* Project is working to shape our collective understanding of global shark fisheries. Pew Environment Group and the *Sea Around Us* Project, Vancouver (Canada). 53 p.

Chapman MD (1987) Women's fishing in Oceania. Human Ecology 15(3): 267-288.

Cumming RL, Aalbersberg WGL, Lovell ER, Sykes H and Vuki VC (2004) Coral reefs of Fiji Islands: current issues. Reef Encounter: Magazine of the International Society for Reef Studies 32: 52-56.

Dalzell P, Adams TJH and Polunin NVC (1996) Coastal fisheries in the Pacific Islands. pp. 395-531 *In* Ansell AD, Gibson RN and Barnes M (eds.), Oceanography and marine biology: an annual review. UCL Press, London.

Deane W (1921) Fijian society: sociology and psychology of the Fijians. MacMillan and Co. Limited, London. 255 p.

DeMers A and Kahui V (2012) An overview of Fiji's fisheries development. Marine Policy 36: 174-179.

Gillett R (2003) Small island developing states of the Southwest Pacific. pp. 121-140 *In* De Young C (ed.) Review of the state of world marine capture fisheries management: Pacific Ocean. Food and Agricultural Organization of the United Nations, Rome.

Gillett R (2007) A short history of industrial fishing in the Pacific Islands. Asia-Pacific Fishery Commission, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok.

Gillett R (2009) Fisheries in the economies of the Pacific Island countries and territories. Asian Development Bank, Mandaluyong City (Philippines). 521 p.

Gillett R (2011) Fisheries of the Pacific Islands: regional and national information. Food and Agriculture Organization of the United Nations, Bangkok. 279 p.

Gilman E, Clarke S, Brothers N, Alfaro-Shigueto J, Mandelman J, Mangel J, Petersen S, Piovano S, Thompson N, Donoso M, Goreb M and Werner T (2007) Shark depredation and unwanted bycatch in pelagic longline fisheries: industry practices and attitudes, and shark avoidance strategies. Western Pacific Regional Fisheries Management Council, Honolulu. 148 p.

Horne J (1881) A year in Fiji: an inquiry into the botanical, agricultural, and economical resources of the colony. Eyre and Spottiswoode, London. 298 p.

IUCN (2011) IUCN Red List of Threatened Species. Version 2011.1. Available at: www.iucnredlist.org [Accessed: November 8, 2011].

Jansen AAJ, Parkinson S and Robertson AFS, editors (1990) Food and nutrition in Fiji: a historical review. Department of Nutrition and Dietetics, Fiji School of Medicine and The Institute of Pacific Studies, The University of the South Pacific, Suva (Fiji). 479 p.

Jennings S and Polunin NVC (1996) Fishing strategies, fishery development and socioeconomics in traditionally managed Fijian fishing grounds. Fisheries Management and Ecology 3: 335-347.

Juncker M, Robert M and Clua E (2006) Coastal shark fisheries in the Pacific: a brief overview of current knowledge. Coral Reef Initiative for the South Pacific, Nouméa (New Caledonia). 38 p.

Kuster C, Vuki VC and Zann LP (2005) Long-term trends in subsistence fishing patterns and coral reef fisheries yield from a remote Fijian island. Fisheries Research 76: 221-228.

Norton R (1990) Race and politics in Fiji, 2nd edition. University of Queensland Press, St Lucia (Australia). 212 p.

Rawlinson NJF, Milton DA, Blaber SJM, Sesewa A and Sharma SP (1995) A survey of the subsistence fisheries and artisanal fisheries in rural areas of Viti Levu, Fiji. Australian Centre for International Agricultural Research. 126 p.

Roth GK (1953) Fijian way of life. Oxford University Press, London. 176 p.

Sadovy Y (2005) Trouble on the reef: the imperative for managing vulnerable and valuable fisheries. Fish and Fisheries 6: 167-185.

Schoeffel P (1985) Women in the fisheries of the South Pacific. *In* Women in development in the South Pacific: Barriers and opportunities. Development Studies Centre, The Australian National University, Canberra.

Sharma SP (1988) Fiji's fisheries data collection and information system. South Pacific Commission, Nouméa (New Caledonia).

Starkhouse BA (2009) What's the catch: uncovering the catch volume and value of Fiji's coral reef-based artisanal and subsistence fisheries. The University of British Columbia, Vancouver (Canada). 120 p.

Swamy K (1999) Shark fisheries in Fiji: their management and issues of future concern. *In* Shotton R (ed.) Case studies of the management of elasmobranch fisheries, volume 2. FAO, Rome.

Teh LCL, Teh LSL, Starkhouse B and Sumalia R (2009) An overview of socio-economic and ecological perspectives of Fiji's inshore reef fisheries. Marine Policy 33: 807-817.

USDS (2010) Background note: Fiji. Bureau of East Asian and Pacific affairs, United States Department of State. Available at: http://www.state.gov/r/pa/ei/bgn/1834.htm# [Accessed: May 25, 2011].

Veitayaki J (1995) Fisheries development in Fiji: the quest for sustainability. Institute of Pacific Studies and the Ocean Resources Management Programme, The University of the South Pacific, Suva (Fiji). 233 p.

Vunisea A (2005) Women's changing roles in the subsistence fishing sector in Fiji. pp. 89-105 *In* Novaczek I, Mitchell J and Vietayaki J (eds.), Pacific voices: Equity and sustainability in Pacific Island fisheries. Institute of Pacific Studies, University of the South Pacific, Suva (Fiji).

Vunivalu R (1957) Colony of Fiji: a handbook, 6th edition. Government Press, Suva (Fiji). 122 p.

Williams PG (1997) Shark and related species catch in tuna fisheries of the tropical Western and Central Pacific Ocean. Case studies of management of elasmobranch fisheries 378, FAO Fish. Tech. Pap., Nouméa (New Caledonia). 860-879 p.

**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.