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 km² (Teh *et al.* 2009), and an Exclusive Economic Zone (EEZ) of 1.28 million km² (www.seaaroundus.org; Figure 1). There is a mixture of fringing and barrier reefs surrounding almost all of the islands (Vunivalu 1957). The climate is tropical but relatively mild due to the position of the islands, which puts them in the path of easterly instead of south-easterly trade winds (Vunivalu 1957). Fiji also experiences heavier rainfall than most tropical countries and in the wet season monsoonal winds accompany the rain (Horne 1881; Vunivalu 1957). Suva, the capital of Fiji, is located on the largest and most populous island, Viti Levu. Although 70% of Fiji's population resides in Viti Levu, the majority are located in coastal areas due to the rough terrain of the interior (USDS 2010). The second largest island is Vanua Levu (Teh *et al.* 2009).

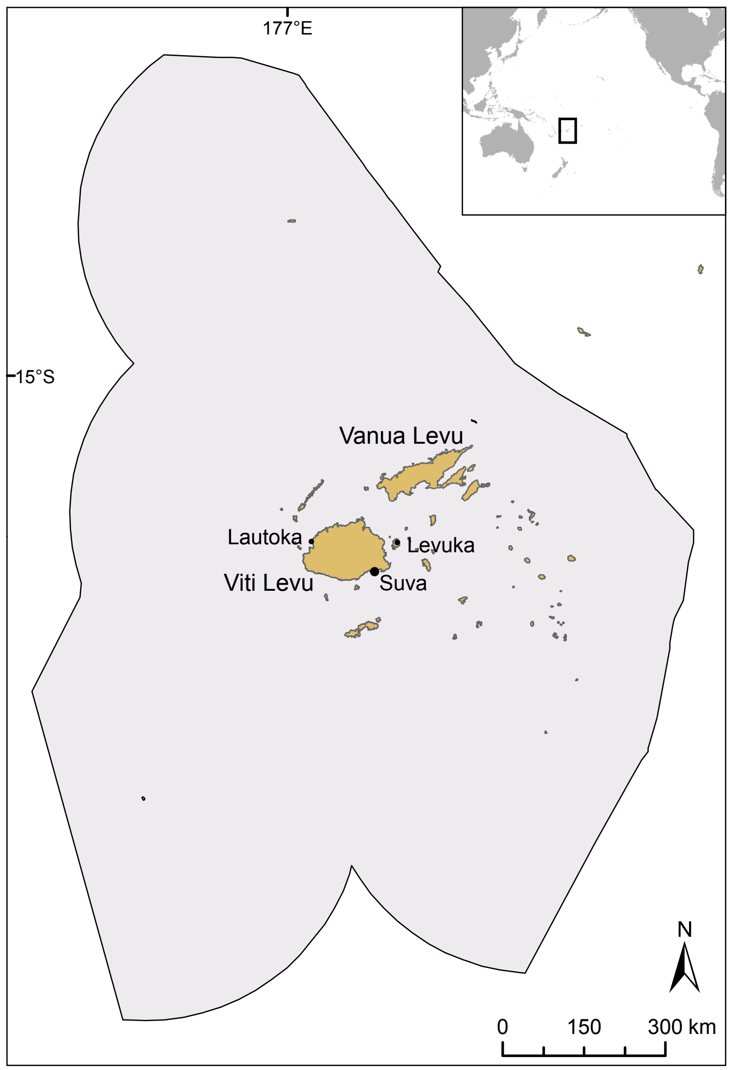

Figure 1. Map of the Republic of Fiji and its EEZ, showing the major cities of Suva, Lautoka, and Levuka, as well as the two largest islands, Viti Levu and Vanua Levu.

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

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[2] See addendum for updating dataset to 2010.

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

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

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

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

Methods

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

Human population data

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

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

Subsistence fisheries

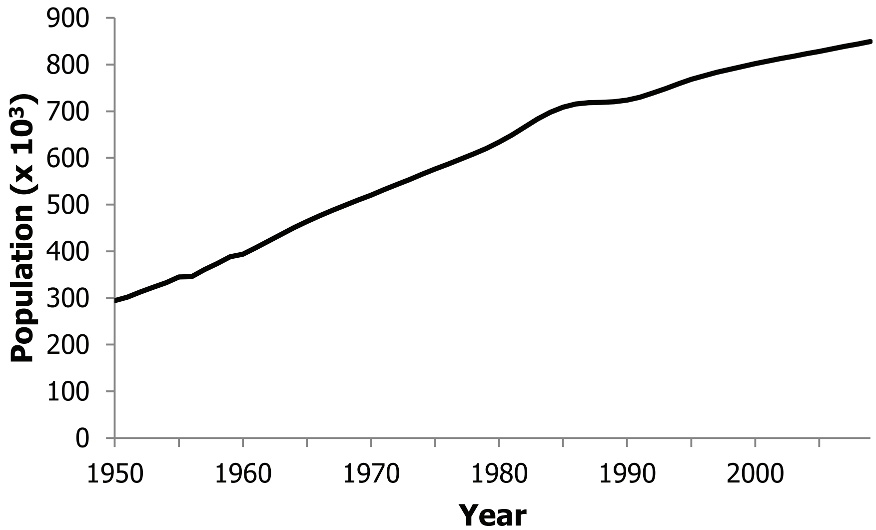

Figure 2. Estimated human population of Fiji, 1950-2009.

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

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

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

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

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

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

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

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

Large-scale commercial fisheries

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

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

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

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

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

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

Spatial allocation

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

Catch Composition

Reported catch

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

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

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

Source: Anon. (1991).

Unreported catch

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

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

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

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

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

Results

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

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

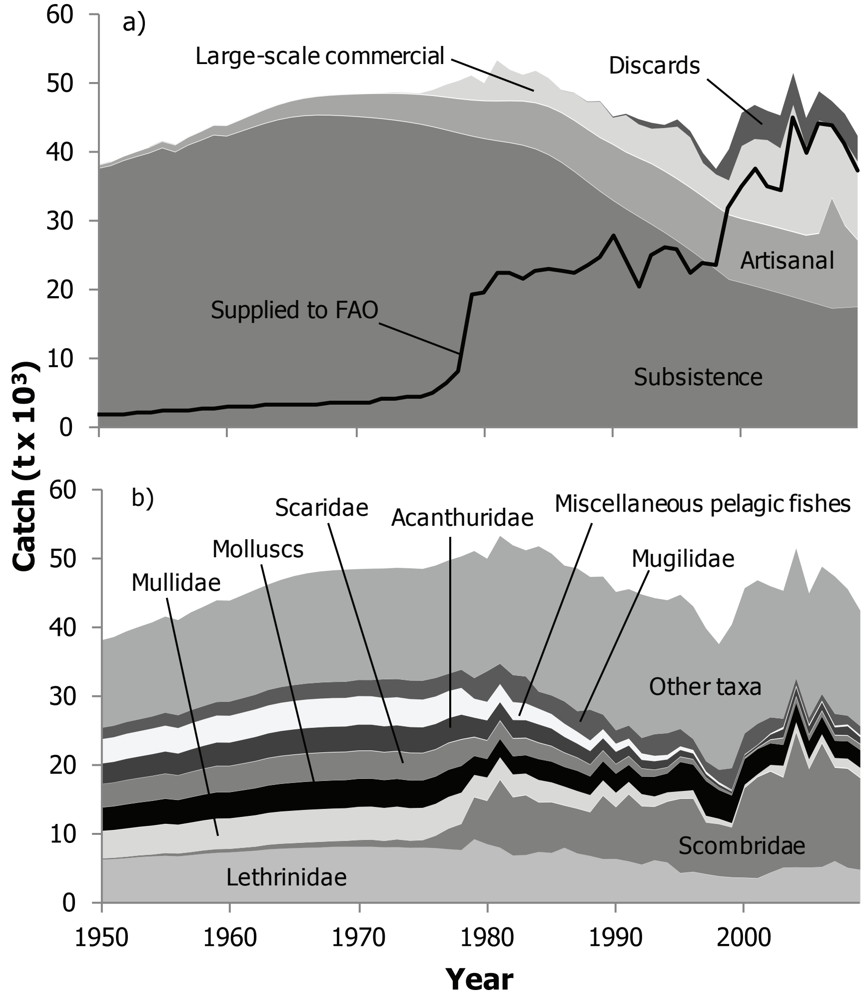

Figure 3. Total reconstructed fisheries catches for Fiji, 1950-2009, (a) by sector, with comparison to the total catch data supplied to the FAO; and (b) by major taxa. The grouping 'other taxa' represents 47 individual taxonomic categories.

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

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

Discussion

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

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

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

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

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

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

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

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

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

Women in fisheries

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

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

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

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

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

Addendum

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

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

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

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

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

[1] Others category includes 47 additional taxonomic groups.