RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR TUVALU (1950-2009)[1]

Kendyl Crawford[a], Sarah Harper[b] and Dirk Zeller[b]
[a] *Department of Marine and Environmental Science, Hampton University*
Hampton, Virginia 23668, USA
[b] *Sea Around Us* Project, Fisheries Centre, University of British Columbia
2202 Main Mall, Vancouver, V6T 1Z4, Canada
kendyl.crawleycrawford@my.hamptonu.edu; s.harper@fisheries.ubc.ca; d.zeller@fisheries.ubc.ca

ABSTRACT

Tuvalu's total marine fisheries catches within its EEZ were reconstructed for the years 1950 to 2009. This reconstruction accounts for officially un- and underreported catches of artisanal and subsistence fishery sectors as well as the baitfish used in the pole-and-line tuna fishery. FAO data were used in combination with data from fish markets, regional reports and consumption data. Total reconstructed catches were estimated to be 69,631 t over the six decades, which is approximately 5 times larger than the amount reported by the FAO on behalf of Tuvalu (12,241 t). Total catches increased from 813 t·year^{-1} in 1950 to 1,607 t·year^{-1} by 2009. The majority of total catches were from the subsistence sector (87%). This investigation reveals the need for an improvement in the accounting of marine fishes catches by all fisheries sectors. Due to the heavy rates of fish consumption in Tuvalu, reliable estimation of catches and resulting resource management decisions will play a role in Tuvalu's future food security.

INTRODUCTION

Tuvalu is an archipelago in the South Pacific consisting of nine atolls; Nanumea, Niutao, Nui, Vaitupu, Nukufetau, Nukulaelae, Niulakita and Funafuti. Tuvalu is located at 8° 31' S, 179° 13' E, approximately halfway between Australia and Hawaii in the south central Pacific (Figure 1). The country's total land area of 26 km^2 is tiny in comparison to its nearly 752,000 km^2 Exclusive Economic Zone (EEZ) (www.seaaroundus.org). Tuvalu is critically vulnerable to sea level rise due to its low-lying topography, with most of the country less than 3m above sea level (Connell, 2003; Sauni and Fay-Sauni, 2005; Rayfuse, 2011; Stephen, 2011). The continental shelf off Tuvalu is minimal; there are patch and fringing barrier reefs immediately surrounded by 1,000 m depths. The inner lagoons provide the only significant shallow water areas (Sauni and Fay-Sauni, 2005).

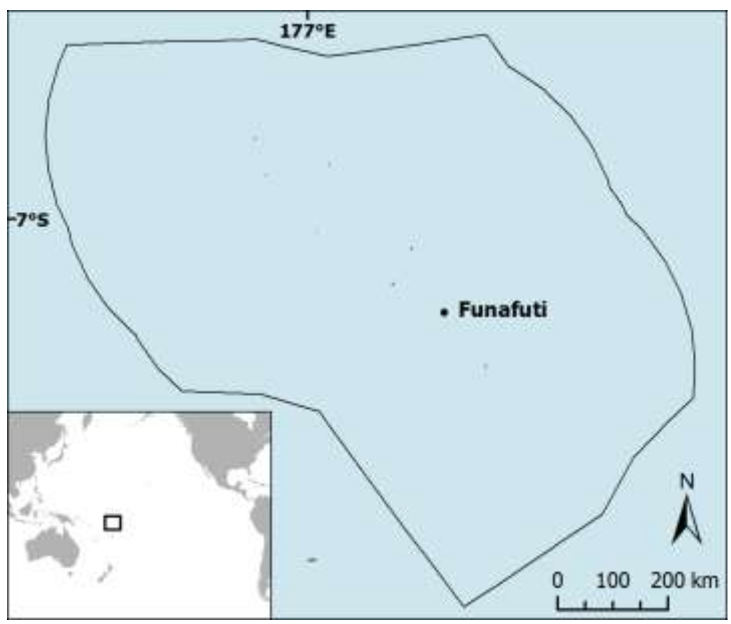

Figure 1: Map of Tuvalu and its Exclusive Economic Zone.

Formerly a British colony known as the Ellice Islands, Tuvalu gained its independence in October 1978. The country has been politically stable and its economy has grown from an initial Tuvalu Trust Fund investment of $ 27 million Australian Dollars (AU$) in 1987 to AU$ 66 million in 2002 (Gemenne and Shen, 2009). As of 2002, the Gross Domestic Product (GDP) of Tuvalu was AU$ 26.9 million, of which 8.2% was from the artisanal fishing industry (Gillett, 2009). The Tuvaluan economy is considered traditional and predominantly non-cash (Sauni and Fay-Sauni, 2005). Marine products, wages and

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remittances sent by family members working overseas - many on foreign fishing vessels - are considered to be the most important sources of income (Sauni and Fay-Sauni, 2005). In the past ten years, annual revenue from foreign fishing fleets has varied, providing between 5.5% and 36.7% of total government revenue and grants (Gillett, 2009). In 1999, Tuvalu received USD$ 5.9 million in foreign fishing access fees. This amount comprised 42.6% of its GDP (Gillett and Lightfoot, 2002). The revenue from foreign tuna fishing is approximately 14.6% of the total value of the fish caught (Gillett, 2009). With Tuvalu receiving such a comparatively small percentage of the value of its fish, the government continues in their attempt to develop commercial fisheries in its vast EEZ, and stimulate economic growth. However, the development of larger-scale commercial fisheries in Tuvalu is hindered by high costs, difficulty raising funds and a lack of infrastructure required for fleet maintenance and operations, processing, internal distribution and export (Gillett, 2002).

The largest component of Tuvalu's fishing activities is subsistence, i.e., for direct consumption. More than 80% of domestic coastal catch in Tuvalu is produced by subsistence fishing (Gillett, 2010). Dalzell (1996) estimated that subsistence and artisanal fisheries make up 87% and 13%, respectively, of Tuvaluan coastal fisheries production. A recent Household Income and Expenditure Survey revealed that fishing contributes to 8% of personal income, after wages and remittances sent from overseas (Anon., 2006). Data on the artisanal sector is incomplete due to the high occurrence of informal bartering (Lambeth, 2000; Poulasi, 2008; WCPFC, 2009, 2010). Fishermen or their wives sell their catch either from home, the roadside using handcarts and ice chests or in small markets (Lambeth, 2000; Gay, 2010). As a result, catch data for the subsistence and artisanal fisheries are largely unknown. As more Tuvaluans try to make the change to working for an income, the artisanal sector is assumed to grow (Sokimi and Chapman, 2005).

The heavy dependence on fish for animal protein is evident through the unique Tuvaluan word '*miti*' which describes a craving specifically for fish. In 2004 and 2005, the urban *per capita* fish consumption in Tuvalu was 68.8 $kg \cdot person^{-1} \cdot year^{-1}$ with 97% of that amount being fresh fish. For rural areas, the *per capita* consumption was 147.4 $kg \cdot person^{-1} \cdot year^{-1}$ (99% being fresh fish) (Gillett, 2009). Tuvalu's seafood consumption rate is among the highest in the world (Gillett and Lightfoot, 2002; Gillett *et al.*, 2001). The island communities of Tuvalu are distinguished not only for their fishing ability, but also their rich knowledge of their environment (Gay, 2010). The close relationship between Tuvaluans and the ocean is readily apparent through their dependence on fish for food security. The island of Niutao, one of the main islands of Tuvalu, has one of the highest population to reef area densities in the region, with 246 people per km^2 of reef (Adams *et al.*, 1996). At the same time, on the atoll of Funafuti, there was a lower population to reef area density of 165 people per km^2 of reef (Adams *et al.*, 1996). However, Funafuti is now home to approximately 5,000 people, 47% of the country's population (Sauni *et al.*, 2008). Even though the urban island has set up management measures such as the 33 km^2 Funafuti conservation area, it is highly urbanized and as such faces problems such as sewage treatment and waste disposal. There is heavy fishing pressure from subsistence needs on this island with many people fishing after work and on the weekends (Sauni *et al.*, 2008). It is estimated that 93% of households on Funafuti eat fresh fish that they catch and 70% of households eat fresh invertebrates that they catch (Sauni *et al.*, 2008). Fish catch rates have increased when compared to estimates from previous years (Sauni and Fay-Sauni, 2005). Thus there is concern for the sustainability of inshore resources in light of the increased fishing pressure and population growth on Funafuti (Adams *et al.*, 1996; Gillett, 2002; Sauni and Fay-Sauni, 2005; Aylesworth and Campbell, 2009).

Fishing in Tuvalu uses a range of techniques including pole-and-line, trolling and reef gleaning, which are used to collect finfish, bivalves, crustaceans and other invertebrates in nearshore and offshore Tuvaluan waters. The fishing roles on Tuvalu, like many other Pacific Islands are divided by gender, with women mainly reef gleaning at low tide, and processing, and men fishing both inshore and offshore. The introduction of outboard engines on canoes in the 1960s and 1970s has made fishing much easier, and consequently, women have felt less of a need for their auxiliary fishing activities (Lambeth, 2000). However, when men are unable to fish because of the weather, women's collecting activities are vital (Chapman, 1987). While fishing techniques vary among the different islands, the main gears used are gillnetting, handlining, castnetting, pole-and-line and spearfishing. Handlines are used to catch demersal fish on the reef (Sauni and Fay-Sauni, 2005). On the outer reefs, spears, handlines, scoop nets and deep bottom methods such as deep-bottom droplining are used (Chapman and Cusack, 1990; Sauni *et al.*, 2008). As of 1991, there were an estimated 200 motorized and 500 non-motorized vessels, most less than 10 m (Gillett, 2003). On the most populated island of Funafuti, there are 10 to 20 commercial vessels (4-5

m) engaged in trolling for mainly skipjack and yellowfin tuna (Gillett, 2003) and some line fishing for reef species (Gillett, 2002).

Fisheries in Tuvalu are dominated taxonomically by skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*), which in 1978 made up half of the total fish catch (Gillett *et al.*, 2001). A more recent estimate suggests skipjack and yellowfin represent approximately 75% of total fish landings (Gillett, 2002). Other pelagic fish such as flying fish (*Cypselurus* spp.) also represent a substantial part of the catch. Flying fish, usually caught at night with the use of scoop nets and lights (Gillett, 2002), are commonly used as baitfish in the tuna pole-and-line fishery (Aylesworth and Campbell, 2009). Fish inhabiting the lagoon and reef habitats such as red snapper (*Lutjanus gibbus*) are also caught but make up a lesser portion of the catch. Bycatch is generally consumed, bartered or given away as a part of the fishery.

In the early 1980s, the government established the National Fishing Corporation of Tuvalu (NAFICOT) tasked with the goal of developing industrial fisheries (Sokimi and Chapman, 2005; Gillett, 2011a). One of the roles of NAFICOT was to manage national fishing vessels. In 1982, Japan donated a pole-and-line vessel, in 1989, Japan donated 7 additional vessels (6 launches and 1 extension vessel), and in 2004, Korea donated two longliners. Community fishing centers (CFC) were developed in the 1990s with foreign aid to provide an income opportunity for fishers and also to redistribute the excess supply of fish to the urban population center of Funafuti through NAFICOT. The CFCs provide salting, drying and at times cold storage facilities. However, ice is not usually present in many of the CFCs or on local fishing vessels because of a lack of transportation infrastructure and water availability (Aylesworth and Campbell, 2009). Presently, most CFCs have fallen into disrepair and rely heavily on government subsidies. In 2009, NAFICOT went bankrupt when the government decided to cease financial support (Gay, 2010). This same year, a joint venture was established between Tuvalu and Taiwan; the first purse seiner flying the Tuvaluan flag, the FV *Taumoana* began fishing in August of that year in Tuvalu, FSM and Kiribati, landing a total of 4,877 t of tuna, most likely skipjack and yellowfin (WCPFC, 2010).

The purpose of this study is to reconstruct total marine fisheries catches by Tuvalu within its EEZ between 1950 and 2010 by accounting for all fishing sectors, as a baseline for the assessment of food security and resource availability. During the completion of this study, it was necessary to make assumptions in order to fill large gaps in data availability because the official reported data includes neither taxonomic specificity nor quantitative detail, especially for the pre-1980 time period.

MATERIALS AND METHODS

The Tuvalu Fisheries Department collects offshore commercial catch data for the national fleet. In addition, the department actively collects monthly reports from various fish markets reporting sales and purchasing information. In 2010, Tuvalu started a national catch database for their inshore fisheries (T. Poulasi, pers. comm., Tuvalu Fisheries Department). Unfortunately, data from 2010 was not yet available at the time of this study. Catch data other than for the national fleet for all years prior to 2010 were not collected by the national Fisheries Department (T. Poulasi, pers. comm., Tuvalu Fisheries Department). The artisanal data collected from fish market reports are limited, as they encompass only the small amount of catch sold within the markets (WCPFC, 2009), whereas much catch is sold informally. Data on subsistence fishery catches have not been collected at all. The national data are considered insufficient for the evaluation and monitoring of fishing activities (Chapman, 2004). However, recent attempts

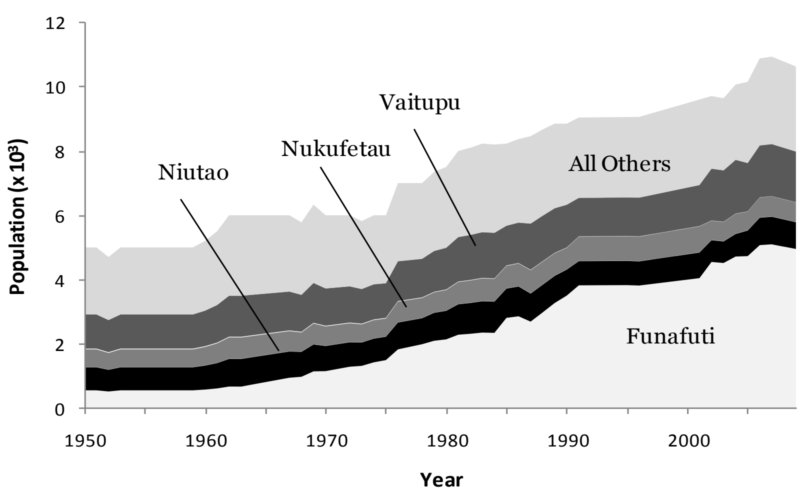

Figure 2. Human population of Tuvalu by major islands, 1950-2009.

have been made to improve data collection. To provide the best picture of Tuvaluan fisheries, data from FAO FishStat, regional reports and independent assessments were accessed and used to develop data anchor points for the estimation of total catches. Interpolations between anchor points were used to derive a complete time series, using a catch reconstruction approach developed by Zeller *et al.* (2006; 2007).

Human Population Data

Population data were obtained in order to convert available *per capita* consumption rates into an estimate of overall demand. National population data were obtained from Populstat (www.populstat.info/ [date accessed: 20 July 2011]) prior to 1997, from the 2008 Biannual Statistical Report (Anon., 2008) for years 2002 to 2007 and from Index Mundi (www.indexmundi.com [date accessed: 20 July 2011]) for 2009. A linear interpolation was used between years of known population data in order to obtain a complete time series. Population data by island were obtained for Funafuti, Niutao, Nukufetau and Vaitupu from Populstat for 1985, 1987 and 1996, a Household Income and Expenditure Survey for 2005 (Anon., 2006) and City Population (www.citypopulation.de [date accessed: 20 July 2011]), for 1979, 1991 and 2002. Over the past 50 years, migration to Funafuti from the other islands has resulted in nearly 50% of the current total population residing on Funafuti, driven mainly by the availability of government jobs (Connell, 2003). The earliest population data found for Funafuti was for 1963 obtained from Populstat. The percentage of the total population which resided in Funafuti in 1963 was applied back in time to 1950. From 1964 to 2005, the population of Funafuti was determined through interpolation of data points. For Niutao, Nukufetau, Vaitupu and all others, the earliest year of data was 1979. Therefore, we calculated the proportion that each of these islands represented and applied these same proportions back to 1950. After 1979, interpolation was done between the island population data. From 2005 to 2010, all island populations were calculated based on 2005 percentages (Figure 2).

Fishing in Tuvalu

The FAO FishStat database was used as the official catch data for Tuvalu (Figure 3). However, FAO data are presented by FAO area and do not delineate the amount taken within EEZ areas. This report aims to reconstruct the catches taken by Tuvaluans within their waters; therefore, it was necessary to disaggregate the catch taken in Tuvalu's EEZ from that taken outside. A significant component of fishing recorded in the FAO data occurred outside of Tuvalu's EEZ. For example, in 1982, Tuvalu fished in a partnership with the Ika Corporation in Fijan waters (SPC, 1994). Tuvalu also fished in Fiji and Solomon Islands in 1987 and 1988 with a peak catch of 1,091 t from the Solomon Islands in 1988 (SPC, 1994; Sauni *et al.*, 2008). In 2009, Tuvalu in a joint venture with the Fong Haur fishing company of Taiwan fished in the Federated States of Micronesia and in Kiribati (WCPFC, 2010). Due to the large proportion of fishing known to occur outside of Tuvalu's EEZ (SPC, 1994; Apinelu, 2004; Sauni *et al.*, 2008; WCPFC, 2010), we assumed 90% of the FAO tuna catch (bigeye (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*) and tuna-like) was taken outside of Tuvalu's waters (Figure 3). Remaining FAO landings (ie., marine fishes nei) were assumed to have been from small-scale fisheries within Tuvalu's EEZ.

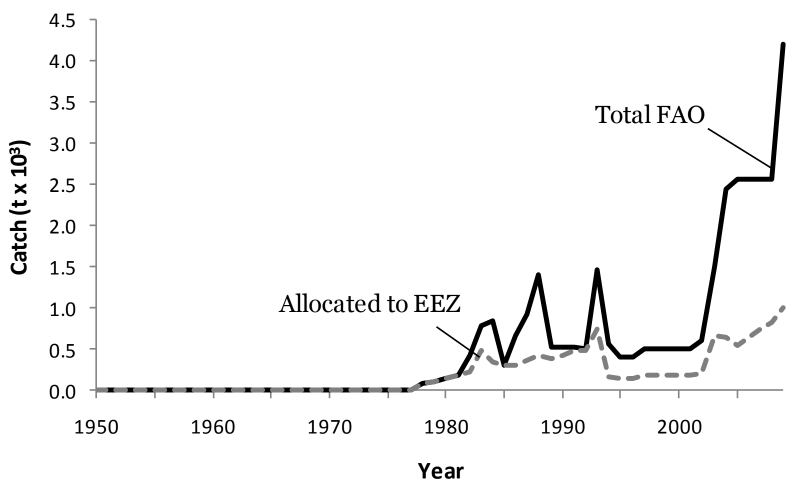

Figure 3. Catches presented by the FAO on behalf of Tuavlu and allocation of FAO data to the Tuvaluan EEZ based on assigning 90% of reported tuna catches to be taken outside EEZ waters, 1950-2009.

Small-scale fisheries

FAO FishStat presents landings of miscellaneous marine fishes from 1950 to 2009. Prior to 1982, FAO landings for Tuvalu are less than 0.5 t·year^{-1} and landings for tuna and tuna-like fishes during this period are zero. Catch amounts or rates from national or independent sources were not readily available for either the artisanal or subsistence sectors; therefore *per capita* consumption rates were used to determine the overall fresh fish demand for Tuvalu (Gillett and Lightfoot, 2002; Sauni *et al.*, 2008; Gillett, 2009). This overall demand was compared to the reported supply to determine the magnitude of underreporting. For 2004, national fresh fish consumption in Tuvalu was calculated using consumption rates for the islands of Funafuti, Nukufetau, Niutao and Vaitupu (Sauni *et al.*, 2008) (Table 1). For the remaining five islands not represented individually, here referred to as 'all others', the average across the four individual islands (i.e., 151.0 kg·person^{-1}·year^{-1}) was used (Sauni *et al.*, 2008). To derive a nation-wide consumption rate, a 2004 weighted average for all islands was calculated (145 kg·person^{-1}·year^{-1}). This rate was used for all of Tuvalu for 2004 and was carried forward, unaltered to 2010 (Gillett and Lightfoot, 2002; Sauni *et al.*, 2008). The 1950 fresh fish consumption rate was assumed to be similar to the rate for the other islands in 2004 (see All others Table 1) with the addition of 5 kg to account for limited imports of protein alternatives available in the later period. The resulting *per capita* consumption rate for 1950 was 155.6 kg·person^{-1}·year^{-1}. A linear interpolation between these two anchor points between the 1950 and the 2004 *per capita* rates was used to complete the time series. The consumption rates were then combined with the human population data to estimate overall demand of fresh fish.

Table 1. Fresh fish consumption rates per island for 2004 (Sauni *et al.*, 2008).

Island	Fresh fish consumption rate (kg/person/year)[a]
Funafuti	135.0
Nukufetau	117.8
Niutao	185.3
Vaitupu	162.5
All Others	150.6

[a]weighted average for all islands 145 kg·person^{-1}·year^{-1}.

To determine the proportion of the total demand supplied by each sector, Dalzell's (1996) breakdown of 13% artisanal and 87% subsistence was used for 1996 to 2009. In 1950, we assumed 100% of the catch to be subsistence and interpolated to 87% subsistence in 1996. The annual artisanal production estimates were then checked to ensure that they exceeded the artisanal landing amounts given in annual reports by the Western and Central Pacific Fisheries Commission (Poulasi, 2008; WCPFC, 2009, 2010). This was necessary as the WCPFC reports reflect only the small fraction of catch landed and received by the CFCs. Fishers normally sell their catch directly to consumers; these transactions are not documented (Poulasi, 2008).

Invertebrates

The people of Tuvalu also consume invertebrates as part of their diet. However, unlike for fresh fish, there is no local commercial fishery for invertebrates (Sauni *et al.*, 2008). Thus, an annual subsistence invertebrate demand was calculated with invertebrate consumption data from the Secretariat of the Pacific Community Coastal Fisheries Program (www.spc.int/coastfish/ [date accessed: 15 July 2011]) (Table 2). Similar to the fresh fish consumption data, invertebrate consumption data were available for Funafuti, Nukufetau, Niutao and Vaitupu. A national average per capita invertebrate consumption rate was calculated to represent the remaining islands. To determine the annual invertebrate demand, the same methodology was used as in determining total demand of fresh fish (see *Small-scale fisheries*). The weighted average consumption rate for invertebrates (3.8 kg·person^{-1}·year^{-1}) was used for 2004 and all years following. For 1950, the national average was used with an adjustment of 2 kg to account for the limited availability of alternate protein sources at that time (i.e., 5.8 kg·person^{-1}·year^{-1}). An interpolation was done between the 1950 (5.8 kg·person^{-1}·year^{-1}) and 2004 (3.8 kg·person^{-1}·year^{-1}) anchor points and the 2004 rate was carried forward unaltered to 2010.

Table 2. Invertebrate consumption rates per island 2004.

Island	Invertebrate consumption rate (kg/person/year)
Funafuti	4.6
Nukufetau	5.6
Niutao	3.6
Vaitupu	0.9
All Others	3.7

Taxonomic breakdown

A substantial portion of both the subsistence and artisanal catch consists of tuna (Gillett *et al.*, 2001). A thorough review of the scientific and grey literature provided numerous estimates of the tuna component of the Tuvaluan catch. Sauni (2008) presents annual tuna landings data for the 1970s of 350 t·year^{-1}. This amount, however, is viewed to be slightly overestimated (Eginton and Mead, 1978). Gillett (2001) reports that 50% of fish sold in Funafuti is tuna. The Pacific Island Fisheries Regional and Country Information report suggested that 75% of all fish landings are ocean species, mainly skipjack and yellowfin tuna (Gillett, 2002). Based on these information sources, an estimate of 300 t was used as an anchor point for 1975. This represents 32.5% of the total demand for 1975. We assumed that tuna consumption was similar in 1950, and allocated 32.5% of the total 1950 catch to tuna. The species composition for the tuna was derived from yearly reports provided by the Tuvaluan government to the Western and Central Pacific Fisheries Commission (Poulasi, 2008; WCPFC, 2009, 2010). The proportion of skipjack to yellowfin tuna represented in the catch were calculated by averaging annual catch data derived from fish market sales for the years 2003 to 2008. To account for other pelagic species, a small portion of the tuna catch (arbitrarily assigned as 10%) was allotted to miscellaneous large pelagic. The remaining 90% were assigned as 54% skipjack and 36% yellowfin tuna (Table 3). Catches were also broken down taxonomically according to fishing sector, either subsistence or artisanal. For the artisanal sector, species compositions given by Dalzell (1996) were used to taxonomically disaggregate all families aside from Scombridae (Appendix A1). The Etelinae subfamily (Family Lutjanidae) was divided into *Etelis* spp. and *Pristipomoides* spp. with each genus receiving half of the Etelinae percentage, to improve taxonomic resolution. Scombridae was excluded, because the tuna component of the artisanal fishery had already been calculated. The invertebrate and fresh fish demands were kept separate for the subsistence sector. The taxonomic breakdown for the subsistence fishery was determined through fish (Appendix Table A2) and invertebrate (Appendix Table A3) catch compositions available in a national report (Sauni *et al.*, 2008). Species catch composition data were available for the islands of Funafuti, Niutao, Nukufetau and Vaitupu for several different habitats such as lagoon, outer reef, sheltered coastal reef and intertidal reef flat. Some species groups that composed a very small percentage of the total catch were grouped and represented at the family level. The invertebrate catch compositions were applied to the invertebrate catch and the fish compositions applied to the fish catch derived from the demand estimates.

Table 3. Taxonomic breakdown of tuna for Tuvalu. Source: (Anon., 1984)

Group	Taxon	Common name	Proportion of catch (%)
Scombridae	*Katsuwonus pelamis*	Skipjack tuna	54
Scombridae	*Thunnus albacares*	Yellowfin tuna	36
Miscellaneous large pelagics	Misc. pelagics	Misc. large pelagics	10

Baitfish

Associated with the pole-and-line fishery for tuna is the use of baitfish, rarely accounted for in fisheries statistics. Baitfish fisheries often operate in parallel to the skipjack pole-and-line fisheries, utilizing the same vessels. Tuvalu's baitfish resources are extremely limited (Gillett, 2011b). In the past, Tuvalu's only pole-and-line fishing vessel, *Te Tautai*, was forced to fish outside of the Tuvaluan EEZ because of the low availability of baitfish (Gentle, 1991).In addition, baitfish resources are more variable around atolls than high islands (Anon., 1984), and atolls like Tuvalu have been less reliable sources of bait. A regional pole-and-line ratio of tuna to baitfish was presented by Gillett (2011b) as 32:1. The dominant species used as baitfish in Tuvalu are *Spratelloides delicatulus, Archamia lineolata, Bregmaceros* spp. and *Atherinomorous lacunoaa* (Anon., 1984). The amount of baitfish used was calculated by taking the estimated tuna catch and applying the 32:1 tuna to baitfish ratio provided by Gillett (2011b) for the region and the taxonomic composition derived from the Tuna Programme (Anon., 1984) was applied (Table 4).

Table 4. Taxonomic breakdown of baitfish for Tuvalu. Source: (Anon., 1984)

Group	Taxon	Common name	Proportion of catch (%)
Clupeidae	*Spratelloides delicatulus*	Delicate round herring	92
Atherinidae	*Atherinomorus lacunosus*	Hardyhead silverside	2
Misc. marine fishes	Misc. marine fishes	Misc. marine fishes	6

Bêche-de-mer

As sea cucumber are not a part of the Tuvaluan diet, they have traditionally received little interest by fisheries managers (Belhadjali, 1997). However, a small bêche-de-mer export industry has developed in

Tuvalu and has become the island's main fishery export item since the late 1970s (Gay, 2010). The industry began after the Fisheries Department became the recipient of UN Development Program funding in 1978. The first export occurred in 1979, 1.8 t of bêche-de-mer sold to Fiji (Belhadjali, 1997). With widely varying production amounts, export continued from 1980 to 1983 (Belhadjali, 1997). Remaining stagnant for a decade, export restarted from 1993 through 1995 supplying Singapore and Fiji. In 2007, harvest in Nukufetau, Nukulaelae and Funafuti began once again with exports to Hong Kong. Only the islands of Funafuti and Nukufetau have suitable habitats for the most profitable sea cucumbers, therefore the sustainability of the bêche-de-mer fishery is of concern (Gay, 2010). The Fisheries Department does not require data on bêche-de-mer catch or exports to be submitted (Gay, 2010). Export weights, nevertheless, were found for all years prior to 2007. Gillett (2009) provided a bêche-de-mer export value of AU$5000 for 2007. From 2007 to 2009, that same export value was used. The monetary value was converted to USD using 2007 exchange rates and the export amount was calculated using the average dollar value per dried kilogram from the years 1993 to 1995 (Belhadjali, 1997). In the processing of sea cucumbers, 90% of their body weight is lost (Dalzell *et al.*, 1996). Thus, all dried weights were converted back to live weights with a conversion factor of ten to represent the bêche-de-mer catch as a component of the total reconstructed catch.

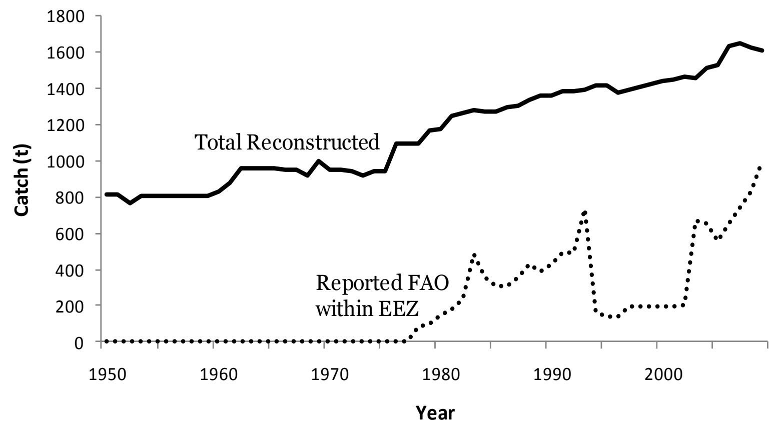

Figure 4. Total reconstructed catch from 1950-2009 for Tuvalu compared to the subset of FAO data assigned to Tuvalu EEZ.

Table 5. Bêche-de-mer catch from 1950-2009.

Year	Catch (t)
1979	18.00
1980	8.05
1981	0.90
1982	1.99
1983-1992	0.00
1993	8.71
1994	36.78
1995	32.28
1996-2006	0.00
2007	3.24
2008	3.24
2009	3.24

RESULTS

Total landings presented by the FAO on behalf of Tuvalu for the 1950-2009 time period were 32,255 t, with essentially 0.25 t·year^{-1} reported until 1977, then fluctuating around 600 t·year^{-1} until the early 2000s when landings increased to 4,198 t by 2009. In contrast, reconstructed data for Tuvaluan marine fishes catch taken within the EEZ were over 67,000 t since 1950, increasing from around 800 t·year^{-1} in 1950 to about 1,600 t·year^{-1} by 2009 (Figure 4). The artisanal sector accounted for just under 6,000 t of fish over the 1950-2009 period, whereas the subsistence sector accounted for over 61,000 t (Figure 5). The most commonly caught families in the subsistence sector were Lethrinidae and Serranidae. The most common species, however, were the blue sea chub (*Kyphosus cinerascens*), the humpback red snapper (*Lutjanus gibbus*) and the bluespot mullet (*Valamugil seheli*). Carangidae, Gempylidae and Lutjanidae were the most common families caught in the artisanal sector. FAO presented catches of tuna and tuna-like

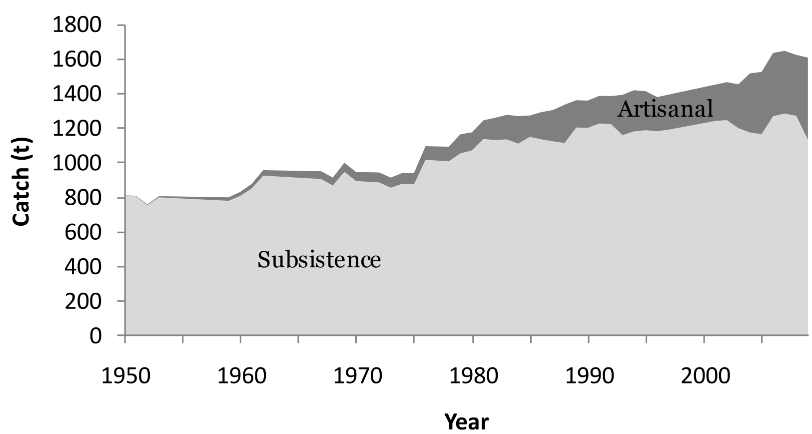

Figure 5. Total reconstructed EEZ catches presented by fishing sector, 1950-2009.

fishes from 1982 onward with a total of 2,223 t. Our reconstruction suggested that 12,438 t of tuna was caught between 1982 and 2009. From 1950 to 1981, 9,347 t of tuna were estimated as part of the reconstruction. A total of 680 t of baitfish were caught for use in the pole-and-line tuna fishery, 92% of which were delicate round herring (*Spratelloides delicatulus*). There were no invertebrates reported in the FAO data. From 1950-2009, a total of 2,070 t of invertebrates were estimated to have been caught. In 1950, the invertebrate catch was 27 t·year^{-1} and by 2009 43 t·year^{-1} of invertebrates were estimated to have been caught. Sea cucumber catch estimates based on bêche-de-mer exports peaked in 1994 at 36.78 t·year^{-1} (Table 5).

DISCUSSION

The FAO FishStat data reported a total of 32,225 t of fish caught by Tuvalu between 1950 and 2009. Of this amount, 12,241 t were determined to have been caught within the Tuvaluan EEZ. In contrast, our total reconstructed catch for 1950 to 2000 was calculated to be 69,623 t. This amount is approximately 5 times more than the official landings presented on Tuvalu's behalf (within their EEZ). The artisanal and subsistence fishery sector catches were assumed to both have been greatly underrepresented by the FAO data. Invertebrates were also not included, even though they comprise an important part of the diet of Tuvaluans. Fisheries catches were underreported particularly during the early years, and official data presented for all years lacked taxonomic detail. In this report, fisheries catches were reconstructed by including all fisheries sectors, such as subsistence, baitfish and invertebrate fisheries. The subsistence fishery sector is important because of its magnitude (Dalzell *et al.*, 1996; Gillett, 2010), but more so because of its implications for food security. For Tuvaluans, fish provides an important source of protein; on Funafuti, households eat fish at least once a week, on the less urbanized islands like Nukufetau households have been reported to eat fish daily (Sauni and Fay-Sauni, 2005). Because of the expense of canned fish and imported meats and the limited opportunities for cash income, it is important for the people of Tuvalu to be able to continue to depend on their fishery resources (Sauni and Fay-Sauni, 2005). In conclusion, although Tuvalu is one of the smallest countries in the world, maintaining reliable data or estimates on its fisheries catches is imperative. The recording of Tuvalu's small-scale fisheries catch amounts with taxonomic detail will enable Tuvalu to more effectively manage its resources.

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APPENDIX A

Appendix Table A1. Taxonomic breakdown of artisanal catch for Tuvalu derived from Dalzell *et al.* (1996).

Family	Common names	Local names	Catch (%)
Lutjanidae	Snappers	Tagau, Taiva, Savane, Palu sega	25.02
Lethrinidae	Emperors or Scavengers	Filoa, Muu, Tanutanu, Gutula, Noto, Saabutu	0.59
Serranidae	Groupers	Gatala, Fapuku, Eve, Sumu	7.13
Carangidae	Jacks and Pompanos	Teu, Tafauli, Ulua, Aseu, Fua ika (Fua ulua), Sokelau	27.85
Gempylidae	Snake Mackerels	Palu	21.54
Sphyraenidae	Barracudas		3.26
Other teleosts	Other bony fish		0.33
Sharks	Sharks		9.98
Istiophoridae	Billfishes		1.87
Belonidae	Needlefishes		1.49
Coryphaenidae	Dolphinfishes		0.93

Appendix Table A2. Taxonomic breakdown of subsistence catch for Tuvalu derived from Sauni *et al.* (2008).

Family	Scientific name	Common name	Local name	Catch (%)
Acanthuridae	*Naso unicornis*	Bluespine unicornfish	Ume	1.72
	Acanthurus guttatus	Whitespotted surgeonfish	Maono	1.73
	Acanthurus lineatus	Lined surgeonfish	Ponelolo	1.01
	Acanthurus triostegus	Convict surgeonfish	Manini	4.45
	Acanthurus xanthopterus	Yellow surgeonfish	Kapalagi	1.17
	Naso lituratus	Orangespine unicornfish	Manini lakau	3.64
	Other Acanthuridae	Surgeonfishes, Tangs, Unicornfishes		1.13
Balistidae	Balistidae	Triggerfishes	Umu	0.04
Caesionidae	*Caesio* spp.	Fusiliers	Ulia	0.41
Carangidae	*Trachinotus baillonii*	Small spotted dart	Sokelau	0.03
	Alectis ciliaris	African pompano	Lalaufou	0.10
	Carangoides ferdau	Blue trevally	Kata	0.28
	Caranx lugubris	Black jack	Tafauli	2.51
	Caranx melampygus	Bluefin trevally	Aseu	0.54
	Caranx sexfasciatus	Bigeye trevally	Teu	0.47
	Elagatis bipinnulata	Rainbow runner	Kamai	0.16
	Scomberoides lysan	Doublespotted queenfish	Ata	0.02
	Selar crumenophthalmus	Bigeye scad	Atule	0.81
	Other Carangidae	Jacks and Pompanos	Aseu	0.54
Chanidae	*Chanos chanos*	Milkfish	Paneava	0.01
Cirrhitidae	*Cirrhitus pinnulatus*	Stocky hawkfish	Patuki	1.68
Exocoetidae	Exocoetidae	Flyingfishes	Isave	2.84
Gempylidae	*Ruvettus pretiosus*	Oilfish	Palu	0.45
Gerreidae	*Gerres* spp.	Mojarras	Matu	3.02
Holocentridae	*Myripristis violacea*	Lattice soldierfish	Malau	3.91
	Sargocentron spiniferum	Sabre squirrelfish	Ta malau	0.47
Kyphosidae	*Kyphosus cinerascens*	Blue sea chub	Nanue	7.69
Labridae	*Thalassoma trilobatum*	Christmas wrasse	Uloulo	0.06
Lethrinidae	*Monotaxis grandoculis*	Humpnose big-eye bream	Muu	0.87
	Lethrinus erythracanthus	Orange-spotted emperor	Saabutu	0.36
	Lethrinus xanthochilus	Yellowlip emperor	Gutula	0.28
	Other Lethrinidae	Emperors or Scavengers	Filoa, Noto / Tanutanu	9.83
Lutjanidae	*Lutjanus kasmira*	Common bluestripe snapper	Savane	1.23

Appendix Table A2. Taxonomic breakdown of subsistence catch for Tuvalu derived from Sauni *et al.* (2008).

Family	Scientific name	Common name	Local name	Catch (%)
	Aphareus rutilans	Rusty jobfish	Palu sega	0.65
	Lutjanus gibbus	Humpback red snapper	Taea	9.77
	Other Lutjanidae	Snappers	-	4.72
Mugilidae	*Valamugil seheli*	Bluespot mullet	Kanase	9.03
	Other Mugilidae	Mullets	Kafakafa, Kanase	5.05
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	Kaivete	0.64
Muraenidae	Muraenidae	Moray eels	-	0.01
Pomacentridae	*Abudefduf septemfasciatus*	Banded sergeant	Mutumutu	0.67
Priacanthidae	Priacanthidae	Bigeye or Catalufas	Matapa	0.04
Scaridae	*Scarus ghobban*	Blue-barred parrotfish	Ulafi	2.03
	Scarus spp.	Parrotfish	Laea	0.71
Serranidae	Serranidae	Groupers and Fairy basslets	Gatala	10.51
	Epinephelus hexagonatus	Starspotted grouper	Eve	0.08
	Epinephelus merra	Honeycomb grouper	Gatala liki	0.15
	Epinephelus polyphekadion	Camouflage grouper	Fapuku	0.47
	Plectropomus laevis	Blacksaddled coralgrouper	Tonu gatala	0.22
	Variola albimarginata	White-edged lyretail	Pula	0.27
Siganidae	*Siganus vermiculatus*	Vermiculated spinefooth	Maiava	1.03
Sphyranidae	*Sphyraena forsteri*	Bigeye barracuda	Pauea	0.24
Miscellaneous	Misc.marine fishes	Misc. marine fishes	-	0.27

Appendix Table A3. Taxonomic breakdown of subsistence invertebrate catch for Tuvalu derived from Sauni *et al.* (2008).

Family	Scientific name	Common name	Local name	Catch (%)
Arcidae	*Anadara* spp.	Ark clams	Koki	0.06
Neritidae	*Nerita polita*	Polished nerite	Sibo	0.07
Octopodinae	*Octopus* spp.	Octopus	Octopus	0.85
Psammobiidae	*Asaphis violascens*	Pacific asaphis	Kasi	5.06
Strombidae	*Lambis truncata*	Giant spider conch	Kalea	2.82
	Strombus luhuanus	Strawberry conch	Panea	53.81
Tridacnidae	*Tridacna maxima*	Elongated giant clam	Fasua	6.37
	Tridacna squamosa	Fluted giant clam	Fasua	2.03
Turbinidae	*Turbo setosus*	Rough turban	Alili	0.84
Miscellaneous Molluscs	Misc. molluscs	Molluscs	-	14.9
Menippidae	*Eriphia sebana*	Smooth redeyed crab	Matamea	0.32
Palinuridae	*Panulirus penicillatus*	Pronghorn spiny lobster	Lobster	12.00
Scyllaridae	*Parribacus antarcticus*	Sculptured mitten lobster	Tuatuaula	0.33
Miscellaneous	Misc. invertebrates	Invertebrates	-	0.54

Appendix B

Appendix B1. FAO landings (t) by Tuvalu in FAO area 71, adjusted reported landings within EEZ and total reconstructed catch, 1950-2009.

Year	FAO landings	Reported landing within EEZ[a]	Total reconstructed
1950	0.25	0.25	813.29
1951	0.25	0.25	811.70
1952	0.25	0.25	761.96
1953	0.25	0.25	809.48
1954	0.25	0.25	808.37
1955	0.25	0.25	807.26
1956	0.25	0.25	806.15
1957	0.25	0.25	805.04
1958	0.25	0.25	803.92
1959	0.25	0.25	802.81
1960	0.25	0.25	833.77
1961	0.25	0.25	880.65
1962	0.25	0.25	959.38
1963	0.25	0.25	958.04
1964	0.25	0.25	956.71
1965	0.25	0.25	955.38
1966	0.25	0.25	954.04
1967	0.25	0.25	952.71
1968	0.25	0.25	916.49
1969	0.25	0.25	1002.29
1970	0.25	0.25	948.71
1971	0.25	0.25	947.38
1972	0.25	0.25	946.04
1973	0.25	0.25	916.37
1974	0.25	0.25	943.38
1975	0.25	0.25	942.20
1976	0.25	0.25	1097.49
1977	0.25	0.25	1095.94
1978	80.00	80.00	1094.38
1979	100.00	100.00	1165.47
1980	150.00	150.00	1177.27
1981	180.00	180.00	1246.29
1982	429.00	234.60	1261.14
1983	784.00	480.70	1277.54
1984	840.00	354.00	1271.06
1985	313.00	309.40	1273.88
1986	660.00	309.00	1293.69
1987	933.00	359.70	1305.72
1988	1409.00	427.10	1336.20
1989	519.00	384.90	1361.98
1990	518.00	429.80	1360.01
1991	526.00	492.70	1387.20
1992	499.00	490.90	1385.80
1993	1460.00	737.30	1393.12
1994	561.00	164.10	1419.79
1995	399.00	140.70	1413.89
1996	400.00	139.00	1380.20
1997	500.00	194.00	1394.60
1998	500.00	194.00	1408.98
1999	500.00	194.00	1423.34
2000	500.00	194.00	1437.64
2001	500.00	194.00	1451.89
2002	600.00	204.00	1466.13
2003	1500.00	672.00	1453.79
2004	2450.00	650.00	1516.54
2005	2560.00	553.00	1525.24
2006	2560.00	652.00	1634.67
2007	2560.00	742.00	1646.32
2008	2560.00	832.00	1623.11
2009	4198.00	995.80	1607.82

[a] FAO data were adjusted by assuming only 10% of FAO reported large pelagic catches originated from within Tuvalu's EEZ.

Appendix B2. Total reconstructed catch (t) by major taxa in Tuvalu, 1950-2009. Others grouping includes 78 taxa.

Year	*Katsuwonus pelamis*	*Thunnus albacares*	other Serranidae	other Lethrinidae	*Lutjanus gibbus*	*Valamugil seheli*	Others
1950	136.84	91.23	55.15	51.58	51.26	47.36	379.86
1951	136.66	91.10	55.03	51.38	51.05	47.16	379.33
1952	128.30	85.53	51.61	48.11	47.79	44.15	356.46
1953	136.32	90.88	54.79	50.98	50.64	46.78	379.09
1954	136.16	90.77	54.68	50.78	50.43	46.59	378.97
1955	135.99	90.66	54.56	50.58	50.22	46.40	378.84
1956	135.82	90.55	54.44	50.38	50.02	46.21	378.72
1957	135.66	90.44	54.33	50.19	49.81	46.02	378.59
1958	135.49	90.33	54.21	49.99	49.61	45.83	378.47
1959	135.33	90.22	54.09	49.79	49.41	45.64	378.34
1960	140.57	93.71	56.14	51.58	51.17	47.27	393.34
1961	148.49	99.00	59.25	54.34	53.90	49.79	415.89
1962	161.79	107.86	64.49	59.04	58.55	54.09	453.54
1963	161.59	107.73	64.36	58.81	58.31	53.87	453.38
1964	161.39	107.60	64.22	58.58	58.07	53.64	453.22
1965	161.19	107.46	64.08	58.34	57.83	53.42	453.05
1966	160.99	107.33	63.94	58.11	57.58	53.20	452.89
1967	160.79	107.20	63.80	57.88	57.34	52.97	452.73
1968	154.71	103.14	61.33	55.53	55.01	50.82	435.97
1969	169.22	112.81	67.02	60.57	59.99	55.42	477.27
1970	160.20	106.80	63.39	57.18	56.62	52.31	452.22
1971	160.00	106.66	63.25	56.95	56.38	52.08	452.05
1972	159.80	106.53	63.11	56.72	56.14	51.86	451.88
1973	154.81	103.21	61.09	54.79	54.22	50.09	438.16
1974	159.40	106.27	62.84	56.26	55.66	51.42	451.53
1975	162.00	108.00	62.17	55.55	54.95	50.77	448.77
1976	185.50	123.67	72.99	65.10	64.38	59.48	526.38
1977	185.27	123.51	72.83	64.83	64.11	59.22	526.17
1978	185.03	123.36	72.67	64.56	63.83	58.97	525.96
1979	194.04	129.36	76.14	67.51	66.73	61.65	570.04
1980	197.75	131.83	77.52	68.60	67.80	62.63	571.13
1981	210.67	140.45	82.51	72.87	72.01	66.52	601.27
1982	213.03	142.02	83.36	73.48	72.59	67.06	609.61
1983	216.18	144.12	84.51	74.35	73.43	67.84	617.12
1984	215.12	143.41	84.02	73.77	72.84	67.29	614.61
1985	215.63	143.75	84.14	73.73	72.79	67.24	616.60
1986	219.02	146.01	85.38	74.67	73.70	68.08	626.83
1987	221.09	147.40	86.11	75.15	74.16	68.51	633.30
1988	226.29	150.86	88.05	76.69	75.67	69.90	648.74
1989	230.70	153.80	89.68	77.95	76.90	71.04	661.92
1990	230.40	153.60	89.48	77.62	76.55	70.72	661.63
1991	235.05	156.70	91.20	78.95	77.85	71.92	675.54
1992	234.85	156.57	91.03	78.65	77.54	71.63	675.54
1993	234.65	156.44	90.87	78.35	77.22	71.34	684.24
1994	234.46	156.30	90.71	78.05	76.91	71.05	712.31
1995	234.26	156.17	90.55	77.75	76.60	70.76	707.80
1996	234.06	156.04	90.38	77.45	76.28	70.47	675.51
1997	236.54	157.70	91.34	78.27	77.09	71.22	682.44
1998	239.03	159.35	92.30	79.09	77.90	71.97	689.34
1999	241.50	161.00	93.26	79.91	78.71	72.71	696.25
2000	243.97	162.65	94.21	80.73	79.51	73.45	703.11
2001	246.43	164.29	95.16	81.54	80.32	74.20	709.95
2002	248.89	165.93	96.11	82.36	81.12	74.94	716.79
2003	246.84	164.56	95.32	81.68	80.45	74.32	710.63
2004	257.42	171.62	99.41	85.18	83.90	77.51	741.51
2005	258.89	172.59	99.97	85.66	84.37	77.95	745.81
2006	277.46	184.97	107.14	91.81	90.43	83.54	799.32
2007	278.89	185.92	107.69	92.28	90.89	83.97	806.67
2008	274.95	183.30	106.17	90.98	89.61	82.78	795.32
2009	276.53	180.67	104.65	89.67	88.32	81.59	786.37