MARINE FISHERIES OF PALAU, 1950-2008: TOTAL RECONSTRUCTED CATCH[1]

Stephanie Lingard, Sarah Harper, Yoshi Ota and Dirk Zeller
Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
s.lingard@fisheries.ubc.ca; s.harper@fisheries.ubc.ca; d.zeller@fisheries.ubc.ca

ABSTRACT

The small Pacific Island nation of Palau has a long history of human settlement. Palau maintained a predominantly traditional lifestyle until the post-war modernization after 1950s, with fishing being a pre-occupation for the majority of its male population. This study estimated Palau's total marine fisheries catches for the 1950-2008 period to be just over 200,000 tonnes. This total was 43% higher than the official reported data as presented by the FAO on behalf of Palau. The discrepancy was mainly due to subsistence catches which were under-reported in the official statistics. The total coastal catches including subsistence and artisanal, were estimated to be 103,480 t 45% higher than the 46,615 t of coastal catches reported over the period. Our findings illustrate the importance of the subsistence sector, with catches representing 60% of coastal fisheries catches. Better monitoring or at least regular comprehensive estimation of the subsistence sector is key to properly account for the social and economic importance of fishing in Palauan society.

INTRODUCTION

Palau, a small country in the Western Pacific, is comprised of 340 islands which lie between 131°-135°E and 2°-8°N, 500 kilometers east of the Philippines (Figure 1). Palau is located within FAO statistical area 71, the Western Central Pacific, has a land mass of approximately 488 km² and an exclusive economic zone (EEZ) of around 604,289 km² (www.seaaroundus.org). The five main inhabited islands of Palau are Kayangel, Babeldoab, Korror, Peliliu, Angaur, and it has two de-populated outer islands, being Sonsorol and Hatohobei (Figure 1). The history of human settlement in Palau is long, with the earliest archaeological findings in Palau dating back over 2400 years (Clark, 2005). In recent human history, Palau has been successively colonized and under external stewardship by different states; Palau was ruled by Spain in the 1880s, Germany from 1899-1913 and Japan from 1914-1944. Following World War II, Palau was administered by the United

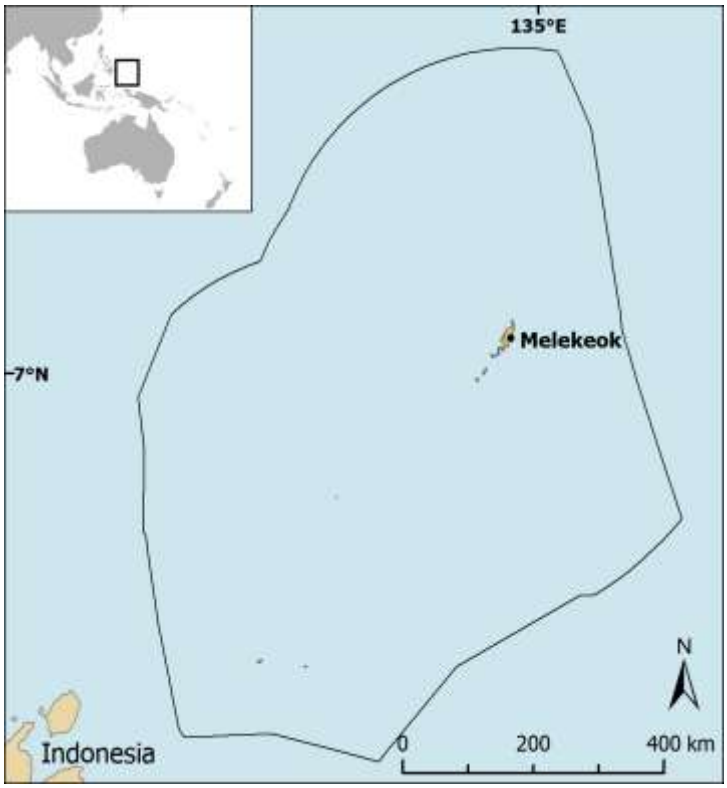

Figure 1. Map of Palau and its Exclusive Economic Zone (solid line).

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States. In 1994, Palau was designated as an independent country under the Compact of Free Association (Anon., 2003a) (Ota, 2006). The Compact of Free Association entails the United States providing military defense to Palau, development aid in the form of annual grants, and scholarship programs for Palauan residence to attend pos- secondary education in the United States. Due to this external support gradual development of some local industries, such as the tourism sector, Palau has the highest per capita GDP among Micronesia, and higher than most small island states in other Pacific region[2].

Traditionally, Pacific islanders have relied on marine resources as their main source of food, and fishing skills and knowledge were recognized as the status symbol of both wisdom and masculinity among many Pacific cultures (Johannes, 1981; Colbert, 2000). Likewise, in Palau, fishers were highly esteemed members of the community (Ota, 2006). Both Johannes (1981) and Ota (2006) have described fishing to be central to the organization of Palauan communities, embodying the gender dichotomy and social stratification, which still supports the basis of the socio-cultural dynamics of the society. In Palauan tradition, for instance, women have traditionally engaged in reef gleaning activities (Chapman, 1987), and farming of taro, while men capture fin fish which make up the majority of Palauan diet (Johannes, 1981; Mathews and Oiterong, 1991). Sharks and larger pelagic species are usually only caught for special occasions (Johannes, 1981).

Prior to colonization, Palauan society was organized into separate communities, each with its own respective chief. Between communities, land and sea barriers were continuous, and each community had proprietorship of sections of the coast line and reef. From ownership of and responsibility for a defined geographical area came a natural conservation ethic (Johannes, 1981). With the succession of colonizing countries, this system was increasingly disturbed by external political control and eventually replaced by modern democracy, which maintains the traditional chieftainship merely as a façade (Ota, 2006). More recently, the increase in the importance of the cash economy has led rapid urbanization of the country as people started seeking work in the capital, Koror (Johannes, 1981; Ota, 2006). In 1990, an estimated 70% of Palauans were living in Korror (Nichols, 1991). Even in the midst of this modernization, fishing has remained both economically and culturally important and is practiced regularly for subsistence purposes, though not commercially, by many Palauans both in their urban and rural settings. However, the centralization of marine resource management to the contemporary governing body has had negative effects on Palauan fishing culture and fish populations from the early days of the Palauan modernization as it slowly replaced the power of traditional community based management (TCBM) system which was based on the indigenous chieftainship (Johannes, 1981). For instance, Johannes (1981) reports that species of the Serranidae (e.g., groupers) were quickly overexploited due to fishers targeting spawning aggregations, which were previously controlled through the traditional community-based management (TCBM) system. Dynamite, poison, and other unsustainable fishing practices have also been employed since the breakdown of the TCBM, resulting in negative impacts on the reef fisheries of Palau (Johannes, 1981).

Since the Japanese occupation of Palau in 1914, tuna have been exploited in Palauan waters, and in recent decades, this has provided an important source of income for Palau, as fishing access fees for foreign vessels were introduced. Gillett(2009) estimated that in 2007 approximately 1.2 million USD were paid to Palau for access to fish in their waters. However, during WWII, all off-shore tuna fishing was halted until 1964 when an American company, Van Camp Seafoods, opened a processing facility in Koror (Lawson, 1991). Van Camp Seafoods operated until 1982. Since then, there has only been one locally based off-shore pole-and-line vessel operating under the Palauan Flag (Nichols, 1991).

The subsistence fishery has been largely unaccounted for in the FAO data for many island countries, despite its significant contribution to food security and local economies (Zeller *et al.*, 2006). It has been noted that Palau's inshore coral reef fishery continues to provide the main source of protein, and financial income for the majority of Palauan people (Johannes, 1981; Ota, 2006). In the recent period it has been estimated that 87% of Palau's population is engaged in coastal artisanal and subsistence fishing activities (Palau International Coral Reef Center, unpublished data in Golbuu *et al*, 2005). The artisanal and subsistence reef fisheries are carried out with a variety of gears. Fish pots, drop lines, trolling, hand

[2] http://www.adb.org/Documents/Fact_Sheets/PAL.pdf [accessed June, 2011]

spears, spear guns, gill nets, set nets (kesokes), and cast nets are the major gear types employed. The major species fished for in the small-scale fishery are snappers (Lutjanidae), emperors (Lethrinidae), groupers (Serranidae), parrot fishes (Scaridae), wrasses (Labridae), rabbitfishes (Siganidae), surgeon fishes (Acanthuridae), trevallies (Carangidae) and herring (Clupeidae) (Nichols, 1991).

Invertebrate fisheries are important components of the local diet and economy, but are poorly represented in official fisheries statistics. In earlier time periods most of the invertebrate fisheries were reported as being handled by women and children, predominantly for subsistence use (Johannes, 1981; Mathews and Oiterong, 1991), but they are now caught by commercial fishers and were largely sold at the local market mainly to the tourism sector (Anon., 2003b; Pakoa *et al.*, 2009). Bêche-de-mer is an important part of the Palauan diet, and is often collected by women during reef gleaning activities (Johannes, 1981; Mathews and Oiterong, 1991; Pakoa *et al.*, 2009). Bêche-de-mer is considered a boom and bust fishery, as the catches can fluctuate substantially year-to-year due to its ease of harvest and the open access nature of this fishery (Dalzell *et al.*, 1996). Other important invertebrate resources in Palau are the mud crab (*Scylla serrata*), land crab (*Cardiosoma hirtipes* and *Cardisoma carnifex*), and coconut crab (*Birgus latro) (*Johannes, 1981; Nichols, 1991; Dalzell *et al.*, 1996).

Since the 1990s, there have been some improvements to the documentation of the offshore and artisanal sectors of Palauan fisheries also reflected in better taxonomic breakdown in FAO data; however, to date no studies exist that include all fisheries components in a single estimate with a complete estimated time series (although Gillet [2009] does provide a very comprehensive estimate for the recent time period). The aim of this study is to make a comprehensive estimate of total marine fisheries catches for Palau that includes the invertebrate, subsistence, artisanal, offshore, and baitfish fisheries sectors over the 1950-2008 time period.

METHODS

For this report, officially reported landings were acquired from FAO (FishStat), and data were obtained from government reports, and independent reports published by the Secretariat of the Pacific Community (SPC) and Asian Development Bank (ADB). For the time period 1990-2007, several estimates of subsistence, artisanal and offshore commercial fisheries catches were available for some years (Nichols, 1991; Adams and Dalzell, 1994; Kitalong and Dalzell, 1994; Dalzell *et al.*, 1996; 2001; Gillett and Lightfoot, 2002; Gillett, 2009). Prior to 1990, few studies on commercial reef and off-shore fisheries were available (Johannes, 1981; Perron *et al.*, 1983; 1984). Data for certain years and for certain sectors were taken from Johannes (2009), Kitalong and Dalzell (1994), Dalzell *et al.*(1996), Gillett and Lightfoot (2002), and Gillett (2009). To derive a complete time series of data (1950-2008), we interpolated linearly between years of known data. Human population data and *per capita* fish consumption rates were used to calculate total seafood demand and secondarily derive subsistence sector catches for the 1950-2008 time period.

Human population

Human population census data were obtained from the Palau Office of Planning and Statistics (http://www.palaugov.net/stats) and used in combination with *per capita* consumption rates to calculate Palau's seafood demand. Linear interpolations were used to create a continuous time series of human population data from 1950 to 2008, as data were not available for all years (Figure 2). To account for the temporary increase in population due to tourists, we converted number of tourists

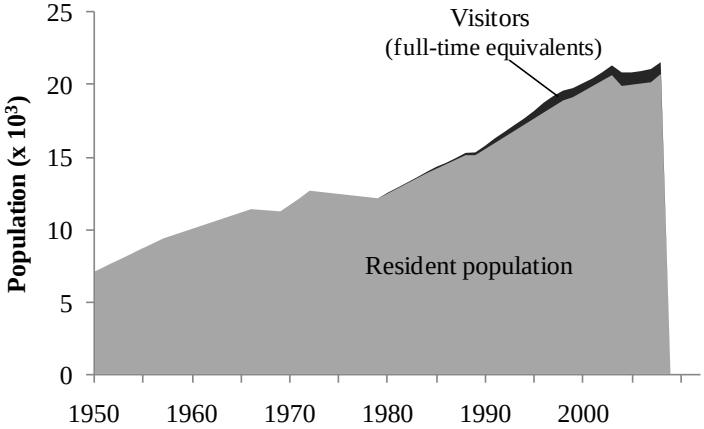

Figure 2. Population of Palau, 1950-2008 with the resident population and the number of visitors converted to full-time equivalents.

into full-time equivalents (Figure 2). To do this, we multiplied the number of visitors by the average number of nights stayed. The length of stay was derived from the estimated number of full-time equivalents presented in Gillette (2009) for the 1990s and the average number of annual visitors for the 1990s taken from the Palau Visitors Authority, published in Yamashita (2000). We estimated the average length of stay to be 3.6 days·visitor^{-1}·year^{-1} and applied this to the time series of visitors, which was for the period 1980-2008. The number of full-time equivalents was added to the resident human population and the total population was then used in conjunction with *per capita* seafood consumption rates to calculate the total demand of fishery products over the study period.

Commercial Fisheries

Inshore fisheries

Several independent studies on commercial inshore fisheries estimate annual catches (Table 1). The PCS (2000) estimate of 865 t has been the most widely agreed upon estimate for coastal fish production in Palau (Gillett, 2009). This estimate was compared to total catches presented by FAO for all species except large pelagics (tuna and billfishes). In 2007, FAO (non-pelagic) landings were found to be 11% higher than the PCS estimate of 865 t·year^{-1} of coastal commercial catch. We assumed that this additional catch (11%) presented in the FAO data was an estimate of non-commercial (subsistence) catches. Therefore, we assumed that 89% of FAO reported landings (excluding large pelagics) represent the coastal commercial (artisanal) catch, while the remaining 11% were considered the reported or estimated component of subsistence catches.

Table 1. Comparison of commercial inshore fisheries catch estimates for the recent period (1990s & 2000s) from various independent sources.

Catch (t/year)	Source
300-400	Shimada (1987 in Nichols, 1991)
250	Kitalong and Dalzell (1994)
865	PCS (2000 in Gillett and Lightfoot, 2002)
736	Anon. (1993 in Dalzell *et al.*, 1996)

Offshore fisheries

Palau's offshore fishery began in the 1920s when Japan occupied the islands. After WWII, tuna fisheries in Palau ceased and it was not until the early 1960s, after a fisheries development program was launched to jump start Palauan offshore fisheries, that tuna fishing resumed. In 1964, a joint-venture company (Van Camp Seafood of the United States) began operating a pole-and-line tuna fishery in Palau, which lasted until 1982 (Anon., 1984). These catches were considered domestic as they were caught and landed by Palau, even though the financing for this fishery was from the United States. Aside from Van Camp Seafood, offshore tuna fisheries in Palau have been mainly foreign fleets, which land their catches outside Palau (Anon., 1944; Gillett and Lightfoot, 2002). After the closing of Van Camp Seafood, only a single domestic pole-and-line vessel remained in operation. Based on our comparison of FAO tuna and billfish landings with other reports (e.g., Gillett, 2010), we concluded that the FAO data were the best available representation of domestic, large pelagic fishery catches.

Due to the minimal bycatch associated with pole-and-line fisheries (Bailey and Williams, 1996; Kelleher, 2005) we did not estimate bycatch, either landed or discarded. However, pole-and-line fisheries do require considerable amounts of live bait which are often caught in reef areas adjacent to the tuna fishing grounds. These catches are rarely accounted for in catch statistics, and we assumed that these were not estimated or included in the FAO data. Therefore, we estimated the amount of fish that was likely caught in order to provide bait for the domestic tuna fishery. Gillette(2011) gives an average tuna-to-baitfish ratio of 26:1 for Palau's pole-and-line fishery between 1964 and 1972. We assumed a similar ratio for the entire 1964-1982 period, when Van Camp Seafood was in operation. This ratio was applied to the total tuna landings from 1964-1982. In 1982, the bait fishery in Palau ceased operations, likely as a result of Van Camp Seafood discontinuing operations in Palau (Anon., 1984). Although one domestic tuna vessel continued to fish after 1982, we did not make any further estimates of baitfish catches. Catch of baitfish was likely dominated by short head anchovy (*Encrasicholina heteroloba*), delicate round herring (*Spratelloides delicatulus*), and Samoan silverside (*Hypoatherina temmincki*). From the estimated catch by species given in the SPC (1984) report on the bait fishery, we derived a species breakdown of 56% *Encrasicholina heteroloba*, 21% *Spratelloides delicatulus* and 8% *Hypoatherina temminckim,* with the remaining 15% being Clupeiformes.

Subsistence fishery

To independently estimate the subsistence catch in Palau, we used *per capita* fish consumption estimates for three separate years, and interpolated linearly between these to derive a complete time series of *per capita* fish consumption rates. The *per capita* consumption rates used were 122 kg·person^{-1}·year^{-1} for 1974 (Johannes, 1981), 135 kg·person^{-1}·year^{-1} for 1999 (Gillett and Lightfoot, 2002), and 115 kg·person^{-1}·year^{-1} for 2007 (Gillett, 2009). Johannes' (1981) estimate of *per capita* fish consumption was calculated using the weight of protein consumed daily, and the landed weight of fish (with weight of bones and scales removed). The estimate from Gillett and Lightfoot (2002) was calculated using the PCS (2000) in-shore catch estimate of 2,115 t adjusted for imports, exports and full time visitor equivalents. The consumption rate calculated from Gillett (2009), which used the same methodology as the Gillett and Lightfoot(2002) and population and visitation data from 2007, was adjusted for imported and exported fishery products and excluded pelagic species which do not form a significant portion of the Palauan diet. Other estimates of *per capita* fish consumption were available (Perron *et al.*, 1983; Preston, 1990) but were general estimates for the South Pacific region or were partially derived using FAO or commercial landings data. We disregarded these estimates based on information regarding the Palauan diet which suggested that although imported food, pigs, and bats contribute in small parts to the Palauan diet, fish still remains the main source of protein (Johannes, 1981; Anon., 2003b; Ota, 2006). Our earliest estimate of *per capita* fish consumption (Johannes, 1981) was carried back fixed from 1974 to 1950 and linear interpolations were used between 1974 and the two later estimates to derive a complete time series of *per capita* fish consumption rates. These rates were then multiplied by the annual human population to derive the total domestic seafood demand. This was then used to determine whether the demand was met through the supply of reported landings. The discrepancy found between these two numbers was then considered unreported subsistence catch. To this we added the 11% of FAO non-pelagic catches that were considered reported subsistence catches. The total subsistence catch (reported + unreported) was then compared to our estimate of reconstructed coastal commercial catches. On average, subsistence catches represented approximately 60% of the total coastal catches (subsistence and artisanal combined). For the South Pacific in general, the ratio of subsistence to total catch can be as high as 80% (Adams and Dalzell, 1994) with the average being around 70%(Gillett, 2009). We thus considered our approach to be conservative.

Table 2. Taxonomic composition of the non-pelagic catches (as proportion of total catch) by family or grouping based on Kitalong and Dalzell (1994) for 1950-1990 and Friedman *et al.* (2007) for 2007-2008. A linear interpolation was used to derive a complete time series between 1990 and 2007.

Family	1950-1983	1984-1990	1991-2006	2007-2008
Acanthuridae	0.141	0.129	linear interpolation	0.104
Carangidae	0.026	0.040	linear interpolation	0.022
Gerridae	0.007	0.002	linear interpolation	0.011
Haemulidae	0.002	0.001	linear interpolation	0.015
Holocentridae	0.004	0.001	linear interpolation	0.011
Labridae	0.010	0.008	linear interpolation	0.008
Lethrinidae	0.119	0.139	linear interpolation	0.268
Lutjanidae	0.085	0.135	linear interpolation	0.140
Mugilidae	0.019	0.005	linear interpolation	0.024
Mullidae	0.010	0.012	linear interpolation	0.023
Scaridae	0.163	0.187	linear interpolation	0.154
Serranidae	0.091	0.093	linear interpolation	0.105
Siganidae	0.116	0.105	linear interpolation	0.105
Others	0.185	0.123	linear interpolation	0.005
Crustaceans	0.020	0.020	linear interpolation	0.005

Invertebrate fisheries

Estimates of invertebrate fisheries catches were not readily available; however, sea cucumber (bêche-de-mer) has been a component of the Palauan diet for centuries (Pakoa *et al.*, 2009). Sea cucumber fisheries often fluctuate considerably from year-to-year (Dalzell *et al.*, 1996); however, catches reported by FAO for this fishery are minimal (<0.5 t), despite it being an important component of the subsistence fishery. Sea cucumber and invertebrates are collected in reef gleaning activities by women (Mathews and Oiterong, 1991). Sea cucumber landings were estimated to be 11.3 t·year^{-1} between 1989 and 1998 (Pakoa *et al.*, 2009). Over 50% of this was for subsistence consumption, 48% was sold in local markets and less than 1%

was exported. Pakoa *et al.* (2009) estimate that in 2007, sea cucumber catches were approximately 65.5 t·year^{-1}. Given the substantial fluctuations characteristic of sea cucumber fisheries and the limited catch data, we used the average of Pakoa *et al.*'s (2009) estimate for the 1990s (11.3 t) and for 2007 (65.5 t). The average of these two was approximately 38.4 t (19.2 t each from artisanal and subsistence sectors), which we applied as the catch for the year 2000. This was converted to a *per capita* rate, and using the population time series, sea cucumber catches were estimated for the entire study period. Sea cucumber catch estimates were then subtracted from the 'other species' category of the artisanal and subsistence catch. (Anon., 2003a)

Crustacean fisheries are also an important part of subsistence and, to a certain extent, commercial fisheries in the South Pacific (Dalzell *et al.*, 1996). Palau's catches of crustacean in the early to mid-1990s were estimated by Dalzell *et al.* (1996) to be 14.4 t·year^{-1}, which represents approximately 2% of artisanal catches. Prior to 1990, FAO catches for Palau present all catches as either miscellaneous marine fishes or pelagic fish species. As of 1990, the FAO provides greater taxonomic detail, which includes several invertebrate categories. Between 1990 and 2008, FAO crustacean categories represent on average 0.8% of the total non-pelagic landings. Crustacean catches were subtracted from the 'other species' category of the artisanal and subsistence catches.

Table 3. Species composition of the families, which dominate the coastal fisheries of Palau based on Friedman *et al.* (2007).

Family	Taxonomy	Proportion of catch by family
Acanthuridae	*Acanthurus xanthopterus*	0.22
	Naso lituratus	0.34
	Naso unicornis	0.21
	Acanthuridae	0.23
Carangidae	*Caranx ignobilis*	0.24
	Caranx melampygus	0.43
	Carangidae	0.33
Gerreidae	*Gerres macrosoma*	0.97
	Gerreidae	0.03
Haemulidae	*Plectorhinchus albovittatus*	0.51
	Plectorhinchus spp.	0.49
Holocentridae	Holocentridae	1.00
Labridae	*Cheilinus undulatus*	0.30
	Choerodon anchorago	0.70
Lethrinidae	*Lethrinus harak*	0.09
	Lethrinus olivaceus	0.19
	Lethrinus rubrioperculatus	0.06
	Lethrinus xanthochilus	0.15
	Lethrinidae	0.51
Lutjanidae	*Aprion virescens*	0.09
	Lutjanus bohar	0.15
	Lutjanus gibbus	0.63
	Lutjanidae	0.13
Mugilidae	Mugilidae	1.00
Mullidae	Mullidae	1.00
Scaridae	*Cetoscarus bicolor*	0.17
	Hipposcarus longiceps	0.45
	Scarus ghobban	0.15
	Scarus oviceps	0.11
	Scaridae	0.12
Serranidae	*Plectropomus areolatus*	0.22
	Plectropomus leopardus	0.25
	Epinephelus spp	0.44
	Serranidae	0.09
Siganidae	*Siganus lineatus*	0.57
	Siganus spp.	0.43

Taxonomic composition

FAO data for Palau have poor taxonomic resolution until the 1990s. For the period 1950-1989, landings are mainly reported as the aggregated grouping, 'miscellaneous marine fishes (MMF)'. Perron (1983) presents a breakdown of the artisanal fishery by family, but these estimates were highly variable. Dalzell *et al.* (1996) has a partial breakdown of the 1992 artisanal fishery including an estimate for the crustacean fishery. Kitalong and Dalzell (1994) have a taxonomic breakdown by family for the years 1976-1990, with two separate breakdowns for the periods 1976-1983 and 1984-1990. Friedman *et al.* (2007) have the most detailed breakdown of the artisanal fishery including species-level composition for catches in four major fishing districts in Palau. Here, we used the breakdown in Kitalong and Dalzell (1994) for the period 1950-1990 and Friedman *et al.* (2007) for 2007 and 2008 (Table 2).

Using Friedman *et al.* (2007) we calculated the taxonomic composition using the weighted average of each fishing district as a proportion of the total catch in the study, and each area (lagoon, sheltered reef, outer reef) as a proportion of the total in each district. The proportion of each species in each region was then weighted according to the fishing area and district. The proportion each species represented in the total catch was taken as the sum of the proportion of the catch by weighted area. To compare this breakdown with that presented in Kitalong and Dalzell (1994), we grouped the species by family (see Table 3). In order to derive a complete time series between 1990 and 2007, we interpolated linearly between the Kitalong and Dalzell (1994) and Friedman (2007) estimates for each taxonomic family. The 1976 estimate was carried back, unaltered to 1950 and the 2007 estimate was carried forward unaltered to 2008.

Using Dalzell *et al.*'s (1996) estimate of crustacean catch for the early 1990s, we assumed 2% of artisanal catches were crustaceans for the period 1950-1990. This was incorporated into our artisanal sector taxonomic breakdown by subtracting 2% from the 'others' category in the original breakdown. In 2007, we assumed a lower proportion of crustaceans (0.5%) in the artisanal breakdown as after 1990 crustacean categories begin to appear in the FAO data. The taxonomic breakdown with crustaceans incorporated was then applied to the unspecified portion of the artisanal catch (miscellaneous marine fish category in the FAO data). We assumed the same species breakdown for the subsistence catch. Sea cucumber catch which was estimated using a *per capita* rate was then subtracted from the 'others' category for the artisanal and subsistence catch in all years.

For each family, a species-level breakdown was derived using Friedman's (2007) estimates (Table 3). This species breakdown was applied to each family group throughout the 1950-2008 time period for the artisanal and subsistence fishery catches.

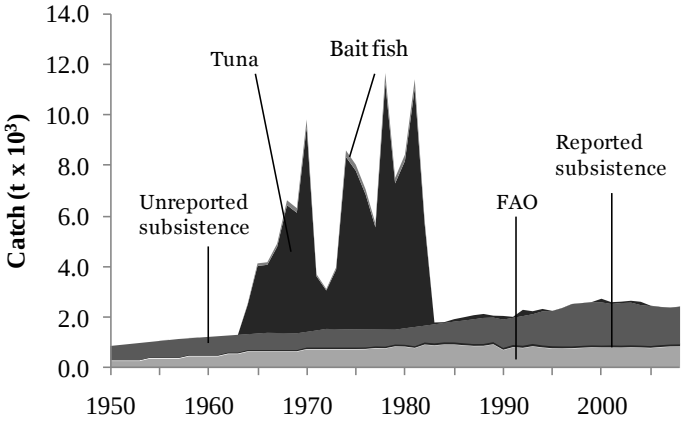

Figure 3. Palau total reconstructed catch including subsistence, artisanal, locally based tuna, baitfish, 1509-2008.

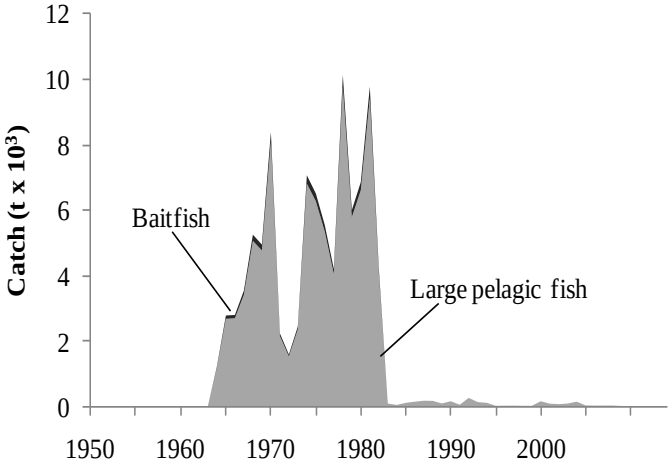

Figure 4. Total catch of large pelagic species and the baitfish associated with the main gear used in this fishery: pole-and-line.

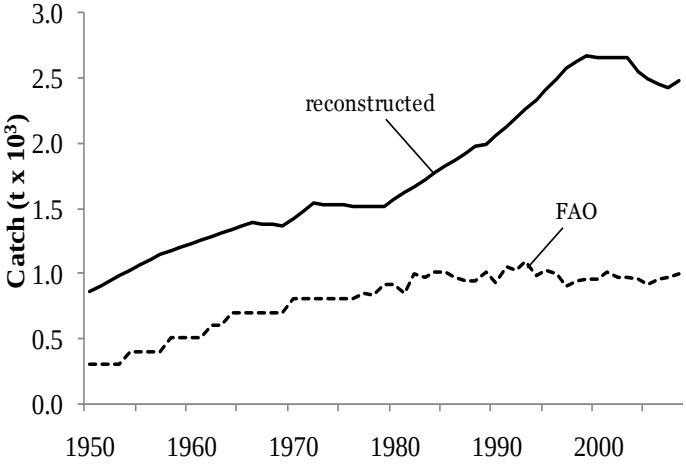

Figure 5. Palau reconstructed and FAO coastal catches 1950-2008.

RESULTS

Our estimate of the total reconstructed catch for Palau, which includes subsistence, artisanal, locally-based tuna fisheries and baitfish totalled 200,817 t for the 1950-2008 time period. This estimate was 43 % higher than the total landings presented by FAO on behalf of Palau for 1950-2008, which was estimated to be 140,483 t (Figure 3). The FAO reports 93,868 t of pelagic species, which were considered to be from the domestic offshore fisheries (Figure 4).

The remaining 49,609 t reported by the FAO were considered to be the coastal fisheries catches. Of the coastal catches presented by the FAO, 89% were considered to be from the commercial (reported artisanal) sector, while the remaining 11% were considered to be non-commercial (reported subsistence) catches (Figure 3). Reported artisanal catches totalled approximately 41,488 t and reported subsistence catches were just over 5,000 t (Figure 5). In addition to the reported subsistence, we estimated another 56,800 t of unreported subsistence (Figure 3). Subsistence catches were estimated to be almost 62,000 t for the 1950-2008 time period. Total coastal catches were estimated to be 103,480 t, 45% higher than the total reported coastal catches (Figure 5.) Thus, total subsistence catches accounted for 60% of total coastal catches. Subsistence catches in 1950 represented 70% of the total coastal catch (total artisanal + total subsistence), decreasing to approximately 50% during the 1970s and 1980s and increasing again to approximately 65% in the recent period (1990s and 2000s; Figure 6).

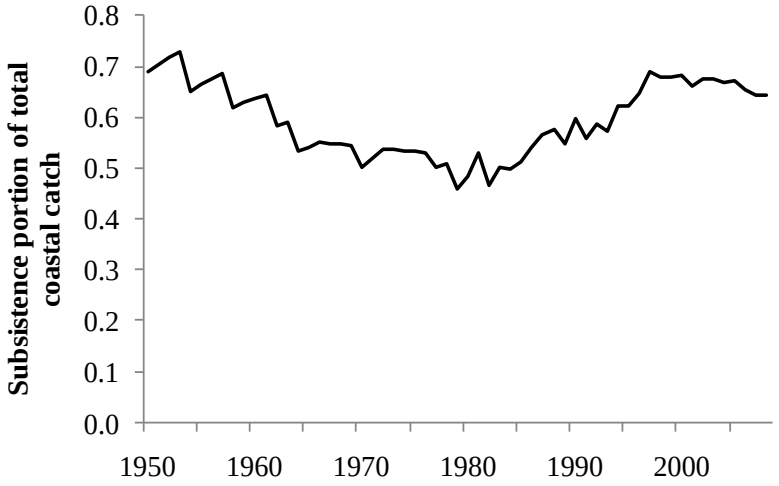

Figure 6. Subsistence portion of the total coastal catch, which includes artisanal and subsistence catches, 1950-2008.

The amount of baitfish caught for use in the pole-and-line fishery was estimated to be almost 3,500 t over the period 1964-1982 (Figure 4).

DISCUSSION

The total reconstructed catch for Palau from 1950-2008 was estimated to be 200,817 tonnes. This estimate is 43% higher than the landings reported by FAO on behalf of Palau for this same period (140,483 tonnes). The difference between these two estimates is mainly attributed to the addition of subsistence catches, which were predominantly unaccounted for in the reported data.

Our work showed that subsistence catches represented an average of 60% of the total domestic catch. For the Pacific Islands region, in general, Adams and Dalzell (1994) estimate that the subsistence catch can represent as much as 80% of the total catch. Currently, an estimated 87% of people are involved in the fishing industry in Palau (Palau International Coral Reef Center, unpublished data in Golbuu *et al.*, 2005). In recent years there has been an increase in the amount of imported food in the Palauan diet (Johannes, 1981; Ota, 2006), but the results of this study show reliance on local reef fish remains high in Palau. The subsistence catch has increased, since 1950, mostly attributed to increase in population size. The subsistence catch will likely continue rising due to a growing population (Anon., 2003a). The majority of the domestic supply of fish in the 1950s was from the subsistence sector (70%) and although the portion of the total domestic catch supplied by subsistence fisheries declined during the 1970s and

1980s,—likely due to an increase in commercial exploitation of fisheries resources—the subsistence sector continues to dominate domestic fisheries catches. The under-reporting of subsistence catches may adversely affect food security in Palau given the importance of this sector to the Palauan culture and diet. Nichols (1991) notes that one species in particular, the humphead wrasse (*Cheilinus undulatus)*, is rarely sold due to a strong preference for this fish in the local diet. It is caught in unknown amounts and usually kept for home consumption. A lack of monitoring and reporting of species important to the subsistence fishery, such as *C. undulatus*, could lead to the silent extirpation of species from Palau's reefs.

The commercial offshore catches in Palau were well documented from 1937-1944 by the Japanese Office of the Chief of Naval Operations. The average catch during this time was approximately 3000 tonnes (Anon., 1944). During WWII, all commercial offshore fishing ceased. Catches prior to WWII, while being quite substantial, are not included as they fall outside the time period considered for this study. Recording of pelagic species, mostly skipjack, began in 1964. From 1964-1982 Van Camp Seafoods operated in Palau, and the catches are well documented in Lawson (1991).

Our estimate of total catches is likely still an under-representation of the actual annual catch due to the conservative approach employed in our estimations and the omission of the recreational fishery sector. The South Pacific Commission (1999) estimates roughly 8.3 t of billfish are taken annually in game fish tournaments in Palau. The major species taken in this fishery are blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Tetrapturus audax*), and sailfish (*Istiophorus platypterus*). Recreational fishing is on the rise in Palau as tourism increases (Nichols, 1991). Better documentation of this fishery is recommended for the conservation of billfish in Palau's EEZ.

Multiple studies have estimated Palau's offshore, artisanal, subsistence and invertebrate fisheries separately; however, this study is the first to combine all these sectors into one comprehensive estimate with a continuous time series from 1950-present. This study revealed some major deficiencies in the availability of fisheries data covering all sectors, with a particular scarcity of data on the subsistence sector, which could be argued is the sector most important to day to day existence of the Palauan people. Our comprehensive estimate of total marine fisheries catches for Palau will hopefully serve as a more realistic baseline from which fisheries management options and tradeoffs can be assessed.

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Appendix Table A1: FAO landings vs. total reconstructed catch for Palau, 1950-2008, in metric tonnes.

Year	FAO landings	Total reconstructed catch
1950	300	863
1951	300	903
1952	300	942
1953	300	982
1954	400	1,021
1955	400	1,061
1956	400	1,100
1957	400	1,140
1958	500	1,167
1959	500	1,195
1960	500	1,222
1961	500	1,250
1962	600	1,277
1963	600	1,304
1964	1,866	2,542
1965	3,370	4,130
1966	3,386	4,174
1967	4,106	4,915
1968	5,756	6,621
1969	5,462	6,309
1970	8,882	9,811
1971	2,943	3,703
1972	2,319	3,118
1973	3,150	3,971
1974	7,608	8,588
1975	7,069	8,026
1976	6,136	7,051
1977	4,883	5,705
1978	10,602	11,647
1979	6,699	7,507
1980	7,516	8,423
1981	10,276	11,396
1982	5,053	5,874
1983	1,041	1,796
1984	1,037	1,808
1985	1,100	1,926
1986	1,100	2,002
1987	1,100	2,083
1988	1,100	2,132
1989	1,090	2,065
1990	1,076	2,201
1991	1,093	2,170
1992	1,271	2,447
1993	1,211	2,388
1994	1,086	2,436
1995	1,027	2,421
1996	1,000	2,512
1997	913	2,585
1998	952	2,640
1999	962	2,672
2000	1,097	2,807
2001	1,086	2,727
2002	1,030	2,714
2003	1,050	2,740
2004	1,081	2,685
2005	935	2,517
2006	969	2,473
2007	986	2,437
2008	1,008	2,492

AppendixTableA2: Total reconstructed catch (t) for Palau by major taxa.Others category represents 58 taxonomic groups including miscellaneous marine fishes.

Year	*Katsuwonus pelamis*	Lethrinidae	*Hipposcarus longiceps*	*Lutjanus gibbus*	*Thunnus albacares*	*Siganus lineatus*	*Siganus* spp.	Others
1950	-	53	63	46	-	57	43	601
1951	-	55	66	48	-	60	45	629
1952	-	58	68	51	-	62	47	657
1953	-	60	71	53	-	65	49	684
1954	-	62	74	55	-	67	50	712
1955	-	65	77	57	-	70	52	739
1956	-	67	80	59	-	73	54	767
1957	-	70	83	61	-	75	56	794
1958	-	71	85	63	-	77	58	814
1959	-	73	87	64	-	79	59	833
1960	-	75	89	66	-	81	60	852
1961	-	76	91	67	-	83	62	871
1962	-	78	93	69	-	84	63	890
1963	-	80	95	70	-	86	64	909
1964	1,025	81	97	72	141	88	66	972
1965	2,497	83	99	73	173	90	67	1,048
1966	2,615	85	101	74	71	92	69	1,068
1967	3,354	84	100	74	52	91	68	1,090
1968	5,039	84	100	74	17	91	68	1,148
1969	4,629	84	99	73	133	90	68	1,133
1970	8,081	87	103	76	1	94	70	1,297
1971	2,133	90	108	79	10	98	73	1,112
1972	1,463	94	112	83	56	102	76	1,132
1973	2,309	94	111	82	41	101	76	1,157
1974	6,647	93	111	82	161	101	75	1,319
1975	5,971	93	111	82	298	101	75	1,297
1976	4,911	93	110	82	412	100	75	1,268
1977	3,592	93	110	81	420	100	75	1,234
1978	9,391	92	110	81	303	100	75	1,495
1979	5,687	92	110	81	1	100	75	1,361
1980	5,580	96	114	84	996	104	77	1,372
1981	6,931	99	117	87	2,480	107	80	1,495
1982	3,438	102	121	90	615	110	82	1,316
1983	75	105	125	92	-	114	85	1,199
1984	32	126	148	151	-	106	80	1,164
1985	82	130	152	156	15	110	82	1,199
1986	112	133	156	159	19	112	84	1,227
1987	139	136	160	164	22	115	86	1,260
1988	119	140	165	168	38	118	89	1,295
1989	72	141	166	169	5	119	89	1,303
1990	80	161	159	162	8	114	86	1,428
1991	-	168	163	169	-	119	89	1,460
1992	61	177	167	175	62	123	92	1,588
1993	-	189	171	182	39	127	95	1,583
1994	-	206	178	192	31	134	100	1,592
1995	-	220	178	193	3	135	101	1,594
1996	-	234	184	203	2	142	106	1,640
1997	-	253	195	217	1	151	113	1,654
1998	-	278	195	221	1	154	115	1,677
1999	-	283	196	225	1	156	117	1,694
2000	-	290	193	225	63	156	116	1,762
2001	-	296	187	220	41	152	114	1,721
2002	-	305	187	223	3	154	115	1,728
2003	-	317	186	225	19	155	116	1,733
2004	-	313	177	217	28	149	112	1,689
2005	-	317	172	214	0	147	110	1,557
2006	-	321	167	211	-	144	108	1,521
2007	-	325	163	209	-	143	107	1,491
2008	-	336	166	212	-	145	109	1,525