WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

Final Report
November 2005

RECONSTRUCTION OF CORAL REEF- AND BOTTOM FISHERIES CATCHES FOR U.S. FLAG ISLAND AREAS IN THE WESTERN PACIFIC, 1950 TO 2002

By

Dirk Zeller, Shawn Booth & Daniel Pauly
Fisheries Centre
Aquatic Ecosystem Research Laboratory
University of British Columbia
2202 Main Mall
Vancouver, BC V6T 1Z4

A Council Authorized by the Magnuson Fishery Conservation and Management Act of 1976
1164 BISHOP STREET · SUITE 1400 · HONOLULU · HAWAII 96813 USA · TELEPHONE (808) 522-8220 · FAX (808) 522-8226
www.wpcouncil.org

Cover Photograph: A lone scissortail sergeant (*Abudefduf sexfasciatus*) in a school of black tail snappers (*Lutjanus fulvus*). Piti, Guam

A publication of the Western Pacific Regional Fishery Management Council pursuant to National Oceanic and Atmospheric Administration Award No. NA03NMF4410349

Final Report

RECONSTRUCTION OF CORAL REEF- AND BOTTOM FISHERIES CATCHES FOR U.S. FLAG ISLAND AREAS IN THE WESTERN PACIFIC, 1950 TO 2002

By

Dirk Zeller, Shawn Booth & Daniel Pauly
Fisheries Centre
Aquatic Ecosystem Research Laboratory
University of British Columbia
2202 Main Mall
Vancouver, BC V6T 1Z4

Prepared for the
Western Pacific Regional Fishery Management Council
1164 Bishop Street, Suite 1400
Honolulu, Hawaii 96813

November 2005

Contents:

1. Executive Summary

Fisheries play an important role in Pacific Island societies. While fisheries for pelagic species such as tuna and billfishes are generally of great commercial significance, near-shore fisheries targeting coral reef-, bottom-species, as well as species closely associated with coral reefs are of more fundamental importance, providing subsistence, recreational, cultural and food security functions. However, these fisheries, owing to their scattered nature, have often been under-represented in accounts of catches in official statistics, due to difficulties in and cost of obtaining reliable 'hard data' covering whole countries. Thus, such catches often remain un- or under-accounted for in official statistics.

Reconstructing historic catches in cases where time-series data are lacking requires assumptions and interpolations between often widely spaced data 'anchor' points. These data points are usually based on local studies, fisheries-unrelated studies (e.g., human population, diet or consumption studies) and unpublished grey literature. Consequently, estimates derived from such alternative and irregular (in time, space and sampling design) sources may be associated with higher data uncertainties than 'hard' time-series. Nevertheless, such approaches are required, as the alternative, i.e., continuing the established pattern of not reporting anything in situations where 'no time-series data' exist, is not useful in light of increasing demands for accountability of marine resource use, and calls for sustainability and ecosystem based approaches to management. Without attempting to fully account for all fisheries catches (even if based on extrapolations), we will not be able to obtain any measure of the likely formal and informal economic, as well as cultural value of marine resources to Pacific Island communities.

The purpose of this project was to assemble available information on catches for the coral reef- and bottom-fisheries of the U.S. flag island areas of the Western

Pacific region, specifically American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), Hawaii, and the other, isolated islands and atolls under U.S. jurisdiction, for the 1950-2002 period. The aim was to derive estimates of total removal of marine resources over this time period, excluding large pelagic fisheries (e.g., tunas and billfishes). Thus, the focus was on coral reef fisheries, including the bottom-fisheries, as well as catches of coastal, reef-associated small pelagic species such as scads and jacks.

This document attempts to reconstruct fish catches based on very limited data and thus required broad interpolation of disparate data and relied upon bold assumptions. The document does not consider other factors which affect *per capita* catches of marine resources such as extensive shoreline development and habitat alterations, environmental changes due to typhoons and ENSO phenomena, changes in lifestyle and diets, the shift in preferences for western food sources and increased availability of cheaper seafood imports from foreign sources.

Overall summary

The catch reconstruction as undertaken here indicated:

- The reconstructed catches for all islands combined suggested a potential decline of 41% in total catches between 1950 and 2002, largely driven by declines in recent years. This contrasted with the pattern observed from the data officially reported by individual countries, which suggested a marginally increasing trend (Figure 1.1);
- The official reported data may have under-represented the reconstructed likely total catches for this time period by a factor of 4.3 (Figure 1.1);
- Excluding the U.S. state of Hawaii, the reconstructed data for the three other U.S. flag island areas (American Samoa, Guam, CNMI) suggested a potential decline of 77% in total catches between 1950 and 2002. This contrasted with the pattern observed from the data officially reported by the

three individual countries, which suggested an increase in catches of about 45% between the start of reported data in 1965 and 2002 (Figure 1.2); and

- The predominantly non-commercial fisheries sectors (shore-based, subsistence, recreational) were likely larger than commercial fisheries in terms of estimated catches.

Individual island entities

For **American Samoa** (Section 3.1), the reconstructed total catches suggested a decline of about 79% in catches for coral reef, bottom and reef-associated pelagic fisheries between 1950 and 2002. Significant also was the 17-fold difference between the reconstructed catches and the reported data. Given the historic focus of data collection systems on reporting commercial catches for economic development purposes, it is not surprising that the reported data for American Samoa represent only the predominantly commercial small-boat bottom-fish catches reported by WPacFIN (plus the large pelagic species excluded here).

For **Guam** (Section 3.2), the reconstruction of historic catches suggested a decline of 86% over the 50 year time period considered here. Important also is the 2.5-fold difference between the reconstructed catches and the reported statistics for the 1965-2002 period. Noteworthy is Guam's commitment to and consistent application of creel surveys to estimate total catches for the last few decades, resulting in what may be the most reliable estimates of total catches for any of the islands considered here.

For the **Commonwealth of the Northern Mariana Islands** (CNMI; Section 3.3), the reconstructed catches suggested a decline of about 50% in catches between 1950 and 2002. Comparing the non-pelagic catches reported by CNMI via WPacFIN with the reconstructed total catches, indicated a 2.2 fold under-reporting of likely total catches by the reported data compared to the reconstructed totals for the 1983-2002 time period of coverage by WPacFIN.

For **Hawaii** (Section 3.4), our reconstruction suggested that the estimated total commercial catches were between 28% and 130% higher than the reported commercial catches. Reconstruction also suggested that non-commercial catches may have increased between 1950 and 1990, but have declined since, and ranged from a low of approximately 931 t·year^{-1} to a high of approximately 3,000 t·year^{-1}. Thus, total catches for non-pelagic species may have peaked in the late 1980s, early 1990s at approximately 4,500 t·year^{-1}, and may have declined to approximately 3,000 t·year^{-1} by 2002. Summed over 1950-2002, non-commercial catches were approximately 1.8 fold higher than reported commercial catches, and reported data (partially reporting commercial catches) may have underestimated likely total catches of non-pelagic species by a factor of 3.7.

For the **other islands** (Midway Atoll, Johnston Atoll, Palmyra Atoll, and Wake, Jarvis, Baker and Howland Islands; Section 3.5), only Johnston, Midway and Wake have small resident populations and small recreational fisheries, with most data not reported in the fisheries statistics. Reconstruction of catches for Johnston atoll suggested catches ranging from about 6 t·year^{-1} (13,000 lbs·year^{-1}) for 1950 to a peak of about 14 t·year^{-1} (32,000 lbs·year^{-1}) in 1985, before declining to approximately 3 t·year^{-1} (6,500 lbs·year^{-1}) by 2002, with the pattern driven by changes in resident population of military and civilian personnel. Overall, an estimated total catch of about 435 t (960,000 lbs) was likely extracted from the near-shore reefs around Johnston Atoll between 1950 and 2002. The relatively small population of military and civilian personnel based on Wake Island were thought to catch on average approximately 890 kg·year^{-1} (1,960 lbs·year^{-1}).

General comments

While local and regional fisheries experts and agencies may be aware of the limited nature of much of the official data (e.g., commercial sectors only), our reconstruction makes the potential scale of the likely under-reporting of total extractions of marine resources evident. While the historic catch estimates proposed here do not represent a stock assessment *per se*, they can be useful for evaluating fisheries and ecosystem status and conditions, i.e., as baselines of likely historic patterns and trends in fisheries catches.

Considering the distinctly different baselines of past catches as presented in this report may shed new light on issues and concerns for fisheries sustainability and ecosystem conservation. Furthermore, reconstructions as presented here illustrate the importance of small-scale and non-commercial fisheries sectors, and suggest an urgent need to account for all fisheries catches in official statistics.

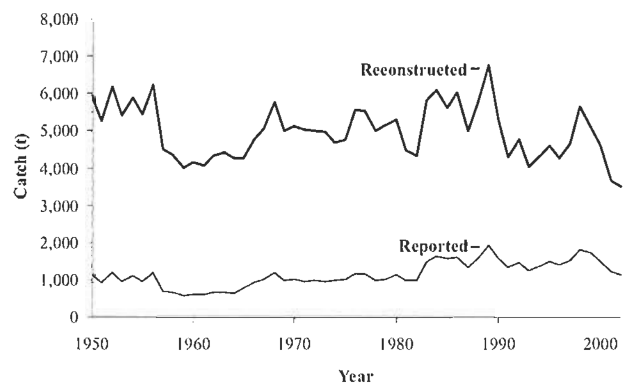


Figure 1.1: Total reconstructed catches of coral reef-, bottom- and reef-associated fisheries for the four main U.S. flag islands of the Western Pacific combined, versus the reported statistics. The under-representation of likely total catches is evident.

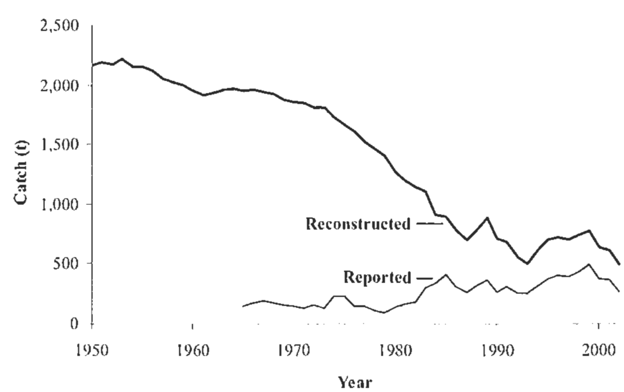


Figure 1.2: Total reconstructed catches of coral reef-, bottom- and reef-associated fisheries for three of the four U.S. flag islands of the Western Pacific considered here (excluding Hawaii), versus the reported statistics. Both the under-representation of likely total catches, as well as the missed decline in catches is evident.

2. General introduction

Fisheries resources have played a key role in defining and shaping Pacific Island communities for centuries (Dalzell, 1998; Anonymous, 2001). While fisheries for pelagic species are often the most significant commercial fisheries in many areas of the tropical Pacific, near-shore coral reef fisheries are generally of more fundamental subsistence, recreational, social and cultural importance for many of the island communities, providing more than just food, trade and recreational resources (Boehlert, 1993; Dalzell, 1996; Dalzell *et al.*, 1996; Dalzell and Adams, 1997). Also, subsistence fisheries in many Pacific Island communities play a particularly vital role in food security as the primary source of protein (Anonymous, 2001). Yet they are often absent from official statistics due to difficulties and costs associated with 'hard-data' quantification of spatially highly dispersed fisheries (Anonymous, 2000). While catches for large pelagics are generally relatively well documented (at least for the last decades), catches for the small-scale, artisanal, subsistence and recreational fisheries are usually not reported to, or estimated by fisheries agencies. Hence, extractions of these marine resources often remain unaccounted for in national and global statistics (Pauly, 1998). The resulting poor understanding of historical trends of total catches are a concern, given recent illustrations of the generally overlooked historical impacts of fishing and other human activities on marine resources and ecosystems (Jackson, 1997; Jackson *et al.*, 2001; Christensen *et al.*, 2003; Pandolfi *et al.*, 2003).

Reconstruction of historic catch time series in cases where 'hard' time series data are lacking often requires interpolation and bold assumptions, justified by the unacceptable nature of the alternative, i.e., eventual interpretation of missing catches as zero (Pauly, 1998). For example, the only global data set of fisheries catches in existence, assembled and maintained by the United Nations Food and Agriculture Organization (FAO, extracted June 2003), based on member country reports, presents total catches for Guam as <200 $t \cdot year^{-1}$ prior to the mid 1980s (the majority being unidentified 'miscellaneous marine fishes'). This clearly is not reflective of true historic catches for an island with 106,000 inhabitants (in 1980), whose human population nearly doubled between 1950-1980, and which historically relied heavily on marine resources for protein. Similarly, catches of non-pelagic species for the Northern Mariana Islands and American Samoa are poorly represented in official fisheries statistics for earlier periods.

Without accounting for fisheries catches for all sectors of a community, we cannot obtain any comprehensive measure of the formal and informal economic as well as cultural value of these resources to the communities, or of the risks excessive fishing may represent to U.S. flag island areas in the Pacific. This is of concern, given that human population growth rates are among the highest in the Pacific (Craig, 2002; Green, 2002) and natural resources in these islands are limited, and perceived to be declining (Craig, 1995). Furthermore, for many of these islands, the growing shift from predominantly subsistence to westernized, cash-oriented economies, combined with increasing development since the Second World War (WWII), has resulted, at least on more heavily populated islands, in significantly diminished availability of coastal marine resources as a result of substantial environmental degradation of near-shore reefs due to coastal development. While localized very heavy fishing is to blame for some of these observed declines, coastal development, construction, discharges, pollution and poor watershed management leading to sedimentation have likely contributed substantially to reduce coral reef habitat- and resource-status. This is particularly the case close to human population centers on the main islands, while more remote locations appear in better shape (Green, 1997; Anonymous, 2001). It should be noted, however, that places that have not experienced widespread development may still suffer stock declines, suggesting that heavy fishing alone can deplete fishery resources on coral reefs.

Given the highly scattered nature of coral reef fisheries, their catches are often not reported (Munro, 1980), despite the data assimilation and technical reporting support provided to U.S. flag island areas by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service through the Western Pacific Fisheries Information Network (WPacFIN, www.pifsc.noaa.gov/wpacfin), and the U.S. Fish and Wildlife Service Fish Restoration Funds. However, in many instances, small-scale studies have been undertaken, reporting local catches or catch rates for specific periods, locations and/or gear types (e.g., Craig *et al.*, 1993). Information is also often 'available' only in difficult-to-access gray literature reports (e.g., Saucerman, 1994), or form part of published studies with a primary focus other than catch reporting (e.g., Craig *et al.*, 1997). Such sources can form the foundation for deriving coral reef fisheries catches, catch rates per unit area, or *per capita* catch rates during a given time interval. These time point estimates provide anchor points of 'hard' data around which total catch estimates can be formed. Once all such data have been extracted, interpolations can be employed to fill in the periods for which hard data are missing. While, at first sight, interpolated periods may seem unsupported by data, the unfortunately common alternative is to leave years blank (no data), which later may invariably be interpreted as catches of zero in the senior policy and economic development arena, which can be far worse than any interpolated estimate (Pauly, 1998). Thus, the key aspect of the approach used here is psychological, as one has to overcome the notion that 'no information is available', which is not only generally incorrect when dealing with fisheries, but may often also be profoundly misleading (Pauly, 1998).

The purpose of the present project was to assemble available information and data on catches for the coral reef- and bottom- fisheries of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI) and Hawaii (Figure 2.1), for the 1950-2002 period. The aim was to derive estimates of total removal of marine resources for this period. The present reconstructions exclude large pelagic fisheries (e.g., tunas and billfishes). The remainder was treated as reef fisheries catches, including the so-called 'bottom-fishery' (Anonymous, 2004), as well as catches of coastal, reef-associated small pelagic species such as carangids, e.g., the big-eye scad (*Selar crumenophthalmus*), culturally important in many islands.

It should be noted that all the island entities considered here have few legislative requirements for reporting of catches (J. Makaiau, WPRFMC, pers. comm.). However, some, such as American Samoa, have instituted legal vehicles requiring the reporting of fish sold (F. Aitaoto, WPRFMC, pers. comm.), or requiring reporting of commercial catches only (e.g. Hawaii).

This report outlines the procedures and data used in the reconstruction, and illustrates and summarizes the highlights for each island entity. The data time-series of source data, and reconstructed estimates of total catches are contained in a set of spreadsheets associated with this report, and available from the Western Pacific Regional Fishery Management Council. The data will also be available at the *Sea Around Us* Project, University of British Columbia Fisheries Centre (www.seaaroundus.org)

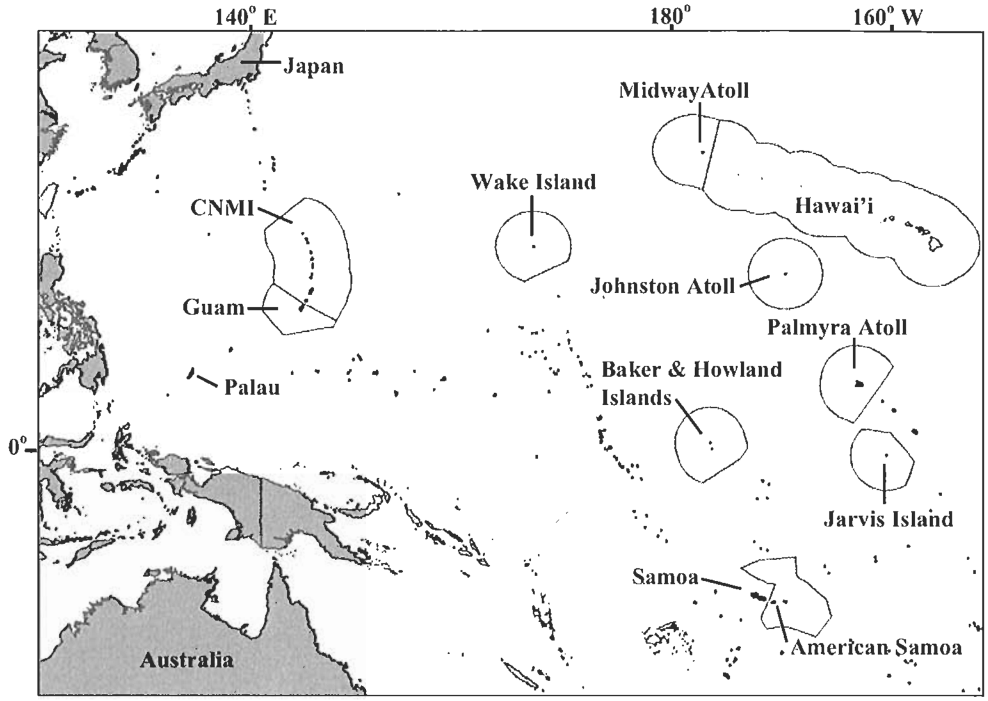


Figure 2.1: Location and EEZs of the U.S. flag island areas in the Western Pacific: American Samoa, Guam, Commonwealth of Northern Mariana Islands, Hawaii, and the other minor islands (Midway, Wake, Johnston, Palmyra, Jarvis, Baker and Howland Islands). Other countries mentioned are also shown. Map courtesy of A. Kitchingman, *Sea Around Us* Project.

3. Methods and Results

3.1 American Samoa

Introduction

American Samoa, the only U.S. territory south of the equator (14° 20'S, 170°W, land area: 200 km^2, Figure 2.1) includes two coral atolls and five volcanic islands, with an EEZ comprising 404,670 km^2. It is composed of the main island Tutuila, the smaller islands of Aunu'u, Ofu, Olosega and Tau, the uninhabited Rose Atoll, and Swains Island. The islands are surrounded by fringing coral reefs (NOAA, 1998), and estimated total coral reef area to 50 m depth is 479 km^2 (A. Graves, National Park of American Samoa, pers. comm.). The reefs around the main island of Tutuila have experienced several major hurricanes, a crown-of-thorns starfish outbreak in the 1970s and a coral bleaching event in 1994, all causing substantial habitat damage (NOAA, 1998). While the coral communities appear to be recovering (Green, 2002), the fish communities around Tutuila appear not. The reefs of the more remote outer islands appear to be in good condition (Green, 1997, 2002).

Tuna canneries and the local government are the two main employers on American Samoa, with canned tuna being the only significant export commodity, supplying about 25% of all canned tuna in the U.S. in the early 1990s (Craig *et al.*, 1993). While tuna canning is the major industry (with most catches being taken in the Western Pacific, outside the American Samoan EEZ), many Samoans practice small-scale farming and fishing, including artisanal fishing for the local market. Significantly, subsistence fisheries play an important role in Samoan culture, and make important informal economic contributions to households, given the generally low levels of wage-income by islanders (Craig *et al.*, 1993; Green, 1997). The population of American Samoa was about 57,000 in 2002, with the majority living on the main island of Tutuila. American Samoa's growth rate is high (2.1% per year, Craig, 2002), and during the 1990s alone, the population increased by 22% (Craig, 2002). This rapid population growth has raised significant concerns about excessive fishing of the resources of American Samoa's main island of Tutuila (Craig *et al.*, 1999; Craig, 2002). Indeed, the shore-based catches on Tutuila appear to have been in decline since at least the 1970s (Ponwith, 1991; Craig *et al.*, 1993).

The American Samoan coral reef fishery has two components, a shore-based subsistence fishery and a boat-based artisanal fishery (Green, 1997), but a clear separation between commercial and non-commercial aspects in each fishery is difficult, as fish from either sector can be sold or retained for personal consumption (Craig *et al.*, 1993).

Approach & methods

In line with Craig *et al.* (1993), one can distinguish four types of domestic fisheries in American Samoa:

a) A shore-based (largely subsistence) fishery;
b) An artisanal, small-boat fishery for bottom-fish;
c) An artisanal fishery for offshore pelagic species; and
d) A recreational tournament fishery targeting large pelagic species.

Catches for (c) and (d) consist of large pelagic species such as tuna (mainly *Thunnus alalunga*, *T. albacares*, *T. obesus*, and *Katsuwonus pelamis*), mahi mahi (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*) and billfishes, and, together with the larger commercial distant water fleets targeting tuna, were not considered here. Thus, our focus is on (a) the shore-based fisheries and (b) the boat-based bottom fisheries.

Examination of the WPacFIN data (www.pifsc.noaa.gov/wpacfin) and associated information (Aitaoto, 1985; Craig *et al.*, 1993; Hamm *et al.*, 2003) indicated that these data primarily pertain to the small-boat fleets, and provided the best estimates for catches of the artisanal sector back to the mid-1980s. The shore-based fishery, which is extensively subsistence based, was first examined by Hill (1978) and Wass (1980) using surveys and interviews. During the first half of the 1990s, an inshore creel survey attempted to estimate shoreline catches for parts of the main island of Tutuila, but was discontinued (Ponwith, 1991; Saucerman, 1996). Between 1991 and 1995, WPacFIN reported shore-based fishery catch estimates based on this survey. However, differences in the estimated catches between WPacFIN records and original sources (Ponwith, 1991; Craig *et al.*, 1993; Saucerman, 1994), combined with uncertainties about the procedure used to derive the database estimates by scaling up from the creel surveys (D. Hamm, NOAA, pers. comm.), suggested that the original sources were more reliable and traceable.

Thus, the procedure employed for reconstructing total catches was:

Boat-based fisheries

1) *1950-1979*: We assumed that the artisanal boat-based fisheries developed after WWII (P. Craig, National Park American Samoa, pers. comm.). Hence, we assumed boat-based catches were zero in 1950, and interpolated *per capita* catch rates between 1950 and the 1980 data point (Table 3.1.1), and expanded to total artisanal catches using population size;
2) *1980-1981*: We used total catches reported in the American Samoa Statistical Digest (Anonymous, 1988) adjusted for pelagic catches (Table 3.1.1). In order to account for pelagic catches for 1980-81, we removed the 1982-84 average percentage for pelagic species (40.8%) as per WPacFIN data (see 3 below);
3) *1982-2002*: WPacFIN data were taken as best estimates of boat-based catches (data extracted: February 04, 2005). We removed pelagic catches by species, thus retaining only bottom-fish and reef-associated species (Table 3.1.1);

Shore-based fisheries

The shore-based (largely subsistence) fisheries were separated into two geographic components, the main island (Tutuila) and 'outer islands' (Ofu, Olosega, T'au and minor islands). This was done for two reasons: (a) the assessments done in the past (Hill, 1978; Wass, 1980; Ponwith, 1991; Craig *et al.*, 1993; Saucerman, 1994, 1996) restricted their sampling to the main island, and (b) the 'outer islands' have not experienced the increasing population (and fishing) pressure of the main island, and were deemed to be more stable in their near-shore fisheries pattern over time, and likely more representative of baseline subsistence catches (Green, 2002, P. Craig, National Park American Samoa, pers. comm.).

The procedure for shore-based catch reconstruction was as follows:

1) Data anchor points:
    a. *Main island (Tutuila)*: For 1950, we assumed a *per capita* catch rate of 36.3 kg·person^{-1}·year^{-1} (80 lbs·person^{-1}·year^{-1}, Table 3.1.1) based on a 40% lower catch rate than that observed for 'outer islands' (see below) due to better opportunities for alternative livelihoods available on Tutuila in 1950 (P. Craig, pers. comm.). For 1980, we relied on the study by Wass (1980) for estimated main island catches of 266,196 kg (586,856 lbs), while for 1991 we used the estimate of 199,129 kg (439,000 lbs) from Craig *et al.* (1993) for the main island (Table 3.1.1). For 1992-1995, we used Saucerman's (1994; 1996) data and percentage decline of catches relative to 1991 (Table 3.1.1). Finally, for the year 2002, we used the maximum estimate by Coutures (2003) of 39,429 kg (86,924 lbs, Table 3.1.1). The maximum, rather then the average estimate was used here, to account for the suggested underestimation of effort (p.15 Coutures, 2003; F. Aitaoto, WPRFMC, pers. comm.).

b. *Outer islands*: Recent work done by P. Craig (unpublished data) for the 'outer islands' indicated that a previous catch estimate for these islands (Craig *et al.*, 1993) was a substantial underestimate. Instead, an estimate of 82 t (180,777 lbs) for 2002 was used (Table 3.1.1), derived as part of an ongoing investigation into subsistence fisheries in American Samoa (P. Craig, unpublished data), and is considered a representative catch under minimal influence of urbanization.

2) Time series interpolation:

a. *Main island (Tutuila)*: For 1951-1979, we interpolated the *per capita* catch rates converted from catch estimates (Table 3.1.1) between 1950 (P. Craig, unpublished data) and 1980 (Wass, 1980), and expanded to estimated total catches using human population statistics;

b. For the period 1981-1990, we used the reported catches for 1980 and 1991 (Table 3.1.1) converted to *per capita* catch rates to interpolated between the anchor years, and expanded catches using the human population sizes on Tutuila from 1981 to 1990;

c. For the period 1996-2001, we interpolated between the 1995 and 2002 catch data points (Table 3.1.1) converted to *per capita* rates, and expanded to catch estimates using human population statistics;

d. *Outer islands*: The estimate of total catches for 2002 (Table 3.1.1) was converted into a *per capita* catch rate for the 'outer islands' of 58.6 $kg \cdot person^{-1} \cdot year^{-1}$ (129.1 $lbs \cdot person^{-1} \cdot year^{-1}$) using population statistics. We carried this *per capita* catch rate back to 1950, and expanded catches using population statistics for these islands.

Species composition

The taxonomic breakdown of artisanal, boat-based catches as reported by WPacFIN for 1989 to 2002 was retained as presented. However, as a large proportion (26-87%) of catches for the earlier period, 1982-1988, was reported as 'miscellaneous' groups ('miscellaneous marine fishes', 'miscellaneous marine bottomfishes', and 'miscellaneous reef fishes'), we applied a proportional species breakdown to the latter two groups, as well as to the interpolated catch estimates for the pre-1982 period. We derived this average proportional breakdown from the reported WPacFIN data for 1989-1993, to exclude the gear specific effects on species composition due to the rapid growth of SCUBA-based spear-fishing between 1994 and 2001, which biased the species breakdowns (P. Craig, unpublished data).

For the shore-based component, taxonomic compositions were reported by Wass (1980) and Saucerman (1994), and formed the basis for allocations. Wass (1980) was used for the 1950-1980 time period, and Saucerman (1994) for 1990 onwards. The percentage taxonomic breakdown for 1981 to 1989 was interpolated from Wass (1980) to Saucerman (1994) at the taxon level described by Wass (1980).

Catch rates

All reconstructed catch estimates were converted to catch rates to permit standardized comparisons between islands and with the literature. Specifically, we converted estimated total catches into catch per surface area of coral reef and into *per capita* catch of seafood (excluding pelagics) using human population data provided by the U.S. Census Bureau. American Samoa has approximately 479 km^2 of coral reefs to a depth of 50 m, with about 108 km^2 and about 17 km^2 associated with the main island Tutuila and the outer inhabited islands, respectively (A. Graves, National Park of American Samoa, unpublished data).

Results

Total catch estimates

Examination of fisheries catch statistics from FAO, with pelagic species removed but miscellaneous groups retained in full, indicated that prior to the early 1970s, no reliable data were submitted by U.S. authorities to FAO for American Samoa (Figure 3.1.1a). The 'miscellaneous' category made up approximately 99% of the reported taxa in the official data reported by FAO up to 1993, and likely contained pelagic species. The data reported by WPacFIN for non-pelagic species, representing American Samoa's official statistics for the small-boat based artisanal fisheries, match the FAO (non-pelagic) pattern fairly well, at least for the latter years (Figure 3.1.1a). While this reflects a well established reporting mechanism from the local to the international level, it also illustrates that the boat-based catches appear to be the only non-pelagic catches reported to FAO.

The catch reconstruction for the shore-based fisheries documented two distinct trends (Figure 3.1.1b). The reconstructed catches for the main island, Tutuila, suggested a decline from 598 t in 1950 to 39 t in 2002, with a short-term drop in the early 1990s following several hurricanes which caused considerable damage on Tutuila (Craig, 2002; Green, 2002; Craig and Green, 2005). In contrast, and driven by the nature of our approach, catches for the 'outer islands' simply reflected the decrease in human population levels on the islands. The overall picture for American Samoa, however, is one of distinctly declining levels of total catches in the shore-based sector of the fisheries (which to a large extend is non-commercial in nature), from an estimated peak of about 752 t in 1950, to the present low of 121 t in 2002 (Figure 3.1.1b).

The reconstructed total catches for American Samoa (boat-based and shore-based combined) suggested a likely decline in catches of 79.34% between 1950 and 2002 (Figure 3.1.1c). Furthermore, the catches (representing small-boat, artisanal fisheries) as reported by American Samoa (Figure 3.1.1a), may have underestimated likely historic catch levels as reconstructed here by a factor of 17.3, and did not document the decline in domestic shore-based fisheries catches experienced by the local population (Figure 3.1.1).

Taxonomic accounting

Our reconstruction increased taxonomic accounting from 11 taxa (plus 'miscellaneous marine fishes') as reported by FAO, to 147 taxa plus two miscellaneous groups: 'marine fishes' and 'marine invertebrates'. We also reduced the proportion of catch reported in the 'miscellaneous' categories from a time series average of 77.2% (range: 0-100%) in FAO and 24.3% (range: 0-87.2%) in WPacFIN to 7.2% (range 0.2-10.0%) in the reconstructed time series. For a complete accounting of taxa, see accompanying data files. The lack of variability in taxonomic patterns between years for the earlier period (pre-1980) was a reflection of the interpolation using fewer hard data points (Figure 3.1.2).

Catch rates

Catch per area of coral reef (to 50 m depth), based on the reconstructed catches for the whole of American Samoa, ranged from about 1.6 $t \cdot km^{-2} \cdot year^{-1}$ in 1950 to 0.4 $t \cdot km^{-2} \cdot year^{-1}$ in 2000 (Table 3.1.2). This decline in area catch rates was driven by the main island, Tutuila, where rates declined from about 5.5 $t \cdot km^{-2} \cdot year^{-1}$ to 1.0 $t \cdot km^{-2} \cdot year^{-1}$ between 1950 and 2000 (Table 3.1.2). Estimated catch rates for the outer islands declined less, from about 9 $t \cdot km^{-2} \cdot year^{-1}$ in 1950 to 5 $t \cdot km^{-2} \cdot year^{-1}$ by 2000 (Table 3.1.2).

The human population of American Samoa has grown rapidly. However, this growth has only occurred on the main island of Tutuila, while the outer islands experienced a steady decline in resident population (Table 3.1.2). Taking into account these changes, the *per capita* catch rate might have declined considerably on Tutuila, from about 36 $kg \cdot person^{-1} \cdot year^{-1}$ in 1950 to 2.0 $kg \cdot person^{-1} \cdot year^{-1}$ in 2000. The *per capita* catch rate for the outer islands did remain constant in our reconstructed data (58.6 $kg \cdot person^{-1} \cdot year^{-1}$, Table 3.1.2) due to the nature of our reconstruction in this data-poor context.

Discussion

The reconstruction of historic catches presented here suggested a 79.3% decline in catches for coral reef-, bottom- and reef-associated small pelagic fisheries around American Samoa between 1950 and 2002. Significant was the 17.3-fold difference between the reconstructed scenario and the statistics reported by American Samoa. Given the historic focus of most national, and by extension FAO databases, on reporting commercial landing statistics for economic development purposes, it is not surprising that the FAO statistics for American Samoa reflect only the (predominantly commercial) small-boat artisanal bottom-fish catches reported through WPacFIN (as well as the large pelagic species excluded here). Nevertheless, national and FAO statistics, increasingly used as indicators of fisheries conditions and trends, under-represent the true nature of fisheries catches for American Samoa over the last 50 years.

In contrast to the boat-based fisheries of American Samoa, the historically large shore-based catch (dominated by subsistence catches), while known to be important (Craig *et al.*, 1993; Dalzell *et al.*, 1996), had not been estimated on a regular basis, nor were annual estimates included in the reported statistics. While the artisanal fisheries (primarily boat-based) clearly make direct economic contributions to American Samoa, subsistence fisheries (predominantly shore-based) play a significant role in local culture, and make important informal economic contributions to households (Craig *et al.*, 1993; Green, 1997).

The shore-based catches on the main island Tutuila have been reported as having declined at least since the 1970s (Ponwith, 1991; Craig *et al.*, 1993). The 79.3% decline in overall reconstructed catches since the 1950s, as reported here, thus supported literature arguments of likely excessive fishing (Craig and Green, 2005). In the past, Pacific islanders have relied heavily on coral reef resources, often as their primary source of protein (Dalzell *et al.*, 1996). While economic and social changes over the last 50-100 years have resulted in islanders' diet becoming more variable, coral reef resources remain a major element in food security (Dalzell *et al.*, 1996). The apparent increases in reef fish imports from Samoa (formerly Western Samoa) may also indicate that local catches from American Samoa cannot meet the demand (Craig *et al.*, 1993). This is also supported by the small size of fish observed in catches and surveys (Craig *et al.*, 1993; Green, 1997), further supporting concerns about excessive fishing. Interestingly, the annual *per capita* catch rates, as estimated here for the main island Tutuila, appeared to have declined from about 36 $kg \cdot person^{-1} \cdot year^{-1}$ to 2.0 $kg \cdot person^{-1} \cdot year^{-1}$ between 1950 and 2000. In contrast, Samoa reported a *per capita* fish consumption rate of at least 32 $kg \cdot person^{-1} \cdot year^{-1}$ (Spalding *et al.*, 2001). Given the proximity and historic cultural affinity between the two Samoas, one could assume that American Samoa would have a similar or slightly lower consumption pattern (due to increased westernization), hence the high and growing rates of imports of reef fishes into Tutuila (Craig *et al.*, 1993). In contrast, *per capita* catch rates for the 'outer islands' were recently estimated at about 58 $kg \cdot person^{-1} \cdot year^{-1}$ (P. Craig, unpublished data). This compares favorably with estimates of 61 $kg \cdot person^{-1} \cdot year^{-1}$ as the average *per capita* catch rate in the Polynesian islands in the mid 1990s (Dalzell *et al.*, 1996), and *per capita* fish consumption rates of 32.5-41.2 $kg \cdot person^{-1} \cdot year^{-1}$ estimated for Fiji (Rawlinson *et al.*, 1996).

Dalzell and Adams (1997) presented catch rates for the main island of Tutuila of 7.04 $t \cdot km^{-2} \cdot year^{-1}$ and 17.03 $t \cdot km^{-2} \cdot year^{-1}$ for the mid 1990s and early 1980s, respectively. These estimates were much higher than those calculated for Tutuila from our reconstructed data (0.7-5.5 $t \cdot km^{-2} \cdot year^{-1}$), and the reasons for this weren't clear. Similarly, our estimated catch rates for 'outer islands' (4.9-9.1 $t \cdot km^{-2} \cdot year^{-1}$), while being higher than for Tutuila, were at the lower end of the estimates presented by Dalzell and Adams (1997).

Table 3.1.1: Sources, values and applicable time periods of data point estimates used for the reconstruction of American Samoan non-pelagic fisheries catches for the boat-based and shore-based fisheries.

Year	Source: Reference	Source: Data	Comment	Catch estimate (t)
Boat-based: American Samoa				
1950	P. Craig (pers. comm.)	0	Assumed started after WWII	0
1980	Anonymous (1988)	69,624 kg (153,493 lbs)	1982-84 pelagic % removed	41
1981	Anonymous (1988)	86,510 kg (190,720 lbs)	1982-84 pelagic % removed	51
1982-2002	WPacFIN[a]	70,738 kg (155,950 lbs) - 7.16×10^6 kg (15.8×10^6 lbs)	Pelagic spp. removed	60-34[b]
Shore-based: Main island (Tutuila)				
1950	P. Craig (pers. comm.)[c]	36.3 $kg \cdot person^{-1} \cdot year^{-1}$ (80 $lbs \cdot person^{-1} \cdot year^{-1}$)	60% of 2002 outer island catch rate	598
1980	Wass (1980)	266,196 kg (586,856 lbs, 8.7 $kg \cdot person^{-1} \cdot year^{-1}$)	Main island estimate	266
1991	Craig et al. (1993)	199,129 kg (439,000 lbs, 4.3 $kg \cdot person^{-1} \cdot year^{-1}$)	Main island estimate	199
1992	Saucerman (1994)	43% decline from 1991	Main island estimate	113
1993	Saucerman (1994)	45% decline from 1992	Main island estimate	62
1994	Saucerman (1996)	89,000 kg (196,209 lbs)	Main island estimate	89
1995	Saucerman (1996)	136,000 kg (299,826 lbs, 2.6 $kg \cdot person^{-1} \cdot year^{-1}$)	Main island estimate	136
2002	Coutures (2003)[d]	39,429 kg (86,924 lbs, 0.7 $kg \cdot person^{-1} \cdot year^{-1}$)	Main island estimate	39
Outer islands (Ofu, Olosega, T'au)				
2002	P. Craig (unpublished data)	82,000 kg (180,077 lbs, 58.6 $kg \cdot person^{-1} \cdot year^{-1}$)	Ongoing investigation	82

[a] www.pifsc.noaa.gov/wpacfin. [b] Catch for 1982 was 60 t, for 2002 34 t, for variability see data files. [c] Based on conservative assumption that *per capita* catch rate was 40% lower than the present day catch rate for the relatively little fished outer islands (P. Craig, unpublished data). [d] Maximum estimate was used to account for reported underestimation of effort.

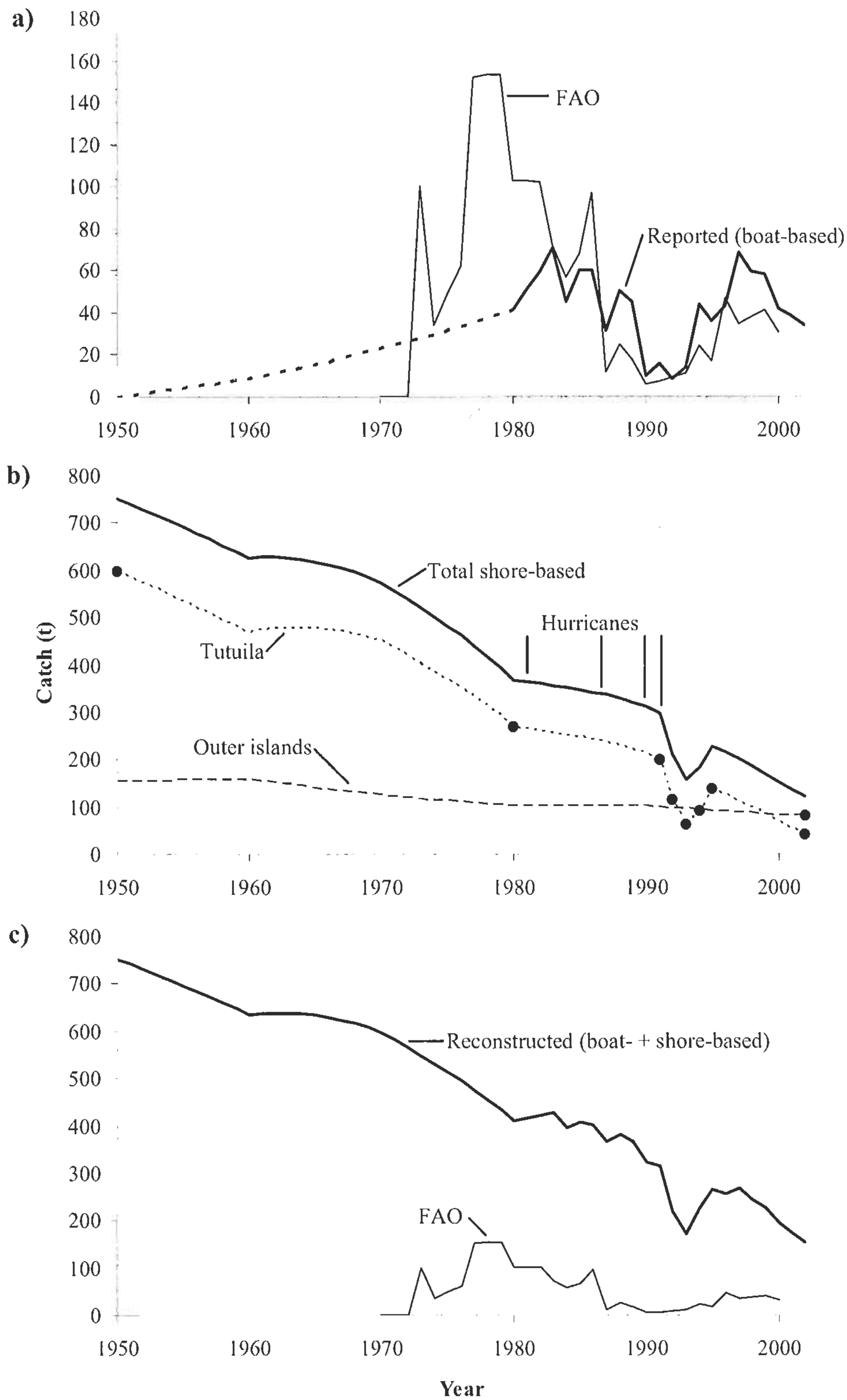
Table 3.1.2: Catch rates for reconstructed coral reef fisheries catches for American Samoa. Estimated catches are presented as catch per surface area of coral reefs to a depth of 50 m, and as *per capita* catch of reef and reef-associated species, for American Samoa in total, and for the 'main' and 'outer' islands separately. For full time-series see data files accompanying this report.

Year	Estimated catch (t)	Catch/area ($t \cdot km^{-2} \cdot year^{-1}$)	Population[a]	*Per capita* catch[b] ($kg \cdot person^{-1} \cdot year^{-1}$)
American Samoa (479 km^2)[c]				
1950	752	1.57	19,100	39.4
1960	635	1.33	20,000	31.7
1970	596	1.24	27,267	21.9
1980	409	0.85	32,418	12.6
1990	322	0.67	47,199	6.8
2000	195	0.41	57,301	3.4
2002	155	0.32	57,716	2.7
Main island (Tutuila; 108.2 km^2)[c]				
1950	598	5.52	16,468	36.3
1960	477	4.41	17,305	27.6
1970	472	4.36	25,155	18.8
1980	307	2.84	30,686	10.0
1990	221	2.05	45,485	4.9
2000	112	1.03	55,886	2.0
2002	73	0.68	56,316	1.3
Outer islands (Ofu, Olosega, T'au; 16.9 km^2)[c]				
1950	154	9.12	2,632	58.6
1960	158	9.34	2,695	58.6
1970	124	7.32	2,112	58.6
1980	101	6.00	1,732	58.6
1990	100	5.94	1,714	58.6
2000	83	4.90	1,415	58.6
2002	82	4.85	1,400	58.6

[a] U.S. Census Bureau, www.census.gov/ipc/www/idbprint.html, accessed August 2004;
[b] excluding pelagic species, and ignoring imports; [c] A. Graves (National Park of American Samoa, unpublished data)

Figure 3.1.1 (see next page): Catch time series for non-pelagic fisheries in American Samoa, with (a) Reported catch for non-pelagic species from two sources: FAO (FISHSTAT 2001 data) and 'reported data' from NOAA, NMFS Western Pacific Fisheries Information Network (WPacFIN). Note that until 1993, FAO reported only two categories ('miscellaneous marine fishes' and 'spiny lobster'), and therefore the 'miscellaneous' category likely contained pelagic species, explaining the discrepancy in catches between the two sources, especially for the 1970s and early 1980s; (b) Reconstructed catches of the shore-based (predominantly subsistence) fisheries of American Samoa as estimated by the present study. Catches were estimated separately for the main island Tutuila, and the outer islands (Ofu, Olosega, T'au and minor islands). Data point estimates used for interpolations are indicated (●). The time periods of major hurricanes in the last 20 years is indicated; and (c) Total reconstructed domestic fisheries catches for American Samoa, comprising the small-boat (largely artisanal) and the shore-based (largely subsistence) fisheries, versus the globally reported statistics based on American Samoan reporting to FAO. Both the distinct under-representation of likely total catches as well as the missed decline in catches was evident when considering only the reported statistics.

Figure 3.1.1 cont.



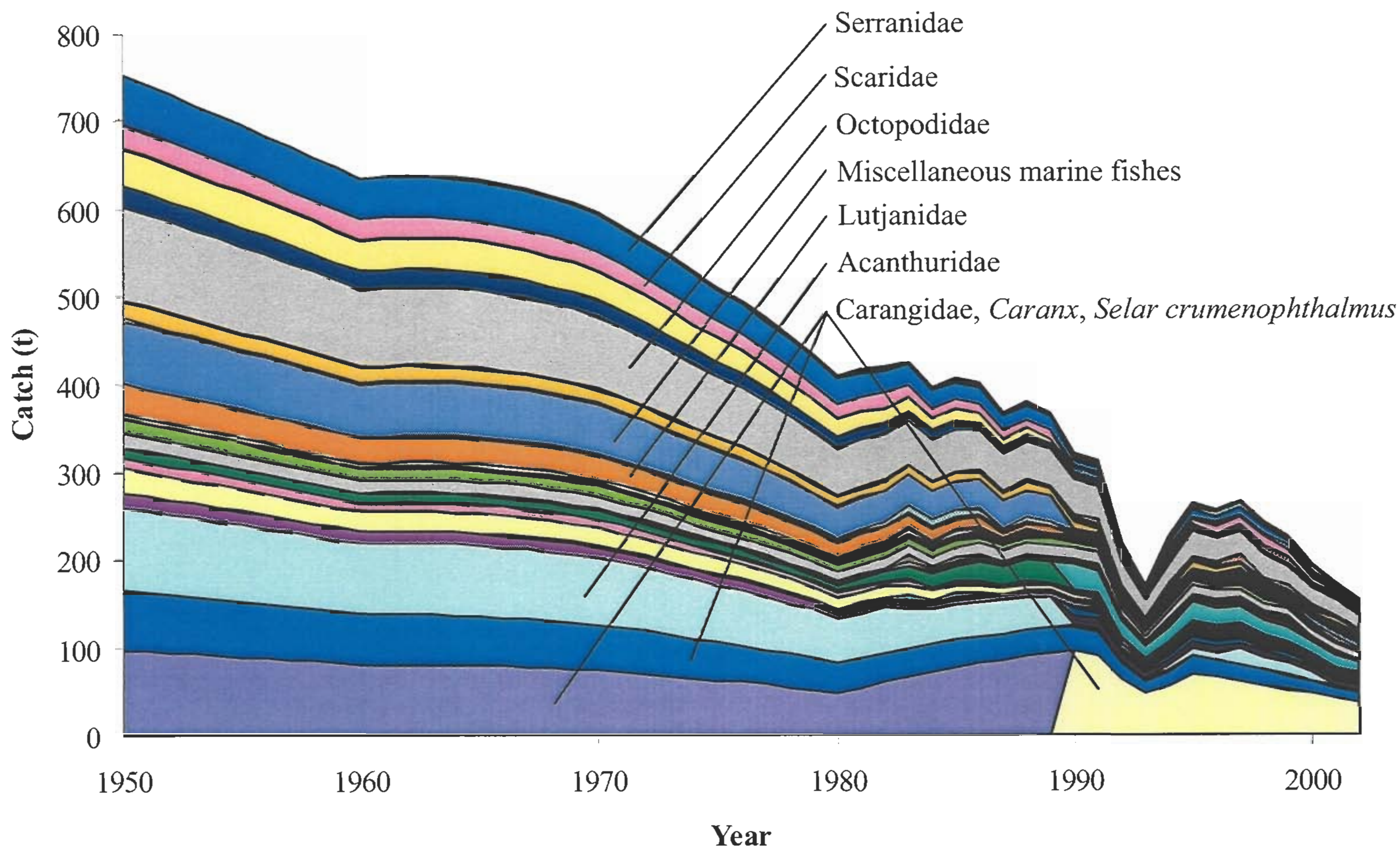


Figure 3.1.2: Taxonomic breakdown of reconstructed total catches for coral reef and reef-associated small pelagic fisheries for American Samoa. For clarity in the present figure we reduced the taxonomic breakdown, and labeled only a subset of largest groups. For complete taxonomic breakdown, see accompanying electronic data files.

3.2 Guam

Introduction

Guam (13° 28' N, 144° 45' E), a U.S. territory, is the southernmost island in the Mariana Archipelago (Figure 2.1). The total reef area is 179 km^2 (Green, 1997; Richmond and Davis, 2002), of which 69 km^2 are within territorial waters (3 nm), while the remainder (110 km^2) is associated with offshore banks within the 210,874 km^2 EEZ (3-200 nm).

A description of the pre- and post-WWII fishery of the former Japanese mandated islands, including Guam, is provided by Smith (1947), illustrating the limitations placed on the indigenous population with regards to any large-scale fisheries development, which remained firmly under Japanese control. This, together with the destruction of the Japanese fishing infrastructure at the end of WWII, resulted in the continuation of the subsistence status of indigenous fisheries on Guam into the late 1940s.

Coral reef fisheries are both economically and culturally important, and have been historically significant in the diet of the population (Hensley and Sherwood, 1993; Richmond and Davis, 2002). The coral reefs around Guam (such as the island's fringing reefs) are considered very heavily fished and degraded due to human activities, while most of the offshore banks are not readily accessible, and appear to be in better condition (Green, 1997; NOAA, 1998). Concerns about excessive fishing of the shallow inner reefs of Guam were expressed as early as 1970 (Hensley and Sherwood, 1993).

Guam's domestic fisheries can be divided into two sectors (ignoring tuna transshipment and distant water fleet catches of large pelagics): small boat-based fisheries (Myers, 1993) and shore-based fisheries (Hensley and Sherwood, 1993). As there are few full-time commercial fishers (J. Calvo, NOAA, pers. comm.), there is little clear distinction between commercial, subsistence and recreational fishing, with many fishing trips contributing to all three sectors. The boat-based fisheries can be subdivided into trolling (targeting large pelagic species), bottom-fishing (mainly targeting snappers and emperors, e.g., *Pristipomoides* spp., *Lethrinus rubrioperculatus*), and reef-based spear-fishing in areas not easily reached from shore. Shore-based fisheries have utilized a variety of gear types, from manual reef-gleaning to various net types and spear-fishing (Hensley and Sherwood, 1993). In the past, fish-weirs had also been in operation in Guam, although their numbers declined over the last few decades (Davis and Sherwood, 1989), and use of weirs ceased in 1989 (G. Davis, NOAA, pers. comm.).

Approach & methods

Catch data for both fisheries sectors have been estimated by the Guam Division of Aquatic and Wildlife Resources (DAWR) since the mid-1960s through the use of two separate creel surveys: boat-based fisheries via a marina-based creel survey (the so called 'offshore survey'), and shore-based fisheries via a shore-based creel survey ('inshore survey'). Fish weir catches were mandated for reporting as part of weir-operating permits, but were likely incomplete. DAWR applied expansion methods to raise the creel survey data to island-wide catch estimates. While specifics of the method, thoroughness of survey, data handling and analyses have varied, especially during the earlier periods, in one way or another, some data existed for almost the entire time period of interest (1950-2002). Since the 1980s, these surveys seemed the most comprehensive procedures for data collection and total catch estimation encountered by this project, with consistent expansion methods applied.

As domestic fisheries in Guam are generally part commercial, part subsistence, part recreational, the reconstruction approach taken was not through commercial and non-commercial differentiation, but rather following the creel survey distinction between boat-based (offshore survey) and shore-based (inshore survey) estimation of catches. Given our focus on bottom- and reef-fisheries (as well as shore-based catches of small, reef associated pelagic species), we ignored the trolling component from the offshore catch reports, while retaining bottom-fishing and boat-based spear-fishing catches.

Supply and demand comparisons, incorporating catch, import and consumption estimates, were undertaken to account for likely underestimated or unreported catches, especially for the earlier periods.

Reported catches

Offshore, boat-based catches (Table 3.2.1)

1950-1964: As no reported information could be obtained for this period, we estimated total likely catch via *per capita* catch rates as part of the supply versus demand approach (see "supply versus demand" section below).

1965-1982: The offshore catch estimates for this time period, which pre-dates WPacFIN reporting, were drawn from the creel survey data as reported in the annual reports of the DAWR (Anonymous, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978; Anderson *et al.*, 1979; Anderson *et al.*, 1980; Anderson and Hosmer, 1981; Myers, 1982). Procedures for expanding the creel surveys data to island-wide catches, as used or suggested by the sources at the time, were accepted. Catches were reported by main gear types (trolling, bottom-fishing, spear-fishing), which permitted the removal of large pelagics caught by trolling gear. While the annual reports covered fiscal year periods, they contained monthly reporting of catches for 1978 to 1982, which permitted assembly of calendar year catch estimates for these years. For 1965-1977, the fiscal year total catch estimates were split in equal parts for allocation to the calendar years incorporated into fiscal accounting periods. In several cases, reports from earlier years acknowledged an assumed under-reporting due to creel survey sampling design by a minimum factor of 2, and recommended adjustments. Thus, we adjusted the reported catch estimates by a factor of 2 for these years.

1983-2002: For this latest period, we relied on the island-wide expanded catch estimates as provided to us by D. Hamm (WPacFIN). These estimates were based on the offshore creel survey as undertaken by the DAWR. These data were reported by taxon, permitting exclusion of large pelagic species.

Inshore, shore-based catches (Table 3.2.1)

1950-1964: Catches were reconstructed as indicated above in the offshore section and documented in the "supply versus demand" section below.

1965-1981: Similar to the offshore fisheries, the inshore catch data for this period were based on the inshore creel survey data as reported in the annual reports of the DAWR (Anonymous, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978; Anderson and Hosmer, 1981), with procedures for expanding the catches accepted as reported at the time. Also included in these figures were the often separately reported catch estimates for octopus and shellfish (based on reef gleaning), fish weirs, and the highly irregular, seasonal catches of juvenile rabbitfish (Siganidae) and big-eye scad (*Selar crumenophthalmus*). We applied adjustment factors for non-surveyed periods as indicated for some years (e.g., Anonymous, 1978). Note that the years 1980 and 1981 were deemed poorly reported due to limited survey coverage (Anderson *et al.*, 1980; Anderson and Hosmer, 1981). Therefore, we replaced the reported catches for 1980 and 1981 with the average catches for 1978-1979, and 1982-1983, respectively.

1982-1984: WPacFIN reported inshore catches back to 1985, thus the data from Hensley and Sherwood (1993) were used here for the 1982-1984 period. It should be noted that these data did not include night fisheries, and therefore under-represented actual catches (G. Davis, NOAA, pers. comm.)

1985-2002: For this period, we relied on the island-wide expanded catch estimates from the inshore creel survey, as undertaken by DAWR, and provided to us by D. Hamm (WPacFIN). These data were reported by taxon.

Supply (imports & catches) versus demand (consumption)

To assess if the reported catches as outlined above accounted for the likely total catches, and to derive estimates of likely catches for the 1950-1964 period, we compared available estimates of total supply (being catches plus imports) with demand (as represented by consumption estimates). For the purpose of supply and demand estimation, we included catches of pelagic species as provided by WPacFIN and DAWR, with a fixed amount carried back to 1950 for the periods pre-dating reporting.

Imports

Information on reported imports was available for 1999, 2000 and 2002 (Department of Commerce, www.admin.gov.gu/commerce), and for 1980 as an estimated *per capita* import rate of 17.7 kg·person^{-1}·year^{-1}, or 39 lbs·person^{-1}·year^{-1} (AECOS, 1983). The 1999-2002 import values were accepted as best estimates. There is a long tradition of bringing fish into Guam as part of people's travels. An apparently large, but unknown portion of these imports are so-called 'cooler-shipped' fish primarily from the Federated States of Micronesia, Palau and the Republic of the Marshall Islands, which were poorly recorded, especially in the earlier periods (G. Davis, NOAA, pers. comm.). To account for under-reporting of 'cooler-shipped' imports in earlier years, we adjusted the 1980 import rate (AECOS, 1983) by 20%, to 21.2 kg·person^{-1}·year^{-1} (46.8 lbs·person^{-1}·year^{-1}). For 1950, we assumed a level of import of approximately half of the adjusted 1980 import rate, i.e., 10.6 kg·person^{-1}·year^{-1} (23.4 lbs·person^{-1}·year^{-1}). We interpolated import rates between the 1950 and 1980 data point estimates, and expanded to total import estimates using human population statistics. We also interpolated and expanded *per capita* import rates between the adjusted 1980 rate (AECOS, 1983) and 1985, at which time we assumed that imports accounted for the difference between reported catches and total consumption (demand) as estimated below.

Demand

Estimates of demand were based on the reported consumption rate of at least 60 lbs·person^{-1}·year^{-1}, or over 27 kg·person^{-1}·year^{-1} for 1980 (AECOS, 1983), which was carried back unaltered to 1950. We accounted for the consumption of pelagic species by removing the reported catches of pelagic species for each year from total consumption for that year, and subsequently derived estimated non-pelagic *per capita* consumption rates via population statistics. For 1985-2002, we assumed that total consumption was accounted for by the sum of reported catches plus estimated imports (see above). Total consumption was adjusted by removing the reported pelagic catches, and 1985-2002 *per capita* non-pelagic consumption rates were derived via human population statistics. For the 1981-1984 period, we interpolated between the 1980 and 1985 non-pelagic consumption rates. Thus, for the more recent years (1985-2002), we assumed that the data for total reported catches (including pelagic species) plus imports, as estimated above, accounted for total seafood consumption by Guam. Hence, we assumed that the expanded estimates of the DAWR creel survey data provided a comprehensive estimate of total catches between 1985 and 2002 (G. Davis, NOAA, pers. comm.). The growing concern about market dumping of incidental by-catch from the pelagic transshipment fleet onto the local seafood market was not considered here, as it is thought to be a recent phenomenon, and would be reflected in declining commercial catch data, as it replaces local fish in the market supply.

Supply versus Demand

To provide some estimates of likely catches for the 1950-1964 period, when no reported data were available (see section on *reported catches* above), we derived a 1950 catch estimate by assuming that the domestic seafood demand was either locally sourced, relying heavily on subsistence fishing (Smith, 1947), or was part of the un-regulated 'cooler-shipped' imports. Given the assumed imports, the 1950 likely total local catch was derived as the difference between consumption estimates and import estimates. Thus, with assumed imports of 10.6 $kg \cdot person^{-1} \cdot year^{-1}$ (23.4 $lbs \cdot person^{-1} \cdot year^{-1}$) and an estimated consumption rate of 26.6 $kg \cdot person^{-1} \cdot year^{-1}$ (58.6 $lbs \cdot person^{-1} \cdot year^{-1}$), this implied a *per capita* catch rate of 16.0 $kg \cdot person^{-1} \cdot year^{-1}$ (35.2 $lbs \cdot person^{-1} \cdot year^{-1}$) for 1950. We interpolated *per capita* catch rates between 1950 and 1965, and expanded to likely total catches using human population statistics.

For the 1950-1984 period, the difference between supply and demand was interpreted as 'unreported' catches (including e.g., night fisheries catches), and were added to the reported catches as outlined above, resulting in the final reconstructed total catches.

Species breakdown

1950-1965: Early DAWR annual reports provided little or no taxonomic breakdown of catches. However, during 1966-1975, a consistent list of taxa was reported, consisting of 30 taxa plus 'miscellaneous marine fishes'. We derived a 3-year average species breakdown (1966-1968), which was applied to the 1950-1964 period.

1966-1975: DAWR reports did report taxonomic breakdown of catches for this period. However, due to reporting inconsistencies between years for some taxa, we utilized an overall 10-year average breakdown based on the combined information for 1966-1975.

1976-1984: We derived a 3-year average breakdown (1973-1975), based on the DAWR 1966-1975 taxonomic reporting, and used it for the 1976-1984 period.

1985-2002: The allocation of catches was based on species breakdown as provided by D. Hamm (WPacFIN). It should be noted that DAWR used to call mayors of villages and conduct surveys during seasonal runs (e.g., big-eye scad) in the 1980s and 1990s to obtain information on catch. Because these phone surveys are no longer conducted, more recent data on scad may be incomplete (J. Gutierrez, DAWR, pers. comm.).

Catch rates

We converted catches into *per capita* catch rates and catch per unit area of coral reef. Given that most non-pelagic catches come from areas close to Guam, we utilized the reef surface area estimate (to 100 m depth) for near-shore reefs within 3 nm of the island (69 km^2), not the area estimate for the EEZ (110 km^2; Green, 1997). This may underestimate the area for bottom-fisheries.

Results

FAO versus reported data

Examination of catch statistics as presented by FAO, with pelagic species removed but miscellaneous groups retained in full, indicated that no catches were reported for the period prior to 1960 (Figure 3.2.1). The data reported by DAWR (our sources only went back to 1965) matched the FAO pattern relatively well, at least until the early 1990s. The approximately two-fold higher catches of DAWR reported data between 1965 and the late 1970s, compared to FAO data, suggested that the data reported to FAO by Guam did not include the two-fold adjustment factor suggested in the earlier DAWR reports.[1] Furthermore, the trends in reported catches diverged in the 1990s; FAO totals generally declined, while the DAWR reported totals increased until 1999 (Figure 3.2.1).

Unreported catches

The relatively low catches reported for the earlier periods (e.g., 1960s, Figure 3.2.1) appeared not to reflect well the higher reliance on local marine resources by the population of Guam at that time. The evaluation of supply (reported catches plus imports) and demand (consumption) using information on imports, catches, and consumption rates suggested a rising supply, driven primarily by increases in imports (Figure 3.2.2). Significantly, however, demand, as suggested by the literature (AECOS, 1983), appeared to exceed supply, at least prior to the mid 1980s (Figure 3.2.2), resulting in unaccounted catches (consumption minus supply), treated here as unreported catches, ranging from 957 t in 1950 to 59 t in 1984 (Figure 3.2.2).

Total reconstructed catches

The catch reconstruction (reported + unreported catches) for coral reef- and bottom-fisheries suggested a different picture to that obtained from the recorded DAWR data for the pre-1985 period (Figure 3.2.3). Our reconstruction suggested a decline in total catches, from 957 t in 1950 to 223 t by 2000 and 129 t by 2002 (Table 3.2.2, Figure

---

[1] These suggested adjustment factors were clearly mentioned in the text of each DAWR report, but not reflected in the tabular data of the reports.

3.2.3). Furthermore, the reported statistics may have been underestimating historic catch levels, as reconstructed here, from the early 1960s to the mid 1980s (Figure 3.2.3).

Species breakdown

Recent reporting (since 1985) provided a detailed taxonomic accounting compared to early periods, which had to be based on multi-year average compositions (Figure 3.2.4). Nevertheless, a few insights may be derived from the taxonomic breakdown in this reconstruction. Several taxa historically contributed considerably to total catches, these being the so-called 'Scombridae-mackerels' (here assumed to include small pelagics such as the big-eye scad), and distinct coral reef fish groups such as siganids, lutjanids, acanthurids and serranids, and octopus (Figure 3.2.4). The limited taxonomic accounting in earlier periods did not permit assessment of long-term changes in catch compositions.

Catch rates

Based on reconstructed data, the *per capita* catch rates for coral reef- and bottom-fisheries may have declined from 16.0 $kg \cdot person^{-1} \cdot year^{-1}$ (35.2 $lbs \cdot person^{-1} \cdot year^{-1}$) to 1.4 $kg \cdot person^{-1} \cdot year^{-1}$ (3.2 $lbs \cdot person^{-1} \cdot year^{-1}$) between 1950 and 2000 (Table 3.2.2). Catch rates per area of coral reef may have declined from 13.9 $t \cdot km^{-2} \cdot year^{-1}$ to 3.2 $t \cdot km^{-2} \cdot year^{-1}$ between 1950 and 2000, based on the near-shore reef areas to 100 m depth (Table 3.2.2).

Discussion

Guam appeared to have established an active commitment to and application of creel surveys as a mechanism to estimate total catches, especially for the last 20+ years. It is to be hoped that this commitment will continue.

The reconstruction of historic catches of coral reef and bottom associated species in Guam, as undertaken here, suggested a decline in catches of 86% over the 50 year time period considered. Also important was the 2.5 fold discrepancy between the reconstructed catches (for 1965-2002) and the reported statistics over the time period for which DAWR reported data exist (1965-2002).[2] The validity of the differences between reported and reconstructed catches is supported by the observation that, at least for the earlier periods, the catch data as reported by our sources (and forming the reported data) were "*probably several times*" less than the actual yields (Anonymous, 1978, p. 1). Concerns about our approach to the 'unreported' catches can be placed into perspective through an alternative, albeit less rigorous consideration:

In 1977, 38.6% of households in Guam were considered to have at least one family member who fished (Anonymous, 1982). The mean catch per surveyed household was 32.7 $kg \cdot household^{-1} \cdot month^{-1}$ (72 lbs), or 392 $kg \cdot household^{-1} \cdot year^{-1}$. Taking an average of 5 people per household (Anonymous, 1982), with a Guam population of 110,000 in 1977, implied 22,000 households (110,000 persons/5 people per household), of which 38.6% (i.e., 8,492 households) had active fishers. These actively fishing households alone could thus be assumed to have caught 3,328,864 $kg \cdot year^{-1}$ in 1977 (8,492 households x 392 $kg \cdot household^{-1} \cdot year^{-1}$). Accounting for pelagic fish in their catch (45.8% of reported catches in 1977 were caught using pelagic gear, Anonymous, 1977, 1978), this would imply a coral reef and bottom fish catch of 1,804,244 $kg \cdot year^{-1}$ for 1977 (3,328,864 $kg \cdot year^{-1}$ x [1-0.458]). This estimate is 2.76 times our total reconstructed catch estimate of 654,345 kg (1,442,568 lbs) for 1977, and 12.6 times the DAWR reported catch of 143,220 kg (315,742 lbs, Figure 3.2.1). Thus, this indirect, effort based approximation validated our contention that likely total catches in the earlier periods were considerably higher than reported data, and also suggested that our reconstruction approach was likely conservative.

The maximum reef area catch rate of 15.0 $t \cdot km^{-2} \cdot year^{-1}$ for 1953 obtained here, based on the reconstructed catch and near-shore reef areas around Guam, while relatively high, was within the published range (0.3-64 $t \cdot km^{-2} \cdot year^{-1}$) for Pacific Islands (Dalzell and Adams, 1997).

[2] Reconstructed data for the entire time period (1950-2002) was 4.5-fold larger then the reported data for the 1965-2002 period.

Table 3.2.1: Sources, values and applicable time periods of hard data points used for the reconstruction of Guam's non-pelagic fisheries catches for the offshore and inshore sectors.

Year	Source		Comment	Catch estimate (t)
	Reference	Data		
Offshore & Inshore				
1950	Supply & Demand Assessment[a]	27.2 $kg \cdot person^{-1} \cdot year^{-1}$ (60 $lbs \cdot person^{-1} \cdot year^{-1}$) => 16.0 $kg \cdot person^{-1} \cdot year^{-1}$ (35.2 $lbs \cdot person^{-1} \cdot year^{-1}$)	Reported consumption rate[b] adjusted for imports and pelagic consumption => adjusted non-pelagic consumption rate used	957
Offshore				
1965-1982	DAWR offshore creel-survey reports	6,546 kg (14,431 lbs) – 177,635 kg (391,614 lbs)	Calendar year catch minus trolling gear (pelagic spp.)	1-36[c]
1983-2002	Data supplied by WPacFIN	165,876 kg (365,690 lbs) – 230,377 kg (507,890 lbs)	Island-wide expansion, Selected taxa excluded[d]	43-65[e]
Inshore				
1965-1981	DAWR inshore creel-survey reports	145,086 kg (319,856 lbs) – 101,925 kg (224,704 lbs)	Incl. octopus, shellfish, fish weirs	145-102[f]
1982-1984	Hensley and Sherwood (1993)	92,176 kg (203,211 lbs) – 141,218 kg (311,329 lbs)	Night fisheries not accounted 1982-1985	92-141[g]
1985-2002	Data supplied by WPacFIN	186,459 kg (411,068 lbs) – 63,417 kg (139,809 lbs)	Island-wide expansion Selected taxa excluded[d]	179-63[h]

[a] This report. [b] AECOS (1983) [c] Reported catch for 1965 was 1 t, for 1982 36 t, see accompanying data files. [d] Taxa excluded: algae, freshwater, land-crab and large pelagic species. [e] Reported catch for 1983 was 43 t, for 2002 65 t, see accompanying data files. [f] Reported catch for 1965 was 145 t, for 1981 102 t, see accompanying data files. [g] Reported catch for 1982 was 92 t, for 1991 141 t, see accompanying data files. [h] Reported catch for 1992 was 179 t, for 2002 63 t, see accompanying data files.

Table 3.2.2: Catch rates for the reconstructed coral reef-, bottom- and reef-associated fisheries catches for Guam. Reconstructed catch estimates are presented as catch per surface area of near-shore coral reefs to a depth of 100 m (69 km^2; Green, 1997), and as *per capita* catch rates. Estimated non-pelagic *per capita* consumption rates are shown also. For full time-series of catches see accompanying data files.

Year	**Reconstructed catch (t)**	**Catch/area**[a] **($t \cdot km^{-2} \cdot year^{-1}$)**	**Population**[b]	***Per capita* catch**	***Per capita* consumption ($kg \cdot person^{-1} \cdot year^{-1}$)**
1950	957	13.9	60,000	16.0	26.6
1960	836	12.1	67,000	12.5	26.6
1970	795	11.5	85,000	9.4	27.0
1980	517	7.5	106,000	4.9	26.1
1990	127	1.8	133,200	1.0	21.3
2000	223	3.2	154,805	1.4	22.0
2002	129	1.9	160,796	0.8	21.7

[a] Green (1997); [b] U.S. Census Bureau, www.census.gov/ipc/www/idbprint.html, accessed August 2004.

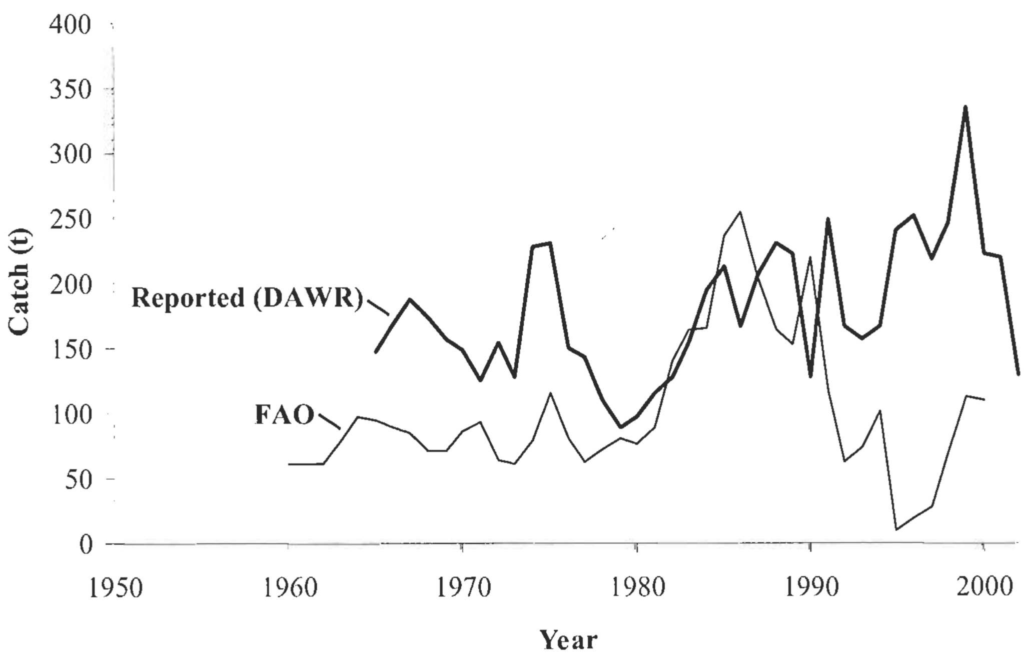


Figure 3.2.1: Fisheries catches of Guam for non-pelagic species as presented by FAO based on reporting by Guam, versus reported catches (DAWR statistics) based on DAWR catch estimates using creel-survey reports.

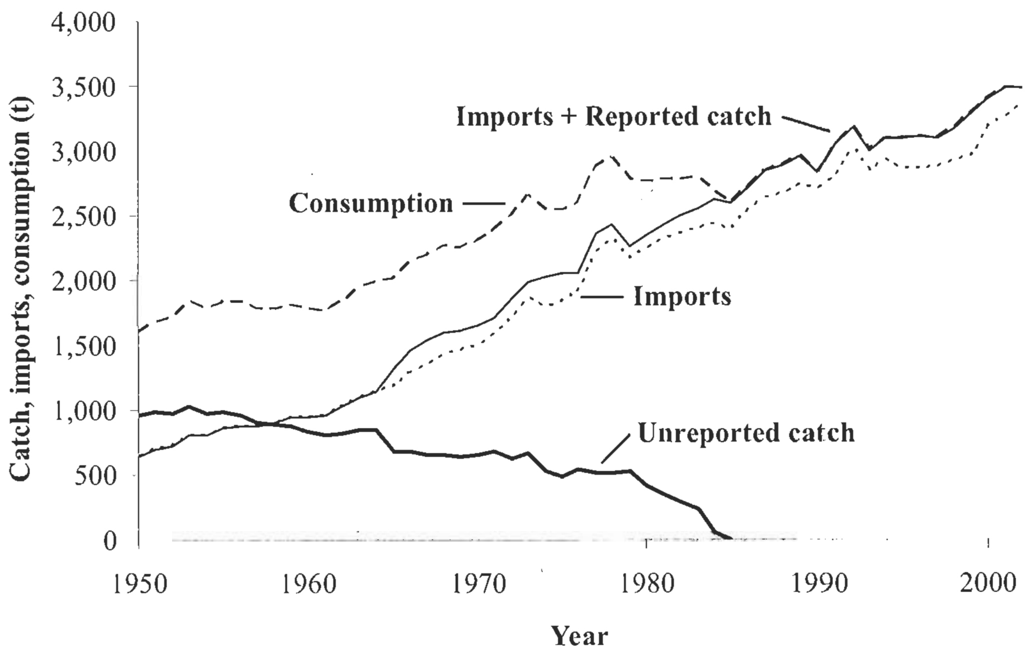


Figure 3.2.2: Estimation of unreported catches for Guam, being the difference between demand (estimated consumption) and supply (imports + reported catches) of seafood.

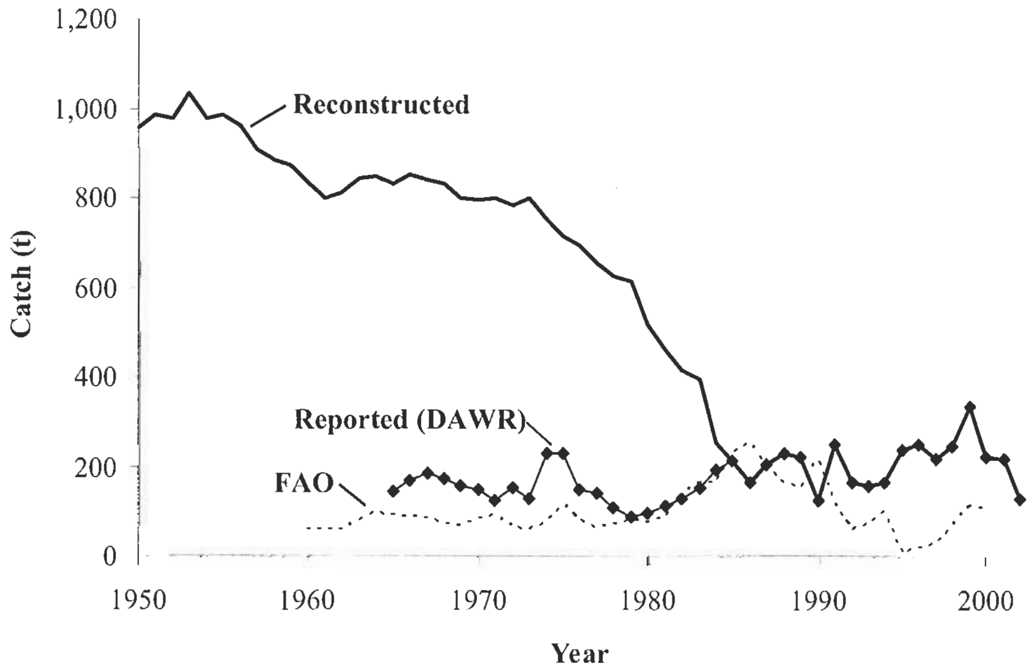


Figure 3.2.3: Total reconstructed coral reef and reef-associated fisheries catches for Guam (reported + unreported catches) versus the reported catches as per DAWR (♦) and the globally reported statistics as per FAO.

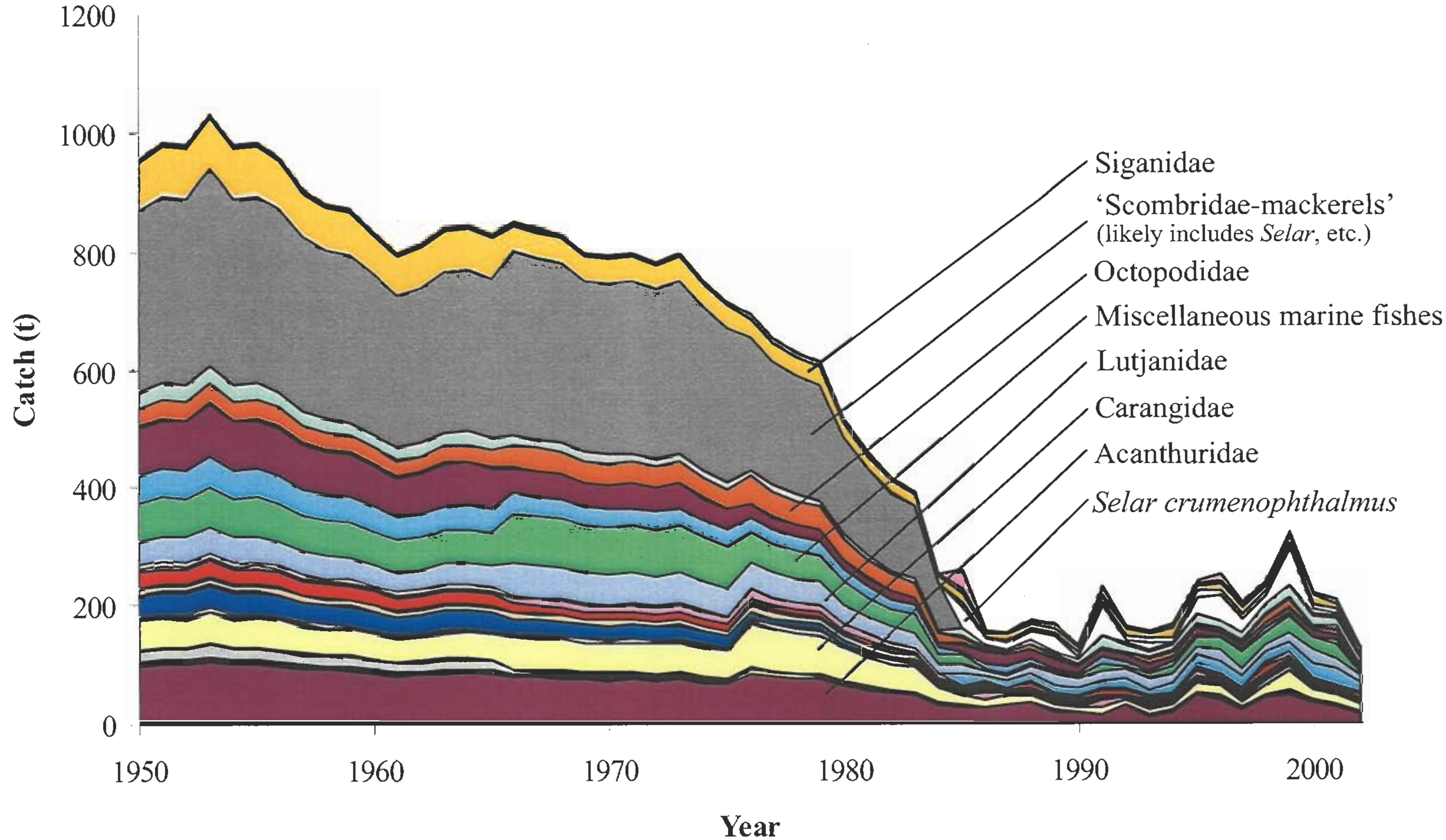


Figure 3.2.4: Taxonomic breakdown of total reconstructed catches for coral reef and reef-associated fisheries for Guam. Fifty taxa are presented, including three miscellaneous groups. We reduced the taxonomic breakdown for graphic clarity, for detailed breakdown see accompanying electronic data files. The category 'Scombridae-mackerels' was reported in early DAWR reports, and was considered to represent small carangids such as *Selar*, which formerly was identified as genus *Scomber*.

3.3 Commonwealth of the Northern Mariana Islands

Introduction

The Commonwealth of the Northern Mariana Islands (CNMI, Figure 2.1) consists of a 680 km long chain of 14 volcanic islands, extending northward from Rota (14^{o} N, north of Guam) to Uracas (20^{o} 5' N) (Gourley, 1997; NOAA, 1998). Over 99% of the human population (69,000 in 2000) is concentrated on the three southern main islands of Saipan (capital, 90% of population), Tinian (2,500) and Rota (3,500). The population has increased rapidly since the 1980s (Figure 3.3.1), driven by the lifting of migration restrictions, combined with foreign investment (Starmer *et al.*, 2002). Tourism and garment manufacturing provide the main sources of foreign income (NOAA, 1998).

CNMI has well developed fringing reefs surrounding most islands, as well as offshore coral reef banks and ridges, including the West Mariana Ridge. The conditions of local reefs vary, with heavy fishing pressure being considered a problem on the main islands, particularly Saipan, due to the large population and more extensive coastal development (Anonymous, 1994; NOAA, 1998; Trianni, 1998). Detailed information on the history and fisheries of CNMI is available elsewhere (Eldredge, 1983; Gourley, 1997; Green, 1997; NOAA, 1998; Starmer *et al.*, 2002).

Following WWII and the expulsion of the very active Japanese fisheries, which exported exclusively to the Japanese mainland during the 1920s and 1930s, subsistence fisheries again dominated (Radtke and Davis, 1995). Due to the loss of most Japanese fishing vessels during WWII, decades of Japanese prohibitions for indigenous fishing outside the reefs, and indigenous preference for near-shore fishing, these subsistence catches were for a long time primarily focused on shore- and lagoon-based fishing (Smith, 1947). This situation prevailed into the late 1960s, and commercial fleet developments did not start until then (Dela Cruz and Stewart, 1997). A short-lived, government sponsored offshore fishing cooperative failed due to technical and marketing problems, lasting from 1946 to 1950 (Radtke and Davis, 1995). Furthermore, by 1970 there were still "*no recreational craft except for a single glass bottom boat*" (Dela Cruz and Stewart, 1997). Essentially, economic development didn't fully start until the 1970s and 1980s (Gourley, 1997), which also contributed to increased fish imports.

Radtke and Davis (1995) considered that the local fishing industry only supplied a small part of the total seafood demand in the 1990s, with imports of fresh and frozen fish accounting for a growing part of the supply. As a result of the establishment of the Trust Territory of the Pacific Islands after WWII, it became an established practice that fish were exported freely between Trust Territories or Guam (Uchida, 1978), setting the precedence for today's regular fish imports into the CNMI from, e.g., Palau.

Subsistence fishing of near-shore coral reef resources was an important daily activity for the local population well into the 1970s (Uchida, 1978). Reviews of resource use by Gourley (1997) and Green (1997) mentioned that many fishers went spear-fishing at night and generally started from the shoreline. Furthermore, in the past, many of the offshore reefs > 100 nm from inhabited islands received relatively little fishing pressure.

The economic boom starting in the late 1980s, driven by tourism and garment manufacturing, was not reflected by significant growth in the commercial fisheries sector (Miller, 2001). However, growth in recreational fisheries came with increased westernization of the economy, which, combined with the increasing availability of boats, blurred the boundaries between subsistence and recreational fishing. Thus, each fishing trip may have commercial, subsistence as well as recreational aspects.

Current catch data collection and processing approaches are described in Hamm *et al.* (2003). The data collection system implemented by CNMI covers only commercial catches using a commercial purchase record system, and hence includes pelagic species excluded in the present report, but also bottom- and reef-fisheries. Prior to 1994, these data related to Saipan only. While Tinian and Rota have been included in the data collection system since 1994 (Graham, 1994), these data are not incorporated into the reported statistics at this stage (D. Hamm, WPacFIN, NMFS, NOAA, pers. comm.). In contrast, catches of non-commercial nature are not accounted for, although day-time creel surveys in Saipan lagoon have been conducted since 1984 (Graham, 1994). It was estimated that the proportion of total commercial landings on Saipan that are reported was approximately 90% (see www.pifsc.noaa.gov/wpacfin). However, as non-commercial catches are not included in the reported data, as much as 50% of the total catches (commercial and non-commercial) may be unreported (Radtke and Davis, 1995).

Approach & methods

WPacFIN resources for CNMI indicated that, while the Saipan data collection system for commercial catches had been in operation since the mid-1970s, only data collected since 1981 were considered accurate enough to be presented by WPacFIN. The data estimated commercial landings in Saipan, based on a voluntary dealer purchase receipt collection system (Radtke and Davis, 1995). Prior to the 1990s, the bottom-fishery was not a very large sector in terms of tonnage, and fishing was dominated by pelagic and reef fisheries (Anonymous, 1987b). However, the bottom fishery increased in the 1990s, and catches have varied over time (Anonymous, 2004). The non-commercial sector (subsistence and recreational fishing) has seen limited monitoring since 1984 using day-time creel surveys in Saipan lagoon (Graham, 1994). While such surveys are useful tools for obtaining information on non-commercial fisheries, to our knowledge, and as confirmed by Graham (1994), these data have not been analyzed or expanded for estimation of CNMI-wide non-commercial catches. We considered two sectors for catch reconstruction: commercial and non-commercial, being cognizant of the fact that most fishing trips might feature some aspects of both components.

Data sources & reconstruction

Commercial

1950-1982: While a small number of former Japanese pelagic fishing vessels were handed over to the local population after WWII to establish a commercial fishing cooperative, this operation had failed by 1950 (Radtke and Davis, 1995). Subsequently, little local commercial fisheries development occurred in the CNMI until the 1960s (Miller, 2001). Thus, for the purpose of the present reconstruction, commercial fisheries catches were set to zero in 1960 (Table 3.3.1), and catch levels interpolated between 1960 and the 1983 value as reported by WPacFIN (see below).

1983-2002: Estimates of commercial landings for recent years (1981-2002) were available via WPacFIN. Given uncertainty around the low catches reported for the first two years of this data series, only the period from 1983-2002 was used here (Table 3.3.1). While the collected data relate to Saipan only, WPacFIN uses an adjustment factor of 20% to expand to CNMI total catches (D. Hamm, WPacFIN, NMFS, NOAA), which includes accounting for the suggested under-recording of commercial landings (Radtke and Davis, 1995).

Non-commercial

Subsistence fishing was an important daily activity in the Northern Marianas after WWII. A survey conducted in the late 1940s estimated that the local population of CNMI traditionally consumed nearly 1 lb of fish$\cdot$person$^{-1}\cdot$day^{-1} (0.45 kg$\cdot$person$^{-1}\cdot$day^{-1}), implying an annual *per capita* consumption of over 300 lbs$\cdot$person$^{-1}\cdot$year^{-1}, or 165 kg$\cdot$person$^{-1}\cdot$year^{-1} (Smith, 1947). While, on first reflection, this may appear a high estimate, it is worth noting that other Pacific islands have reported similarly high consumption rates as recently as the late 1990s, e.g., Kiribati (183 kg$\cdot$person$^{-1}\cdot$year^{-1}), Palau (124 kg$\cdot$person$^{-1}\cdot$year^{-1}), Federated States of Micronesia (119 kg$\cdot$person$^{-1}\cdot$year^{-1}), or Tuvalu (113 kg$\cdot$person$^{-1}\cdot$year^{-1}) (Gillett, 2002). However, in order to remain conservative in our reconstruction approach, we have reduced the consumption rate used in the present study (see this section: *1950-1983*). U.S. military support to the local population after WWII included large food subsidies, further supporting our reduced consumption rate. Significantly, given that shortly after the war, virtually no vessels were available for exploitation of offshore resources for subsistence use, we assumed that non-commercial catches in 1950 were based predominantly on inshore resources.

1950-1983: To estimate the likely non-commercial catches for this period, we relied on published information on *per capita* consumption for the late 1940s. According to Smith (1947), the indigenous population of CNMI consumed nearly 1 lbsperson^{-1}·day^{-1} (0.45 kg·person^{-1}·day^{-1}, 166 kg·person^{-1}·year^{-1}) in the late 1940s. To account for both the lower consumption by the small non-indigenous population, and U.S. military food support after WWII, as well as to remain conservative in our estimation, we reduced this rate by over 50% to 0.2 kg·person^{-1}·day^{-1} (72.6 kg·person^{-1}·year^{-1}) as the annual *per capita* consumption rate for 1950 (Table 3.3.1). Given the predominant subsistence nature and inshore, coral reef species focus of local fisheries in 1950, we assumed this *per capita* consumption rate of 72.6 kg·person^{-1}·year^{-1} was applicable as *per capita* catch rate for 1950. We interpolated *per capita* catch rates between this 1950 level and the catch rate estimated for 1984 (see below), and expanded to total non-commercial catch estimates via human population census data (Figure 3.3.1; U.S. Census Bureau, www.census.gov).

1984-1992: As data point estimate for 1984, we relied on Radtke and Davis (1995), who suggested that non-commercial catches may have accounted for approximately 63% of total catches, which corresponded to a non-commercial to commercial catch ratio of 1.7:1 (Table 3.3.1). Thus, we assumed higher reliance on non-commercial (e.g., subsistence) fishing in the early 1980s compared to the 1990s (see below). We interpolated the proportion of non-commercial catches between 1984 and 1993 (see below), and expanded using reported commercial catches.

1993-2002: In their analysis of Saipan's seafood market, Radtke and Davis (1995) estimated that by the 1990s, approximately 50% of total catches were not reported, as they formed the non-commercial component. Thus, the non-commercial component of the reconstruction for the time period 1993-2002 was set equal to the total commercial catches as estimated above (Table 3.3.1). In contrast, Graham (1994), leaning on Dalzell (1993), used a ratio of 1.7:1 for subsistence to commercial catches, which is higher than the 1:1 ratio assumed here. However, in order to remain conservative in our estimations, we chose the lower ratio for the 1990s.

Species composition

The taxonomic breakdown for commercial catches between 1983-2002, as documented by WPacFIN, was utilized. Given that these data rely upon purchaser recorded information, taxonomic accounting is relatively poor, and report a large proportion of catches as 'miscellaneous' categories. The estimated reconstructed commercial catches between 1960 and 1982 were assigned to a three-year average species breakdown (1983-1985) derived from the reported commercial catches.

While the inshore creel survey described by Graham (1994) does collect taxonomic information on non-commercial catches, to our knowledge, this information has not been digitized or analyzed. Thus, information on taxonomic composition of the non-commercial sector was sparse for our reconstruction. We utilized the taxonomic breakdown as presented in appendices 5.2.1 and 5.2.2 of Anonymous (1994), based on the species and family compositions for night and day operations combined. We recognize that this taxonomic breakdown was incomplete.

Catch rates

Estimated total reconstructed catches (excluding pelagic species) were converted into *per capita* catch rates using human population data (Figure 3.3.1), and into catch per surface area of coral reef. Total coral reef area to a depth of 100 m for CNMI is nearly 580 km^2, with 534 km^2 within the EEZ (3-200 nm) and approximately 45 km^2 within the 3 nm near-shore waters (Gourley, 1997; Green, 1997). Given that most fishing in CNMI occurs near the three main islands, the coral reef area estimate for these islands (28.8 km^2; Green, 1997) was used for unit area calculations. While Graham (1994) reported larger area estimates (to 30 m depth) for Saipan and Tinian than those used here, his estimates contained lagoon areas. In order to remain consistent in the type of habitat (i.e., coral reef) used for comparison with the other island areas covered in this report (even if depth contours differed), we chose to use the smaller area estimates focusing on coral reef habitat type presented by Gourley (1997) and Green (1997). This does not negate the fact that the lagoon areas constitute important fishing grounds, as they historically produced a large percentage of fish catches, but was simply undertaken to enable comparisons between areas and with literature values.

Results

FAO versus local reported data

Evaluation of FAO fisheries catch data as reported for CNMI, with pelagic species removed, but the miscellaneous group retained in full, indicated that prior to 1957 no data were reported. Also, data prior to the late 1970s were poorly represented as fixed amounts of miscellaneous marine fishes (Figure 3.3.2). For the latter years (since the early 1990s), the statistics as documented by WPacFIN matched the general FAO pattern fairly well (Figure 3.3.2). This reflected a relatively well established reporting mechanism from the local to the global level, at least for the last decade. Significantly, though, it illustrated that non-commercial catches were not accounted for in the national CNMI statistics, nor in the international data supplied to FAO.

Non-commercial catches

The catch reconstruction for the subsistence/recreational sector (Figure 3.3.3) suggested that annual catches of around 450 t (1,000,000 lbs) were likely maintained until the 1970s, but may have declined since to the levels of commercial landings (around 90-135 t, or 200,000-300,000 lbs) by the early 2000s.

Thus, the reported fisheries statistics for CNMI (as represented via NOAA WPacFIN since 1983, and FAO[3] since 1957) for non-pelagic fisheries catches may have underestimated likely historic catches as reconstructed here (Figures 3.3.3, 3.3.4). Significantly, neither official data source has documented the potential 50% decline in coral reef fisheries catches over the last five decades (Figures 3.3.3, 3.3.4). The data as

[3] Early FAO data includes large pelagic species as 'miscellaneous marine fishes'.

reported by CNMI (via WPacFIN) may have underestimated likely total catches by as much as 2.2 fold for the 1983-2002 period of coverage (Figure 3.3.3). Note that data as reported by FAO for CNMI may have underestimated likely total catches by approximately 3.0 fold over the 1957-2000 period of coverage (Figure 3.3.4).

Taxonomic accounting

Information on taxonomic composition of non-pelagic catches for CNMI was exceedingly sparse, primarily because of the nature and source of commercial data, as well as the fact that the creel survey based information for non-commercial catches was not available (Graham, 1994). Thus, we had to rely on limited information for non-commercial composition (Anonymous, 1994). The reliance on purchaser recorded commercial data resulted in extensive 'pooling' of taxa into 'miscellaneous' categories, which were generally uninformative (Figure 3.3.5). The low taxonomic resolution made assessment of likely qualitative changes in catches not feasible.

Catch rates

Given that, traditionally, the majority of fishing for reef- and bottom-fish in CNMI occurred in near-shore areas, total reconstructed catch estimates (coral reef-, bottom- and reef–associated pelagic species) per area of coral reef (to 100 m depth) were based on reef areas within the 3 nm territorial waters. Furthermore, given that over 99% of the population lives (and fishes) around the three main islands, catch per area was assessed for the entire CNMI near-shore reef area (45 km^2) and the near-shore reef areas for the three main islands (28.8 km^2) only (Green, 1997). Thus, between 1950 and 2002, estimated annual catch per reef area may have declined from 10.1 $t \cdot km^{-2} \cdot year^{-1}$ to 4.7 $t \cdot km^{-2} \cdot year^{-1}$, and from 15.8 $t \cdot km^{-2} \cdot year^{-1}$ to 7.3 $t \cdot km^{-2} \cdot year^{-1}$ for CNMI (45 km^2) and main islands reef areas (28.8 km^2), respectively (Table 3.3.2).

The human population of CNMI grew rapidly over the last 2 ½ decades (Figure 3.3.1, Table 3.3.2). However, this growth mainly occurred on the main island of Saipan, and to a lesser extent on the other two main islands. Taking into account these population changes, the *per capita* catch rate may have declined from a high of potentially 72.6 kg·person^{-1}·year^{-1} (160 lbs·person^{-1}·year^{-1}) in 1950 to 2.9 kg·person^{-1}·year^{-1} (7.1 lbs·person^{-1}·year^{-1}) by 2002 (Table 3.3.2).

Discussion

The reconstructed catches for non-pelagic species in CNMI as presented here suggested a potential decline in catches of 50% between 1950 and 2002. Comparing the FAO non-pelagic catches, which represented CNMI commercial landings (including the 'miscellaneous' category which likely contained pelagic species for early years), with the reconstructed total catches of non-pelagic taxa as estimated here, suggested a 3.0 fold under-representation of likely total extractions of marine resources for the 1957-2000 period of FAO coverage available at the time of this analysis. Considering the data reported by CNMI via WPacFIN suggested a 2.2 fold under-representation of likely total catches for the 1983-2002 time period of WPacFIN coverage.

Overall, the reconstruction as undertaken here suggested the need to a) examine, analyze and expand island-wide the non-commercial creel survey data collected since 1984 (Graham, 1994) to provide a basic time line of likely developments; and b) establish and maintain a creel-survey approach that permits regular country wide estimations and expansions of non-commercial catches.

Table 3.3.1: Sources, values and applicable time periods of hard data points used for the reconstruction of non-pelagic fisheries catches for the commercial and non-commercial sectors of the Commonwealth of the Northern Mariana Islands (CNMI).

Year	Source		Comment	Catch estimate (t)
	Reference	Data		
Commercial				
1960	Miller (2001)	~0 lbs	Little commercial fishing pre 1960	0
1983-2002	WPacFIN[a]	187,536 kg (413,442 lbs) - 222,130 kg (489,708 lbs)	Large pelagic species removed	76-106
Non-commercial				
1950	Smith (1947), Uchida (1983)	0.45 kg·person^{-1}·day^{-1} (1 lb·person^{-1}·day^{-1}) = 166 kg·person^{-1}·year^{-1} (365 lbs·person^{-1}·year^{-1})	Reduced to conservative estimate of 0.2 kg·person^{-1}·day^{-1} (0.44 lbs·person^{-1}·day^{-1}) = 72.6 kg·person^{-1}·year^{-1}	456
1984	Radtke and Davis (1995)	165,938 kg (365,826 lbs)	Non-commercial to commercial 1.7:1	166
1993-2002	Radtke and Davis (1995)	87,125 kg (192,075 lbs) - 105,740 kg (233,114 lbs)	Non-commercial = commercial	87-106[b]

[a] Catch for 1983 was 76 t, for 2002 106 t, see accompanying data files. [b] Catch for 1993 was 87 t, for 2002 106 t, see accompanying data files.

Table 3.3.2: Catch rates for reconstructed coral reef fisheries catches for the Commonwealth of the Northern Mariana Islands (CNMI). Estimated catches are presented as catch per surface area of near-shore coral reefs to a depth of 100 m (within 3 nm) for the entire CNMI (45 km^2; Green 1997) and for three main islands (28.8 km^2; Green, 1997), and as *per capita* catch of reef and reef-associated species.

Year	Estimated catch (t)	Catch/area[a] (t·km^{-2}·year^{-1}) CNMI (45 km^2)	Catch/area[a] (t·km^{-2}·year^{-1}) Main islands (28.8 km^2)	Population[b]	*Per capita* catch (kg·person^{-1}·year^{-1})
1950	456	10.14	15.84	6,286	72.6
1960	478	10.61	16.58	8,861	53.9
1970	468	10.41	16.27	12,359	37.9
1980	346	7.68	12.00	16,890	20.5
1990	257	5.72	8.93	44,037	5.8
2000	224	4.98	8.56	69,706	3.2
2002	211	4.70	7.34	74,003	2.9

[a] Green (1997); [b] U.S. Census Bureau, www.census.gov/ipc/www/idbprint.html, accessed August 2004.

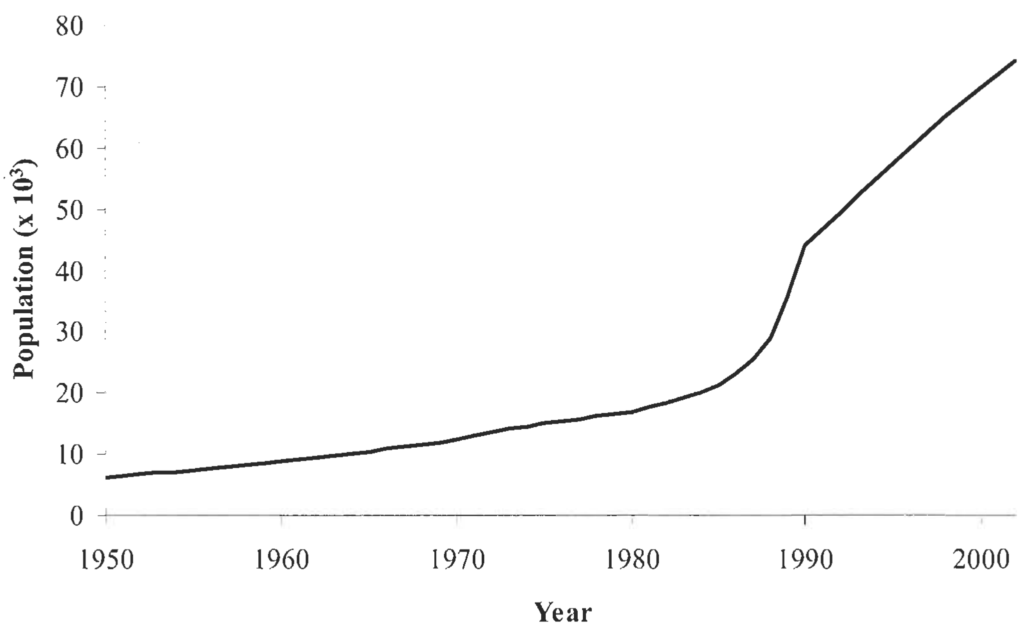


Figure 3.3.1: Human population trend for the Commonwealth of the Northern Mariana Islands (CNMI), showing the rapid growth in population since the 1980s based on the lifting of immigration restrictions and increased foreign investments (mainly in tourism and garment manufacturing).

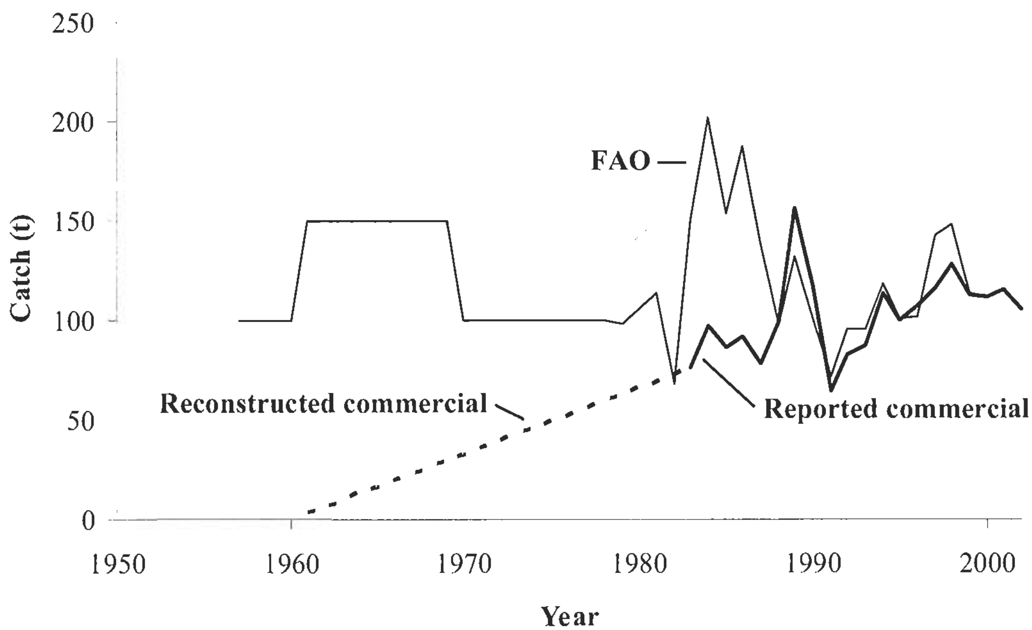


Figure 3.3.2: Catches for non-pelagic species as presented by FAO based on reporting by the Commonwealth of the Northern Mariana Islands (CNMI), versus commercial catches based on WPacFIN (1983-2002, reported commercial) and interpolation from assumed starting point of commercial fishing in 1960 (reconstructed commercial).

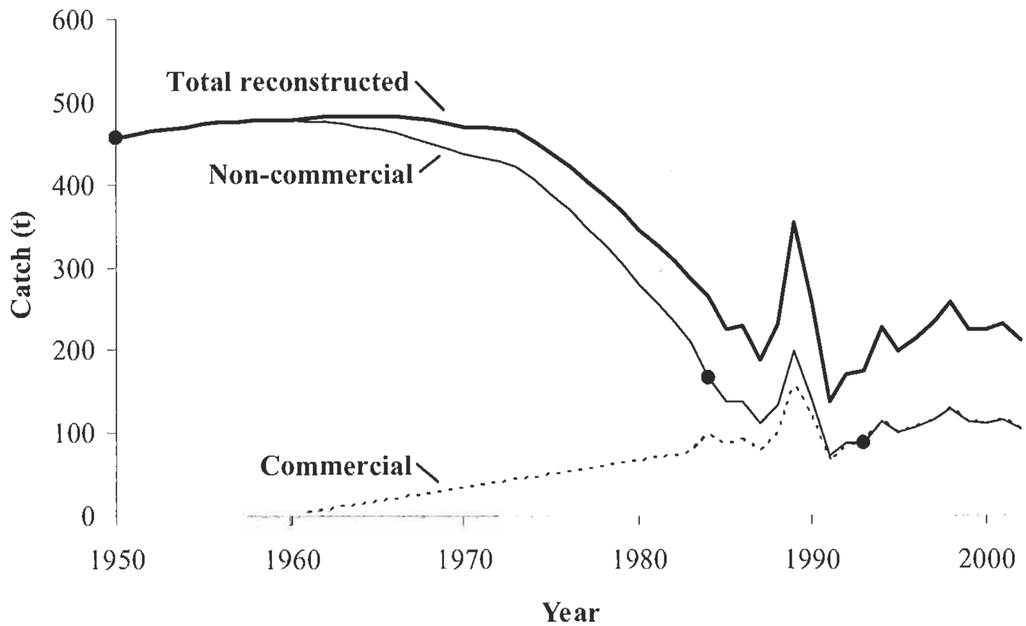


Figure 3.3.3: Total reconstructed catches for the Commonwealth of the Northern Mariana Islands (CNMI), consisting of the combination of reported commercial catches (as per Figure 3.3.2) and reconstructed non-commercial catches. Data point estimates used for non-commercial estimation are shown also (●).

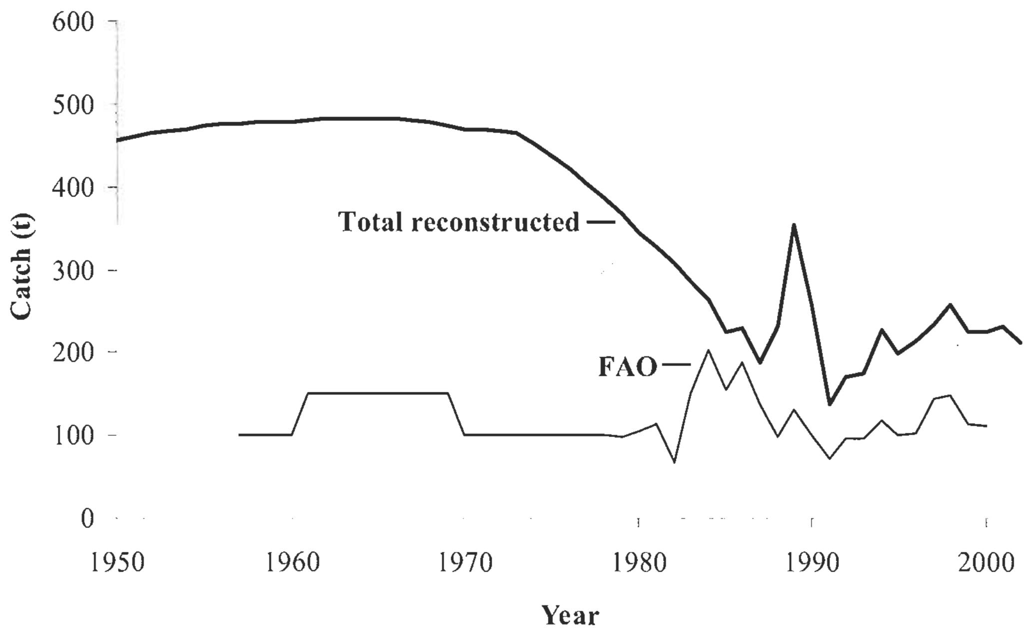


Figure 3.3.4: Total reconstructed coral reef and reef-associated fisheries catches (commercial plus non-commercial catches) for the Commonwealth of the Northern Mariana Islands (CNMI) versus the globally reported statistics as per FAO, based on country reports. Both the likely under-representation of total catches as well as the missed likely decline in catches was evident when considering only the global statistics.

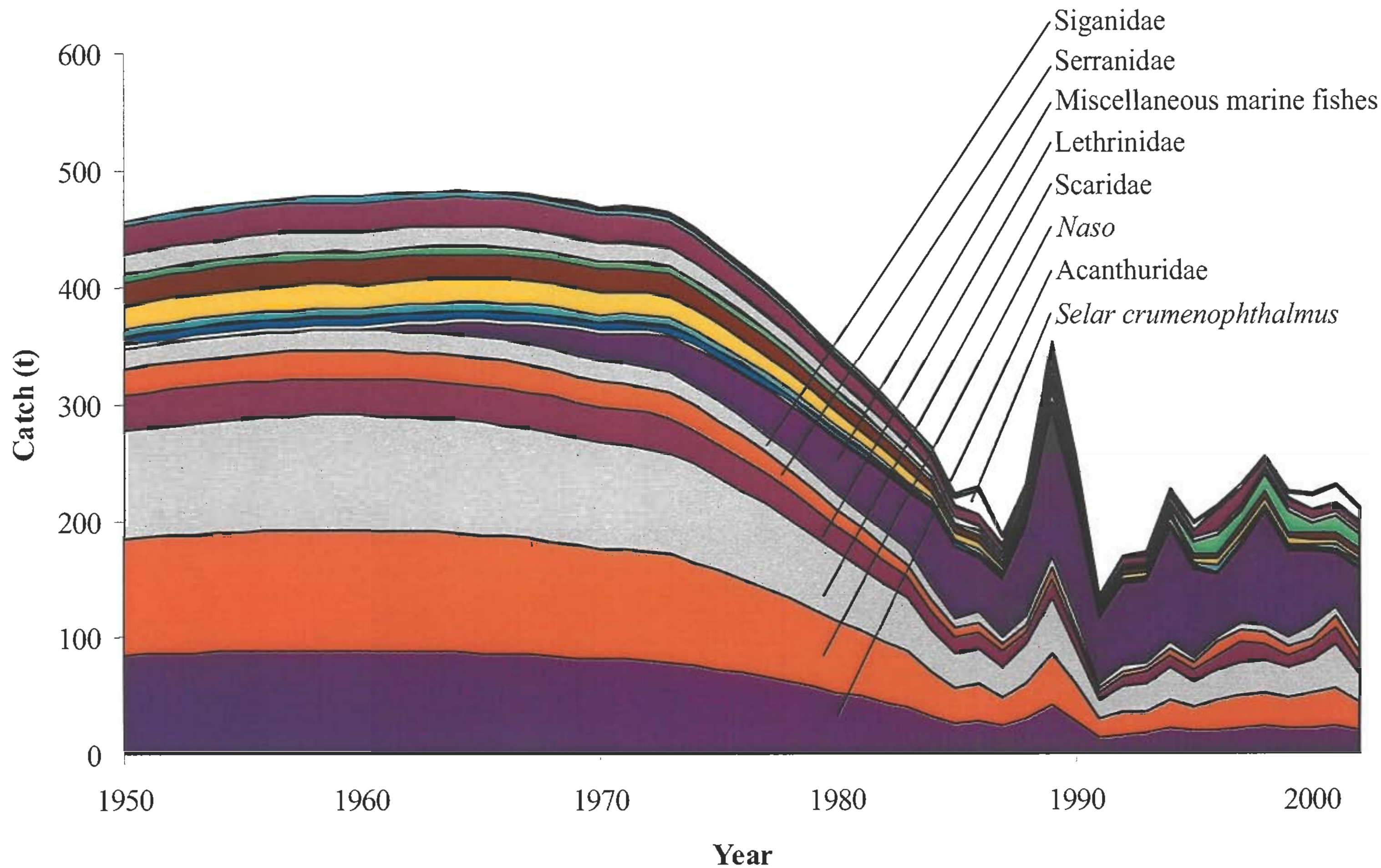


Figure 3.3.5: Taxonomic breakdown of total reconstructed catches for coral reef and reef-associated fisheries for the Commonwealth of the Northern Mariana Islands (CNMI). A total of 150 taxa (plus two 'miscellaneous' categories) are presented in the electronic data, but where summarized to 34 taxonomic groups for graphic illustration. For detailed breakdown see accompanying electronic data files.

3.4 Hawaii

Introduction

Hawaii, surrounded by an EEZ of 2,098,455 km^2, comprises an island archipelago spread over 2,400 km (19°-28° N and 155°-178° W, Figure 2.1), and consists of eight large and 124 small islands, coral reefs and shoals (Gulko *et al.*, 2002). Approximately 80% of the coral reefs in the Hawaiian archipelago are located in the essentially uninhabited Northwestern Hawaiian Islands (NWHI), and are considered to have reef fish stocks that are in good condition (NOAA, 1998). In contrast, many coral reef fish stocks of the Main Hawaiian Islands (MHI) are considered very heavily fished, and many reefs degraded due to urbanization and environmentally insensitive development (Garrod and Chong, 1978; NOAA, 1998; DeMartini *et al.*, 1999; Friedlander and DeMartini, 2002; Gulko *et al.*, 2002). Thus, there has been a substantial decline in near-shore resources in the MHI over the last few decades (Shomura, 1987, 2004).

Hawaii's coral reef ecosystems are estimated to provide a net benefit of about $360 million per year to the state's economy, while the overall value of Hawaii's coral reef ecosystems has been estimated at nearly $10 billion (Cesar and van Beukering, 2004). With regards to extractive use, the majority of commercial fisheries revenue (80-90%) is from pelagic fisheries, rather than coastal coral reef resources (Gulko *et al.*, 2002), which instead have a substantial cultural, subsistence and recreational value, both extractive and non-extractive (e.g., dive tourism).

Reviews of Hawaiian coral reefs can be found in Friedlander (1996) and Green (1997), while a general overview of inshore fisheries in a historic and social context was provided by Lowe (2001; 2004). The distinct differences in status of coastal marine resources between the privately owned island of Ni'ihau, where more traditional lifestyles and management patterns were maintained, and the other, more westernized islands also supported the observations of significant depletion of inshore resources throughout much of the MHI (Lowe, 2001). Lowe (2001) also provided additional evidence for excessive fishing being responsible for the observed resource decline in the MHI, as fishes inside coastal military areas on Kauai that were closed to the public due to security considerations increased rapidly in abundance and size distributions. Furthermore, recreational fisheries also reported declining mean size and average catch per fishing trip for many species, with trends being similar between islands (Anonymous, 1987a).

Fishing, both commercial and non-commercial, plays a significant role in Hawaii, and the two sectors blend into each other (Helvey *et al.*, 1987), as many so-called recreational fishers sell part of their catch, which is illegal under State law. These sold 'recreational' catches are thus not captured by the commercial reporting scheme (Anonymous, 1987a), leading to underreporting of commercial catches (Hamnett, 1991). On most islands, true 'subsistence' fishing is rare, as many non-commercial fishers engage in fishing for enjoyment without relying heavily on fishing as a source of food (Smith, 1993). A description of the development of the commercial fisheries, with focus on the offshore component can be found in Pooley (1993), and an ecological perspective of the inshore fisheries was presented by Smith (1993), while fisheries impacts on biodiversity of reef fishes of Hawaii were discussed by DeMartini *et al.* (1999).

Because of the distance from populated islands, the NWHI are generally only frequented by a small number of commercial fishers in larger boats. Furthermore, as recreational and commercial activities are prohibited within the 10-20 fathom isobath, many of the inshore resources have not been exploited since WWII and are likely relatively pristine (Friedlander, 1996).

For Hawaii, only commercial fisheries data are available from national sources, with database records going back to 1948. The Hawaiian Division of Aquatic Resources (HDAR) reports on commercial fisheries for both the MHI as well as NWHI, using a commercial landings database based on monthly trip reports by licensed commercial fishers (Green, 1997). However, there is thought to be considerable under- and non-reporting of commercial catches (Hamnett, 1991; Friedlander, 1996).

For recent years, recreational and subsistence fisheries catches are thought to be equal to or greater than the reported commercial landings (Friedlander, 1996; Green, 1997; Gulko *et al.*, 2002; Anonymous, 2004). While regular creel surveys have been initiated on Oahu in the early 2000s, as part of the Marine Recreational Fishery Statistics Survey (www.hawaii.gov/dlnr/dar/surveys/), these surveys focus heavily on boast-based fishing, and are considered to underestimate shore-based catches (K. Lowe, Division of Aquatic Resources, pers. comm.). Poaching, taking of under-sized fish, out-of-season catches, combined with large numbers of recreational fishers are thought to contribute to excessive fishing (Friedlander and Parrish, 1997; Gulko *et al.*, 2002). Overall, total catches of marine resources are considered under-reported in the official statistics (Gulko *et al.*, 2002).

The MHI bottom-fish fishery is showing signs of stress, as evidenced by declines in CPUE, and evaluations of Spawning Potential Ratios indicate potential recruitment overfishing (Anonymous, 2004). In contrast, bottom-fish resources in the NWHI appear relatively healthy (Anonymous, 2004). The deep-slope sector concentrates on approximately a dozen major species (Polovina, 1987), with prime focus on eteline snappers (Lutjanidae), jacks (Carangidae) and a single species of grouper (*Epinephelus quernus*, Serranidae) at depths of 30-150 fathoms (~50-300 m). These species have been fished on a smaller, subsistence basis for hundreds of years, and commercially since the early 20th century (Anonymous, 2004). Presently, they support numerous non-commercial and commercial fishers in the MHI, but only commercial fishers in the mostly uninhabited NWHI (Anonymous, 2004).

Approach & methods

The Hawaii Division of Aquatic Resources (HDAR) kindly provided us with the reported, commercial landings data for bottom-, invertebrate- and coral reef-fisheries from 1950 to the present. Data were pooled by the two main areas (MHI and NWHI), and some species catch was pooled to conform to data confidentiality rules. Data confidentiality is a legal requirement in cases with fewer than three fishers reporting a catch per reporting area (Pooley, 1999).

No requirements exist for recreational marine fishing licensing or reporting in Hawaii (Smith, 1993; Dye and Graham, 2004), despite the substantial proportion of the resident population (and visiting tourists) who engage actively in fishing (Helvey *et al.*, 1987). However, several attempts have been made to develop and investigate estimates of this sector, at least on a spatially and temporally limited scale (e.g., Anonymous, 1987a; Hamm and Lum, 1992; Everson, 1994; Kahiapo and Smith, 1994; Friedlander, 1996; Friedlander and Parrish, 1997; Everson and Friedlander, 2004). More recently, regular creel surveys have been conducted for the most heavily populated island of Oahu as part of the Marine Recreational Fishery Statistics Survey (www.hawaii.gov/dlnr/dar/surveys/). However, these surveys focus heavily on boat-based fishing, and are thought to underestimate shore-based catches (K. Lowe, Hawaii Division of Aquatic Resources, pers. comm.). Therefore, non-commercial fisheries catches were estimated indirectly, via estimated ratios of total catch versus reported commercial catch. These ratios were derived and assembled by K. Lowe (Hawaii Division of Aquatic Resources) based on extensive coverage of the available information sources.

Commercial landings

Commercial landings statistics were provided by HDAR via D. Hamm (WPacFIN) as a breakdown by taxon, year, and geographic areas (MHI, NWHI). For the present analysis, algae, freshwater, coral and large pelagic species were excluded. Confidential data by taxa were pooled into higher groupings (e.g., family).

Given that there is known to be considerable under-reporting of commercial landings (Brock, 1947; Hamnett, 1991; Friedlander, 1996; Anonymous, 2003), a reporting adjustment was applied to annual reported commercial catches, based on 12 estimated ratios for 'total commercial to reported commercial catch' derived by K. Lowe (Hawaii Division of Aquatic Resources) based on a variety of data sources (**Rc** in Table 3.4.1). The ratios were linearly interpolated for years between ratios, and applied to reported commercial catches to derive estimates of total commercial catches (i.e., total commercial catches = reported commercial catches * **Rc**).

Non-commercial catches

Most studies on non-commercial (i.e., recreational and subsistence) fisheries in Hawaii were either spatially restricted (e.g., Everson, 1994; Kahiapo and Smith, 1994; Everson, 1995; Friedlander and Parrish, 1997), or focused on a small, although important, sub-sector of these diverse fisheries (e.g., Gaffney, 2000; Friedlander and Dalzell, 2004). These case-studies provided a variety and diversity of data and information.

More recently, the consensus appeared to be that non-commercial catches were about equal to or larger than reported commercial catches (Friedlander, 1996; Gulko *et al.*, 2002; Anonymous, 2004). The small-boat based recreational fisheries was the target of several fisheries and economic studies (Anonymous, 1987a; Hamm and Lum, 1992), while the shore-based sector has been investigated by, for example, Kahiapo and Smith (1994). With few exceptions (e.g., Anonymous, 1987a; Friedlander, 1996), most studies were generally spatially restricted, e.g., Kaneohe Bay on Oahu (Everson, 1994), Hilo Bay on Hawaii (Kahiapo and Smith, 1994), or Hanalei Bay on Kauai (Friedlander and Parrish, 1997). Furthermore, information on recreational gear-specific catch per unit effort (CPUE) can be found in Friedlander and Parrish (1997).

The reconstruction of the non-commercial catches were based on an indirect approach, via estimated ratios of 'total catch to reported commercial catch' that were derived by K. Lowe (Hawaii Division of Aquatic Resources) based on a large range of sources (**R** in Table 3.4.1). Available information permitted five ratios to be estimated between 1950 and 1990. The ratios were linearly interpolated for years between ratios, while the 1990 ratio was carried forward to 2002 unaltered. These ratios were then applied to the reported commercial catches for each year to derive total catches (i.e., total catches = reported commercial catches * **R**). By subtracting the above derived 'total commercial catches' from the 'total catches', we obtained estimates of non-commercial catches (i.e., non-commercial = total catches – total commercial catches).

Taxonomic breakdown

The reported commercial catch data were provided by HDAR via WPacFIN at taxon level. The non-commercial catches were assigned to taxa using two data point distributions. We pooled and averaged the percentage composition of catches as reported by Hamm and Lum (1992), Everson (1994) and Friedlander and Parrish (1997), and thus derived an average proportional taxonomic breakdown for the late 20th century, comprising 34 taxa plus two miscellaneous categories ('miscellaneous marine fishes' & 'miscellaneous marine invertebrates'). This formed our taxonomic breakdown for the non-commercial catches for the end-point of our time period (2002). For the start of the time series in 1950, we used an indirect method to obtain an estimated taxonomic breakdown, based on catch compositions in 1900 as reported by Cobb (1903). The proportional composition of catches were interpolated between 1900 (Cobb, 1903) and the derived 2002 composition to derive the proportional composition for 1950, comprising 36 taxa. We acknowledge that this implied an unlikely linear change in catch compositions between 1900 and 2002, interrupted by the social, cultural and economic changes associated with two World Wars. However, the seafood assemblage in 1950 was probably intermediate between those in 1900 and 2002.

Catch rates

To assess if our reconstruction fell within reasonable limits for fisheries production from coral reef- and reef associated-bottom areas, we converted the reconstructed catch estimates to coral reef area-based estimates, using area estimates reported by Green (1997). Given that essentially all non-commercial, and the majority of commercial fishing occurs in the MHI, area catch rates were estimated for both MHI only (using non-commercial and MHI commercial catches), and the entire Hawaiian archipelago, using coral reef area estimates for MHI (2,535 km^2) and MHI plus NWHI (14,089 km^2), respectively (Green, 1997).

We also estimated *per capita* catch rates based on our reconstructed catch totals (non-pelagic species), which were compared to available literature estimates of *per capita* consumption for the 1960s and 1970s for Hawaii (excluding seafood imports but including pelagic species) based on Garrod and Chong (1978) and Hudgins (1980). Note that this comparison does not account for pelagic catches in the reconstructed data, and thus reconstructed catch rates were expected to be considerably lower.

Information on non-domestic seamount fishery (not incorporated in figures)

Catch data for deepwater fisheries within U.S. waters, by U.S. vessels, are included in the HDAR commercial data. However, both the former Soviet Union as well as Japan targeted fish resources on seamounts in the central North Pacific, including seamounts, such as the Hancock seamounts, located in waters that later fell within the U.S. EEZ. We obtained some information on non-U.S. catches from seamounts, and mention these here for completeness, and as an illustration of the historical extent of fishing, even in relatively remote areas. The deep water trawl fisheries on the central North Pacific seamounts expanded rapidly after exploratory fishing by Soviet trawlers in 1967, and in 1969 Japanese vessels entered the fishery (Uchida and Tagami, 1984). Soviet vessels ceased operations on the Hancock seamounts after declaration of the EEZ by the USA in 1976 (Somerton and Kikkawa, 1992), while Japanese fishing continued under U.S. quota and observer arrangements (Uchida and Tagami, 1984). The main targets were armorhead (*Pseudopentaceros wheeleri*) and alfonsin (*Beryx* spp.).

The combined Soviet and Japanese catches of armorhead in the central North Pacific increased rapidly to a peak of ~164,000 t in 1973, before declining equally rapidly to 875 t by 1978 (Somerton and Kikkawa, 1992). Japanese catches fluctuated widely during their fisheries development phase up to 1972, before reaching levels of 18,952-34,538 $t \cdot year^{-1}$, and began to decline after 1974 (Uchida and Tagami, 1984). However, CPUE peaked earlier and declined steadily into the early 1980s (Uchida and Tagami, 1984), indicating that over-exploitation of the resources occurred rapidly, and was only partially compensated for by significantly increasing effort levels. The majority of catches were obtained from seamounts located outside the waters subsequently comprising the U.S. EEZ (e.g., on the Milwaukee seamount group, Kimmei, and Mellish seamounts). The Hancock seamounts, within the 200 nm region, received between 1-29% of the entire central North Pacific Japanese effort between 1972-76, with catches ranging from 653-8,518 t, and averaging 2,804 $t \cdot year^{-1}$ (Uchida and Tagami, 1984). In total, landings from the Hancock seamounts accounted for 3-34% (average <7%) of the entire central North Pacific seamount landings of armorhead alone. By 1976, less than 10-years after discovery, resources, especially of alfonsin, were already on the decline, resulting in target shifting to less 'desirable' species such as rockfish (*Sebastes matsubari*). By 1978 the Japanese catch rate on the Hancock seamounts was 2.1 $t \cdot hour^{-1}$, and declined to 0.7 $t \cdot hour^{-1}$ by 1979 (Uchida and Tagami, 1984). While early season catch rates in 1980/81 were slightly higher, it soon became evident that the stocks had been fished out, and by 1984 the Japanese discontinued fishing on the Hancock seamounts (Somerton and Kikkawa, 1992).

The reported catches for the three monitored Japanese vessels fishing on Hancock between 1978 and 1981 were combined with the more uncertain data for the 1969-1976 period (Uchida and Tagami, 1984) to obtain an expanded total catch of the Japanese fleet on the Hancock seamounts from 1969-1981 (Table 3.4.4). Soviet catches prior to 1976, specific to the Hancock seamounts were not available, although Soviet trawlers were reported to have caught 133,400 t of armorhead between late 1969 and mid 1970 on the major seamounts fished by Soviet trawlers at the time (including Emperor chain, Milwaukee group, and Hancock seamounts). Thus, likely catches by Soviet vessels on the Hancock seamounts alone could readily have averaged 10,000 $t \cdot year^{-1}$ during the early period, which we assumed to have declined by $10\% \cdot year^{-1}$ thereafter (Table 3.4.4).

The seamount fisheries on the Hancock seamounts within the U.S. EEZ in the NWHI have been closed since August 1986 (Anonymous, 2004). However, as about 99% of the known armorhead seamount habitat in the central North Pacific occurs outside the U.S. EEZ, sustainability of this likely vulnerable deep-water stock (Roberts, 2002; Lack *et al.*, 2003) would require binding international agreements with all countries fishing these species on the high seas. Japanese trawler fleets continue to fish in international waters, and the Spawning Potential Ratio for armorhead is low, at about 10% of the threshold level for recruitment overfishing, indicating a collapsed fishery (Anonymous, 2004).

Results & discussion

Reported commercial catches (excluding large pelagic species) indicated that catches were high in the early 1950s (approximately 1,100 $t \cdot year^{-1}$), then declined sharply to a low of 600 $t \cdot year^{-1}$ (1.38 million $lbs \cdot year^{-1}$) by 1960 (Table 3.4.2, Figure 3.4.1). Since the late 1960s, reported commercial catches increased steadily (with inter-annual fluctuations) to a peak of approximately 1,600 $t \cdot year^{-1}$ (3.46 million $lbs \cdot year^{-1}$) by 1989, before declining again by 2002 (Figure 3.4.1). The overall trends were similar for both MHI and NWHI. However, the MHI contributed, on average, 88.3% (range: 63.4-98.5%) to commercial catches (Figure 3.4.1). The basic trajectory of the commercial catches between 1950 and 2002 appeared to be driven by the patterns observed for the deepwater bottom fishery (Polovina, 1987), reflecting the active bottom fish fleet prior to and shortly after WWII. For the period between the late-1950s to the mid-1970s, the fishery was predominantly focused on the MHI (Polovina, 1987), also reflected by the low reported landings for the NWHI. Furthermore, the 'slump' in catches observed from the 1960s to the early 1970s were the result of early overcapitalization of the Hawaiian fisheries after WWII, resulting in declining fish prices due to market saturation (Anonymous, 1984). As efforts to control landings failed, many fisheries left the industry, which remained depressed until the 1970s (Anonymous, 1984).

The estimation of under-reporting of commercial catches (e.g., Hamnett, 1991), as undertaken by K. Lowe (HDAR), and resulting in adjustment ratio **Rc** (Table 3.4.1), suggested that total commercial catches were between 28% and 130% higher than reported catches (Figure 3.4.1). Furthermore, this adjustment suggested that the peak in total commercial catches in 1989 consisted of potentially 2,900 t·year^{-1} (6.53 million lbs·year^{-1}, Figure 3.4.1).

The reconstruction suggested that non-commercial catches for non-pelagic species (i.e., coral reef- and bottom-species) were consistently lower than total commercial catches until the early 1980s, after which they generally appear to exceeded total commercial catches (Figure 3.4.2). Overall, non-commercial catches appear to have increased between the 1950s and 1990. However, there is increasing evidence that these catches have been declining in more recent years, as also evidenced in Figure (3.4.2). Overall, non-commercial catches for non-pelagic species might have ranged from a low of 931 t in 1959 (2.05 million lbs) to a high of 3,056 t in 1986 (6.74 million lbs, Figure 3.4.2).

The combined commercial and non-commercial catches for non-pelagic species suggested that total reconstructed catches peaked in the late 1980s, early 1990 at approximately 4,500 t·year^{-1} (10.09 million lbs), before declining by 2002 to 3,012 t·year^{-1} (6.64 million lbs), a level of catches not seen since 1982 (Figure 3.4.2). Our reconstruction also suggested that, summed over the entire time period, non-commercial catches were approximately 1.8-fold higher than reported commercial landings. These estimates are likely conservative, especially for earlier periods, given our assumptions outlined above. In particular, the use of ratios dependent on reported commercial catches to derive non-commercial catches may have led to underestimates of non-commercial catches during the 1960s and 1970s, a time of depressed commercial fisheries (due to market saturation, see above). This factor may not have influenced non-commercial fisheries equally. Overall, the official statistics (reported commercial landings only) may have underestimated likely total catches of non-pelagic species by a factor of 3.7 over the entire time period. Most significantly, the lack of regular, state wide estimates and data on all non-commercial catches is rather unfortunate.

Taxonomic breakdown

Based on the taxonomic breakdown available to us (Figure 3.4.3), the groups accounting for the major component of catches were the reef associated small pelagic species, especially the carangids, and in particular the big-eye scad (*Selar crumenophthalmus*) and mackerel scad (*Decapterus macarellus*). Important contributions were also made by lutjanids (especially *Pristipomoides filamentosus*), octopus, Mullidae, and lobster (Figure 3.4.3).

Catch rates

The coral reef area-based catch rates for MHI only (using non-commercial and MHI commercial catches) suggested that catch levels may have increased from 1.38 $t{\cdot}km^{-2}$ in 1950 to 2.07 $t{\cdot}km^{-2}$ in 1989, before declining to 1.12 $t{\cdot}km^{-2}$ by 2002 (Table 3.4.3). Inclusion of the smaller, commercial NWHI fisheries encompassing a much larger reef area, suggested total Hawaiian area based catch may have varied little, from 0.27 $t{\cdot}km^{-2}$ in 1950 to 0.21 $t{\cdot}km^{-2}$ by 2002 (Table 3.4.3). An analysis of fisheries catches for Hanalei Bay on Kauai was undertaken by Friedlander and Parrish (1997), resulting in an overall aerial yield estimate of 3.6 $t{\cdot}km^{-2}{\cdot}year^{-1}$. While this estimate was considerably higher than our MHI archipelago peak estimate of 2.07 $t{\cdot}km^{-2}{\cdot}year^{-1}$ for 1989, it supported our conservative approach.

The calculated *per capita* catch rates based on our reconstructed commercial and non-commercial catch totals (excluding large pelagic species) suggested a declining trend from 7.6 $kg{\cdot}person^{-1}{\cdot}year^{-1}$ in 1950 to 2.4 $kg{\cdot}person^{-1}{\cdot}year^{-1}$ in 2002 (Table 3.4.3). Comparing our estimates (without pelagic catches) to available literature estimates of *per capita* consumption for the 1960s and 1970s for Hawaii (excluding seafood imports, but including pelagic species, Table 3.4.3) suggested that either our estimates are underestimating local catches (and thus support our conservative approach), or pelagic species account for a substantial proportion of local consumption.

Table 3.4.1: Estimated ratios used to derive total commercial catches and total catches for Hawaiian non-pelagic fisheries, based on data for reported commercial catches provided by the Hawaii Division of Aquatic Resources. **Rc**: Ratio of total commercial catches to reported commercial catches, accounting for the under-reporting of commercial catches; **R**: Ratio of total catches to reported commercial catches, permitting estimation of non-commercial catches as differences between total catches and total commercial catches. Ratios presented here were derived by K. Lowe (Hawaii Division of Aquatic Resources) based on a range of local data and information sources. Derivation of these ratios can be obtained from K. Lowe. The present ratios were linearly interpolated for intermediate years.

Year	Rc Total commercial catch : reported commercial catch	R Total catch : reported commercial catch
1950	1.70:1[a]	3.27:1[a]
1980	2.30:1[b]	4.00:1[c]
1985	1.64:1[d]	4.00:1[c]
1988	1.73:1[e]	4.00:1[c]
1990	2.00:1[e]	3.50:1[f]
1991	2.00:1[e]	-
1992	1.28:1[d]	-
1993	1.32:1[d]	-
1996	1.37:1[d]	-
2000	1.53:1[d]	-
2001	1.53.1[d]	-
2002	1.53:1[d]	3.50:1[g]

[a] (Anonymous, 1984); [b] (Cooper and Pooley, 1982; Higuchi and Pooley, 1985); [c] (Anonymous, 1986); [d] S. Pooley (NOAA, NMFS, Pacific Islands Fisheries Center, pers. comm.); [e] (Hamnett, 1991); [f] (Kahiapo and Smith, 1994; Gaffney, 2000; Everson and Friedlander, 2004); [g] We assumed same ratio for 2002 as for 1990.

Table 3.4.2: Reported commercial catches, by decade, for Hawaiian non-pelagic fisheries, and derived estimates of total commercial catches, non-commercial catches, and total catches.

Year	Human population	Catch (t)			
		Reported commercial[a]	Total commercial[b]	Non-commercial[c]	Total[d]
1950	498,000	1,152	1,959	1,809	3,768
1960	642,000	629	1,194	1,014	2,208
1970	770,000	873	1,833	1,445	3,278
1980	694,691	1,009	2,320	1,714	4,034
1990	1,112,703	1,309	2,617	1,963	4,580
2000	1,212,343	1,131	1,730	2,227	3,957
2002	1,240,663	861	1,317	1,695	3,012

[a] Source: HDAR via D. Hamm, WPacFIN; [b] Adjusted for unreported commercial catches via **Rc** from Table 3.4.1, **Rc** being linearly interpolated between data point years; [c] Non-commercial = total catch – total commercial catch; [d] Estimated from reported commercial catch via **R** from Table 3.4.1, **R** being linearly interpolated between data point years

Table 3.4.3: Area and *per capita* catch rates from the present study, compared with published consumption rates of seafood in Hawaii (excluding imports) for selected years.

Year	Catch/area, present study ($t \cdot km^{-2}$)		*Per capita* catch rates, present study ($kg \cdot person^{-1} \cdot year^{-1}$)	Literature consumption rates ($kg \cdot person^{-1} \cdot year^{-1}$)
	MHI ($2,535\ km^2$)	MHI+NWHI ($14,089\ km^2$)	Reconstructed, non-pelagic totals	Commercial data, pelagics included
1950	1.38	0.27	7.57	-
1960	0.83	0.16	3.44	-
1965	0.90	0.17	3.32	18.1[a]
1970	1.27	0.23	4.26	11.7[b]
1971	1.23	0.23	3.97	11.7[b]
1972	1.25	0.23	3.87	11.1[b]
1973	1.23	0.23	3.73	9.7[b]
1974	1.15	0.21	3.40	8.8[b]
1975	1.18	0.22	3.50	8.9[b]
1976	1.53	0.28	4.37	9.3[b]
1977	1.52	0.29	4.37	10.3[b]
1980	1.48	0.29	5.81	-
1990	1.56	0.33	4.12	-
2000	1.48	0.28	3.26	-
2002	1.12	0.21	2.43	

[a] Garrod and Chong (1978). [b] Hudgins (1980).

Table 3.4.4: Catches from Hancock seamount between 1970-81 by the Japanese and Soviet seamount-groundfish trawl fleets. Modified and extrapolated from Uchida and Tagami (1984) and Uchida (1978). Data not incorporated in other tables or figures, and provided only to serve as depository of information on historic fisheries catches in waters associated with Hawaii.

	Japanese catch (t)				**Approximated Soviet catch (t)**
Year	**Armorhead (*Pseudopentaceros wheeleri*)**	**Alfonsin (*Beryx* spp.)**	**Others**	**Total**	**Total[b]**
1967	-	-	-	-	500.0
1968	-	-	-	-	5,000.0
1969	-	-	-	100[a]	10,000.0
1970	156.4	1.4	2.2	160.0	10,000.0
1971	234.6	2.1	3.2	240.0	9,000.0
1972	1,974.9	17.9	27.2	2,020.0	8,100.0
1973	8,327.8	75.7	114.6	8,518.0	7,290.0
1974	1779.3	16.2	24.5	1,820.0	6,560.0
1975	638.4	5.8	8.8	653.0	5,900.0
1976	1104.8	10.0	15.2	1,130.0	5,310.0
1977	0.0	0.0	0	0[a]	0
1978	407.1	3.7	5.6	416.4	0
1979	13.5	24.7	26.1	64.3	0
1980	734.7	34.2	26.2	795.1	0
1981	597.8	37.9	26.0	661.7	0

[a] Japan entered the fishery in 1969, whose value is estimated here; no fishing occurred in 1977. [b] We assumed a linear increase in catches between the start of the Russian seamount fishery in 1967 and 1969, and a 10% decline in catches per year after the peak year of 1970. Soviet vessels ceased fishing within U.S. EEZ upon declaration of zone in 1976-77.

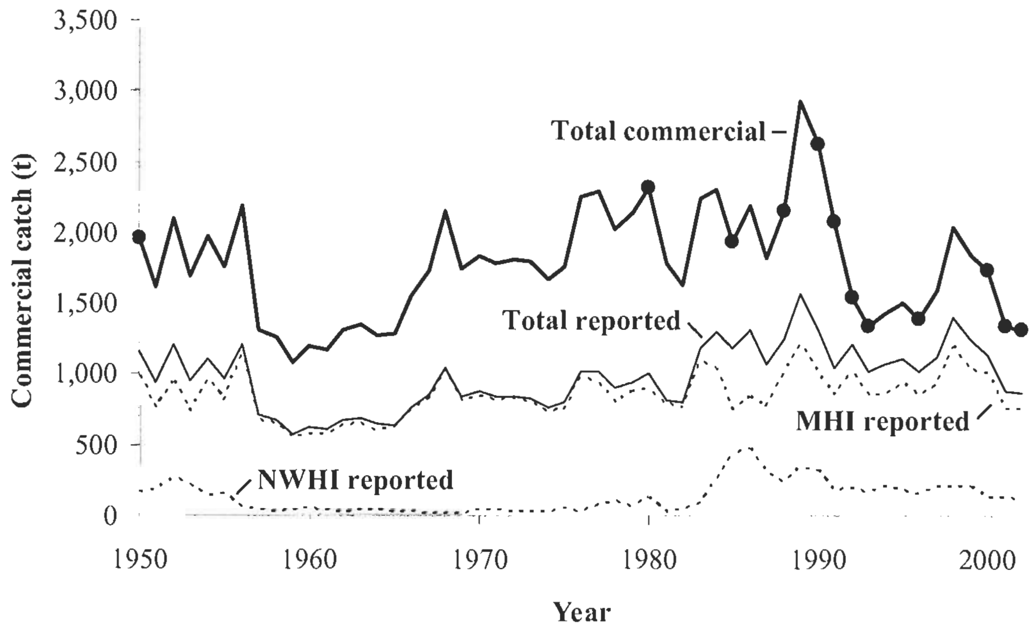


Figure 3.4.1: Time series of commercial catch data reported by HDAR for the non-pelagic fisheries for Hawaii, consisting of catches reported for the Main Hawaiian Islands (MHI) and the Northwestern Hawaiian Islands (NWHI). Shown also is the adjusted estimate of total commercial catches (for MHI + NWHI), based on the **Rc** ratios from Table 3.4.1, deemed to account for underreporting. Reported commercial catches provided by HDAR via D. Hamm (WPacFIN), **Rc** estimated by K. Lowe (HDAR). Data point estimates used for total commercial catches, based on **Rc** ratios from Table 3.4.1 are shown also (●). Ratios for intervening periods were interpolated linearly.

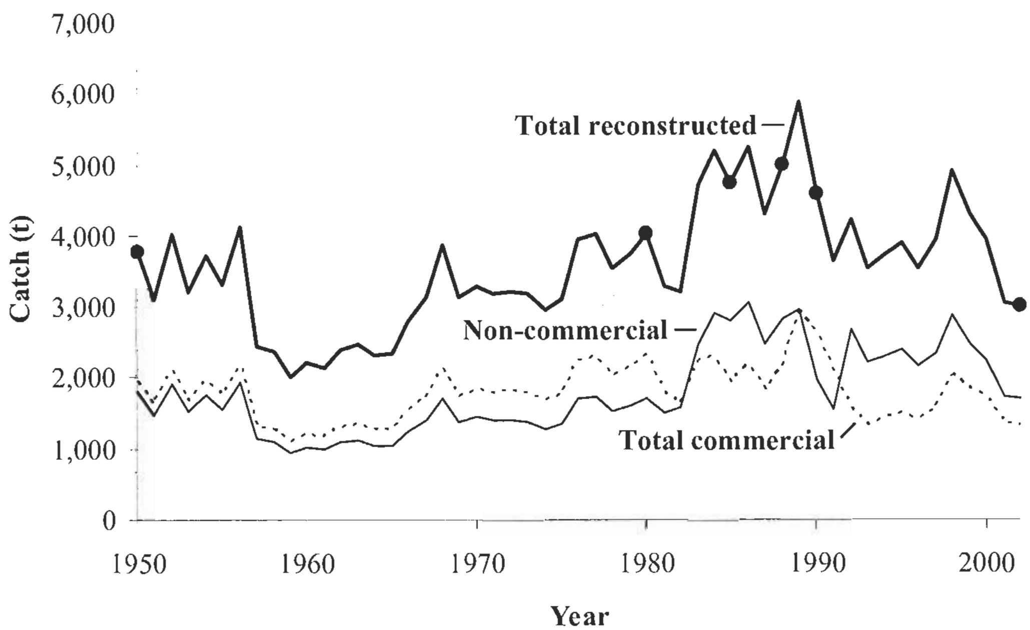


Figure 3.4.2: Total reconstructed catches of non-pelagic fisheries of Hawaii, consisting of the estimated total catches, derived from reported commercial data using **R** ratios from Table 3.4.1. Shown also are the components comprising total catch: total commercial catches and the indirectly derived estimates of non-commercial catches (non-commercial catch = total catch – total commercial catch). Data point estimates used for total catch estimation, based on **R** ratios from Table 3.4.1 are shown also (•).Ratios for intervening periods were interpolated linearly.

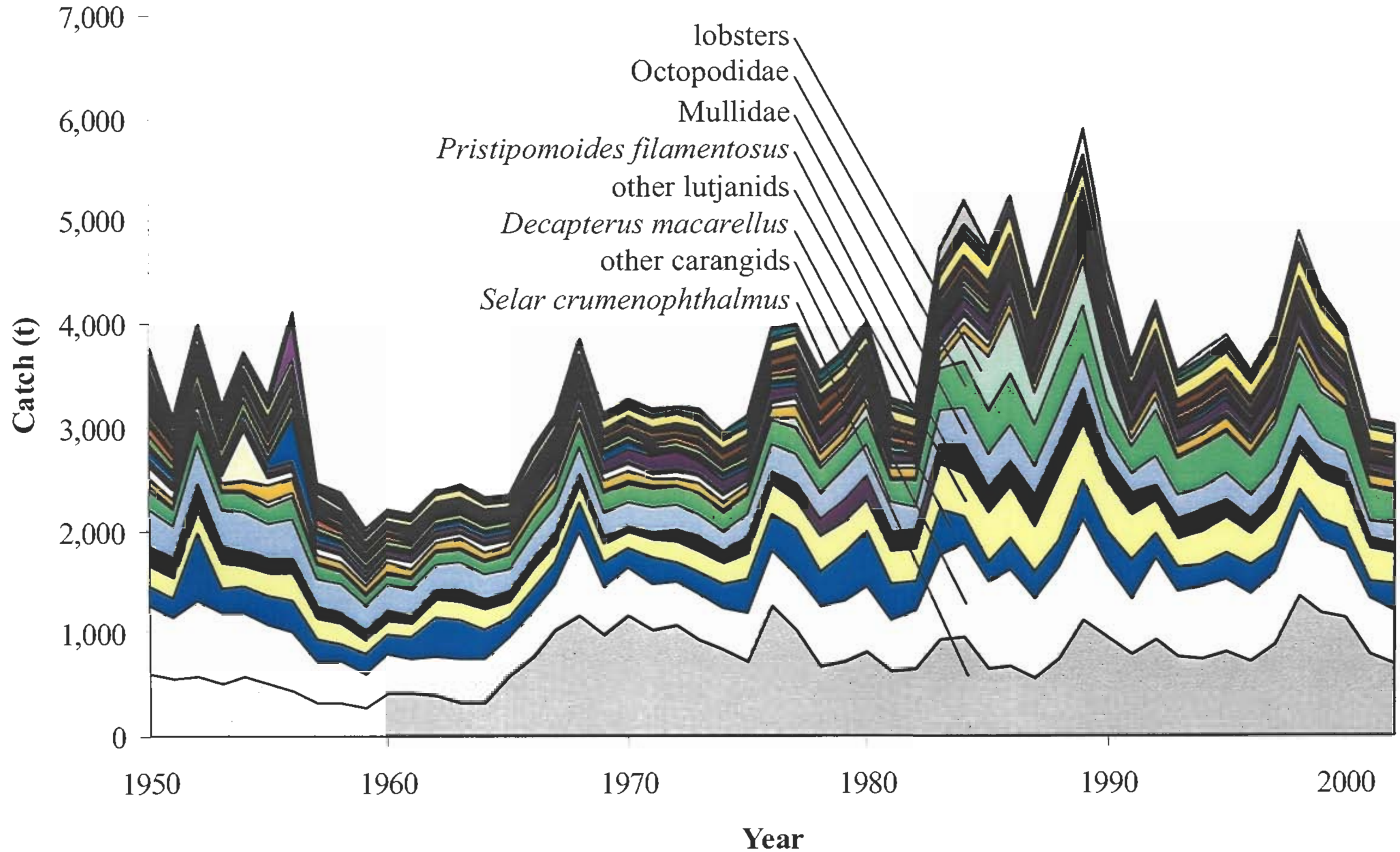


Figure 3.4.3: Taxonomic breakdown of total reconstructed catches for coral reef and reef-associated fisheries for Hawaii. A total of 151 taxa (plus two 'miscellaneous' categories) are presented in the electronic data, but where summarized to 58 taxonomic groups for graphic illustration. For detailed breakdown see accompanying electronic data files.

3.5 Other islands

The so-called 'other islands', being Midway Atoll, Johnston Atoll, Palmyra Atoll, and Wake, Jarvis, Baker and Howland Islands (Figure 2.1), are generally either uninhabited, or have only small populations of temporary contract workers or government officials, or were host to very limited tourism-based recreational fishing, e.g., Midway Atoll (Anonymous, 2001). The coral reefs in these remote areas are deemed to be generally in good condition, although localized impacts due to construction and pollution from military activities have occurred (Green, 1997; Anonymous, 2001). Low to very low levels of fishing for recreation or food occurred at some of these, mainly Johnston and Midway Atolls, and Wake Island (Green, 1997; Anonymous, 2001). The estimated ex-vessel value (in 1999 U.S. dollars) for these fisheries was thought to be approximately $32,000·year^{-1}, of which coral reef fisheries comprised $22,000·year^{-1}. It can be assumed that the majority of these values were based on the controlled charter sport-fisheries that was based at Midway Atoll (see below), and was not likely to include recreational and self-consumption 'value' from the other islands.

Johnston Atoll has been controlled by the U.S. military since WWII, and more recently has been used for chemical ammunitions storage and destruction via incineration (Anonymous, 2001). At Johnston Atoll, the population of temporary workers has a long history of fishing for recreation and self-consumption. In the past, an average of 1,200 military and civilian personnel were stationed on Johnston, by 2004 this had declined to approximately 300 people (World Factbook, www.cia.gov/cia/publications/factbook). Holocentridae, Acanthuridae, Carangidae, Mullidae and Scaridae comprised the main taxa of coral reef fish being caught, using primarily hook-and-line fishing, spear-fishing and throw-nets (Irons *et al.*, 1990). No statistics on catches were available, other than those based on a creel survey conducted in the late 1980s by Irons *et al.* (1990). We utilized the reported catches (in numbers of fish) in combination with estimates of average weight per fish (using ¾ of max size from FishBase, www.fishbase.org) to estimate catch weight. Use of ¾ of maximum size seemed justified by the fact that most of the catches at Johnston are of fairly large sized fish (Green, 1997). This provided us with catch estimates and species composition for the 1985-1990 period. Assuming that average resident population size between 1950 and 1985 was about 1,200 people, and by 2004 had reduced to about 300, we converted the catch estimates to *per capita* catch rates. We expanded catch estimates from 1990-2002 using interpolated average catch rates (1985-1990) and human population estimates. Backwards, we assumed that the population size remained constant at 1,200 people between 1950-1985, but we reduced the 1985-1990 average catch rate by 2% per year back to 1950 to account for the effects of gear technology creep and the likely increasing use of local recreational fishing opportunities over time. This resulted in estimated catches ranging from about 6 $t \cdot year^{-1}$ (13,000 $lbs \cdot year^{-1}$) for 1950 to a peak of about 14 $t \cdot year^{-1}$ (32,000 $lbs \cdot year^{-1}$) in 1985, before declining to approximately 3 $t \cdot year^{-1}$ (6,500 $lbs \cdot year^{-1}$) by 2002 (Figure 3.5.1). Overall, an estimated total catch of about 436 t (960,000 lbs) was likely extracted from the near-shore reefs around Johnston Atoll over the 50+ year period considered here (Figure 3.5.1)

At Midway Atoll, a National Wildlife Refuge, an ecotourism based sport-fishing sector developed, under guidelines and rules developed by the U.S. Fish and Wildlife Service (Anonymous, 2001). Rules included maximum number of visitors (100 $people \cdot week^{-1}$), catch-and-release (with the exception of world records) for example for *Caranx* spp., strict limits of allowed retention for self-consumption on-island (1 $lobster \cdot person^{-1} \cdot day^{-1}$ and 1 $fish \cdot person^{-1} \cdot day^{-1}$), and prohibition of catch of bottom-fish and other coral reef species, such as octopus, sea urchins, corals etc. Catches appeared to be in the range of about 4.5 $t \cdot year^{-1}$ (10,000 $lbs \cdot year^{-1}$) of finfish, and 0.18 $t \cdot year^{-1}$ (400 $lbs \cdot year^{-1}$) of lobster and other crustaceans (Table 3.4f in Anonymous, 2001).

Palmyra Atoll was home to a seaplane base and other defense facilities during WWII, and the U.S. Navy continuously occupied the Atoll until 1949 (Anonymous, 2001). In the 1960s, the atoll returned to private ownership, and in 2001, The Nature Conservancy purchased the atoll from the previous owners. The majority of the atoll and surrounding waters have been declared National Wildlife Refuge, while approximately one-third of the atoll will be retained for ecotourism. Recreational and self-consumption fishing was likely occurring during and after WWII, and commercial fishing trips were occasionally made by Hawaii-based vessels for bottom-fishing and coastal shark finning. At present, one seafood company holds a license, but is not operating a commercial fishing operation at Palmyra or nearby Kingman Reef (Anonymous, 2001). However, it is unlikely that significant catches or coral reef species have been taken from Palmyra Atoll over the last 50+ years.

Jarvis, Howland and Baker Islands were used as weather stations and military outposts during WWII, but presently are National Wildlife Refuges administered by the U.S. Fish and Wildlife Service (Anonymous, 2001). They are uninhabited except for periodic visits by scientists under special permits. While recreational and subsistence fishing was likely to have occurred at these islands during and shortly after WWII by the resident population, it seemed likely that, at least for the last decades, no significant near-shore fishing for coral reef- or bottom-fish had occurred at these locations.

Wake Island has no records of ever having held a permanent population, although Marshall Islanders visited the island occasionally (Anonymous, 2001). The island played an important role in the Pacific campaign of WWII, and hosted an airbase under Navy control. After WWII, the U.S. Federal Aviation Authority used the island until the early 1960s, after which responsibility was transferred to various federal agencies until 1994 when the Department of the Army took on administrative use of Wake Island (Anonymous, 2001). It is currently a candidate for National Wildlife Refuge status. There are approximately 110 people working on the island, and some low intensity recreational and food fishing is thought to occur (Green, 1997). We assumed similar *per capita* use patterns as for Johnston Atoll, suggesting an average catch of approximately 0.9 $t \cdot year^{-1}$ (1,960 $lbs \cdot year^{-1}$, Figure 3.5.1).

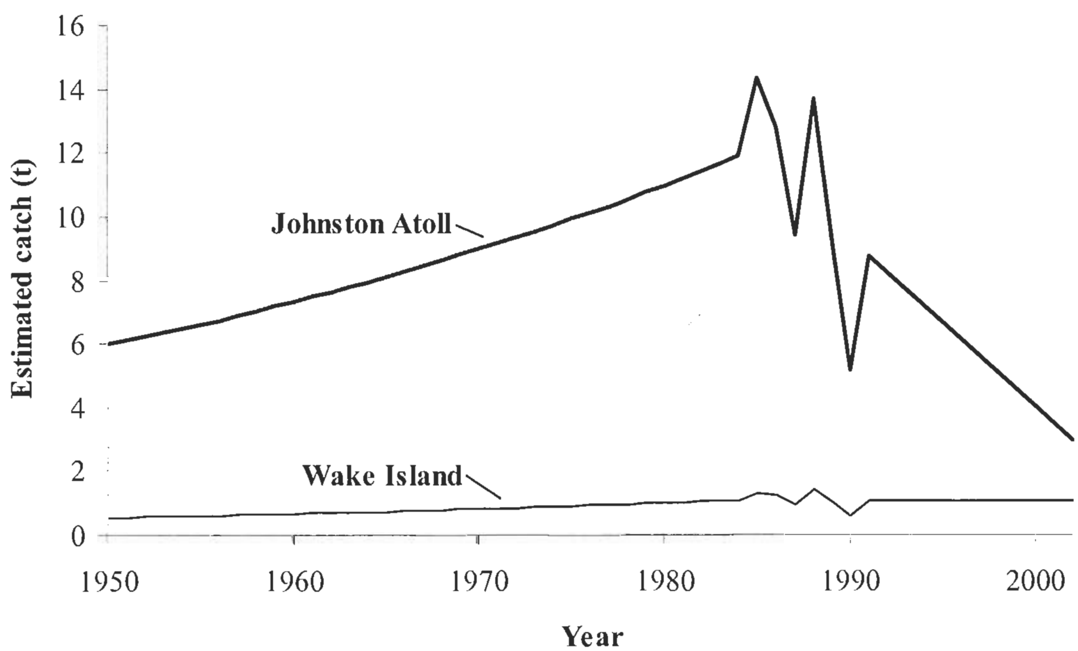


Figure 3.5.1: Total reconstructed catch estimates for the recreational coral reef fisheries for Johnston Atoll and Wake Island. Estimates were based on data modified from Irons *et al.* (1990) as reported in Green (1997). The distinct decline in estimated catches for Johnston Atoll after 1990 were the result of a declining resident population of military and civilian personnel.

4. Conclusions

The catch reconstruction for the U.S. flag island areas of the Western Pacific undertaken here provided for several main conclusions with regards to coral reef, bottom- and reef-associated pelagic species:

1) The reconstruction of historic catches for all islands combined suggested a likely decline of total catches of approximately 41% between 1950 and 2002, largely driven by declines in recent years (Figure 4.1). This pattern contrasted with that observed from the reported data alone, which suggested a marginally increasing trend (Figure 4.1);
2) Summed over the entire time period considered here, the reported data under-represented by a factor of 4.3 the likely total catches based on the reconstructions (Figure 4.1);
3) Excluding the U.S. state of Hawaii, the reconstructed data for the three other U.S. flag island areas (American Samoa, Guam, CNMI) suggested a potential decline of 77% in total catches between 1950 and 2002. This pattern contrasted with that observed from the data officially reported by the three individual countries alone, which suggested an increase in catches of about 45% between the start of reported data in 1965 and 2002 (Figure 4.2);
4) For all island entities combined, the predominantly non-commercial fisheries sectors (as roughly approximated here by shore-based, inshore or non-commercial catches), although apparently declining, appeared historically larger than commercial fisheries in terms of estimated catches (Figure 4.3);
5) Excluding the U.S. state of Hawaii, non-commercial fisheries sectors (as roughly approximated here by shore-based, inshore or non-commercial catches) were historically considerably larger than, and more recently approximately equal to commercial fisheries in terms of estimated catches (Figure 4.4);

6) In conjunction with the generally increasing population base on these islands, and a general tendency for centralization of population density on one or more main islands, the *per capita* catch rates have declined (Table 4.1); and
7) The catch rates per surface area of coral reefs have declined on all island entities, although only marginally for Hawaii (Table 4.2). However, the rates estimated using our reconstruction were within published ranges of production for Pacific Islands (e.g., Dalzell, 1996; Dalzell *et al.*, 1996; Dalzell and Adams, 1997), though generally at the lower end, confirming the likely conservative estimations used in our approach. Nevertheless, with respect to the centralized population pressures, exploitation levels on coral reefs close to population centers are very high.

With regards to our use of and comparison to reported data (national statistics and FAO data), we acknowledge that FAO FishStat as well as most national statistics were originally designed as an economic development and monitoring tool, thus explaining their focus on commercial catches (with the likely exception of Guam). Nevertheless, these data are being increasingly used to present global and national fisheries conditions and resources status and trends. Thus, the under-representation of likely total catches as indicated here may lead directly to erroneous interpretation of the status of fisheries within the U.S. flag islands. While local and regional agencies are aware of the official data being incomplete, the full scale of the potential under-representation over the entire time period was made evident through our reconstruction. While the historic catch estimates proposed here do not represent a stock assessment *per se*, they can be useful for evaluating fisheries and ecosystem status and conditions, i.e., as baselines of likely historic patterns and trends in fisheries catches.

The approach used here, relying on ‘anchor points’ of data obtained from published and unpublished literature, interpolated for missing-data years and expanded using human population data, resulted in catch estimates that allowed accounting for all fisheries sectors. We acknowledge that our estimates clearly are not statistically ‘accurate’ in the sense of being close to 'true' time-series values, which are obviously not known. However, of fundamental importance is the realization that, given our conservative approach to estimation, the present estimates are less 'wrong' than the current default of reporting nothing for fisheries sectors not accounted for in official figures. We have shown clearly that ignoring the catches of non-commercial sectors of fisheries in the U.S. flag island areas of the Western Pacific may have resulted in a skewed picture of the historic catch trends as well as catch volumes for coral reef resources in these islands.

We realize that catch reconstruction procedures such as ours are associated with high data uncertainty; this is the nature of alternative, non-standardized data sources. Especially the data paucity for the earlier periods was a shortcoming and concern. Nevertheless, our approach was based on the best data and information available to us at the time, and throughout we endeavored to remain conservative in our estimation, thus adding a precautionary layer to the data. Significantly, our overall finding was that of declining total catches. Ours was not the first time that such trends have been suggested for these islands, although the present report is likely the first that clearly and fully visualized the likely scale of these trends, especially for American Samoa, Guam and CNMI.

We would like to point out that simply observing declining catches may not necessarily imply causation by excessive fishing alone, as other factors may also contribute to such trends. These include changes in lifestyles, cash incomes and dietary preferences of the local populations, as well as environmentally insensitive developments (e.g., Boehlert, 1993; DeMartini *et al.*, 1999; Friedlander and DeMartini, 2002) resulting in coastal habitat degradation and pollution, potentially leading to stock declines.

Finally, and in our opinion most significantly, we suggest strongly that all responsible agencies should be mandated to implement and maintain regular estimation procedures to account for and report (nationally and internationally) all catches taken by all fisheries sectors. From our perspective, Guam may offer a good example and starting point for such considerations. Given the high costs of creel surveys, likely one of the most suitable methods for estimating highly dispersed and de-centralized non-commercial fisheries, considerations could be given to regular, albeit non-annual approaches for estimation of non-commercial catches.

Table 4.1: *Per capita* catch rates (kg·person^{-1}·year^{-1}) for the main U.S. Pacific flag islands.

Year	American Samoa	Guam	CNMI	Hawaii
1950	39.4	16.0	72.6	7.6
1960	31.8	12.5	53.9	3.4
1970	21.9	9.4	37.9	4.3
1980	12.6	4.9	20.5	5.8
1990	6.8	1.0	5.8	4.1
2000	3.4	1.4	3.2	3.3
2002	2.7	0.8	2.9	2.4

Table 4.2: Catch rates per surface area of coral reefs (t·km^{-2}) for the main U.S. Pacific flag islands.

Year	American Samoa	Guam	CNMI	Hawaii	
				MHI	MHI + NWHI
1950	1.57	13.87	15.84	1.38	0.27
1960	1.33	12.12	16.58	0.83	0.16
1970	1.25	11.53	16.27	1.27	0.23
1980	0.85	7.49	12.00	1.48	0.29
1990	0.67	1.84	8.93	1.56	0.33
2000	0.41	3.23	7.79	1.48	0.28
2002	0.32	1.87	7.34	1.12	0.21

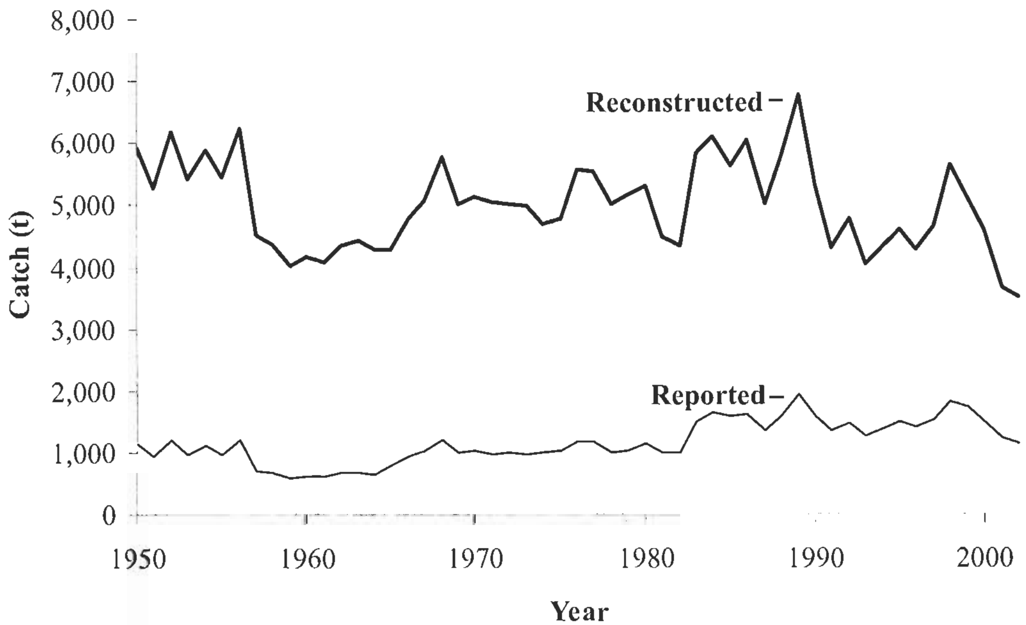


Figure 4.1: Total reconstructed catches of coral reef-, bottom- and reef-associated fisheries for the four main U.S. flag islands of the Western Pacific combined, versus the reported statistics. The under-representation of likely total catches is evident.

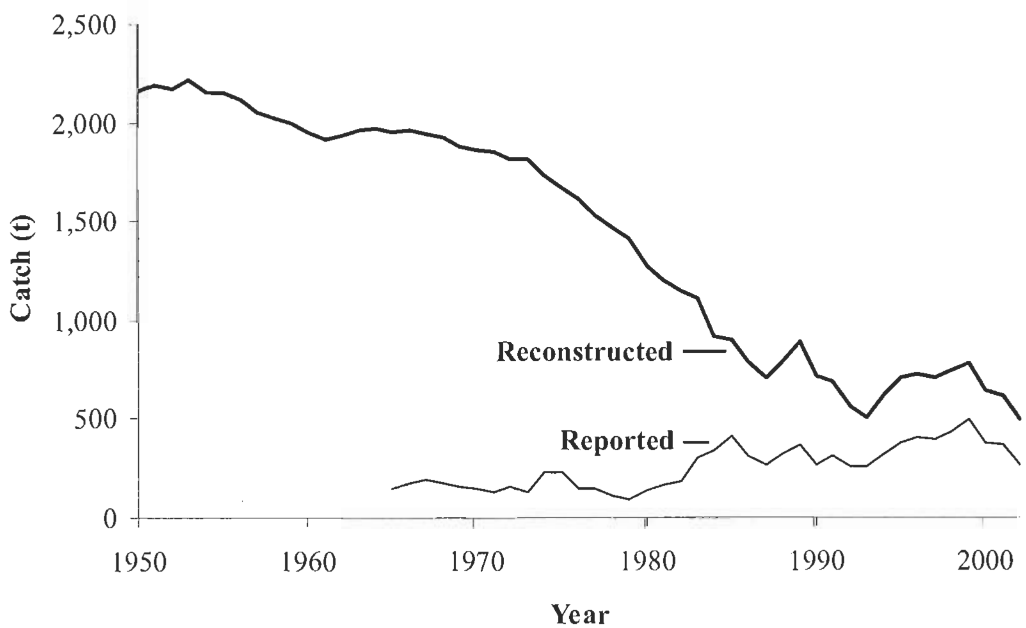


Figure 4.2: Total reconstructed catches of coral reef-, bottom- and reef-associated fisheries for three of the four U.S. flag islands of the Western Pacific considered here (excluding Hawaii), versus the reported statistics. Both the under-representation of likely total catches, as well as the missed decline in catches is evident.

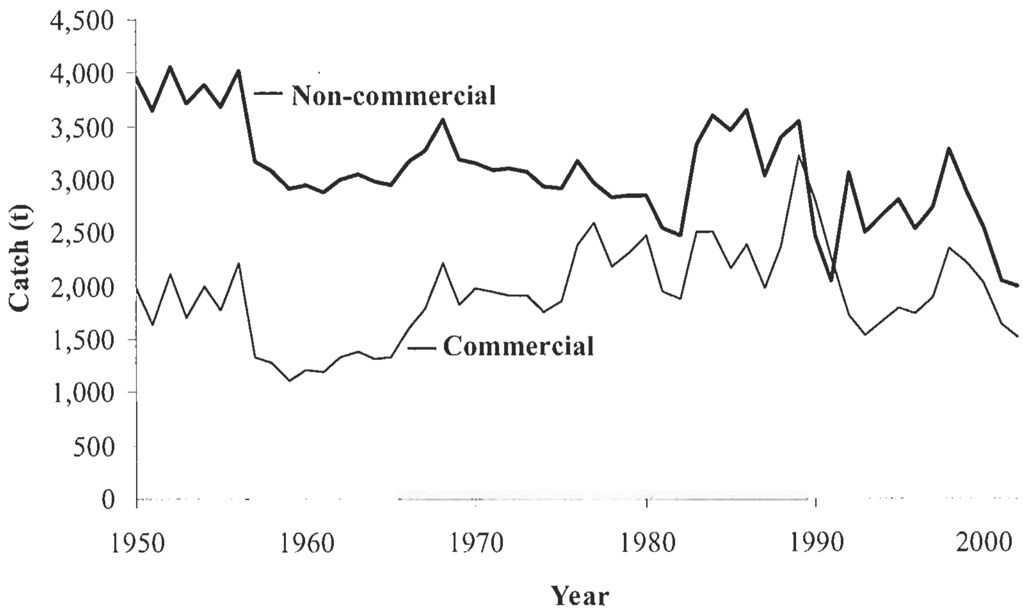


Figure 4.3: Reconstructed catches for the four main U.S. flag island entities combined, separated into predominantly commercial (or boat-based, offshore) and predominantly non-commercial (or shore-based, inshore) components.

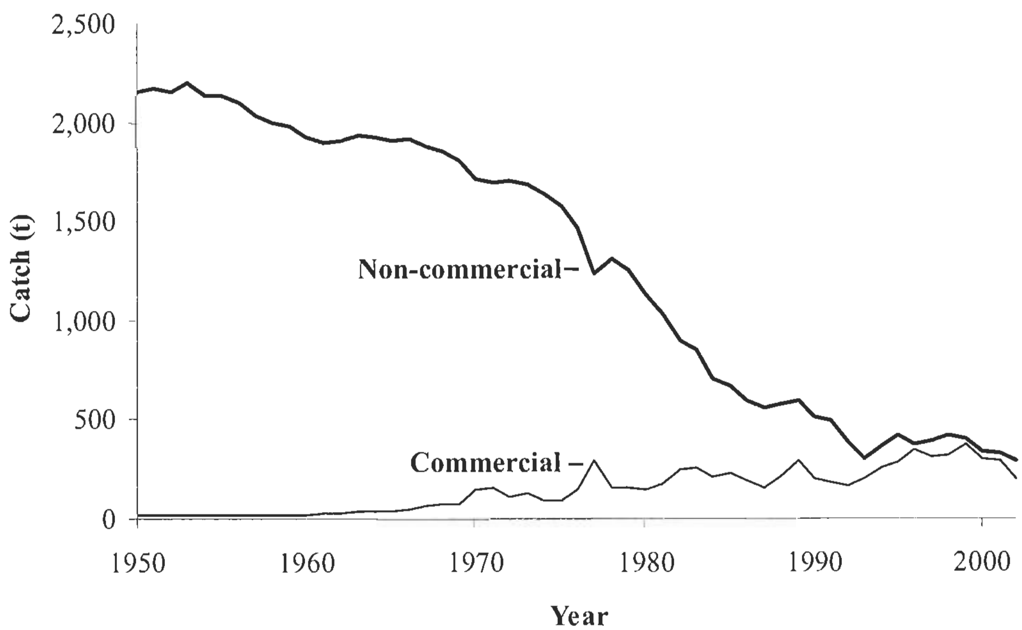


Figure 4.4: Reconstructed catches for three of the four U.S. flag island entities considered here (excluding Hawaii), separated into predominantly commercial (or boat-based, offshore) and predominantly non-commercial (or shore-based, inshore) components.

5. Acknowledgements

P. Dalzell and J. Makaiau assisted greatly in obtaining available sources of data and information, and facilitated the search of the WPRFMC library for existing reports and reference material. P. Dalzell also contributed from his personal library. The assistance provided by W. Ikehara and R. Kokubun from the Hawaii Division of Aquatic Resources (HDAR), and D. Hamm from the Western Pacific Fisheries Information Network (WPacFIN) at the Pacific Islands Fishery Science Centre, NMFS, NOAA, was greatly appreciated. Council staff located on the individual islands (J. Calvo – Guam, F. Aitaoto – American Samoa, J. Ogumoro – CNMI) have also assisted with literature and data searches, and have provided us with information, such as local government reports going back to the 1960s. Valuable additional assistance, data, analytical input and feedback was provided by others, including P. Craig (National Parks Service, American Samoa), G. Davis (NOAA-NMFS, Pacific Islands Regional Office) and K. Lowe (Hawaii Division of Aquatic Resources). Helpful comments by a range of reviewers contributed significantly to this report, and were greatly appreciated. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

6. References

AECOS. 1983. Central and Western Pacific Regional Fisheries Development Plan. Report to Pacific Basin Development Council, Honolulu, Hawaii, Kailua, Hawaii, 175 p.

Aitaoto, F. 1985. Domestic commercial fishery in American Samoa. Annual Report, Office of Marine Resources, Government of American Samoa, Pago Pago, 16 p.

Anderson, R. D. and A. Hosmer. 1981. Annual Report Fiscal Year 1981. Division of Aquatic & Wildlife Resources, Guam, 202 p.

Anderson, R. D., R. L. Kock, H. G. Tucker and C. M. Wille. 1979. Annual Report Fiscal Year '79. Division of Aquatic & Wildlife Resources, Guam, 339 p.

Anderson, R. D., A. Hosmer, D. Morris and J. Beaver. 1980. Annual Report Fiscal Year '80. Division of Aquatic & Wildlife Resources, Guam, 206 p.

Anonymous. 1965. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 5-20 p.

Anonymous. 1966. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 3-14 p.

Anonymous. 1967. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 4-17 p.

Anonymous. 1968. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 1-13 p.

Anonymous. 1969. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 72-82 p.

Anonymous. 1970. Survey of Guam's fish population and fishing methods. Division of Aquatic & Wildlife Resources, Guam, 43-52 p.

Anonymous. 1971. Survey of Guam's fish population and fishing methods. pp. 1-12 *in* Anonymous, editor. Annual Report Fiscal Year '71. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1972. Survey of Guam's fish population and fishing methods. pp. 1-12 *in* Anonymous, editor. Annual Report Fiscal Year '72. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1973. Survey of Guam's fish population and fishing methods. pp. 1-10 *in* Anonymous, editor. Annual Report Fiscal Year '73. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1974. Survey of Guam's fish population and fishing methods. pp. 1-9 *in* Anonymous, editor. Annual Report Fiscal Year '74. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1975. Survey of Guam's fish population and fishing methods. pp. 1-14 *in* Anonymous, editor. Annual Report Fiscal Year '75. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1976. Survey of Guam's fish population and fishing methods. pp. 1-11 *in* Anonymous, editor. Annual Report Fiscal Year '76. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1977. Survey of Guam's fish population and fishing methods. pp. 1-19 *in* Anonymous, editor. Annual Report Fiscal Year '77. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1978. Survey of Guam's fish population and fishing methods. pp. 1-42 *in* Anonymous, editor. Annual Report Fiscal Year '78. Division of Aquatic & Wildlife Resources, Guam.

Anonymous. 1982. Fisheries Data Compilation Project (Guam), final report. Funded by Western Pacific Regional Management Council, prepared by Pacific Basin Environmental Consultants (Guam), Honolulu, 40 p.

Anonymous. 1984. Hawaii fisheries statistics system design study. Division of Aquatic Resources, Department of Land and Natural Resources, Honolulu, 187 p.

Anonymous. 1986. Hawaii Fisheries Plan 1985. Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, Honolulu, 163 p.

Anonymous. 1987a. A report on resident fishing in the Hawaiian Islands. Developed by: Meyer Resources. Southwest Fisheries Center, National Marine Fisheries Service, Administrative Report H-87-8C, Honolulu, 74 p.

Anonymous. 1987b. Commonwealth of the Northern Mariana Islands. Report to the Western Pacific Regional Fisheries Management Council, Honolulu, 10 p.

Anonymous. 1988. American Samoa Statistical Digest 1988. Economic Development and Planning Office, American Samoa Government, Pago Pago, 136 p.

Anonymous. 1994. Biological analysis of the nearshore reef fishery of Saipan and Tinian. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands, Technical Report 94-02, Saipan, 125 p.

Anonymous. 2000. Cities, Seas, and Storms. Managing change in Pacific Island economies. Volume III: Managing the use of the ocean. The World Bank, Washington, D.C., XIII + 43 p.

Anonymous. 2001. Final Fisheries Management Plan for Coral Reef Ecosystems of the Western Pacific Region. Western Pacific Regional Fishery Management Council, Honolulu, 341 + 352 + 383 p.

Anonymous. 2003. State of Hawaii 2001 Fishery Statistics. Report prepared by Division of Aquatic Resources and the Western Pacific Fishery Information Network, Honolulu, 52 p.

Anonymous. 2004. Bottom fish and seamount groundfish fisheries of the Western Pacific region, 2002 Annual Report. A report of the Western Pacific Regional Fishery Management Council, NOAA award Number NA07FC0025, Honolulu, 174 p.

Boehlert, G. W. 1993. Fisheries and marine resources of Hawaii and the U.S.-associated Pacific Islands: An introduction. Marine Fisheries Review 55: 3-6.

Brock, V. E. 1947. Report of the Director, Division of Fish and Game. Report of the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii. Biennial period ending June 30, 1946, Honolulu, 48-62 p.

Cesar, H. S. J. and P. J. H. van Beukering. 2004. Economic valuation of the coral reefs of Hawai'i. Pacific Science 58: 231-242.

Christensen, V., S. Guénette, J. J. Heymans, C. J. Walters, R. Watson, D. Zeller and D. Pauly. 2003. Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries 4: 1-24.

Cobb, J. N. 1903. The Aquatic Resources of the Hawaiian Islands. Part II Section III. The commercial fisheries of the Hawaiian Islands. Bulletin of the United States Fish Commission 23: 715-765.

Cooper, J. C. and S. G. Pooley. 1982. Total seafood volume in Hawaii's wholesale fish market. NOAA, NMFS, Southwest Fisheries Science Center, Admin. Rept. H-82-15, Honolulu, 12 p.

Coutures, E. 2003. The shoreline fishery of American Samoa. Department of Marine and Wildlife Resources Biological Report Series No 102, Pago Pago, 22 p.

Craig, P. 1995. Are tropical nearshore fisheries manageable in view of projected population increases? South Pacific Commission and Forum Fisheries Agency workshop on the management of South Pacific inshore fisheries. Manuscripts collection of country statements and background papers. Tech. Doc. Integr. Coast. Fish. Manag. Proj. S. Pac. Comm. 11(Vol. 1), Noumea (New Caledonia), 197-208 p.

Craig, P. 2002. Status of coral reefs in 2002: American Samoa. pp. 183-187 *in* Turgeon, D. D., R. Asch, B. Causey, R. Dodge, W. Jaap, K. Banks, J. Delaney, B. Keller, R. Speiler, C. Matos, J. Garcia, E. Diaz, D. Catanzaro, C. Rogers, Z. Hillis-Starr, R. Nemeth, M. Taylor, G. Schmahl, M. Miller, D. Gulko, J. Maragos, A. Friedlander, C. Hunter, R. Brainard, P. Craig, R. Richond, G. Davis, J. Starmer, M. Trianni, P. Houk, C. Birkeland, A. Edward, Y. Golbuu, J. Gutierrez, N. Idechong, G. Paulay, A. Tafileichig and N. Vander Velde, editors. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, M.D.

Craig, P. and A. Green. 2005. Overfished coral reefs in American Samoa: no quick fix. Reef Encounter in press.

Craig, P., B. Ponwith, F. Aitaoto and D. Hamm. 1993. The commercial, subsistence, and recreational fisheries of American Samoa. Marine Fisheries Review 55: 109-116.

Craig, P., J. H. Choat, L. M. Axe and S. Saucerman. 1997. Population biology and harvest of the coral reef surgeonfish *Acanthurus lineatus* in American Samoa. Fishery Bulletin 95: 680-693.

Craig, P., N. Daschbach, S. Wiegman, F. Curren and J. Aicher. 1999. Workshop Report and Development of 5-year Plan for Coral Reef Management in American Samoa (2000-2004). American Samoa Coral Reef Advisory Group, Government of American Samoa, Pago Pago, 28 p.

Dalzell, P. 1993. Coastal fisheries production in the South Pacific. pp. 27-29 *in* Anonymous, editor. SPC Newsletter 66. SPC, Noumea.

Dalzell, P. 1996. Catch rates, selectivity and yields of reef fishing. pp. 161-192 *in* Polunin, N. V. C. and C. M. Roberts, editors. Reef Fisheries. Chapman & Hall, London.

Dalzell, P. 1998. The role of archaeological and cultural-historical records in long-range coastal fisheries resources management strategies and policies in the Pacific Islands. Ocean and Coastal Management 40: 237-252.

Dalzell, P. and T. J. H. Adams. 1997. Sustainability and management of reef fisheries in the Pacific Islands. Proceedings of the eight international coral reef symposium 2: 2027-2032.

Dalzell, P., T. J. H. Adams and N. V. C. Polunin. 1996. Coastal fisheries in the pacific islands. Oceanographic Marine Biology Annual Review 34: 395-531.

Davis, G. and T. S. Sherwood. 1989. Inshore Fisheries Survey. pp. 33-46 *in* Anonymous, editor. Annual Report Fiscal Year '89. Division of Aquatic & Wildlife Resources, Guam.

Dela Cruz, P. Q. and W. H. Stewart. 1997. A graphical presentation of selected economic and social indicators for the Commonwealth of the Northern Mariana Islands. Department of Commerce, CNMI Government, Saipan, 66 p.

DeMartini, E. E., B. C. Mundy and J. J. Polovina. 1999. Status of nearshore sports and commercial fishing and impacts on biodiversity in the tropical insular Pacific. pp. 339-355 *in* Eldredge, L. G., J. E. Maragos, P. F. Holthus and H. F. Takeuchi, editors. Marine and Coastal Biodiversity in the Tropical Island Pacific Region. Volume 2: Population, Development, and Conservation Priorities. Pacific Science Association, Honolulu.

Dye, T. S. and T. R. Graham. 2004. Review of archaeological and historical data concerning reef fishing in Hawaii and American Samoa. Report to WPRFMC, Honolulu, 160 p.

Eldredge, L. G. 1983. Summary of environmental and fishing information on Guam and the Commonwealth of the Northern Mariana Islands: historical background, description of the islands, and review of the climate, oceanography, and submarine topography. NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-40, Guam, 181 p.

Everson, A. 1994. Fishery data collection system for fishery utilization study of Kaneohe Bay. Two year interim report. Main Hawaiian Islands Marine Resources Investigation, Hawaii Division of Aquatic Resources, Technical Report 94-01, Honolulu, 45 p.

Everson, A. 1995. Catch, effort, and yields for a coral reef fishery at Kaneohe Bay, Hawaii. Draft 6/95, Honolulu, 25 p.

Everson, A. and A. Friedlander. 2004. Catch, effort, and yields for coral reef fisheries in Kane'ohe Bay, O'ahu and Hanalei Bay, Kaua'i: a large urban and a small rural embayment. pp. 108-128 *in* Friedlander, A., editor. Status of Hawaii's Coastal Fisheries in the New Millennium, revised 2004 edition. Proceedings of the 2001 fisheries symposium sponsored by the American Fisheries Society, Hawai'i Chapter. Hawai'i Audubon Society, Honolulu, Hawaii.

Friedlander, A. 1996. Assessment of the coral reef resources of Hawaii with emphasis on waters of federal jurisdiction. Western Pacific Regional Fishery Management Council, Honolulu, 62 p.

Friedlander, A. and J. D. Parrish. 1997. Fisheries harvest and standing stock in a Hawaiian Bay. Fisheries Research 32: 33-50.

Friedlander, A. and E. E. DeMartini. 2002. Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. Marine Ecology Progress Series 230: 253-264.
Friedlander, A. and P. Dalzell. 2004. A review of the biology and fisheries of two large jacks, ulua (*Caranx ignobilis*) and omilu (*Caranx melampygus*), in the Hawaiian archipelago. pp. 171-185 *in* Friedlander, A., editor. Status of Hawaii's Coastal Fisheries in the New Millennium, revised 2004 edition. Proceedings of the 2001 fisheries symposium sponsored by the American Fisheries Society, Hawai'i Chapter. Hawai'i Audubon Society, Honolulu, Hawaii.
Gaffney, R. 2000. Evaluation of the status of the recreational fishery for ulua in Hawai'i, and recommendations for future management. DAR Technical Report 20-02, Honolulu, 35 p.
Garrod, P. V. and K. C. Chong. 1978. The fresh fish market in Hawaii. Hawaii Agricultural Experimental Station Departmental Paper 23 (2M), College of Tropical Agriculture, University of Hawaii, Honolulu, 24 p.
Gillett, R. 2002. Pacific Island fisheries: regional and country information. Asia-Pacific Fishery Commission, FAO Regional Office for Asia and the Pacific. RAP Publication 2002/13, Bangkok, 168 p.
Gourley, J. 1997. The Commonwealth of the Northern Mariana Islands: An assessment of the coral reef resources under local and federal jurisdiction. Western Pacific Regional Fishery Management Council, Contract 96-WPC-119, report prepared by Micronesian Environmental Services, Saipan, Honolulu, 69 p.
Graham, T. 1994. Reef fish resources of the CNMI: A review of the fisheries, research, and management. DFW Technical Report 94-03. Department of NAtural Resources, Division of Fish and Wildlife, Saipan, Commonwealth of the Northern Mariana Islands, 45 p.
Green, A. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Western Pacific Regional Fisheries Management Council, NOAA Award Report NA67AC0940, Honolulu, 281 p.
Green, A. 2002. Status of coral reefs on the main volcanic islands of American Samoa. Department of Marine and Wildlife Resources, Pago Pago, 86 p.
Gulko, D., J. Maragos, A. Friedlander, C. Hunter and R. Brainard. 2002. Status of coral reefs in the Hawaiian Archipelago. pp. 155-182 *in* Turgeon, D. D., R. Asch, B. Causey, R. Dodge, W. Jaap, K. Banks, J. Delaney, B. Keller, R. Speiler, C. Matos, J. Garcia, E. Diaz, D. Catanzaro, C. Rogers, Z. Hillis-Starr, R. Nemeth, M. Taylor, G. Schmahl, M. Miller, D. Gulko, J. Maragos, A. Friedlander, C. Hunter, R. Brainard, P. Craig, R. Richond, G. Davis, J. Starmer, M. Trianni, P. Houk, C. Birkeland, A. Edward, Y. Golbuu, J. Gutierrez, N. Idechong, G. Paulay, A. Tafileichig and N. Vander Velde, editors. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, M.D.
Hamm, D. and H. K. Lum. 1992. Preliminary results of the Hawaii small-boat fisheries survey. Southwest Fisheries Center, National Marine Fisheries Service, Administrative Report H-92-08, Honolulu, 35 p.

Hamm, D., N. T. S. Chan and C. J. Graham. 2003. Fishery statistics of the Western Pacific Volume XVIII: Territory of American Samoa (2001), Commonwealth of the Northern Mariana Islands (2001), Territory of Guam (2001), State of Hawaii (2001). NOAA Fisheries, Pacific Islands Fisheries Science Center Administrative Report H-03-02, Honolulu, 172 p.

Hamnett, M. P. 1991. Fisheries. pp. 38-48 *in* Anonymous, editor. Hawaii Ocean Resources Management Plan, Technical Supplement. Hawaii Ocean and Marine Resources Council, Department of Business, Economic Development and Tourism, State of Hawaii, Honolulu.

Helvey, M., S. J. Crooke and P. A. Milone. 1987. Marine recreational fishing and associated state-federal research in California, Hawaii, and the Pacific Island Territories. Marine Fisheries Review 49: 8-14.

Hensley, R. A. and T. S. Sherwood. 1993. An overview of Guam's inshore fisheries. Marine Fisheries Review 55: 129-138.

Higuchi, W. and S. G. Pooley. 1985. Hawaii's retail seafood volume. NOAA, NMFS, Southwest Fisheries Science Center, Admin. Rept. H-85-6, Honolulu, 31 p.

Hill, H. B. 1978. The use of nearshore marine life as a food resource by American Samoans. M.Sc. University of Hawaii, Honolulu Pages p.

Hudgins, L. L. 1980. Per capita annual utilization and consumption of fish and shellfish in Hawaii, 1970-1977. Marine Fisheries Review 42: 16-20.

Irons, D. K., R. K. Kosaki and J. D. Parrish. 1990. Johnston Atoll resource survey final report - Phase six (21 Jul 89 - 20 Jul 90). Dept. of the Army, U.S. Army Engineer District, Honolulu, Fort Shafter, Hawaii. *in* Anonymous, editor. Final Fisheries Management Plan for Coral Reef Ecosystems of the Western Pacific Region. Western Pacific Regional Fishery Management Council, 2001, Honolulu.

Jackson, J. B. C. 1997. Reefs since Columbus. Coral Reefs 16: S23-S32.

Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourgue, R. H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner and R. R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638.

Kahiapo, J. and M. K. Smith. 1994. Shoreline creel survey of Hilo Bay: 1985-1990. Main Hawaiian Islands Marine Resources Investigation, Hawaii Division of Aquatic Resources, Technical Report 94-02, Honolulu, 31 p.

Lack, M., K. Short and A. Wilcock. 2003. Managing risk and uncertainty in deep-sea fisheries: lessons from Orange Roughy. TRAFFIC Oceania and WWF Australia Endangered Seas Programme 73 p.

Lowe, M. K. 2001. The status of inshore fisheries ecosystems in the main Hawaiian Islands at the dawn of the millennium: cultural impacts, fisheries trends and management challenges. pp. 236 *in* Friedlander, A. M., editor. Symposium Proceedings: Status of Hawaii's coastal fisheries in the new millennium. American Fisheries Society, Honolulu.

Lowe, M. K. 2004. The status of inshore fisheries ecosystems in the main Hawaiian Islands at the dawn of the millennium: cultural impacts, fisheries trends and management challenges. pp. 12-107 *in* Friedlander, A., editor. Status of Hawaii's

Coastal Fisheries in the New Millennium, revised 2004 edition. Proceedings of the 2001 fisheries symposium sponsored by the American Fisheries Society, Hawai'i Chapter. Hawai'i Audubon Society, Honolulu, Hawaii.

Miller, S. A. 2001. Economic assessment of the domestic fisheries development potential of the Commonwealth of the Northern Mariana Islands. National Marine Fisheries Service, NOAA, Saltonstall-Kennedy Grant Program, Grant Number: NA 96FD0471, Saipan, 127 p.

Munro, J. L. 1980. Stock assessment models: applicability and utility in tropical small-scale fisheries. pp. 35-47 *in* Saila, S. B. and P. M. Roedel, editors. Stock assessment for tropical small-scale fisheries. University of Rhode Island, Kingston.

Myers, R. F. 1982. Offshore Creel Census. pp. 2-22 *in* Anonymous, editor. Annual Report Fiscal Year '82. Division of Aquatic & Wildlife Resources, Guam.

Myers, R. F. 1993. Guam's small-boat-based fisheries. Marine Fisheries Review 55: 117-128.

NOAA. 1998. The extent and condition of US coral reefs. *in*. Miller, S.L. and Crosby, M.P. NOAA's State of the Coast Report. Silver Spring, MD. Available at: http://state_of_coast.noaa.gov/bulletins/html/crf_08/crf.html.

Pandolfi, J. M., R. H. Bradbury, E. Sala, T. P. Hughes, K. A. Bjorndal, R. G. Cooke, D. McArdle, L. McClenachan, M. J. H. Newman, G. Paredes, R. R. Warner and J. B. C. Jackson. 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science 301: 955-958.

Pauly, D. 1998. Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11: 4-10.

Polovina, J. J. 1987. Assessment and management of deepwater bottom fishes in Hawaii and the Marianas. pp. 505-532 *in* Polovina, J. J. and S. Ralston, editors. Tropical Snappers and Groupers. Biology and Fisheries Management. Ocean Resource and Marine Policy Series, Westview Press, Boulder.

Ponwith, B. 1991. The shoreline fishery of American Samoa: a 12-year comparison. Department of Marine and Wildlife Resources Biological Report Series, No. 22, Pago Pago, 51 p.

Pooley, S. G. 1993. Hawaii's marine fisheries: some history, long-term trends, and recent developments. Marine Fisheries Review 55: 7-19.

Pooley, S. G. 1999. Honolulu laboratory policy on confidentiality of fisheries operations data. FMPI, Conf.1299, Honolulu, 2 p.

Radtke, H. and S. Davis. 1995. Analysis of Saipan's seafood markets. Report for: Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands, RFP94-0006, Saipan, XV + 89 + appendices p.

Rawlinson, N. J. F., D. A. Milton, S. J. M. Blaber, A. Sesewa and S. P. Sharma. 1996. A survey of the subsistence and artisanal fisheries in rural areas of Viti Levu, Fiji. ACIAR Monograph #35, Australian Centre for International Agricultural Research, Canberra, 138 p.

Richmond, R. H. and G. W. Davis. 2002. Status of the coral reefs of Guam. pp. 189-194 *in* Turgeon, D. D., R. Asch, B. Causey, R. Dodge, W. Jaap, K. Banks, J. Delaney, B. Keller, R. Speiler, C. Matos, J. Garcia, E. Diaz, D. Catanzaro, C.

Rogers, Z. Hillis-Starr, R. Nemeth, M. Taylor, G. Schmahl, M. Miller, D. Gulko, J. Maragos, A. Friedlander, C. Hunter, R. Brainard, P. Craig, R. Richond, G. Davis, J. Starmer, M. Trianni, P. Houk, C. Birkeland, A. Edward, Y. Golbuu, J. Gutierrez, N. Idechong, G. Paulay, A. Tafileichig and N. Vander Velde, editors. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, M.D.

Roberts, C. 2002. Deep impact: the rising toll of fishing in the deep sea. Trends in Ecology and Evolution 17: 242-245.

Saucerman, S. 1994. The inshore fishery of American Samoa, 1991 to 1993. Department of Marine and Wildlife Resources, DMWR Biological Report Series, Pago Pago, 35 p.

Saucerman, S. 1996. Inshore fisheries documentation. Annual Report of the Department of Marine and Wildlife Resources, Pago Pago, 29 p.

Shomura, R. S. 1987. Hawaii's marine fishery resources: yesterday (1900) and today (1986). Southwest Fisheries Center, National Marine Fisheries Service, Administrative Report H-87-21, Honolulu, 14 p.

Shomura, R. S. 2004. A historical perspective of Hawai'i's marine resources, fisheries, and management issues over the past 100 years. pp. 6-11 *in* Friedlander, A., editor. Status of Hawaii's Coastal Fisheries in the New Millennium, revised 2004 edition. Proceedings of the 2001 fisheries symposium sponsored by the American Fisheries Society, Hawai'i Chapter. Hawai'i Audubon Society, Honolulu, Hawaii.

Smith, M. K. 1993. An ecological perspective on inshore fisheries in the main Hawaiian Islands. Marine Fisheries Review 55: 34-49.

Smith, R. O. 1947. Survey of the fisheries of the former Japanese mandated islands. Fishery Leaflet 273, U.S. Fish and Wildlife Service, Department of the Interior, Washington, 105 p.

Somerton, D. A. and B. S. Kikkawa. 1992. Population dynamics of pelagic armorhead *Pseudopentaceros wheeleri* on southeast Hancock seamount. Fishery Bulletin 90: 759-769.

Spalding, M. D., C. Ravilious and E. P. Green. 2001. World Atlas of Coral Reefs. University of California Press, London, 424 p.

Starmer, J., M. Trianni and P. Houk. 2002. Status of coral reefs in The Commonwealth of the Northern Mariana Islands. pp. 195-204 *in* Turgeon, D. D., R. Asch, B. Causey, R. Dodge, W. Jaap, K. Banks, J. Delaney, B. Keller, R. Speiler, C. Matos, J. Garcia, E. Diaz, D. Catanzaro, C. Rogers, Z. Hillis-Starr, R. Nemeth, M. Taylor, G. Schmahl, M. Miller, D. Gulko, J. Maragos, A. Friedlander, C. Hunter, R. Brainard, P. Craig, R. Richond, G. Davis, J. Starmer, M. Trianni, P. Houk, C. Birkeland, A. Edward, Y. Golbuu, J. Gutierrez, N. Idechong, G. Paulay, A. Tafileichig and N. Vander Velde, editors. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, M.D.

Trianni, M. S. 1998. Summary and further analysis of the nearshore reef fishery of the Northern Mariana Islands. Division of Fish and Wildlife, Department of Lands and Natural Resources, Commonwealth of the Northern Mariana Islands, Technical Report 98-02, Saipan, 64 p.

Uchida, R. N. 1978. The fish resources of the Western Central Pacific Islands. FAO Fisheries Circular No. 712, FIRM/C712, Rome, 53 p.

Uchida, R. N. and D. T. Tagami. 1984. Groundfish fisheries and research in the vicinity of seamounts in the North Pacific Ocean. Marine Fisheries Review 46: 1-17.

Wass, R. C. 1980. The shoreline fishery of American Samoa: past and present. pp. 51-83 *in* Munro, J. L., editor. Marine and coastal processes in the Pacific: ecological aspects of coastal zone management. Papers presented at a UNESCO seminar held at Motupore Island Research Centre, University of Papua New Guinea. United Nations Educational Scientific and Cultural Organization, Jakarta Pusat.

7. Appendix 1: Project proposal

Reconstruction of fisheries catches for U.S.-associated islands in the Western Pacific Region

December 2003

D. Pauly & D. Zeller
Fisheries Centre
University of British Columbia

Introduction:
Fisheries resources have played a key role in defining and shaping Pacific island communities for centuries. While pelagic fisheries are the commercially most significant fisheries in the islands under regulation by the Western Pacific Regional Fishery Management Council (WPFMC), inshore coral reef fisheries are generally of more fundamental subsistence, recreational, social and cultural importance for many of the island communities, providing more than just food, trade and recreational resources (Boehlert 1993; WPFMC 1999). However, while catches for the commercial large-pelagic fisheries are generally relatively well documented (at least for the last decade), catches for the small-scale, artisanal fisheries are often not reported to fisheries agencies. Hence, extractions of these marine resources usually remain unaccounted for in regional, national and global statistics (Pauly 1998).

Reconstruction of historic catch time series often may require interpolation and bold assumptions, justified by the unacceptable nature of the alternative, i.e., accepting catches as zero (Pauly 1998, Zeller *et al.* 2001). For example, the only global data set of fisheries catches in existence, assembled and maintained by the United Nations Food and Agriculture Organization (FAO), reports total catches for Guam as < 200 t prior to the mid 1980s (the majority being unidentified 'miscellaneous marine fishes'). Clearly, this is not reflective of true catches for an island nation whose human population nearly doubled between 1950 - 1980, from approximately 60,000 to over 100,000. Furthermore, already by the early 1990s, concerns over serious overfishing and habitat destruction were reported for Guam's near-shore marine environments (Hensley and Sherwood 1993). Similarly, non-pelagic catches for the Northern Mariana Islands and American Samoa are poorly represented in FAO fisheries statistics, especially for the pre-1990 period. Without accounting for fisheries catches for all sectors of a community, we cannot obtain any measure of the true commercial as well as cultural value of these resources to the communities, or of the risks overfishing may represent for Western Pacific Island societies. This is especially a concern, given that growth rates in some areas of the Pacific (e.g., American Samoa) are among the highest in the world and natural resources in the small Pacific islands are limited, and perceived to be declining (Craig 1995; Tulagi and Green 1995). It is thus evident that reconstructing past catches, especially for the generally un-reported small-scale coral reef fisheries is crucial for establishing baselines for fisheries management and conservation, and the maintenance of the livelihoods and cultures of island societies.

We propose to assemble available information and data on catches for the coral reef fisheries of the islands for which the WPFMC has responsibility, for periods between 1950-present, as well as incorporate available sources for pelagic catches by areas (e.g., EEZ) in conjunction with access agreements (official and un-official), using the methods outlined below. The aim is to derive estimates of total removal of marine resources for this period.

Methods:
Given that most coral reef fisheries catches are not mandated for reporting, little time series data can be expected to exist. However, in many instances, local scale studies have been undertaken, reporting local catches or catch rates for some periods, locations and/or gear types (e.g., Craig and Penwith 1993; Dalzell 1996; Craig *et al.* 1997). Much information is also often hidden in unpublished, so-called gray literature reports, or form part of published studies that often have a primary focus other than catch reporting (e.g., Craig *et al.* 1997 for American Samoa). Such sources will form the foundation for deriving catches or catch rates per unit of effort (e.g., per fisher) during a given time interval. These estimates provide point estimates, and will form anchor points of 'hard' data around which catch estimates will be build. Of particular importance are catch rate information (catch person^{-1} time period^{-1}), as this will enable us to derive estimates of likely total catch year^{-1} in conjunction with data being assembled, by our project, on small scale fishers and population demographics for the same time periods (Jackie Alder, UBC Fisheries Centre, pers. comm.). Thus, once all quantitative data have been extracted, interpolations can be employed to 'fill in' the periods for which data are missing. While, at first sight, interpolated periods may seem unsupported by data, the alternative is to leave years blank ("no data"), which later will invariably be interpreted as catches of zero (see example above), which is far worse than an interpolated estimate (Pauly 1998).

Thus, the key part of this approach is psychological, as one has to overcome the notion that "no information is available", which is the wrong default assumption if dealing with fisheries (Pauly 1998). Records or studies generally exists that document parts of the activities, which can then be judiciously interpreted.

Given that several of the islands under WPFMC jurisdiction are officially un-inhabited (e.g., Palmyra Atoll, Jarvis Island, Baker Island, Howland Island) or have only limited contract or military personnel (e.g., Johnston Atoll, Wake Island), primary focus of the coral reef catch reconstruction would initially focus on American Samoa, Guam, the Northern Mariana Islands, and the Hawaiian Islands (for which extensive catch records already exist).

While catch information for pelagic fisheries are in far better shape (especially for recent years), official datasets generally report these catches on very large spatial scales (e.g., FAO area 71 for entire Western Central Pacific). Such information is of limited use in ecosystem considerations, and we propose to update this information through incorporation of catch information from EEZs, as well as integration of access agreements for other nations to EEZs of individual island territories. A global database of such agreements has been established as part of the *Sea Around Us Project*, and is being updated on an ongoing basis. This information will be incorporated in the distribution and allocation of pelagic catches, by fishing countries, to EEZs of all island territories associated with the WPFMC.

Results and outputs:
We suggest that the output from this project will be in two formats: electronic, web-based catch time series, and traditional printed report.

Firstly, the reconstructed catch time series will be integrated into the global fisheries catch database established by the *Sea Around Us Project* at the Fisheries Centre (accessible at www.saup.fisheries.ubc.ca), stratified by island/territory. Thus, the reconstructed catch series will replace FAO FISHSTAT data within this database for those taxonomic entities for which improved catch data were obtained. This database is searchable by country/island/territory, with results freely available via the web, and forms the foundation of work recently published in *Nature* documenting over-reporting of global fisheries catches due to mis-reporting by China (Watson and Pauly 2001). The electronic catch time series will also be provided directly to WPFMC. Individual, web-based country/island territory catch time series on the SAUP web site will be clearly labeled with the Council logo, acknowledging its support, and providing a direct web-link to the WPFMC website.

Secondly, a written report will be produced. At the discretion of the funding agency, this report may either be in the form of a volume in the *Fisheries Centre Research Report* series (ISSN 11989-6727), which are abstracted in Aquatic Science and Fisheries Abstracts, ensuring researchers around the world can become aware of this material, or in the form of a direct, unpublished report to the Council, or both. It will outline the work undertaken, the data and information sources utilized, and the results of the reconstructed catch time series for the areas covered.

Should time permit, results may be presented in mid-2004 at either the *10th International Coral Reef Symposium* in Okinawa (Theme: Stability and degradation of coral reef ecosystems), or at the *International Institute of Fisheries Economics & Trade (IIFET 2004)* in Tokio (Theme: What are responsible fisheries?), in a co-joint presentation between *Sea Around Us Project* and WPFMC staff.

Literature cited in proposal:

Boehlert G.W. 1993. Fisheries and marine resources of Hawaii and the U.S.-associated Pacific Islands: An introduction. *Marine Fisheries Review* 55(2): 3-6

Craig P.C. 1995. Are tropical nearshore fisheries manageable in view of projected population increases? South Pacific Commission and Forum Fisheries Agency workshop on the management of South Pacific inshore fisheries. Manuscripts collection of country statements and background papers, SPC, Noumea (New Caledonia). Tech. Doc. Integr. Coast. Fish. Manag. Proj. S. Pac. Comm. 11(Vol. 1): 197-208.

Craig P.C. and Penwith B. 1993. The commercial, subsistence, and recreational fisheries of American Samoa. *Marine Fisheries Review* 55(2): 109-116.

Craig P.C., Choat J.H., Axe L.M. and Saucerman S. 1997. Population biology and harvest of the coral reef surgeonfish *Acanthurus lineatus* in American Samoa. *Fishery Bulletin* 95: 680-693.

Dalzell P. 1996. Catch rates, selectivity and yields of reef fishing. In: NVC Polunin and CM Roberts (eds.) *Reef Fisheries*. pp. 161-192, Chapman & Hall; London.

Hensley R.A and Sherwood T.S. 1993. An overview of Guam's inshore fisheries. *Marine Fisheries Review* 55(2): 129-139

Pauly D. 1998. Rational for reconstructing catch time series. *EC Fisheries Cooperation Bulletin* 11(2): 4-10.

Tulagi F. and Green A. 1995. Community perception of changes in coral reef fisheries in American Samoa. South Pacific Commission and Forum Fisheries Agency workshop on the management of South Pacific inshore fisheries. Manuscripts collection of country statements and background papers, SPC, Noumea (New Caledonia). Tech. Doc. Integr. Coast. Fish. Manag. Proj. S. Pac. Comm. 11(Vol. 1): 517-535.

Watson R. and Pauly D. 2001. Systematic distortions in world fisheries catch trends. *Nature* 414: 534-536.

WPFMC 1999. The Value of the Fisheries in the Western Pacific Fishery Management Council's Area. Western Pacific Regional Fishery Management Council. Web-published news item available at: www.wpcouncil.org/documents/value.pdf.

Zeller D., Watson R. and Pauly D. (eds.) 2001. Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort and National/Regional Data Sets. *Fisheries Centre Research Reports* 9(3), 254 pp.

8. Appendix 2

8.1 Summary of reviews and revision

An earlier draft version of the present report (dated March-2005) had been reviewed by nine (9) reviewers. These reviews were addressed in the revised version tabled for the August 22-23, 2005 workshop held in Honolulu. This revised version was subsequently reviewed by an additional four (4) reviewers from local resource agencies, whose comments are appended below (**reviewer's comment**), and whose comments were incorporated as appropriate in the final revised report presented here. Our responses to these comments (**authors' response**) are indicated in each case. The present final revised version of the report, having been reviewed by a total of 13 reviewers, addresses earlier concerns about documentation of statistical methods, perceived incomplete literature search, and considerations regarding communication with local jurisdictions.

Furthermore, the basic methods applied in the present report are now available in the primary literature (Zeller, D., S. Booth, P. Craig and D. Pauly. 2005. Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. *Coral Reefs* DOI 10.1007/s00338-005-0067-4, available at: dx.doi.org/10.1007/s00338-005-0067-4), and have thus been independently peer-reviewed within the obvious constraints of the underlying assumptions and the lack of historical hard time series data.

8.2 Comments from local resource agencies, and responses

F. Aitaoto (American Samoa)

Reviewer's comment:

a. I **strongly recommend** that the paragraph (just 5 lines) on page 85 starting, *"We would like to point out that simply observing ....."* should be in the Executive Summary. Leaving this paragraph towards the back of the report may lead directly to erroneous interpretation of the status of the fisheries. These few lines will do wonders in minimizing erroneous interpretations by the media and politicians who generally don't bother reading interpretations of the statistics.

Authors' response:

Inclusion into the Executive Summary of the statement from the conclusion was done.

Reviewer's comment:

b. Even though an explanation was given during the workshop on why pre 1980 artisanal bottomfish statistics from FAO was used, I feel that in keeping with the Council's recent standard of "using the best available" data for its management duties, FAO data for that period shouldn't be used. Data from the Dory Project may contain the "best data available" on bottomfish for 1974 to 1976 (*WPRFMC Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region, 1990 Annual Report) and should be used instead of the FAO data.*

Authors' response:

The reviewer expressed concerns about 'use of FAO data for pre-1980 period'. We would like to re-iterate here what is explained in the methods section: At no stage was FAO data used as source for reconstructed data. FAO data purely served for visual comparison purposes.

Reviewer's comment:

c. The Coutures. E. 2003 report **shouldn't be used at all** because the author clearly states that "the analysis showed a bias in the protocol implying an underestimation of the effort ..". Additionally, the two areas surveyed don't represent the subsistence fishing occurring in most areas (McConnaughey 1993) and some aspects of the methodology are questionable. [you can reference me on this comment]

Authors' response:

The reviewer expressed concerns about the use of the study by Coutures (2003), and suggested that the associated methodology had flaws. We appreciate these concerns, and have revisited the source. We have changed the data used, by utilizing Coutures' maximum estimated catch, rather than the average estimated catch as 2002 estimate. While we appreciate that concerns might exist about this study, many sources of information in this study (especially grey literature) have some methodological problems associated with them, yet we have to utilize these, while keeping in mind their shortfalls. The same applies in this case, and we consider that by utilizing the higher (maximum) estimate for 2002 we may account for this problem. Clearly, this issue supports our call for more regular, properly designed and executed sampling for estimation of total catches in the future, which will permit revision of Coutures' estimate.

Reviewer's comment:

d. John McConnaughey. 1993. The Shoreline Fishery of American Samoa in FY'92. DMWR Biological Report Series, No.41 (copy available and this report may have already been considered).

Investigator	Report period	Subsistence catch estimate
McConnaughey	FY91	440,000 pounds: ***McConnaughey may be used for the 1991 estimate instead of Craig et. Al (1993).***
" "	FY92	334,000 pounds (***is this comparable to Saucerman?***)

Authors' response:

We thank the reviewer's presentation of an additional source for the early 1990's shoreline fisheries catches (McConnaughey, 1993). These data are virtually identical to the values presented by Craig *et al.* (1993) and we have decided to retain this reference as source, primarily as it is more readily available as published literature.

Reviewer's comment:

e. Update below:

Calendar Year	Artisanal bottomfish catch	CPUE
2003	26,239 pounds	16.2 pounds/hr and highest since 1989.

Source: WPRFMC, 2003 Bottomfish Annual Report

David C Hamm agreed during the workshop to look into the WPacFIN data to see if the other data source (Commercial Receipt/Invoice System) was included/considered. I hope this has been done for the final report.

Authors' response:

The proposed update for 2003 is interesting, but beyond the scope of the report, which covers the 1950-2002 period throughout.

Jay Gutierrez (Guam)

Reviewer's comment:

1. The main concern is the use of the data. There should be a disclaimer within the document for the Guam data. This disclaimer should state that the document cannot be used for stock assessment purposes. Because there are various assumptions and uncertainties such as with imports within the document, the actual situation may not be reflected. The Department understands the hard work and the coordination that the Western Pacific Fisheries Management Council undertook regarding the document.

Authors' response:

The reviewer requested inclusion of a statement as disclaimer that the document cannot be used for stock assessment purposes. We have incorporated a statement indicating that this is not a stock assessment in the final document.

Reviewer's comment:

2. The ability for families to harvest fish differently is also a concern. For example, the use of refrigerators and the ability to store fish may have played a role in the amount of fish that was harvested.

Authors' response:

The reviewer suggested that refrigeration and ability to store fish may have played a role in the amount of fish that was caught. We also discussed this point with Gerry Davis during the data workshop in August 2005. While we acknowledge that these factors may influence the amount of fish that can be stored from any one fishing trip, and thus influence the amount caught per trip, we are not convinced that it would result in a fundamental change in the total amount of fish a person (or family) catches for eating on an annual basis. Note that we consider this point here only with respect to non-commercial catches, and acknowledge that refrigeration has a substantial influence on commercial operations. However, this would be reflected in the reported commercial data, thus would not need to be additionally addressed by the reconstruction. We do appreciate that access to refrigeration may indeed change temporal non-commercial effort distribution, but fail to see how it would influence annual non-commercial catches.

Reviewer's comment:

3. DAWR used to call the mayors of villages and conduct surveys during seasonal runs (i.e. big-eye scad) in the 1980's and 1990's to obtain information on harvest. Because this is not conducted anymore, there may be an illusion of a collapse when in actuality it is an artificial collapse.

Authors' response:

The reviewer pointed out that DAWR used to survey village mayors during seasonal runs (e.g., big-eye scad) to obtain catch information, but this is no longer done. Thus, the decline in scad catches observed in the data in the last few years may be an artefact of changed sampling. We appreciate this point being drawn to our attention, and have incorporated this information in the final report. Nevertheless, based on the data available to us, scad catches appeared to have declined most in the early-mid 1980s, i.e., during a time when the village surveys were still being conducted.

Reviewer's comment:

4. Authors should be acknowledged for all DAWR reports instead of listing them as anonymous. Credit needs to be given to those individuals who wrote the reports.

Authors' response:

The issue of DAWR reports being cited as "Anonymous" is being raised. The material we were able to obtain from the local contacts unfortunately did not permit authors to be identified for many of the earlier reports, despite numerous attempts to obtain this information. During the data workshop, Gerry Davis kindly offered to obtain this information, with assistance from Jay Gutierrez. We have received updated reference details for two reports, but the remainder was not identifiable. Thus, we had no option but to continue citing these reports as "Anonymous".

Reviewer's comment:

5. There are other annual reports written by DAWR staff then what is listed in your document. These should probably be obtained as well.

Authors' response:

We are not aware of any other relevant reports, although we have examined several that were deemed not useful for our purposes. Repeated attempts to obtain other annual reports were unsuccessful.

Mike Trianni (CNMI)

[Page numbers refer to March 2005 report version]

Reviewer's comment:

Page 3.

"For the Commonwealth of the Northern Mariana Islands (CNMI; Section 3.3), the reconstructed catches indicated a decline of about 48% in catches between 1950 and 2002. Comparing the officially reported non-pelagic catches with the reconstructed catches, indicated a 3 fold under-representation of catches by the officially reported data, compared to the reconstructed totals."

This statement really only refers to the Southern Islands of Saipan, Tinian, and Rota, and most probably only Saipan and Tinian, and even then the lee aspects of those islands. It should be qualified as such, especially as this is part of the introduction of a document that covers a number of different areas, and the reader may not be interested in a comprehensive perusal of the document.

Authors' response:

The reviewer suggested that the executive summary statement about CNMI should only apply to the main islands of Saipan and Tinian. We disagree, as the reported commercial data account for other areas through an adjustment factor for both underreporting on the main islands and non-recorded catches for the other islands (D. Hamm, WPacFIN, pers. comm.), and the non-commercial reconstructed data are focused on *per capita* catches, thus reflecting human population density and use patterns holistically, although not spatially. Hence, the summary statement applies to CNMI in total. As this report is about catches, and not stock status (where we agree that main islands differ probably substantially from other islands), we feel that our summary applies CNMI wide in terms of holistic catch patterns.

Reviewer's comment:

Page 39. First Paragraph. The description of the CNMI does not mention the West Mariana Ridge (WMR), which is one of the three geologic arcs of the CNMI.

Authors' response:

The WMR was added to the description of CNMI.

Reviewer's comment:

Second Paragraph. To quote Magnunson-Stevens:

"The Magnuson-Stevens Act defines the terms 'overfishing' and 'overfished' to mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield (MSY) on a continuing basis." The question here then becomes: what is the consideration of the spatial extent of the fisheries in the CNMI that are deemed to be experiencing 'overfishing'? In the context of reef fisheries, it is most likely that the food fish being harvested on a local basis are genetically similar over a wide range, e.g. the Southern Islands, the entire CNMI. As comprehensive genetic analyses of the coral reef food finfish in the CNMI have yet to be realized (such studies are in fact incomplete for the vast majority of fisheries worldwide), the definite use of the work 'overfishing', or 'overfished' for coral reef finfish fisheries in the CNMI is hasty. In relation to the author's use of the word 'overfishing' on this page, I believe the concerns expressed by Graham (1994) and Trianni (1998) were taken out of context. Those report(s) explicitly note the decreases of both CPUE between fishing zones and time periods in the Southern Islands (SI), and size/length between SI fishing zones and time periods, and also between SI and Northern Islands (NI). But, both reports point out, in the very same paragraphs where 'overfishing' was mentioned, the limitations of the data and potential impacts of other variables on the results presented. The concept of 'overfishing' is a rather different condition that implies the target species of a fishery are approaching a critical biological threshold. In contrast, the fisheries addressed by Graham (1994) and Trianni (1998) focused on harvest in the SI, and then on only two of four islands, and none of the associated banks/reefs near the islands, or those ~20 miles to the W, NW, and N. Although concern about local depletion was paramount apprehension with regard to species approaching a critical biological threshold was not.

Authors' response:

Concerns were expressed about use of the terms 'overfished' and 'overfishing', which in the original draft version (March 2005) were used in the international, academic definition, rather then the more strictly defined U.S. legal definition. The reviewer's concern was in line with general comments expressed by members of the data workshop and was revised in the final report. Broad consensus was expressed during this workshop to avoid the terms 'overfished' and 'overfishing', as it has a distinct legal definition in U.S. fisheries law. Thus, throughout the document, this term was replaced with 'very heavy fishing' or 'excessive fishing', unless a clear literature references specifically referred to 'overfishing' in line with U.S. definition.

Reviewer's comment:

Third Paragraph. It is not clear that all indigenous fishing during the Japanese period was restricted to within the reef, as Carolinian canoes were probably present during that era, and these people caught and consumed pelagic fish. Nor is it clear that there was an indigenous "preference" for reef fish.

Authors' response:

The reviewer expressed uncertainty about the literature citation of Radtke and Davis (1995), suggesting that during the Japanese occupation of CNMI, local populations were essentially limited to near-shore fishing. We appreciate this comment, it would make for an interesting anthropological, archaeological and historical research topic. However, with regards to our catch reconstruction, this aspect is peripheral, as we substantially reduced the literature cited *per capita* catch rate for non-commercial catches for 1950. Thus, what limited catches of non-reef and non-bottom species might have been taken by Carolinian canoes would readily be accounted for by the reduced catch rates used.

Reviewer's comment:

Page 40. Second paragraph. The statement, taken from Executive Summary of Green (1997), and re-quoted by Zeller et al. as "...suggested that to this day many of the offshore reefs within the EEZ receive relatively little fishing pressure, since most local fishers do not like to venture far from shore". The Green (1997) report failed to capture the context of the fishing grounds in question. I have attached a map to try and help correct this misperception. The following banks are fished on a regular basis; Rota Banks, Esmeralda Banks, Dump Coke, 300 Reef, Goat Island Reef, Tatsumi Reef, Marpi Reef and Malakis Reef. Other banks/reefs/islands such as Pakapaka, Peligro, Farallon de Medinilla (FDM), White Tuna, ESE Reef, Sonome Reef, Anatahan, Sarigan, Anarigan, Zealandia and Isor, are all visited as weather permits. Access to FDM is also limited during military training exercises. Only the larger CNMI commercial fishing vessels visit the islands and banks along the main island chain from Guguan north, although a Community Demonstration Project in the form of a 'Remote Fishing Station' has recently begun operations at Alamagan, where shore based artisinal-type harvest will occur. The only banks/reefs that are typically not accessed by CNMI fishermen include those of the WMR; Arakane, Pathfinder, Bank A, etc., which are at least 100 miles from the main island chains. To state "most local fishers do not like to venture far from shore" is an uninformed discredit to the advanced sea-going experience of most CNMI fishermen.

Authors' response:

We have corrected our statement regarding offshore fishing in CNMI.

Reviewer's comment:

Page 41 Approach and Methods.

Landings of bottom fish have oscillated considerably over time, coincident with success and failures of the NI bottom fishery. If landings are small relative to pelagic and reef fisheries, their value is high.

Authors' response:

We have modified this section to better reflect the changes in the bottom fisheries.

Reviewer's comment:

Page 42. Data Sources and reconstruction

Non-commercial

What is the source of the lack of subsistence pelagic fishing following WWII, other than Smith (1947). Were local fishermen interviewed?

Authors' response:

Local fishermen were not interviewed, as time-limits and resources did not permit this. Furthermore, such an approach, while very useful, needs to be undertaken by researchers highly trained in anthropological fisheries science, which are in a better position to establish the trust of local communities and fishers, and interpret short- and long-term memory information. This was beyond the scope, design and outline of the present project, but should be considered by local agencies.

Reviewer's comment:

Page 43. *1950-1983*. The interpolation based on the 0.2 kg per day figure does not appear to take into account any variation in food-type consumption preferences/tendencies over time, nor does it appear to take into account any changes in fishing, as the pelagic sector would have grown during this time period. Are the authors assuming that all non-commercial fishing during this time period was for reef fish?

Authors' response:

Changes over time from 1950 to 1983 were accounted for indirectly via a) using a catch rate over 50% smaller than published consumption rate, and b) by interpolating this 1950 anchor point to the 1983 data. This last point also accounts for increasing use of pelagic species over time.

Reviewer's comment:

Results Page 45

Non-commercial catches. The second paragraph appears to make a strong statement about a significant decline in reef fisheries catches, irrespective of the fact that such a specific decline was arrived at in a less than formal manner. Does Figure 3.3.3 refer to reef fish only, or is it a composite of all fisheries in the CNMI?

Authors' response:

All figures refer to non-pelagics only. Throughout the report, 'pelagics' are defined as large tuna and billfish species. In contrast, reef-associated pelagics, such as carangids and mackerels are included in our reconstruction. Our statement about likely decline in catches is clearly based on our reconstruction, with all inherent and presented assumptions and caveats. To further reduce misunderstanding, we have increased the cautionary wording throughout the report.

Reviewer's comment:

Page 46. It is unclear how the authors arrived at the conclusion that reef fisheries in the entire CNMI have declined from 10.1 to 5.5 tons per kilometer square? In fact, it is unclear how the stated decline for only the Southern Islands can be substantiated. It is probably appropriate, to mitigate these conclusions to the spatial extent of Saipan, and perhaps Tinian.

Authors' response:

The suggested decline in area catch rates is simply based on the reconstructed data. As indicated in the report, much of the catches are taken in the vicinity of the main islands, or at least in southern waters.

Reviewer's comment:

Although the population growth of the CNMI has increased rapidly over the past 25 years, this report does not to take into account that the local population has remained fairly constant over that time. Also, the report does not consider what exactly the composition of that total population number is, especially since that number was used to determine the steep decline in reef fish landings over time, and what their food preferences/consumption rates were/are.

Authors' response:

The reviewer's concern about misuse of the human population growth is unwarranted, as we did not use population size to estimate catches during the latter part of the time series, only in the early years, during which numbers of so-called 'non-locales' were low.

Reviewer's comment:

The report is a gross back-calculation of fisheries landings over time implied from a constant historical consumption rate and available commercial data. Although the report points out various shortcomings with regard to the CNMI DFW data collection protocol, the authors draw strong conclusions based on that data. The report would have benefited from an onsite visit by one of the authors to meet with local natural resource managers and fishermen.

Authors' response:

The reviewer's statement is not correct, as our approach does not use a 'constant historical consumption rate', as we only use such rates at the anchor point year, and then interpolated between anchor points. While we accept the criticism of lack of on-site visit, the mandate of this project did not envisage this. However, we hope that the present report may serve as sufficient impetus for Council, or local agencies, to consider an in-depth historical catch reconstruction as a major, longer-term project to derive a better baseline for CNMI. Such endeavours should be undertaken by local researchers, or personnel with long-standing contacts in the islands. Similar sentiments were expressed by others, e.g., Kimberley Lowe for Hawaii, who has initiated her own investigation into historical catches for Hawaii, early results of which have contributed significantly to this report (see Hawaii section).

K. Lowe (Hawaii)

Reviewer's comment:

Overview:

This report presents a broad brush approach to developing much needed inshore ("coral reef") fisheries time series data long known to be incomplete or missing for American Samoa, Guam, the Commonwealth of the Northern Marianas Islands, Hawaii and other Pacific island states, nations, archipelagos and atolls associated with the United States of America. The non-commercial element of fisheries in these regions is known to be substantial yet, as is seen throughout the world, has been monitored sporadically at best in most cases. Commercial fisheries have been monitored more consistently, but data are incomplete and the further back one goes, the less detail is available regarding species composition or fishing effort.

Using limited sources they were able to locate in the time available, the authors made an attempt to "reconstruct" total catch for these fisheries. Their sources include:

Officially reported catch statistics ("official statistics"), based on commercial catch reports from fishers or other government/industry sectors;

Economic, ecological and fisheries reports, including a few literature-based estimates of the ratio of commercial to total or recreational/subsistence catch in one area or another;

Catch estimates from a few active fishing surveys with varying methodology and target fishery sectors (intercept vs. roving surveys; shoreline, coastal vs. near-shore pelagic fisheries; variable proportions of commercial, recreational and subsistence fishers; surveys conducted at different times of day, in different habitats, etc.).

Their overall method was to create a loosely connected series of "anchor points", based on the sum of estimated commercial and non-commercial data, and fit a total catch curve through these reference points. The estimates of commercial and non-commercial catch were developed using a different set of assumptions for each area and time frame according to data sources and commercial-to-noncommercial catch proportions referenced from the literature. In this manner, they filled in gaps in official statistics to the extent possible, using as few as three (3) anchor points over a 50-year time series.

To their credit, the authors acknowledge the limitations of their approach, which cannot be relied upon for detail, but which provides a useful indication as to where a more in-depth analysis of inshore fisheries might be needed. The limitations and assumptions are described sincerely throughout the report, each with its advantages and pitfalls. However, they do not provide in-depth information about the limitations and assumptions of the references used to develop anchor points. This is a crucial oversight, because the choice of anchor points in many ways determines overall trends in their outcome, leading to findings, which are described with more apparent certainty than is warranted.

Based on this constructed data set, the authors interpret a significant decline in inshore fisheries for each region and the US-associated "Western" Pacific as a whole. Although such decline may exist, the analysis performed does not prove it. Although analyses of the data constructed using these calculations provides a useful perspective and insight into broad trends in Pacific inshore fisheries, the limitations and assumptions upon which these insights are based must be kept in perspective to avoid the pitfalls of ascribing an unwarranted precision to their interpretation or extrapolating these findings to a level of ecological detail not supported by their methods. The report represents a valuable contribution to Pacific fisheries literature, providing a good faith effort at summarizing and synthesizing published and unpublished reports, historical records and such for each region. To improve on such analyses, local expertise is needed.

Authors' response:

We thank the reviewer for her concise summary and perceptive interpretation of our approach and rationale for undertaking this work. We accept the reviewer's concerns about us expressing excessive certainty in our results in the earlier draft version of this report. We have endeavored to substantially reduce this emphasis while increasing our emphasis on the uncertainty associated with this analysis. We strongly support the reviewer's comments regarding the need for local expertise to take on the task to build on and improve on our initial estimates.

Reviewer's comment:

Comments for Hawaii:

Looking at Hawaii data, more specific observations can be made. The importance of the anchor points to the whole analyses warrants a more intensive effort to develop these points as accurately and completely as possible. The effort needed to develop a larger number of anchor points is also worth the investment. Most fisheries studies that have been conducted for Hawaii have made an effort to determine what proportion of the total catch is represented by commercial fisheries data. Other anchor point references can be found.

The authors provide a good review of available literature, however a review of the causes of temporal differences in the estimated proportion of commercial to non-commercial catch from the literature cited is not provided. A more in-depth look at references cited indicates significant differences in the mean and variance around selected anchor points. For example, Hamm and Lum (1992) and Everson (1995) estimate total harvest for the tako (octopus) fishery in Kāne'ohe Bay at 21,000-34,000. The mean from 1990-1993 ≈ 27,072 lbs checks fairly well between studies and Everson's work indicates his estimates were higher because the small boat survey sampling period was gauged at such a time as to miss many of the tako fishers, who left and returned before sunrise when the small boat survey started. Regardless, Hamm and Lum's underestimated value of 106,116 lbs for the whole island of Oahu (1990 only), when compared to Smith's (1993) statewide reported commercial total of 12,800 lbs, indicates that total reported commercial landings for the state were underrepresented by well over 8:1 (probably a lot more, considering the abundance of tako resources on Maui and other islands). This comparison brings some of the differences affecting survey outcome, depending on the fisheries targeted by each survey.

Not only could more anchor points be available, but there are significant differences in the reliability of the anchor points chosen. Differences in the basis for one author versus another's assessment of the ratio of commercial to total catch, or recreational/subsistence to commercial, used to establish "anchor points" around which to interpolate other data are not described. This is an important concern, because throughout Hawaii's fisheries literature there are references to a wide range of ratios for these values. A critical analysis of this information would have provided a more solid basis for interpreting the reliability of one anchor point versus another, which in turn would help put the validity of overall trends into perspective. For example the 1986 anchor point is based in part on the Meyer Resources small boat study (cited as Anonymous, 1987b), which was limited in fishery sector, temporal and geographic scope (detecting a portion of the fishery), but is bolstered with other survey consumer and market data from different sources. Everson's (1992, 1995) fishing survey was conducted in actual coral reef habitat in Kāne'ohe Bay, but was not used. The 2002 anchor point appears to be based on a simple statement (Friedlander, 1996) that recreational catches were "at least equal to or larger than the reported commercial landings". It is doubtful that Friedlander made such an assertion in any quantitative sense.

Recreational/subsistence fishers today outnumber commercial fishers by at least 20:1. I do not make this statement thinking someone will multiply the commercial catch by a factor of 20. There are so many differences between the target species and fishing effort of these sectors and not all fishers within a given sector catch or fish in the same manner. These statements are made to say that bias could contribute significantly to the perceived decline in catch after the 1980s? The intricacies of these considerations merit more than a cursory examination.

Looking a little more in-depth at the series of extrapolations and conversions producing the 1986 anchor point, the authors describe using data from the Hilo shoreline fish catch survey (Kahiapo and Smith, 1994). They use data from the Keaukaha shoreline, a lava rock fishery with limited reef habitat frequented by various spear and net fishermen (gill and throw netting to the extent possible from the rocks into a dangerously pounding surf), extrapolating this catch to the majority of shoreline in the state. Underwater surveys of the Keaukaha Shoreline show a unique mixture of goatfishes, surgeonfishes, carangids, small pelagics and a few other species not typical in diversity, relative abundance or density to most of Hawaii. Fishers at Keaukaha are equally remarkable for their tenacity (diving into the surf with spear or net), scheduling (odd times of day, not all surveyed due to dangers and drug use), and numbers (Hilo is a sparsely populated area). Data from this unique arc have been extrapolated by the authors to all the fishers estimated by the National Survey of Fishing, Hunting and Wildlife-Associated Recreation (Anonymous, 1998b and 2001), and smoothed based on a 1985 estimate of boat to shore fishers (Anonymous, 1987a), then culled by 55% thought to be attributable to non-pelagic species not mentioned in the Hilo survey. At the end of the calculations, the relationship between the original data and the interpolated catch estimate is speculative at best.

Although the authors provide an in-depth description of the limitations and assumptions of their own analyses, such information is not provided for most of the references cited. Thus, although the description of status of near-shore and coral reef fisheries and ecosystems is based on different subsets of commercial fish catch data (Shomura, 1987; Pooley, 1993; Smith, 1993), fishery-wide surveys across sectors (Everson, 1994, Kahiapo and Smith, 1994; Friedlander and Parrish, 1997), whole-ecosystem transects including exploited and unexploited stocks (Friedlander, 1996; Gulko, et al., 2002); and surveys of targeted sectors of fisheries (Anonymous, 1987b, Hamm and Lum, 1992), the authors do not mention these differences.

The discussion of species groups is as generalized as the overall approach. For example, species composition of Hawaii commercial fish catch data was summarized from gross totals, then a percentage applied to get estimates of family proportions (Fig. 3.4.4). This transpired, despite the fact these data are provided by species (or species groups) to DAR. The DAR data used to produce both sources (conglomerates and family proportions) would have provided considerably more detail. In short, although reported commercial data are incomplete, they tell us a lot more about species composition, distribution, catch rates, etc. than this report. True collaboration, requiring more time and effort, could produce a more useful product. It is encouraging to see that such collaboration is being contemplated.

The treatment of inshore fisheries habitat as homogeneous throughout the report is similarly broad brush, leading to a discussion of all inshore fisheries as "coral reef fisheries", despite the preference of different fish groups for different habitats.

Some of the fish groups, such as goatfishes and mullet clearly prefer soft bottom habitat. Parrotfishes inhabit the reef part of the time, except during their nightly foraging activity. None of the complexity of coral reefs and inshore habitats is addressed. In fairness, this may not have been feasible, based on the limited time and scope dedicated to this effort. There is nothing wrong with this, as long as it is understood that everything is lumped into broad categories. From a local perspective, it is not clear what bottomfish (deep slope snappers, carangids and groupers) and seamount species are doing in a discussion of coral reef fisheries. Looking at the poor fit of this discussion to Hawaii's coral reef fisheries from a local perspective, the fit for other Pacific island areas may be equally loose.

Authors' response:

The primary comment made by the reviewer, also re-iterated by her during the data workshop in August 2005, related to the need to improve the anchor points for Hawaii's catches. With respect to this concern, the reviewer offered to assist us and use her local expertise to review available reports and publications, and form a set of anchor points to assist in deriving more representative estimates for Hawaii's catches. Her excellent effort resulted in the formation of two sets of ratio estimators spanning 1950 to 2002, one to obtain total commercial catch from reported catch (thus adjusting reported commercial catches for underreporting of commercial catches), and the second estimating total catches based on reported commercial catches. These ratios were linearly interpolated for intervening years and used to derive total commercial catches, non-commercial catches and total catches, all based on reported commercial catches. Thus, the entire data section for Hawaii was substantially revised and modified, and is now more comprehensively in line with local expert knowledge.

The reviewer's concern about the poor taxonomic breakdown of the commercial data used in the draft report has also been expressed by others during the workshop in August 2005. This problem has been addressed with the help of D. Hamm (WPacFIN), who provided the HDAR commercial catch data by taxon, summarized by MHI and NWHI only. By eliminating statistical reporting areas (which were included in the draft version data set), we were able to eliminate confidentiality problems of data, and were able to utilise more detailed taxonomic accounting.

With regards to the reviewer's comment about why bottomfish were included in catch reconstruction of coral reef fisheries. From the outset, this project was designed to cover everything except the large pelagic species (not just 'coral reef fish'). In this regards our initial title for the report was slightly misleading. Furthermore, given that many shallow water reef families are also the same families as the deeper water bottom species (e.g., Lutjanidae, Serranidae), and the likelihood of much information potentially being only at the family level, suggested that we should include the bottomfish species in this report.

Reviewer's comment:

Conclusions

The caution should be made not to generalize these results outside the context in which they are presented. The report is well written and allows one to get a different perspective on local fisheries. It does not pretend to provide a comprehensive assessment. The authors should be commended for their effort and honesty, and many of their general conclusions are supported to a certain extent by local knowledge. But when it comes to assessment, caution should be used in interpreting the findings. Data used are not limited to reef fisheries and are not consistent across yearly assessments. This is fine, because local fishers are concerned about inshore fisheries, not just coral reef fisheries. But let's keep this in perspective.

Although the findings are easily over-generalized, one can get the truth from this report. It indicates a decrease in fish catch, but doesn't give an index of depletion. Population growth suggests a likelihood of declining catch rates, but it clearly states much remains undocumented (changing eating patterns, increased/decreased import/exportation of seafood, etc.). The report does not say inshore fish resources declined 78%; it talks about catches. It does not pretend to provide an assessment, nor does it address catch rates. It gives no indication whether or how much fishing effort or CPUE has declined. Caution should be applied in quoting the estimated 78% decline, given that the greatest weakness in the data lies in the forced fit to the decreasing catch region of the curve (the 2002 "anchor point").

Fishers and researchers in the main Hawaiian Islands indicate the need to rebuild ecosystems and fish stocks, but existing reports are as reliable (or more) as the present estimate for Hawaii. What the report clearly indicates is a need for improved monitoring of Hawaii's fisheries, and it points toward methods that might be used to develop better estimates from available data. Local researchers who have access to more complete information and time to delve more fully into geographic and temporal variability should follow up on these insights, but a collaboration could be even more fruitful.

Authors' response:

We concur with the reviewer's assessment. We also note that due to the substantial change in data for Hawaii between the earlier draft version and the present final version, the associated conclusions have also changed from the earlier draft version.