Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years

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Abstract—Nearshore fisheries in the tropical Pacific play an important role, both culturally and as a reliable source of food security, but often remain under-reported in statistics, leading to undervaluation of their importance to communities. We re-estimated nonpelagic catches for Guam and the Commonwealth of the Northern Mariana Islands (CNMI), and summarize previous work for American Samoa for 1950–2002. For all islands combined, catches declined by 77%, contrasting with increasing trends indicated by reported data. For individual island entities, re-estimation suggested declines of 86%, 54%, and 79% for Guam, CNMI, and American Samoa, respectively. Except for Guam, reported data primarily represented commercial catches, and hence under-represented contributions by subsistence and recreational fisheries. Guam's consistent use of creel surveys for data collection resulted in the most reliable reported catches for any of the islands considered. Our re-estimation makes the scale of under-reporting of total catches evident, and provides valuable baselines of likely historic patterns in fisheries catches.

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Small-scale nearshore fisheries in the tropical Pacific are of fundamental importance for subsistence, social and cultural purposes, in addition to providing food, trade, and recreational resources (e.g., Dalzell et al., 1996). These fisheries commonly play a vital role in providing a secure supply of protein on many Pacific Islands. Yet, catches for the small-scale fisheries in these islands are typically not estimated by the fisheries agencies. This lack of data on estimated catch applies especially to the non-commercial sectors (e.g., subsistence and recreational) and is generally justified by real or perceived difficulties and costs associated with quantification of these very spatially dispersed fisheries. Hence, extractions of these marine resources are usually underestimated in official statistics, as are their economic and social importance (Zeller et al., 2006b).

An approach to retroactively estimate catches in cases where reliable time series data are lacking applies a "re-estimation" approach to approximate historic catch time series (Zeller et al., 2006a). Such an approach typically requires subjective inferences and interpolations. This approach is justified, despite data uncertainties, given the less acceptable alternative outcome, namely that subsequent users of the available data will interpret nonreported or missing data as zero catches.

Without accounting for total catches from all sectors, it is not possible to obtain any comprehensive measure of the formal and informal economic value of these resources, or of the risks excessive fishing may represent to an island entity. The lack of these two measures is of concern, given that human population growth rates in many Pacific island countries are high and natural resources in these islands are limited. Furthermore, the growing shift from predominantly subsistence to market-based cash-oriented economies, as well as increasing development since World War II, has contributed to declines in coastal marine resources. Although localized overfishing may be responsible for some of these observed declines, anthropogenic factors such as coastal development, pollution, and poor watershed management have likely also contributed to the degradation and reduction of coastal habitat and in the productivity of the resource (Friedlander and DeMartini, 2002).

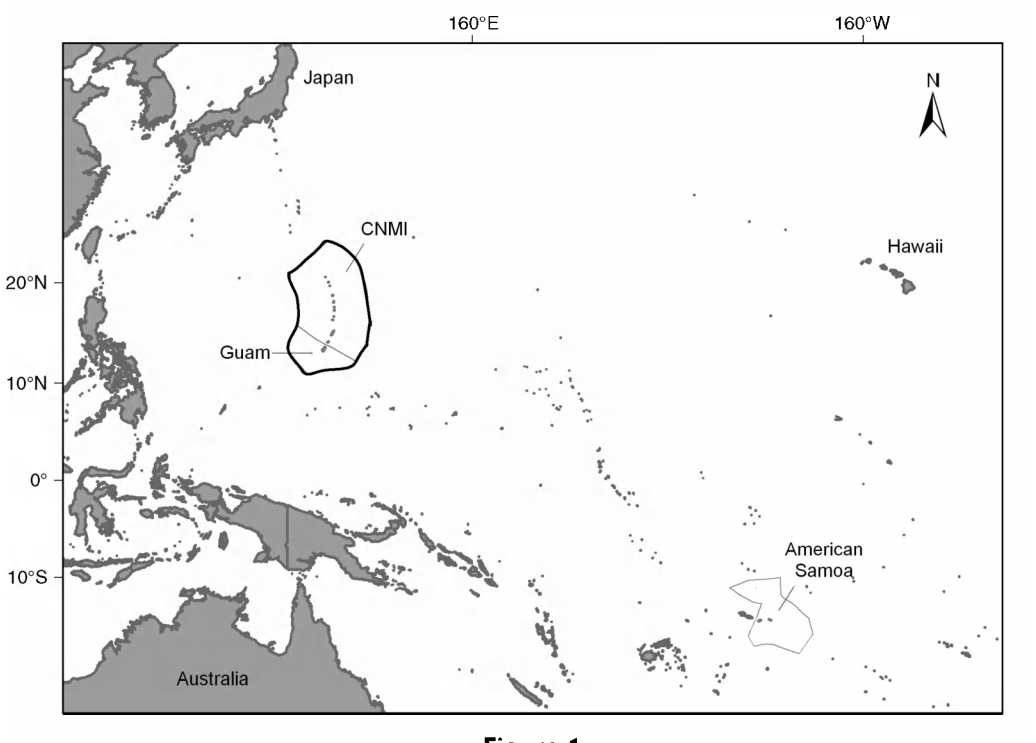

Figure 1

Location and Exclusive Economic Zones (areas outlined) of the major U.S. flag-associated island areas in the western Pacific covered in this study: Guam, Commonwealth of the Northern Mariana Islands (CNMI), and American Samoa. The Pacific Remote Island Areas (minor islands) also under U.S. flag jurisdiction are excluded from present consideration (Zeller et al.[3]). Map courtesy of A. Kitchingman and C. H. Close, *Sea Around Us* Project, Fisheries Centre, University of British Columbia.

This is particularly true close to human population centers on main islands, whereas the status of stocks in more remote areas is generally better. Obviously, places that have not experienced widespread development may still suffer stock declines because overfishing alone can deplete fishery resources on coral reefs.

The U.S. National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA-NMFS), through its Western Pacific Fishery Information Network (WPacFIN[1]), provides data collection, assimilation, and technical reporting support to U.S. flag-associated island areas in the Pacific (Fig. 1). The coverage of this electronic information source only dates back to the early 1980s and differs between islands. There is near-complete coverage for some areas, such as Guam, and very limited coverage for others, such as Commonwealth of the Northern Mariana Islands (CNMI). For the U.S. western Pacific region, this centralized data depository is largely the result of the development of WPacFIN programs in each of the island areas in the early 1980s. All the islands considered here have few legislative requirements for reporting of catches; however, some, such as American Samoa, have instituted legal mandates that require the number of fish sold be reported. Generally, the focus of reported data has been primarily on commercial harvests (e.g., the small-boat based fisheries of American Samoa) and have not covered other sectors, such as the shore-based fisheries (Zeller et al., 2006a).

However, many small-scale studies have been undertaken to assess these missing sectors, reporting local catches or catch rates for specific periods, locations, or gear types (e.g., Craig et al., 1997). Such data sources can form the foundation for deriving catches, catch rates per unit of area, or per capita catch rates during a given time interval for these sectors of the fishery. These time-point estimates provide anchor points of concrete data upon which total catch estimates can be based. Once all such data have been extracted from their disparate sources, interpolations can be employed to fill in the periods for which quantitative data are missing. Thus, the key aspect of the approach used here is psychological, and managers have to overcome the notion that no information is available, which is not only an incorrect assumption when dealing with fisheries but a profoundly misleading one

[1] Western Pacific Fishery Information Network (WPacFIN). NOAA-National Marine Fisheries Service, Pacific Islands Fisheries Science Center, 2570 Dole Street, Honolulu, 96822–2396. Website: http://www.pifsc.noaa.gov/wpacfin (accessed 1 November 2005).

(Pauly[2]). Here, we report on work undertaken for the U.S. Western Pacific Regional Fishery Management Council to account for unreported catches (Zeller et al.[3]).

Island areas

Guam Guam (13°28′N, 144°45′E) is the southernmost island in the Mariana Archipelago (Fig. 1), and has a potential coral reef ecosystem habitat area to 100 fathom (183 m) depth, within an Exclusive Economic Zone (EEZ), of approximately 276 km^2 (including offshore banks). Of this area, 202.8 km^2 are associated with the island of Guam directly (Rohmann et al., 2005). Guam's coral reef fisheries are both economically and culturally important and have been historically significant in the diet of the human population (Hensley and Sherwood, 1993). Limitations were placed on the indigenous population with regards to any large-scale fisheries development during the Japanese occupation period (Smith[4]). These limitations, together with the destruction of the Japanese fishing infrastructure at the end of WWII, resulted in a heavy reliance on subsistence fisheries in Guam into the late 1940s. The near-shore coral reefs around Guam are considered heavily fished and degraded, and concerns about overfishing were raised as early as 1970 (Hensley and Sherwood, 1993). Most of the less accessible offshore banks, however, appear to be in better condition.

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). Because there are few full-time commercial fishermen, there is little distinction between commercial, subsistence, and recreational fishing, and many fishing trips contribute to all three segments. In the past, tidal fish-weirs were used in Guam, although their numbers declined over the decades, and the use of weirs ceased in 1989.

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: a marina-based boat-centered creel survey (offshore survey), and a shore-based creel survey (inshore survey). The reporting of fish weir catches was mandated as part of weir-operating permits but the data were likely incomplete. Various expansion methods have been applied in the past to raise the creel survey data to island-wide catch estimates, but these have been standardized since the mid-1980s in collaboration with WPacFIN. However, specifics of the method and thoroughness of a survey, of data handling, and of analyses have varied during the earlier periods. Since the early 1980s, these survey data have been reported through WPacFIN, and are the most comprehensive series of catch estimates used in the present study.

Commonwealth of the Northern Mariana Islands (CNMI) The Commonwealth of the Northern Mariana Islands (CNMI, Fig. 1) consists of a 680 km chain of 14 volcanic islands, extending northward from Rota (14°9′N, 145°12′E) to Farallon De Pajaros (20°32′N, 144°54′E). Over 99% of the human population (69,000 in 2000) is concentrated on the three southern main islands of Saipan, Tinian, and Rota. The population has increased rapidly since the 1980s, driven by fewer restrictions on immigration and by the prosperity from the main industries—tourism and garment manufacturing.

CNMI are a group of islands with fringing reefs (surrounding most islands) and offshore coral reef banks and ridges. The conditions of local reefs vary; heavy fishing pressure is considered a problem for the sustainability of the reefs on the main islands, particularly the island of Saipan, because of its large population and more extensive coastal development.

Following WWII and the expulsion of the active Japanese fisheries, subsistence fisheries again dominated the catch. Because of the loss of most Japanese fishing vessels, and decades of Japanese restrictions on indigenous fishing outside local reefs, early subsistence catches were focused on near-shore and lagoon-based resources. Subsistence fishing for near-shore resources was an important daily activity for the local population well into the 1970s, whereas commercial and recreational fleet developments did not start until the 1960s, and westernized economic development did not accelerate until the 1970s and 1980s. The local economic boom starting in the late 1980s, driven by tourism and garment manufacturing, did not result in significant growth of the commercial fisheries sector. Thus, the local fishing industry supplied only a small part of the total seafood demand in the 1990s, and imports accounted for a growing part of the supply. Growth in recreational fisheries came instead with increased westernization of the economy which, combined with increased availability of boats, blurred the boundaries between subsistence and recreational fishing. Thus, each fishing trip today may have commercial and subsistence, as well as recreational aspects.

The Division of Fish and Wildlife (DFW) for CNMI conducted a data collection system for commercial catches since the mid-1970s but reported data have only been available since the early 1980s through WPacFIN. The estimated commercial landings in Saipan are based on a voluntary dealer purchase receipt collection system and are adjusted by WPacFIN for the remainder of CNMI. The noncommercial sector (subsistence and

[2] Pauly, D. 1998. Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11:4–10.

[3] Zeller, D., S. Booth, and D. Pauly. 2005. Reconstruction of coral reef- and bottom-fisheries catches for U.S. flag island areas in the Western Pacific, 1950 to 2002. Western Pacific Regional Fishery Management Council, 1164 Bishop St., Suite 1400, Honolulu, HI 96813. Website: http://www.wpcouncil.org/bottomfish.htm (accessed 17 October 2006).

[4] 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, 1849 C Street, NW, Washington, DC 20240, 105 p.

recreational fishing) has been subject to limited monitoring since 1984 and day-time creel surveys have been undertaken for the Saipan lagoon only. However, these data have not been analyzed or expanded for estimation of CNMI-wide noncommercial catches and were not available to us.

American Samoa American Samoa is the only U.S. territory south of the equator (14°20′S, 170°W, Fig. 1), and its small-scale fisheries consist of shore-based and boat-based sectors (Zeller et al., 2006a). A clear separation between commercial and noncommercial aspects in each fishery is difficult because fish from either sector can be sold or retained for personal consumption (Craig et al., 1993). The existing catch data on the predominantly commercial boat-based sector by the American Samoa Department of Marine and Wildlife Resources (DMWR) has been reported through WPacFIN since the early 1980s. The noncommercial sector, especially as relating to shore-based fisheries, is not monitored and catches are not reported on a regular basis. However, a short-lived DMWR survey of shore-based fisheries, as well as other local studies, was conducted sporadically on this sector between 1980 and 2002. Recently, total nonpelagic fisheries catches for both sectors were re-estimated back to 1950 by Zeller et al. (2006a), and these findings will be relied upon in the present study.

Aims

The purpose of our study was to assemble available information and data on catches of the small-scale, near-shore fisheries for nonpelagic species of the major U.S. flag-associated island areas in the western Pacific for 1950–2002, namely Guam, the Commonwealth of the Northern Mariana Islands (CNMI), and, in summary form, for the previously estimated catches for American Samoa (Zeller et al., 2006a). Although American Samoa's catches were published separately (Zeller et al., 2006a), they are summarized in the present study for completeness. The U.S. State of Hawaii was excluded from present considerations because the economic, social and noncommercial fishery conditions and data differed substantially from those of the other islands, and required a different method for reconstructing the data. Also excluded was the information available for the limited (predominantly recreational) catches taken on the Pacific Remote Island Areas (PRIAs or minor islands) reported on elsewhere (Zeller et al.[3]). The aim was to derive estimates of likely total removal of marine resources for the 1950–2002 period. The present re-estimation excludes pelagic species (i.e., tunas and billfishes) that are the target of large-scale fisheries, even if these species are also caught by small-scale, local sectors. Small-scale fisheries in our study targeted both deeper water species (such as lutjanids, lethrinids, and serranids), as well as coastal, reef-associated small pelagic species (such as carangids, including the culturally important big-eye scad [*Selar crumenophthalmus*]).

Materials and methods

The catch re-estimation approach utilized here consists of six general steps based on work done for the Western Pacific Regional Fishery Management Council (Zeller et al.[3]) and Zeller et al. (2006a):

1 Identification of existing reported catch times series, e.g., local reports, and data presented by the Western Pacific Fishery Information Network (WPacFIN[1]) on behalf of local agencies;
2 Identification of sectors, time periods, species, gears, etc. not covered by (1), i.e., missing catch data, via literature searches and consultations;
3 Search for available alternative information sources to supply the missing catch data in (2), through extensive literature searches and consultations with local experts;
4 Development of data anchor points in time for missing data items, and their expansion to island- or country-wide catch estimates;
5 Interpolation for time periods between data anchor points for total catch, generally with per capita catch rates; and
6 Estimation of final total catch times series estimates for total catch, combining reported catches (1) and interpolated, island-expanded missing data series (5).

Island areas differed in terms of fisheries sectors, their coverage of reported data, and available alternative information. Details of available alternative information sources for each island area, all reference material for data sources used (non-refereed publications), and the specifics of data anchor point estimation can be found in a report to the U.S. Western Pacific Regional Fishery Management Council (Zeller et al.[3]).

Guam

Catches for both boat- and shore-based fisheries sectors have been estimated by DAWR since the mid-1960s through the use of two creel surveys (offshore survey and inshore survey). In the more recent years, DAWR applied expansion methods to extrapolate island-wide catch estimates from creel survey data. The fish weir catch estimates were likely incomplete.

Because domestic fisheries in Guam are generally part commercial, part subsistence, and part recreational, the re-estimation approach taken was not by differentiation of the commercial and noncommercial sectors, but rather by following the creel-survey distinction between boat-based (offshore survey) and shore-based (inshore survey) estimations of catches (Table 1). Given our focus on nonpelagic fisheries, we excluded the trolling section for large pelagic species from the offshore catch reports and retained bottom-fishing and boat-based spear-fishing catches. Comparisons of supply and demand, with the use of reported catch (including pelagic taxa), as well as estimates of imported

seafood and domestic seafood consumption rates, were undertaken to estimate potentially unreported catches, as well as to estimate total likely catch for the 1950–64 period for which no other reported information was available (see "Supply versus demand" heading below, Table 2).

Offshore boat-based catches

1965–82: The offshore catch estimates for this time period, which pre-dates WPacFIN reporting, were drawn from the creel survey data as reported in DAWR annual reports. Procedures for expanding survey data to island-wide catches, as listed or applied by the various data sources, were generally accepted. For example, reports from earlier years indicated under-reporting due to sampling design limitations of the creel surveys by a minimum factor of two, and we adjusted the reported catch estimates correspondingly for these years (Zeller et al.[3]).

1983–2002: We relied on the island-wide expanded catch estimates as provided by WPacFIN, based on offshore creel surveys undertaken by DAWR. These data

Table 1

Data sources, available time series data, and data anchor points for catch re-estimation for Guam. DAWR: Division of Aquatic and Wildlife Resources; WPacFIN: Western Pacific Fishery Information Network. X=yes.

Sector	Year(s)	Source	Official data (reported)	Missing data (unreported)	Catch (t)
Offshore, boat-based	1965–82	Guam DAWR offshore creel survey reports	X		1–36
Offshore, boat-based	1983–2002	WPacFIN, DAWR	X		43–65
Inshore, shore-based	1965–81	Guam DAWR inshore creel survey reports	X		145–102
Inshore, shore-based	1982–84	Hensley and Sherwood (1993)		X	92–141
Inshore, shore-based	1985–2002	WPacFIN, DAWR	X		179–63
Offshore and inshore	1950	Reported consumption rate[1]		X	957

[1] Adjusted for imports and consumption of pelagic species.

Table 2

Data sources and data anchor points for import and consumption estimation, forming part of the supply (reported catch and estimated imports) and demand (consumption estimates) approach used for catch re-estimation for Guam.

Supply or demand	Item	Year(s)	Source	Comments	Annual per capita rate (kg)	Guam total (kg)
Supply	Import	1950	Assumption	Half of adjusted 1980 rate[1]	10.6	636,850
Supply	Import	1980	Import rate	17.7 kg/person/year, adjusted for cooler-shipped fish by 20%	21.2	2,250,204
Supply	Import	1999	Dept. of Commerce		19.5	2,962,380
Supply	Import	2000	Dept. of Commerce		20.5	3,180,014
Supply	Import	2002	Dept. of Commerce		20.9	3,359,137
Demand	Consumption	1950	Assumption	Same as 1980, adjusted for pelagics	26.6	1,593,940
Demand	Consumption	1980	Consumption rate	Adjusted for pelagics	26.1	2,766,977
Demand	Consumption	1985–2002	Assumption	Consumption = imports + reported catches	22.6–21.7	2,595,204–3,488,267

[1] This accounts for the lower air-and boat-based travel between islands in 1950 compared to 1980.

were reported by taxon, and thus allowed us to exclude large pelagic species.

Inshore, shore-based catches

1965–81: The inshore catch data for this period were based on the inshore creel survey data as reported in the DAWR annual reports, including the often separately reported estimates for octopus and shellfish (based on reef-gleaning), fish weirs, and the highly irregular, seasonal catches of juvenile rabbitfishes (Siganidae) and big-eye scad. Procedures for expanding the catches were accepted as reported at the time. We applied or accepted adjustment factors for nonsurveyed periods as provided or used by the fishery data sources (Zeller et al[3]). The years 1980 and 1981 were deemed poorly reported because of limited survey coverage. Therefore, we replaced the reported catches for 1980 and 1981 with the average catches for 1978–79 and 1982–83, respectively.

1982–84: Data from Hensley and Sherwood (1993) were used for the 1982–84 period because WPacFIN has reported inshore catches only since 1985. It should be noted that these data did not include those from night fisheries and therefore under-represented actual catches.

1985–2002: We used the island-wide expanded catch estimates from the inshore creel survey, as undertaken by DAWR, and provided by WPacFIN.

Supply (imports and catches) versus demand (consumption) To assess whether the reported catches as outlined above accounted for the likely total catches and to derive estimates of likely catches for the undocumented 1950–64 period, we compared estimates of total supply (reported catches plus estimated imported catches) with demand as approximated 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 of 39 t/year carried back from 1959 to 1950, based on DAWR's estimated annual pelagic catch for 1960–62.

Imports Information on reported imports was available for 1999 and 2002 (Guam Department of Commerce[5]), which were converted to per capita rates (1999: 19.5 kg/person; 2002: 20.9 kg/person) using human population statistics (U.S. Census Bureau[6]), and for 1980 as an estimated annual per capita import rate of 17.7 kg (Table 2). There is a long-standing tradition of bringing fish into Guam as part of personal travel. A large, but unknown portion of these imports are so-called cooler-shipped fish and are primarily from the Federated States of Micronesia, Palau, and the Republic of the Marshall Islands. These imports have been poorly recorded, especially in the earlier periods. To account for under-reporting of cooler-shipped imports in earlier years, we adjusted the 1980 annual per capita import rate by 20%, to 21.2 kg. For 1950, we assumed a level of import of half of the adjusted 1980 import rate (i.e., 10.6 kg; Table 2), to account for the much lower air- and boat-based travel between the various islands in 1950 compared to 1980. We linearly interpolated import rates between the 1950, 1980, 1999, and 2002 import data anchor point estimates and expanded these to total import estimates using human population statistics.

Another factor that may have influenced rates of import and harvest is aquaculture. There is potentially a considerable (but unknown) volume of locally farmed tilapia, catfish, and milkfish that is sold without regulation through small-scale markets and road-side vendors, and these products are not reported or recorded. Currently, it is not possible to estimate the impact of aquaculture on the present estimation of catches.

Demand Estimates of demand were based on the reported annual per capita consumption rate of 27 kg of seafood for 1980 (Zeller et al[3])—a rate that was carried back unaltered to 1950. We thus assumed the same relative consumption patterns for 1950 as for 1980, which may underestimate the seafood consumption patterns for 1950, and thus is adding a conservative component to our estimation. 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 nonpelagic per capita consumption rates with population statistics (Table 2).

For 1985–2002, we assumed that total consumption was accounted for by the sum of reported catches plus estimated imported catches. Total consumption was adjusted by removing the reported pelagic catches, and the 1985–2002 per capita nonpelagic consumption rates were derived with human population statistics (Table 2).

For the 1981–84 period, we interpolated per capita nonpelagic consumption rates between the 1980 and 1985 data anchor points. The growing concern about market dumping of incidental bycatch from the pelagic transshipment fleet onto the local seafood market was not considered in the present study because it is thought to be a relatively recent phenomenon. It would be reflected in declining commercial reported catch data because it replaces local fish in the commercial market supply.

Supply versus demand To derive estimates of catches for the 1950–64 period, we assumed that domestic seafood supply was either locally caught, relying heavily on subsistence fishing, or was part of the cooler-shipped imports. Given the assumed imports, the likely total local catches were derived as the difference between import estimates and consumption estimates (Table 2). Thus, in 1950, an assumed per capita import of 10.6 kg of seafood and an estimated per capita consump-

[5] Guam Department of Commerce. 2005. Website: http://www.admin.gov.gu/commerce (accessed 15 January 2005).

[6] U.S. Census Bureau. 2005. Website: http://www.census.gov/cgi-bin/ipc/idbsprd (accessed 15 January 2005).

Table 3

Data sources, available time series data, and data anchor points for catch re-estimation for the Commonwealth of the Northern Mariana Islands. WPacFIN=Western Pacific Fishery Information Network; DFW=Division of Fish and Wildlife.

Sector	Year(s)	Source	Official data (reported)	Missing data (unreported)	Catch (t)
Commercial	1960	No commercial fishing		X	0
Commercial	1983–2002	WPacFIN, DFW	X		76–106
Noncommercial	1950	Per capita consumption		X	456[1]
Noncommercial	1984	Proportion of total catch		X	166[2]
Noncommercial	1993–2002	Proportion of total catch		X	87–106[3]

[1] Reported per capita seafood consumption of 0.45 kg/day was reduced by 50% to remain a conservative estimate.
[2] In 1984 noncommercial catches represented about 63% of total catches, corresponding to a noncommercial to commercial ratio of 1.7:1.
[3] By the early 1990s, the noncommercial catch accounted for about 50% of total catches. This ratio was carried to 2002.

tion rate of 26.6 kg, implied a per capita catch rate of 16.0 kg for 1950.

For the 1965–84 period, the difference between reported catches and supply/demand estimates was interpreted as unreported catches (e.g., unrecorded night fisheries catches in the early 1980s), and were added to the reported catches (since 1965), resulting in the final re-estimated total catches.

Catch rates We converted re-estimated catches into per capita catch rates using human population statistics and catch per unit area of the depth-defined potential coral reef ecosystem habitat area (*sensu* Rohmann et al., 2005). Given that most nonpelagic catches come from areas relatively close to Guam, we used the potential reef area estimate (to 100 fathom=183 m depth) for reefs associated directly with the island of Guam (202.8 km^2), not the reef area estimate for the EEZ (276 km^2; Rohmann et al., 2005). The reef area may slightly underestimate the area for bottom-fisheries, particularly for the post-1980 period, when an increasing proportion of commercial bottomfish catches (up to 30%) likely originated from offshore banks.

CNMI

Commercial catches Estimates based on data collected by DFW of commercial landings for recent years (1981–2002) were available through WPacFIN. Given uncertainty surrounding the low catches reported for the first few years of this data series, only the period from 1983 through 2002 was used (Table 3). Because the collected data relate to Saipan only, WPacFIN uses an adjustment factor of 20% to expand to CNMI total catches, which is thought to account for much of the known under-recording of commercial landings. Because there was little local commercial fisheries development in the CNMI until the 1960s, we assumed commercial catches were zero in 1960 (Table 3) and linearly interpolated catches between 1960 and the 1983 value as reported by WPacFIN.

Noncommercial catches Noncommercial catches are not reported in CNMI. Although limited monitoring has existed since 1984 for the Saipan lagoon only, these data have not been analyzed and were not available to us.

1950–83: Subsistence fishing was an important daily activity in the Northern Marianas after WWII, and it was estimated that in the late 1940s the local population traditionally consumed nearly 0.45 kg/person/day, implying an annual per capita seafood consumption of over 165 kg (Smith[4]). Although this rate of consumption may appear a high estimate, other Pacific islands have reported similarly high annual per capita consumption rates as recently as the late 1990s, e.g., Kiribati (183 kg), Palau (124 kg), Federated States of Micronesia (119 kg), or Tuvalu (113 kg) (Gillett[7]). To account for lower fish consumption by the small nonindigenous population, the likely inclusion of pelagic species in the reported consumption rate, 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 72.6 kg/person/year (0.2 kg/person/day) as the assumed per capita consumption rate for 1950 (Table 3). Furthermore, given that virtually no vessels were available for exploitation of offshore resources shortly after WWII, we assumed that noncommercial catches in 1950 were based almost exclusively on near-shore resources. We linearly interpolated the per capita catch rates between this 1950 level and the catch rate estimated for 1984 (see below) and expanded these to a total noncommercial catch estimate with the use of human population census data.

1984–2002: In 1984, noncommercial catches were thought to have accounted for approximately 63% of total catches, which corresponded to a noncommercial-

[7] Gillett, R. 2002. Pacific Island fisheries: regional and country information. RAP Publication 2002/13, 168 p. Asia-Pacific Fishery Commission, FAO Regional Office for Asia and the Pacific, Maliwan Mansion, Phra Atit Road, Bangkok 10200, Thailand.

Table 4
American Samoa reconstructed catch summary, by decade. Summarized from Zeller et al. (2006a).

Year	Official reported catch (t)	Unreported catch (t)	Total estimated catch (t)
1950	—	752	752
1960	—	635	635
1970	—	596	596
1980	41	368	409
1990	10	312	322
2000	42	152	195
2002	34	121	155

to-commercial catch ratio of 1.7:1 (Table 3). By the early 1990s, approximately 50% of total catches were thought to be not reported because they constituted noncommercial catches. Thus, the noncommercial catch value for the time period 1993–2002 was set equal to the total commercial catches (Table 3). Thus, we assumed higher reliance on noncommercial fishing in the early 1980s compared to the 1990s. We interpolated the proportion of noncommercial catches between 1984 and 1993 and expanded them by using reported commercial catches.

Catch rates Re-estimated catches were converted to per capita catch rates by using human population census data, and to catch per unit area of the depth-defined potential coral reef ecosystem habitat area (*sensu* Rohmann et al., 2005). Total potential coral reef area to a depth of 100 fathoms (183 m) for CNMI is 476 km^2 (Rohmann et al., 2005). Given that most fishing in CNMI occurs near the three main islands, the coral reef area estimate for these islands (331.2 km^2) was used here also (Rohmann et al., 2005).

American Samoa

Total catches for nopelagic species for American Samoan have been re-estimated independently by Zeller et al. (2006a), and are summarized by decade in Table 4. American Samoan catches were included in the present study for completeness in the re-estimation of total time series catches for the U.S. flag-associated Pacific island areas.

Results

The catch re-estimation for nonpelagic species for the major U.S. flag-associated island areas in the western Pacific combined (excluding Hawaii) indicated two main points (Fig. 2A):

1 a substantial discrepancy between officially reported catch data and potential total catches as re-estimated here and by Zeller et al. (2006a). For the time period for which reported data existed (1965–2002), such data may have yielded an underestimate of likely total catches by as much as a factor of 4.55. This discrepancy was largest in early years; and
2 a potential decline of 77% occurred in total catches, from an estimated 2165 t in 1950 to 496 t in 2002. This decline contrasted with the trend observed from the data reported by individual island entities—namely an increasing trend from 147 t in 1965 to 269 t in 2002.

Individual islands

For Guam, the re-estimation indicated a decline of 86% in catches of nonpelagic species over the 50-year time period considered here. There was also a 2.5-fold difference between the re-estimated catches and the reported statistics for the 1965–2002 period, driven by underreporting of catches in earlier periods. Guam's ongoing commitment to and consistent application of creel surveys to estimate total catches has resulted in what may be the most reliable estimates of total catches for any of the islands considered here, at least since the mid-1980s (Fig. 2B). Based on the re-estimated data, the annual per capita catch rates for Guam's coral reef- and bottom-fisheries may have declined from 16.0 kg to 0.8 kg between 1950 and 2002 (Table 5). Catch rates per area of potential coral reef habitat (to 100 fathom=183 m depth) appear to have declined from 4.7 t/km^2/year to 0.6 t/km^2/year between 1950 and 2002 (Table 5).

For CNMI, the re-estimated catches indicated a decline of about 54% in catches of nonpelagic species between 1950 and 2002. Comparing the catches reported by CNMI from WPacFIN with the re-estimated total catches, we found a 2.2-fold under-reporting of potential total catches by the reported data, compared to the re-estimated totals for the 1983–2002 time period of coverage by WPacFIN (Fig. 2C). Taking into account CNMI's rapid human population growth over the last two decades, we surmise that the annual per capita catch rate may have declined from a high of 72.6 kg in

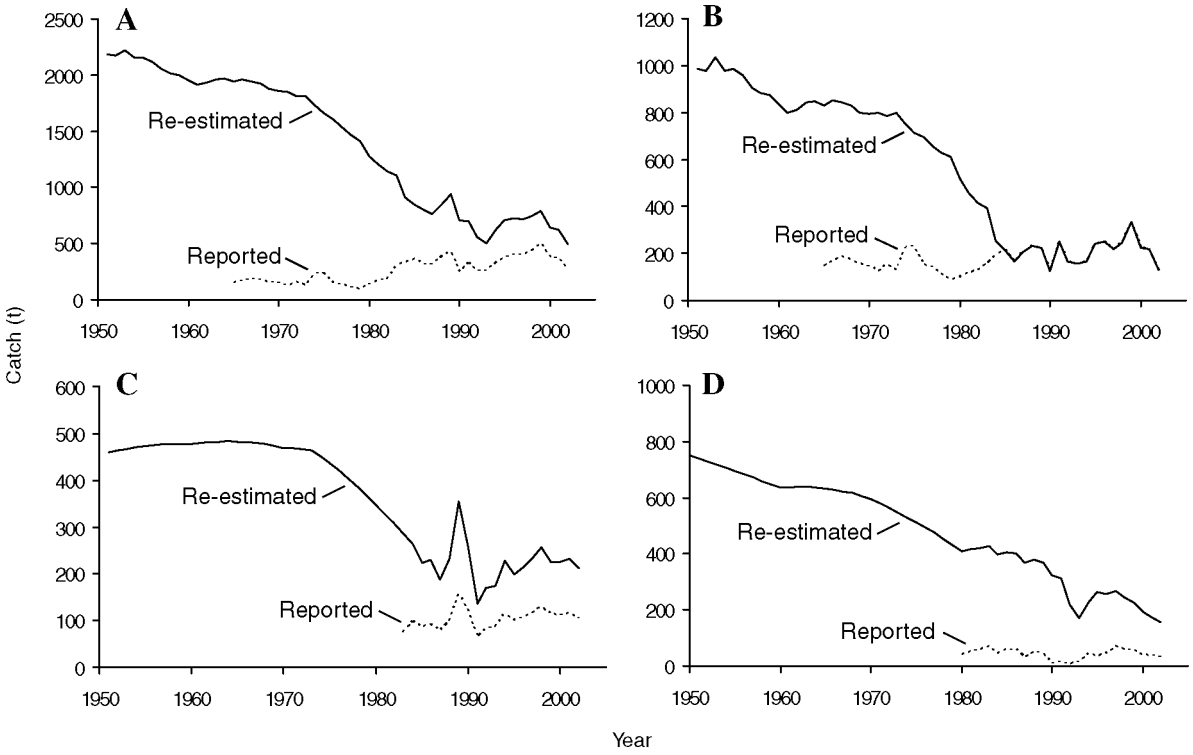

Figure 2

Re-estimated catches of small-scale, coral-reef fisheries for the major U.S. flag-associated island areas in the western Pacific (Guam, Commonwealth of the Northern Mariana Islands [CNMI], and American Samoa), versus the statistics officially reported by these island entities through the Western Pacific Fishery Information Network. Both the under-representation of likely total catches, as well as the likely decline in catches is evident in each case. Total re-estimated catches (**A**) summed over all the major U.S. flag-associated island areas of the western Pacific considered here; (**B**) for Guam versus the catches reported by Division of Aquatic and Wildlife Resources; (**C**) for CNMI versus the statistics officially reported by Division of Fish and Wildlife; and (**D**) for American Samoa versus the statistics officially reported by Department of Marine and Wildlife Resources (Figure 2D modified from Zeller et al., 2006a).

Table 5

Catch rates for the re-estimated small-scale fishery catches for Guam and the Commonwealth of the Northern Mariana Islands (CNMI), excluding pelagic species. Catch estimates are presented as per capita catch rates, and as catch per surface area of potential coral reef habitat to a depth of 100 fathom (183 m, Rohmann et al., 2005).

	Per capita catch (kg/year)		Catch/area (t/km^2/year)		
				Commonwealth of the Northern Mariana Islands	
Year	Guam	Commonwealth of the Northern Mariana Islands	Guam (202.8 km^2)	All islands (476 km^2)	Main islands (331.2 km^2)
1950	16.0	72.6	4.7	1.0	1.4
1960	12.5	53.9	4.1	1.0	1.4
1970	9.4	37.9	3.9	1.0	1.4
1980	4.9	20.5	2.5	0.7	1.0
1990	1.0	5.8	0.6	0.5	0.8
2000	1.4	3.2	1.1	0.5	0.7
2002	0.8	2.9	0.6	0.4	0.6

1950 to 2.9 kg by 2002 (Table 5). Given that over 99% of the human population of CNMI lives around the three main islands, the catch per reef habitat area was assessed for both the entire CNMI reef area (476 km^2) and also for the reef areas of the three main islands (331.2 km^2). Thus, between 1950 and 2002, estimated annual catch per km^2 reef area appears to have declined from 1.0 t to 0.4 t, and from 1.4 t to 0.6 t for the entire CNMI reef area (476 km^2) and main islands reef areas (331.2 km^2), respectively (Table 5).

The historic fisheries catches for American Samoa, as re-estimated by Zeller et al. (2006a), indicated a potential decline of about 79% in small-scale fisheries catches of nonpelagic species between 1950 and 2002 (Fig. 2D; modified from Zeller et al., 2006a). There was also a 7-fold difference between the re-estimated catches and the reported data for the 1980–2002 time period.

Discussion

Local and regional fisheries experts often acknowledge that they are aware of the limited nature of much of the official data, but rarely are willing or able to quantify the missing catches. Our re-estimation makes the potential scale of under-reporting of total extractions of marine resources evident. Specifically, our study illustrates not only the potential discrepancy by a factor of 4.55 between what was reported and what may have been caught (for the period of data reporting), but also indicates the potential scale of declines (77% overall for all areas combined) in total catches over the last 50 years. Although the historic catch estimates proposed here obviously do not represent a formal stock assessment, they are useful as baselines of potential historic patterns and trends in fisheries catches.

Regarding our comparison of catch data to those from official, reported fisheries, we acknowledge that most fisheries statistics were originally designed as an economic development and monitoring tool, where there was a common focus on commercial catches (with the exception of Guam). Nevertheless, reported data are being increasingly used to present national and global fisheries conditions and status and trends of resources. Thus, the under-representation of likely total catches as indicated here may lead directly to an erroneous interpretation of the status of fisheries within the U.S. flag-associated islands. Significantly, the situation of under-reporting contributes to the continued marginalization of small-scale fisheries (Pauly, 1997), and the ongoing under-valuation of the direct and indirect economic and social contribution of noncommercial (e.g., subsistence, and increasingly recreational) fisheries to the economic well-being of these islands (Zeller et al, 2006b). Such underestimations of catch histories may also have repercussions for the move towards ecosystem-based fisheries management.

The general approach used here, which relies on anchor points of data obtained from a variety of peer-reviewed and non-refereed data sources, moderated by conservative assumptions, and interpolated for missing-data years, results in catch estimates that accounted for all fisheries sectors. We acknowledge that our estimates clearly are not statistically rigorous in the sense of approximating "true" time-series values, which are obviously not known. However, given our conservative approach to estimation, the present estimates are less wrong than the current default of reporting zero catch for fisheries sectors not considered in official figures. Ignoring the catches of noncommercial sectors of fisheries in the U.S. flag-associated island areas of the western Pacific has likely resulted in a skewed picture of the historic catch trends, as well as the magnitude of catches for nonpelagic, near-shore resources in these islands.

Catch estimation procedures such as ours are associated with high data uncertainty; this is the nature of alternative, non-standardized data sources. The paucity of data for the earlier periods was an acknowledged shortcoming to our approach; nevertheless, our approach is based on the best data and information available. We endeavored to remain conservative in our estimation throughout the period of examination; thereby incorporating a precautionary aspect into the data. Our conservative approach can be placed into context by the following consideration.

The re-estimation of catches for Guam, as undertaken here, indicates a decline in catches of 86%, and a 2.5-fold discrepancy between the re-estimated catches and the reported statistics over the time period for which DAWR reported data exist (1965–2002). The validity of the differences between reported and re-estimated 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 (Zeller et al.[3]).

Concerns about our approach to the unreported catches can be placed into perspective through an alternative, albeit less rigorous estimation (Zeller et al.[3]). In 1977, 38.6% of households in Guam were considered to have at least one family member who fished, and mean monthly catch per surveyed household was 32.7 kg, or 392 kg/year. With an average of 5 people per household and a population of 110,000 in 1977 for Guam, these figures imply 22,000 households (110,000 people/5 people per household), of which 38.6% (i.e., 8492 households) had active fishermen. These actively fishing households alone could thus have caught 3,328,864 kg in 1977 (8492 households with catch rate of 392 kg). Accounting for pelagic fish in their catch (45.8% of reported catches in 1977 were caught with pelagic gear), this calculation would imply a nonpelagic catch of 1,804,244 kg for 1977 (3,328,864 kg×[1–0.458]). This admittedly very indirect estimate is 2.76 times our total reconstructed nonpelagic catch estimate of 654,345 kg for 1977, and 12.6 times the DAWR reported catch of 143,220 kg. Thus, this indirect approximation supports our contention that our re-estimation approach was conservative, and total catches in the earlier periods were considerably higher than those of the reported data.

We appreciate that using linear interpolation of per capita catch rates between anchor points (particularly if widely spaced in time) may introduce additional data uncertainties associated with potential behavioral (changes in lifestyle and dietary preferences) and socioeconomic (move towards cash-economy) changes in the human population over that time period. This uncertainty in turn may lead to over- or underestimation of catches for a given year, for the period between anchor points. However, given the bounds provided by the anchor point data, such uncertainties would primarily influence the shape of the resultant catch curve for the period between each set of anchor points. Given the paucity of other supportive data, the only reliable alternative approach would have been a simple linear interpolation of catches between anchor points. On closer examination of our reconstructed data (see Fig. 2, the source of present data [Zeller et al.[3]], and Zeller et al., 2006a), such linear interpolation would only result in relatively small differences compared to our present approach. For example, a simple linear interpolation of anchor point catches would have smoothed the slight rise in reconstructed catches for CNMI between 1950 and 1980 (Fig. 2C). Overall, however, the broad conclusions and general trends observed here would not have been substantially affected.

The area catch rates as estimated here indicate catch rates ranging from 0.4 to 4.7 t/km^2/year. These estimates are all at or near the lower end of the only other comprehensive range of estimates (0.3–64 t/km^2/year) established for the Pacific region (Dalzell and Adams, 1997). However, all area catch rates are heavily influenced by the definition of coral reef area, which here was taken as depth defined (100 fathoms=183 m) potential coral reef ecosystem habitat as defined by Rohmann et al. (2005), which may represent overestimates of true coral reef habitats around each island. Nevertheless, the present estimates indicate that our reconstructed catch estimates, even for the early years, may likely be feasible in a broader ecological context.

Although the overall finding of our study was that of declining total catches, such declining catches may not necessarily be the result of excessive fishing alone because other factors may also contribute to the decline. These include changes in lifestyles, cash incomes, and dietary preferences of the local populations (as indicated above), as well as habitat degradation and pollution resulting from environmentally insensitive developments (Friedlander and DeMartini, 2002). All these factors can potentially lead to declines in the size of fish stocks and catches. Nevertheless, our results do indicate likely substantial changes over the last 50+ years in fisheries catches and should form important baselines for a move towards ecosystem-based resource and habitat management in the U.S. western Pacific region, particularly as other lines of evidence (e.g., declines in mean size of fish) also indicate that overfishing or stock declines may indeed be occurring in many areas (e.g., Craig et al., 1993).

Finally, and in our opinion significantly, we suggest strongly that all responsible agencies should be required to implement and maintain regular estimation procedures to account for and report all catches taken by all fisheries sectors. According to the data from the present study, Guam may offer a good example and starting point for such considerations. Guam has established an active commitment to creel surveys during the last 20+ years as a mechanism to estimate total catches. It is to be hoped that this commitment will continue. Given the high costs of creel surveys (which are the most suitable method for estimating highly dispersed and de-centralized noncommercial fisheries), resource-limited developing countries should give considerations to regular, albeit nonannual surveys for estimation of noncommercial catches. Well executed and comprehensive noncommercial catch estimates undertaken every 2–5 years are better than the current scenario of virtually no data collection.

Management agencies and policy makers should consider the distinctly different baselines of past catches as presented in this study, as they shed new light on issues and concerns for fisheries sustainability and ecosystem conservation. Furthermore, re-estimations, as presented here, illustrate the importance of small-scale and noncommercial fisheries sectors and indicate a need to account for all fisheries catches in official statistics.

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