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American Samoa Archipelagic Fishery Ecosystem Report

By Marlowe Sabater and Ray Tulafono

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American Samoa Archipelagic Fishery Ecosystem Report

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Contents

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LIST OF FIGURES

LIST OF TABLES

Executive Summary

This initial report on the archipelagic fishery ecosystem of American Samoa hopes to provide an initial framework for the reporting of fish catches and catch per unit effort (CPUE) trends for the territory and to assist the Western Pacific Regional Fishery Management Council's archipelagic approach to fishery management. The report provides an overview of the CPUE trends over time for each species group and determines the status of the species group complexes included in the fisheries. This is the first attempt of the Department of Marine and Wildlife Resources to use catch to biomass ratios to estimate fishing mortality and determine the trend over time in order to provide an insight on how the fishery interacts with the fish stocks. The report assesses the condition of the harvested insular fish stocks using data collected from the boat- and shore-based fisheries and underwater census surveys. These were analyzed to determine long-term trends in catch landing, CPUE, biomass and fishing mortality of the top six species groups per gear used in the American Samoa insular fisheries. The report does not cover fisheries for tuna and other highly migratory, open-water pelagic species.

For the boat-based sector, bottomfish, spear and mixed troll-bottomfish comprised 96% of the total landing from 1986 to 2008 while merely 4% came from troll and atule fishing. Top catches from these methods combined were snappers (30% of the total catch), surgeonfish (20%), miscellaneous bottomfish (16%), emperors (15%), parrotfish (10%) and groupers (9%). The CPUE trends for these species groups depended on the method used but were generally constant over the years with the exception of snappers, which had an increasing CPUE in the mixed troll-bottomfish fishery.

The shore-based fishery is comprised of spear, rod and reel, gleaning, gillnet, handline, throw net and bamboo pole. The first four methods contributed 83% of the total catch from 1990 to 2008 while handline, throw net and bamboo pole contributed 9%, 6%, and 2%, respectively. The top six catches landed by the shore-based fishing methods combined were bigeye scad (locally known as atule at 29% of the total catch), mollusks (24%), surgeonfish (19%), jacks and groupers (13%), invertebrates (9%) and parrotfish (7%). The CPUE for the shore-based fishery was constant to slightly decreasing over a 19-year period as affected by the gleaning of invertebrates and fishing for atule, mullets and squirrelfish. The decline can be attributed to changes in the nature of the fishery, the biology of the animals and the interaction of fishing with other factors such as habitat limitation and degradation. In some cases, CPUE was shown to be increasing, such as in the gleaning of mollusks, spearing of surgeonfish and parrotfish, and using rod and reel for grouper.

General linear trends in fish biomass plotted from underwater census data showed an increasing biomass for parrotfish, surgeonfish and emperors; constant linear trends for snappers and groupers; and a decrease for jacks. Average biomass ranged from 213,000 lbs for groupers to 1,070,000 lbs for parrotfish.

Catch to biomass ratio was used as a measure of fishing mortality. Short-term trends covering eight time periods showed a constant fishing mortality for surgeonfish; a slight decrease for snappers, groupers and emperors; and an increase for jacks and parrotfish. Fishing mortality ranged from 0.5% for jacks to 4.5% for snappers. Overall fishing mortality was estimated at 2.5% for Tutuila and 1.4% when considering the archipelagic stock.

The report indicates that the coral reef fish stocks are not being subject to intense fishing pressure given that (1) fishing effort has been declining over three decades; (2) fish biomass and abundance are increasing; and (3) CPUE and fishing mortality remain stable.

Photo courtesy of Marlowe Sabater

Acknowledgments

The authors acknowledge and thank the following grantors, partners and collaborators for their funding, support and assistance to make this report possible: (1) Sportfish Restoration Grant of the Office of Federal Assistance, which funded the Inshore Fishery Documentation Program that generated the shoreline fishery statistics and the Key Reef Species Program that generated the biomass estimates for some years; (2) National Marine Fisheries Service through the Insular Fishery Agreement, which generated the boat-based fishery statistics; (3) Western Pacific Fishery Information Network, which collated all the data and generated data summaries for the report; (4) Western Pacific Regional Fishery Management Council for providing technical assistance, guidance and a forum for this report to be useful through its reporting system; and (5) Dr. Ivor Williams for the biomass estimate data and habitat expansion values that generated the fishing mortality estimates.

Photo courtesy of Alice Lawrence

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Introduction

Samoans have inhabited the islands known today as American Samoa for 3,500 years. Throughout this period, even after the first Western contact in the 18th century, they have relied on the ocean for their sustenance. Traditional coral reef fishing is concentrated in the lagoons and shallow reef areas. Traditional methods included gleaning and using bamboo poles with lines and baits or with a multi-pronged spear attached. The deepwater and pelagic fisheries have traditionally used wooden canoes, hand-woven sennit lines with shell hooks and stone sinkers, and lures made of wood and shell pieces.

The coral reef fishery evolved from traditional methods to modern rod and reel using nylon lines and metal hooks, some throw and gillnets, and spears while SCUBA diving. This latter method was introduced in 1994, restricted for use by native American Samoans only around 1997–1998 and banned in 2002, following recommendations of biologists from the Department of Marine and Wildlife Resources and local scientists. Along with the evolution of the gears used in the coral reef fishery, the nature of coral reef fishing also evolved from subsistence to recreational. Commercial fishing for coral reef-associated species has been considered low except during the SCUBA spear period.

The establishment of tuna canneries in the 1950s slowly changed the nature of fishing within the territory. Pelagic fishing for tuna and trevally had mostly been done by handline and troll. A shift to longline occurred in mid 1990s following the example of the neighboring Independent State of Samoa. The domestic longline fishery employs aluminum catamarans called alia usually around 40 feet in length and monofilament lines with 350 hooks per set deployed from hand-powered reels. Most of the participants in this small-scale fishery are native American Samoans. Most of the catches are sold to the local cannery while some are retained to supply the local markets and for personal use.

American Samoa's bottomfish fishery boomed between 1982 and 1985, after which catches declined as many skilled and full-time commercial bottomfish fishermen converted to troll. The result was a significant decrease in fishing effort and increasing catch rates for those remaining in the fishery until 1989. The trends in catch landing, effort and CPUE do not provide any conclusive evidence that catch decline was due to depletion of the stock as the catch trends were mostly driven by the migration from bottomfish to troll and longline. Bottomfish profits and revenues suffered devastating blows from four separate hurricanes: Tusi in 1987, Ofa in February of 1990, Val in December of 1991 and Heta in January of 2004. Fuel prices have gradually soared in the past four years causing yet another strain in the bottomfish fishery. The average price of local bottomfish has also declined due to the shift of demand to imported bottomfish, which competes closely with local prices. In 2004, 60% of coolers imported from the Independent State of Samoa on the *Lady Naomi* ferry were designated for commercial purposes; the Commercial Invoice System identified 50% of these coolers as bottomfish. On the other hand, current levels of landing, effort and CPUE are similar to those in the early 1980s and bottomfish is starting to become a more lucrative fishery than pelagic fishing, due to closure of one of the local canneries and a limited market for pelagic fish.

Today, American Samoa's insular, or archipelagic, fishery has a wide range of fishing methods that can be divided into a boat-based fishery where the main fishing platform is the alia and a shore-based component with a vast array of fishing methods, namely, gleaning, rod and reel, spear, gillnet, bamboo pole and throw net.

Total Catch Landing Using All Boat- and Shore-Based Fishing Methods

Calculations: Total landings were combined from the different fishing methods taken from the interview phase of the boat-based and shore-based fishery data collection. These methods have the potential to extract small coastal pelagic fish, coral reef fish, bottomfish and benthic invertebrates. The database for the boat-based fishery extends back to 1986 while the shore-based database is available from 1990. The boat-based data was truncated to start in 1990 in order to have a total catch from both datasets. Note that the data from 1997 to 2001 are all boat-based since the data from the shore-based fishery were not incorporated into the database due to lack of standardization with existing data. Only the top six species groupings are reported. The data shown are expanded data. Details of the data collection procedures and brief description of the expansion are described in Oram et al. (2010a, 2010b).

Trends and Interpretation: Surgeonfish ranked the highest landing for all boat- and shore-based fishing methods. The total surgeonfish landing from 1990 to 2008 was 307,433 lbs averaging 16,181 lbs per year. The highest landing occurred in 1997 at 49,629 lbs. This was during the peak of the SCUBA spear period. The catch declined from thereon due to exclusion of non-American Samoans from the fishery (the majority of the spearfishers were Tongans) in response to the high harvest rate. The lowest landing was in 2003 at 3,089 lbs after which the catch landing gradually increased. Assuming that the catch-year relationship is linear, the overall catch landing in the 19-year period is relatively constant. Surgeonfish landing comes mostly from boat- and shore-based spearfishing.

A similar trend was seen in the snappers landing where the overall linear trend is constant over the years. Snappers were harvested mostly by bottomfish and mixed troll-bottomfish methods, i.e., trolling while enroute to the bottomfish site. This was the second highest in total landings at 300,922 lbs with an annual average of 15,838 lbs. The highest landing (at least in what was covered by this period) was in 2001 with 27,654 lbs while the lowest was in 2006 at 4,484 lbs. This time series for snappers did not capture the period that had significant landing of deepwater bottomfish from early to mid 1980s with the existence of a fresh bottomfish export fishery to Hawaii.

The bigeye scad, locally known as atule, had the third highest landing with a total of 232,991 lbs averaging around 15,533 lbs per year. This is a traditional fishery where the majority of the village communities join the harvest when a large school of scads comes in the coastal water to spawn. Atule is harvested mostly using either the traditional coconut fronds or modern gillnets and sometimes rod and reel. The highest landing was in 1991 with an astounding 117,140 lbs. This is a pulse fishery that has zero landings some years. The overall linear trend of decreasing catch is due to decreased fishing effort and no recent strong aggregation pulse.

The fourth highest landing came from mollusks comprised of mostly turbo shells and giant clams. The total landing was 186,755 lbs averaging about 11,672 lbs per year. These mollusks were mostly harvested by the gleaning and SCUBA spear methods. The overall linear catch shows a decreasing trend over the years. The stocks may have declined because they are slow-growing, highly accessible species, and high effort can be concentrated on small, shallow reef areas they inhabit. Giant clams were deemed to be locally rare based on oral accounts and observations. The high mollusks landing in the early to mid 1990s can be attributed to the use of SCUBA in harvesting deep mollusk stocks. These are particularly vulnerable as they are sessile organisms with limited mobility. However, the steepness of the decline in catch may have been due to the gleaning and SCUBA-assisted harvest data being combined from 1990 to 1996 whereas from 2002 to 2008 the dataset included gleaning only.

The fifth highest landing came from jacks from the troll, mixed troll-bottomfish, and rod-and-reel methods.

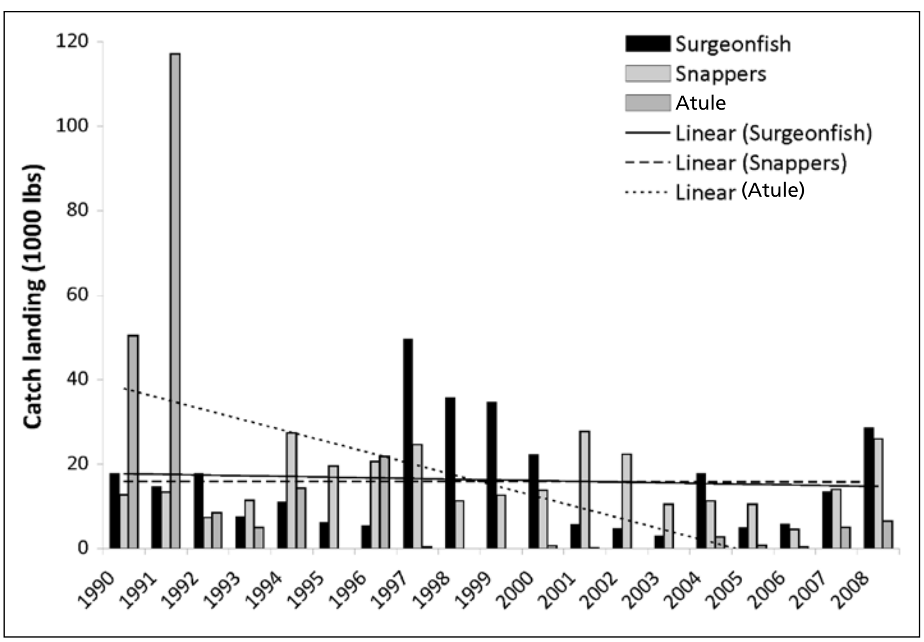


Figure 1. Overall catch landing of the top 1 to 3 species groups from the boat- and shore-based fisheries combined.

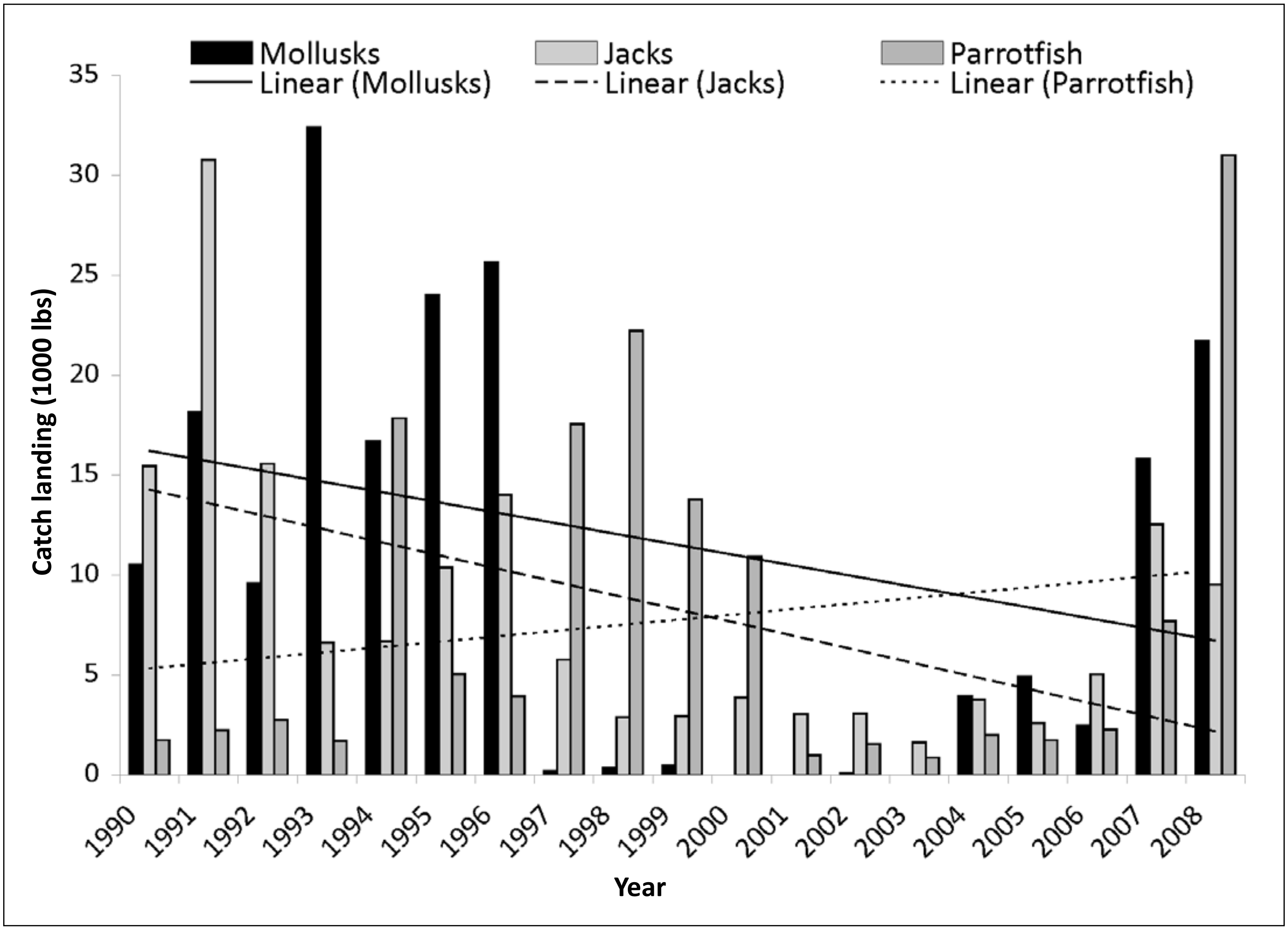


Figure 2. Overall catch landing of the top 4 to 6 species groups in the boat- and shore-based fisheries combined.

The total landing for jacks over the 19-year period was 155,796 lbs averaging 8,200 lbs per year. The highest jacks landing was in 1991 with 30,761 lbs, and lowest was in 2003 with 1,620 lbs. Although the overall catch trend indicates a linear decline in jacks landing (figure 2), the CPUE for the shore-based rod and reel method was constant to slightly decreasing (figure 27) and the CPUE for the mixed troll-bottomfish method was constant to slightly increasing (figure 17).

The sixth highest catch landing came from parrotfish with a total landing of 147,525 lbs averaging about 7,764 lbs per year. The highest landing was in 2008 at 30,991 lbs, and lowest was in 2003 at 843 lbs. Parrotfish is mostly harvested in the boat- and shore-based spear fisheries and to some extent the gillnet fishery. The data shown from 1997 to 2002 are all from the boat-based spear fishery since the data for the shore-based fishery during this period were not integrated into the database. The increase in catch landing from 1994 to 1998 is attributed to the SCUBA spear method. The recent increase in parrotfish landing was due to the snorkel spear fishery only. The overall linear catch trend shows an increase in parrotfish landing over 19 years. The CPUE of parrotfish in the spear fishery has been constant to slightly decreasing over the years (figure 12).

Overall Catch Landing by Boat-Based Fishing Methods

Calculations: Total landings were segregated to different fishing methods taken from the interview phase of the boat-based fishery data collection. These methods have the potential to extract small coastal pelagic fish, coral reef fish, bottomfish and benthic invertebrates. Bottomfish, spear and mixed troll-bottomfish methods make up 96% of the total catch for the whole reporting period. These three methods will be discussed in more detail in the succeeding section.

Trends: The bottomfish method had the highest average catch landing of 27,593 lbs over a 23-year time period. The various peaks in the bottomfish fishery occurred in 1986, 2001 and 2008 landing 59,191 lbs, 50,181 lbs and 54,208 lbs, respectively. The spear fishery had significant catch landings in the late 1980s and late 1990s reaching peak landings of reef fishes in 1988 (53,160 lbs), 1997 (84,083 lbs) and 1998 (77,442 lbs). The overall average catch landing from the spear fishery, snorkel and SCUBA combined, was at 24,313 lbs. Interestingly, the peaks in the spear fishery seem to coincide with the troughs in the bottomfish fishery.

The mixed troll-bottomfish method came third in coral reef fish landing bringing in an average catch of 8,525 lbs. This is a combined trip where trolling is conducted as the boat transits between bottomfish grounds. This fishery became significant in the late 1980s achieving peak landings in 1986 (35,188 lbs), 1989 (28,707 lbs) and 1995 (19,803 lbs).

Trolling is a small-scale fishery that appears to have had constant landings over the years achieving the highest landing in 1988 (4,698 lbs) and averaging around 1,807 lbs.

Atule fishing is a sporadic, mostly offshore fishery that sometimes utilizes boats to maximize the catch. This fishery's highest activity occurred only in recent years landing 3,458 lbs and 2,884 lbs of bigeye scad in 2007 and 2008, respectively.

Interpretation: An interesting pattern emerged in the analysis of the fishing method trends where peaks in one fishing method relatively coincide with the low catch landings in other methods particularly in the bottomfish, spear and mixed troll-bottomfish methods. This could reflect the dynamics of the fisheries, with a transition from the lucrative bottomfish fishery of the early 1980s to the mixed troll-bottomfish method to maximize efficiency of the trip and eventually to the highly efficient SCUBA spear method. After the peak in 1997, catch landings of reef fish declined as non-American Samoan fishermen became excluded from this method. Prior to the exclusion, the majority of the SCUBA spearfishers were Tongans. The downward trend continued until the institution of the SCUBA spear ban in 2002. During the downward trend in the SCUBA spear fishery, bottomfish landings re-emerged to the same level as in the late 1990s. Careful examination of the fishing effort will have to be done in order to verify this pattern.

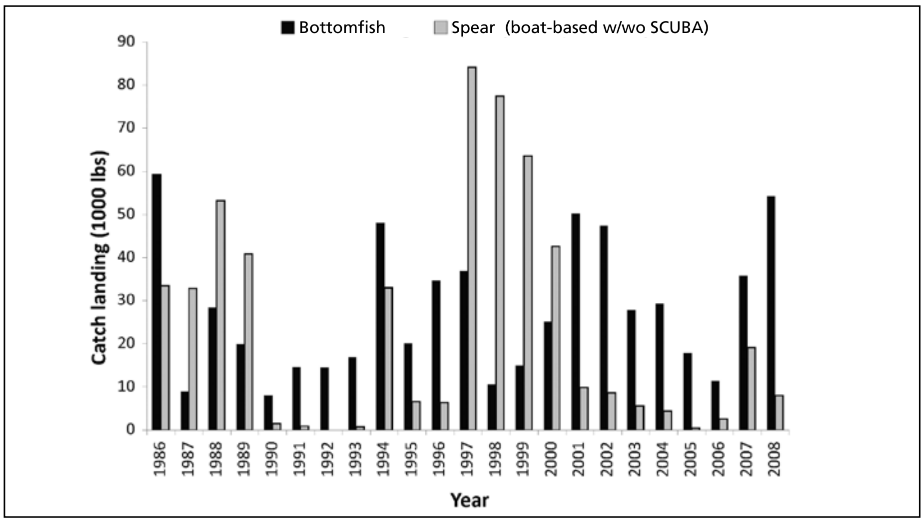


Figure 3. Overall catch by bottomfish and boat-based spear methods from 1986 to 2008.

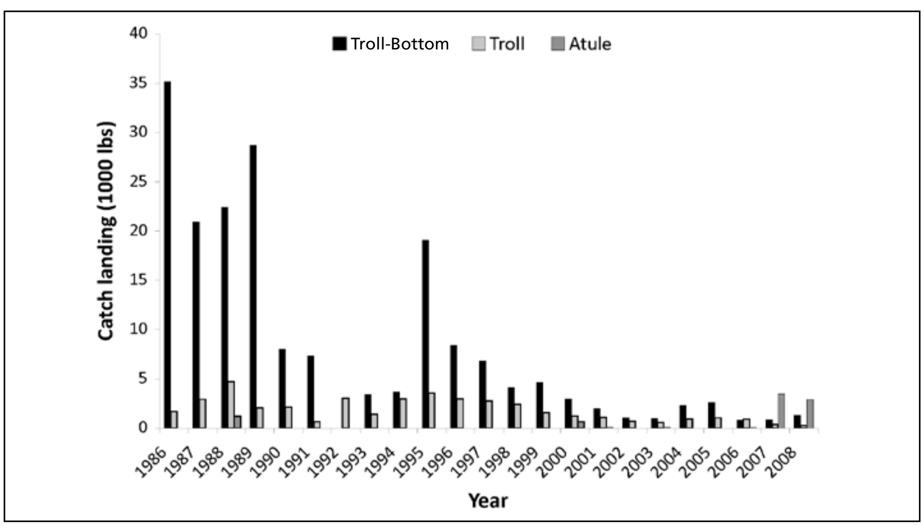


Figure 4. Overall catch by mixed troll-bottomfish, purely troll and traditional atule fishing from 1986 to 2008.

Overall Boat-Based Catch Landing by Species Groups

Calculations: Catch landing for each species group was extracted from the boat-based creel database of the Western Pacific Fishery Information Network (WPacFIN). The overall catch per species group was derived from the top three boat-based fishing methods (bottomfish, spear and mixed troll-bottomfish) combined.

Trends: The boat-based catches were dominated by snappers coming from the bottomfish fishery. This was followed by surgeonfish landed from the spear fishery particularly from 1994 to 2001. Miscellaneous bottomfish came third in the overall catch landings particularly from 1996 to 1999. Among these three groups, the snapper complex appeared to have more regular landings as compared to surgeonfish and miscellaneous bottomfish, which exhibited peaks in landings brought about by changes in the fisheries and data collection methods.

The fourth highest catch was the emperors dominated by the red gill emperor (*Lethrinus rubrioperculatus*) from the shallow-water bottomfish complex. Parrotfish ranked fifth, particularly from 1994 to 2001 from the spear fishery. The groupers ranked sixth and came from the bottomfish and mixed troll-bottomfish fisheries.

Interpretation: The overall catch landing trends show some characteristic peaks and troughs that could be explained by changes in the fisheries. The peak in the miscellaneous bottomfish catches from 1986 to 1988 was due to data being lumped into this group because of limited identification skills of the data collection technicians. This skill was refined during the succeeding years. Peaks for surgeonfish and parrotfish from 1994 to 2000 were due to high landings from the spear fishery utilizing SCUBA. The landings declined thereafter due to the implementation of the SCUBA Spearfishing Ban (ASCA 24.0915). The troughs from 1990 to 1992 and in 2005 were brought about by hurricanes (Ofa, Val and Heta) that devastated the fishing fleet.

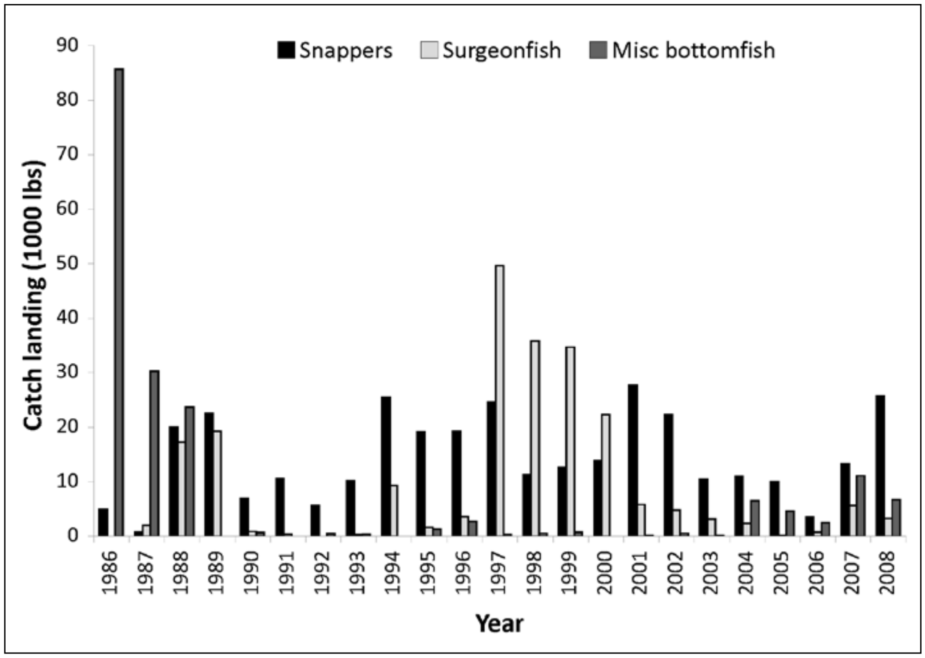


Figure 5. Overall catch landing of the top 1 to 3 species groups in the combined boat-based fishery.

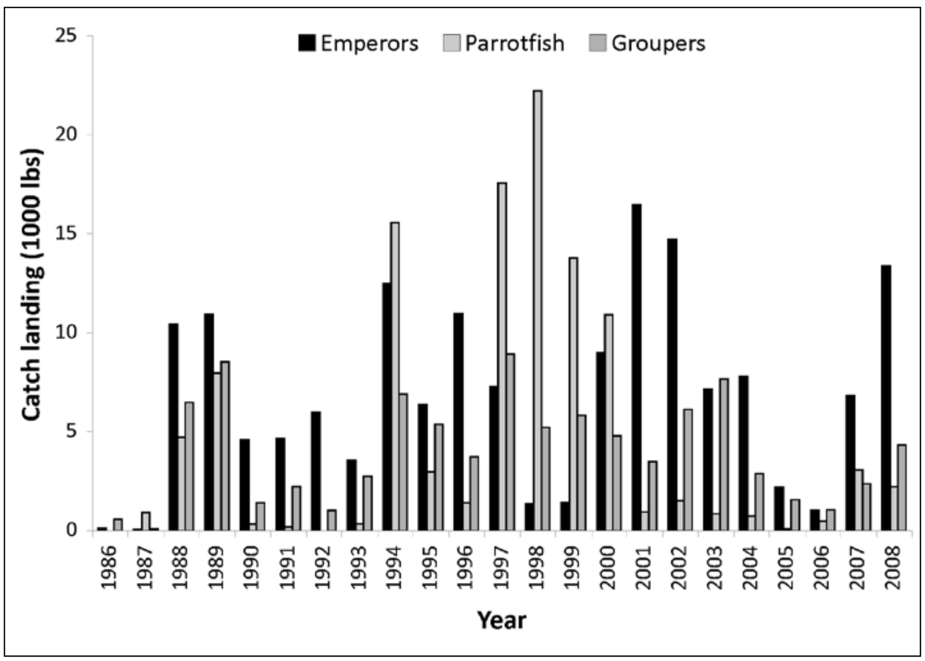


Figure 6. Overall catch landing of the top 4 to 6 species groups with all methods in the combined boat-based fishery.

Catch Landing of Top Species Groups in the Bottomfish Fishery

Calculations: The total catch landing from the bottomfish method was segregated into different coral reef fish families to come up with species group level estimates and derive inferences on the status from the trends over time. Species group level information was derived from the catch interviews. Only the top six species groups, which comprised approximately 91 to 98 percent of the total bottomfish catch, will be discussed.

Trends: Snappers, primarily eteline snappers from the deep bottomfish complex and lutjanids from the shallow water complex, dominated the bottomfish catch. Catch landings for snappers had a series of fluctuations but appeared generally constant over the years. Peak landings in 1994, 1997, 2001 and 2008 accounted for 23,648 lbs; 20,516 lbs; 26,273 lbs; and 24,940 lbs, respectively. Individual species group trends did not deviate from the overall trend in terms of the bottomfish fishery. For example, the peaks and troughs of emperors coincide with the temporal trends in the bottomfish fishery (figure 3). The catch landing appeared constant over the years averaging about 5,904 lbs over a 23-year period. Miscellaneous bottomfish is a category where unidentified species are dumped as well as other bottomfish that were not sampled. After a peak in 1986, landings drastically declined before reemerging in 2000. The average miscellaneous bottomfish landing was around 5,396 lbs almost similar to the emperors landing.

The fourth dominant catch under the bottomfish fishery was groupers, averaging about 2,372 lbs per year over 23 years with the highest landing in 2003 at 7,382 lbs. The catch landings declined after that but has increased in the last two years. The landings for jacks fluctuated over the years but averaged about 1,726 lbs per year with the highest landing in 1997 at 4,018 lbs. Other finfish included species that were not sampled and were the remaining part of the fish cooler from the approximated total weight and number. It averaged about 815 lbs per year with the highest catch landing in 1994 at 3,192 lbs. Interestingly, the trends and patterns in the species groups shown in this time series of bottomfish landing exhibited similar behavior in terms of peaks and troughs indicative of it being a multispecies fishery that may have no preference for a single group of bottomfish stock or the gear is not selective to a particular species group.

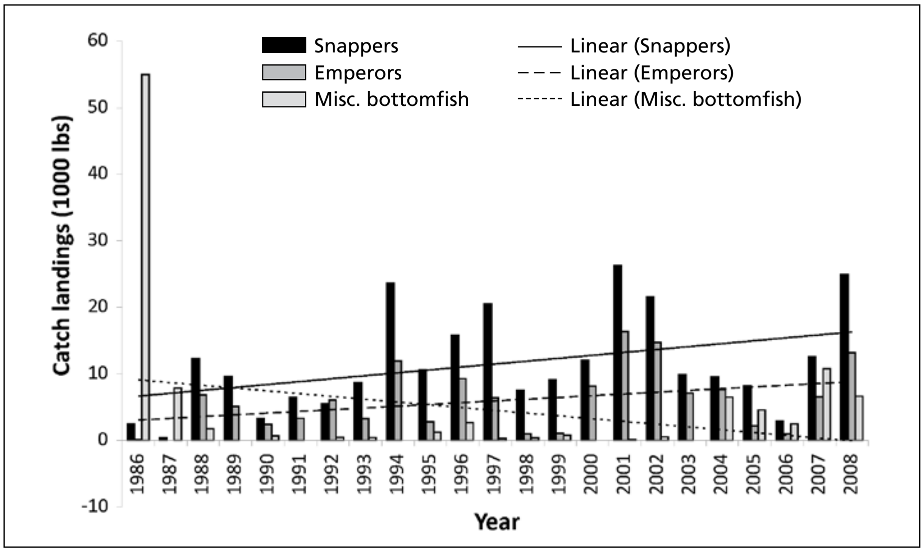


Figure 7. Catch landing of the top 1 to 3 species groups in the bottomfish fishery.

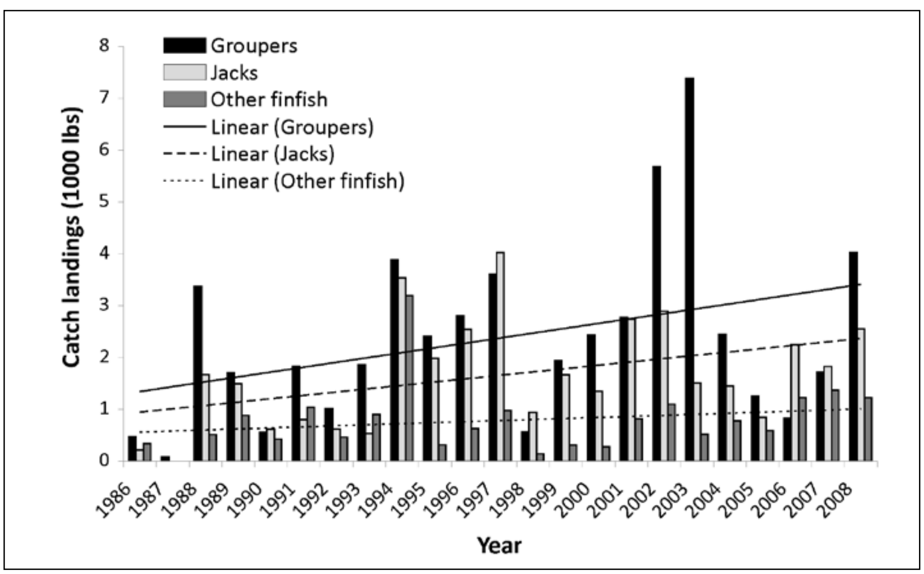


Figure 8. Catch landing of the top 4 to 6 species groups in the bottomfish fishery.

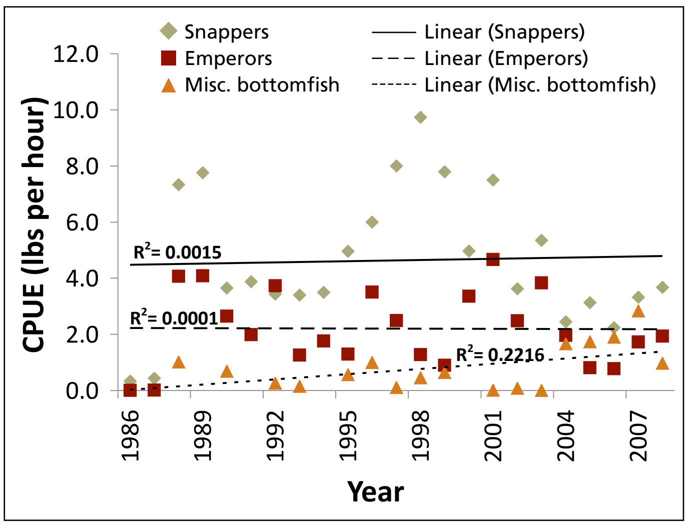
Interpretation: The dominant species groups harvested under the bottomfish fishery are snappers composed of both deepwater (usually eteline snappers) and shallow-water complex (mainly *Lutjanus gibbus* and *L. kasmira*). This fishery has experienced fluctuations in terms of participation. In the late 1980s the majority of the alia fleet shifted to more lucrative longlining while others combined the bottomfish trip with trolling. The characteristic increase in landings in early 2000 was due to a shift from the spear fishery to bottomfish brought about by the ban of the SCUBA spear method. Emperors, groupers and jacks follow the same trend as the snappers indicating that this fishery is non-selective or non-targeting. The pattern in the miscellaneous bottomfish was different and can be attributed to improvements in the identification skills of the data collectors.

Catch Per Unit Effort of Top Species Groups in the Bottomfish Fishery

Calculations: The total effort for the bottomfish fishery was taken from the catch interview phase of the boat-based fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 23-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time to roughly detect any signal of potential overexploitation of stocks.

Trends: The CPUE of snappers fluctuated over the past 23 years with the highest CPUE recorded in 1998 at 9.74 lbs/hr and the average at 4.63 lbs/hr. The emperors had slightly lower CPUEs than the snappers and less variation from the linear trend line. The average CPUE of emperors was 2.2 lbs/hr with the highest CPUE at 4.66 lbs/hr. Higher CPUE were found in the recent years for miscellaneous bottomfish, which reached a peak in 2007 at 2.84 lbs/hr. The CPUE for groupers and jacks followed the same fluctuations over the 23-year time period with an average of 0.99 lbs/hr and 0.75 lbs/hr, respectively. The other finfish averaged about 0.32 lbs/hr.

Interpretations: There was no apparent trend in CPUE over the 23-year period. The R^2 values range from 0.0001 for emperors to 0.2215 for miscellaneous bottomfish. This is indicative of no significant increase or decrease in the CPUE for the bottomfish fishery over the time period examined. The peaks in the CPUE points were cancelled by the points in the troughs.



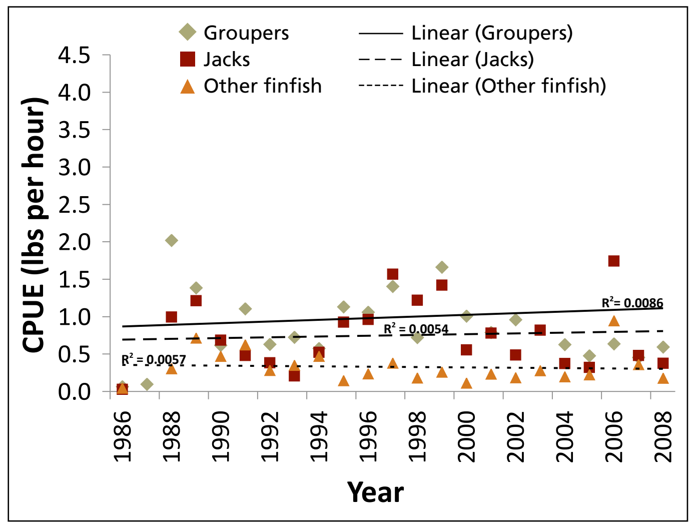


Figure 9. Catch per unit effort (in lbs per hour) of the top 1 to 6 species groups in the bottomfish fishery.

Catch Landing of Top Species Groups in the Boat-Based Spear Fishery

Calculations: The total catch landing from the boat-based spear fishery was segregated into different coral reef fish families to come up with species group level estimates and derive inferences from the trends over time. Species group level information was derived from the catch interviews. Only the top five species groups, which comprise more than 96.7% of the total coral reef spear catches, will be discussed.

Trends: An estimated 493,873 lbs of coral reef fish were landed from 1986 to 2008. Forty-five percent of the

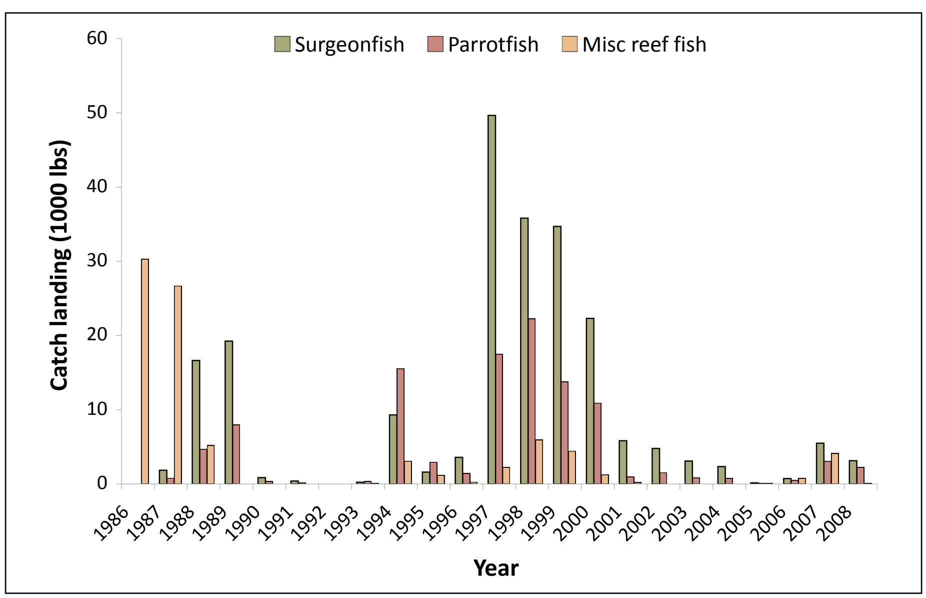


Figure 10. Catch landing of the top 1 to 3 species groups in the boat-based fishery.

landings was comprised of surgeonfish (averaging 10,536 lbs per year), followed by parrotfish making up 22% of the landings (averaging 5,164 lbs per year). The peak landings of surgeonfish and parrotfish occurred from 1987 to 1989 and from 1997 to 2000, which coincide with the introduction of the SCUBA spear method. Miscellaneous reef fishes were mostly dominant during the first two years because data collectors were not trained to identify fish to species level. This group accounted for an average of 5,362 lbs per year making up 17% of the total landed catch. Crustaceans, comprised mainly of slipper and spiny lobsters, made up approximately 8% of the total catch landing with an average of 1,758 lbs per year. Groupers made up merely 5% of the total catch averaging about 1,166 lbs per year. The trends in the crustacean and grouper landings followed the same pattern as the parrotfish and surgeonfish landings with peaks during the SCUBA spear period.

Interpretations: The introduction of the SCUBA spear method allowed for easier access to fish increasing the efficiency in catching with minimal increase in effort. This efficiency resulted in the ban against the use of such method due to high potential in reaching maximum sustainable yield if allowed on longer terms. Surgeonfish and parrotfish are the most abundant species groups on the reef (Green 2002; Sabater and Tofaeono 2007). These are also the preferred fish by the local populace based on recent oral interviews (Kilarski et al. 2005) and archaeological data (Nagaoka 1993). This is indicative that the local fishery somewhat prefers fish species that are readily available and is not selective towards what is rare.

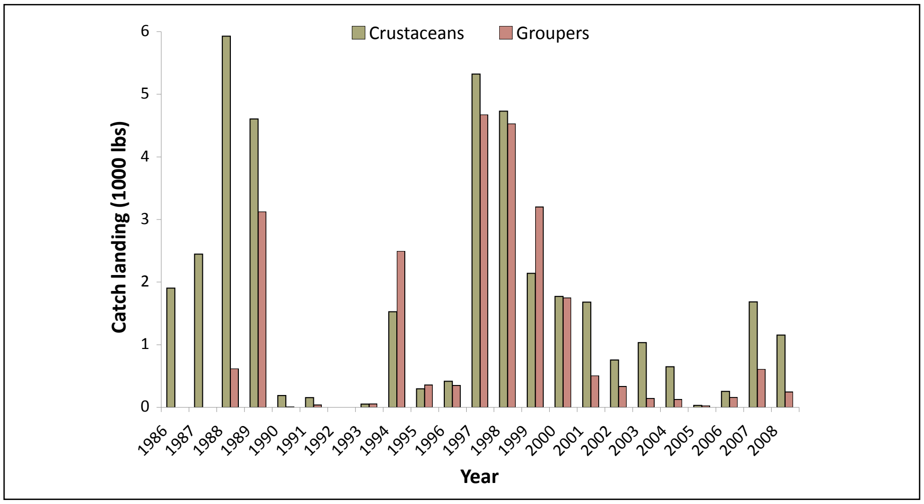


Figure 11. Catch landing of the top 4 to 6 species groups in the boat-based spear fishery.

Catch Per Unit Effort of Top Species Groups in the Boat-Based Spear Fishery

Calculations: The total effort for the boat-based spear fishery was taken from the catch interview phase of the boat-based fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 23-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time and roughly detect any signal of potential overexploitation of stocks. Only the CPUE for surgeonfish, parrotfish, miscellaneous reef fish, crustaceans and groupers are reported.

Trends: The CPUEs for the top three species groups—namely, surgeonfish, parrotfish and miscellaneous reef fish—were relatively constant over 23 years. There was an increase in the CPUEs from 1995 to 2001, during the SCUBA spear period. The rate of increase, however, varied between species groups. The CPUE for surgeonfish had a drastic increase during the introduction of SCUBA in the spear fishery and rapidly declined after reaching a peak in 1997. It remained steady from 1998 to 2002 at roughly 11.5 lbs/hr after which it declined to the current low of 3 lbs/hr. Parrotfish had a slight rise during the SCUBA spear years but not as drastic as surgeonfish, and it did not show an intermediate steady phase after reaching the peak CPUE in 1997. It continued to decrease and was constant at around 3.5 lbs/hr. The miscellaneous reef fish did not manifest such fluctuations as found in surgeonfish and parrotfish.

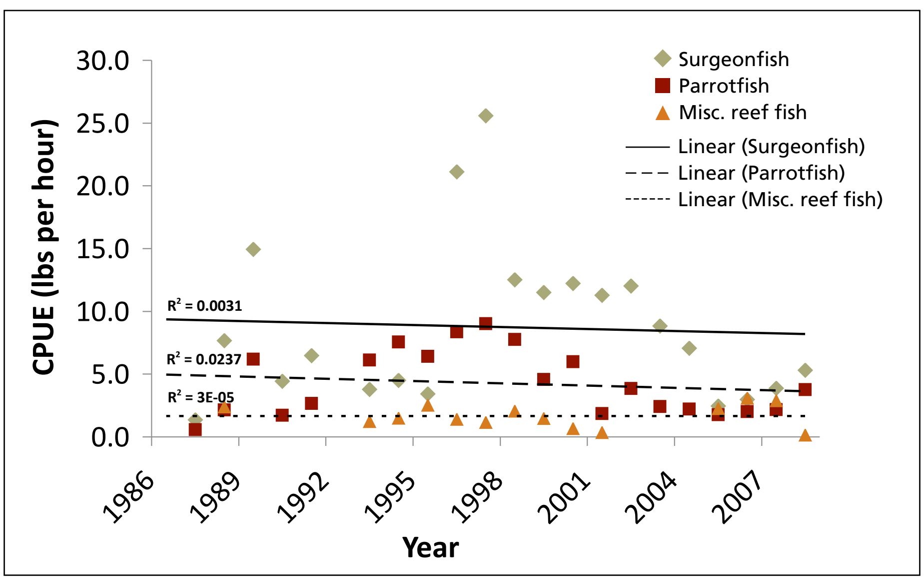


Figure 12. Catch per unit effort (in lbs per hour) of the top 1 to 3 species groups in the boat-based spear fishery.

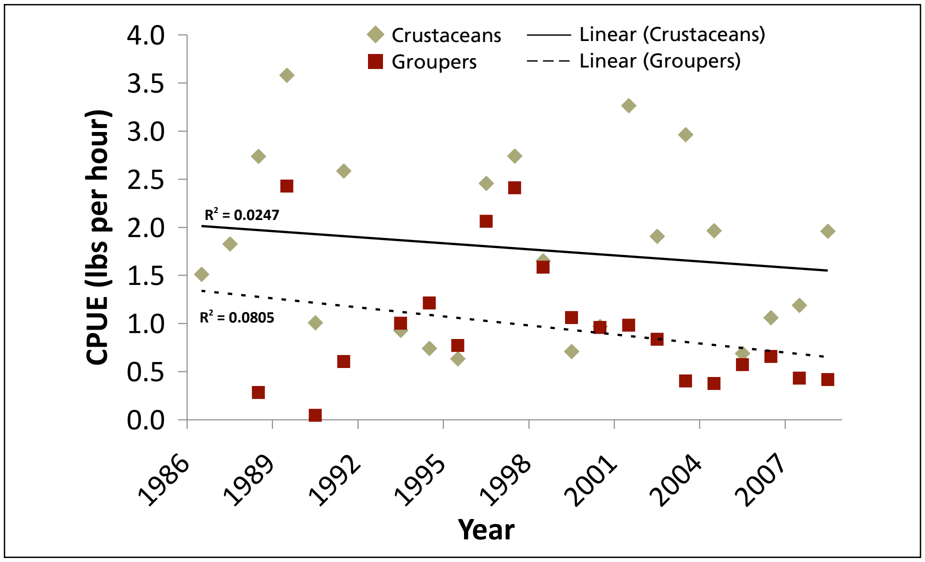


Figure 13. Catch per unit effort (in lbs per hour) of the top 4 to 5 species groups in the boat-based spear fishery.

The lows prior to and after the high during the SCUBA spear period cancelled any long-term effect of SCUBA spear in the overall CPUE trend.

Crustaceans and groupers (figure 13) show a slight decrease in CPUE over the 23-year period. The annual data points for crustaceans, mainly lobsters, fluctuated widely over the years. Groupers showed similar trends as other reef fish with a peak in 1997, a decline thereafter and a low CPUE in recent years.

Interpretations: The patterns in CPUE for the boat-based spear fishery were clearly affected by gear efficiency particularly for coral reef fishes. The increase in CPUE from 1994 to 1998 reflected the use of SCUBA, which allowed fishermen longer time underwater to seek fish and to access deeper populations, thereby increasing their harvesting potential. Without SCUBA, the spear fishermen's time underwater and depth of fishing interaction were limited by how long they could hold their breath. CPUE was low before and after the SCUBA spear period. This pattern, however, does not hold for crustaceans where several peaks in CPUE were found before and after the introduction of SCUBA in the fishery. This pattern can be attributed to the habitat specificity of crustaceans to shallow waters and the patchy distribution of crustacean populations. The lobster population, for example, is mostly found in break areas where SCUBA use is not appropriate.

Catch Landing of Top Species Groups in the Mixed Troll-Bottomfish Fishery

Calculations: The total catch landing from the mixed troll-bottomfish method was segregated into different coral reef fish families to come up with species group level estimates and derive inferences from the trends over time. Species group level information was derived from catch interviews. Only the top six species groups, which account for approximately 84% to 98% of the total mixed troll-bottomfish catch, will be discussed.

Trends: The top six catches, in order of decreasing dominance, are miscellaneous bottomfish, snappers, emperors, groupers, jacks and other finfish. These same species groups dominate the bottomfish fishery. The 23-year catch landing data showed two distinct landing peaks in five out of the six species groups, one in 1989 and the second in 1995. All of the species groups exhibited a gradual decrease in landings thereafter.

The miscellaneous bottomfish landing averaged about 7,051 lbs per year. Note, however, that this average was related to the lack of higher resolution in species identification during the initial years of the time series. The snappers averaged about 2,889 lbs per year and attained its highest landing in 1989 at 12,157 lbs. The emperors showed the same trend, peaking in 1989 at 3,498 lbs and averaging about 946 lbs per year. Similarly, groupers and other finfish had the highest landings in 1989 at 3,696 lbs and 1,951 lbs, respectively. Groupers averaged about 659 lbs per year while other finfish averaged roughly half of that value. Jacks had generally the same trend as the other species groups but peaked in 1995 at 3,233 lbs and averaged 659 lbs per year.

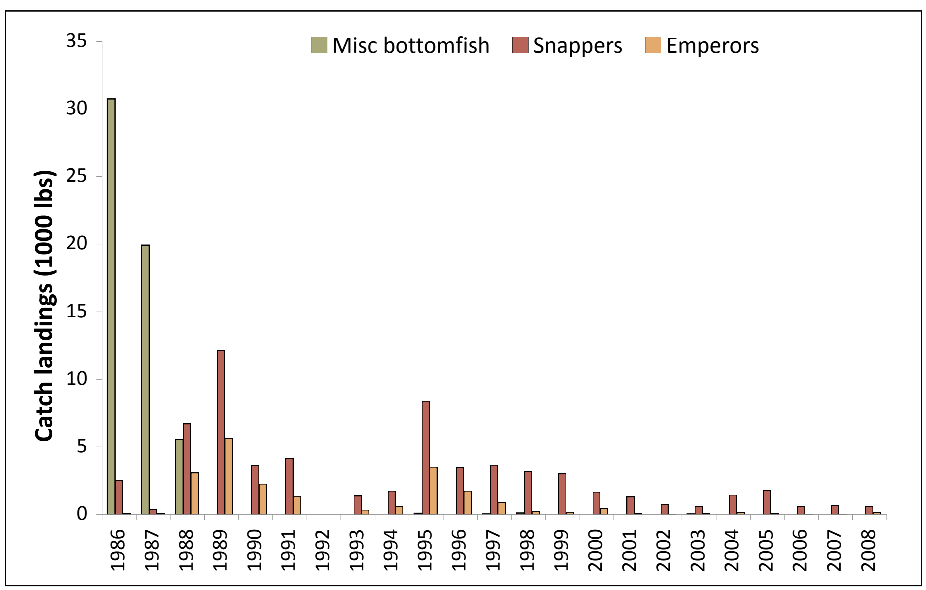


Figure 14. Catch landing of the top 1 to 3 species groups in the mixed troll-bottomfish fishery.

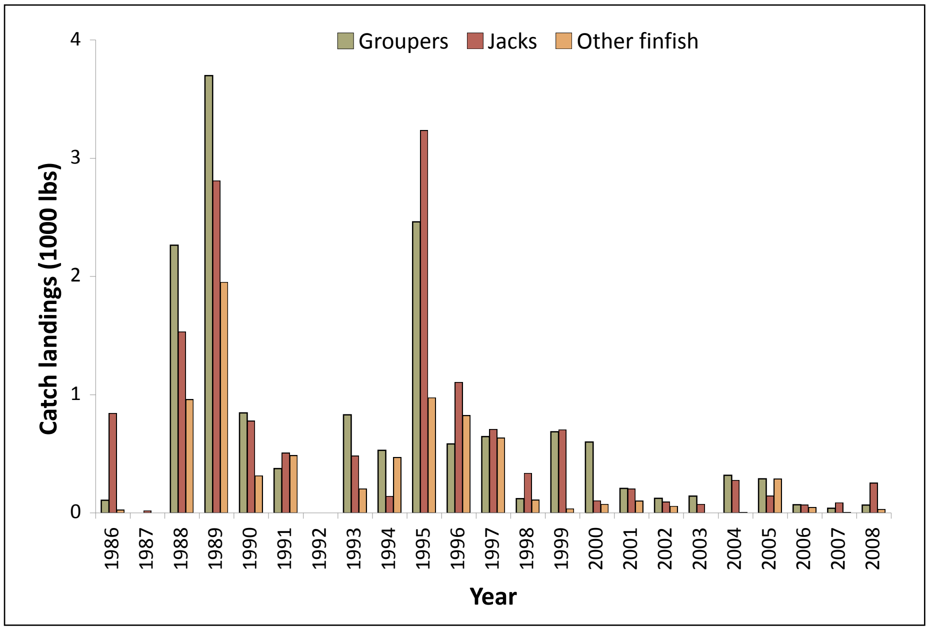


Figure 15. Catch landing of the top 4 to 6 species groups in the mixed troll-bottomfish fishery.

Interpretation: The trend in the miscellaneous bottomfish is attributed mainly to the inability of the staff to identify the species during the early years of the time series. Most of the bottomfish were dumped under the miscellaneous bottomfish bin during this period. Measures to improve the data collection method were subsequently made as seen in the data where the miscellaneous bottomfish landings decreased and the landings for the other species groups increased. The level of catches for the mixed troll-bottomfish fishery has declined in the past decade for snappers, emperors, groupers and jacks. This period coincides with the resurgence of the bottomfish fishery.

Catch Per Unit Effort of Top Species Groups in the Mixed Troll-Bottomfish Fishery

Calculations: The total effort for the mixed troll-bottomfish fishery was taken from the catch interview phase of the boat-based fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 23-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time and roughly detect any signal of potential overexploitation of stocks. Only the CPUE for snappers, emperors, groupers and jacks are reported. The miscellaneous bottomfish and other finfish categories are too broad in terms of trying to infer the status or changes in the stock or species complex and, therefore, are not reported.

Trends: The CPUE trend for snappers in the mixed troll-bottomfish fishery has been increasing over 23 years with an R^2 of 0.2934. The CPUE peaked in 2000 at 10.8 lbs/hour and was lowest in 1987 at 0.13 lbs/hr. This was attributed to the mixed troll-bottomfish fishery

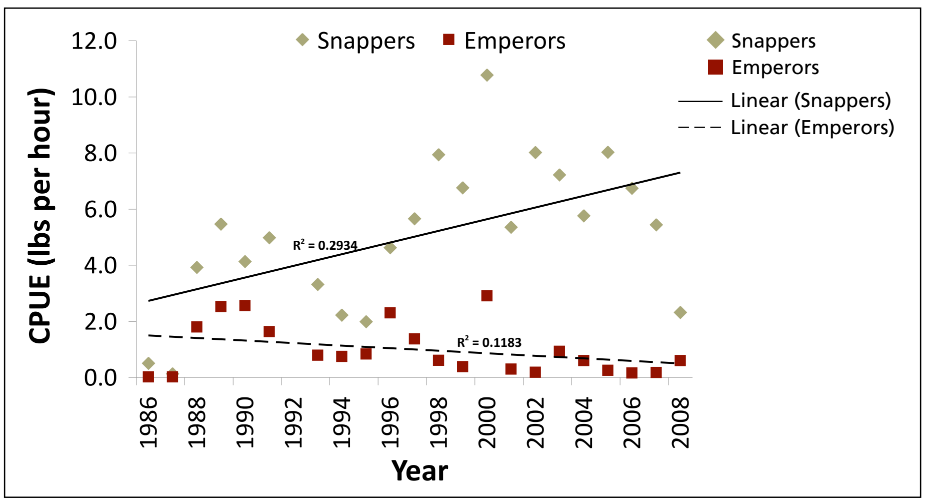


Figure 16. Catch per unit effort (in lbs per hour) of the top 1 and 2 species groups in the mixed troll-bottomfish fishery.

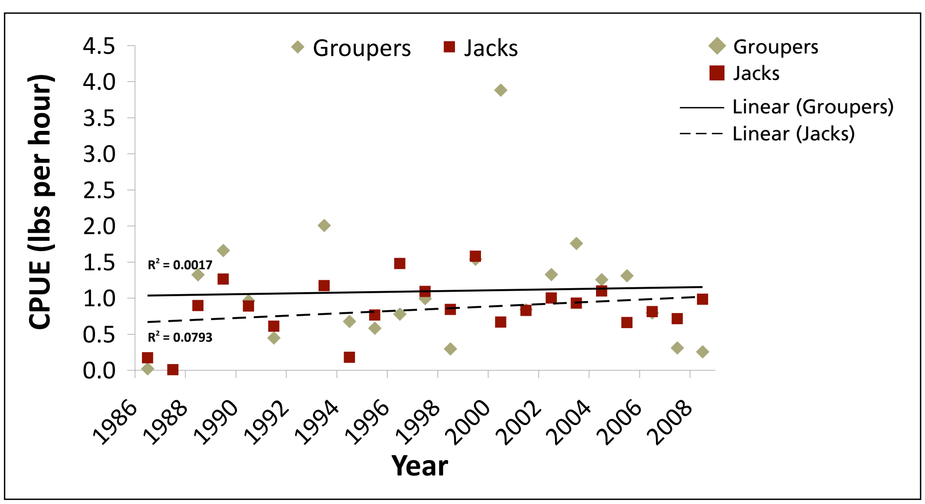


Figure 17. Catch per unit effort (in lbs per hour) of the top 3 and 4 species groups in the mixed troll-bottomfish fishery.

shifting to longline. The emperor CPUE showed a negligible decrease over 23 years. The emperor CPUE peaked in 2000 at 2.9 lbs/hr and was lowest in 1987 at 0.0143 lbs/hr. The CPUE for emperors was consistently lower than snappers.

Groupers are mostly caught using the bottomfish gear. The grouper CPUE has been constant over the years. It peaked in 2000 at 3.8 lbs/hr and was the lowest in 1986 at 0.02 lbs/hr. The same held true for jacks. The CPUE trend has been relatively constant to slightly increasing with the peak CPUE in 1996 at 1.48 lbs/hr and lowest CPUE in 1987 at 0.0071 lbs/hr. Jacks are mostly caught by the troll method; however, deepwater jacks, particularly black jacks and giant trevally, are caught with bottomfish gear.

Interpretations: The CPUE pattern showed some degree of fluctuation at five-year intervals. Nonetheless, the CPUE of emperors, groupers and jacks showed no apparent trend. However, the snappers had a noticeable increasing trend over the long term. This can probably be attributed to the fact that, in this mixed method fishery, snappers is the dominant catch by the bottomfish method, which uses less effort (i.e., time) than trolling.

Overall Catch Landing by Shore-Based Fishing Methods

Calculations: Landings taken from the interview phase of the shore creel fishery data collection were segregated to the different fishing methods known to extract coral reef fishes and other marine resources. No data are presented for 1997 to 2001 because the shore-based surveys during this period were conducted using various methods that were not comparable to the existing data. Therefore, they were not integrated into the database.

Trends: The average landing by the shore-based fishery was dominated by the spear method, which averaged 23,035 lbs over a 19-year span. The spear data presented is a combination of both SCUBA- and snorkel-assisted spear landings. The data from 1990 to 1994 was mostly snorkel spear. SCUBA spear was introduced in 1994 and persisted until the ban in 2002. The catch landing from the shore-based spear fishery declined during the predominantly boat-based SCUBA spear period. Catch landing increased again after the ban was implemented. The fishery has landed only snorkel spear catches from that time until present. Landings spiked in 2008 at 87,171 lbs.

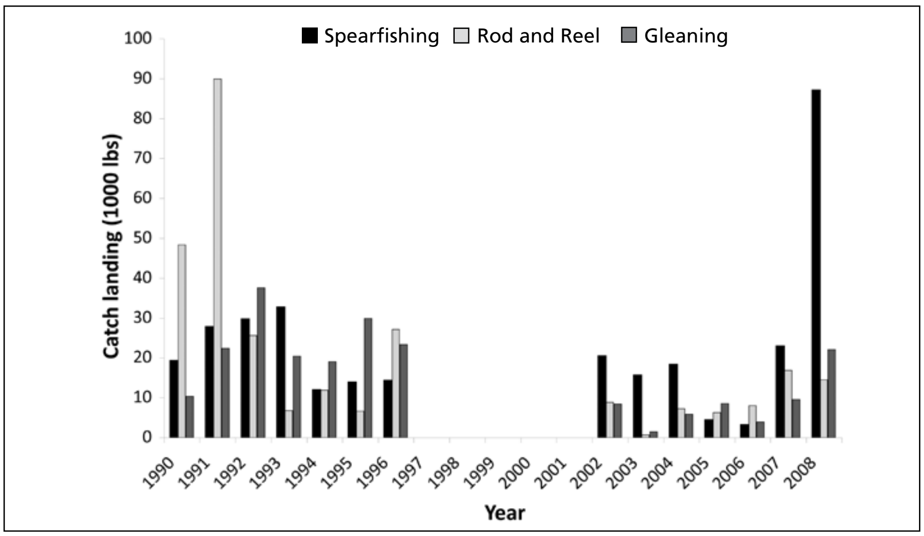


Figure 18. Overall catch by shore-based spear, rod and reel, and gleaning methods from 1990 to 2008.

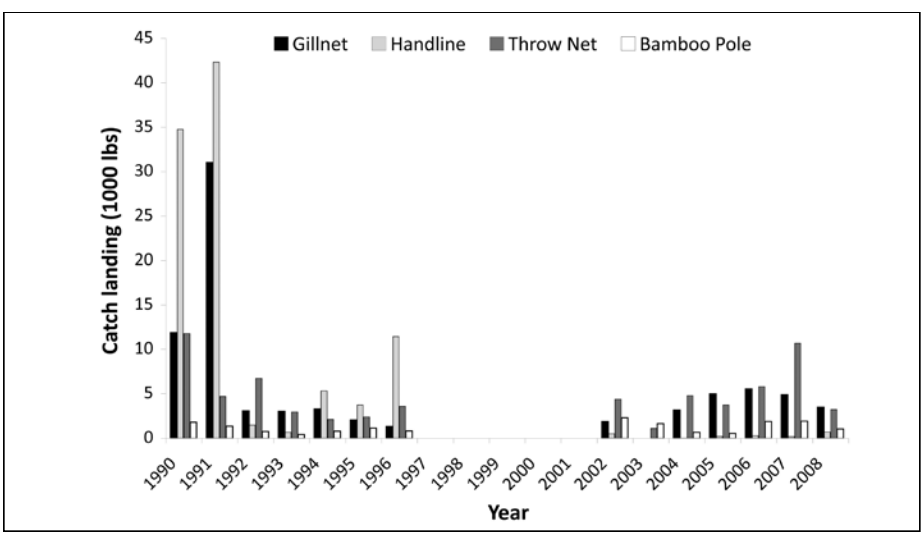


Figure 19. Overall catch by gillnet, handline, throw net and bamboo pole methods from 1990 to 2008.

The rod-and-reel method landed a 19-year average of 19,983 lbs of reef fish. It was a dominant fishing method in the early 1990s and, in recent years, landed approximately 7,000 lbs. The landings in 2007 and 2008 were an order of magnitude higher than the five preceding years.

Gleaning is a regular fishing method employed by common village folks harvesting octopus and shellfish. It landed a long-term average of 16,003 lbs. Landings were higher in the 1990s than in recent years.

Gillnet was categorized into two types: active and passive. Passive gillnet was dominant in the 1990s while active gillnet was common in recent years. Passive gillnets landed an average of 7,939 lbs while active gillnets landed approximately half of that at 3,420 lbs.

Handline was also popular in the 1990s, but virtually no one in the shore-based fishery uses this method at present. This method landed a long-term average of 7,831 lbs per year.

Throw net landings were almost constant over the long term, landing an average of 4,881 lbs, while the traditional bamboo pole method landed an average of approximately 1,208 lbs.

Interpretation: The trend for the shore-based fishery was affected by the introduction of SCUBA to the boat-based spear fishery. Landings of coral reef fish were high in the shore-based fishery during the period when the snorkel spear method was solely used and declined after SCUBA was introduced. This is indicative of the fishery shifting to a more efficient method of harvesting reef fish. The decline in the shoreline spear landings coincided with the significant increase in boat-based spear landings. After the ban on the SCUBA spear method, the landings of reef fish from the shore-based spear fishery increased.

The 2008 spike in landings is an artifact of the expansion of a low number of catch-and-effort interviews.

The fishermen interviewed had a high harvest; thus the expansion was blown out of proportion.

The trends in the rod-and-reel and gleaning fisheries, where more landings were in the 1990s than in recent years, could be indicative of less participation in the fisheries. This can also be attributed to a shift in the nature of the fishery from subsistence to more recreational given that the population is moving towards seeking paid employment rather than engaging in fishing activities (Kilarski et al. 2006; Levine and Allen 2009; Sabater and Carroll 2009).

A shift within a gear type was also seen in the gillnet fishery. Initially a passive gear, it evolved into a more active gear where the fishermen stay with the gear and actively harvest the catch. Interestingly, the passive gillnet yielded more catch than the active gillnet probably due to the variations in the number of hours the nets are soaked.

Throw net is considered as an active gear where the fishermen actively seek large schools of fish. While hit and miss, it appears to have regular landings of reef fish each year.

Traditional fishing gears like handline and bamboo pole had the least landings, possibly due to fewer people engaging in these fisheries. Elderly fishermen who were interviewed indicate that the current generation is less interested in using traditional fishing methods (Levine and Allen 2009).

Overall Shore-Based Catch Landing by Species Groups

Calculations: Catch was extracted from the shore creel database of the WPacFIN. The overall catch per species group was derived by aggregating shore-based fishing methods (gleaning, SCUBA and snorkel spear, rod and reel, active and passive gillnet, throw net, bamboo pole and handline). Note: No data was available for expansion from 1997 to 2001

Trends: Atule (*Selar crumenopthalmus*, or bigeye scad) dominated the shore-based catches from 1990 to 1992 and declined thereafter. This was followed by mollusks, particularly giant clams and turbo shells, which dominated the shore-based catches from 1993 to 1996. In recent years, surgeonfish almost equaled the mollusks landings. Surgeonfish is a common catch from the spear fishery. It reached a first peak in 1992, had relative constant landings from 2002 and peaked again in recent years. These are mostly dominated by *Ctenochaetus striatus* and *Acanthurus lineatus.*

The fourth dominant species group among the shore-based catches is jacks from the rod-and-reel fishery. The catch peaked in 1991 and had a steady decline thereafter reaching a secondary peak in 1996. Catch records showed a third peak in recent years, particularly in 2007. Parrotfish is a dominant group targeted by the spear fishery. The catch was relatively constant from 1990 to 1996 and suddenly increased in 2008 to 28,771 lbs. Gleaning for invertebrates like octopus, sea cucumber and sea urchin was high in 1991 and 1992 and was no longer a dominant activity in recent years.

Interpretation: The traditional atule fishery is considered a hit-and-miss fishery. Some years it has very high catches, and most years it has very low catches. This trend reflects the nature of the fish. A transient pelagic species, atule comes into the reef in large schools to spawn for a couple of days and disperses after the aggregation. Landing patterns also appear to be affected by participation of the locals in this fishery. The traditional ways of fishing are currently limited to the older individuals. According to interviews with elderly fishermen in American Samoa, the present generation no longer practices traditional forms of fishing (Levine and Allen 2009).

Gleaning for mollusks often occurs during spring tide. This is a regular activity being conducted by villagers more frequently during the 1990s and less extensively in recent years.

The highest landings of surgeonfish occurred in years prior to and after the SCUBA spear period of 1994 to 2001. This was indicative of shifting of fishing preference to a more efficient gear type. After the SCUBA spear ban, the catch landings returned to levels before the gear was introduced.

This pattern was almost similar to the parrotfish landings. The peak in 2008 will be investigated further as it could have been influenced by the expansion of a low number of catch and effort interviews.

Jacks and invertebrates had high landings in the early to mid 1990s. Rod and reel fishing for jacks and gleaning for invertebrates are conducted during spring tides.

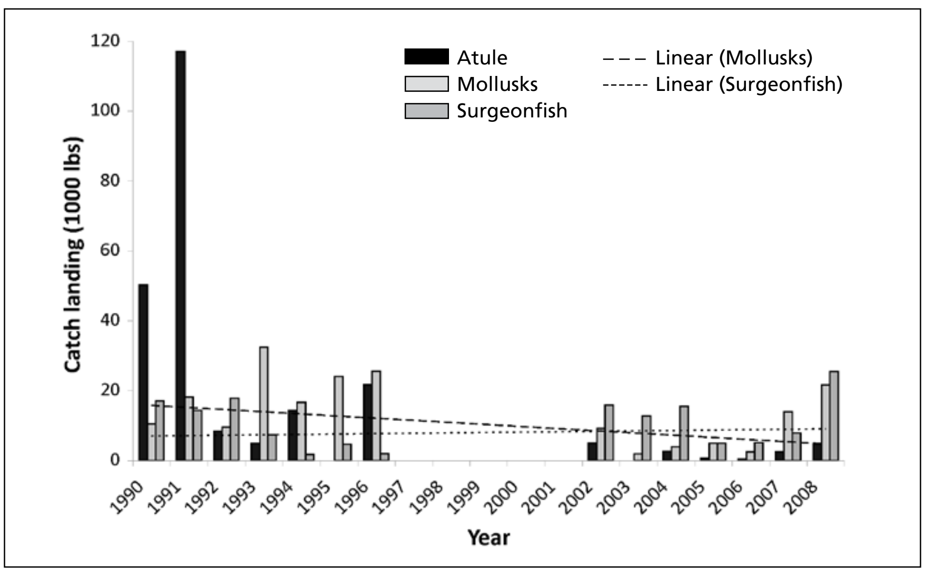


Figure 20. Overall catch landing of the top 1 to 3 species groups with all methods combined in the shore-based fishery.

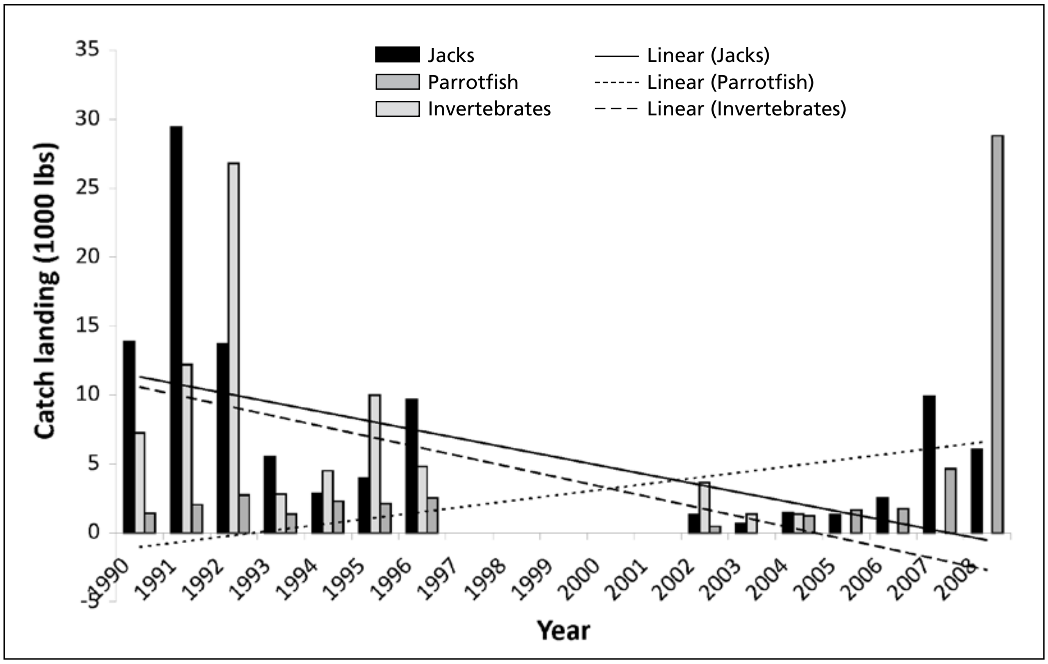


Figure 21. Overall catch landing of the top 4 to 6 species groups with all methods combined in the shore-based fishery.

Catch Landing of Top Species Groups in the Gillnet Fishery

Calculations: The total catch landing from the gillnet method was taken from the catch interview phase of the WPacFIN shore-based fishery data collection. This was segregated into different coral reef fish families to come up with species group level estimates and derive inferences from the trend over time. Only the top four species groups are discussed as they accounted for more than 92.2% of the total coral reef gillnet catches. No data is presented for 1997 to 2003 as regular creel surveys were not conducted during this period due to lack of funding. Shore-based creel survey reports were conducted by contract researchers in DMWR, however, they were not incorporated in the WPacFIN database. The graph shows a combined passive and active gillnet trend. The data shown in 1990s were from passive gillnets where the gear was deployed and left overnight, gathering fish in the process. The data shown in the mid to late 2000s were active gillnets where the fishermen actively tended their nets and removed catches as they came.

Trends: Atule dominated the passive gillnet fishery with the highest landing in 1991 at 29,458 lbs, which accounted for 59% of the total catch. This was probably timed with a strong atule run. Mullets made up 18% of the total catch in the gillnet fishery, with an estimated 1,033 lbs landed per year. Mullets had a peak landing in 1990 at 9,497 lbs. Surgeonfish and parrotfish made up 15% and 8% of the total catch landing, with approximately 807 lbs and 431 lbs, respectively. Active gillnets catch mostly these species groups.

Interpretations: Gillnet is a nominal shoreline fishing method compared to rod-and-reel, spear and gleaning. This method landed an average of 4,185 lbs of reef fish per month. This method was observed to be deployed during periods with special occasion in the village, such as funerals, village feasts and weddings. Currently, the gillnet fishery is very inactive.

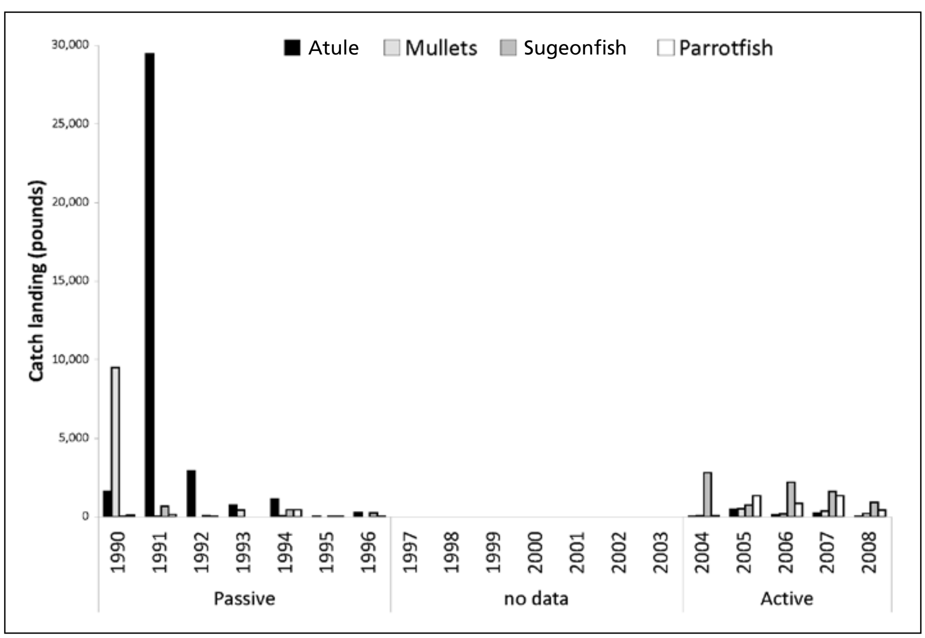


Figure 22. Catch landing of the top 1 to 4 species groups in the gillnet fishery.

Catch Per Unit Effort of Top Species Groups in the Gillnet Fishery

Calculations: The total effort for the shoreline gillnet fishery was taken from the catch interview phase of the creel (shore-based) fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 19-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time to roughly detect any signal of potential overexploitation of stocks as evidenced by a long-term decrease in CPUE (a scenario where the catch decreases with increasing effort). Only the CPUE for surgeonfish, parrotfish, mullets and atule are reported.

Trends: The trends shown in figure 23 may have been influenced by the change in the nature of the gillnet fishery from active gillnets from the early to mid 1990s to passive gillnets from the mid to late 2000s. The catchability levels of both nets were assumed to be similar since the difference between active and passive gillnets is merely the presence of the fishermen tending the nets. Mullets and atule show a decreasing CPUE. High CPUEs were recorded for mullet in 1990 and for atule in 1991 and 1992. Recent years show very low CPUEs for both. In contrast, surgeonfish and parrotfish show an increase in CPUE over time. Parrotfish had shown a smooth linear increase (R^2=0.561) whereas surgeonfish had a high CPUE recorded in 2004.

Interpretations: Surgeonfish, parrotfish and mullets are the dominant fishes on the reef flats where gillnets are deployed. Atule is a coastal pelagic species that occur in huge numbers depending on the strength of the aggregation pulse. Mullets also occur in schools in areas with sand bottom substrates. The decreasing CPUE of atule could be due to the high amount of effort during the aggregation runs.

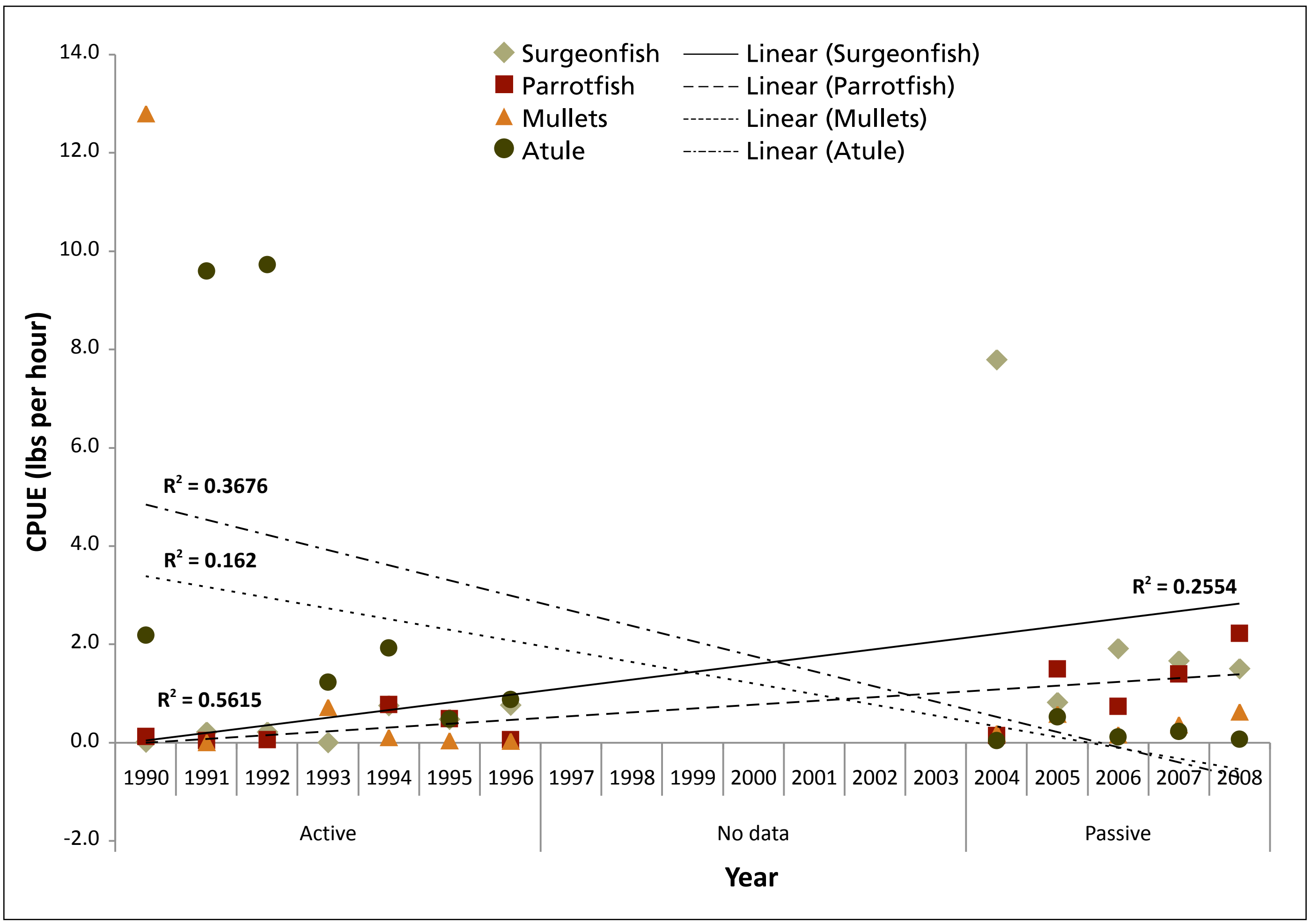


Figure 23. Catch per unit effort (in lbs per hour) in the gillnet fishery.

Catch Landing of Top Species Groups in the Gleaning Fishery

Calculations: The total catch landing from the gleaning method was segregated into different species groups to come up with group level estimates and derive inferences from their trends over time. Group level information was derived from the catch interviews. Only the top three species groups are discussed as they account for more than 92.2% of the total coral reef gleaning catches. No data is presented from 1997 to 2003 as regular creel surveys had not been conducted due to lack of funding and the shore-based creel surveys conducted by contract researchers in DMWR were not incorporated in the WPacFIN database as they were incomparable.

Trends: Mollusks, such as turbo shells and giant clams, dominated the gleaning catches from the near-shore coral reef fishery. This species group made up 71% of the total landing. Mollusk catches averaged 9,940 lbs per year peaking at 20,056 lbs in 2008. The lowest landing was recorded in 2006 at 1,581 lbs.

Invertebrates include octopus, sea cucumbers, urchins and other invertebrates not identified by the data collector. Invertebrate landings were minimal in the past decade as compared to the 1990s. The peak of invertebrate landings was in 1992 at 26,341 lbs. Invertebrate landings averaged about 6,488 lbs per year making up 16.5% of the total catch.

Crustaceans landed by the shore-based fishery were mostly lobsters and mantis shrimp. Very minimal landings occurred in the previous decade. Some crustacean landings were recorded in early to mid 1990s. The peak was in 1994 at 2,408 lbs. Crustacean landings averaged about 738 lbs per month making up merely 4% of the total catch

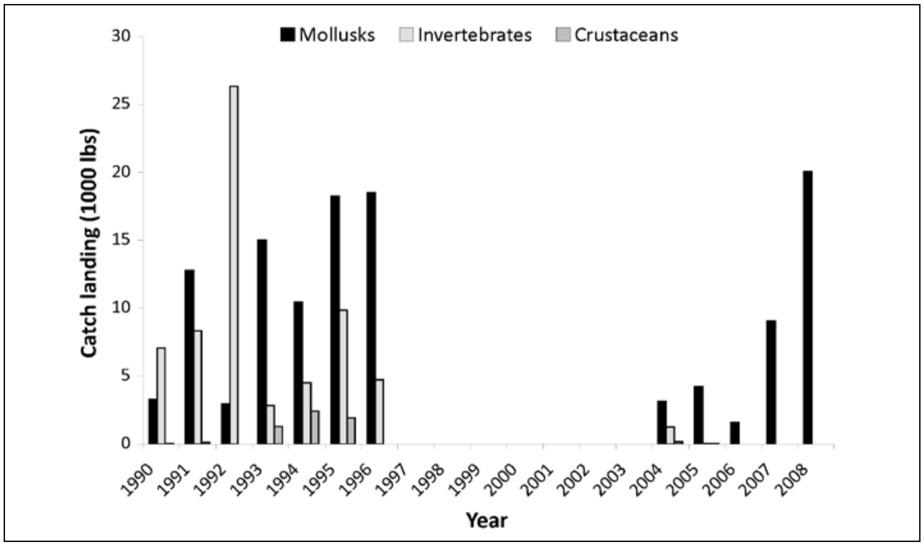


Figure 24. Catch landing of the top 1 to 3 species groups in the gleaning fishery.

Interpretations: Gleaning activities were mostly conducted during low tide. Best gleaning conditions are during spring tide where the water recedes to its lowest level exposing more reef area. This makes this fishery intermittent and exploitive only during selective periods. Much of the gleaning activities were conducted during the 1990s. With increasing opportunities for locals to enter paid labor, fishing effort has declined over the years thereby resulting in decreased gleaning activities.

Catch Per Unit Effort of Top Species Groups in the Gleaning Fishery

Calculations: The total effort for the shoreline gleaning fishery was taken from the catch interview phase of the creel (shore-based) fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 19-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time and roughly detect any signal of potential overexploitation of stocks as evidenced by a long-term decrease in CPUE (a scenario where the catch decreases with increasing effort). Only the CPUE for mollusks, invertebrates and crustaceans are reported.

Trends: There was no notable change in the trend of crustaceans CPUE over a 19-year timeframe. The highest calculated CPUE was in 1994. The invertebrates, however, showed a decrease in CPUE. This would include octopus, sea cucumbers and sea urchins. Octopus is the primary target for this fishery. The highest CPUE was recorded in 1992 and lowest in 2005. Conversely, the CPUE for mollusks increased over time with the peak in 2008 and lows in 1992 and 2006. The mollusks group includes turbo shells and giant clams.

Interpretations: The CPUE trends varied among the different harvested groups in the gleaning fishery. The crustacean fishery was very patchy with fewer fishermen entering this fishery. Most people harvest octopus (invertebrate species group) particularly during low tide. The decline in the invertebrate CPUE may be reflective of fishery decline coupled with habitat degradation brought about by land-based sources of pollution or trampling due to the nature of the fishery. On the other hand, mollusk harvest rates were increasing over the years probably due to more harvest of smaller gastropods and less of the giant clams. Giant clams have been reported as overharvested, and this has been taken as a fact even without any proper stock assessment. Gleaning of mollusks is a popular activity during low tide for not only professional fishermen but also those harvesting for recreational and subsistence purposes.

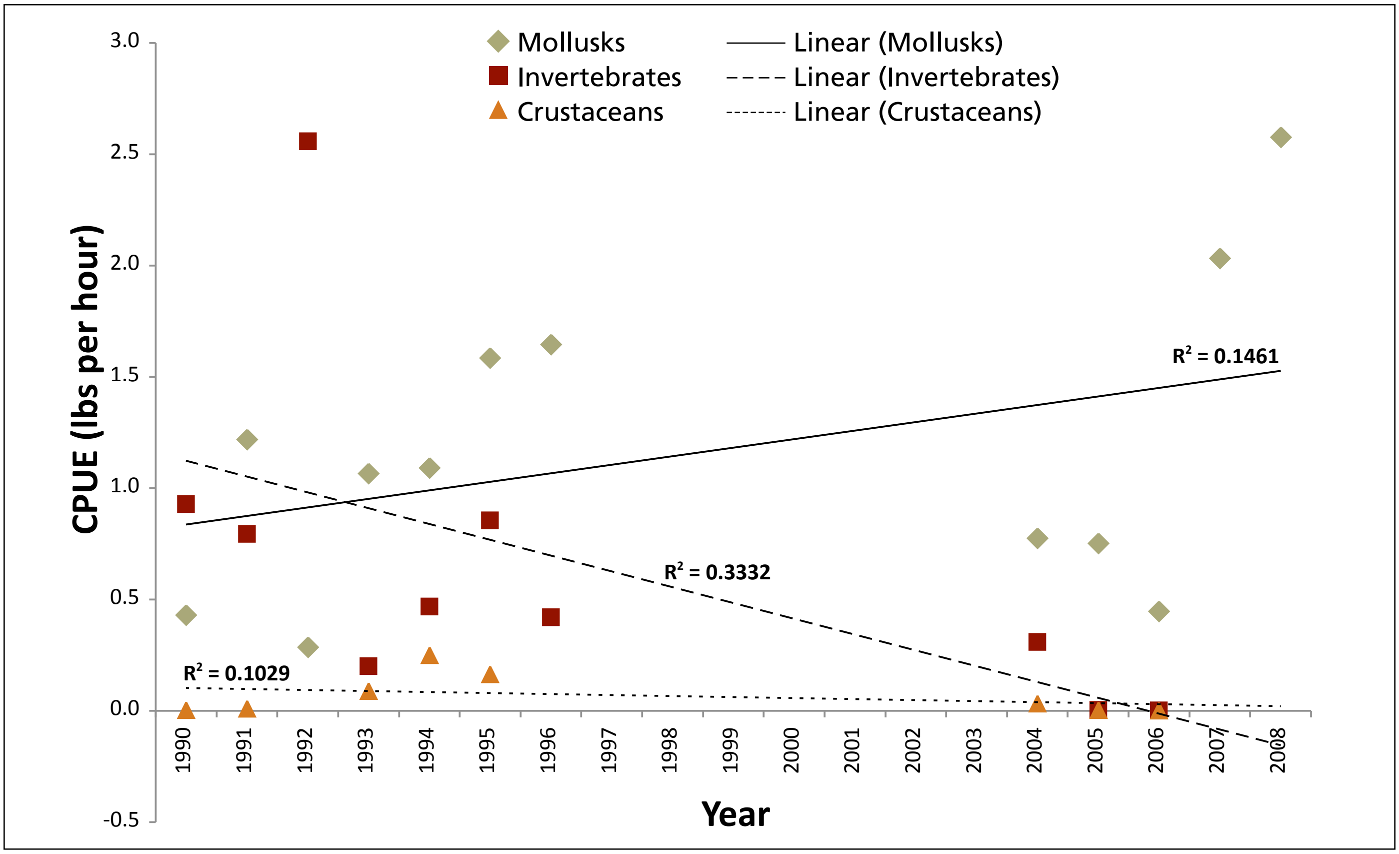


Figure 25. Catch per unit effort (in lbs per hour) in the gleaning fishery.

Catch Landing of Top Species Groups in the Rod and Reel Fishery

Calculations: The total catch landing from the rod-and-reel method from the shore-based fishery was segregated into different coral reef fish families to come up with species group level estimates and derive inferences from their trends over time. Group level information was derived from the catch interviews. Only the top four species groups are discussed as they make up more than 89.3% of the total coral reef rod-and-reel catch. No data is presented for 1997 to 2003 as regular creel surveys were not conducted during this period due to lack of funding. The available shore-based creel survey reports conducted by DMWR contract researchers during this period were not comparable to existing data and were not incorporated into the WPacFIN database.

Trends: Atule dominated the rod-and-reel catch during the early 1990s reaching a peak in 1991 at 51,015 lbs. Two other peaks occurred in 1990 and 1996, landing approximately 32,774 lbs and 12,684 lbs, respectively. The annual landing for atule was roughly 11,611 lbs and accounted for 45.6% of the total rod-and-reel catch over a 19-year period.

Jacks made up 29.2% of the total catch landing, with an average of 6,189 lbs annually. Higher landings were recorded in early to late 1990s. In recent years, landings have been minimal, except in 2007 when 9,366 lbs were landed by rod and reel.

Squirrelfish catches were predominant in 1992 and 1996, with landings of 9,416 lbs and 4,916 lbs, respectively.

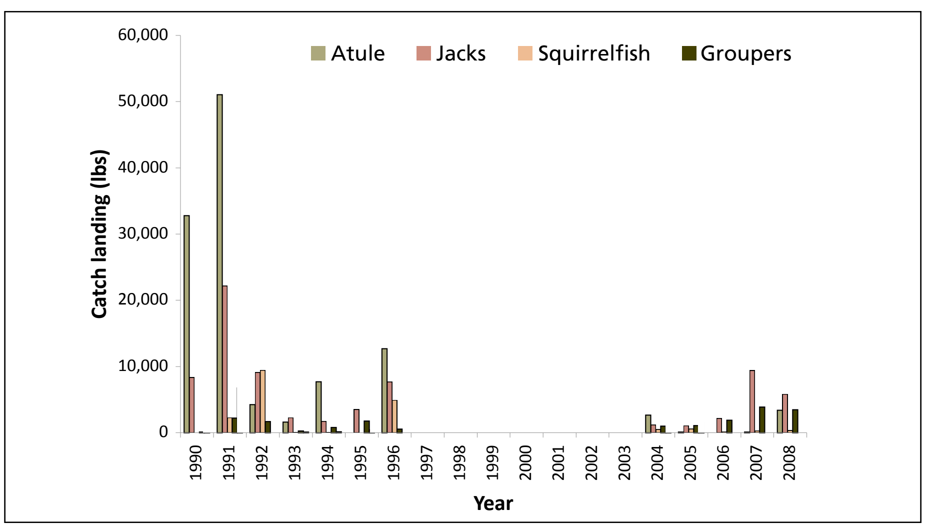


Figure 26. Catch landings of the top 1 to 4 species groups in the rod and reel fishery.

This species is nocturnal, and the landings reflect the fishing patterns existing in this fishery. These catches make up 7.3% of the total rod-and-reel catch, with an average of 1,853 lbs per year.

Grouper landings averaged 1,534 lbs per year, contributing almost equally with squirrelfish in terms of total landing. Grouper catches have been more predominant in recent years with the peak landing occurring in 2007 at 3,871 lbs.

Interpretations: The rod-and-reel fishery in American Samoa has experienced a decline in fishing effort over the years because most of the subsistence fishermen are opting for paid employment over a subsistence lifestyle. This is evident in the low landings in recent years compared to past years. The fishery may have shifted from purely subsistence to recreational fishing. The recent five-year average landing in this fishery is an order of magnitude higher than in the gillnet and handline fisheries and two orders of magnitude higher than the bamboo pole fishery but two times less than the gleaning fishery.

The rod-and-reel fishery also showed a transition from a night time fishery to a day fishery. This is evident in the catches of squirrelfish. There were more squirrelfish landing in the 1990s than recent years. Squirrelfish are nocturnal animals. Higher landings in the 1990s indicate that fishermen went out to fish at night, and low to no catches in the recent years indicate that fishermen no longer go out at night to fish.

Catch Per Unit Effort of Top Species Groups in the Rod and Reel Fishery

Calculations: The total effort for the shoreline rod-and-reel fishery was taken from the catch interview phase of the creel (shore-based) fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 19-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time and roughly detect any signal for potential overexploitation of stocks as evidenced by a long-term decrease in CPUE (a scenario where the catch decreases with increasing effort). Only the CPUE for atule, jacks, squirrelfish and groupers are reported.

Trends: Generally, the CPUE for this shore-based fishery appears to be declining except for groupers. Atule had a significant decline in CPUE with the peak in 1991.The data points are patchy since this is a pulse fishery. Squirrelfish also had a declining CPUE possibly related to the shift in the nature of the fishery in general combined with the biology of the species. Jacks appeared to have a constant to slightly declining CPUE. The peak CPUE was attained in 1992, and the lowest CPUE was recorded in 2004. Conversely, groupers experienced an increasing CPUE over the 19-year timeframe. The highest CPUE was

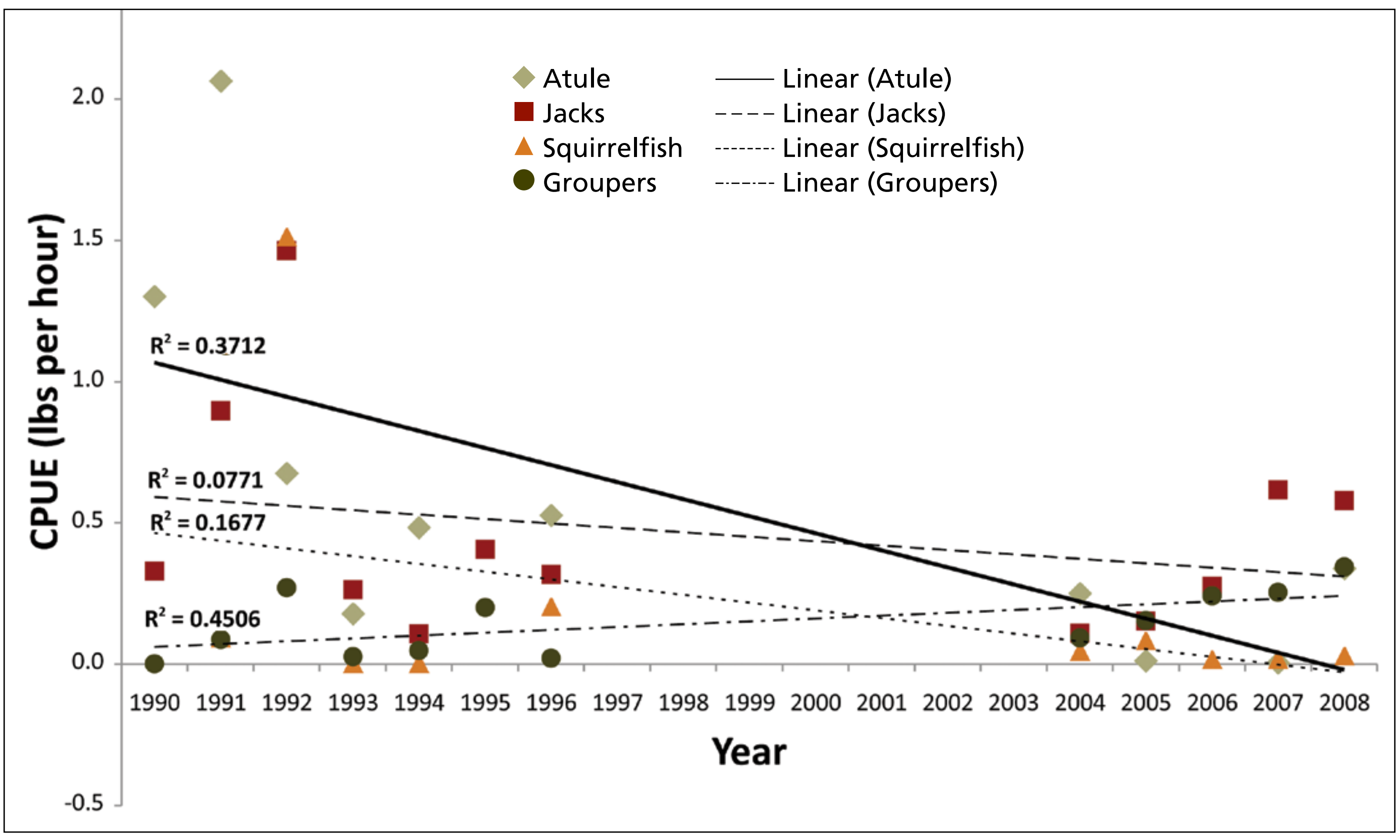


Figure 27. Catch per unit effort (in lbs per hour) in the rod and reel fishery.

recorded in 2008 and lowest in 1990. The highest CPUE was recorded in 2008 and lowest in 1990.

Interpretations: The atule CPUE trend can be attributed to the fact that this is a transient coastal pelagic species where the level of the landing is dependent on the strength of the pulse aggregation run. Atule is a fast-growing, short-lived species with high recruitment rates and large fluctuations in its aggregation.

The decline in the squirrelfish CPUE can be attributed to the shift in the timing when the rod-and-reel method is being used. In the past, this method was commonly practiced during dusk and dawn. In recent years, this method is practiced during the daytime. Because squirrelfish are nocturnal, they are not being caught when most rod-and-reel fishing is occurring recently. In comparison, in earlier years, there was a higher potential for interaction due to the timing of the fishing activity then.

The CPUE for jacks has been relatively constant. Its occurrence in the shallow-water reef area is more regular than atule and probably timed with the tide. Fishing for jacks occurs during high tide along the shoreline or low tide along the reef crest. Jack landings have also been constant over the years.

Groupers, on the other hand, appear to have an increasing CPUE. The most common groupers on the shallow waters are *Epinephelus hexagonatus* and *E. tauvina*. These groupers were sighted frequently on every survey of the reef flats indicating the level of abundance of this species. However, length frequency distribution analysis should be conducted to determine whether these fish are being impacted by the fishery.

Catch Landing of Top Species Groups in the Shore-Based Spear Fishery

Calculations: The total catch landings of the spear method from the shore-based fishery were segregated into different coral reef fish families to come up with species group level estimates and to derive inferences of their trends over time. Group level information was derived from the catch interviews. No data is presented for 1997 to 2003. Due to lack of funding, regular creel surveys had not been conducted and the available shore-based creel survey reports conducted by DMWR contract researchers were not incorporated into the WPacFIN database because they were not comparable. A comprehensive study of the spear fishery was conducted by Page (1998).

Trends: The species group that dominated the coral reef spear fishery catch was the surgeonfish, particularly the brown bristletooth (*Ctenochaetus striatus*) and blue-lined surgeonfish (*Acanthurus lineatus*), locally known as "pone'" and "alogo", respectively. Surgeonfish made up 34% of the total catch landing with approximately 6,247 lbs per year. The peak of the surgeonfish catch was in 2008, with 27,699 lbs landed. This was followed by mollusks, particularly tridacnids and turbo shells, with a catch landing average of 7,924 lbs per year making

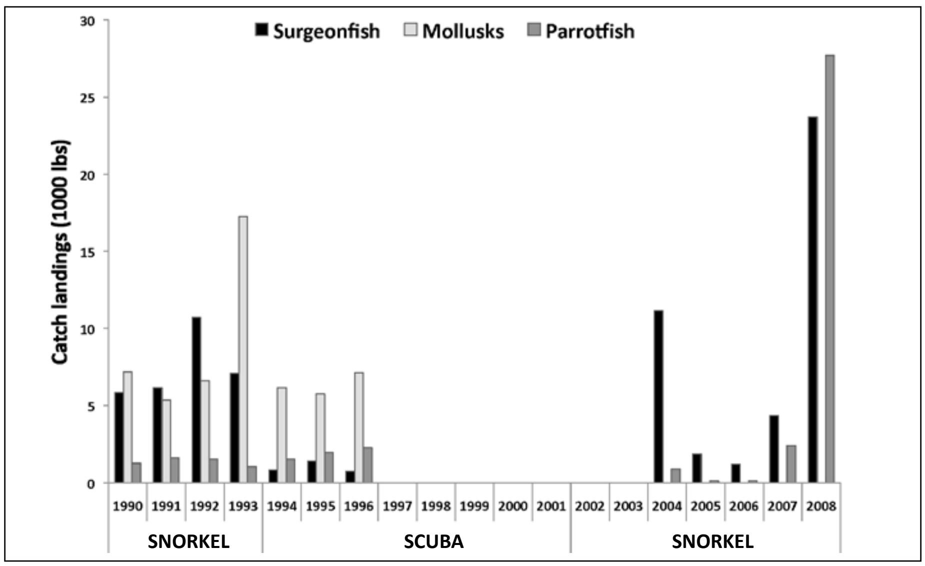


Figure 28. Catch landing of the top 1 to 3 species groups in the shore-based spear fishery.

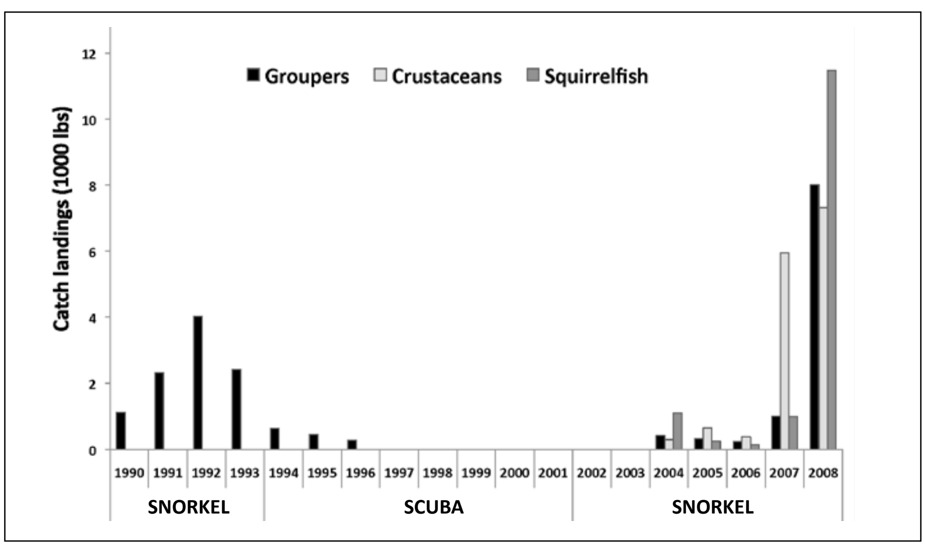


Figure 29. Catch landing of the top 4 to 6 species groups in the shore-based spear fishery.

up 25% of the total spear catch from 1990 to 2008. Most of the catches came from the 1990s. No catches had been reported in recent years. Parrotfish made up 19% of the spear fishery landings, with an annual average of 3,532 lbs per year. The highest catch was in 2008 at 27,699 lbs. Ten percent of the spear catches was groupers, with approximately 1,770 lbs landed annually. The highest landing was in 2008 yielding 8,007 lbs. Crustaceans and squirrelfish equally accounted for 6% of the spear landings, with an average of 2,919 lbs and 2,794 lbs, respectively. The highest landings were again reported in 2008.

Interpretations: The nature of the spear fishery has changed in American Samoa over the years. In the early 1990s, it was dominated by the snorkel spear method, with fishermen using Hawaiian slings. This fishery shifted with the introduction of SCUBA. However, the SCUBA spear method was more profitable in the boat-based fishery to access deepwater coral reef fishes than in the shore-based fishery. There was a noticeable decline in the mid 1990s in the shore-based spear fishery since participants shifted to the boat-based SCUBA spear fishery. After the ban of this method in 2002, the participants reverted back to using the shore-based snorkel spear method and landed a record catch in 2008 of 78,202 lbs of various coral reef assemblages. The recent increase in squirrelfish landings also indicates that this fishery is shifting to a night fishery or fishers using this method are gaining access to shallow-water crevices where most of these fishes reside.

Catch Per Unit Effort of Top Species Groups in the Shore-Based Spear Fishery

Calculations: The total effort for the shoreline spear fishery was taken from the catch interview phase of the creel (shore-based) fishery data collection. This was then divided to the total catch landing per species group to come up with an estimate of the CPUE expressed in lbs per hour (lbs/hr). This was plotted over a 19-year time series. A simple regression line was fitted to the CPUE points to approximate the trends over time to roughly detect any signal for potential overexploitation of stocks as evidenced by a long-term decrease in CPUE (a scenario where the catch decreases with increasing effort). Only the CPUE for the surgeonfish, parrotfish and grouper species groups are reported.

Trends: The first seven years of data reported was a combination of SCUBA- and snorkel-assisted spear methods. It was followed by a period where no usable data were being collected. When data collection resumed in 2004, only the snorkel spear method was occurring as the SCUBA spear method had been banned in 2002. From 1990 to 1993 when snorkel spear was the sole method being used, the CPUE was higher for surgeonfish and groupers as compared to the succeeding period when SCUBA spear was also employed and the fishermen shifted from shore-based to boat-based. The reverse is true for parrotfish where CPUE was higher during the SCUBA spear years. Overall, the grouper CPUE remained constant while surgeonfish and parrotfish exhibited an increase in CPUE over the 19-year period.

Interpretations: It is interesting to note the variations in CPUE among species groups prior to and during the SCUBA spear period. The trend was higher CPUE for surgeonfish and groupers prior to the SCUBA spear period (1990 to 1993) and decreased CPUE during the SCUBA spear period (1994 to 2001). This trend can be attributed to a probable shift in species preference from surgeonfish and groupers to parrotfish. Also, the SCUBA spear method was employed at night with fishermen targeting sleeping parrotfish, which are easier to catch than surgeonfish and groupers.

The overall increases in CPUE for surgeonfish and parrotfish by the spear fishery reflect increases in population abundance for these species groups, which have been determined by fishery independent surveys.

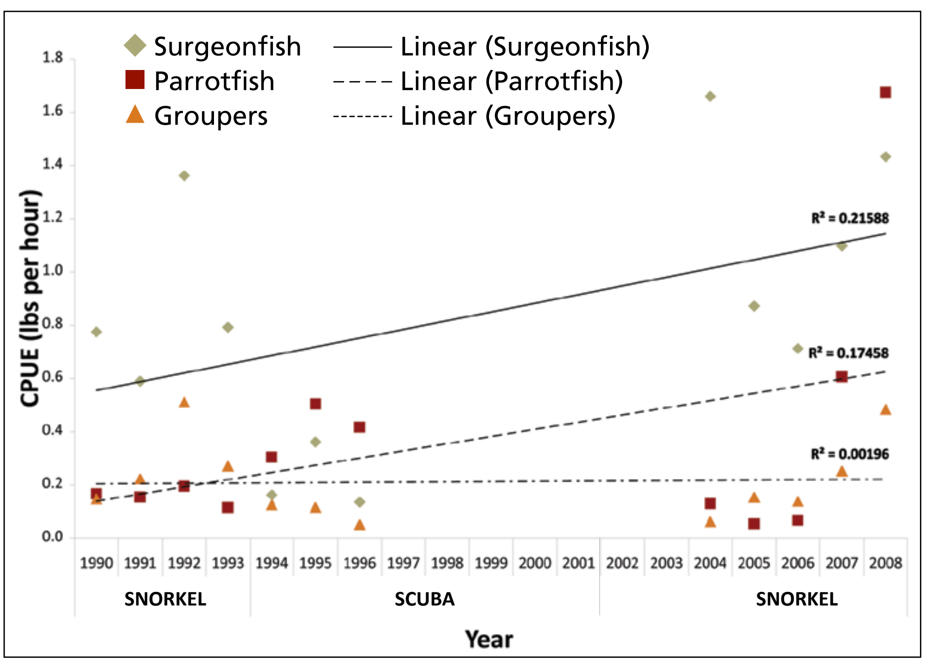


Figure 30. Catch per unit effort (in lbs per hour) in the shore-based spear fishery

Mean Inflation Adjusted Prices of Miscellaneous Bottomfish, Miscellaneous Reef Fish, Surgeonfish, Parrotfish, Snappers and Crustaceans

Calculations: The average prices for the miscellaneous bottomfish, miscellaneous reef fish, surgeonfish, parrotfish, snappers and crustaceans were calculated by dividing total revenue for each group by total weight sold. The inflation-adjusted prices were calculated by multiplying the unadjusted annual average price by the annual calculated consumer price index (CPI) for American Samoa using 2009 as the base.

Trends and interpretations: The mean prices of miscellaneous bottomfish averages to about $2.91 per lbs over a 19-year record. The highest price was recorded in 1993 at $4.33 and lowest in 2005 at $2.34 per lb. The overall linear trend in the mean inflation adjusted price has been slightly decreasing over the years. On the other hand, miscellaneous reef fish has an average of $2.69 per lb with highs in 1994 and 1997 at $2.94 per lb. The steepness of the linear overall mean inflation adjusted price of miscellaneous reef fish was less as compared miscellaneous bottomfish but generally decreasing.

For individual species groupings, the overall trend was similar to the broader groupings (miscellaneous bottom and reef fish), where there was a general slight decline in the mean inflation adjusted price. Surgeonfish has an average of $2.68 per lb, which was close to parrotfish at $2.73 per lb. Both were generally harvested in the spear fishery. In contrast, snappers and crustaceans, particularly lobsters, had higher CPI adjusted prices. Snappers had an average price of $3.27 per lb and were characterized by two major peaks at 1992 and 1997–98 at $4.65 per lb and $4.45/$4.29 per lb, which coincide roughly with the periods of low miscellaneous bottomfish landings. Crustacean prices were the highest among all groups reported averaging $5.08 per lb with the highest prices recorded in 1992 and 1993 at $5.89 and $5.90 per lb, respectively.

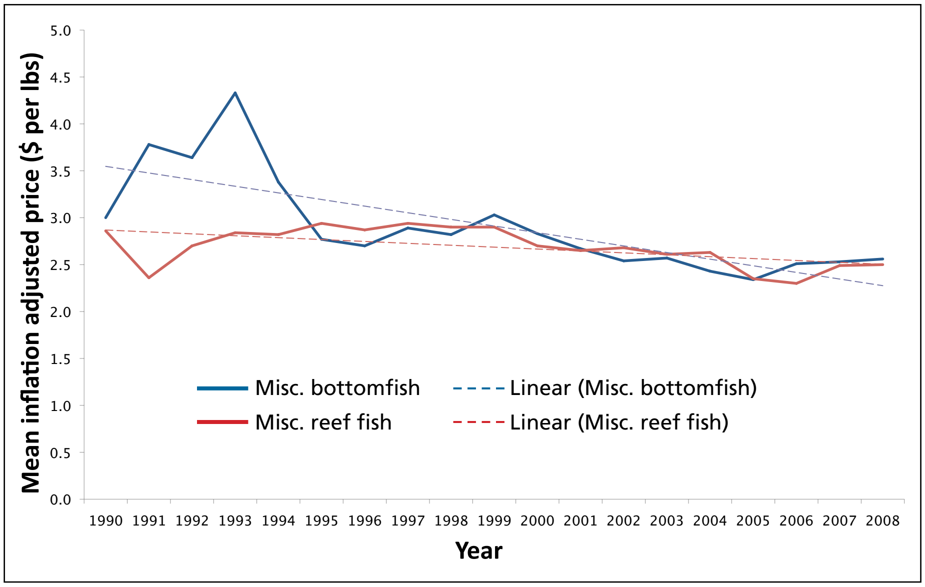


Figure 31. Trends in the mean inflation adjusted prices of miscellaneous bottomfish and miscellaneous reef fish.

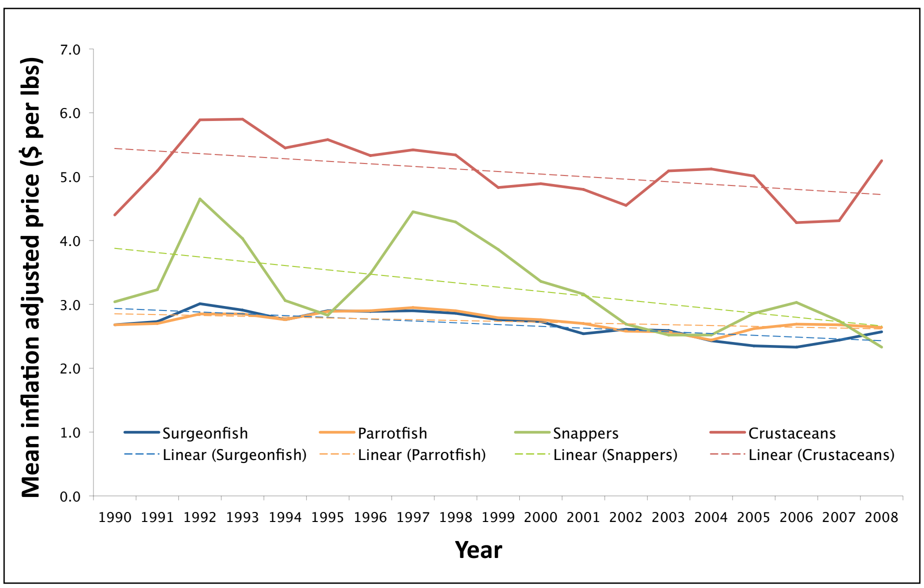


Figure 32. Trends in the mean inflation adjusted prices of surgeonfish, parrotfish, snappers and crustaceans.

Commercial Landing Average Prices of Miscellaneous Bottomfish, Miscellaneous Reef Fish, Surgeonfish, Parrotfish, Snappers and Crustaceans

Calculations: The commercial landing average prices for the miscellaneous bottomfish, miscellaneous reef fish, surgeonfish, parrotfish, snappers and crustaceans were calculated by dividing total revenue for each group by total weight sold. These prices were not adjusted for inflation.

Trends and interpretations: The average commercial landing price of miscellaneous bottomfish was about $2.07 per lb over a 19-year record. The highest price was recorded in 1993 at $2.64 per lb and the lowest in 1990 at $1.68 per lb. The overall linear trend in the commercial landing price has been slightly increasing over the years. On the other hand, miscellaneous reef fish had an average of $1.93 per lb with highs in 2008 at $2.50 per lb. The linear overall commercial landing price of miscellaneous reef fish has been steeper than that of miscellaneous bottomfish.

For individual species groupings, the overall trend was similar to the broader groupings (miscellaneous bottomfish and reef fish), with a slight increase in the average commercial landing prices. Surgeonfish had an average of $1.93 per lb, which was close to parrotfish with $1.97 per lb. Both were generally harvested in the spear fishery. In contrast, snappers and crustaceans, particularly lobsters, had higher commercial landing prices. Snappers had an average price of $2.32 per lb and three major peaks in 1992, 1997, and 2006 at $2.83, $3.01, and $2.67 per lb, respectively, which coincide roughly with the periods of low bottomfish landing. Crustacean prices were the highest among all groups reported, averaging at $3.66 per lb with the highest prices recorded in 2008 at $5.25 per lb.

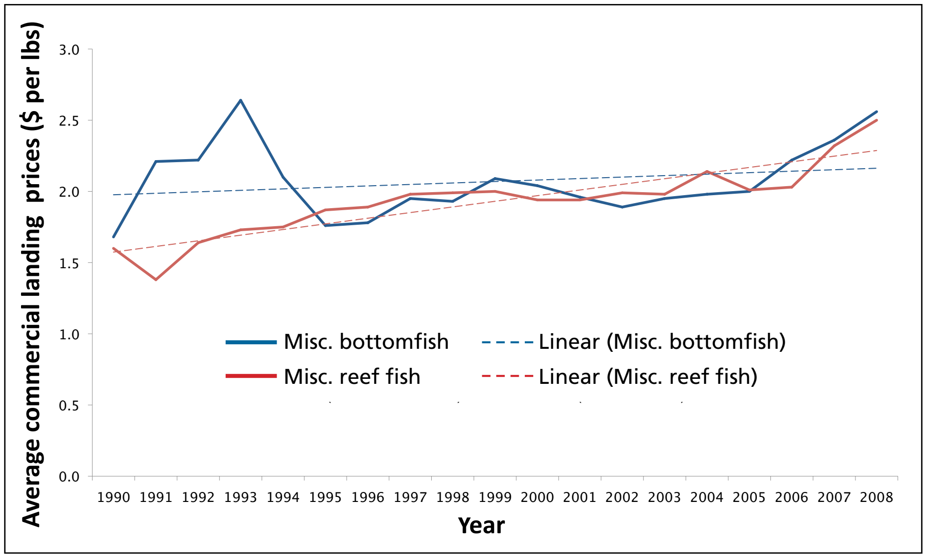


Figure 33. Trends in the average commercial landing prices of miscellaneous bottomfish and miscellaneous reef fish.

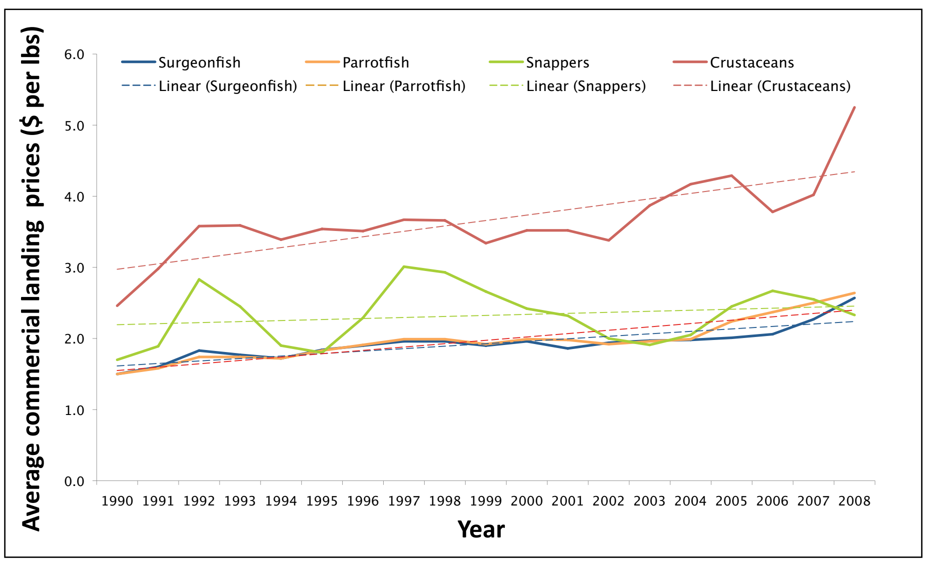


Figure 34. Trends in the average commercial landing prices of surgeonfish, parrotfish, snappers and crustaceans.

Underwater fish visual census survey is a common tool in coral reef management that allows for estimation of fish abundance and corresponding biomass by using count and length estimates. A common method widely used is the belt-transect where fishes are identified and recorded in a fixed width and length (i.e., a fixed area). This method was used by Green (2002), Sabater and Tofaeono (2006), and the National Ocean and Atmospheric Administration—Coral Reef Ecosystem Division (NOAA–CRED) of the Pacific Island Fisheries Science Center in their bi-annual surveys from 2002 to 2008 (Brainard et al. 2008). The biomass estimates generated from these surveys were used as the basis for a standing stock estimate based on occurrence of fish species/species groups on hard bottom habitats from 0 to 30 meter depth. The habitat estimate was taken from the mapping section of NOAA–CRED. The habitat was used as the expansion parameter, and it is assumed that the species groups are homogeneously distributed along this habitat.

Catch to biomass ratios can also be used to determine fishing mortality and provide insight on how much is taken out by the fishery relative to the biomass/standing stock—the lower the fishing mortality, the lower the risk of stock collapse.

Long-Term Biomass Trends of Selected Species Groups

Calculations: A summary of biomass data over time for surgeonfish (Acanthuridae), jacks (Carangidae), emperors (Lethrinidae), snappers (Lutjanidae), parrotfish (Scaridae) and groupers (Serranidae) from 1996 to 2008 is shown in figure 35. Data from 1996 and 2002a were from Green (2002). The 2002b, 2004, 2006b and 2008 data were from NOAA–CRED (Brainard et al. 2008). The 2006a and 2007 data were from Sabater and Tofaeono (2006). The weights of the individual fish were derived from the allometric weight formula $W = a \times L^b$ where L is the weight of the fish; a and b are constants derived from L-W regression taken from the following sources: Sudekum, Parrish et al. 1991; Choat and Axe 1996; FishBase 2000; Kulbicki, Guillemot et al. 2005. The resultant weight value was converted to biomass density by multiplying the individual weight to the number of individuals observed divided by the area of the transect expressed in kilograms per hectare. The expanded standing biomass estimate (Table 1) was calculated by multiplying the biomass density by the total area estimate of hard bottom habitat from 0–30 meters from which most surveys were conducted. The estimate of the hard bottom habitat were derived from the habitat mapping work of

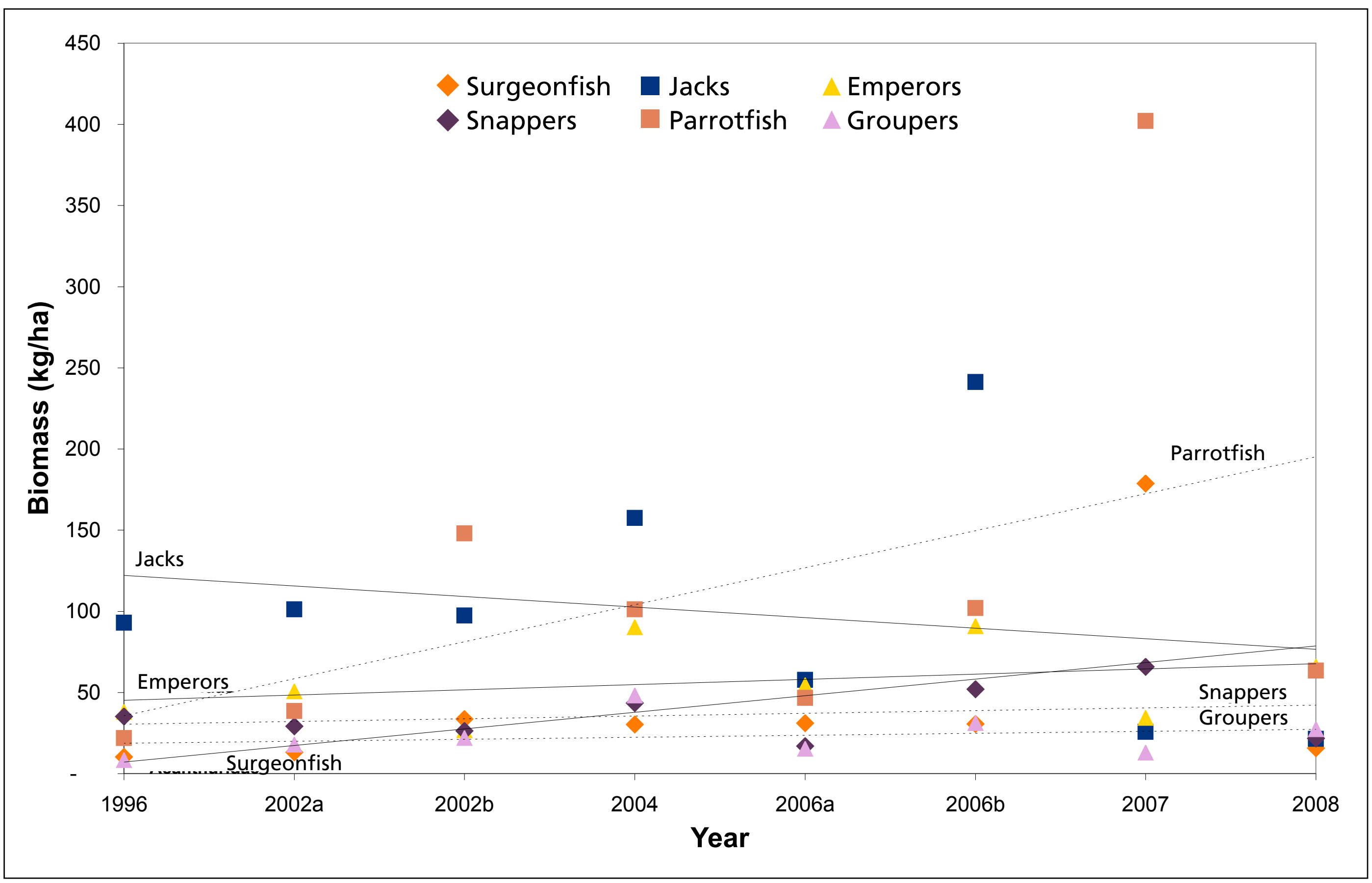


Figure 35. Trends in biomass of surgeonfish, jacks, emperors, snappers, parrotfish and groupers from 1996 to 2008.

Table 1. Standing biomass estimates (in 1,000 lbs) of harvested coral reef fish species groups on 0–30 meter, hard-bottom habitat from 1996 to 2008.

Expanded biomass (x 1000) across 0-30m hard bottom habitat									
Species Group	1996	2002a	2002b	2004	2006a	2006b	2007	2008	Average
Surgeonfish	96	121	311	280	288	283	1657	145	398
Jacks	862	938	902	1459	535	2235	237	198	921
Emperors	353	470	248	836	506	842	320	611	523
Snappers	326	270	243	402	157	482	610	202	336
Parrotfish	203	358	1371	938	432	945	3724	588	1070
Groupers	79	166	205	447	143	289	120	254	213

NOAA-CRED (Williams 2010). The biomass estimate is for Tutuila only. The expanded biomass values were converted to lbs to be consistent with the catch landing units where both data will be used to estimate fishing mortality using the catch to biomass ratio (see next section). The biomass trends over time were plotted in figure 35.

Interpretation: The commonly harvested species groups belong to the following coral reef fish families: Acanthuridae (surgeonfish), Carangidae (jacks), Lethrinidae (emperorfish), Lutjanidae (snapper), Scaridae (parrotfish), and Serranidae (groupers). Parrotfish had the highest standing biomass over a 12-year average. The highest recorded biomass was in 2007 at 3.7M lbs. Jacks ranked second followed by emperors at 921,000 lbs and 398,000 lbs, respectively. Surgeonfish ranked fourth and snappers placed fifth with an estimated biomass of 398,000 lbs and 336,000 lbs, respectively. Groupers had the lowest biomass among the six major species groups having an estimated biomass of 213,000 lbs.

The fish biomass over time for each species group being targeted (figure 35) shows a generally increasing linear trend at various rates. Parrotfish and surgeonfish show the greatest increment of increase over time. A slight increase in biomass is seen in emperors whereas groupers and snappers remain relatively constant. The general linear trend for jacks, on the other hand, is decreasing over the years. Given that this is a transient coastal pelagic species, it is not well represented in most of the belt transect surveys, which are mostly applicable to demersal and non-highly mobile fauna.

There are some limitations to the biomass estimates shown as they cover only stocks that were found in areas where the surveys were conducted (summarized by Williams 2010). Populations from other habitats are not included, and populations that occur in the same habitat with patchy distribution are underestimated. This also assumes that the detection and occupancy factor of the species belonging to these families are constant. Detection and habitat occupancy for each species varies depending on the habitat preference, behavior, environmental conditions and distribution of the animals (MacKenzie et al. 2006). Animals that are found deeper than the survey depths are also underrepresented particularly deepwater snappers and groupers. Highly migratory and transient coastal pelagic species, like jacks and Scombridae (mackerels, tunas, bonitos, etc.), are also underrepresented since they spend most of their time in open water.

Long-Term Fishing Mortality Trends of Selected Species Groups

Calculations: Estimates of the fishing mortalities were derived from the catch to biomass ratios. The combined total catches of the six major species groups—surgeonfish (Acanthuridae), jacks (Carangidae), emperors (Lethrinidae), snappers (Lutjanidae), parrotfish (Scaridae) and groupers (Serranidae) —from 1996 to 2008 taken from the shore-based and boat-based fisheries were divided by their respective expanded biomass estimate described in the previous section. The summary of the data is shown in Table 2, and the fishing mortality trends are shown in figure 36. The best fit linear trend line was added in the graph to show general trends in fishing mortality over time.

Interpretation: The fishing mortality for the major species groups being harvested was considered low based on an eight data point average ranging from 0.005 (0.5%) to 0.045 (4.5%). The highest fishing mortality was computed from the snappers at 4.5% followed by surgeonfish at 3.7%. Emperors and groupers were almost equal at 1.7% and 1.6%, respectively. The lowest fishing mortalities were computed for parrotfish and jacks at 0.06% and 0.05%, respectively.

The linear trends in fishing mortality for the six harvested species groups were generally constant to decreasing over time except for two cases (figure 36). The surgeonfish showed a constant fishing mortality whereas emperors, groupers and snappers showed a slight decline. Despite the steep increase in biomass, parrotfish showed an increase in fishing mortality due to an order of magnitude increase in catch landing in 2008 with a concurrent one order of magnitude decrease in fish biomass from 2007 to 2008. This resulted in a five-fold increase in fishing mortality in the last year as compared to all the preceding years. On the other hand, because jacks are a transient coastal pelagic species, its biomass is underrepresented in transect surveys, but it is a major fish being harvested in the boat- and shore-based fisheries. Jacks ranked as the fifth dominant fish being harvested in the boat-based bottomfish and mixed troll-bottom fisheries and second in the shore-based rod-and-reel fishery.

This analysis comes with sets of limitations in terms of both the catch and biomass data. The main issue is the observation-gear development overlap. Fishing mortality is best estimated by catch to biomass ratio if the effectiveness of fishing gear overlaps significantly with the spatial distribution of the

Estimated Fishing Mortality Trend Using Catch to Biomass Ratio from 1996 to 2008

Expanded catch landing (x 1000 lbs) from boat and shore-based fishery

Species Group	1996	2002a	2002b	2004	2006a	2006b	2007	2008	Average
Surgeonfish	5.5	20.6	20.6	17.9	5.8	5.8	13.5	28.7	15
Jacks	9.7	1.3	1.3	1.5	2.5	2.5	9.9	6.1	4
Emperors	11.0	14.7	14.7	7.8	1.0	1.0	6.8	13.4	9
Snappers	19.3	22.3	22.3	11.0	3.5	3.5	13.3	25.6	15
Parrotfish	3.9	2.0	2.0	2.0	2.2	2.2	7.7	31.0	7
Groupers	3.7	6.1	6.1	2.9	1.0	1.0	2.4	4.3	3

Expanded biomass (x 1000 lbs) across 0-30m hard bottom habitat

Species Group	1996	2002a	2002b	2004	2006a	2006b	2007	2008	Average
Surgeonfish	96	121	311	280	288	283	1657	145	398
Jacks	862	938	902	1459	535	2235	237	198	921
Emperors	353	470	248	836	506	842	320	611	523
Snappers	326	270	243	402	157	482	610	202	336
Parrotfish	203	358	1371	938	432	945	3724	588	1070
Groupers	79	166	205	447	143	289	120	254	213

Catch to biomass ratio = fishing mortality

Species Group	1996	2002a	2002b	2004	2006a	2006b	2007	2008	Average
Surgeonfish	0.057	0.170	0.066	0.064	0.020	0.021	0.008	0.198	0.037
Jacks	0.011	0.001	0.001	0.001	0.005	0.001	0.042	0.031	0.005
Emperors	0.031	0.031	0.059	0.009	0.002	0.001	0.021	0.022	0.017
Snappers	0.059	0.082	0.092	0.027	0.022	0.007	0.022	0.127	0.045
Parrotfish	0.019	0.006	0.001	0.002	0.005	0.002	0.002	0.053	0.006
Groupers	0.047	0.037	0.030	0.006	0.007	0.004	0.020	0.017	0.016

Table 2. Summary of catch, biomass and fishing mortality data from 1996 to 2008 of six major species groups harvested in the American Samoa fishery.

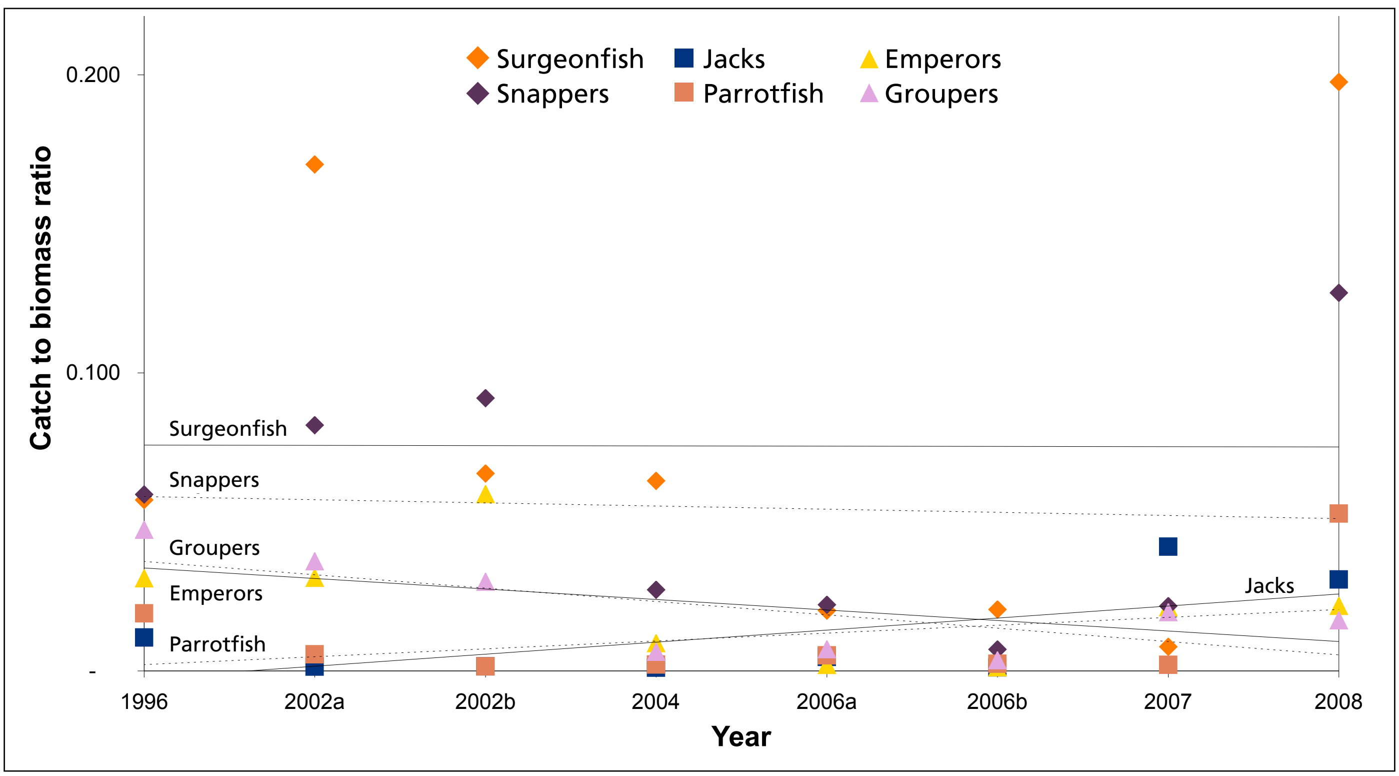


Figure 36. General linear trends in fishing mortality using catch to biomass ratios for the top species groups harvested.

target fish. The catch to biomass ratio is a poor predictor of fishing mortality if the overlap is minimal, for instance when (1) the fishery is operating only along the edge of the animal distribution; (2) the animal distribution is highly patchy; and/or (3) there is depth incongruence between the gear deployment and animal habitat. Examples are the shallow and deep grouper-snapper complexes. Bottomfishing is usually carried out at depths of 300 to 600 feet catching eteline snappers and some shallow-water assemblages. The majority of the recent snapper landings are from the shallow-water complex, but the deepwater component is still substantial. Most of the underwater census surveys are conducted at 30 to 100 feet maximum. Thus the majority of the snapper assemblages being represented by the underwater census surveys are the shallow-water complex. In the future, representative species from each "capture" method will have to be evaluated closely to determine applicability of using catch to biomass ratio as a proxy for fishing mortality.

Island- and Archipelagic-Scale Estimates of Fishing Mortality

Calculations: An estimate of the fishing mortality was derived from the catch to biomass ratio. The combined total catches of the six major species groups—surgeonfish (Acanthuridae), jacks (Carangidae), emperorfish (Lethrinidae), snappers (Lutjanidae), parrotfish (Scaridae) and groupers (Serranidae)—from 1996 to 2008 taken from the shore-based and boat-based fisheries were divided by their respective expanded biomass estimate described in the previous section. The biomass estimates came from the NOAA-CRED data for cruise year 2008 only summarized by Williams (2010). The summary of the data is shown in Table 3. The estimated archipelagic biomass was taken from the visual census data combined for all the islands (Tutuila, Ofu-Olosega, Tau, Rose and Swains) whereas the Tutuila biomass was from Tutuila only. The catch landing data was averaged over a period of 20 years. Two separate fishing mortality estimates were generated: one for Tutuila only and the other for the archipelago to provide an insight on the percent contribution of other island biomasses on reducing the fishing mortality rates. The Tutuila fishing mortality was estimated by using the catch to biomass ratio of the 20-year catch average with the Tutuila standing biomass for each species group. The archipelagic fishing mortality was estimated by using the same catch to biomass ratio except the biomass used was for all island units. It is recognized that the catch landing data may be underestimated since the data from the Manu‘a Islands (Ofu-Olosega and Tau) is sparse. The biomass data is also underestimated due to reasons stated in the previous section.

Interpretation: The total standing biomass for the archipelagic stock was roughly twice that of the biomass of Tutuila alone. The archipelagic biomass is comprised of the combined biomass of Tutuila, Ofu-Olosega, Tau, Rose and Swains. This result is only logical given that Tutuila has more coral reef associated habitat areas (4,448 ha) than the Manu‘a Islands, Rose and Swains combined (3,188 ha) (NOAA-NCCOS 2005). Interestingly, if one compares the ratio of Tutuila habitat area to the archipelagic habitat area against fish biomass of Tutuila to the archipelagic biomass, one will come up with an almost equal proportion at 0.58 and 0.55, respectively. This indirectly shows the effect habitat availability and extent of the habitat availability on biomass. Similarly, a manipulative experiment by Bohnsack et al. (1994) in Florida using artificial reef structures on sand bottom showed biomass increasing with the size of the reef. Moreover, 94% to 98% of the biomass was comprised of mostly older juvenile and adult colonists.

No reliable data exist for the boat-based commercial fish landing for the Manu‘a Islands, but it is assumed that the majority of the commercial fishing occurs in Tutuila where most of the commercial fishing boats are based. The Manu‘a Islands and especially Swains fisheries are considered to be more on a subsistence level. Comparing the subsistence fishing between Tutuila and Ofu (an island in the Manu‘a group), there is more fishing effort occurring in Ofu with 1,272 fishing gear deployments along a 9.5 km survey area (Craig et al. 2008) as opposed to Tutuila with 800 deployments along a 23.7 km sampling area (Coutures 2003) both with almost similar sampling methods and number of sampling sweeps. It was estimated based on unpublished fishery data taken from the WPacFIN database that 58% of the top six species groups comes from the boat-based fishery and 42% from the shore-based fishery.

Table 3. Estimated fishing mortality on island and archipelagic scales for the major targeted species groups and species of concern.

Species Group	Visual Census Data (2008)		Fishery Data	Adjusted Fishing Mortalities	
	Archipelagic Biomass (lbs)	Tutuila Biomass only (lbs)	Catch - 20 yr ave (lbs)	$FM_{archipelagic}$ ($Catch_{Ave}/A_{biomass}$)	$FM_{Tutuila}$ ($Catch_{Ave}/T_{biomass}$)
Emperors	142,052	93,529	8,314	5.9%	8.9%
Goatfish	64,341	45,492	478	0.7%	1.1%
Groupers	251,288	95,680	5,969	2.4%	6.2%
Jacks	129,683	56,351	7,939	6.1%	14.1%
Parrotfish	962,975	598,237	6,057	0.6%	1.0%
Reef shark	86,308	15,644	87	0.1%	
Rudderfish	19,175	4,424	432	2.3%	9.8%
Snappers	337,665	137,419	16,890	5.0%	12.3%
Squirrelfish	100,586	32,714	2,663	2.6%	8.1%
Wrasse	215,655	117,176	802	0.4%	0.7%
Surgeonfish	1,775,574	1,095,494	14,005	0.8%	1.3%
Others	1,890,055	1,269,789	5,917	0.3%	0.5%
TOTAL	**5,975,358**	**3,561,950**	**69,553**	**1.2%**	**2.0%**

Table 4. Summary of adjusted catch, biomass and fishing mortality data from 1996 to 2008 of six major species groups harvested in the American Samoa fishery. The catch landing was adjusted by a factor of 17 to account for underestimation described by Zeller et al. (2006, 2007).

Estimated Fishing Mortality Trend Using Catch to Biomass Ratio from 1996 to 2008

Adjusted catch landing (x 1000 lbs) from boat and shore-based fishery based on Zeller et al. 2005

Species group	1996	2002a	2002b	2004	2005	2006a	2006b	2007	2008	Average
Surgeonfish	95	357	357	309	87	101	101	233	496	237
Jacks	167	23	23	26	22	44	44	171	105	69
Emperors	190	254	254	135	38	18	18	118	231	140
Snappers	334	385	385	190	172	60	60	230	443	251
Parrotfish	68	35	35	34	30	39	39	133	536	105
Groupers	64	106	106	50	27	18	18	41	75	56

Expanded biomass (x 1000 lbs) across 0-30m hard bottom habitat

Species group	1996	2002a	2002b	2004	2005	2006a	2006b	2007	2008	Average
Surgeonfish	96	121	311	280	4337	288	283	1657	145	836
Jacks	862	938	902	1459	556	535	2235	237	198	880
Emperors	353	470	248	836	2541	506	842	320	611	747
Snappers	326	270	243	402	3639	157	482	610	202	703
Parrotfish	203	358	1371	938	5131	432	945	3724	588	1521
Groupers	79	166	205	447	232	143	289	120	254	215

Catch to biomass ratio = fishing mortality

Species group	1996	2002a	2002b	2004	2005	2006a	2006b	2007	2008	Average
Surgeonfish	0.99	2.94	1.15	1.10	0.02	0.35	0.36	0.14	3.42	0.284
Jacks	0.19	0.02	0.03	0.02	0.04	0.08	0.02	0.72	0.53	0.079
Emperors	0.54	0.54	1.03	0.16	0.01	0.03	0.02	0.37	0.38	0.187
Snappers	1.02	1.43	1.58	0.47	0.05	0.38	0.12	0.38	2.19	0.357
Parrotfish	0.33	0.10	0.03	0.04	0.01	0.09	0.04	0.04	0.91	0.069
Groupers	0.82	0.64	0.52	0.11	0.12	0.13	0.06	0.34	0.29	0.261

The same ratio exists if one takes only the common species groups in both the shore- and boat-based fisheries (i.e., parrotfish and surgeonfish) from 1990 to 2008.

The overall fishing mortality for Tutuila is merely 2.0%. A similar principle used by Friedlander and Parrish (1997) yielded an estimate of 1.3% for Hanalei Bay on the island of Kauai, Hawaii, and the fish community was not considered to be severely overfished. Considering that these estimates are very low, the stock biomass and spawning potential ratio (SPR) remain in good shape, and risk of stock collapse is minimal given that the fishing mortality is inversely related to these parameters (Goodyear 1993, Mace and Sissenwine 1993, Katsukawa 1997). Allowing for stock inputs from other areas assuming that the islands are connected, the fishing mortality is a much lower 1.2%, which is almost equal to the Kauai estimate. This low overall and constant to declining trend in fishing mortality (except for the two cases as described in the previous section) can be attributed to the general decline in commercial and subsistence fishing effort concurrent with the increasing biomass of certain reef fish species groups (Sabater and Carroll 2009).

Zeller et al. (2006, 2007) described the reported catch landing in American Samoa to be underestimated by a factor of 17 based on a reconstruction model using per capita demand driven by the increasing human population numbers. If the calculation is correct, then adjustments will have to be made to increase the catch landing by a factor of 17. Table 4 shows the adjusted catch landing for all six harvested species groups and the corresponding change in the fishing mortality rates. Table 5 shows the adjusted catch landing for the archipelago and Tutuila with the corresponding fishing mortality.

Table 5. Adjusted estimated fishing mortality on island and archipelagic scales for the major targeted species groups and species of concern. The catch landing was adjusted by a factor of 17 to accommodate for the underestimation described by Zeller et al. (2006, 2007).

Species Group	Visual Census Data (2008)		Fishery Data		Adjusted Fishing Mortalities	
	Archipelagic Biomass (lbs)	Tutuila Biomass Only (lbs)	Catch - 20 yr ave (lbs)	Adjusted Catch Landing (x17)	$FM_{archipelagic}$ ($Catch_{Ave}/A_{biomass}$)	$FM_{Tutuila}$ ($Catch_{Ave}/T_{biomass}$)
Emperors	142,052	93,529	8,314	141,338	99.5%	151.1%
Goatfish	64,341	45,492	478	8,126	12.6%	17.9%
Groupers	251,288	95,680	5,969	101,473	40.4%	106.1%
Jacks	129,683	56,351	7,939	134,963	104.1%	239.5%
Parrotfish	962,975	598,237	6,057	102,969	10.7%	17.2%
Reef shark	86,308	15,644	87	1,479	1.7%	
Rudderfish	19,175	4,424	432	7,344	38.3%	166.0%
Snappers	337,665	137,419	16,890	287,130	85.0%	208.9%
Squirrelfish	100,586	32,714	2,663	45,271	45.0%	138.4%
Wrasse	215,655	117,176	802	13,634	6.3%	11.6%
Surgeonfish	1,775,574	1,095,494	14,005	238,085	13.4%	21.7%
Others	1,890,055	1,269,789	5,917	100,589	5.3%	7.9%
TOTAL	**5,975,358**	**3,561,950**	**69,553**	**1,182,401**	**19.8%**	**33.2%**

Adjusting the catch landing by a factor of 17 resulted in a dramatic increase in fishing mortality. The very high fishing mortality underscored in Table 5 signifies stock depletion due to fishing to the point that the stocks are subject to collapse in certain years. Fishing mortality above 1 indicates more than 100% has been removed from the population due to fishing, and some estimates had harvested twice to three times more than the standing stock. However, the fishing mortality average over the years ranges from 6.9% for parrotfish to 35.7% for snappers. If depletion occurs in some of the years then the biomass trend should show a dramatic decrease over time, which was not the case as shown in the previous section.

The overall fishing mortality showed similar results where localized depletion may have occurred for Tutuila particularly for emperors, groupers, jacks, snappers and squirrelfish. This could be due to the underestimation of these species groups due to wide spatial and depth distribution beyond the survey depths. Parrotfish and surgeonfish were abundant in the given survey depth, which has a good overlap with the fishery, and showed a reasonable fishing mortality at around 21.7% and 17.2%, respectively. Looking at the system as an archipelagic unit, emperors and jacks appear to be severely depleted. Parrotfish and surgeonfish fishing mortality were reduced to 10.7% and 13.4%. The total fishing mortality for these species groups on an archipelagic scale was at 19.8% and on Tutuila at 33.2%.

Further investigation is needed to assess whether the underestimation of a factor of 17 is valid. The adjustment factor seems to be an overestimate. The factor was based on per capita demand wherein the increasing population was used as the driver for the reconstruction. The assumption here was that the demand for fish (where using per capita demand makes sense) is tightly coupled with fishing effort. An increase in demand due to increase in population would result in increase in fishing effort. Using per capita demand for fish assumes there is no change in the diet over the years and the population has strong affinity for fish for their sustenance. This also assumes that imports of fish from the neighboring island states have no bearing in the reconstruction. This is not the case for American Samoa as summarized by Sabater and Carroll (2009).

There are certainly some limitations in using catch to biomass ratios to estimate fishing mortality, but it provides some rough insight on the level of depletion occurring in the coral reef fishery. Further investigation and refinement in the analysis and data gathering are needed to improve the estimates. Nonetheless, this is the first report generated by the Department of Marine and Wildlife Resources that looks into the short-term trends in fishing mortality and the changes in the fishery over time.

Conclusion

The overall health of the coral reef fishery in American Samoa appears to be stable based on trends in CPUE, biomass and abundance, and fishing mortality. The coral reef has supported the local population for more than three thousand years. The small-scale nature of the contemporary commercial and recreational fisheries along with decreasing fishing effort over time has resulted in sustainability amidst the changing coral reef environment brought about by the shifts in the local socio-economic conditions, urbanization of certain population centers and climate change. Focus should be given to the interplay of the different factors, may they be from land- or sea-based anthropogenic sources or natural disturbances, to effectively manage the coral reef fishery resources under an ecosystem-based management approach.

Photo courtesy of Ben Carroll

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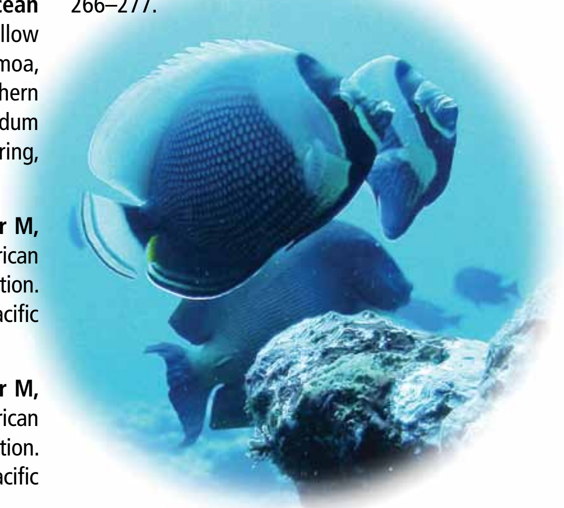

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