PSA for CNMI Inshore Fishery Species

Report for Western Pacific Regional Fishery Management Council

Cassie Pardee

7/16/2014

This report is prepared for WPRFMC on the current vulnerability of reef fish in the inshore fishery of the Commonwealth of the Northern Mariana Islands using a productivity and susceptibility analysis (PSA).

Table of Contents

List of Tables

List of Figures

Introduction

CNMI Location and Overview

The Mariana archipelago extends approximately 400 m from the island of Guam (13^o Latitude) northward to Uracas located at 20^o Latitude (**Error! Reference source not found.**). Although all 5 islands of the archipelago are a part of the United States, they are divided politically into two entities; the Territory of Guam and the Commonwealth of the Northern Mariana Islands (CNMI). The CNMI is inclusive of all 14 islands north of Guam.

Guam is the largest island in the archipelago, followed in decreasing size by islands of Saipan, Tinian and Rota which are part of the CNMI. Of all the islands in the archipelago, these support permanent resident populations.

The Mariana island arc system is geologically divided into two general types: the older southern islands (Guam, Rota, Aguigan, Saipan, Tinian and Farallon de Medinilla) are characterized as raised limestone platforms with dormant volcanoes, while the northern islands (Anatahan, Sariguan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas are considered "recent" (Eldredge,1983) and several are still volcanically active.

The geologically older six southern raised limestone islands have better developed fringing and/or barrier reef systems while the volcanic northern islands have relatively little coral reef development. The CNMI has a total land mass of approximately 457 km^2 and an Exclusive Economic Zone (EEZ) covering 777,000 km^2 (SPC, 2009)

The 2010 US census recorded a total population of the CNMI of 53,883; a decrease of 22% from the 2000 census. The CNMI population is limited and unevenly distributed among the three populated islands of Rota, Tinian and Saipan. Saipan accounted for 89% (48,220) of the total CNMI population, while Tinian and Rota islands supported 6% (3,136) and 5% (2,527), respectively.

The CNMI has two recognized indigenous groups; Chamorro and Carolinian. The Chamorro ethnic group[1] comprises 32% (17,510) and the Carolinian communities make up 5% (2,461) of the 2010 CNMI population. Other island residents originate from the Philippines, Japan, China, Korea, Bangladesh, and Thailand.

In recent history, the CNMI was supported by two primary industries; garment manufacturing and tourism. By 2005, the garment manufacturing industry was completely phased out due to US international trade agreements. Tourism is currently the largest and only industry in the CNMI and is most prevalent on Saipan. Tourists arriving by air dominate the arrival statistics. The few sea arrivals are made up of military vessels arriving for R&R, AMSEA vessels anchored off shore, and a rare occasional cruise ship for a day-visit.

[1] Includes 'Chamorro and other groups' category from the 2010 US Census

CNMI Reef Fish Fishery Overview and History

Fishing is common in CNMI and the indigenous residents have a long history of fishing for subsistence, cultural practices, sharing, and for selling (WPRFMC 2011; MacDuff and Roberto 2012). Although a majority of fishers reported selling enough fish to cover operating costs, the primary purpose for fishing is to provide food for their families (Allen and Amesbury 2012; Severance, Franco et al. 2013).

A majority of people eat fish between one to three times a week (van Beukering, Haider et al. 2006). Holidays such as Easter, Lent, fiestas, baptisms, and funerals are important and fishing effort typically increases during these times (Allen and Amesbury 2012; Severance, Franco et al. 2013). The demand for fresh fish is also high at the beginning of the month when food stamps are distributed and on government paydays (Allen and Amesbury 2012).

After World War II, inshore subsistence fishing dominated the catch because most of the fishing vessels were lost after the Japanese fishery was banned. Commercial and recreational fisheries did not develop until 1960's with an increase in the economy and boat availability. About 63% of total catches were assumed to come from noncommercial catches in 1984; but by the early 1990's the commercial fishing rate had increased to make up about half of the catch composition (Zeller, Booth et al. 2007).

Currently, the main commercial fishery is comprised of small boats (12-24 ft outboard-powered) running one-day trolling operations (Allen and Amesbury 2012; Hamm, Quach et al. 2012). Shore fishing and bottom fishing are also common in CNMI. Reef fish make up a majority of the total commercial catch and is an important part of the local diet (van Beukering, Haider et al. 2006; Hamm, Quach et al. 2012; WPRFMC 2012). However, in recent years, fishery managers have reported a decrease in the number of commercial fishermen, fish vendors, and total commercial landings due to the downturn in the economy (Allen and Amesbury 2012).

Saipan fresh fish vendors believe that spearfishing makes up 92% to 98.4% of the total reported catch of reef fish for 2011, 2012, and 2013 (PIFSC Bio-Sampling Program [2]); with a majority (>70%) of speared reef fish originating from nighttime spearing operations (Allen and Amesbury 2012; Houk, Rhodes et al. 2012). Other gears used for catching reef fish included hook and line (1% to 7.1%) and talaya net (0.6% to 1.6%) for 2011 through 2013 (PIFSC Bio-Sampling Program [2]

The price-per-pound for coral reef fish in the CNMI has declined over the past 26 years (WPRFMC 2011; MacDuff and Roberto 2012). In response to an increase in commodity prices and a decrease in fish prices, Micronesian fishers have increased the volume of their catch to offset financial losses (Rhodes, Warren-Rhodes et al. 2011). However, three important reef fish (parrotfish, emperors, and surgeonfish) have demonstrated a cyclical pattern in the CNMI with an increase in prices during the past ten years (MacDuff and Roberto 2012). The average price

[2] These values are subject to change as data quality control efforts progress; this data is not to be cited.

per pound of reef fish given to fisherman was about $2.50; with a total commercial value around $274,000 in 2009 (WPRFMC 2011; Allen and Amesbury 2012).

Several different important fishery species may be at risk for overexploitation. Total CNMI reef catches have declined by about 54% between 1950 and 2004 (Zeller, Booth et al. 2007). However, reported commercial reef fish landings on Saipan from all major fresh fish vendors has remained fairly consistent from 2011 to 2013; 109,062 lbs, 102,087 lbs. and 109,243 lbs, respectively (PIFSC Bio-Sampling Program [2]). These landings include fin fish, lobster, octopus, and crabs. The top coral reef inshore fin fish species landed are parrotfish, emperorfish, rabbitfish, surgeonfish, jacks and goatfish (Table 1).

Length frequency comparisons have indicated that fish were significantly larger in the non-populated Northern Islands when compared to sizes caught from the southern populated islands (Trianni 1998). *Scarus rubroviolaceus* is one of the most frequently caught parrotfish in Saipan and Tinian markets (Trianni 1998; Houk, Rhodes et al. 2012). There was a greater percentage of terminal phase parrotfish in the Northern Islands than in Saipan and Tinian (Trianni 1998).

Naso unicornis is another commonly targeted reef fish (Houk, Rhodes et al. 2012; Bejarano, Golbuu et al. 2013). *N. unicornis* has been labeled as one of the more vulnerable herbivores throughout Micronesia, because of its relatively low-redundancy functional role and high exploitation rate (Bejarano, Golbuu et al. 2013). Using a L_{50} value generated by the FishBase life history modeling tool, Houk, Rhodes et al (2012) found 90% of *N. unicornis* sampled during a 2009 Saipan market study were harvested below their L_{50}. However, this claim was later refuted when the same analysis was conducted using the L_{50} value derived from a University of Guam research project. Size data from 5,480 *N. unicornis* measured from Saipan markets (2011 through 2013) found 39 % were harvested under their L_{50} (PIFSC Bio-Sampling Program [2]).

Fishery Management Overview

The nearshore (0-3 nm) submerged lands surrounding nine of the CNMI islands were officially conveyed to the CNMI Government by Congressional action in January 2014. While these near shore resources are under the management authority of the local Department of Lands and Natural Resources, certain aspects of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) are enforced.

Federal management measures

From a federal perspective, the Mariana Island Archipelago Fishery Ecosystem Plan (FEP) addresses the management needs of the fishery resources of Guam and CNMI and implements an ecosystem approach that was approved by NOAA (WPRFMC 2011). There are currently no existing assessments on coral reef stocks, and the status of the species or species groups is widely unknown; therefore maximum sustainable yield (MSY) and optimum yield estimates for coral reef management unit species (MUS) are unknown (WPRFMC 2011). The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) of 2006, requires the implementation of annual catch limits (ACLs) and accountability measures to end overfishing by the year 2012 (MSRA 2006). The acceptable biological catch limits (ABCs) for most of the coral reef species are based on catch only data equal to the 75th percentile of the entire catch time series (MacDuff and Roberto 2012). ABCs were determined by using the expanded catch landing time series from both boat and shore-based creel surveys (MacDuff and Roberto 2012). ACLs were then set equal to ABC because catch were small relative to the estimated biomass from CRED Rapid Ecological Assessment (Williams, Richards et al. 2010; MacDuff and Roberto 2012). The current ACLs for common CNMI reef fish species are 27,466 lbs for emperor fish, 7,459 lbs for atulai (*Selar crumenopthalmus*), 6,884 lbs for surgeonfish, 5,519 lbs for groupers, 3,784 lbs for parrotfish, and 2,537 lbs for rabbitfish (MacDuff and Roberto 2012; WPRFMC 2012).

In 2013, grouper, rabbitfish and atulai all exceeded their ACL estimates (WPRFMC 2013). The grouper fishery exceeded its ACL due to an increased catch by boat based methods with a high CPUE. The rabbitfish also slightly exceeded its ACL was due to high CPUE of several interviews of cast netters.The atulai catch was almost doubled that of the ACL and was caught mainly by boat-based fishers. Although the overage could not be explained, atulai catches are highly variable (John Gourley, personal communication 2014).

Local management measures

Coral reef fisheries are difficult to manage due to the many gear types used to harvest multiple species and the logistical difficulty of obtaining good quality data for management purposes. In CNMI gear and size restrictions are virtually impossible to enforce (Bearden, Brainard et al. 2005). Size restriction regulations for reef fish were attempted in 1991 and were a complete failure and later abandoned in 1992 (John Gourley, personal communication 2014).

In 2003 bans were placed on gill, drag and surround nets except for cultural exemptions (Allen and Amesbury 2012; MacDuff and Roberto 2012). However, Rota and Tinian amended the ban to allow non-commercial gill netting with permits on each island in 2010 and 2011 respectively (MacDuff and Roberto 2012). Before the 2003 gill net ban, gillnetting accounted for 22% of the landings in 2000 (MacDuff and Roberto 2012).

Using SCUBA while fishing has been illegal since 2002. Houk, Rhodes et al. (2012) suggest SCUBA is still being utilized in the spear fishery because catch composition in CNMI is similar to that of the Guam SCUBA spear catch. In addition, catch composition is also different from the free-diving harvest in Guam and Yap based on the dominance of parrotfish and reduction of evenness across other fish families. However, actual catch composition data was not included in the report.

Fishery Data Bases

There are currently three different data sets (Commercial Purchase, CREEL surveys, and the PIFSC Bio-Sampling Program) used to monitor reef fish landings and describe species composition for Saipan fishers. All three data sets were utilized to develop a list of reef fish species important to inshore fisheries.

Commercial Purchase Data Base

The Division of Fish and Wildlife (DFW) has been collecting fishery data in Saipan since the mid 1970's (Hamm, Quach et al. 2012). Fishery data is obtained by trip tickets in Saipan where an estimated 90% of landings are made (Hamm, Quach et al. 2012). Numbered invoices are provided to all first-time fish purchasers (hotels, restaurants, stores, fish markets, and roadside vendors). The buyers complete an invoice for each fish purchase made directly from fishers with a copy going to DFW. Since the commercial purchase invoice system is limited to Saipan landed fish, landings are adjusted through an expansion algorithm developed by Western Pacific Fishery Information Network (WPacFIN) that estimates 100% of the commercial landings for the CNMI. Data summaries are generated which report on commercial landings and economic information on the bottomfish and pelagic fisheries.

A new law (PL 17-89) requiring the mandatory reporting and recording of all commercially harvested and sold fish was signed into law in 2012. The goal of this new law is to obtain 100% timely reporting and accurate fish identification from the vendors/fishermen to DFW. The CNMI DFW has been developing regulations and planning to conduct several outreach events with the various fish vendors and fishermen. Consequently, the implementation has been gradual and the current data collection system still relies heavily on the voluntary cooperation of vendors to identify and record all fish sold (Hamm, Quach et al. 2012). Due to the large number of species comprising catches, most of the reef fish catch is reported as either 'assorted reef fish' or to family level for the more important (or expensive) reef species (Table 1).

CREEL Survey

DFW uses two different creel surveys to estimate total annual boat and shore based effort and catch per unit effort (CPUE) on the island of Saipan (Table 2) (MacDuff and Roberto 2012). DFW staff conducts random surveys throughout the year. Multiple snapshots of effort and CPUE are collected and subsequently expanded to generate annual estimates of catch.

The boat based creel survey has been in effect since 2000, and collects information on commercial and non-commercial fishing activities at the three most active launching docks on the island of Saipan (WPRFMC 2012). The sampled docks include Sugar Dock, Fishing Base, and Smiling Cove Marina. Two types of data are collected: western lagoon trailer count, which estimates fishing effort at all of Saipan's ports; and the access point (port) survey, which estimates CPUE from only the sampled docks. The data is then expanded at a stratum level in order to estimate landings by gear type for the entire CNMI boat fishery (WPRFMC 2012). The shore-based Creel survey uses a stratified randomized data collection design which covers the Western Lagoon of Saipan which included active shoreline access points and has been collecting data since 2005 (WPRFMC 2012). The participation count, which estimates effort, involves quantifying fishing activity (number of fishermen and gear) from shore, location and weather information on randomly selected days. The interview portion collects information from fishermen on length, weight, species composition, gear used, bycatch, location and time spent fishing. The collected effort and CPUE data is expanded to create annual estimated landings for shore based landings (WPRFMC 2012).

The shore-based creel survey is limited to the shoreline and not set up to intercept “in-water” fishing activities, such as spearfishing. There is such a small window of opportunity to catch “in-water” fishing activities because surveyors do not have access to interviews. This creates gaps in the data collected and is not representative of the actual landings occurring in the CNMI.

PIFSC Bio-Sampling Program

The Bio-Sampling Program is funded by the Pacific Islands Fishery Science Center (PIFSC) and managed by a private contractor working in concert with the local DFW office. This program focuses on collecting commercial reef fish landings, catch composition, and life history information on Saipan landed reef fish. Data collection started January 2011 and continues to the date of this report. To date, the Bio-Sampling Program has surveyed over 1,900 night spear catches comprising 174 species and over 134,000 reef fish. The bio-sampling data focuses on night time spearfishing activities, therefore the bio-sampling project compliments the data collected by the CREEL surveys (WPRFMC 2012).

Productivity Susceptibility Assessment

Using all three fishery data sources (trip invoice, CREEL surveys, and bio-sampling data), 26 inshore reef species were chosen for a PSA analysis of the inshore CNMI fishery (Table 4). Species were chosen based on prevalence in commercial catch data from all three data sources. The 26 inshore reef species represent ten common reef fish families. Recommended species were reviewed by local DFW and NOAA fisheries staff.

The vulnerability of a stock depends on two factors: the productivity of a stock (life history characteristics) and the susceptibility (amount that a fishery can negatively impact species) (Stobutzki, Miller et al. 2001; Patrick 2009). A Productivity-Susceptibility Analysis (PSA) is a semi-quantitative and rapid risk assessment tool to assess the vulnerability of US fish stocks from becoming overfished (NOAA.Fisheries.Toolbox 2010). The productivity and susceptibility of a stock is determined by scoring a standardized set of attributes for both productivity and susceptibility (NOAA.Fisheries.Toolbox 2010). The most vulnerable of stocks are those with a high susceptibility score and a low productivity score (Patrick 2009). NOAA-Fisheries identified vulnerability as a useful measure for grouping data-poor stocks into relevant management complexes and developing precautionary harvest rules (NOAA.Fisheries.Toolbox 2010).

Productivity Attributes

Productivity is defined as the capacity of the stock to recover once the population is depleted, which depends on life-history characteristics of a stock (Stobutzki, Miller et al. 2001). The following seven productivity attributes have previously been integrated into other PSA analyses and are currently the criteria used in the PSA tool from the NOAA fishery toolbox (Table 5).

- **Maximum age (t_{max}):** Maximum age is directly related to natural mortality rate (M). Species with a lower mortality rate generally have a larger maximum age (Patrick 2009). Fish with a maximum age greater than 20 years were categorized as low productivity. Maximum ages between 10-20 years were rated as moderate productivity and species with a maximum age less than 10 years were classified as high productivity.
- **Maximum size (L_{max}):** Maximum size can be used as an indicator of species relative recover rate. In general, larger species live longer and recover more slowly than smaller sized species (Stobutzki, Miller et al. 2001). Fish with a maximum size less than 50 cm had a high productivity rating, 50-150 cm received a moderate productivity rating, and those species larger than150 cm were ranked as low productivity.
- **Growth coefficient (k):** The von Bertalanffy growth coefficient measures how rapidly a fish reaches its maximum size. Species with k values less than 0.25 received a low productivity rating, k values between 0.25-0.50 were moderately productive, and values greater than 0.50 scored a high productivity rating.
- **Natural mortality (M):** Natural mortality reflects a population's productivity. A high mortality rate requires a higher level of production (Patrick 2009). For species with no published natural mortality rate, M was estimated using Hoenig et al. (1983) mortality equation with maximum age and a 5% survival rate at maximum age. Natural mortalities that exceeded 0.5 received high productivity scoring, 0.25-0.50 moderate productivity, and species with a natural mortality less than 0.25 were considered as low productivity.
- **Reproductive strategy:** Broadcast spawners usually produce more young than brooding species. Therefore, broadcast spawners may have the ability to recover faster (Stobutzki, Miller et al. 2001). Species classified as broadcast spawners were ranked as high productivity, species that guarded their eggs were rated moderately productive, and brooding species had a low productivity scoring.
- **Age at maturity (t_{mat}):** Age at maturity is generally positively correlated to maximum age. Long-lived species tend to be older at first maturity than shorter lived stocks (Patrick 2009). Species that matured within 2 years scored high productivity, between 2-4 years represented moderate productivity, and species that matured after 4 years received a low productivity rating.
- **Mean trophic level:** Lower trophic level stocks are generally more productive than higher trophic level stocks (Patrick 2009). Trophic levels were based on trophic scores calculated by Pauly et al. (1998). Herbivorous species with a trophic level less than 2.5 had high productivity, omnivores with a trophic level between 2.5 and 3.5 had moderate productivity, and piscivores above a 3.5 trophic level were classified as low productivity.

Susceptibility Attributes

Susceptibility is defined as the likelihood of a species to be captured and impacted by a fishery (Stobutzki, Miller et al. 2001; Patrick 2009). The following five susceptibility attributes have previously been integrated into other PSA analyses and are currently the criteria used in the PSA tool from the NOAA fishery toolbox (Table 5).

- **Management Strategy:** Stocks managed with catch limits where a fishery can be closed before limits are exceeded have a low susceptibility to overfishing. Conversely, a stock without catch limits or accountability measures have a much higher susceptibility to overfishing (Patrick 2009). Those species with catch limits and proactive accountability ranked as low susceptibility. Species with catch limits but reactive accountability measures were given moderate susceptibility, and the species without catch limits or accountability measures had a high susceptibility rating.
- **Water-column position:** This is the position (max depth) of the species in a water column as compared with fishing gear (Stobutzki, Miller et al. 2001). Species with a deeper depth range are considered less vulnerable to fishing (Graham et al. 2011). Species with a maximum depth of less than 20 m were considered as highly susceptible. Depth ranges between 30-40 m were ranked as moderately susceptible, and those species deeper than 40 m had a low susceptibility ranking.
- **Day/night catchability:** Different species will be more susceptible to different gear types based on the time of day it is caught and the time of day a gear is used (Stobutzki, Miller et al. 2001). The catch rate at different times of day was quantified using Graham (1994). Fish that were more likely to be caught during the day time had a low susceptibility rating, species which were more frequently captured at night had a moderate susceptibility score, and species that were caught both during the night and the day were given a high susceptibility score.
- **Desirability/value:** This assumes that highly valued fish are more susceptible to becoming overfished due to increased effort. Dealer price per pound was used to value the fish (Patrick 2009). Fish with an average price below $3.50 received a low susceptibility rating, prices between $3.50 and $4.00 were given moderate susceptibility scores, and those species with an average price above $4.50 were ranked as highly susceptible. Current dealer retail costs for Saipan landed reef fish were provided by Micronesian Environmental Services.
- **Fishery impact on habitat:** Certain gear types may have indirect effect on species due to damage it causes to the habitat (Patrick, 2009). A species with fishery impacts on habitat that were more than minimal or temporary and not mitigated received a high susceptibility rating. Adverse effects with mitigation received a moderate susceptibility rating, while fishery impacts that had little or no adverse impacts received a low susceptibility rating.

Data Quality Criteria

Many tropical fishery species are considered data-poor stocks which can lead to errors in a risk assessment (Stobutzki, Miller et al. 2001; Cheung, Pitcher et al. 2005; Patrick 2009). Using life history traits from other regions as a proxy may also lead to errors since many tropical species have differing growth rates and maturity rates in different areas (DeMartini, Langston et al. 2014; Taylor and Choat 2014).

Patrick et al. (2009) created a data quality index in order to report the data quality as a separate value from the risk assessment (Table 6). The data quality score is a weighted average of the data quality scores for each individual attribute and gives the overall belief in the score (Patrick 2009). If data is missing for a specific attribute (data quality score of 5), the attribute is not used in the computation of the vulnerability score but it will be reflected in the overall data quality score; therefore a stock with missing data for many different attributes will have a low data quality score (Patrick 2009).

Methods

Gathering life history traits

A literature search was conducted for life history traits on all of the 26 selected species. Scientific name and common name were used to conduct searches on FishBase as well as Google Scholar. Life history traits from studies within the Marianas were given priority and then searches were expanded outwards into the Caroline Islands, Hawaii and even further to any relevant data for each specific species.

After the initial literature was compiled queries were sent out to tropical fishery experts to review the completeness of the references. Life history references were sent to and feedback was received from: Lennon Thomas, ISC Scientific Support JIMAR; John Gourley, Micronesian Environmental Services; Dr. Edward DeMartini, Research Fishery Biologist NOAA; Dr. Ivor Williams, Reef Fish Researcher CRED; and Dr. Marc Nadon, Fisheries Assessment Specialist. Life history traits were stored in a database. Appendix one is the complete list of life history references used by species.

PSA Analysis

The Productivity and Susceptibility Analysis (Patrick 2009) was conducted using the 26 selected coral reef fishery species important to the CNMI to determine each species vulnerability to overfishing. The list of life history traits (Table 7) is the compilation of the different literature gathered for each species. The collected life history parameters were then ranked based on the PSA attributes and the source of the data was also ranked (Table 6). The ranked data for each species were then entered into the PSA model to give a productivity, susceptibility and vulnerability score for each species.

The seven productivity and five susceptibility (Table 5) attributes were used in the analysis. The productivity and susceptibility scores were given a weighted average of all the individual attribute scores. Each attribute was given the same weight of two as suggested by Patrick et al. (2009). Stocks with low productivity and high susceptibility scores received a higher vulnerability score. Each of the attribute scores was also given a data quality rank (Table 6). Data quality scores of greater than 3.5 were considered low data quality, 2.0-3.5 were given moderate data quality, and less than 2.0 were considered high data quality (Patrick 2009).

The resulting vulnerability sores were grouped using a hierarchical cluster analysis to determine possible management groups. Within sum of squares was used to determine the number of groups using the "elbow method".

Vulnerability scores were correlated against productivity scores, susceptibility scores, and data quality to determine which aspect had the greatest influence on the overall vulnerability ranking. Sensitivity to individual attributes was also tested by removing a single attribute and correlating the new vulnerability score to the original sore.

Vulnerability scores were correlated against calculated vulnerability scores from a PSA conducted in Guam on inshore reef fish (Thomas, in review 2014). In order for better comparison against the Guam PSA susceptibility and vulnerability attributes that were common to Guam attributes were given the same bin categorization for high, medium, and low. Shared attributes between the Guam and CNMI PSA included: maximum age, maximum size, von Bertalanffy growth coefficient, natural mortality, age at maturity, mean trophic level, vertical overlap, and value of the fishery. Attributes that were independent to the CNMI were reproductive strategy, management strategy, day/night catchability, and fisher impact of habitat.

Productivity, susceptibility and vulnerability scores were also correlated against vulnerability scores from Cheung et al. (2005). The vulnerability score calculated by Cheung et al. was based on productivity, abundance trends and life history characteristics generated from FishBase (Cheung, Pitcher et al. 2005).

Results

Productivity and Susceptibility Scores

Data for all attributes were not available for all species. Life history traits varied within and among families; although trophic levels were fairly consistent within family groupings (Table 7). Maximum ages ranged from 6 years (*Scarus ghobban*) to 39 years (*Naso lituratus*), with 50% of data recorded for species. Natural mortality ranged from 0.15 (*Scarus rubroviolaceus*) to 1.47 (*Siganus argenteus*); with data available for 54% of species. Maximum size was scored for all species and ranged from 22.1 cm (*Acanthurus lineatus*) to 89.7 cm (*Carnax melampygus*). K values ranged from 0.12 (*A. lineatus*) to 1.41(*Scarus ghobban*), and was available for 77% of species. Age at maturity ranged from less than one year (*Selar crumenophthalmus*) to 4.5 years (*Naso unicornis*), data was available for 46% of species. Trophic levels was available for all species and ranged from 2.0 (Scaridae, Siganidae, and *A. lineatus*) to 4.5 (*C. melampygus*).

PSA Results

Vulnerability scores ranged from 1.87 to 0.88 (Table 8). A majority of the species had medium data quality rankings, while three species were categorized as low data quality; no species had a high data quality score (Figure 3). The top three most vulnerable species were *Kyphosus vaigiensis* (1.87; medium data quality), *Cheilio inermis* (1.76; low data quality), and *Leptoscarus vaigiensis* (1.66; medium data quality). The least vulnerable species was *Caranx melampygus* (0.88; medium data quality).

Productivity and susceptibility scores also varied within families (Table 8). The three most productive species were all in family Scaridae, and all had medium data quality scores. *Chlorurus sordidus* had the highest productivity score (2.86). The lowest productivity scores were *Monotaxis grandoculis* (1.43) and *C. inermis* (1.43); both had low data quality scores. *K. vaigiensis* and *Leptoscarus vaigiensis* tied for the highest susceptibility score (2.20; medium data quality). The three species with the lowest susceptibility were *C. melampygus* (1.20; medium data quality), *M. grandoculis* (1.40; low data quality), and *Lethrinus obsoletus* (1.40; low data quality).

Within group sum of squares indicated that six clusters was the optimum number of groups based on the vulnerability scores (Figure 7). Only one cluster was comprised of a single family of Scaridae. However, other species in the family Scaridae were found in other clusters. The two species from the family Caragidae were also found within the same cluster which also contained species from different families. All other families were mixed between clusters (Figure 5). Trophic groups also varied between clusters except for the cluster of only Scaridae (Figure 6).

Pearson correlation analysis showed a strong negative correlation between productivity and vulnerability (r= -0.80). Susceptibility, however, was not significantly correlated with vulnerability. The productivity data quality was strongly positively correlated with vulnerability (r=0.71); with no corresponding correlation between susceptibility data quality and vulnerability.

The vulnerability scores were not found to be sensitive to the removal of a single factor (Table 9). All vulnerability scores with a removed attribute were highly correlated (>0.90) to original vulnerability scores. The lowest correlation resulted from removing the breeding strategy attribute (r=0.91). The removal of a single attribute did not affect overall vulnerability scores.

There were nineteen shared species between the CNMI PSA and the Guam PSA. The vulnerability scores of those species were positively correlated (r=0.51). However, both productivity and susceptibility scores were not significantly correlated between CNMI and Guam.

Productivity, susceptibility, and vulnerability were not significantly correlated to risk of extinction scores calculated by Cheung et al. (2005). Vulnerability and susceptibility had weak (<0.30) positive correlations to scores calculated by Cheung et al. (2005), while the productivity score was slightly negatively correlated (-0.28).

Discussion

Productivity scores had a much larger impact on the overall vulnerability score than susceptibility. The productivity ratings were based on a species life history traits. In areas such as CNMI, there have been few published reports on coral reef fish life history parameters, so most of the data came from areas outside of the Marianas archipelago. Life history proxies from other regions may introduce error in the analysis because many coral reef fish species have different growth rates, maximum sizes, and age at maturity for different locations (DeMartini, Langston et al. 2014; Taylor and Choat 2014). Poor productivity data quality also had a strong positive correlation to the overall vulnerability score; indicating the worse the life history data, the higher the vulnerability score.

The calculated vulnerability scores for CNMI were positively correlated to the vulnerability scores in Guam. This indicates that species in both regions share approximately the same level of vulnerability to fishing. However, the productivity and susceptibility scores were not correlated between regions indicating a difference in PSA analysis or data input.

Calculated PSA vulnerability scores were not strongly correlated to the calculated vulnerabilities from Cheung et al. (2005). The differences in vulnerabilities could be due to differing life history parameters. Cheung et al. (2005) used readily available life history data from FishBase for a wide variety of species using a fuzzy logic system. The vulnerability scores calculated would not take into account regional differences in life history parameters or regional susceptibility parameters. Instead it would give a general vulnerability score for species as a whole across the entire habitat range.

In order to improve the vulnerability analysis, there should be more effort to gaining regional specific life history traits for common fishery species. Otoliths and gonads are currently being collected by DFW and MES staff for several commercially important reef species for further in-depth life history studies. These species include *Lethrinus obsoletus*, *Lethrinus atkinsoni*, *Naso unicornis*, *Parupeneus barberinus*, *Mulloidchthys flavolinetus*, *Scarus ghobban*, *Cheilinus undulatus*, *Cheilinus trilobtus* and *Siganus argenteus*. The collection of supplemental life history data to be combined with existing DFW data will start for *A. lineatus* and *N. lituratus* in July 2014. (John Gourley, personal communication 2014).

The PSA results and cluster analysis indicate that species within family groupings have varying levels of vulnerability to fishing pressures within CNMI. Species within a family can respond differently to fishing based on life history and susceptibility characteristics (Jennings 1999). Species in the same family that fall into different cluster groupings has management implications, because only species with similar life history traits and susceptibility to fishing should be managed together (Patrick 2009).

This PSA can be used either by selecting the most vulnerable species within a family and using that species to monitor and manage all the species within a family; or by managing species based on the clustering analysis. The PSA should be updated on a regular basis as management and fishing pressure change, and as more regional life history data are produced. The PSA analysis gives insight into the potential for commercially important species to be overfished based on life history parameters and susceptibility to fishing pressure. The PSA also gives insight into how different species within a family can have different vulnerabilities to fishing pressure within the same region.

Literature Cited

Allen, S. D. and J. R. Amesbury (2012). Commonwealth of the Northern Mariana Islands As a Fishing Community, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center.

Bearden, C., R. Brainard, et al. (2005). "The state of coral reef ecosystems of the Commonwealth of the Northern Mariana Islands." The state of coral reef ecosystems of the United States and Pacific Freely Associated States: 2005: 399-441.

Bejarano, S., Y. Golbuu, et al. (2013). "Ecological risk and the exploitation of herbivorous reef fish across Micronesia." Mar. Ecol. Prog. Ser **482**: 197-215.

Cheung, W. W., T. J. Pitcher, et al. (2005). "A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing." Biological Conservation **124**(1): 97-111.

DeMartini, E. E., R. C. Langston, et al. (2014). "Spawning seasonality and body sizes at sexual maturity in the bluespine unicornfish, Naso unicornis (Acanthuridae)." Ichthyological Research: 1-9.

Hamm, D. C., N. T. S. Chan, et al. (2003). Commonwealth of the Northern Mariana Islands (2001). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **18**.

Hamm, D. C., N. T. S. Chan, et al. (2004). Commonwealth of the Northern Mariana Islands (2002). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **19**.

Hamm, D. C., N. T. S. Chan, et al. (2005). Commonwealth of the Northern Mariana Islands (2003). Fishery Statisitics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **20**.

Hamm, D. C., N. T. S. Chan, et al. (2006). Commonwealth of the Northern Mariana Islands (2004). Fishery Statisitics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **21**.

Hamm, D. C., N. T. S. Chan, et al. (2007). Commonwealth of the Northern Mariana Islands (2005). Fishery Statisitics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **22**.

Hamm, D. C., M. M. Quach, et al. (2008). Commonwealth of the Northern Mariana Islands (2006). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **23**.

Hamm, D. C., M. M. Quach, et al. (2009). Commonwealth of the Northern Mariana Islands (2007). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **24**.

Hamm, D. C., M. M. Quach, et al. (2010). Commonwealth of the Northern Mariana Islands (2008). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **25**.

Hamm, D. C., M. M. Quach, et al. (2011). Commonwealth of the Northern Mariana Islands (2009). Fishery statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **26**.

Hamm, D. C., M. M. Quach, et al. (2012). Commonwealth of the Northern Mariana Islands (2010). Fishery Statistics of the Western Pacific, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. **27**.

Houk, P., K. Rhodes, et al. (2012). "Commercial coral-reef fisheries across Micronesia: A need for improving management." Coral Reefs **31**(1): 13-26.

Jennings, S., J.D. Reynolds, N.V.C Polunin (1999). "Predicting the Vulnerability of Tropical Reef Fishes to Exploitation with Phylogenies and Life Histories." Conservation Biology **13**(6): 1466-1475.

MacDuff, S. and R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelacig FIshery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery Management Council, Honolulu Hawaii 96813 USA, WPRFMC.

MSRA (2006). MSRA (Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006).

NOAA.Fisheries.Toolbox (2010). Productivity and Susceptibility Analysis (PSA), . http://nft.nefsc.noaa.gov/PSA.html#Version.

Patrick, W. S., P. Spencer, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortes, K. Bigelow, W. Overholtz, J. Link, P. Lawson (2009). Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six U.S. fisheries. , U.S. Department of Commerce. **NOAA Technical Memorandum:** 90.

Rhodes, K. L., K. Warren-Rhodes, et al. (2011). "Market Forces and Nearshore Fisheries Management in Micronesia."

Severance, C., R. Franco, et al. (2013). "Effort Triggers, Fish Flow, and Customary Exchange in American Samoa and the Northern Marianas: Critical Human Dimensions of Western Pacific Fisheries 1." Pacific Science **67**(3): 383-393.

Stobutzki, I., M. Miller, et al. (2001). "Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch." Environmental Conservation **28**(02): 167-181.

Taylor, B. and J. Choat (2014). "Comparative demography of commercially important parrotfish species from Micronesia." Journal of fish biology.

Trianni, M. S. (1998). Summary and Further Analysis of the Nearshore Reef Fishery of the Northern Mariana Islands, Division of Fish and Wildlife Commonwealth of the Northern Mariana Islands**:** 64.

van Beukering, P., W. Haider, et al. (2006). The economic value of the coral reefs of Saipan, Commonwealth of the Northern Mariana Islands, US Department of Commerce, National Oceanic and Atmospheric Administration, National Oceanographic Data Center, Coral Reef Conservation Program.

Williams, I. D., B. L. Richards, et al. (2010). "Differences in reef fish assemblages between populated and remote reefs spanning multiple archipelagos across the central and western Pacific." Journal of Marine Biology **2011**.
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.
WPRFMC (2012). Annual Catch Limits for the Mariana Archipelago. www.wpcouncil.org. W. P. R. F. M. Council.
WPRFMC (2012). Archipelagic Fishery Ecosystem Annual Report. M. Sabater. Honolulu Hawaii 96813 USA, Western Pacific Regional Fishery Management Council.
WPRFMC (2013). Report of the Marianas Archipelago Fishery Ecosystem Plan Advisory Panel Meeting. CNMI Sub-Panel. DLNR Conference Room**:** 5.
Zeller, D., S. Booth, et al. (2007). "Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years." Fishery Bulletin **105**(2): 266-277.

Tables

Table 1: Highest reported catches (lbs) from trip invoice reports (2005-2010). Listed in order of largest total landings to smallest. Bold species indicate family groupings (Hamm, Chan et al. 2003; Hamm, Chan et al. 2004; Hamm, Chan et al. 2005; Hamm, Chan et al. 2006; Hamm, Chan et al. 2007; Hamm, Quach et al. 2008; Hamm, Quach et al. 2009; Hamm, Quach et al. 2010; Hamm, Quach et al. 2011; Hamm, Quach et al. 2012; Houk, Rhodes et al. 2012).

	INVOICE TICKET REPORTS						
SPECIES	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**TOTAL**
Parrotfish (misc.)	7,293	21,000	26,919	30,738	26,547	16,220	128,717
Bigeye Scad	8,680	14,942	26,490	38,461	25,765	12,847	127,185
Emperor (mafute/misc.)	17,766	6,297	10,825	10,289	12,768	6,104	64,049
Rabbitfish (misc.)	2,110	8,452	6,603	2,976	1,687	3,251	25,079
Surgeonfish (misc.)	3,212	7,598	2,102	1,440	2,432	4,430	21,214
Jacks (misc.)	1,547	1,978	2,503	1,785	2,294	792	10,899
Jobfish (uku)	866	230	3,762	2,743	1,780	1,101	10,482
Grouper (misc.)	2,477	1,317	2,012	2,932	768	222	9,728
Blueline Snapper	596	1,747	2,651	1,424	1,478	1,492	9,388
Unicornfish (misc.)	146	131	399	526	1,296	984	3,482
Wrasse (misc.)	210	143	1,562	1,018	365		3,298
Goatfish (misc.)	123	552	244	205	830	1,331	3,285
Blackjack	1,104	277	307	171	130	594	2,583
Orangespine unicornfish	50	70	462	323	313	1,123	2,341
Bigeye Emperor		151	399	617	125	53	1,345
Squirrelfish (misc.)		47	144		215	416	822
Mullet	46	76	31			394	547
Giant trevally	66		148	24	55	64	357
Barracuda	10	33	33	61	24		161
Misc. Reef Fish	55,584	88,904	58,813	46,939	38,528	30,971	319,739

REPORTED CREEL CATCH (COMBINED)			
SPECIES	SHORE	BOAT	TOTAL
Redgill Emperor	76	52,470	52,546
Emperor (mafute/misc.)	3,777	24,576	28,353
Bigeye Scad	6,252	13,625	19,878
Blackspot Emperor	11,313	7,641	18,954
EE: Juvenile Jacks	16,387	113	16,500
Parrotfish (misc.)	7,767	6,797	14,565
Goatfish (misc.)	5,720	4,125	9,844
Mullet	8,634	951	9,585
Jobfish (uku)	296	7,849	8,144
Orangespine Unicornfish	3,760	4,245	8,004
Surgeonfish (misc.)	4,113	3,696	7,809
Black Tip Grouper	28	7,321	7,349
Barracuda	475	6,623	7,098
Triggerfish (misc.)	874	5,481	6,354
Blackjack	48	6,258	6,306
Longnose Emperor	640	5,458	6,098
Mojarra	5,561	0	5,561
Jacks (misc.)	818	4,500	5,318
Bluespine Unicornfish	1,671	3,588	5,258
Unicornfish (misc.)	1,781	3,464	5,244
Yellowstripe Emperor	3,551	1,387	4,938
Blueline Snapper	33	4,301	4,334
Yellow Spotted Trevally	215	3,447	3,662
Rudderfish (misc.)	1,201	2,431	3,631
Goatfish (juvenile-misc)	3,507	0	3,507
Forktail Rabbitfish	1,615	1,799	3,414
Grouper (misc.)	1,108	1,967	3,076
Lyretail Grouper	10	2,989	2,999
Wrasse (misc.)	1,932	1,024	2,955
Needlefish	2,534	175	2,709
Rabbitfish (Juv.)	2,562	113	2,675
Catfish (Striped eel)	2,520	0	2,520
Cigar Wrasse	2,386	121	2,507
Yellowtail Emperor	749	1,488	2,237
Soldierfish (misc.)	642	1,437	2,079
Dash & Dot Goatfish	1,326	443	1,769
Gold Spotted Rabbitfish	1,643	56	1,699
Goby	24	1,554	1,579
Squirrelfish (misc.)	627	942	1,569
Convict Tang	828	701	1,529
Bluebanded Surgeonfish	761	667	1,427
Snapper (misc. shallow)	316	1,080	1,397
Scribbled Rabbitfish	1,248	86	1,334
Yellowlips Emperor	147	1,177	1,323
Bluefin Trevally	944	374	1,318
Yellowfin Surgeonfish	184	1,085	1,269

Table 2 (left): Top species (kg) reported from combined CREEL surveys: 2000-2011 off shore and 2005-2012 inshore. Listed in order of largest total catch to smallest. Bold species indicate family

Table 3: Species list of dominant commercially landed species from Saipan markets from primarily free-dive/spear (January 2011-December 2013). Listed in order of largest to smallest landings in pounds (Unpublished data from the PIFSC Bio-Sampling Program; John Gourley, personal communication).

BIO-SAMPLING DATA			
SCIENTIFIC NAME	**COMMON NAME**	**POUNDS**	**NUMBER**
Naso unicornis	Bluespine unicornfish	6,877	5,988
Scarus rubroviolaceus	Red-lipped parrotfish	5,857	2,703
Naso lituratus	Orangespine unicorn	5,757	13,167
Acanthurus lineatus	Bluebanded surgeonfish	5,282	14,121
Siganus argenteus	Forktail rabbitfish	3,056	8,775
Parupeneus barberinus	Dash dot goatfish	1,985	5,080
Scarus ghobban	Blue-Barred Parrotfish	1,841	2,915
Chlorurus microrhinos	Steephead parrotfish	1,585	
Hipposcarus longiceps	Pacific longnose parrotfish	1,535	1,633
Lethrinus atkinsoni	Yellowtail emperor	1,441	3,060
Mulloidchthys flavolinetus	Yellowstripe goatfish	1,405	6,530
Monotaxis grandoculis	Large-eye emperor	1,218	
Kyphosus vaigiensis	Brassy chub	1,168	
Kyphosus cinerascens	Blue sea chub	1,132	
Leptoscarus vaigiensis	Seagrass parrotfish	1,057	1,733
Chlorurus sordidus	Bullethead parrotfish	1,035	1,812
Lethrinus obsoletus	Orange-striped emperor	1,016	2,607
Cheilinus trilobatus	Tripletail wrasse	986	1,574
Siganus spinus	Scribbled Rabbitfish		4,157
Mulloidichthys vanicolensis	Yellowfin goatfish		2,142
Siganus punctatus	Gold-spotted rabbitfish		1,975
Myripristis murdjan	Red soldierfish		1,913
Sargocentron spiniferum	Longjawed Squirrelfish		1,560

Table 4: List of top caught inshore species from Saipan to include in PSA analysis. Species are listed alphabetically by scientific name.

SCIENTIFIC NAME	COMMON NAME
Acanthurus lineatus	Bluebanded surgeonfish
Carnax melampygus	Bluefin trevally
Cheilinus trilobatus	Tripletail wrasse
Cheilio inermis	Cigar wrasse
Chlorurus microrhinos	Steephead parrotfish
Chlorurus sordidus	Bullethead parrotfish
Epinephelus merra	Honeycomb grouper
Hipposcarus longiceps	Pacific longnose parrotfish
Kyphosus cinerascens	Highfin rudderfish silver
Kyphosus vaigiensis	Brassy chub
Leptoscarus vaigiensis	Seagrass parrotfish
Lethrinus atkinsoni	Yellowtail emperor
Lethrinus harak	Blackspot emperor
Lethrinus obsoletus	Orange-striped emperor
Monotaxis grandoculis	Large-eye emperor
Mulloidchthys flavolinetus	Yellowstripe goatfish
Mulloidichthys vanicolensis	Yellowfin goatfish
Naso lituratus	Orangespine unicorn
Naso unicornis	Bluespine unicornfish
Parupeneus barberinus	Dash dot goatfish
Plotosus lineatus	Striped eel catfish
Scarus ghobban	Blue-Barred parrotfish
Scarus rubroviolaceus	Red-lipped parrotfish
Selar crumenophthalmus	Bigeye scad
Siganus argenteus	Forktail rabbitfish
Siganus spinus	Scribbled rabbitfish

Table 5: Productivity and susceptibility attributes and scoring criteria. A score of three indicates high productivity/susceptibility whereas a score of one represents low productivity/susceptibility. Scoring is based on the PSA Version 1.4 tool from NOAA Fisheries Toolbox (Stobutzki, Miller et al. 2001; Patrick 2009).

Productivity Attributes	Low (1)	Moderate (2)	High (3)
T_{max}	> 20 years	10-20 years	< 10 years
L_{max}	> 150 cm	50-150 cm	< 50 cm
k	< 0.25	0.25-0.50	> 0.50
M	< 0.25	0.25-0.50	> 0.50
Reproductive strategy	Bear live young/ brooders	Guard eggs and/or young	Broadcast spawners
T_{mat}	> 4 years	2-4 years	< 2 years
Trophic level	Piscivore > 3.5	Omnivores 2.5-3.5	Herbivores < 2.5
Susceptibility Attributes	**Low (1)**	**Moderate (2)**	**High (3)**
Management Strategy	Targeted stocks have catch limits and proactive accountability measures; Non-target stocks are closely monitored.	Targeted stocks have catch limits and reactive accountability measures	Targeted stocks do not have catch limits or accountability measures; Non-target stocks are not closely monitored.
Vertical overlap	> 40 m	30-40 m	< 30 m
Day/night catchability	Higher catch rate during the day	No difference between night and day	Higher catch rate at night
Desirability/ Value	Stock is not highly valued or desired by the fishery < $3.50	Stock is moderately valued or desired by the fishery $3.50-$4.00	Stock is highly valued or desired by the fishery > $4.50
Fishery Impact of Habitat in General for Non-targets	Adverse effects are absent, minimal or temporary	Adverse effects more than minimal or temporary but are mitigated	Adverse effects are more than minimal or temporary and are not mitigated

Table 6: Data quality criteria from Patrick et al. 2009.

SCORE	DESCRIPTION	EXAMPLE
1	Best data: Based on data for the stock and area of interest that is established and substantial	Data rich stock assessment, published literature that uses multiple methods
2	Adequate data: Limited coverage and corroboration, or for some other reason not deemed as reliable as Tier 1 data.	Limited temporal or spatial data, relatively old information.
3	Limited data: Estimates with high variation and limited confidence. May be based on similar taxa or life history strategy	Similar genus or family.
4	Very limited data: Expert opinion based on general literature review from wide range of species or outside of region.	General data-not referenced
5	No data: No information to base score on-not included in the PAS but included in the data quality index.	

Table 7: Life history traits on 26 selected PSA species for CNMI. Listed in alphabetical order. References for data are found in appendix one. Various maximum lengths (L_{max}) and price were obtained through personal communication with CNMI DFW staff. Data from personal communication are in bold.

Scientific name	t_{max}	L_{max} (cm)	K	M	Breeding strategy	t_{mat}	Trophic Level	Vert. Dist	Time of catch	Price
Acanthurus lineatus	25	**23.5**	0.12	0.24	broadcast	4	2.0	15	Day/Night	**$3.00**
Caranx melampygus	8	89.7	0.23	0.27	broadcast	2	4.5	190	Day	**$3.00**
Cheilinus trilobatus		**35.2**			broadcast		3.5	30		**$4.50**
Cheilio inermis		50.0			broadcast		4.0	30		$2.39
Chlorurs sordidus	9	**30.8**	1.15	0.25	broadcast	1.30	2.0	50	Day/ Night	**$4.50**
Chlorurus microrhinos	15	**56.9**	0.34	0.2	broadcast	3.7	2.0	50	Night	**$4.50**
Epinephelus merra		**28.9**	0.40		broadcast		3.8	20		**$4.50**
Hipposcarus longiceps	12	**52.0**	0.76	1.02	broadcast	3	2.0	40	Night	**$4.50**
Kyphosus cinerascens		**44.4**	0.25				2.3	45	Day	**$3.00**
Kyphosus vaigiensis		**49.5**					2.0	25	Day/ Night	**$3.00**
Leptoscarus vaigiensis		**35.2**			broadcast		2.3	10	Night	**$4.50**
Lethrinus atkinsoni		**35.1**	0.31				3.5	30	Night	**$3.00**
Lethrinus harak	13	**29.7**	0.27	0.29		3.8	3.6	20		**$3.00**
Lethrinus obsoletus	14	**29.0**	0.38	0.21			3.4	30		**$3.00**
Monotaxis grandoculis		**47.5**					3.3	100	Night	**$3.00**
Mulloidichthys flavolineatus	12	**31.4**	0.21	0.25	broadcast		3.2	76		**$3.00**
Mulloidichthys vanicolensis		**27.7**	0.97		broadcast	<1	3.6	113	Day/Night	**$3.00**
Naso lituratus	39	**30.1**	0.35	0.86	broadcast	3	2.3	30	Day/Night	**$3.00**
Naso uniconus	30	**53.6**	0.14	0.41	broadcast	4.5	2.2	80	Night	**$3.00**
Parupeneus barberinus		**37.3**	0.21		broadcast		3.2	100	Night	**$3.00**
Plotosus lineatus	7	32.0	0.45	0.43			3.5	60		$2.60
Scarus ghobban	6	36.6	1.41	0.5	broadcast	2	2.0	36		$3.25
Scarus rubroviolaceus	20	**52.6**	0.66	0.15	broadcast	2.6	2.0	36	Night	**$4.50**
Selar crumenophthalmus		**26.5**	0.61		broadcast	0.6	4.0	170		**$3.50**
Siganus argenteus		**34.1**	0.75	1.47			2.0	40	Night	**$4.50**
Siganus spinus		**25.6**					2.0	50		**$4.50**

Table 8: PSA results for 26 coral reef fishery species. Productivity, susceptibility, data quality and overall vulnerability scores are listed. One is low and three is high. Species listed from highest to lowest vulnerability.

Rec. Num	STOCK		Productivity		Susceptibility		Vulnerability
			Score	Quality	Score	Quality	Score
11	*Kyphosus vaigiensis*	Brassy chub	1.57	4.29	2.20	2.40	1.87
5	*Cheilio inermis*	Cigar wrasse	1.43	4.57	1.80	2.80	1.76
12	*Leptoscarus vaigiensis*	Seagrass parrotfish	1.86	4.14	2.20	2.40	1.66
4	*Cheilinus trilobatus*	Tripletail wrasse	1.71	4.14	2.00	3.00	1.63
8	*Epinephelus merra*	Honeycomb grouper	1.71	4.00	2.00	2.40	1.63
16	*Monotaxis grandoculis*	Large-eye emperor	1.43	4.29	1.40	2.60	1.62
13	*Lethrinus atkinsoni*	Yellowtail emperor	1.57	4.00	1.60	2.40	1.55
25	*Siganus spinus*	Scribbled rabbitfish	1.57	4.29	1.60	3.00	1.55
1	*Acanthurus lineatus*	Bluebanded surgeonfish	2.00	2.14	2.00	2.40	1.41
10	*Kyphosus cinerascens*	Highfin rudderfish silver	1.71	4.14	1.40	2.40	1.35
15	*Lethrinus obsoletus*	Orange-striped emperor	1.71	3.57	1.40	3.00	1.35
24	*Siganus argenteus*	Forktailed rabbitfish	2.14	3.71	2.00	2.40	1.32
14	*Lethrinus harak*	Blackspot emperor	1.86	2.57	1.60	2.80	1.29
2	*Scarus rubroviolaceus*	Red-lipped parrotfish	2.29	2.57	2.00	2.40	1.23
20	*Naso unicornus*	Bluespine unicornfish	1.86	2.29	1.40	2.20	1.21
26	*Parupeneus barberinus*	Dash Dot goatfish	1.86	3.86	1.40	2.60	1.21
21	*Plotosus lineatus*	Striped eel catfish	2.00	4.14	1.60	3.20	1.17
9	*Hipposcarus longiceps*	Long-nose parrotfish	2.57	2.29	2.00	2.40	1.09
22	*Scarus ghobban*	Blue-barred parrotfish	2.57	2.71	2.00	2.80	1.09
7	*Chlorurus microrhinos*	Steephead parrotfish	2.29	2.29	1.80	2.40	1.07
6	*Chlorurs sordidus*	Bullethead parrotfish	2.86	2.14	2.00	2.40	1.01
19	*Naso lituratus*	Orangespine unicornfish	2.43	2.29	1.80	2.20	0.98
23	*Selar crumenophthalmus*	Bigeye scad	2.14	3.14	1.40	3.00	0.95
17	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	2.29	3.00	1.60	2.60	0.93
18	*Mulloidichthys vanicolensis*	Yellowfin goatfish	2.29	2.86	1.60	2.40	0.93
3	*Caranx melampygus*	Bluefin trevally	2.14	3.14	1.20	2.40	0.88

Table 9: Result of PSA sensitivity analysis. Attributes were removed one at a time and correlated against original vulnerability score. The attribute listed is the one removed from the analysis. The number of species scored for each attribute and the total frequency is also noted.

Attribute	Number Scored	Frequency (%)	Pearson Correlation Coefficient
Productivity			
Maximum age (T_{max})	13	50	0.96
Maximum size (L_{max})	26	100	0.98
Von Betalanffy growth (K)	20	77	0.96
Natural Mortality (M)	14	54	0.97
Breeding strategy	17	65	0.92
Age at 50% maturity (T_{mat})	12	46	0.97
Trophic level	26	100	0.96
Susceptibility			
Management strategy	26	100	0.99
Vertical Overlap	26	100	0.95
Day/Night catchability	16	62	0.96
Fishery Value	26	100	0.91
Fishery impact on Habitat	26	100	0.97

Figures

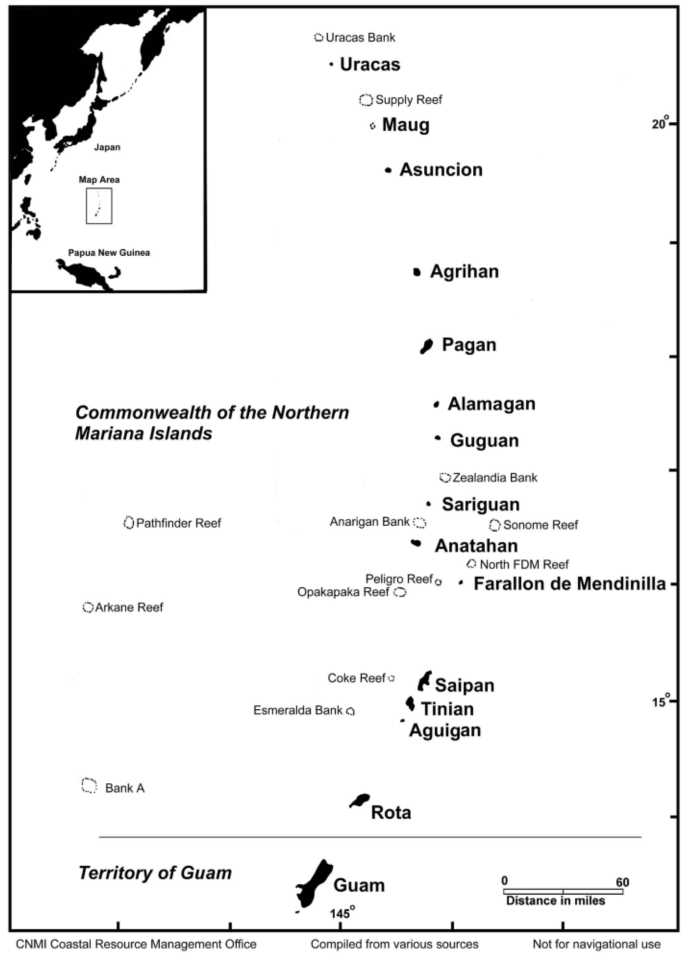

Figure 1: Map of the Marianas archipelago.

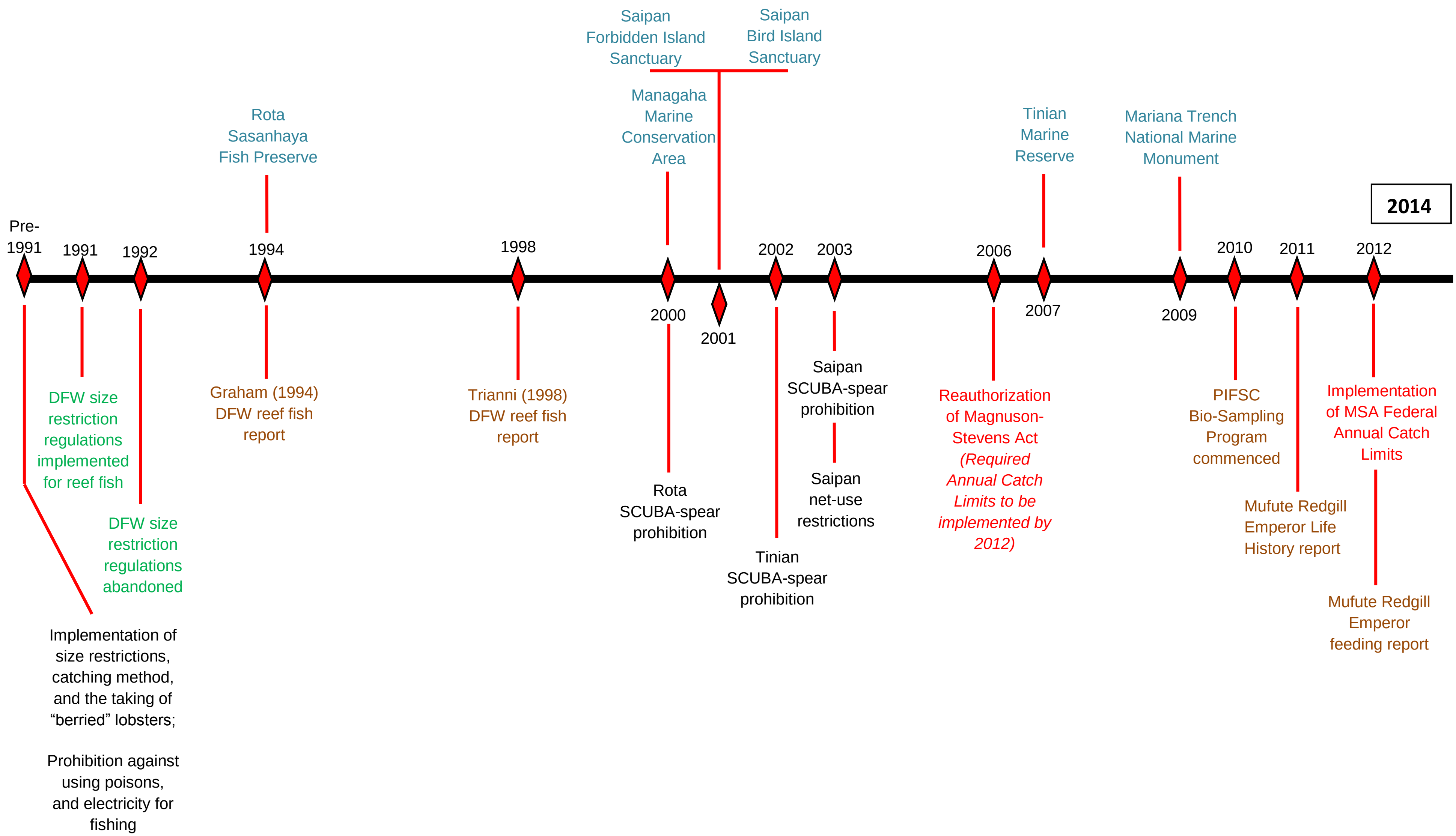

Figure 2: Timeline of Federal and CNMI conservation and management measures implemented for CNMI near shore fishery resources (Figure courtesy of John Gourley, 2014).

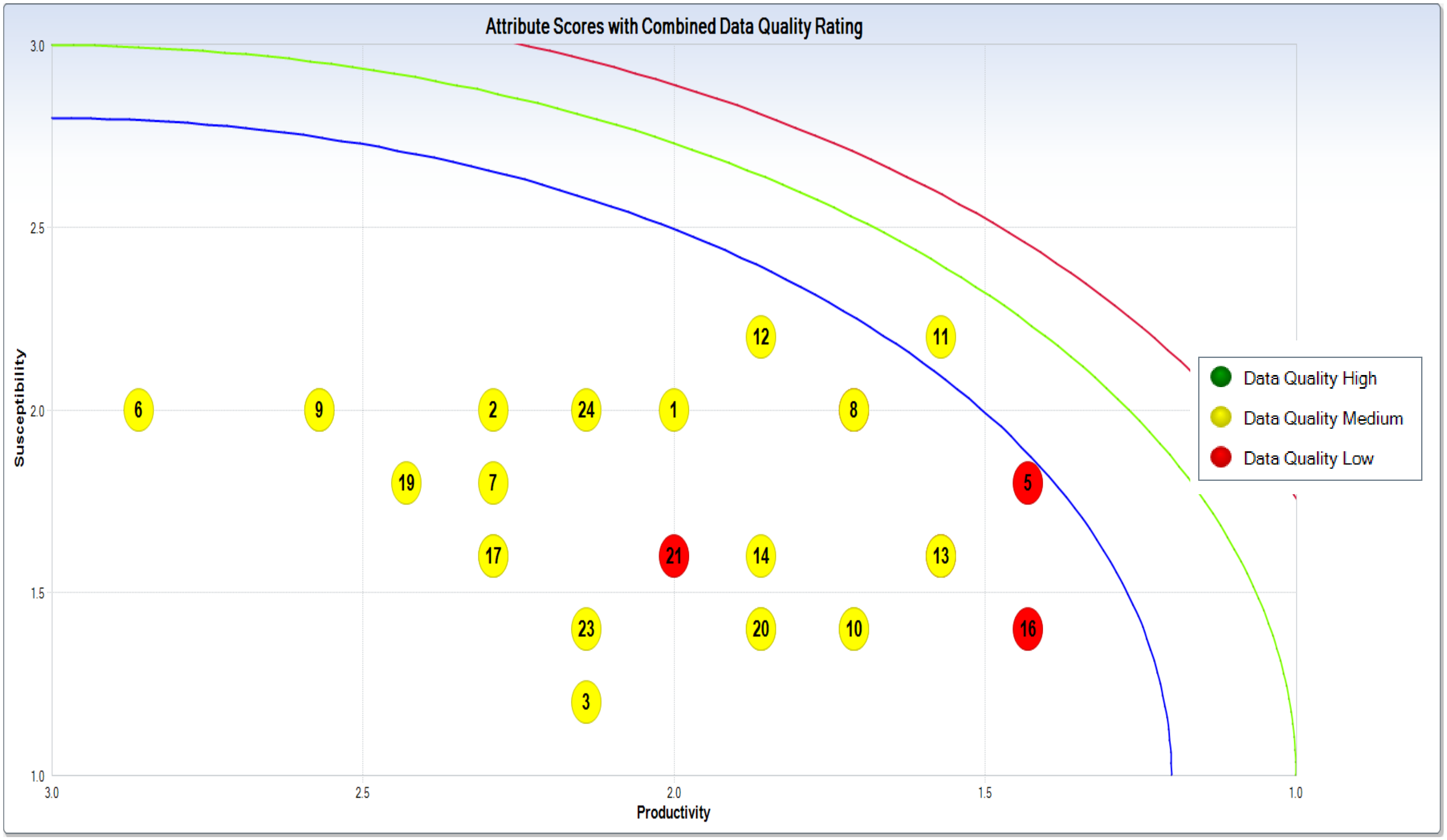

Figure 3: Results of productivity and susceptibility analysis of 26 coral reef fishery species in CNMI. Colors indicate data quality used for scoring. Number represents individual species (Table 8). Colored lines represent vulnerability scores of 1.8 (blue) 2.0 (green) and 2.14 (red). Low productivity and high susceptibility scores resulted in high vulnerability scores.

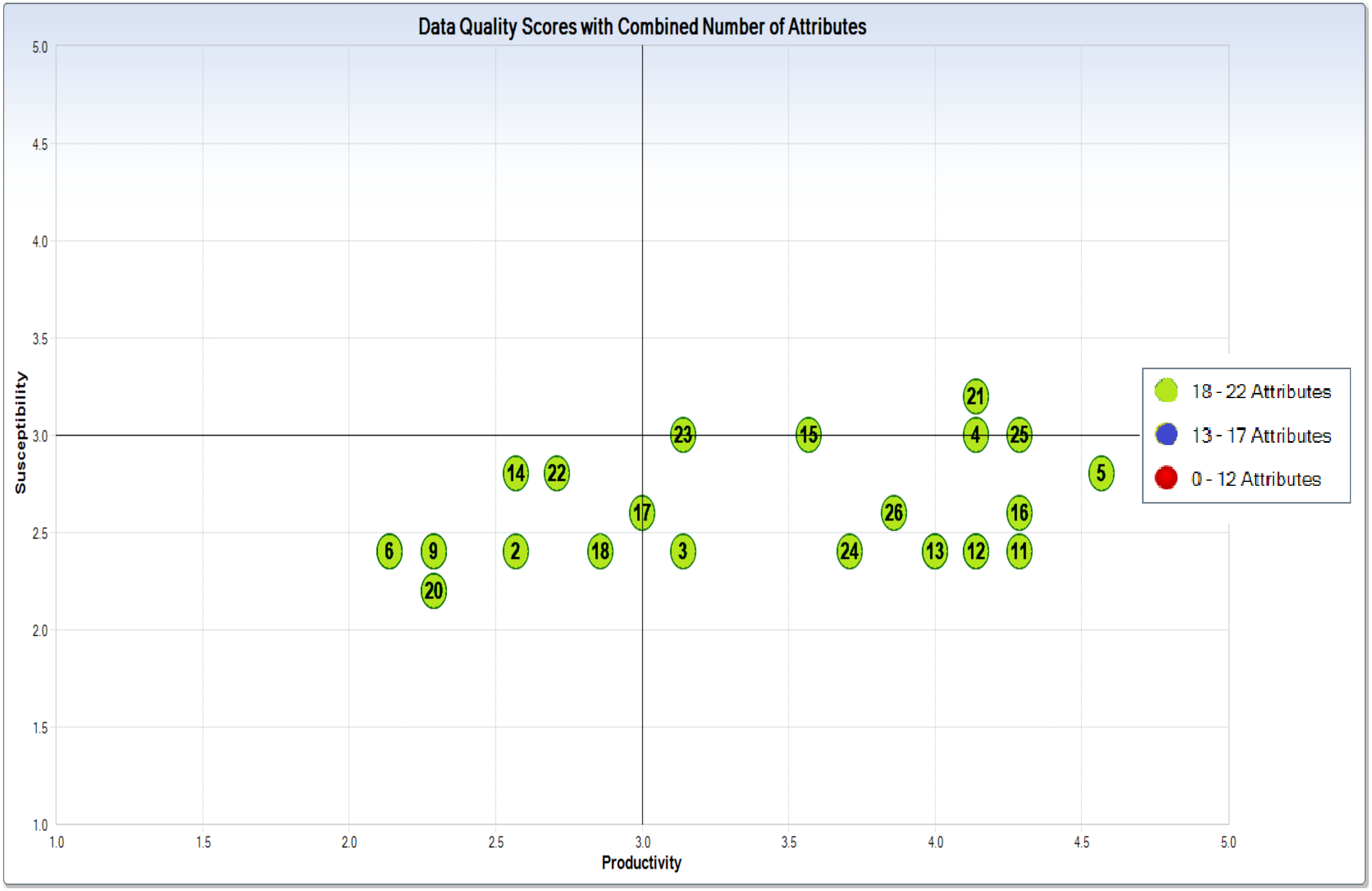

Figure 4: Data quality scores for productivity and susceptibility. Numbers represents species (Table 8).

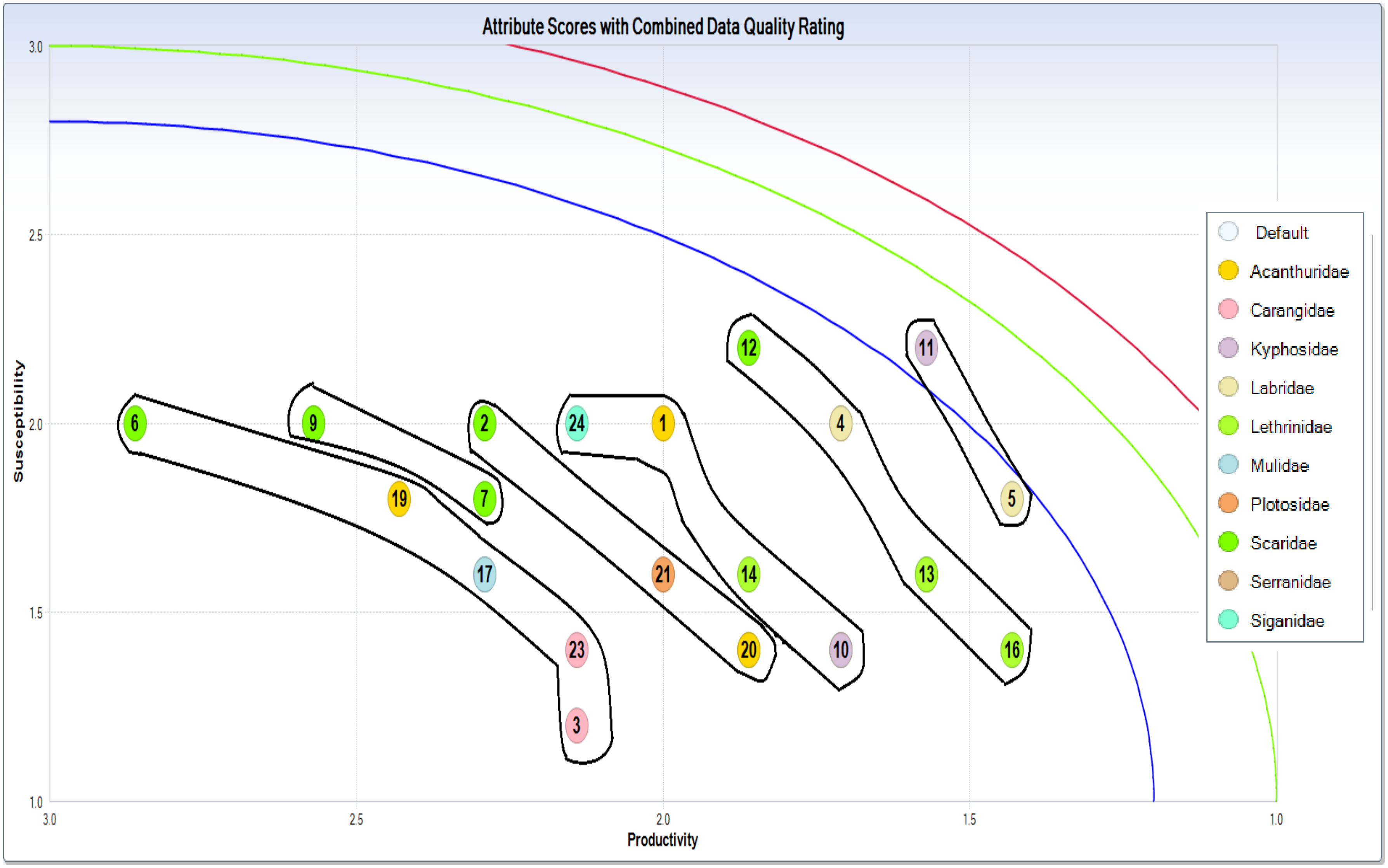

Figure 5: Results of productivity and susceptibility analysis of 26 coral reef fishery species in CNMI. Colors indicate species family. Number represents individual species (Table **8**). Solid black lines represent eight clusters identified by hierarchical cluster analysis.

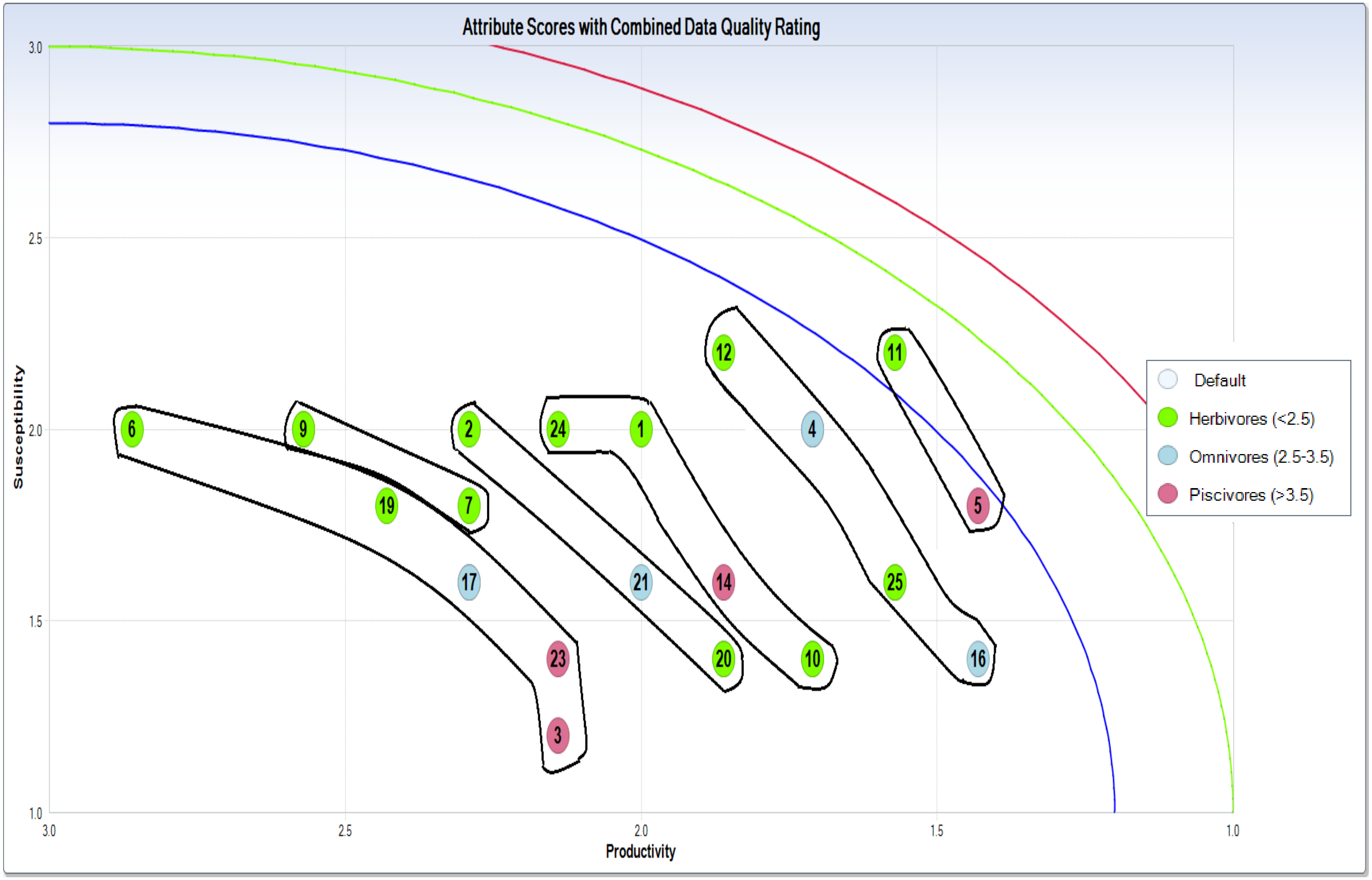

Figure 6: Results of productivity and susceptibility analysis of 26 coral reef fishery species in CNMI. Colors indicates trophic level. Number represents individual species (Table 8). Solid black lines represent eight clusters identified by hierarchical cluster analysis based on vulnerability scores.

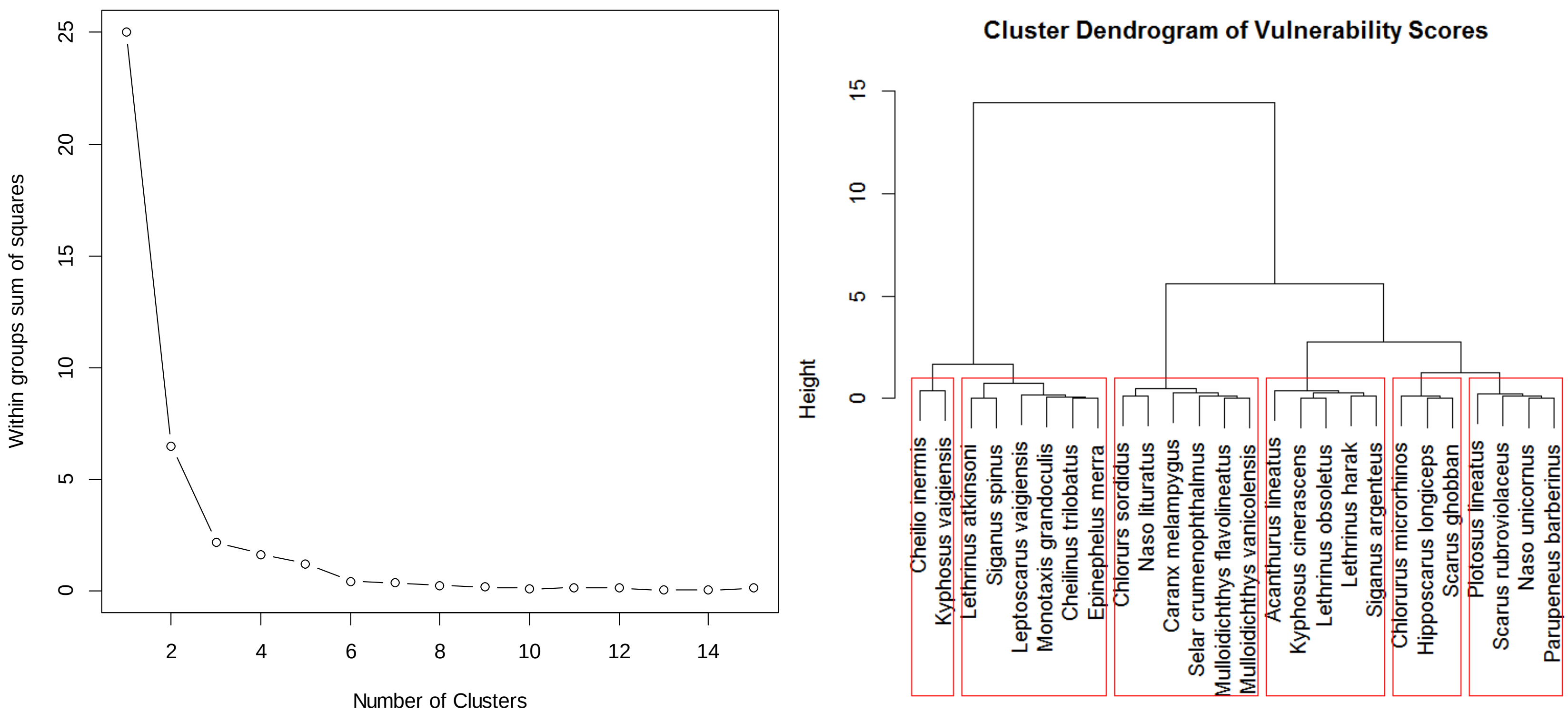

Figure 7: Plot (left) and dendrogram (right) based on the hierarchical cluster analysis using vulnerability scores. Six clusters were used based on the "elbow" method.

Appendix 1: Coral reef life history references by species

***Acanthurus lineatus*:**

Baensch, H.A. and H. Debelius (1997). Meerwasser atlas. Mergus Verlag GmbH, Postfach 86, 49302, Melle, Germany. 3rd edition. 1216 p.

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

Breder, C.M. and D.E. Rosen (1966). Modes of reproduction in fishes. T.F.H. Publications, Neptune City, New Jersey. 941 p.

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

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

Gust, N., Choat, J.H., and Ackerman, J.L. (2002). Demographic plasticity in tropical reef fishes. Marine Bioogy. 140:1039-1051.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Reginal Fishery management Council, Honolulu Hawaii 96813 USA

Randall, J.E. (1986). Acanthuridae. In M.M. Smith and P.C. Heemstra (eds.) Smiths' sea fishes. Springer-Verlag, Berlin: 811-823.

Randall, J.E., (2002). Surgeonfishes of the world. Mutual Publishing and Bishop Museum Press, Hawai'i. 123 p.

Caranx melampygus:

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

IGFA (2001). Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, USA.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Reginal Fishery management Council, Honolulu Hawaii 96813 USA

Randal, J.E. (2007). Reef and shore fishes of the Hawaiian Islands. Sea Grant College Program Univiersity of Hawai'i, Honolulu. 545p.

Smith, G.C. and J.D. Parrish (2002). Estuaries as nurseries for the jacks *Caranx ignobilis* and *Caranx melampygus* (Carangidae) in Hawaii. Estuarine Coastal and Shelf Science. 55: 347-359.

Sudekum, A.E., Parrish, J.D., Radtke, R.L., Ralston, S. (1991). Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fisheries Bulletin 89:493-513.

Chelinus trilobatus:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
Lau, P.P.F. and L.W.H. Li (2000). Identification guide to fishes in the live seafood trade of the Asia-Pacific region. World Wide Fund for Nature, Hong Kong. 137 p.
Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.
Murty, V.S. (2002). Marine ornamental fish resources of Lakshadweep. CMFRI Special Publication No. 72. 384 p.
Myers, R.F. (1991). Micronesian reef fishes. Second Ed. Coral Graphics, Barrigada, Guam. 298 p.
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Cheilio inermis:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
Myers, R.F. (1991). Micronesian reef fishes. Second Ed. Coral Graphics, Barrigada, Guam. 298 p.
Westneat, M.W. (2001). Labridae. Wrasses, hogfishes, razorfishes, corises, tuskfishes. P. 3381-3467. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 6. Bony fishes part 4
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Chlorurs michrohinos:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.
Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
Choat, J.H., L.M. Axe and D.C. Lou (1996). Growth and longevity in fishes of the family Scaridae. Marine Ecology Progress Series 145:33-41.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Reginal Fishery management Council, Honolulu Hawaii 96813 USA
McIlwain, J., B. Taylor, et al. (2009). Parrotfish Population Dynamics from the Marianas Islands, with a Description of the Demographic and Reproductive Characteristics of Chlorurus Sordidus: Final Report to WPRFMC, Univeristy of Guam Marine Lab.

Randall, J.E., G.R. Allen and R.C. Steene (1990). Fishes of the Great Barrier Reef and Coral Sea. University of Hawaii Press, Honolulu, Hawaii. 506 p.

Taylor, B. M. (2012). Life history assessment of commercially important and functionally diverse parrotfish species from Guam, Guam Coral Reef Initiative: 37.

Taylor, B. and J. Choat (2014). Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.

Chlorurs sordidus:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

DeMartini, E.E., A.M. Friedlander and S.R. Holzwarth (2005). Size at sex change in protogynous labroids, prey body size distributions, and apex predator densities at NW Hawaiian atolls. Marine Ecology Progress Series 207:259-271.

Fischer, W., I. Sousa, C. Silva, A. de Freitas, J.M. Poutiers, W. Schneider, T.C. Borges, J.P. Feral and A. Massinga (1990). Fichas FAO de identificaçao de espécies para actividades de pesca. Guia de campo das espécies comerciais marinhas e de águas salobras de Moçambique. Publicaçao preparada em collaboraçao com o Instituto de Investigaçao Pesquiera de Moçambique, com financiamento do Projecto PNUD/FAO MOZ/86/030 e de NORAD. Roma, FAO. 1990. 424 p.

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Reginal Fishery management Council, Honolulu Hawaii 96813 USA

McIlwain, J., B. Taylor, et al. (2009). Parrotfish Population Dynamics from the Marianas Islands, with a Description of the Demographic and Reproductive Characteristics of Chlorurus Sordidus: Final Report to WPRFMC, Univeristy of Guam Marine Lab.

Taylor, B. M. (2012). Life history assessment of commercially important and functionally diverse parrotfish species from Guam, Guam Coral Reef Initiative: 37.

Taylor, B. and J. Choat (2014). Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.

Epinephelus merra:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.

Bagnis, R., P. Mazellier, J. Bennett and E. Christian, (1984). Poissons de Polynésie, 5th Edition. Société Nouvelle des Editions du Pacifique, Elysées, France.

Heemstra, P.C. and J.E. Randall, 1993. FAO Species Catalogue. Vol. 16. Groupers of the world (family Serranidae, subfamily Epinephelinae). Rome: FAO. FAO Fish. Synop. 125(16):382 p.

Lieske, E. and R. Myers, (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.
Loubens, G., (1980). Biologie de quelques espèces de poissons du lagon Néo-Calédonien. III. Croissance. Cah. Indo-Pac. 2:101-153.
Munro, J.L. and D. McB. Williams (1985). Assessment and management of coral reef fisheries: biological, environmental and socio-economic aspects. p. 543-578. In Proceedings of the Fifth International Coral Reef Congress, Tahiti, 27 May-1 June 1985.
Murty, V.S., (2002). Marine ornamental fish resources of Lakshadweep. CMFRI Special Publication No. 72. 384 p.

Hipposcarus longiceps:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA
McIlwain, J., B. Taylor, et al. (2009). Parrotfish Population Dynamics from the Marianas Islands, with a Description of the Demographic and Reproductive Characteristics of Chlorurus Sordidus: Final Report to WPRFMC, Univeristy of Guam Marine Lab.
Myers, R.F. (1999). Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics, Barrigada, Guam. 330 p.
Taylor, B. M. (2012). Life history assessment of commercially important and functionally diverse parrotfish species from Guam, Guam Coral Reef Initiative: 37.
Taylor, B. and J. Choat (2014). Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.

Kyphosus cinerascens:

Broad, G. (2003). Fishes of the Philippines. Anvil Publishing, Inc., Pasi City. 510 p.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA
Munro, J.L. and D. McB. Williams (1985). Assessment and management of coral reef fisheries: biological, environmental and socio-economic aspects. p. 543-578. In Proceedings of the Fifth International Coral Reef Congress, Tahiti, 27 May-1 June 1985. Vol. 4. Antenne Museum-EPHE, Moonea, French Polynesia.

Smith, M.M., 1986. Kyphosidae. p. 603-604. In M.M. Smith and P.C. Heemstra (eds.) Smiths' sea fishes. Springer-Verlag, Berlin.
Yamaguchi et al. (2011). Spawning season and size at sexual maturity of *Kyphosus bigibbus* (Kyphosidae) from northwest Kyushu, Japan. Icthyological Research 58:283-287.

Kyphosus vaigiensis:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
Lau, P.P.F. and L.W.H. Li (2000). Identification guide to fishes in the live seafood trade of the
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA
Masuda, H., K. Amaoka, C. Araga, T. Uyeno and T. Yoshino (1984). The fishes of the Japanese Archipelago. Vol. 1. Tokai University Press, Tokyo, Japan. 437 p. (text).

Leptoscarus vaigiensis:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.
Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA
Randall, J.E., 1986. Scaridae. p. 706-714. In M.M. Smith and P.C. Heemstra (eds.) Smiths' sea fishes. Springer-Verlag, Berlin

Lethrinus atkinsoni:

Carpenter, K.E. and G.R. Allen (1989). FAO Species Catalogue. Vol. 9. Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. FAO Fish. Synop. 125:118 p.
Dalzell, P., S. Sharma and G. Nath (1992). Estimation of exploitation rates in a multispecies emperor (Pisces: Lethrinidae) fishery in Fiji, based on length frequency data. p. 43-50.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
Kuiter, R.H. and T. Tonozuka (2001). Pictorial guide to Indonesian reef fishes. Part 1. Eels-Snappers, Muraenidae - Lutjanidae. Zoonetics, Australia. 302 p

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Williams, D.McB. and G.R. Russ (1994). Review of data on fishes of commercial and recreational fishing interest in the Great Barrier Reef. Great Barrier Reef Marine Park Authority Res. Publ. No. 33. 103 p.

<u>Lethrinus harak:</u>

Carpenter, K.E. and G.R. Allen (1989). FAO Species Catalogue. Vol. 9. Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. FAO Fish. Synop. 125:118 p.

Dalzell, P., S. Sharma and G. Nath (1992). Estimation of exploitation rates in a multispecies emperor (Pisces: Lethrinidae) fishery in Fiji, based on length frequency data. p. 43-50.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

Loubens, G., 1980. Biologie de quelques espèces de poissons du lagon Néo-Calédonien. II. Sexualité et reproduction. Cah. Indo-Pac. 2(1):41-72.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Taylor, B. (2008). M.Sc. Thesis. The effects of protected area management on the population biology and reproduction of *Lethrinus harak* from the inshore waters of Guam. University of Guam.

Taylor, B. M. and J. L. McIlwain (2010). Beyond abundance and biomass: effects of marine protected areas on the demography of a highly exploited reef fish. Marine Ecology Progress Series 411: 243-258.

<u>Lethrinus obsoletus:</u>

Carpenter, K.E. and G.R. Allen (1989). FAO Species Catalogue. Vol. 9. Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. FAO Fish. Synop. 125:118 p.

Kitalong, A.H. and P. Dalzell (1994). A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fish. Res. Tech. Doc. No. 6, South Pacific Comission, Noumea, New Caledonia.

Lasi, F. (2003). Age, growth, mortality rates and reproductive biology of three Fijian emperor fishes (Pisces: Lethrinidae): Lethrinus harak: Forsskal 1775, *Leththrinus obsoletus* Forsskal 1775 and *Lethrinus atkinsoni* Seale 1910 M.Sc. Thesis. University of South Pacific.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Sommer, C., W. Schneider and J.-M. Poutiers (1996). FAO species identification field guide for fishery purposes. The living marine resources of Somalia. FAO, Rome. 376 p.

Monotaxis grandoculis:

Carpenter, K.E. and G.R. Allen (1989). FAO Species Catalogue. Vol. 9. Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. FAO Fish. Synop. 125:118 p.

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Mulloidichthys flavolineatus:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

Cole, Kathleen - Size-dependent and age-based female fecundity and reproductive output for three Hawaiian goatfish (Family Mullidae) species, *Mulloidichthys flavolineatus* (yellowstripe goatfish), *M. vanicolensis* (yellowfin goatfish), and *Parupeneus porphyreus* (whitesaddle goatfish).

Holland, K.N., et al. (1993). Movements, distribution and growth rates of the white goatfish *Mulloidichthys flavolineatus* in a fisheries conservation zone. Bulletin of Marine Science 52: 982-992.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

Myers, R.F. (1999). Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics, Barrigada, Guam. 330 p.

Wahbeh, M.I. (1992). Aspects of the reproduction biology and growth of two species of goatfish (Mullidae) from Aqaba, Red Sea. Senckenb. Marit. 22(3-6):255-264.

WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Mulloidichthys vanicolensis:

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

Jehangeer, M.I. (2003). Some population parameters of the goatfish, Mulloidichthys vanicolensis from the lagoon of Maurituis. p. 82-88. ACP-EU Fish. Res. Rep. 14, 281p.

Sommer, C., W. Schneider and J.-M. Poutiers (1996). FAO species identification field guide for fishery purposes. The living marine resources of Somalia. FAO, Rome. 376 p.

Wahbeh, M.I. (1992). Aspects of the reproduction biology and growth of two species of goatfish (Mullidae) from Aqaba, Red Sea. Senckenb. Marit. 22(3-6):255-264.

WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Naso lituratus:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

DAWR (2012). Age-based reproductive profile of orangespine (Naso lituratus) and bluespine (Naso unicornis) unicornfish in Guam. Guam.

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

Kitalong, A. and P. Dalzell (1994). A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Project Technical Document no. 6.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

Randall, J.E., (2002). Surgeonfishes of the world. Mutual Publishing and Bishop Museum Press, Hawai'i. 123 p.

Robertson, D.R. (1991). Increases in suregeon fish populations after mass mortality iof the sea urchin Diadema antillarum in Panama indicate food limitiation. Mar. Biol. 111, 437-444.

WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Naso unicornis:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

DAWR (2012). Age-based reproductive profile of orangespine (Naso lituratus) and bluespine (Naso unicornis) unicornfish in Guam. Guam.

DeMartini, E. E., R. C. Langston, et al. (2014). "Spawning seasonality and body sizes at sexual maturity in the bluespine unicornfish, Naso unicornis (Acanthuridae)." Ichthyological Research: 1-9.
Eble, J., R. Langston, and B. Bowen (2009). Growth and reproduction of Hawaiian Kala, *Naso unicornis*. Fisheries Local Action Strategy, Final Report, Division of Aquatic Resources, Honolulu, HI.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
Kitalong, A. and P. Dalzell (1994). A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Project Technical Document no. 6.
Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.
Robertson, D.R. (1991). Increases in suregeon fish populations after mass mortality iof the sea urchin Diadema antillarum in Panama indicate food limitiation. Mar. Biol. 111, 437-444.
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

<u>Parupeneus barberinus:</u>

Allen, G.R. and M.V. Erdmann (2012). Reef fishes of the East Indies. Perth, Australia: University of Hawai'i Press, Volumes I-III. Tropical Reef Research.
Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.
Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.
Wahbeh, M.I. and A. Ajiad (1985). Reproductive biology and growth of the goatfish, *Parupeneus barberinus* (Lacepède), in Aqaba, Jordan. J. Fish Biol. 26:583-590.
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

<u>Plotosus lineatus:</u>

Kajikawa, H. (1973). Determination of age and growth in the marine catfish Plotosus anguilaris by the use of otoliths. Sci. Rep. Shima Marineland 2:5-22.
Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.
Myers, R.F. (1999). Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics, Barrigada, Guam. 330 p.
Thresher, R.E. (1984). Reproduction in reef fishes. T.F.H. Publications, Inc. Ltd., Neptune City, New Jersey. 399 p.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Scarus ghobban:

Allsop, D.J. and S.A. West (2003). Constant relative age and size at sex change for sequentially hermaphroditic fish. J. Evol. Biol. 16:921-929.

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

Grandcourt, E.M. (2002). Demographic characteristics of a selection of exploited reef fish from the Seychelles: preliminary study. Mar. Freshwat. Res. 53:123-130.

Humann, P. and N. Deloach, 1993. Reef fish identification. Galápagos. New World Publications, Inc., Florida. 267 p

Lau, P.P.F. and L.W.H. Li (2000). Identification guide to fishes in the live seafood trade of the Asia-Pacific region. World Wide Fund for Nature, Hong Kong. 137 p.

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Sousa, M.I. and M. Dias, 1981. Catálogo de peixes de Moçambique - Zona Sul. Instituto de Desenvolvimento Pesqueiro, Maputo. 121 p.

Taylor, B. and J. Choat (2014). Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.

Scarus rubroviolaceus:

Barlow, G. W. (1981). Patterns of parental investment, dispersal and size among coral-reef fishes. Env. Biol. Fish. 6:65-85.

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.

Grandcourt, E.M. (2002). Demographic characteristics of a selection of exploited reef fish from the Seychelles: preliminary study. Mar. Freshwat. Res. 53:123-130.

Howard, K. G. (2008). Community Structure, Life History, and Movement Patterns of Parrotfishes: Large Protogynous Fishery Species. Doctor of Philosophy Dissertation, University of Hawai'i

Humann, P. and N. Deloach, 1993. Reef fish identification. Galápagos. New World Publications, Inc., Florida. 267 p

MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA

Taylor, B. M. (2012). Life history assessment of commercially important and functionally diverse parrotfish species from Guam, Guam Coral Reef Initiative: 37.

Taylor, B. and J. Choat (2014). Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.

Selar crumenopthalmus:

Honebrink, R. (1990). Fishing in Hawaii: a student manual. Education Program, Division of Aquatic Resources, Honolulu, Hawaii. 79 p.
Kuiter, R.H. and T. Tonozuka (2001). Pictorial guide to Indonesian reef fishes. Part 1. Eels-Snappers, Muraenidae - Lutjanidae. Zoonetics, Australia. 302 p.
MacDuff, S., R. Roberto (2012). Chapter 3: Commonwealth of Northern Mariana Islands Fishery Ecosystem Report. Archipelago Fishery Ecosystem Annual Report. M. Sabater. Western Pacific Regional Fishery management Council, Honolulu Hawaii 96813 USA
Ralston, S. and H.A. Williams (1988). Depth distributions, growth, and mortality of deep slope fishes from the Mariana Archipelago. NOAA Tech. Memo. NMFS. NOAA-TM-NMFS-SWFC-113, 47 p.
Smith-Vaniz, W.F. (1995). Carangidae. Jureles, pámpanos, cojinúas, zapateros, cocineros, casabes, macarelas, chicharros, jorobados, medregales, pez pilota. p. 940-986. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter and V. Niem (eds.) Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental. 3 Vols. FAO, Rome.
Weng, K. C. M. and J. R. Sibert (2000). Analysis of the fisheries for two pelagic carangids in Hawaii. SOEST 00-04; JIMAR 00-332. University of Hawaii, School of Ocean and Earth Science & Technology (SOEST): Honolulu. 78p.

Siganus argenteus:

Graham, T. (1994). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian. CNMI Division of Fish and Wildlife Technical Report: 94-02.
Kitalong, A.H. and P. Dalzell (1994). A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fish. Res. Tech. Doc. No. 6, South Pacific Comission, Noumea, New Caledonia.
Myers, R.F. (1999). Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics, Barrigada, Guam. 330 p.
Tharwat, A. A. (2005). Fishery assessment of the rabbitfish Siganus canaliculatus from the Arabian Gulf, Saudi Arabia. Egypt. J. Aquat. Biol. & Fish., 9: 117-136.
Woodland, D. (1997). Siganidae. Spinefoots, rabbitfishes. p. 3627-3650. In K.E. Carpenter and V. Niem (eds.) FAO Identification Guide for Fishery Purposes. The Western Central Pacific. 837 p.
WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

Siganus spinus:

al Sakaff, H. and M. Esseen (1999). Occurrence and distribution of fish species off Yemen (Gulf of Aden and Arabian Sea). Naga ICLARM Q. 22:43-47.

Horstmann, U. (1975). Some aspects of the mariculture of different siganids species in the Philippines. Philipp. J. Sci. 12:5-20.

Lieske, E. and R. Myers (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

Tharwat, A. A. (2005). Fishery assessment of the rabbitfish *Siganus canaliculatus* from the Arabian Gulf, Saudi Arabia. Egypt. J. Aquat. Biol. & Fish., 9: 117-136.

WPRFMC (2011). Mariana Archipelago Fishery Ecosystem Plan 2009 Annual Report. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813.

C:\Users\Researcher\AppData\Roaming\Microsoft\Word\ \l "_ENREF_16" \o "Trianni, 1998 - 87"