*5.D(2)
124 SSC

This report was prepared for WPRFMC on the current vulnerability of inshore fishery species of the Hawaiian Islands using a productivity and susceptibility analysis (PSA).

Hawaii PSA for Inshore Fishery Species

Report for Western Pacific Regional Fishery Management Council

Cassie Pardee June 13, 2016

Contents

List of Tables

List of Figures

Hawaiʻi Fishing Overview and History

The people of Hawaiʻi have a close connection to the sea, and fishing is an important part of that connection. Even before modern fishery management, Hawaiians enforced social and cultural controls on fishing through a code of conduct (Poepoe et al. 2003, McClenachan and Kittinger 2013). Resource management was based on identification of specific times and places where fishing was banned to avoid disrupting biological processes and habitats of important fish species (Poepoe et al. 2003). Fishing practices and management have changed since traditional times, but fishing still remains an important cultural aspect for people living in Hawaiʻi.

In the 1900's, Hawaiʻi's population was around 150,000 consisting mostly of native Hawaiians; coastal catch was approximately 6.2 million pounds (Shomura 2004). Today, the population of Hawaiʻi has grown to 1.2 million residents with an average of 6.9 million tourists; and coastal fishery landings have increased to 23.4 million pounds (Shomura 2004). The Hawaiʻi inshore fishery is a multi-species fishery where the majority (91%) of the commercial catch is comprised of 47 species (Smith 1993). From 2009-2013 an average of 412,000 lbs of inshore fish were caught commercially. The top five families of commercial inshore reef fish included: Surgeonfish (30%), Parrotfish (17%), Squirrelfish (15%), Goatfish (14%), and Jacks (11%) (Figure 1).

Recreational coral reef fishing is also a popular pastime in Hawaiʻi and most likely exceeds the commercial catch (DeMello 2004, Everson and Friedlander 2004, Williams and Ma 2013). The recreational estimates produced by Marine Recreational Fish Program (MIRP) indicate that the recreational fishery is twice as large as the commercial sector in pounds landed (Williams and Ma 2013). Other studies from Hanalei Bay, Kauaʻi and Maunalua Bay, Oʻahu, estimated that recreational catch could exceed commercial catch by an order of magnitude (Friedlander and Parrish 1997, Kittinger 2013). As Hawaiʻi has no recreational saltwater fishing license or reporting requirements, there is no data to demonstrate the actual recreational catch. The large number of people fishing and not reporting landings makes estimating the total amount of reef fish caught and the effects of the recreational and subsistence fishing on the coral reef marine resources difficult.

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) of 2006, requires the use of annual catch limits (ACLs) and accountability measures to end overfishing (H.R. 2006). For species lacking stock assessments, such as many coral reef species, ACLs were determined using the 75th percentile of commercial data records from 1966-2011 (Table 1) (NOAA-NMFS-2012-0226).

Productivity and Susceptibility Analysis

Coral reef fisheries have high species diversity but little resources for management and monitoring. Therefore, in many cases, species are managed by family groupings instead of by individual species (Cheung et al. 2005). However, many coral reef species within the same family often have varying vulnerabilities to fishing. Calculating vulnerability of a species based on the productivity and susceptibility to fishing has been recommended as a first step in assessing data-poor fisheries (Rosenberg et al. 2007).

Vulnerability is based on Patrick et al. (2009) definition as “the potential for the productivity of the stock to be diminished by direct and indirect fishing pressure.” Thus, the vulnerability of a species depends on two factors: productivity and susceptibility (Stobutzki et al. 2002, Patrick et al. 2009). Productivity is the ability of a species to recover once the population has been depleted, which depends on varying life-history characteristics (Stobutzki et al. 2002). Susceptibility is how likely a species is to be captured or impacted by a fishery (Stobutzki et al. 2002, Patrick et al. 2009). Species with the highest vulnerability are those with low productivity and high susceptibility.

A species vulnerability can be calculated by scoring a standardized set of productivity and susceptibility attributes using a Productivity Susceptibility Analysis (PSA) (Patrick et al. 2009). A PSA is a semi-quantitative and rapid risk assessment tool to assess the vulnerability of 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). By calculating species vulnerabilities towards fishing, managers can set catch limits based on vulnerability levels or choose a highly vulnerable species as an indicator species in a family stock.

Methods

Species Selection

Based on the top five families from near shore commercial catch records (Figure 1), twenty commonly caught inshore species were selected as a part of a Hawaiʻi PSA to estimate the vulnerability towards fishing for common inshore species (Table 2). Species were chosen based on prevalence in commercial catch from 2004-2013 using commercial fishery logbook data.

The commercial logbook records are the longest source of data on Hawaiʻi’s fisheries, and include catch weight, gear used, and hours fished (Smith 1993). Any person who sells any portion of their catch is required to have a State of Hawaiʻi commercial fishing license and submit a monthly report to the Department of Land and Natural Resources (DLNR).

The twenty selected species represent more than 90% of the total inshore commercial catch; and make up ten different common inshore fishery families. A majority of the selected species are categorized as Management Unit Species (MUS) in the Hawaiʻi Fishery Management Plan. Species were reviewed by DAR and Council staff to ensure the species selected are main targeted species.

Gathering Life History Traits

A literature search was conducted to collect life history traits for each of the twenty selected species from Hawaiʻi. Life history traits of interest were: maximum age (T_{max}), maximum length (L_{max}), age at maturity (T_{mat}), the von Bertalanffy Growth parameter (k), natural mortality (M), trophic level, and maximum depth. Scientific names as well as common names were used to conduct literature searches. If information from published papers could not be found, the search was expanded to Fishbase.org. In cases where no published information was available, life history traits were estimated using the life-history tool from Fishbase.org (Froese et al. 2005).

Productivity Attributes and Scoring

The productivity of a species is defined as the capacity of a stock to recover once the population is depleted (Stobutzki et al. 2001). Assessing multiple life history traits allows for a more comprehensive assessment of productivity of species (Patrick et al. 2009).

Six different life history attributes were used to score the productivity of each species. Productivity traits were scored 1-3 based on the attributes listed below (Table 3). These attributes have been previously integrated into other coral reef PSA analyses in Guam, CNMI, and American Samoa. The productivity scoring bins for each attribute were the same as the PSA analyses conducted in CNMI, American Samoa and Guam so comparisons could be made

- **Maximum age (t_{max}):** Maximum age is directly related to natural mortality rate (M), because species with a large maximum age generally have a low mortality rate (Patrick et al. 2009). Species that have a longer lifespan are usually less productive than shorter lived species. Selected species t_{max} ranged from 53 years (*N. unicornis*) to 3 years (*C. carolinus).*
- **Maximum size (L_{max}):** In general, larger species live longer and recover more slowly than smaller sized species. Therefore larger species tend to be less productive than smaller species (Stobutzki et al. 2002). The range for L_{max} was between 217 cm (*C. ignobilis*) and 21.0 cm (*A. olicaceus*).
- **Growth coefficient (*k*):** The von Bertalanffy growth coefficient measures how rapidly a fish reaches its maximum size. Long lived species tend to have lower growth rates than more productive faster growing species (Froese and Binohlan 2000). When *k* estimates were unavailable in the literature, they were estimated from L_{max} using the Life-History tool at Fishbase (Froese et al. 2005). Values for *k* ranged from 1.3 (*M. vanicolensis*) to 0.11 (*C. ignobilis*).
- **Natural mortality (M):** Natural mortality reflects a population's productivity; a high mortality rate requires a higher level of production to maintain population levels (Patrick et al. 2009). Natural mortality was calculated using Hoenig's (1983) mortality equation by assuming a 5% survival rate at t_{max}. Estimates for *M* ranged from 1.00 (*C. carolinus*) to 0.06 (*N. unicornis*).
- **Age at maturity (t_{mat}):** Age at maturity is usually positively correlated to maximum age, with longer lived species maturing later than shorter lived species (Patrick et al. 2009). When t_{mat} was unknown, it was estimated with the Life-History tool using L_{max} from Fishbase (Froese and Binohlan 2000, Froese et al. 2005). Values for t_{mat} ranged from 7.5 years (*N. unicornis*) to 1 year (*A. triostegus,* and *M. vanicolensis*)

- **Mean trophic level:** Species with lower trophic levels are generally more productive than species with higher trophic levels (Patrick et al. 2009). Trophic data were gathered from Fishbase which used a function of trophic levels of organisms in the diet (Pauly 1998). Selected species represented piscivores (>3.5), omnivores (3.5-2.5), and herbivores/planktivores (<2.5)

Susceptibility Attributes and Scoring

Susceptibility of a species towards fishing can be divided further into catchability and management attributes (Patrick et al. 2009). Four different susceptibility attributes were chosen to represent both the management and the catchability of the species. Susceptibility traits were scored 1-3 based on the attributes listed below (Table 4). Most of these attributes were previously integrated into PSA analyses for American Samoa, Guam and CNMI, and the scoring for those attributes (water-column position and spatial behavior) were based off of the previous PSAs for comparisons of final results.

- **Water-column position:** Water-column position (max depth) is the position of a species in a water column compared with fishing gear (Stobutzki et al. 2002). Species with a deeper depth range are considered less vulnerable to fishing than those species that inhabit shallow waters (Graham et al. 2011). Depth ranges were collected from Fishbase and ranged from 36 m (*S. rubroviolaceus*) to 250 meters (*P. meeki*) (Froese et al. 2005).
- **Desirability/value:** The value of a species may indicate the susceptibility of that species towards fishing. Highly valued fish are assumed to be more susceptible to becoming overfished due to increased fishing effort (Patrick et al. 2009). Average price per pound for 2015 from Division of Aquatic Resources Dealer surveys were used to value the fish. Fish prices ranged from $1.33 (*A. olivaceus*) to $9.77 (*P. porphyreus*).
- **Spatial Behavior:** This category describes the behavioral response for individuals and groups which might increase/decrease catchability (Patrick et al. 2009). Spatial behavior was categorized using Cheung et al. (2005) equation for spatial behavior. Groups of fish aggregating together at varying times and spatial scales based on spawning, feeding, migration, or defense may be more vulnerable to fishing than species which occur singly or in small groups (Cheung et al. 2005, Patrick et al. 2009). Scoring was based off qualitative descriptions from Fishbase using keywords such as: groups, colonies, aggregations, schools, and single (Cheung et al. 2005).
- **Management Strategy:** Susceptibility to overfishing may also depend on the effectiveness of the management strategy (Rosenberg et al. 2007, Patrick et al. 2009). Stocks with catch limits where the fishery can be closed before limits are exceeded have low susceptibility to overfishing; while a stock without catch limits or accountability measures have a much higher susceptibility to overfishing (Patrick et al. 2009). Management strategy was defined based off of family ACL and other catch regulations

(e.g. bag limits, minimum size) gathered from the DLNR regulation website (http://dlnr.hawaii.gov/dar/fishing/fishing-regulations/marine-fishes-and-vertebrates/).

Data Quality Scoring

Even though life history traits of coral reef species are becoming more available, demographic information can vary for the same species depending on geographic, latitudinal, and habitat areas (Choat and Robertson 2002, DeMartini et al. 2014). Even if life history information has been calculated for a coral reef species in Australia, it may not be the equivalent for the same species in Hawaiʻi. Differences in life history traits have been recorded between fish from continental reef structures and the same species from oceanic islands; likely due to geological evolutionary history and productivity (Brett Taylor, personal communication 2015). Therefore, it is important to take into consideration the region and age of the study when considering life history data. Patrick et al. (2009) created a data quality score index based on five tiers ranging from best data to no data in order to assess life history attributes and provide an estimate of uncertainty (Table 5).

All productivity and susceptibility traits were given a corresponding data quality score based on Patrick et al. (2009) data quality index. 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 et al. 2009). Published data taken from Hawaiʻi had the highest data quality with a score of one. Conversely life history traits which were estimated using the life-history tool from Fishbase.org had the lowest data quality with a ranking of four

PSA

Productivity and susceptibility attributes listed above were entered into the Productivity and Susceptibility Analysis tool from NOAA Fisheries Toolbox (2010). Productivity and Susceptibility attributes with corresponding data quality scores can be found in Tables 6 and 7 respectively. All attributes were given a set weight of two as suggested by Patrick et al. (2009).

For those parameters estimated by the Life-History tool from Fishbase, a second PSA was run adjusting the data quality score to five (no data available), and adjusting the attribute to the most conservative score (lowest productivity or the highest susceptibility) in order to see how life history estimates affected the PSA vulnerability outcome.

Analyzing PSA Vulnerability Results

Resulting vulnerability scores from the PSA were analyzed to determine similarities and relationships with other attributes. Vulnerability scores were grouped using a hierarchical cluster analysis to determine similarities between species. Species were divided into groups using within-group sum of squares with the “elbow method” to determine the optimal number of clusters.

Vulnerability scores were correlated with productivity, susceptibility, and data quality scores to determine what had the greatest influence on vulnerability. Productivity, susceptibility, and vulnerability scores were also compared against PSAs from Guam, CNMI, and American Samoa, as well as vulnerability scores from Cheung et al. (2005) generated based on productivity, abundance, and life history traits gathered from Fishbase (Cheung et al. 2005).

Results

Life History Input Review

Overall the selected species had a wide range of life history characteristics with species scoring evenly across the productivity attributes (high, medium, and low). A majority (11 species) of the selected species were piscavores, which was scored as low productivity for the trophic level attribute. Nine species received low productivity scores for natural mortality. Maximum length only had one species with a low productivity score. The rest of the productivity attributes had between four and seven species with low productivity ranks. *Myripristis berndti* had five attributes scored with low productivity scores. For most species (55%), age at maturity was unavailable from the literature and was therefore estimated from the Fishbase Life-History tool. Thus, age at maturity had the poorest data quality score. Aside from age at maturity, the rest of the productivity attributes had a majority of published species specific information from Hawaii, scoring high data quality scores (score of 1).

Most (53%) of the species had low susceptibility scores (score of 1) throughout all of the attributes. The only exception was most species (55%) had a moderate susceptibility score (score of 2) for value (average price per pound). The spatial behavior trait had the most species with high susceptibility scores (five species). The majority of species had maximum depths greater than 40 meters (deeper than a majority of fishing methods) which related to low susceptibility for vertical overlap. However, maximum depth does not mean that species occupy most of their time at these depths. Management strategy only had two species (*K. cinerescens* and *P meeki*) that had no set ACL for family or other catch regulations; resulting in high susceptibility scores. Ten species had additional management regulations such as minimum catch size or bag limits, which ranked as low susceptibility scores.

PSA Results

Two different PSA runs were conducted, the first used estimates from the Life-History tool from Fishbase when data was missing (data quality 4, with Fishbase estimated parameter), and the second run used the most conservative parameter input for missing data (data quality of 5, and most conservative parameter input). Vulnerability scores between both runs (with and without Fishbase estimates) were highly correlated ($r=0.78$, p-value < 0.001). Productivity and susceptibility scores were also highly correlated (productivity $r=0.69$, p-value < 0.001; susceptibility $r=0.99$, p-value <0.001) between the different runs.

Even though the two vulnerability scores were highly correlated, species without estimated attributes from Fishbase had higher vulnerability scores and a higher ranking than when life history parameters were estimated using Fishbase. Vulnerability scores using Fishbase estimate ranged from 1.83 (*Albula glossodonta*) to 0.25 (*Calotomus carolins*) (Table 8), while the vulnerability scores without Fishbase estimate ranged from 1.98 (*Mulloidichthys pflugeri*) to 0.25 (*Calatomus carolinus*) (Table 8).

The poorer the data quality, the higher the uncertainty which will raise the overall vulnerability score of species. Data quality (productivity and susceptibility) had a higher correlation to vulnerability scores without Fishbase estimates than with Fishbase (without Fishbase: productivity data quality: r=0.40, susceptibility data quality: r=0.18; with Fishbase: productivity data quality: r=0.-0.15, susceptibility data quality: r=0.16). For species with no data, the default attribute values were set as the most conservative (susceptibility 3, productivity 1). For example, *M. pflugeri* vulnerability was in the 50th percentile using Fishbase estimates, but it had the highest vulnerability scores without the Fishbase estimates due to a lack of published data. Species with very little published data will appear more vulnerable than species with more published life history traits.

In both runs productivity was strongly negatively correlated to vulnerability (without Fishbase r=-0.97, p-value <0.001; with Fishbase r=-0.94, p-value<0.01). Therefore, less productive species will have higher vulnerability scores. The two least productive species using Fishbase estimates were *A. glossodonta* and *Myripristis berndti*. *C. orthogrammus* and *M. pflugeri* were the least productive species without Fishbase estimates. The most productive species with and without Fishbase estimates were *C. carolinus* and *M. vanicolensis*.

Susceptibility was significantly positively correlated to vulnerability without Fishbase estimates but not significantly correlated with Fishbase estimates (without Fishbase r=0.51, p-value=0.02; with Fishbase r=0.30, p-value=0.20), indicating that susceptibility had more of an impact without Fishbase estimations on the vulnerability. The most susceptible species for both runs were *K. cinerescens, M. pflugeri, P. dentex,* and *M. cephalus.* The least susceptible species on both lists was *N. unicornis,* which was also one of the least productive species when using Fishbase estimates.

Vulnerability Groupings

The within-group sum of squares indicated that seven clusters were the optimal number of groups based on vulnerability scores (Figures 2 and 3). The cluster groupings of species showed that vulnerability, productivity, and susceptibility varied among families. Seven species fell into the same group for both runs (with and without Fishbase estimates). *A. glossodonta* and *M. berndti* were in the most vulnerable grouping for both PSA runs. *C. carolinus* was grouped by itself in both runs as least vulnerable. Aside from *C. carolinus,* no other groupings had the all of the same species for both runs. All groupings in both runs had species from various families (Figure 4).

Comparison with Guam PSA, CNMI PSA, and Fuzzy Logic vulnerabilities

The PSA's from Hawaiʻi, American Samoa, CNMI, and Guam had three species in common: *N. unicornis*, *C. melampygus*, and *K. cinerescens.* The PSA without Fishbase estimated attributes was used in order to compare results across regions. The Hawaiʻi productivity scores were highly correlated to Guam (r^2=0.76), slightly correlated to CNMI (r^2=0.39) and not correlated to American Samoa (r^2=0.00). Conversely, Hawaiʻi's susceptibility score was highly correlated to American Samoa (r^2=0.96), with little correlation to Guam (r^2=0.26), and no correlation to CNMI (r^2=0.00). Hawaiʻi's overall vulnerability score was strongly correlated to both CNMI and Guam with a weak correlation to American Samoa. (CNMI r^2=0.98, Guam r^2=0.85, and American Samoa r^2=0.47).

The fuzzy logic vulnerability scores calculated by Cheung et al. (2005) were positively correlated to the vulnerability scores from the Hawaiʻi PSA (r=0.51, p-value =0.02). The fuzzy logic vulnerability scores were also negatively correlated to the PSA productivity scores (r=-0.46, p-value =0.04), but were not correlated to susceptibility scores.

Discussion

The two different PSA runs showed species with few published life history traits will appear more vulnerable when there is no data with the most conservative estimate used as opposed to using an estimate from Fishbase. Therefore, species with very little published data may appear more vulnerable than they actually are. Fishbase estimates were used as a proxy for life history traits that were unavailable in order to lessen the impact of no data on vulnerability scores. However, the estimates from Fishbase are created from a computer program with general information from other species of fish. Therefore, it may not be the most reliable data source which is why Fishbase estimates were given a data quality score of four.

Even with the varying vulnerabilities, *A. glossodonta* was ranked in the most vulnerable species category for both runs. *A. glossodonta* is known as ʻŌʻio in Hawaiʻi. The ʻŌʻio fishery has historically been culturally important and today is commonly targeted in commercial, recreational, and subsistence fisheries (Kamikawa et al. 2015). While the recreational ʻŌʻio fishery is expanding, the commercial catch has declined 99% since the 1900s (Friedlander et al. 2008, Kamikawa et al. 2015). The declining commercial fishery supports the high vulnerability of ʻŌʻio within the PSA assessment.

The ʻŌʻio Tagging project started in 2003 and since then has had over 700 fishers recording more than 10,600 fishing hours and tagging over 3,000 ʻŌʻio (Kamikawa et al. 2015). The project has provided important biological data on *A. glossodonta* (used in this analysis) as well as builds a working relationship between fishers and fishery scientists (Kamikawa et al. 2015). *A. glossodonta* had a high data quality score based on the life history data specific to Hawaiʻi; therefore *A. glossodonta's* vulnerability ranking is due to the input and not due to poor data quality.

While there were correlations between the shared PSA species in Hawaiʻi and the outlying territories, this could be due to the lack of site specific information for reef fish from the outer islands. The Hawaiʻi PSA had 46% of the data coming from Hawaiʻi specific literature, while American Samoa only had 12% of the data from American Samoa. Species from all three regions shared data sources due to the dearth of local life history information for coral reef species. Some of the life history data used in the PSA's in Guam, CNMI, and American Samoa came from Hawaiʻi and other regions outside of the location of study. Hawaiʻi has a higher latitude than all of the other territories therefore life history data from Hawaiʻi species is expected to vary from those islands at lower latitudes with warmer waters. Life history proxies from other regions can introduce error in the analysis because many coral reef species have varying growth rates, maximum size, and age at maturity in different regions (DeMartini et al. 2014, Taylor and Choat 2014). In order to improve the vulnerability scores of common coral reef fishery species, localized life history information is needed, especially for those species with very few published life history traits.

The cluster analysis from the PSA indicate that species within the same family have varying vulnerability levels based on fishing and life history traits. Species in the same family with varying vulnerabilities have management implications. Only those species with similar vulnerability to fishing should be managed together; therefore, family groupings might not be the best management scheme (Patrick et al. 2009). The most vulnerable species within a family can be selected as an indicator species for species managed under family groupings. The results of this PSA allow managers to see which species might be more at risk to overfishing based on life history characteristics and susceptibility to fishing pressure.

Works Cited

Cheung, W. W. L., T. J. Pitcher, and D. Pauly. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological Conservation 124(1):97–111.

Choat, J., and D. Robertson. 2002. Age-Based Studies on Coral Reef Fishes. Pages 57–80 Coral Reef Fishes. Academic Press.

DeMartini, E., R. Langston, and J. Eble. 2014. Spawning seasonality and body sizes at sexual maturity in the bluespine unicornfish, Naso unicornis (Acanthuridae). Ichthyological Research 61:243–251.

Friedlander, A., J. Caselle, and J. Beets. 2008. Biology and ecology of the recreational bonefish fishery at Palmyra Atoll National Wildlife Refuge with comparisons to other Pacific islands. … and bonefish fisheries. ….

Froese, R., and C. Binohlan. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate. Journal of Fish Biology.

Froese, R., M. Lourdes, D. Palomares, and D. Pauly. 2005. FishBase Life History Tool.

Graham, N. A. J., P. Chabanet, R. D. Evans, S. Jennings, Y. Letourneur, M. Aaron Macneil, T. R. McClanahan, M. C. Ohman, N. V. C. Polunin, and S. K. Wilson. 2011. Extinction vulnerability of coral reef fishes. Ecology letters 14(4):341–8.

H.R. 2006. Magnunson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. Page 5946 (109th).

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality-rates. Fishery Bulletin 82:898–903.

Kamikawa, K. T., A. M. Friedlander, K. K. Harding, A. Filous, M. K. Donovan, and E. Schemmel. 2015. Bonefishes in Hawai'i and the importance of angler-based data to inform fisheries management. Environmental Biology of Fishes 98(11):2147–2157.

McClenachan, L., and J. N. Kittinger. 2013. Multicentury trends and the sustainability of coral reef fisheries in Hawaiʻi and Florida. Fish and Fisheries 14(3):239–255.

NOAA Fisheries Toolbox. 2010. Productivity and Susceptibility Analysis (PSA).

Patrick, W. S., P. Spencer, O. Ormseth, J. Cope, J. Field, and D. Kobayashi. 2009. Use of Productivity and Susceptibility Indices to Determine Stock Vulnerability , with Example Applications to Six U . S . Fisheries. Fisheries (Bethesda) (October).

Pauly, D. 1998. Fishing Down Marine Food Webs. Science 279(5352):860–863.

Poepoe, K. K., P. K. Bartram, and A. M. Friedlander. 2003. The use of traditional Hawaiian knowledge in the contemporary management of marine resources. Fisheries Center Research Reports 11(1):328–339.

Rosenberg, A., D. Agnew, E. Babcock, A. Cooper, C. Mogensen, R. O'Boyle, J. Powers, G. Stefánsson, and J. Swasey. 2007. Setting annual catch limits for U.S. fisheries: An expert working group report.

Shomura, R. 2004. A Historical Perspective of Hawaii's Marine Resources, Fisheries, and Management Issues over the past 100 years. Pages 6–11 Status of Hawaii's Coastal Fisheries in the New Millennium, revised 2004 edition. Proceedings of the 2001 fisheries symposium sponsered by the American Fisheries Society, Hawaii Chapter.

Smith, M. K. 1993. An Ecological Perspective on Inshore Fisheries in the Main Hawaiian Islands. Marine Fisheries Review 55(2):34–49.

Stobutzki, I., M. Miller, and D. Brewer. 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation 28(02):167–181.

Stobutzki, I., M. Miller, and D. Brewer. 2002. 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 84(2):383–402.

Tables

Table 1: 2014 ACLs for Hawaii coral reef fishery families based on the 75th percentile of total catch (1966-2011) per family.

FAMILIES	2014 ACL
Acanthuridae-surgeonfish	80,545
Scaridae-parrotfish	33,326
Holocentridae-squirrelfish	44,122
Mullidae-goatfish	125,813
Carangidae-jacks	193,423

Table 2: Selected species for Hawaiian PSA analysis based off of prevalence in commercial catch data. Total catch was summed from Commercial Marine Landings Summary Trend Report from 2004-2013. Species are listed by Family from largest to smallest catch (lbs).

Family	Species	Common name Hawaiian/ English	Total (04-13)
Acanturhidae	*Acanthurus dussumieri*	Palani/ Eyestripe surgeon	304,998
Acanturhidae	*Naso unicornis*	Kala/ Bluespine unicornfish	262,579
Acanturhidae	*Acanthurus triostegus*	Manini/ Convict tang	131,802
Acanturhidae	*Acanthurus xanthopterus*	Pualu/ Yellowfin surgeon	88,105
Acanturhidae	*Acanthurus olivaceus*	Na‘ena‘e/ Orangespot	76,941
Alulidae	*Albula vulpes*	Oio/ Bonefish	92,324
Carangidae	*Caranx ignobilis*	White ulua/ Giant trevally	177,161
Carangidae	*Pseudocaranx dentex*	Butaguchi/ Thicklipped jack	79,129
Carangidae	*Caranx melampygus*	Omilu/ Bluefin trevally	74,846
Carangidae	*Carangoides orthogrammus*	Papa/ Yellowspot trevally	64,358
Holocentridae	*Myripristis berndti*	‘u‘u/ Soldierfish	488,570
Kyphosidae	*Kyphosus cinerescens*	Nenue/ Rudderfish	255,583
Lutjanidae	*Lutjanus fulvus*	Toau/ Blacktail Snapper	40,899
Mulgilidae	*Mugil cephalus*	‘ama‘ama/ Striped Mullet	88,317
Mullidae	*Mulloidichthys vanicolensis*	Weke red/ Yellowfin goatfish	293,000
Mullidae	*Parupeneus porphyreus*	Kumu/ Whitesaddle goatfish	51,282
Mullidae	*Mulloidichthys pflugeri*	Weke nono / Orange goatfish	47,488
Priacanthidae	*Priacanthus hamrur*	‘aweoweo/ Hawaiian Bigeye	48,868
Scaridae	*Scarus* spp.	Uhu/ Parrotfish	529,429
	Calotomus carolinus	Uhu/ Stareye parrotfish	
	Scarus rubroviolaceus	Uhu/ Redlipped parrotfish	

Table 3: Scoring criteria for productivity attributes. A score of one indicates low productivity whereas a score of three represents high productivity. Scoring is based on the PSA Version 1.4 tool from NOAA Fisheries Toolbox (Stobutzki et al. 2002, Patrick et al. 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
T_{mat}	> 4 years	2-4 years	< 2 years
Trophic level	Piscivore > 3.5	Omnivores 2.5-3.5	Herbivores < 2.5

Table 4: Scoring criteria for susceptibility attributes. A score of one indicates low susceptibility to fishing, whereas a score of three represents high susceptibility towards fishing. Scoring is based on the PSA Version 1.4 tool from NOAA Fisheries Toolbox (Stobutzki et al. 2002, Patrick et al. 2009).

Susceptibility Attributes	**Low (1)**	**Moderate (2)**	**High (3)**
Vertical overlap	> 40 m	30-40 m	< 30 m
Desirability/ Value	Stock is not highly valued/desired by the fishery < $2.00	Stock is moderately valued/desired by the fishery $2.00-$4.00	Stock is highly valued/desired by the fishery > $4.00
Behavior/ Catchability	Usually solitary or pairs < 40	Small groups or aggregations 40-60	Frequently Schooling >60
Management Strategy	Stocks have catch limits and proactive accountability measures.	Stocks have catch limits and reactive accountability measures.	Targeted stocks do not have catch limits or accountability measures.

Table 5: 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 PSA but included in the data quality index.	

Table 6: Productivity attributes and data quality (Score) for each species. Colors are based on productivity scoring criteria (Table 3): red indicates low productivity, yellow indicates medium productivity, and green indicates attributes with high productivity. Bold italicized values were estimated from the Life-History tool on Fishbase (Froese et al. 2005).

Scientific name	**T_{max}**	**Score**	**L_{inf}**	**Score**	**K**	**Score**	**M**	**Score**	**T_{mat}**	**Score**	**Trophic level**	**Score**
Acanthurus dussumieri	28.0	2	37.1	1	0.30	2	0.11	1	***1.2***	***4***	2.0	3
Acanthurus olivaceus	33.0	2	21.0	2	1.07	2	0.09	2	2.0	2	2.3	3
Acanthurus triostegus	***3.5***	***4***	21.7	1	0.35	1	***0.86***	***4***	1.0	1	2.8	3
Acanthurus xanthopterus	34.0	2	42.6	2	0.29	2	0.09	2	***2.0***	***4***	2.9	1
Naso unicornis	53.0	1	51.2	1	0.17	1	0.06	1	7.5	1	2.3	1
Albula glossodonta	14.0	1	76.2	1	0.10	1	0.05	1	4.2	3	3.7	3
Carangoides orthogrammus	***9.0***	***4***	70.0	3	***0.33***	***4***	***0.33***	***4***	***2.0***	***4***	4.5	1
Caranx ignobilis	11.0	2	217.0	1	0.11	1	0.27	1	***2.0***	***4***	4.2	1
Caranx melampygus	7.0	2	104.1	1	0.23	1	0.43	1	2.0	1	4.5	1
Pseudocaranx dentex	***9.0***	***4***	89.0	1	0.30	3	***0.33***	4	***2.0***	***4***	3.9	1
Myripristis berndti	27.0	1	27.1	1	0.15	1	0.11	1	***4.9***	***4***	3.7	3
Kyphosus cinerescens	***7.1***	***4***	41.0	2	0.25	3	***0.42***	***4***	***1.7***	***4***	2.5	3
Lutjanus fulvus	34.0	2	27.0	2	0.40	2	0.09	*2*	4.0	2	3.6	3
Mugil cephalus	16.0	3	40.1	3	0.45	3	0.19	3	6.0	2	2.5	3
Mulloidichthys pflugeri	***6.0***	***4***	40.0	2	***0.45***	***4***	***0.50***	***4***	***1.5***	***4***	3.9	1
Mulloidichthys vanicolensis	5.0	1	26.7	1	1.30	1	0.6	1	***1.0***	***4***	3.6	3
Parupeneus porphyreus	6.0	1	54.7	1	0.54	1	0.5	1	***1.6***	***4***	4.0	1
Priacanthus meeki	***4.2***	***4***	33.0	3	0.61	3	***0.71***	***4***	***1.1***	***4***	4.2	3
Calotomus carolinus	3.0	2	45.5	1	0.91	2	1.00	2	1.1	2	2.0	3
Scarus rubroviolaceus	22.0	1	51.2	1	0.288	1	0.14	1	4.0	1	2.0	2

Table 7: Susceptibility attributes and data quality (Score) for each species. Colors are based on susceptibility scoring criteria (Table 4): red indicates high susceptibility, yellow indicates medium susceptibility, and green indicates attributes with low susceptibility.

Scientific name	Max Depth	Score	Value	Score	Spatial Behavior	Score	Management Strategy	Score
Acanthurus dussumieri	130	3	$ 1.77	1	48	2	Family ACL: 80,545	1
Acanthurus olivaceus	46	2	$ 1.33	1	48	2	Family ACL: 80,545	1
Acanthurus triostegus	90	3	$ 3.11	1	52	3	Min size:5 in Family ACL:80,545	1
Acanthurus xanthopterus	100	3	$ 1.68	1	80	2	Family ACL: 80,545	1
Naso unicornis	180	3	$ 1.89	1	0.8	3	Min size:14 in Family ACL:80,545	1
Albula glossodonta	84	3	$ 1.53	1	64	3	Min size: 14 in No ACL	1
Carangoides orthogrammus	168	3	$ 3.63	1	16	3	Family ACL: 193,423	1
Caranx ignobilis	188	1	$ 2.87	1	0.6	3	Min size: 16 in for sale Bag limit:20 Family ACL: 193,423	1
Caranx melampygus	190	3	$ 3.26	1	48	3	Min size: 16 in for sale Bag limit:20 Family ACL: 193,423	1
Pseudocaranx dentex	238	1	$ 3.33	1	80	3	Family ACL: 193,423	1
Myripristis berndti	159	3	$ 4.49	1	24	3	Family ACL: 44,122	1
Kyphosus cinerescens	45	3	$ 2.02	1	40	3	None	1
Lutjanus fulvus	75	3	$ 3.92	1	16	3	Family ACL: 65,102	1
Mugil cephalus	120	3	$ 4.65	1	112	3	Closed Season (Dec-Mar) Min size:11 in Family ACL: 41,112	1
Mulloidichthys pflugeri	110	2	$ 4.21	1	80	3	Min size: 7 in (except Maui) Family ACL: 125,813	1
Mulloidichthys vanicolensis	113	3	$ 3.66	1	52	3	Min size: 7 in (except Maui) Family ACL: 125,813	1
Parupeneus porphyreus	140	3	$ 9.77	1	0.6	3	Min size: 10 in (except Maui) Family ACL 125,813	1
Priacanthus meeki	250	3	$ 3.88	1	36	3	None	1
Calotomus carolinus	71	1	$ 3.92	1	0.2	3	Min size: 12 in (except Maui) Family ACL: 33,326	1
Scarus rubroviolaceus	36	3	$ 3.92	1	48	3	Min size: 12 in (except Maui) Family ACL: 33,326	1

Table 8: PSA results with Fishbase estimates (left) and without Fishbase estimates (right) for selected inshore fishery species. Productivity (data quality), susceptibility (data quality), and overall vulnerability scores are listed. One is low and three is high. Species listed based on record number which corresponds to numbered circles in Figure 4.

Rec. Num	**Stock**	**With Fishbase**			**Without Fishbase**		
		Productivity	Susceptibility	Vulnerability	Productivity	Susceptibility	Vulnerability
1	*Acanthurus dussumieri*	2.17 (2.17)	1.5 (1.75)	0.97	1.83 (2.33)	1.5 (1.75)	1.27
2	*Acanthurus olivaceus*	2.17 (2.17)	1.5 (1.5)	0.97	2.17 (2.17)	1.5 (1.5)	0.97
3	*Acanthurus triostegus*	2.67 (2.33)	1.5 (2)	0.6	2 (2.67)	1.5 (2)	1.12
4	*Acanthurus xanthopterus*	1.83 (2.17)	1.75 (1.75)	1.39	1.67 (2.33)	1.75 (1.75)	1.53
5	*Naso unicornis*	1.5 (1)	1 (2)	1.5	1.5 (1)	1 (2)	1.5
6	*Albula glossodonta*	1.33 (1.67)	1.75 (2)	1.83	1.33 (1.67)	1.75 (2)	1.83
7	*Carangoides orthogrammus*	2 (3.33)	1.5 (2)	1.12	1.17 (4)	1.5 (2)	1.9
8	*Caranx ignobilis*	1.5 (1.67)	1.25 (1.5)	1.52	1.33 (1.83)	1.25 (1.5)	1.69
9	*Caranx melampygus*	1.83 (1.17)	1.5 (2)	1.27	1.83 (1.17)	1.5 (2)	1.27
10	*Pseudocaranx dentex*	2 (2.83)	2 (1.5)	1.41	1.33 (3.33)	2 (1.5)	1.94
11	*Myripristis berndti*	1.33 (1.83)	1.75 (2)	1.83	1.33 (2)	1.75 (2)	1.83
12	*Kyphosus cinerescens*	2.5 (3.33)	2 (2)	1.12	1.67 (3.83)	2 (2)	1.67
13	*Lutjanus fulvus*	1.67 (2.17)	1.5 (2)	1.42	1.67 (2.17)	1.5 (2)	1.42
14	*Mugil cephalus*	1.83 (2.83)	2 (2)	1.54	1.83 (2.83)	2 (2)	1.54
15	*Mulloidichthys pflugeri*	2.14 (3.43)	2 (1.75)	1.32	1.29 (4)	2 (1.75)	1.98
16	*Mulloidichthys vanicolensis*	2.67 (1.83)	1.5 (2)	0.6	2.33 (2)	1.5 (2)	0.83
17	*Parupeneus porphyreus*	2.33 (1.5)	1.5 (2)	0.83	2 (1.67)	1.5 (2)	1.12
18	*Priacanthus meeki*	2.67 (3.5)	1.75 (2)	0.82	1.67 (4)	1.75 (2)	1.53
19	*Calotomus carolinus*	3 (2)	1.25 (1.5)	0.25	3 (2)	1.25 (1.5)	0.25
20	*Scarus rubroviolaceus*	1.83 (1.17)	1.75 (2)	1.39	1.83 (1.17)	1.75 (2)	1.39

Figures

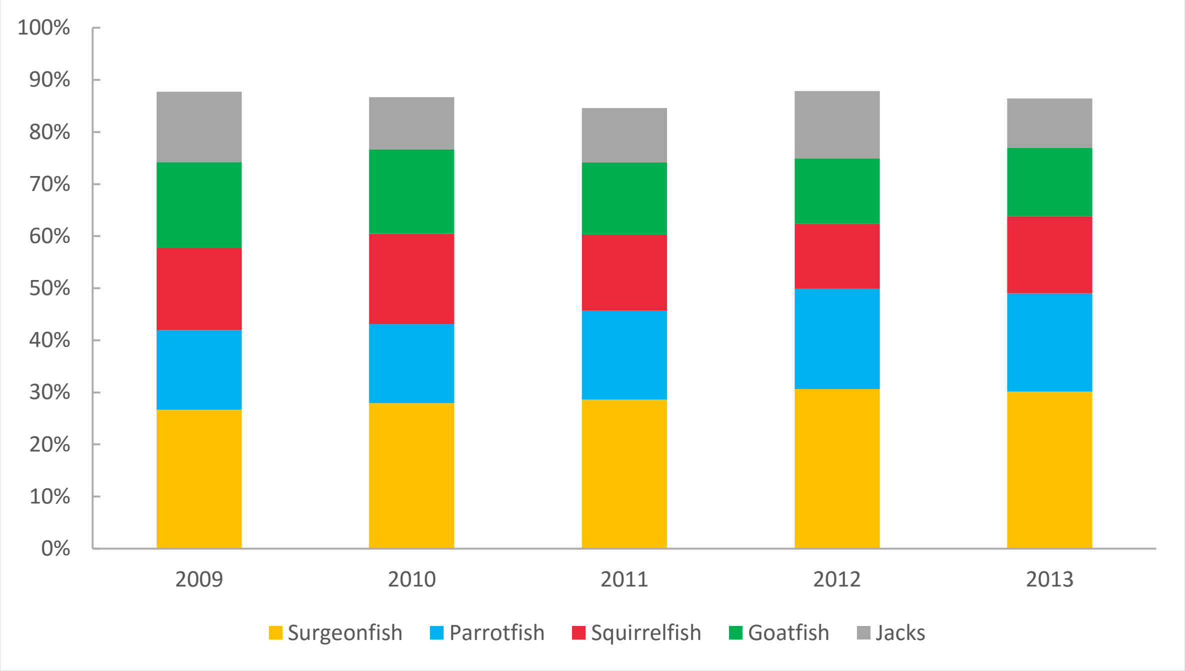


Figure 1: Percentage of commercial catch for the top five families from 2009-2013. Total catch was summed for each family from Commercial Marine Landings Summary Trend Report from 2009-2013.

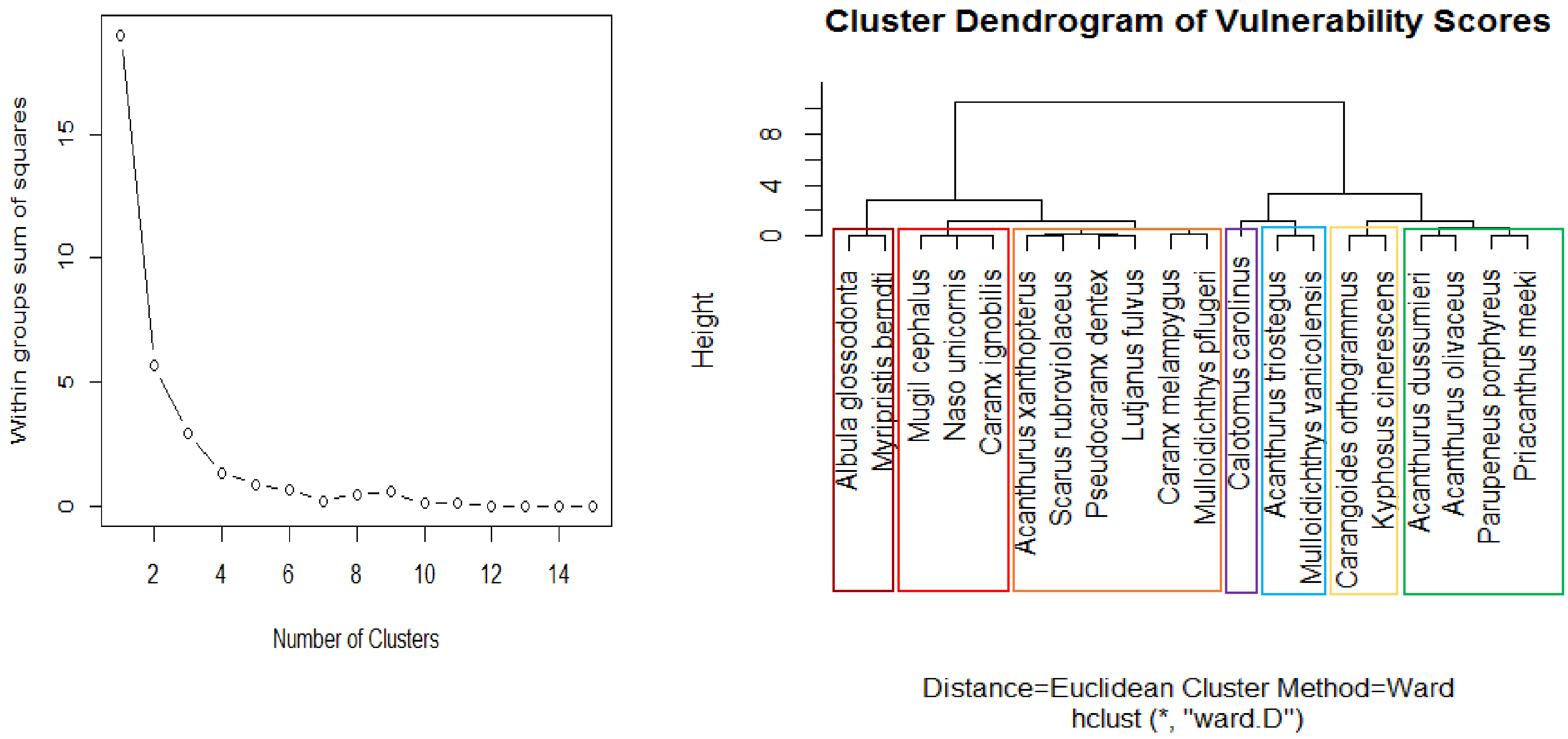


Figure 2: Plot (left) and dendrogram (right) based on the hierarchical cluster analysis using vulnerability scores using Fishbase estimates. Seven clusters were used based on the “elbow” method. Colored boxes indicate level of vulnerability from highest vulnerability species (dark red) to least vulnerable species (purple).

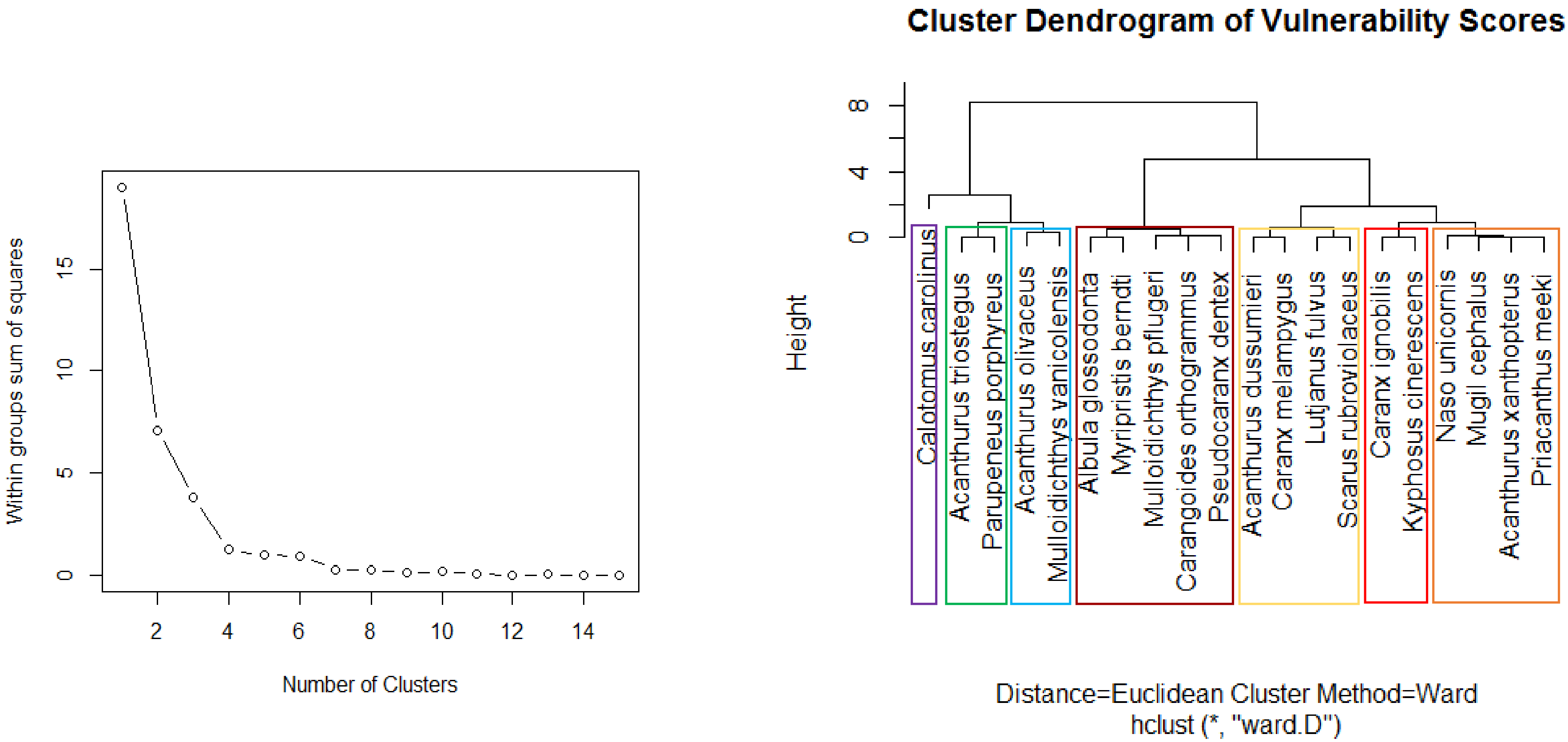


Figure 3: Plot (left) and dendrogram (right) based on the hierarchical cluster analysis using vulnerability scores without Fishbase estimates. Seven clusters were used based on the “elbow” method. Colored boxes indicate level of vulnerability from highest vulnerability species (dark red) to least vulnerable species (purple)

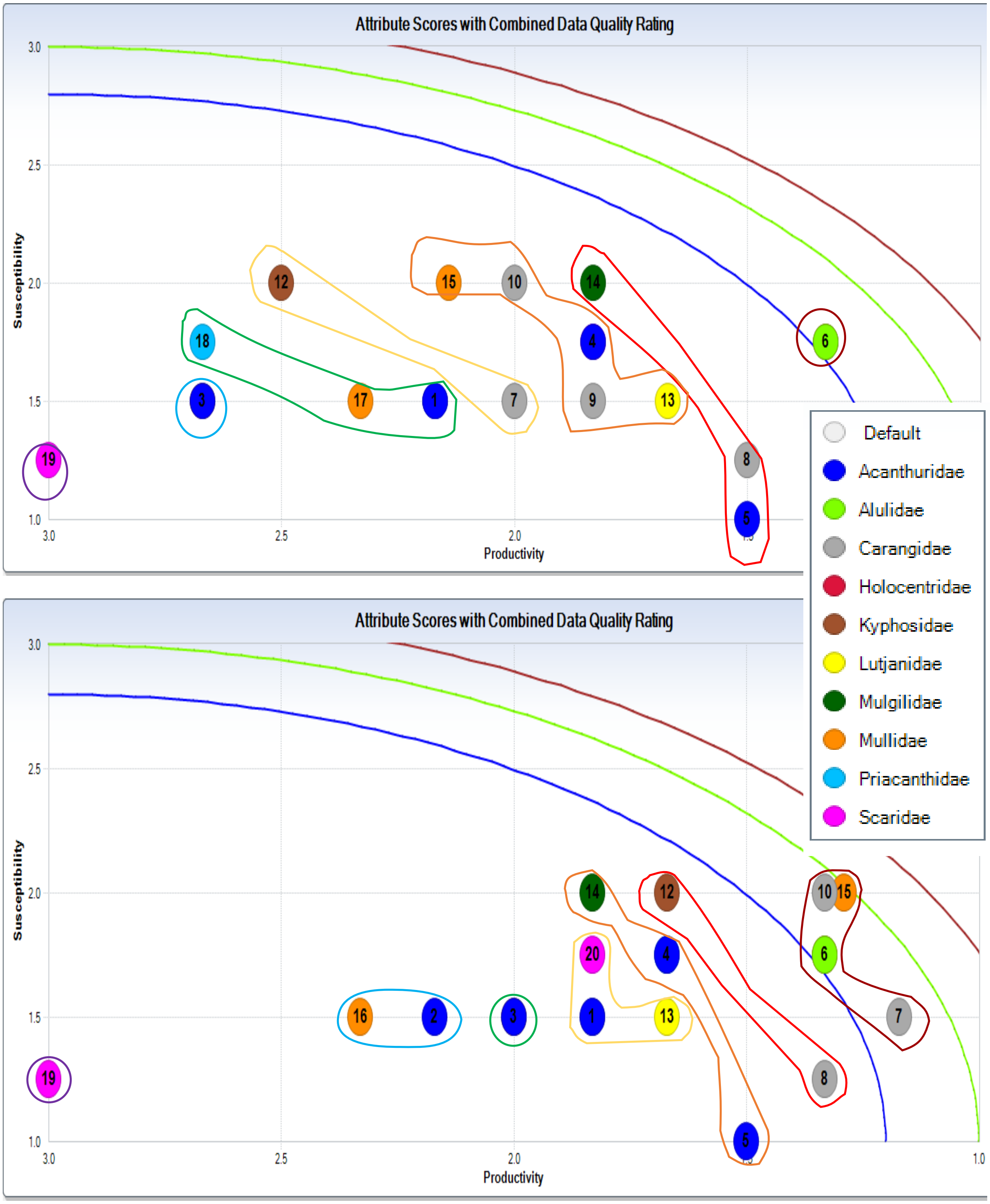
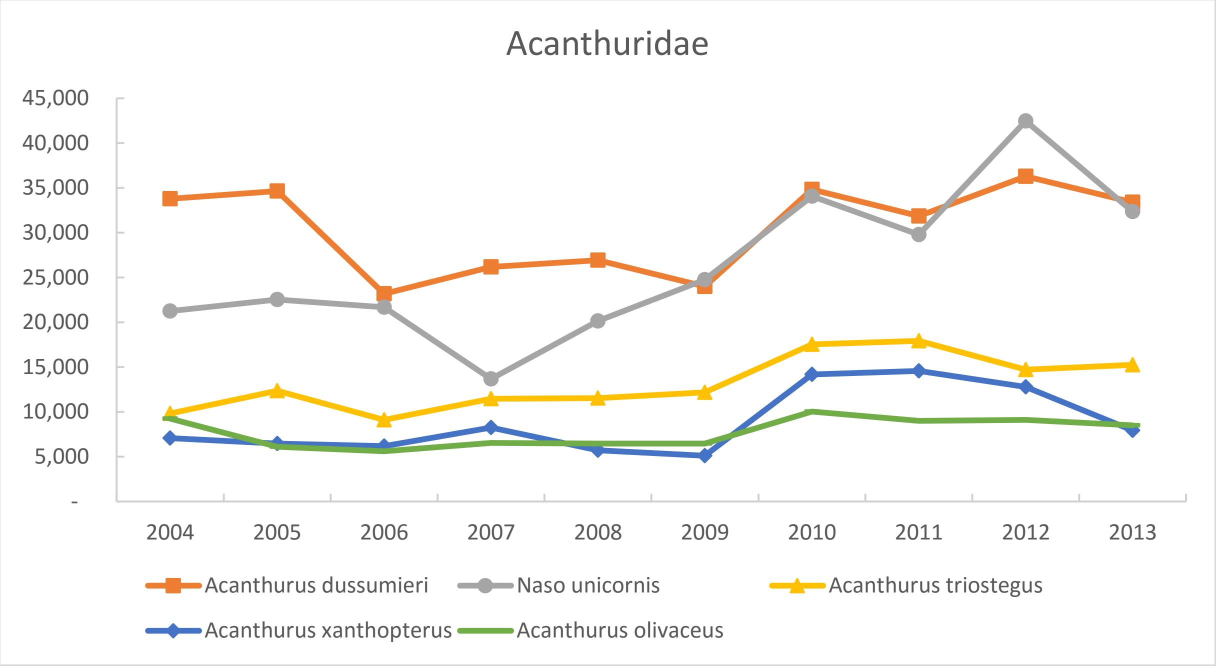
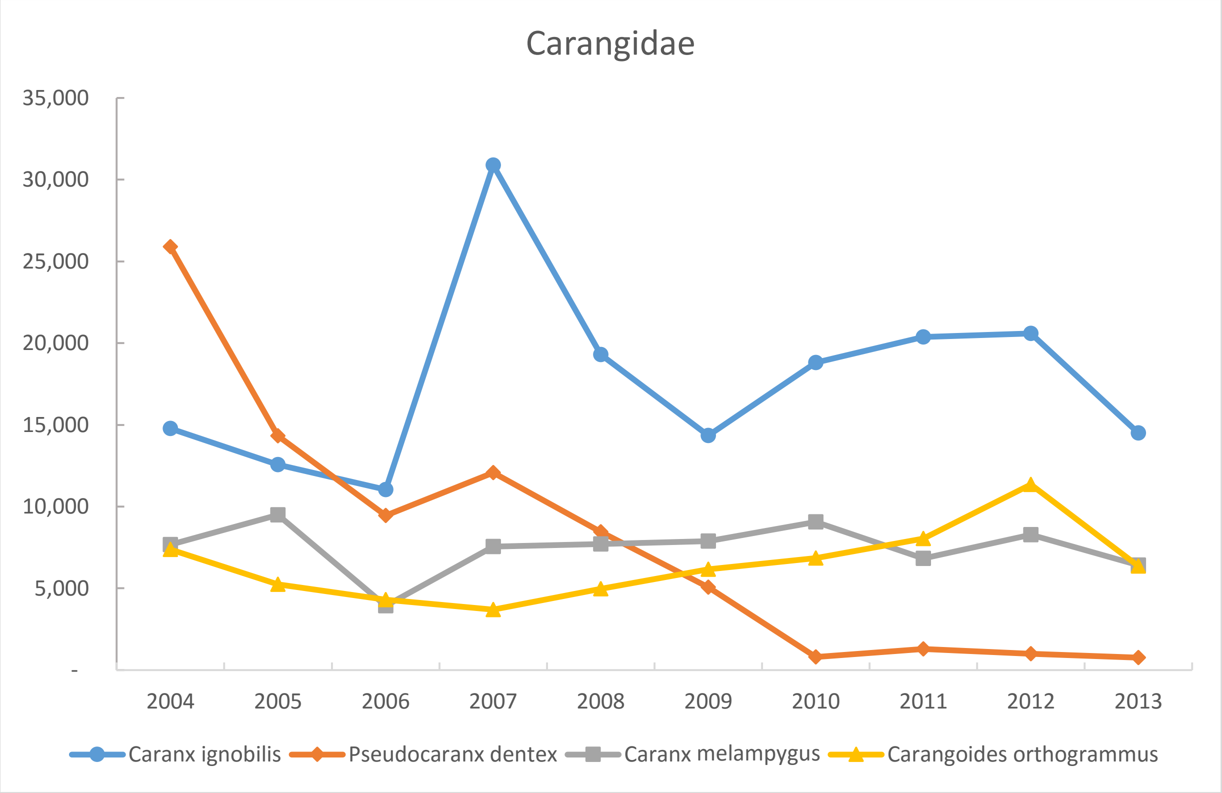


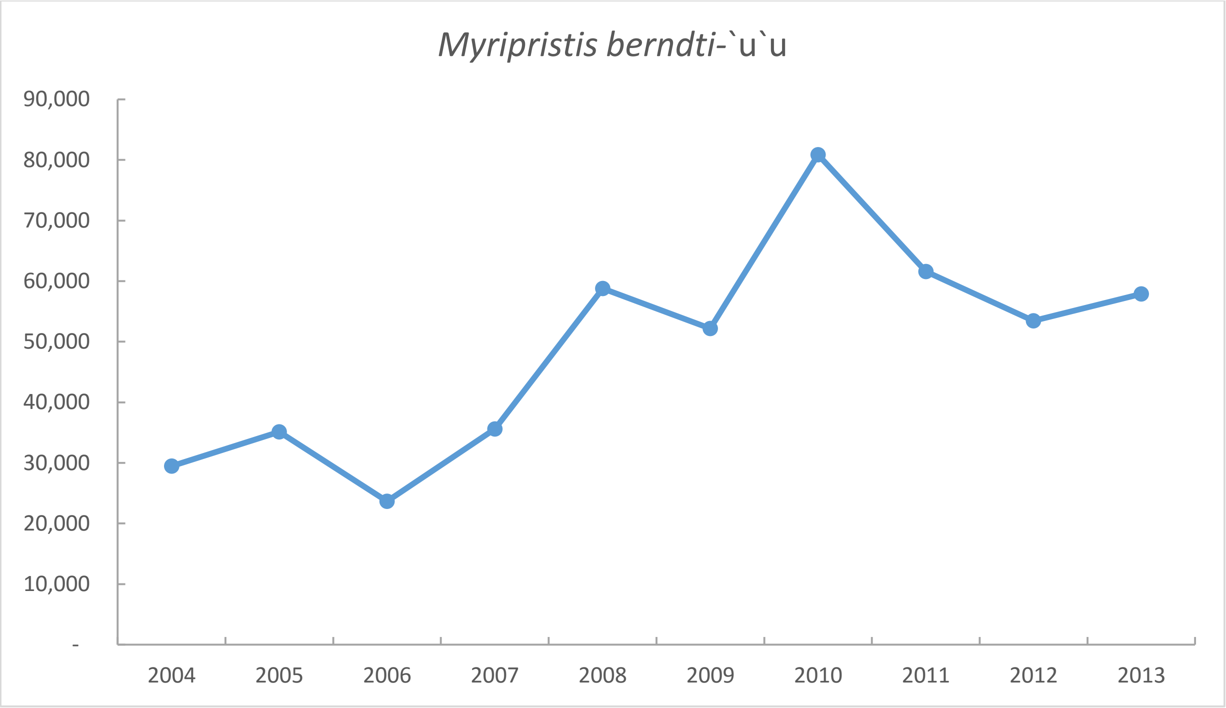
Figure 4: Results of the PSA with Fishbase estimates (top) and without Fishbase estimates (bottom). Colored circles indicate species family. Number represents individual species (Table 8). Colored lines encircling the speices represent the eight clusters identified by hierachical cluster analysis (Figure 2 and 3). The most vulnerable clusters are dark red (upper right) flowing to least vulnerable in puple (lower left).

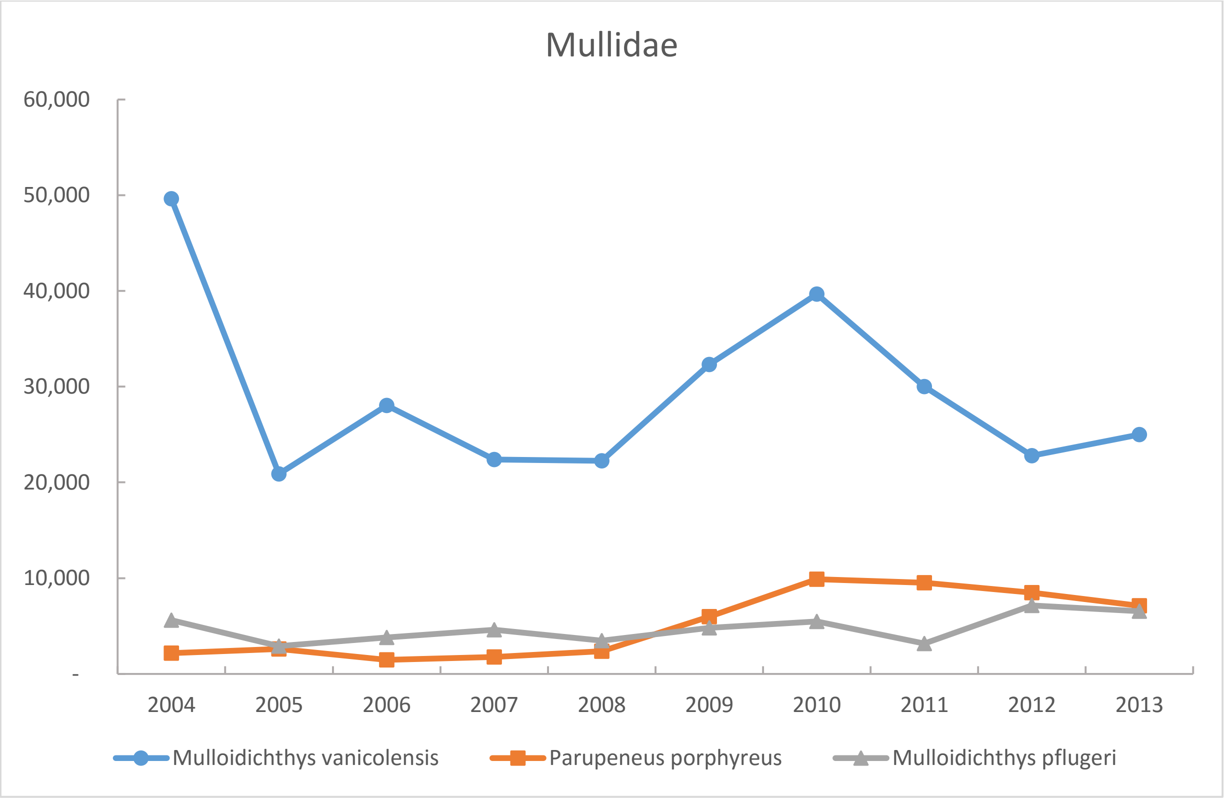
Appendix 1: Commercial Catch for Hawaiian selected species

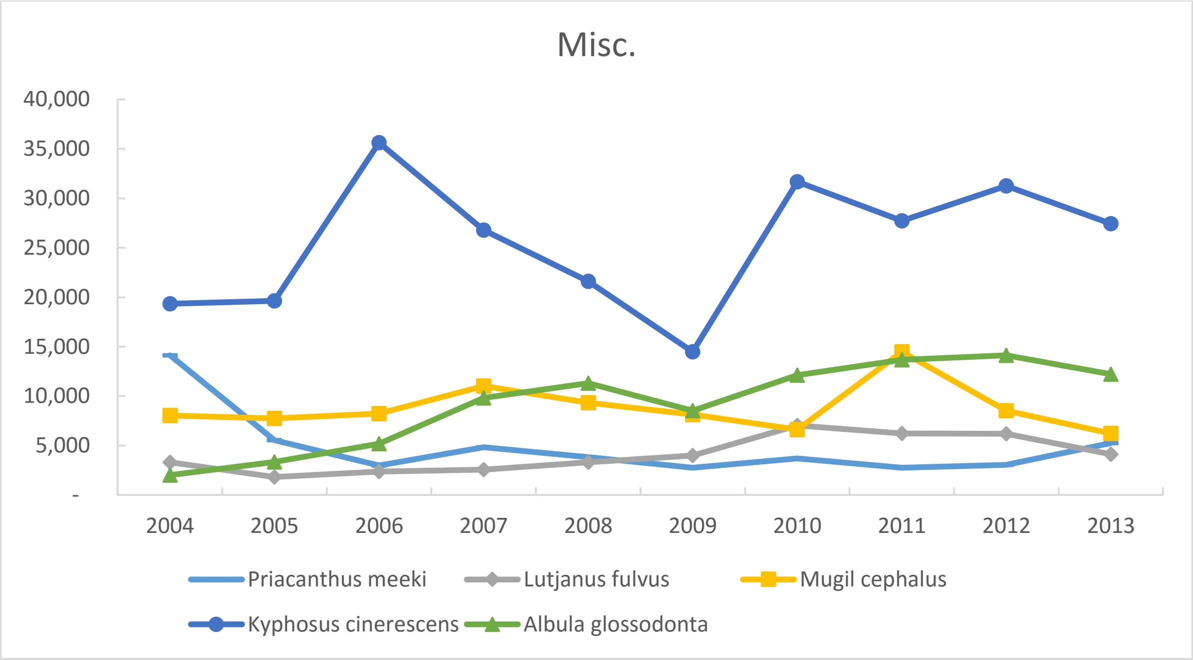
Figures A1-A5: Commercial recorded catch (lbs) by species per family 2004-2013. Recorded catch from Commercial Marine Landings Summary Trend Report (2004-2013). From: http://dlnr.hawaii.gov/dar/fishing/commercial-fishing/






Myripristis berndti-`u`u
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


Mullidae
60,000
50,000
40,000
30,000
20,000
10,000
-
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Mulloidichthys vanicolensis
Parupeneus porphyreus
Mulloidichthys pflugeri


Misc.
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Priacanthus meeki
Lutjanus fulvus
Mugil cephalus
Kyphosus cinerescens
Albula glossodonta

Appendix 2: Bibliography of life history traits by species with corresponding data quality score.

Acanthuridae

Acanthurus dussumieri

Reference	Location of Study	Data Quality
Choat, J.H., D.R. Robertson, 2002. "Age-Based Studies on Coral Reef Fishes" Chapter 3 Coral Reef Fishes. Academic Press	GBR	2
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Sano, M., M. Shimizu and Y. Nose, 1984. Food habits of teleostean reef fishes in Okinawa Island, southern Japan. University of Tokyo Bulletin, no. 25. v,128p. University of Tokyo Press, Tokyo, Japan. 128 p	Japan	3
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Acanthurus olivaceus

Reference	Location of Study	Data Quality
Choat, J.H., D.R. Robertson, 2002. "Age-Based Studies on Coral Reef Fishes" Chapter 3 Coral Reef Fishes. Academic Press	GBR	2
Sano, M., M. Shimizu and Y. Nose, 1984. Food habits of teleostean reef fishes in Okinawa Island, southern Japan. University of Tokyo Bulletin, no. 25. v,128p. University of Tokyo Press, Tokyo, Japan. 128 p	Japan	3
Myers, R.F., 1991. Micronesian reef fishes. Second Ed. Coral Graphics, Barrigada, Guam. 298 p	Micronesia	2

Acanthurus triostegus

Reference	Location of Study	Data Quality
Randall, J.E., 1961. "A contribution to the biology of the convict surgeonfish of the Hawaiian Islands: *Acanthurus triostegus sandvicensis."* Pac. Sci. 15(2): 215-272	Hawaii	1
Hiatt, R.W. and D.W. Strasburg, 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. Ecol. Monogr. 30(1):65-127.	Marshall Islands	3
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Acanthurus xanthopterus

Reference	Location of Study	Data Quality
Choat, J.H., D.R. Robertson, 2002. "Age-Based Studies on Coral Reef Fishes" Chapter 3 Coral Reef Fishes. Academic Press	Australia	2
Randall, J.E., 1985 "Guide to Hawaiian reef fishes." Harrowood Books, Newton Square, PA 19073, USA. 74 p.	Hawaii	2
Krupp, F., 1995. Acanthuridae. Sangradores, cirujanos, navajones. p. 839-844. 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.	Central Pacific	3

Naso unicornis

Reference	Location of Study	Data Quality
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Eble, J.A., Langston, R., and Bowen, B.W. (2009). Growth and reproduction of Hawaiian Kala, *Naso unicornis* (Honolulu, Hawaii: Fisheries Local Action Strategy, Division of Aquatic Resources).	Hawaii	1
Randall, J.E., 2002. Surgeonfishes of the world. Mutual Publishing and Bishop Museum Press, Hawai'i. 123 p.	Global	3
Bacchet, P., T. Zysman and Y. Lefèvre, 2006. Guide des poissons de Tahiti et ses îles. Tahiti (Polynésie Francaise): Editions Au Vent des Îles. 608 p.	Tahiti	3

Alulidae

Albula glossodonta

Reference	Location of Study	Data Quality
Kamikawa, Keith T., et al. 2015. Bonefishes in Hawai'i and the importance of angler-based data to inform fisheries management. *Environmental Biology of Fishes* 98.11: 2147-2157.	Hawaii	1
Crabtree, R.E., C.W. Harnden, D. Snodgrass and C. Stevens, 1996. "Age, growth, and mortality of bonefish, Albula vulpes, from the waters of the Florida Keys." Fish.Bull. 94: 442-451.	Florida	2
Pfeiler, E., D. Padron and R.E. Crabtree, 2000. "Growth rate, age and size of bonefish from the Gulf of California." J.Fish Biol. 56(2): 448-453.	Florida	2

Carangidae

Carangoides orthogrammus

Reference	Location of Study	Data Quality
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.	East Indies	3
Meyer, C. G., K. N. Holland, B. M. Wetherbee, and C. G Lowe, 2001. "Diet, resource partitioning and gear vulnerability of Hawaiian jacks captured in fishing tournaments." Fisheries Research 53.2: 105-113.	Hawaii	1
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Caranx ignobilis

Reference	Location of Study	Data Quality
Fry, G.C., Brewer, D.T., and Venables, W.N., 2006. Vulnerability of deepwater demersal fishes to commercial fishing: evidence from a study around a tropical volcanic seamount in Papua New Guinea. Fish. Res. *81*.	Papua New Guinea	2
Sudekum, A.E., J.D. Parrish, R.L. Radtke and S. Ralston, 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish. Bull. 89:493-513.	Hawaii	1
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Mundy, B.C., 2005. Checklist of the fishes of the Hawaiian Archipelago. Bishop Museum Bulletins in Zoology. Bishop Mus. Bull. Zool. (6):1-704.	Hawaii	1

Caranx melampygus

Reference	Location of Study	Data Quality
Fry, G.C., Brewer, D.T., and Venables, W.N., 2006. Vulnerability of deepwater demersal fishes to commercial fishing: evidence from a study around a tropical volcanic seamount in Papua New Guinea. Fish. Res. *81*.	Papua New Guinea	2
Sudekum, A.E., J.D. Parrish, R.L. Radtke and S. Ralston, 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish. Bull. 89:493-513.	Hawaii	1
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Pseudocaranx dentex

Reference	Location of Study	Data Quality
Uchiyama, J.H. and Kazama, T.K., 2003. Updated weight-on-length relationships for pelagic fishes caught in the central North Pacific Ocean and bottomfishes from the northwestern Hawaiian Islands. National Oceanic and Atmospheric Administration, Pacific Islands Fisheries Science Center Administrative Report H-03-01, 34.	Hawaii	1
Annala, J.H., K.J. Sullivan and C.J. O'Brien (comps.), 1999. Report from the Fishery Assessment Plenary, April, 1999: stock assessments and yield estimates. Unpublished report held in NIWA library, Wellington. 430 p.	Australia	3
Mundy, B.C., 2005. Checklist of the fishes of the Hawaiian Archipelago. Bishop Museum Bulletins in Zoology. Bishop Mus. Bull. Zool. (6):1-704.	Hawaii	1
Honebrink, R., 1990. Fishing in Hawaii: a student manual. Education Program, Division of Aquatic Resources, Honolulu, Hawaii. 79 p.	Hawaii	1

Holocentridae

Myripristis berndti

Reference	Location of Study	Data Quality
Craig, M.T., and Franklin, E.C., 2008. Life history of Hawaiian “redfish”: a survey of age and growth in “aweoweo (*Priacanthus meeki*) and u”u (*Myripristis berndti*). Kaneohe, Hawaii: HIMB.	Hawaii	1
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Allen, G.R. and M.V. Erdmann, 2012. Reef fishes of the East Indies. Perth, Australia: Universitiy of Hawai'i Press, Volumes I-III. Tropical Reef Research.	East Indies	3
Parrish, J.D., J.E. Norris, M.W. Callahan, J.K. Callahan, E.J. Magarifuji and R.E. Schroeder, 1986. Piscivory in a coral reef fish community. p. 285-297. In C.A. Simenstad and G.M. Cailliet (eds.) Contemporary studies on fish feeding. Dr. W. Junk Publishers, Dordrecht, The Netherlands.		3

Kyphosidae

Kyphosus cinerascens

Reference	Location of Study	Data Quality
Longenecker, Ken, et al., 2014. Six-Year Baseline Information: Size Structure and Reproduction of Exploited Reef Fishes Before Establishing a Management Plan at Kamiali Wildlife Management Area, Papua New Guinea.	Papua New Guinea	2
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.	Papua New Guinea	3
Kuiter, R.H., 1993. Coastal fishes of south-eastern Australia. University of Hawaii Press. Honolulu, Hawaii. 437 p.	Australia	3
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	Somalia	3
Broad, G., 2003. Fishes of the Philippines. Anvil Publishing, Inc., Pasi City. 510 pp.	Philippines	3

Lutjanidae

Lutjanus fulvus

Reference	Location of Study	Data Quality
Shimose, T. and Nanami, A., 2014. Age, growth, and reproductive biology of blacktail snapper, Lutjanus fulvus, around the Yaeyama Islands, Okinawa, Japan. Ichthyological Research, 61(4), pp.322-331.	Japan	2
Randall, J.E. and V.E. Brock, 1960. Observations on the ecology of Epinephelinae and lutjanid fishes of the Society Islands, with emphasis on food habits. Trans. Am. Fish. Soc. 89(1):9-16.	French Polynesia	3
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Mulgilidae

Mugil cephalus

Reference	Location of Study	Data Quality
Thomson, J.M., 1963. Synopsis of the biological data on the grey mullet *Mugil cephalus* Linnaeus 1758. CSIRO Division of Fisheries and Oceanography, Fisheries Synopsis 1. 65 p.	Australia	2
Annala, J.H. (comp.), 1994. Report from the Fishery Assessment Plenary, May 1994: stock assessments and yield estimates. Unpublished report held in MAF Fisheries Greta Point library, Wellington. 242 p.	New Zealand	3
Aguirre, A. L. I., & Gallardo-Cabello, M. 2004. Reproduction of Mugil cephalus and M. curema (Pisces: Mugilidae) from a coastal lagoon in the Gulf of Mexico. Bulletin of Marine Science, 75(1), 37-49.	Mexico	2
Wells, R., 1984. The food of the grey mullet (*Mugil cephalus* L.) in Lake Waahi and the Waikato River at Huntly. N.Z. J. Mar. Freshwat. Res. 18(1):13-19.	New Zealand	3
Harrison, I.J., 1995. Mugilidae. Lisas. p. 1293-1298. 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.	Central Pacific	3

Mullidae

Mulloidichthys vanicolensis

Reference	Location of Study	Data Quality
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Cole, K.S., 2009. 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).	Hawaii	1
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.	East Indies	3
Parrish, J.D., J.E. Norris, M.W. Callahan, J.K. Callahan, E.J. Magarifuji and R.E. Schroeder, 1986. Piscivory in a coral reef fish community. p. 285-297. In C.A. Simenstad and G.M. Cailliet (eds.) Contemporary studies on fish feeding. Dr. W. Junk Publishers, Dordrecht, The Netherlands.	Global	3

Mulloidichthys pflugeri

Reference	**Location of Study**	**Data Quality**
Myers, R.F., 1991. Micronesian reef fishes. Second Ed. Coral Graphics, Barrigada, Guam. 298 p	Marianas	2
Honebrink, R., 1990. Fishing in Hawaii: a student manual. Education Program, Division of Aquatic Resources, Honolulu, Hawaii. 79 p.	Hawaii	1

Parupeneus prophyreus

Reference	**Location of Study**	**Data Quality**
Moffitt, R.B. (1979). Age, growth, and reproduction of the kumu, *Parupeneus porphyreus* (Honolulu: PhD thesis. University of Hawaii at Manoa).	Hawaii	1
Nadon, M. O., J.S. Ault, I.D. Williams, S.G. Smith, G.T. DiNardo "Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwest Hawaiian Islands". Plos One 10:8	Hawaii	1
Hobson, E.S., 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72(4):915-1031.	Hawaii	1
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Priacanthidae

Priacanthus meeki

Reference	**Location of Study**	**Data Quality**
Chakraborty, S.K., R.S. Biradar, A.K. Jaiswar and R. Palaniswamy, 2005. Population parameters of some commercially important fishery resources of Mumbai coast. Central Institute of Fisheries Education, Deemed University, Versova, Mumbai, 63 p.	India	3
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.	Mozambique	3
Lieske, E. and R. Myers, 1994. Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.	Indo Pacific	3

Scaridae

Calotomus carolinus

Reference	Location of Study	Data Quality
Taylor, B. and J. Choat 2014. Comparative demography of commercially important parrotfish species from Micronesia. Journal of fish biology.	CNMI/ Guam	2
Hawaii Cooperative Fishery Research Unit. 2008. Biology of Parrotfish in Hawaii. University of Hawaiʻi at Manoa Campus, Honolulu, Hawaiʻi 96822-2279.	Hawaii	1
Bruce, R.W. and J.E. Randall, 1985. A revision of the Indo-West Pacific parrotfish genera Calotomus and Leptoscarus (Scaridae: Sparisomatinae). Indo-Pac. Fish. (5):32 p.	Indo Pacific	3
Mundy, B.C., 2005. Checklist of the fishes of the Hawaiian Archipelago. Bishop Museum Bulletins in Zoology. Bishop Mus. Bull. Zool. (6):1-704.	Hawaii	1

Scarus rubroviolaceus

Reference	Location of Study	Data Quality
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	Hawaii	1
Bellwood, D.R. and J.H. Choat, 1990. A functional analysis of grazing in parrotfishes (family Scaridae): the ecological implications. Environ. Biol. Fish. 28:189-214.	Hawaii	2
Humann, P. and N. Deloach, 1993. Reef fish identification. Galápagos. New World Publications, Inc., Florida. 267 p	Galapagos	3