



META-ANALYSIS OF REEF FISH DATA IN HAWAII: BIOGEOGRAPHY AND GRADIENTS OF HUMAN IMPACTS



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Executive Summary

- **One of the major obstacles to wise management of coral reef fisheries is the lack of sound information** on population abundance at spatial scales commensurate with the uses of these resources. This information is critical to developing sustainable fisheries management strategies, improving management of existing Marine Protected Areas (MPAs), designing future MPA networks, and aiding in the development of comprehensive marine spatial planning.
- There are currently a number of disparate data sets for reef fishes from around the Hawaiian Islands but no single data set is spatially comprehensive enough to explain the natural and anthropogenic processes that affect the distribution, abundance, and size of reef fishes around the state. **This study, for the first time, has synthesized all these data sets into a single and spatially comprehensive database** in order to characterize reef fish assemblages around Hawaii while controlling for habitat, wave exposure, and geographic influences.
- We compiled **25 datasets, representing more than 25,000 individual fish surveys** from throughout the entire Hawaiian Archipelago since the year 2000. These data were rigorously checked for errors and integrated into a common database with a standardized structure.
- **Information on fish species life history and ecology** (e.g., length-weight parameters, trophic position, movement, feeding ecology) are imperative to the assessment of fish populations. We used this opportunity to compile all known information on these fishes so that a **standardized database is now available** for the scientific community.
- Length-weight relationships of reef fishes were compared over time and space. Overall the relationship across all species did not change over time, however **on average fishes in the Northwestern Hawaiian Islands (NWHI) were heavier for a given length than in the main Hawaiian Islands (MHI)**.
- We developed **the first ever bioregionalization of the Hawaiian Archipelago** based on abundance and biomass of reef fishes. Results show clear separation between the MHI and NWHI but also a number of additional faunal breaks driven primarily by the relative abundance of **endemic species**.
- **Endemic species were much more common at the northern end of the chain** and showed a strong and statistically significant negative correlation with latitude. Endemics made up 52-55% of the numerical abundance at the northern end of the archipelago but only 17% on Hawaii Island in the extreme south.

- We conducted unconventional assessments for 52 species within the MHI by comparing their abundance to the NWHI (Papahānaumokuākea Marine National Monument-PMNM)—a large (362,073 km²), virtually unfished reference area. **This preliminary assessment has identified a number of species that require immediate management action. Over one-quarter of the species (27%) examined in the MHI appeared to be depleted below 10% of unfished abundance, while 42% were below 25% of unfished abundance.**
- The traditional Hawaiian district or **moku** was used as a unit of spatial stratification. **Moku explained 63% of the variability in resource fish biomass** and explained much of the variability in many other fish assemblage metrics. We attributed a number of biological, physical, and human demographic information to each moku for analytical purposes.
- **Biomass of resource species was negatively correlated with human population pressure among mokus.** We used human population per moku divided by shoreline length for that moku as an index of human population pressure. There was a strong negative relationship between resource fish biomass and human population pressure showing that biomass was extremely low in areas with high human population pressure and even modest human population pressure had a negative impact on fish assemblage structure. However, a number of remote areas with low human populations maintain high standing stock of fishes and these areas are likely important refugia for maintaining fisheries production and biodiversity functioning in the MHI.
- **Resource fish biomass was highest in mokus with northern and easterly exposures.** Mokus with southern and westerly exposures have less severe sea conditions resulting in greater accessibility and therefore heavier fishing pressure in these locations.
- **MMAs around the populated areas of Oahu and Maui showed higher biomass relative to fished areas. However, overall biomass within these protected areas was lower than MMAs on Hawaii Island and Lanai, where overall human pressure is lower.**
- **Ahihi-Kinau Natural Area Reserve on Maui was the most effective fully protected MMA** when MMA size is considered in calculating total resource fish biomass.
- **Older MMAs had the highest resource fish biomass while newer MPAs had fewer numbers and smaller sizes of resource fishes.**

Overall, this synthesis is the first ever, comprehensive examination of reef fish assemblage structure across Hawaii. The results show clear, distinct bioregions across the archipelago that give us a better understanding of reef fish macroecology and have important implications for management at the regional scale. The findings from this study also highlight the negative impacts of human population pressure on reef fishes, particularly around Oahu and Maui. When compared with the NWHI, a large proportion (42%) of MHI reef fish stocks were below 25% of unfished abundance. However, there are still remote areas in the MHI that provide refugia and help sustain fish stocks, therefore these areas are important conservation hotspots. MMAs were shown to be effective in conserving fishes, especially around Oahu and Maui where fishing pressure is extremely high outside of MMAs. However, most of these areas are too small to have substantial fisheries benefits. As a result, a more holistic approach that includes community-based management, expansion of the MMA network with a greater emphasis on no-take reserves, improvements to current fisheries regulations including enhanced enforcement efforts, and finally a greater emphasis on marine education and ocean awareness are necessary.

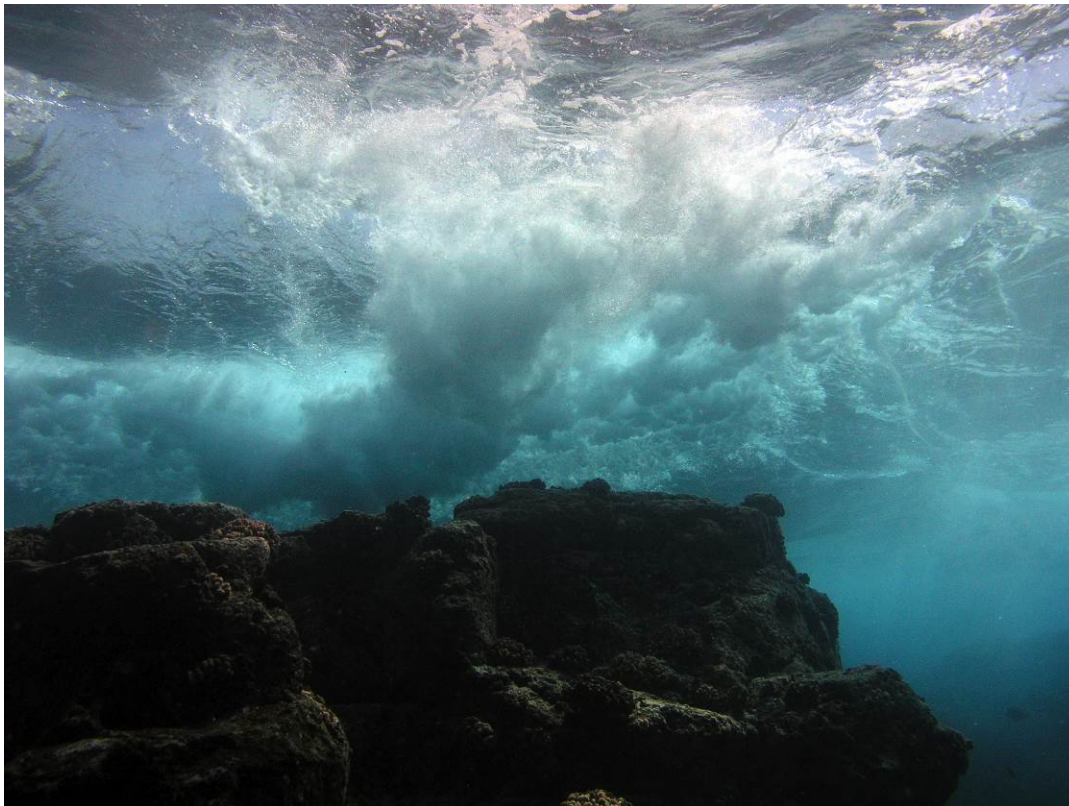


Photo: K.Stamoulis

Introduction and Background

Overfishing is thought to be one of the major reasons for the decline in coral reef resources across Hawaii and elsewhere (Friedlander and DeMartini 2002, Williams et al. 2008). These declines are also associated with, land-based pollution, destruction of habitat, invasive species and other threats, which are driven at the underlying level by a growing human population, export-driven markets for resources, access to technological innovations (e.g., motorized boats and freezers for storing catch), introduction of new and overly efficient fishing techniques (e.g. inexpensive monofilament gill nets, SCUBA, GPS), and loss of traditional conservation practices (Friedlander et al. 2003, 2008, 2013). Further, there is poor compliance with state fishing laws and regulations and insufficient enforcement, which are partially attributed to lack of resources and capacity.

Hawaii's coral reef fisheries provide livelihoods, sustenance, recreation, and help to perpetuate cultural practices in the Hawaiian Islands. One of the major obstacles to wise management of coral reef fisheries resources is the lack of good information on population abundance at spatial scales commensurate with the uses of these resources. Although many people acknowledge declines in certain reef fishes in Hawaii over time, there is little agreement on the causes of these declines.

There are currently a number of disparate data sets for reef fishes around the Hawaiian Islands but no single data set is spatially comprehensive enough to understand the natural and anthropogenic processes that affect the distribution, abundance, and size of reef fishes around the state. This information is critical to developing sustainable fisheries management strategies, improving management of existing MMAs, helping to design future MMA networks, and aiding in the development of comprehensive marine spatial planning.

This study describes population structure of reef fishes across the entire archipelago and therefore helps to elucidate the spatial patterns of abundance that are useful for informing management and marine spatial planning. This study, for the first time, compiles all known existing reef fish visual census data from Hawaii into a single dataset. Additionally, we have attributed all species within the database with information on life history and functional traits.

This study synthesizes this information into three major topics:

- I. Spatial and temporal comparison of length-weight relationships
- II. Bio-regionalization of Hawaiian fish fauna
- III. Fish assemblage structure across a gradient of human impact

Regional database of species life history

Information on fish species life history and ecology are imperative to the assessment of fish populations. This includes information such as length-weight parameters, trophic position, and feeding ecology. Length-weight parameters are used to calculate biomass from underwater visual census where size and counts of fishes are recorded. Numerous researchers in the state of Hawaii use these data on a regular basis, yet a standardized fish species database does not yet exist. We used this opportunity to bring together all known information on these fishes by combining species data from contributors and will publish this information so that a standardized database will be available for future efforts among the entire research community (Appendix 1). This will greatly increase uniformity as research moves forward.

Regional database of fish census data

We developed a standard template and compiled known fish census data into a comprehensive database. Data sets were identified from around the archipelago that collectively represents a variety of habitats, depths, and human influences. Nine individual researchers and managers of monitoring programs were contacted resulting in 25 datasets and over 22,000 individual surveys.

Spatial and temporal comparison of length-weight relationships

Length-weight relationships in fishes are central to understanding the status and condition of fish populations, and are critical for estimating biomass from length observations (Froese 2006, Pauly 1993). The first goal of this study is to publish length-weight relationships for Hawaiian fishes for the first time. Data on weight and length of reef fishes were gathered from multiple sources, including an extensive database held by the Hawaii Cooperative Fishery Research Unit at the University of Hawaii dating back to 1980 when large collections occurred in the Northwestern and Main Hawaiian Islands. Additional data were gathered from multiple sources dating back to 2002 and covering the entire archipelago. The extent of these surveys allowed for further analysis of spatial and temporal changes in fish condition.

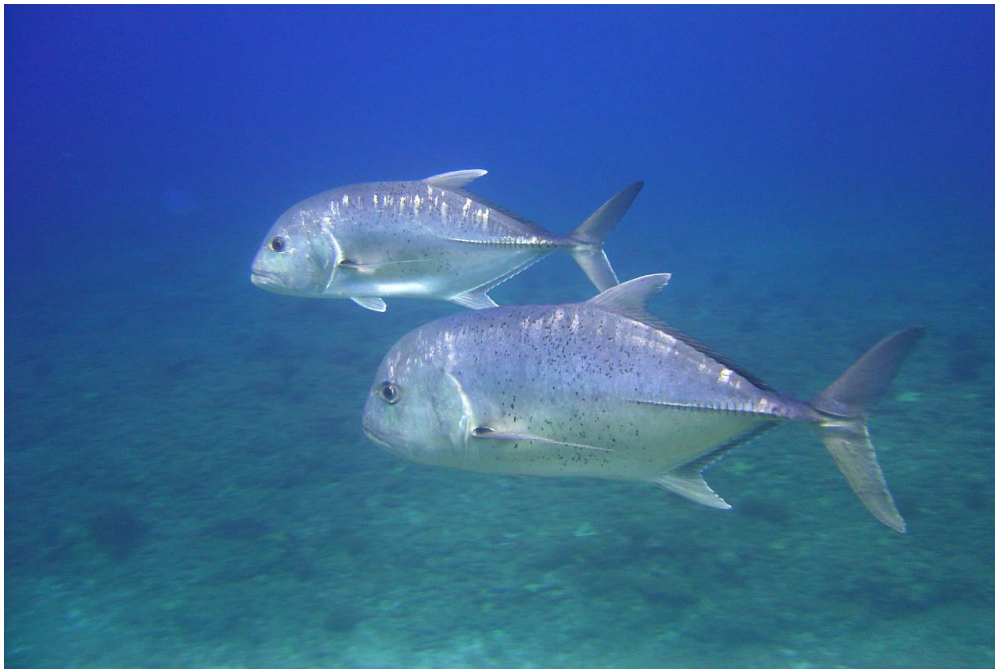
Bio-regionalization of Hawaiian fish fauna

Delineating regions is important in advancing our understanding of the biogeography and ecology of ecosystems, as well as understanding the historical and evolutionary forces shaping biodiversity patterns. From an applied point of view, this delineation is also very important in the identification of conservation priorities based on the composition of species assemblages. A biogeographic framework was developed to examine natural and anthropogenic factors that influence patterns of reef fish assemblage structure across one of the most

unique and isolated marine ecosystems on earth. We combined the observational data with information on each species' life history traits and known geographic distributions to develop hypotheses about spatial patterns of abundance and biomass along latitudinal, oceanographic and anthropogenic gradients. Geographic patterns were explored following a rigorous quantitative approach, with analyses covering various metrics (e.g. numerical density, biomass, trophic structure) based on concepts from biogeography theory. This work serves to identify important faunal breaks and spatial patterns of fish assemblage structure across the archipelago that will help to define regional management strategies in Hawaii and contribute to our understanding of reef fish macroecology.

Fish assemblage structure across a gradient of human impacts

Spatial variation in fish assemblages is evident throughout the archipelago and has been shown to correlate with human population pressure (Williams et al. 2008). We extend our understanding of the status and structure of fish assemblages across a human impact gradient by comparing metrics based on traditional Hawaiian management boundaries (mokus). This included comparisons of the relative influences of human population density and physical and anthropogenic factors on distribution, abundance, and size of reef fish around the state. We also evaluated existing MPAs based on their size and time since establishment.



Giant Trevally – ulua aukea (*Caranx ignobilis*) Northwestern Hawaiian Islands. Photo: K. Stamoulis

Regional database of fish census data

Data from government and non-government sources were compiled into a single database in a consistent structure. Individual researchers and lead persons for monitoring programs were contacted to acquire data on underwater visual surveys of fish assemblages. The final database covered 25 individual datasets from 9 principal investigators. Encompassing these are 7 major data sources (Table 1).

Table 1. Summary of fish datasets compiled from government and non- government sources and used in this analysis.

Data Source	Point of Contact	Survey Method	Total Number Surveys	Count of Islands	Years of Surveys
CRAMP	Kuulei Rodgers	Belt	371	8	2000, 2001, 2002, 2012
RAMP/CRED	Ivor Williams	Belt & SPC	5118	17	2000-2012
DAR	Walsh, Sparks, Schumacher	Belt	8980	4	2004-2012
FERL	Alan Friedlander	Belt	662	3	1993, 1994, 1999, 2000, 2003-2007, 2010-2012
FHUS	Alan Friedlander	Belt	1463	4	2002-2004, 2006-2008
NPS	Eric Brown	Belt	501	2	2004-2012
TNC	Erik Conklin	Belt	814	4	2009-2012

Meta-data from each dataset were compiled and analyzed to identify spatial and temporal gaps in these data. One previous study has been conducted using visual census of fishes within the Main Hawaiian Islands (Williams *et al.* 2008), but these data were limited in spatial extent and habitat. In addition, large efforts to collect additional data have occurred since 2006 when this analysis was conducted. Figure 1 presents a comparison of the spatial extent of data collection in the Main Hawaiian Islands in Williams *et al.* 2008 and the current analyses. Large gaps in the previous dataset included the west coast of Hawaii, north coast of Molokai, south and west Kauai, south and east Oahu, and Kaho'olawe, and are now covered by our more comprehensive dataset. Additionally, increased sampling around Ni'ihau, west Maui, and all coastlines of Oahu provide additional power to the analyses and allow us to identify general patterns among islands with greater certainty. Likewise, this study has incorporated data from the entire Hawaiian Archipelago, including 18 islands with sites spanning nearly 10° of latitude and over 2,500 km (Figure 2, Table 2).

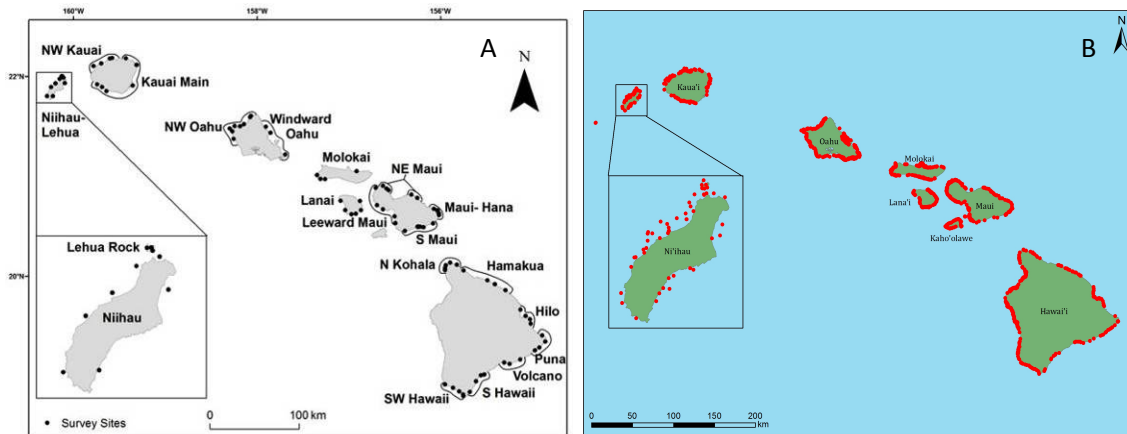


Figure 1. Comparison of spatial coverage of data points in the MHI from (A) previous analysis in Williams (2008), and (B) current study database.

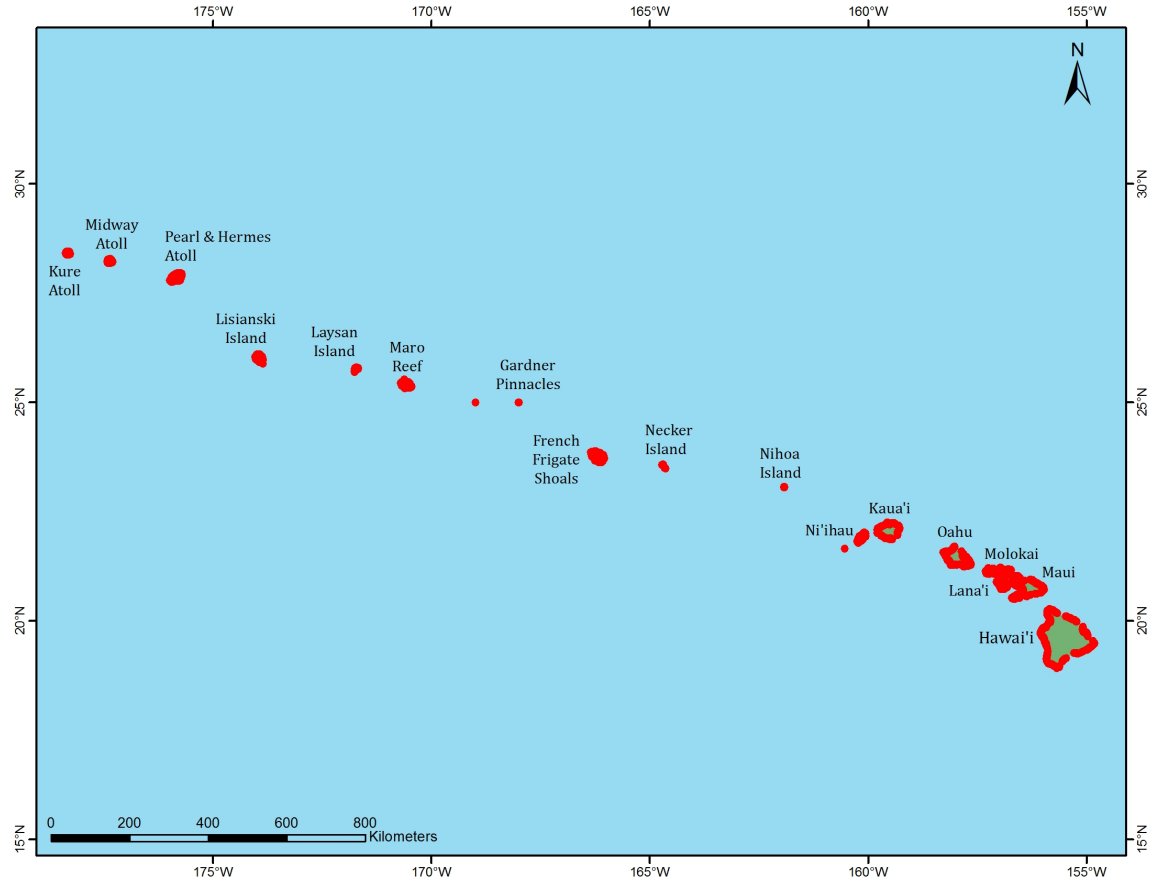


Figure 2. Individual surveys sites across the Hawaiian Archipelago.

Data collection efforts varied considerably across the islands (Figure 3, Table 2), with Hawaii Island having the largest level of effort followed by Maui and Oahu. Hawaii DAR contributed 46% of the 22,103 surveys, followed by NOAA CRED

(34%), and the Fisheries Ecology Research Lab at the University of Hawaii (FERL) (13%). Nearly 47% of the surveys were conducted around Hawaii Island, followed by 11% on Maui and Oahu. The number of surveys increased dramatically after 2003 due to increased efforts by NOAA CRED and Hawaii DAR. The efforts by NOAA CRED have been scaled back in recent years but efforts by TNC and FERL have increased (Figure 4).

Table 2. Number of surveys for each island, ordered from north to south and attributed by data source.

Island	Dataset							Total
	CRAMP	RAMP	DAR	FERL	FHUS	NPS	TNC	
Kure		678						678
Midway		565						565
Pearl & Hermes		1070						1070
Lisianski		535						535
Laysan		239						239
Maro		644						644
Gardner		60						60
French Frigate		908						908
Necker		133						133
Nihoa		32						32
Kauai	83	296		192				571
Niihau	10	256						266
Oahu	57	368	462	446	882		125	2340
Molokai	29	259		24		263		575
Maui	98	508	1405		446		51	2508
Lanai	26	266	235		73			600
Kahoolawe	8						44	52
Hawaii	69	668	8138		620	238	594	10327
Grand Total	380	7485	10240	662	2021	501	814	22103

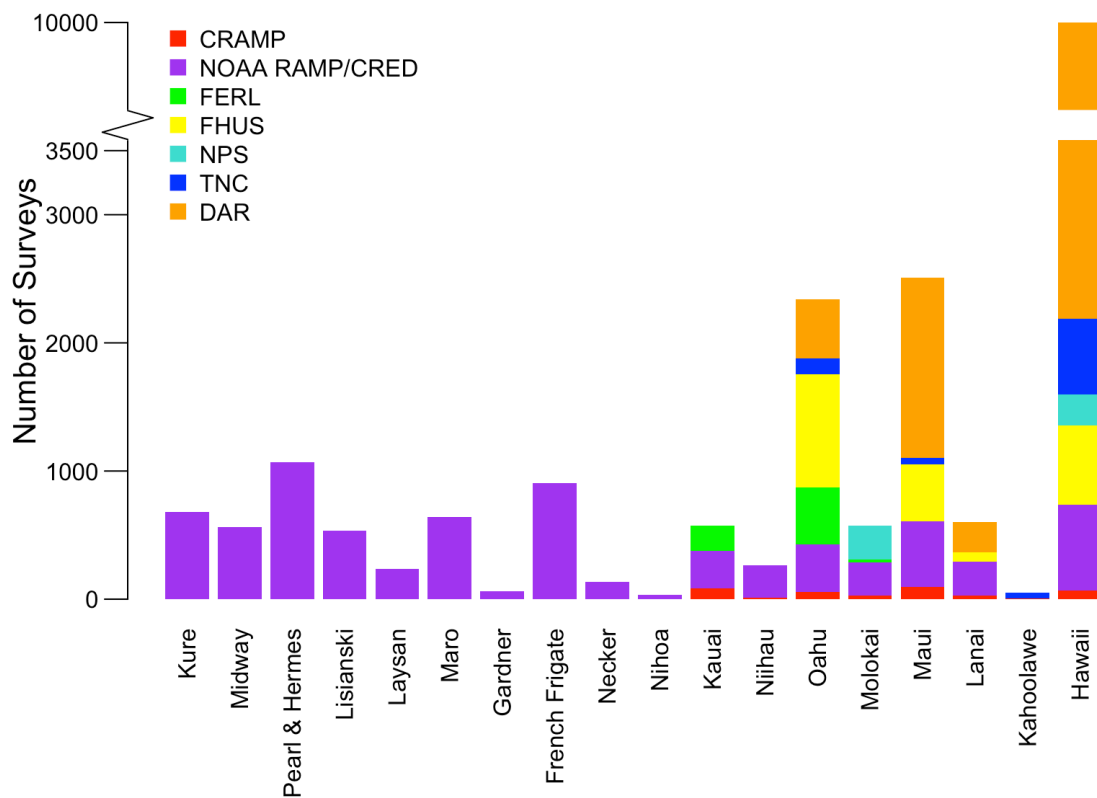


Figure 3. Number of surveys for each island, ordered from north to south and attributed by data source.

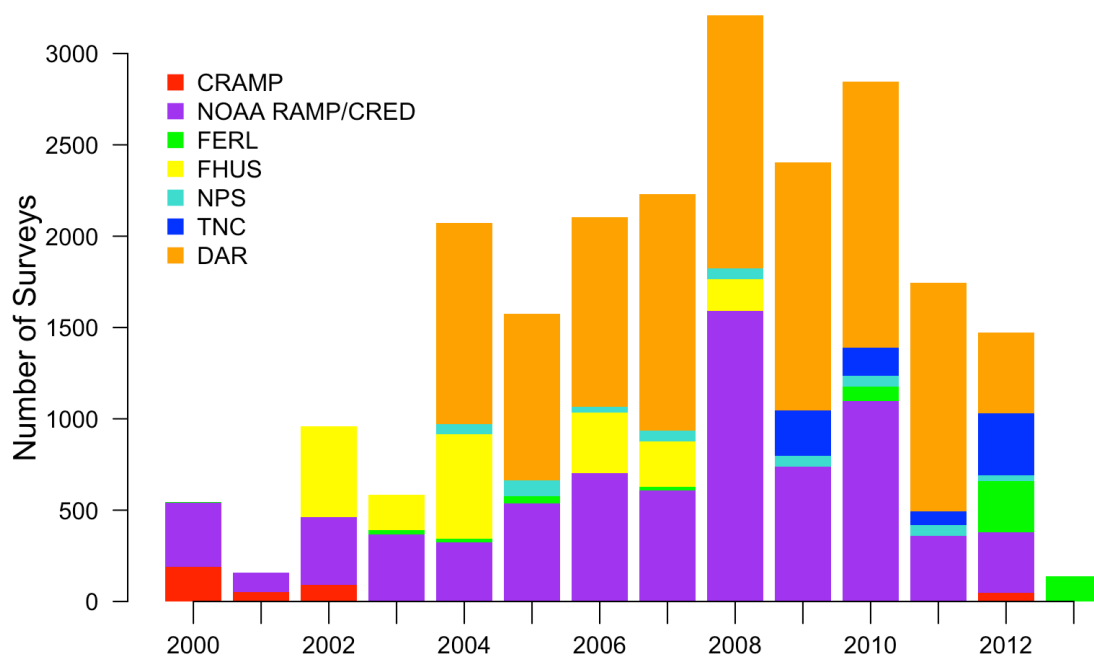


Figure 4. Number of surveys by year, attributed by data source.

Spatial and temporal comparison of length-weight relationships

Length-weight relationships of fishes are central to understanding the status and condition of fish populations and critical for estimating biomass from length observations. This relationship is also among the most common model used in fisheries science (Pauly 1993). Despite their critical importance, length-weight relationships are only known for a restricted suite of species and are confined in geographic coverage. This is particularly true and important for Hawaii, which is one of the most isolated archipelagos on earth and has a high number of endemic fishes. Hawaii is also situated at the furthest extent of the tropics and can be characterized as a sub-tropical environment; therefore length-weight relationships for wide-ranging species may be different in Hawaii than in more tropical locations.

Length-weight relationships also provide a useful comparison of fish condition since weight at a given length is greater for a fish in better condition (Tesch 1968, Froese 2006). This is related to the concept of allometry, where growth follows a power law function with the slope of the regression between weight and length equal to 3 if the weight of the fish does not change as it gets longer. If the slope is different than 3 the fish exhibits allometric growth and can either become skinner or heavier as it grows (Tesch 1968). Changes in this relationship provide insight into relative differences in 'condition' between populations, or for a given population over time.

Variability in life history also has implications for fisheries management and our understanding of population dynamics. Length-weight relationships can be compared to examine the relative condition or robustness of population, both spatially and temporally. Variation in weight of fishes can occur for a variety of reasons, including density-independent and density-dependent factors.

In this study, length-weight relationships were described for 112 fish species specific to nearshore Hawaiian waters (Appendix II). Data were compiled from multiple sources, including a historic database dating back to 1979 from the Hawaii Cooperative Fishery Research Unit at the University of Hawaii. These historic data were matched with more contemporary sampling, providing a unique opportunity to compare relationships in space and time.

The goals of the project were three-fold:

- a) Publish Hawaii-specific length-weight parameters for coral reef fishes, with particular focus on endemic species
- b) Conduct a comparison of fish length-weight relationships between two time periods: 1979-1985 and 2002-2012, which represent different ocean productivity regimes due to changes in the Pacific Inter-decadal Oscillation (PDO)
- c) Conduct a comparison of fish length-weight relationships between the Main and Northwestern Hawaiian Islands

A temporal comparison of fish length-weight relationships between the 1980s and the 2000s provides a unique opportunity to evaluate differences in a change in oceanic productivity associated with the Pacific Decadal Oscillation (PDO). Polovina *et al.* (2008) studied decadal changes in productivity boundaries in Hawaii and found two distinct decadal periods. The northern portion of the archipelago prior to 1987 was characterized by greater vertical mixing, resulting in more productive winters during this time period compared to today. This leads to the hypothesis that for a give length, fish should be heavier in the 1980s when productivity was greater. Spatial comparisons of fish length-weight relationships between the Main and Northwestern Hawaiian Islands allows for further testing of hypotheses related to biophysical gradients while controlling for time. Total abundance of fishes varies greatly between the Main and Northwestern islands and is hypothesized to be related to high fishing pressure in the populated, Main Hawaiian Islands (Friedlander & DeMartini 2002, Williams et al. 2008).

Database

Available data were compiled for all coral reef-associated fishes in Hawaiian waters from a wide range of data sources and time periods. The majority of these data come from the Hawaii Cooperative Fisheries Research Unit's inventories of fishes from poison stations in the NWHI and from Puako, West Hawaii in the 1980s. Additional data were compiled by contacting individual researchers and from large-scale collections of fishes in the NWHI from research cruises for genetic sampling. This was supplemented with additional information from published sources, theses, and grey literature.

The resulting database is comprised of 17,354 individual observations of fishes from 282 species. Of those, 196 species had >10 observations. Data were quality controlled and corrected by careful evaluation of each data point. Outliers and suspicious data points were removed from analysis on the basis of assumed misidentification, incorrect units, and other data entry errors. This resulted in another 84 species without adequate information or that did not conform to assumptions of the linear models. A final list of 109 species with adequate information and data were used to conduct length-weight analysis (Appendix II).

Length measurements were provided as standard length (SL), fork length (FL) or total length (TL). All measurements were converted to TL using relationships between SL/FL and TL established from the database and from known sources via FISHBASE (Froese and Pauly 2013).

Model

The allometric equation for weight at length was provided by Keys (1928) and further refined by Le Cren (1951) in the form:

$$W = aL^b$$

where W is weight in grams, L is length in cm, and a and b are fitting parameters. The equation is commonly calculated in logarithmic form as:

$$\log W = \log a + b \log L$$

Models were fit to the log-form with standard least-squares regression for each species individually and for the groups of species combined. Fitted parameters were back-transformed with a bias-correction factor that included an adjustment for the transformation bias. This is necessary since back-transformation from a log-scale underestimates the mean value on the original scale since the log-scale mean is equal to the geometric mean. The bias-correction factor took the form:

$$e^{\sigma^2/2}$$

Temporal Comparison

Fish condition can be explained by the fitting parameter b from the allometric equation defined above which describes the slope of the curve. Fishes with a slope greater than 3 exhibit positive allometric growth, meaning an individual weighs more for a given length. Overall, the relationship between length and weight for 21 species of fishes did not change significantly over time, however comparisons suggest that many species were heavier for a given length in the 1980s compared to more recently. Fishes collected between 1979 and 1985 had slopes ranging from 2.8-3.5, whereas collections for the same species from 2002-2012 had slopes ranging from 2.3-3.3 with the tail of the distribution skewed towards smaller numbers in the more recent data (Figure 5). The mean slopes were not significantly different between time periods ($t=1.5$, $df=37.8$, $p=0.14$). Overall, species exhibited more positive allometric growth in the earlier time period with the mean value greater than 3 ($t=1.9$, $df=20$, $p=0.07$).

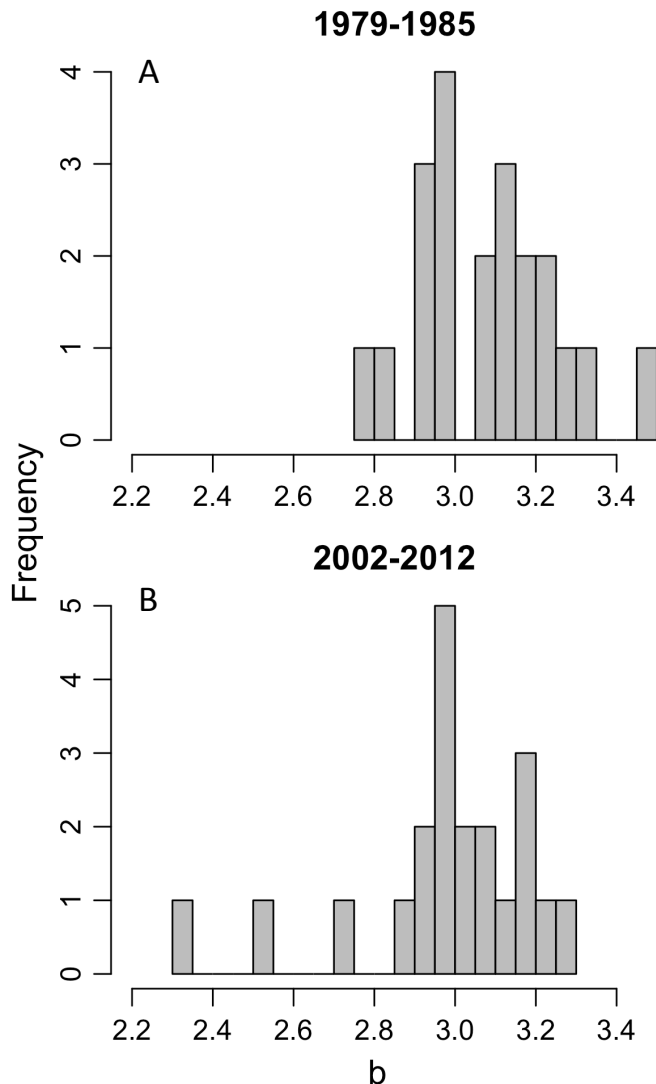


Figure 5. Distribution of values for slope of length-weight regression for 21 species in two time periods

Comparing the slope of the length-weight regression for individual species provides information about the direction of change in individual species condition across changes in the inter-decadal oscillation. There were a greater number of species with slopes less than 3 in 2002-2012 ($n=9$) than in the earlier, more productive time period (Figure 6). Those species with a greater slope in the more recent time period (2002-2012) were different from our prediction that the greater productivity during the last decadal oscillation would result in better conditions for fish growth.

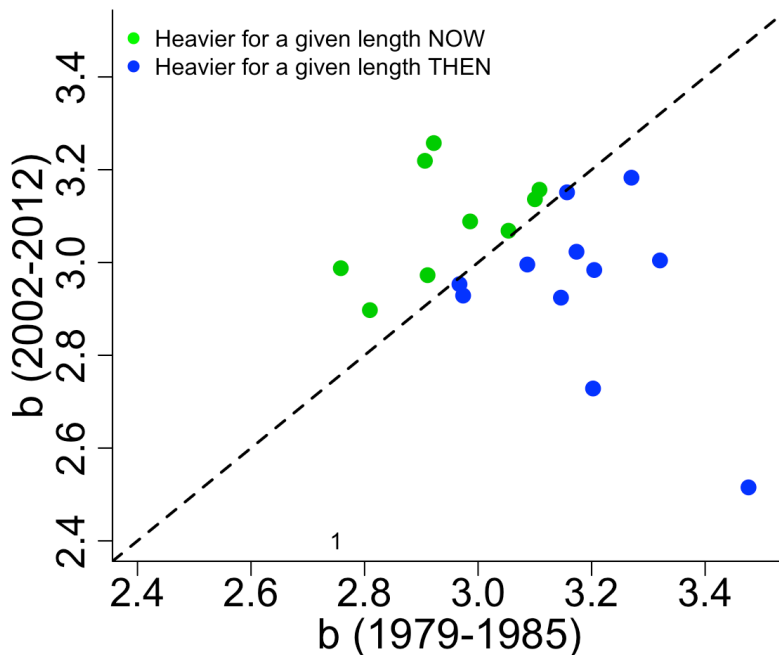


Figure 6. Comparison between slopes for each species in 1979-1985 and 2002-2012. Points above the line represent species with a greater slope in the more recent time period (green) and points below the line represent species with a greater slope in the earlier time period (blue).

Spatial Comparison

Comparisons of length-weight relationships between the Main Hawaiian Islands and the Northwestern Hawaiian Islands were restricted to the most recent time frame to avoid confounding results of space and time. In general, the NWHI experiences a different oceanographic regime than the MHI with colder winters and warmer summers with greater productivity. This leads to the hypothesis that fishes in the NWHI will be larger for a given length compared with the MHI.

Length-weight relationships were compared for 23 species between the NWHI and MHI. The slope of the length-weight relationship was significantly higher in the NWHI compared to the MHI ($t=-2.23$, $df=33.14$, $p=0.03$; Figure 7). Slopes in the MHI did not differ significantly from 3 ($t=0.16$, $df=22$, $p=0.87$; Figure 7a). Conversely, slopes in the NWHI were, on average, significantly greater than 3,

and therefore fishes tended to be heavier as length increased ($t=-2.60$, $df= 22$, $p=0.02$; Figure 7b)

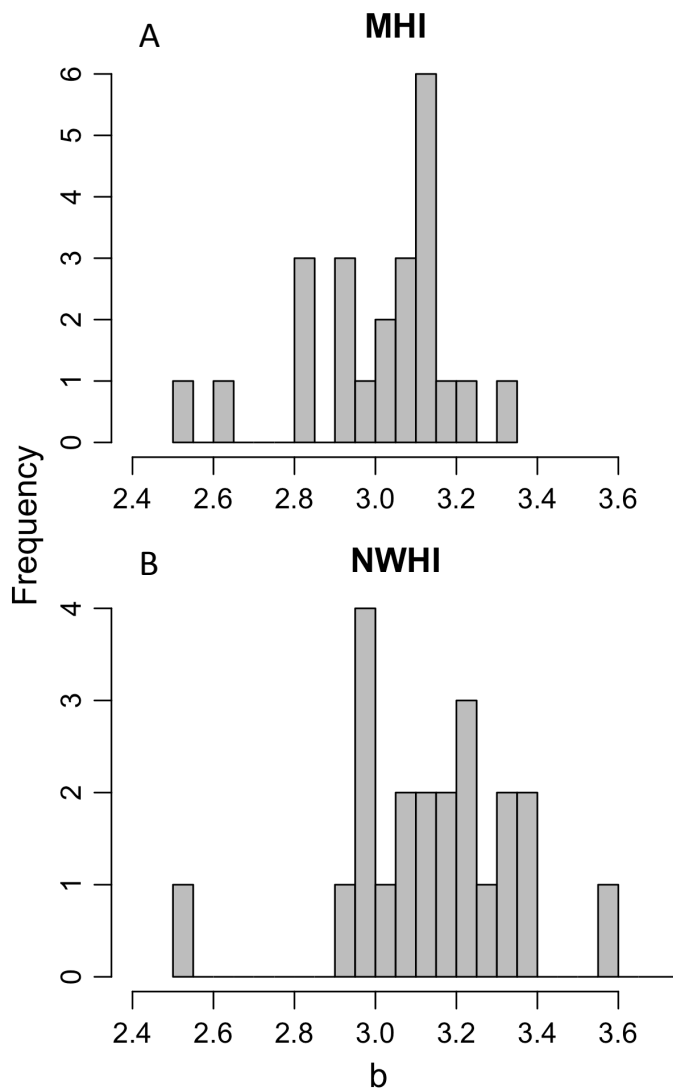


Figure 7. Distribution of values for slope of length-weight regression for 23 species in the MHI and NWHI

Within individual species, the slope of the length-weight regression provides information about the direction of change in individual species' condition between the MHI and NWHI. Sixteen species had a greater slope in the NWHI then the MHI compared to only 7 with the opposite pattern (Figure 8). Interestingly, 5 out of 7 endemic species had a greater slope in the NWHI then the MHI. Endemic species tend to be in greater abundance in the NWHI suggesting that this variation in life history is not due to density-dependent processes since this pattern is contrary to expectation.

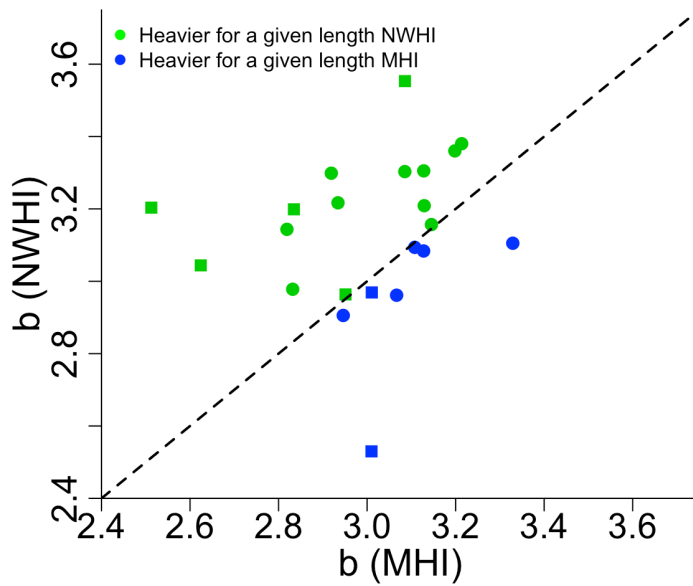


Figure 8. Comparison between slopes for each species in MHI and NWHI. Points above the line represent species with a greater slope in the NWHI (green) and points below the line represent species with a greater slope in MHI (blue). Squares represent endemic species.

Differences in the relationship between weight and length were assessed across time and space for a subset of species with paired comparisons. This is a unique opportunity where a large amount of data on life history attributes of Hawaiian fishes was assembled into a single database allowing for testing hypotheses about changes in condition of Hawaiian reef fishes. Overall the relationship across all species did not change over time, however on average, fishes in the Northwestern Hawaiian Islands (NWHI) were heavier for a given length than in the main Hawaiian Islands (MHI).



Reef fish, Hawai'i Island. Photo: K. Stamoulis

Bio-regionalization of Hawaiian fish fauna

Fish assemblages were well separated in ordination space based on the nMDS analyses (Figure 9). Analysis by biomass showed greater separation ($R = 0.57$, $p < 0.01$) than by abundance ($R = 0.47$, $p < 0.01$). There was high concordance within the MHI by biomass with Niʻihau and Molokai showing separation from the MHI cluster. Within the NWHI, there was also high concordance with Nihoa, Maro, and Laysan being outliers. Numerical abundance showed less concordance both within and between regions.

Figure 9. Comparison of fish assemblage structure between the MHI and NWHI. Results of nonmetric multi-dimensional scaling plot of islands by region for (A) biomass (g/m²) and (B) abundance (#/m²). Minimum convex polygons are drawn around each region for visual purposes. Analysis of similarity (ANOSIM) between MHI and NWHI (A) R=0.57, $p<0.01$, (B) R=0.47, $p<0.01$.

The distribution of species abundance by range size shows a striking pattern with endemics dominating in the NWHI, particularly around the three most northern islands (Figure 10-11). This distribution flattens out as you move down the chain and is significantly correlated with latitude (Figure 12; $R^2=0.81$, $p<0.01$).

Disproportionate recruitment of endemics at higher-latitude reefs may be related to better growth and survivorship after settlement onto reefs, higher levels of within-reef and regional reseedling at higher latitudes, or other factors (DeMartini and Friedlander 2004).

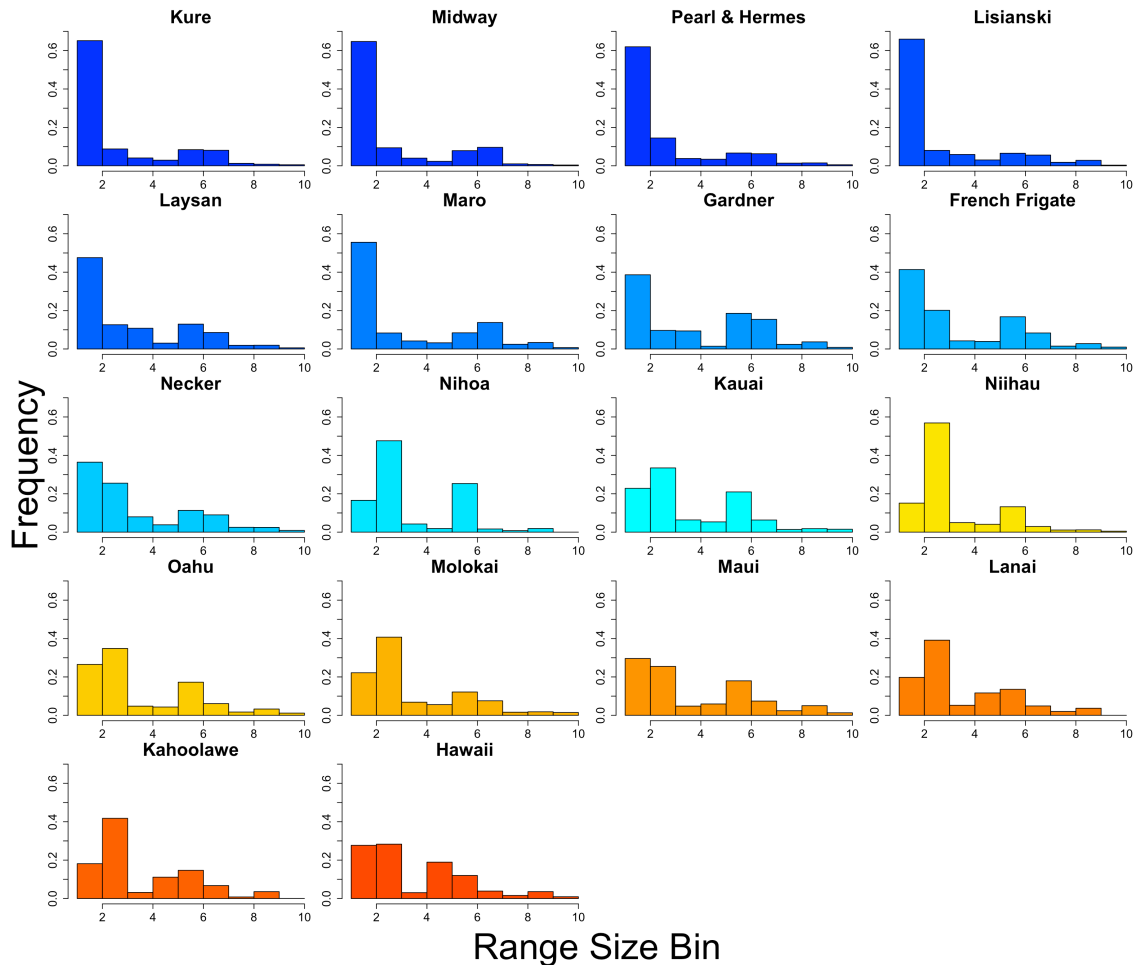


Figure 10. Distribution of numerical abundance of fishes across range sizes throughout the Hawaiian Archipelago. Species range size is binned into 10 even bins ranging from 14.5×10^4 to $24.5 \times 10^6 \text{ km}^2$.

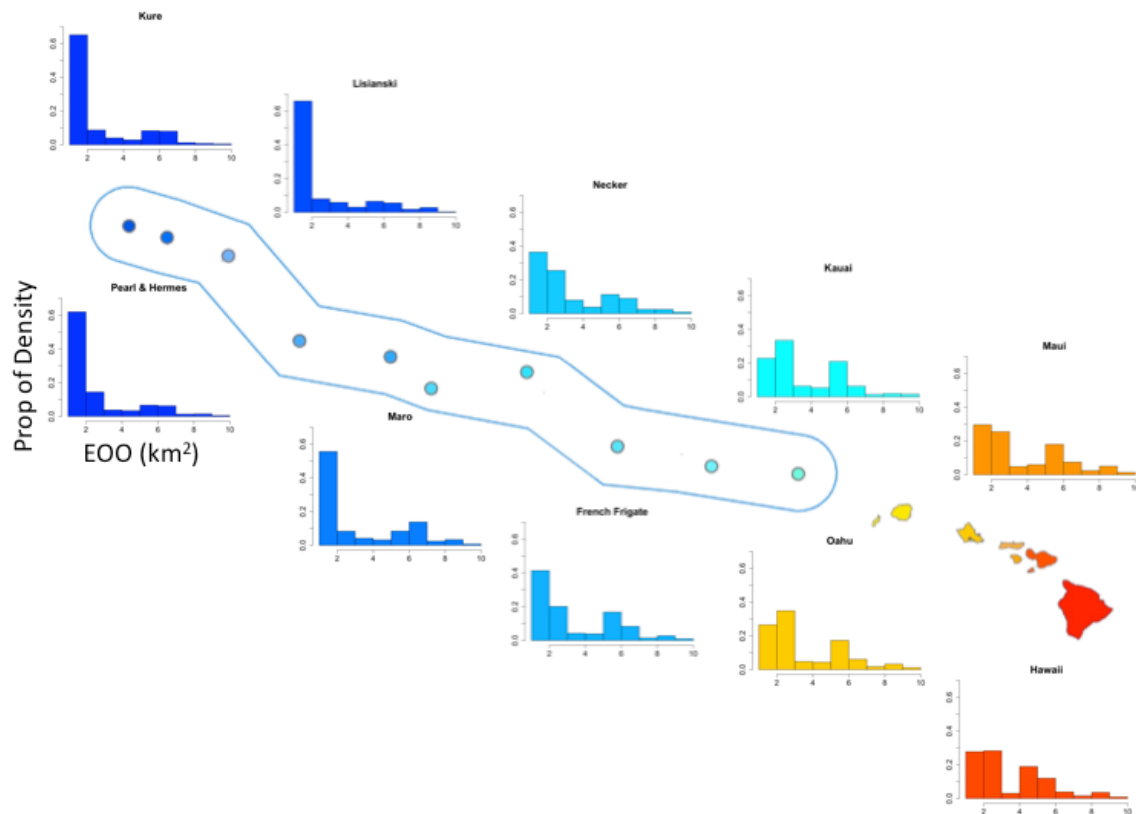


Figure 11. Spatial presentation of the distribution of numerical abundance of fishes across range sizes and the Hawaiian Archipelago.

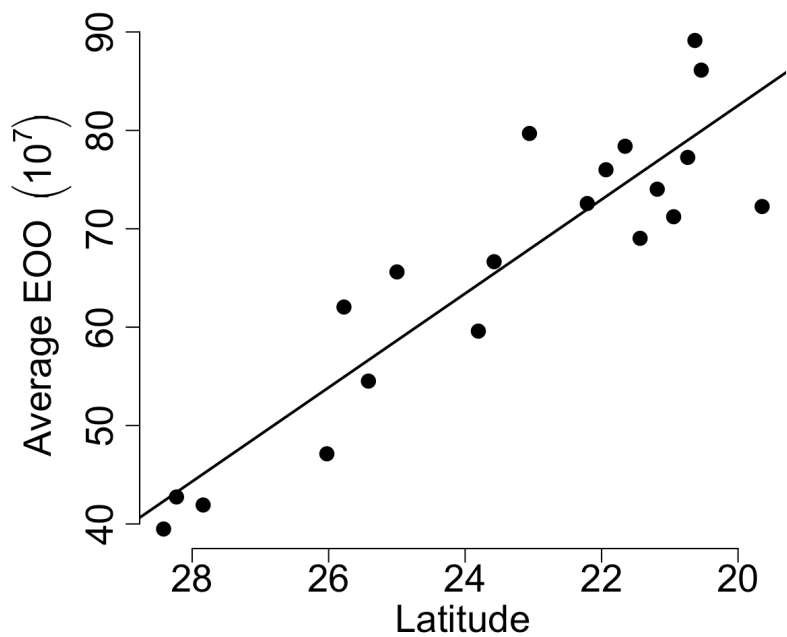


Figure 12. Mean range size of fishes measured as extent of occurrence (EOO) as a function of island latitude ($R^2=0.81$, $p<0.01$).

There is an interesting relationship between endemics and widely ranging Indo-Pacific species (Figure 13). Endemics dominate numerically in the higher latitudes and the switch to dominance by Indo-Pacific species occurs around 25° latitude. This represents an important zoogeographic faunal break in reef fishes within the archipelago.

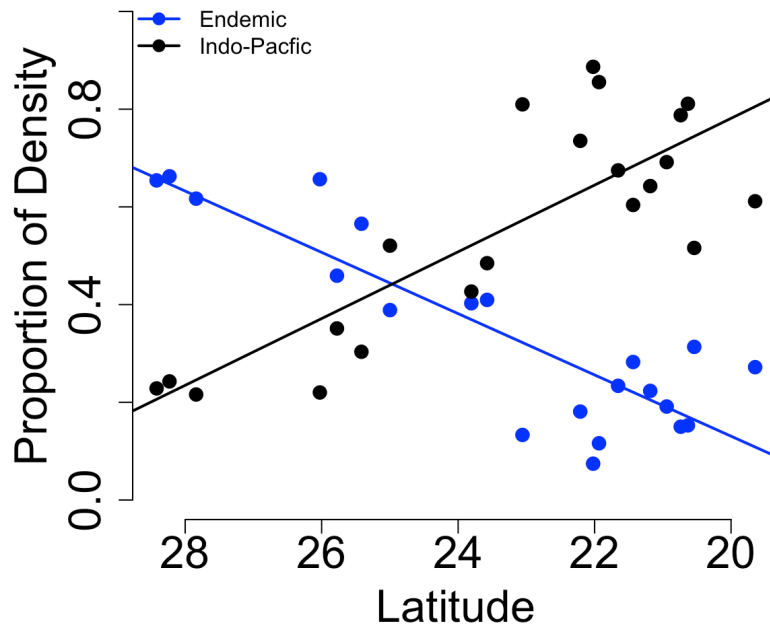


Figure 13. Proportional density of endemics compared to density of fish with Indo-Pacific distributions across latitude.

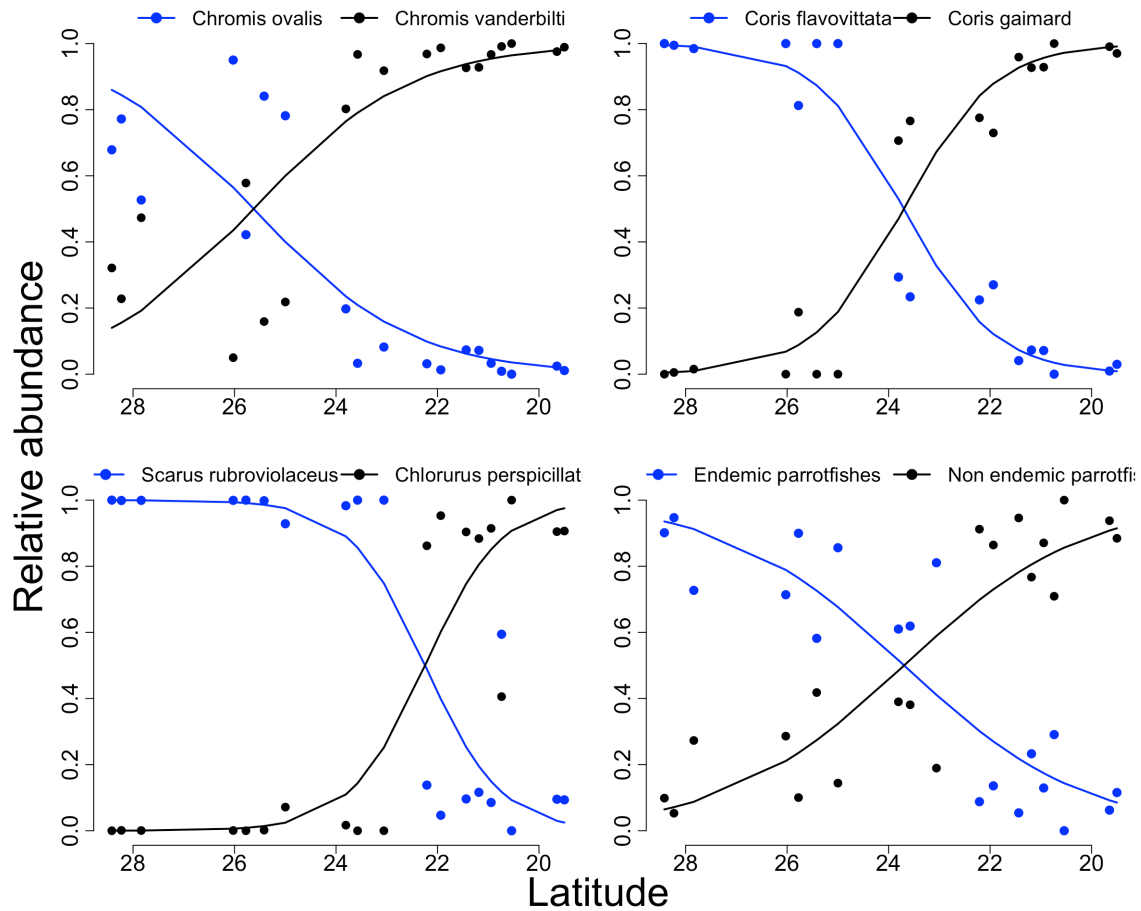


Figure 14. Relative density of endemic species (blue) compared to their wide-ranging relatives (black) across a latitudinal gradient. The Y axis is the relative numerical density for A-C and relative biomass density for D. Lines are fits of a logistic regression for endemic species (blue) and non-endemics (black).

Examination of endemics and their sister species show similar trends and faunal discontinuities (Figure 14). This is true for the genera *Chromis* (a damselfish) and *Coris* (a wrasse); however, parrotfishes show a faunal break further down the chain, with the break occurring between the MHI and NWHI.

Based on the abundance of endemic and non-endemic species, we see several faunal breaks that have important implications for management and our increased understanding of the demography and zoogeography of reef fishes (Figure 15).

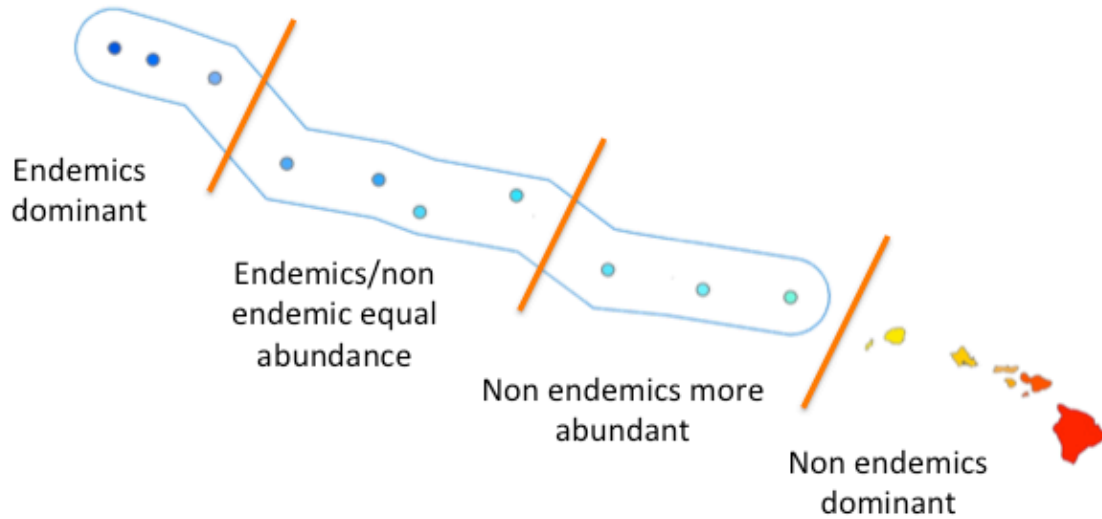


Figure 15. Faunal breaks across the Hawaiian Archipelago based on abundance of endemic and non-endemic fishes.

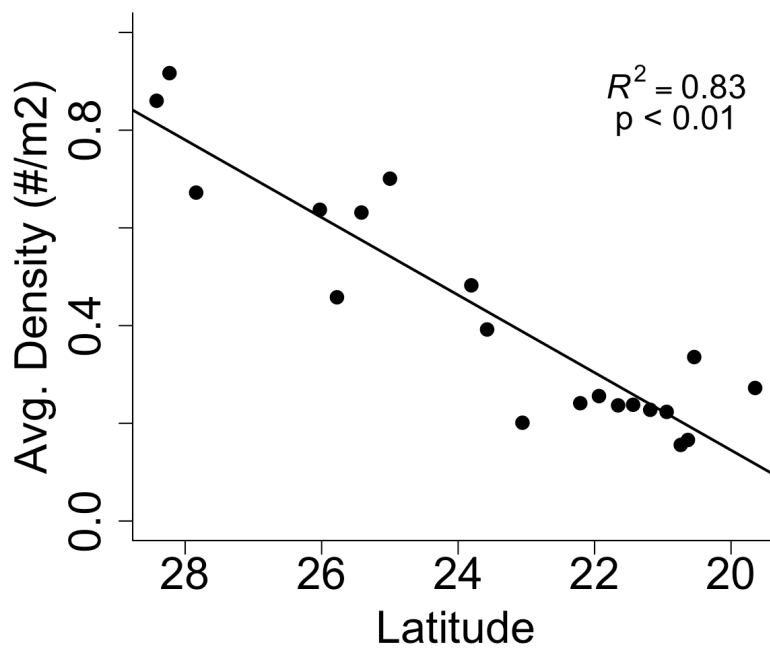


Figure 16. Average density of endemic fish species as a function of latitude ($R^2=0.83$, $p<0.01$)

Endemic species were much more common numerically at the northern end of the chain (Figure 16), accounting for 52-55% of numerical density compared to only 17% on Hawaii Island to the extreme south.

Fish assemblage structure across a gradient of human impacts

Overfishing is thought to be one of the major reasons for coral reef decline around the state and elsewhere. One of the major obstacles to wise management of coral reef fisheries resources is the lack of good information on fish population abundance at spatial scales commensurate with the uses of these resources. Here we describe attributes of fish assemblages across the state and therefore elucidate the spatial patterns of abundance that will help inform proper management and Marine Spatial Planning.

We extend our understanding of the status and structure of fish assemblages across a human impact gradient by comparing metrics based on traditional Hawaiian management boundaries (mokus). This includes comparisons of the relative influences of human population density and physical and anthropogenic factors on distribution, abundance, and size of reef fishes around the state. We also evaluated existing MPAs based on their size and time since establishment.

Assessment of stock structure

Scientific management guidance is lacking for most reef fishes in Hawaii due to the exacting data requirements and many assumptions of conventional stock assessment models. The lack of conventional advice often leads to management paralysis even amidst strong claims about fisheries collapses based on analysis of limited or selective data. We produced unconventional preliminary assessments for 52 species within the main Hawaiian Islands (MHI) by comparing their abundances to the Northwestern Hawaiian Islands (NWHI) Marine National Monument—a large, virtually unfished reference area.

We examined species that were present in the commercial catch database, with an average annual catch of >1000lbs, hereafter referred to as resource species. All but 52 species were removed from full consideration due to a skewed biogeographic distribution—identified using a Spearman rank correlation analysis of biomass densities on latitude throughout the archipelago—inappropriateness of the sampling method (e.g., for schooling coastal pelagic species, extreme habitat specialization or depth range), or inadequate sample sizes (we required observations in at least 20 sites in the NWHI to allow testing for skewed distribution).

Over one-quarter (27%) of the species examined in the main Hawaiian Islands appeared to be depleted below 10% of unfished abundance, while 42% were below 25% of unfished abundance (Figure 17). Large mobile predators were especially affected, but many other resource species appeared to have poor stock condition as well.

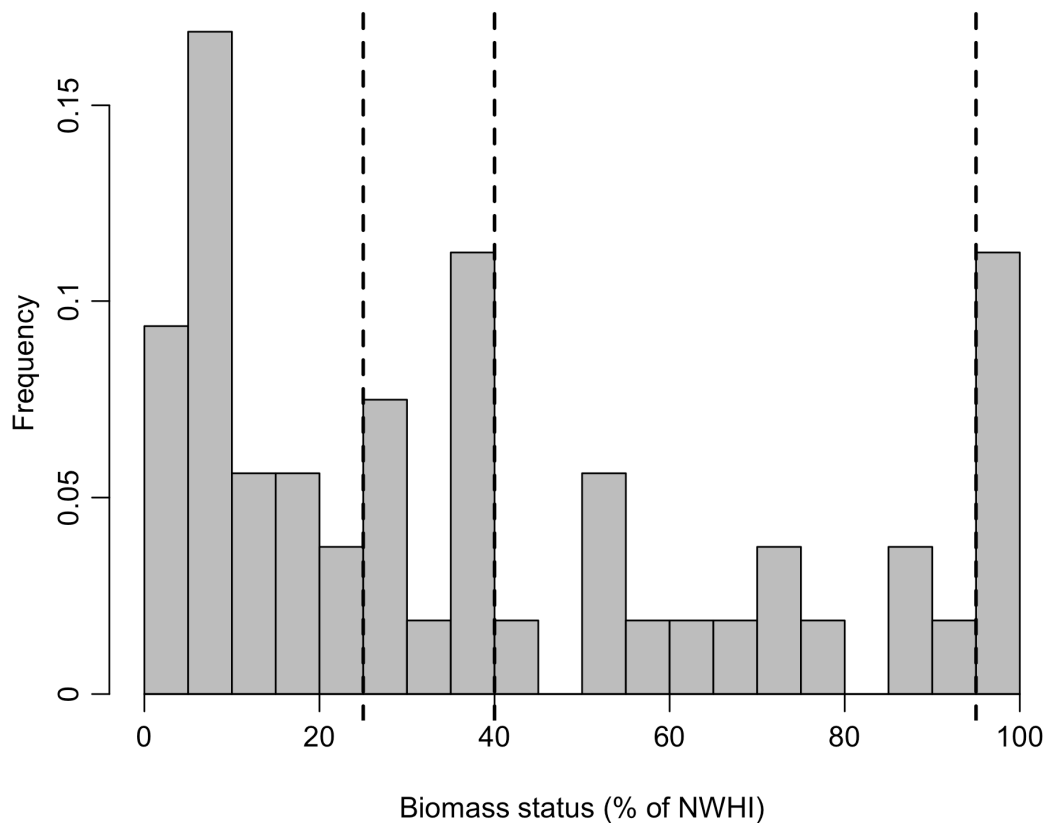


Figure 17. Distribution of stock status estimates for 52 targeted species without a latitudinal bias; biomass status is biomass in the MHI as a percent of the NWHI. Dotted lines represent three status levels, <25% of NWHI are depleted or in critical condition, <40% of NWHI are below desired levels, and >90% of NWHI are hyperabundant.

Major drivers of resource fish biomass

Exploratory analyses of drivers of resource fish biomass were conducted using Boosted Regression Trees (BRT). BRTs are grounded in traditional regression analysis but take advantage of adaptively combining large numbers of regressions in a tree framework that can provide high predictive performance to identify primary variables and their interactions (Elith et al 2008). BRTs were constructed using the routines *gbm* and *gbm.step* in the package *dismo* in the R statistical program version 3.0.0 (R Development Core Team).

A series of habitat and human demographic variables were attributed to individual surveys to input into BRT to evaluate the relative influence of possible drivers of fish assemblage patterns in Hawaii. Multiple habitat metrics were calculated using ArcGIS 10 (ESRI). A 30 m buffer was created for each survey point to quantify habitat metrics. Habitat metrics representing benthic structure were derived from bathymetric surfaces. For the Main Hawaiian Islands, SHOALS LiDAR data (Irish and Lillycrop 1999) was available for the majority of

the survey area and was interpolated at a 5 m resolution. In the Northwestern Hawaiian Islands there was very little LiDAR coverage and multi-beam bathymetry was patchy with sparse coverage in shallow areas. In this case, bathymetry surfaces derived from satellite imagery provided the most complete coverage and were therefore used for calculating habitat metrics. Since this product had a resolution of 4m, it was re-sampled to 5 m to match the MHI data. For each metric, cell values within each site buffer were averaged to create a single measure for each site. Structural metrics included average depth, aspect (slope direction), slope (in degrees), and curvature (slope of slope). These structural metrics have been shown by previous research to influence fish assemblage characteristics in Hawaii and elsewhere (Wedding and Friedlander 2008, Pittman et al. 2011, Stamoulis and Friedlander 2013). Distance to shore (Schmiing et al. 2013) was also calculated for each site.

Benthic cover is another important habitat variable that influences fish assemblages. NOAA's Biogeography Branch has created habitat maps for both the MHI (2007) and NWHI (2003). However, these maps were produced using different methods and have different spatial resolutions. The NWHI maps were produced using an unsupervised (automated) classification method and have a much larger spatial resolution ($\text{MMU} = 100 \text{ m}^2$) compared to the MHI maps ($\text{MMU} = 1 \text{ acre}/4047 \text{ m}^2$) that were hand digitized using a supervised method. For this reason, the NWHI maps were down-sampled to match the MHI maps, which involved a process of eliminating or aggregating habitat patches smaller than 1 acre. Habitat classes also differed between the maps, so a general classification scheme was developed to make them comparable. Finally, each survey point was attributed with a habitat cover type.

For the purpose of providing relevant spatial comparisons, the traditional Hawaiian district or moku was chosen as a unit of spatial stratification. Mokus roughly correspond to biophysical attributes of island ecosystems such as leeward/windward and wet/dry districts of islands (Malo 1951). At the local (ahupua'a) and district (moku) levels, fishing activities were strictly regulated by a system of rules that were embedded in socio-political structures and religious systems (the kapu system) (Friedlander et al. 2013). While the basic unit of land management was the ahupua'a, the basic unit of marine resource management and harvesting was the moku or district (Davianna McGregor pers. comm.).

While the Hawai'i statewide GIS program (<http://planning.hawaii.gov/gis/>) provides a GIS shapefile of ahupua'a and moku boundaries, there is no definitive source for this information. The difficulty arises from several factors: 1) Early Hawaiians left no maps, 2) in Hawaiian history, several volcanic eruptions have modified or destroyed ahupua'a and/or moku boundaries, 3) boundaries were well established at the shoreline but more ambiguous upslope and offshore, 4) the conquest and unification of the islands destroyed sovereign boundaries, and 5) current boundaries set by various indigenous and historic authorities are in conflict (Juan Wilson pers. comm.). For these reasons, we found the most

Mokus of the Hawaiian Islands

Figure 18. Map of mokus across the main Hawaiian Islands.

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Table 3. Attributes of mokus organized by island

Moku Name	Island	Moku area km²	Shoreline length km	Exposure	Human population	Boating facilities
KONA HAW	Hawaii	2,243	115	W	47,106	4
KAU	Hawaii	2,335	103	S	8,389	2
PUNA HAW	Hawaii	1,356	82	E	45,173	1
HILO	Hawaii	1,807	66	E	51,920	4
HAMAKUA	Hawaii	771	50	N	9,485	0
KOHALA	Hawaii	1,962	72	W	20,462	3
KONA KAH	Kahoolawe	53	27	S	0	0
KOOLAU KAH	Kahoolawe	63	26	N	0	0
MANA	Kauai	112	17	W	133	0
KONA KAU	Kauai	524	44	S	22,392	5
PUNA KAU	Kauai	360	37	E	32,494	6
KOOLAU KAU	Kauai	109	22	N	5,985	0
HALELEA	Kauai	232	21	N	4,152	2
NAPALI	Kauai	101	24	N	30	0
KONA LAN	Lanai	190	40	W	2,817	2
KOOLAU LAN	Lanai	176	38	E	3	0
LAHAINA	Maui	84	15	W	12,664	4
KEALALOLOA	Maui	111	19	S	1,234	1
KULA	Maui	282	10	W	30,344	0
HONUAULA	Maui	149	28	S	4,214	1
KAHIKINUI	Maui	108	13	S	10	0
KAUPO	Maui	145	15	S	108	0
KIPAHULU	Maui	63	10	S	160	0
HANA	Maui	97	21	E	1,507	1
KOOLAU MAU	Maui	246	21	N	450	1
HAMAKUALOA	Maui	164	20	N	11,434	1
HAMAKUAPOKO	Maui	180	13	N	19,378	0
WAILUKU	Maui	152	27	E	52,003	1
KAANAPALI	Maui	111	19	W	8,805	1
KALUAKOI	Molokai	158	39	S	695	1
PALAAU	Molokai	118	9	S	1,209	0
KONA MOL	Molokai	186	42	S	4,084	1
KALAWA	Molokai	113	27	N	48	0
KOOLAU MOL	Molokai	104	39	N	1,099	1
KONA NIH	Niihau	105	38	W	92	0
PUNA NIH	Niihau	68	23	S	65	0
KOOLAU NIH	Niihau	12	13	E	11	0
WAIANAE	Oahu	159	29	W	47,578	2
EWA	Oahu	461	86	S	339,568	5
KONA OAH	Oahu	173	30	S	339,212	7
KOOLAUPOKO	Oahu	207	71	E	142,866	9
KOOLAULOA	Oahu	211	42	E	20,829	1
WAIALUA	Oahu	339	27	N	47,416	1

Most human related metrics were calculated at the moku scale (Table 3). Average population for each moku was calculated using the 2010 census data. Because census blocks did not correspond with moku boundaries, a 1 ha resolution grid was developed where each cell contained the average population density (pop/ha) for that census block. The cells corresponding to each moku were then sampled and summed to calculate the total population for each moku. Total population of each moku was divided by the shoreline length of that moku to provide an index of fishing pressure (Williams et al. 2008). Thus mokus with large populations and small shorelines were weighted more heavily. The number of boating facilities per moku was also used as an indication of fishing pressure (Williams et al. 2008).

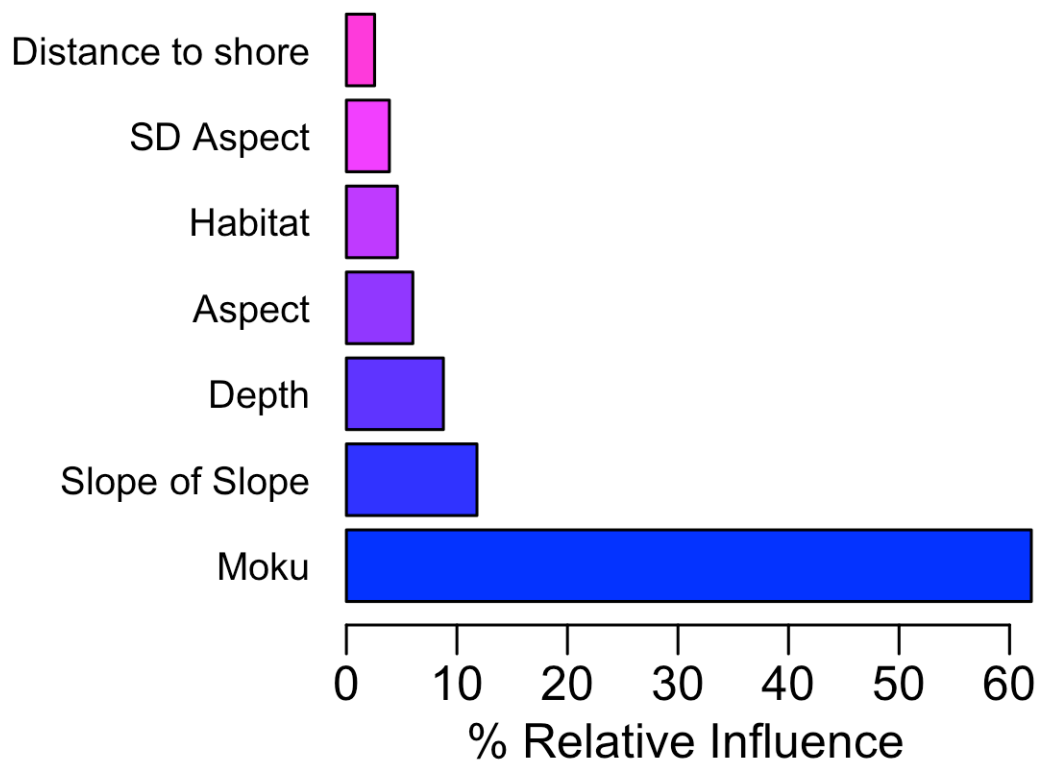


Figure 19. Result of boosted regression tree analysis displaying top 7 variables that explained the most variance in resource fish biomass in the Main Hawaiian Islands.

A final model from the boosted regression tree analysis resulted in an output of the relative importance or influence of each variable included (Figure 19) with a higher relative influence indicating a stronger effect on resource fish biomass. Overall, the model explained 35% of the total variation in the data with over 60% of the relative variation explained by moku, followed by 12% explained by slope of slope, which has been shown previously to be an important habitat predictor of fish biomass (Wedding and Friedlander 2008, Pittman et al. 2011, Stamoulis and Friedlander 2013).

Total fish biomass was lowest in the mokus around populated areas of Oahu and Maui, with intermediate biomass in more remote locations around the MHI (Figure 20). Obvious differences in apex predator biomass are observed between the MHI and NWHI, with only the most remote locations in the MHI sustaining modest apex predator biomass. Additionally, many of the locations with low overall biomass also had low biomass of herbivores with implications for reef resilience. In fact, many of the locations with low herbivore biomass are also areas where macroalgae is problematic and threatens reef health.

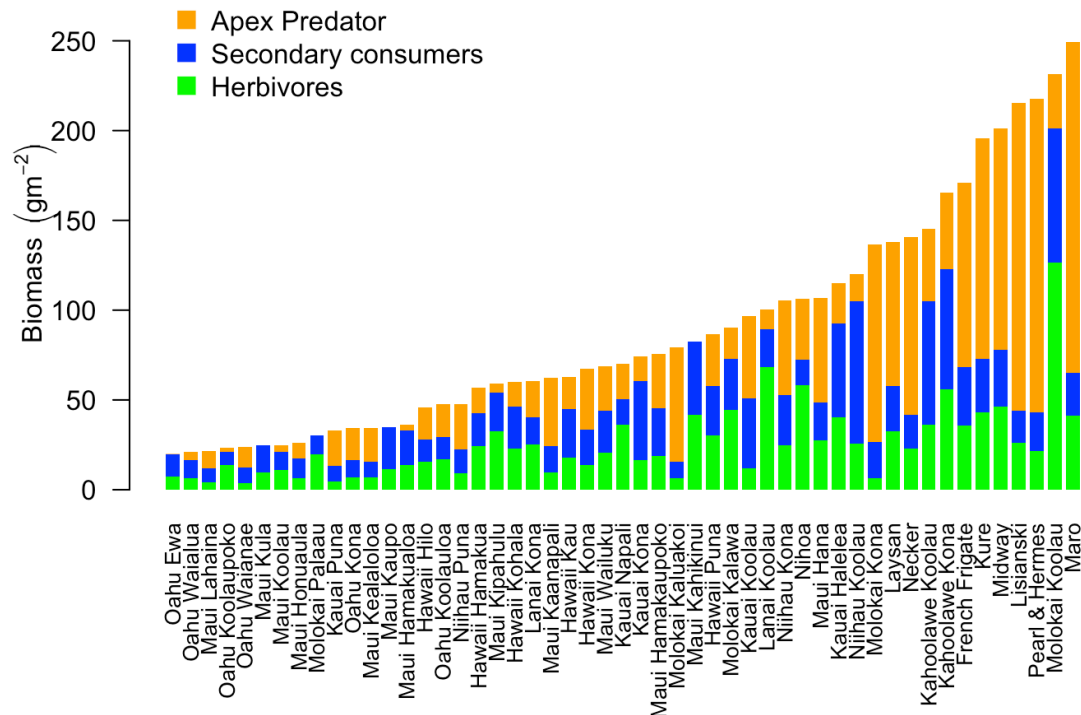


Figure 20. Total fish biomass broken into three trophic categories for each moku in the MHI and island in the NWHI, ordered by total fish biomass.

Biomass of resource species was negatively correlated with human population density among mokus ($r_s = -0.57$, $p < 0.01$; Figure 21A-B). We used human population per moku divided by shoreline length for that moku as an index of human population pressure. There was a strong negative binomial relationship between target fish biomass and human population density showing that biomass was quite high in areas with little human population pressure (Figure 21B). Mokus around the populated areas of Oahu and Maui had the lowest biomass of resource fish overall and these locations also had few apex predators. There was a strong negative correlation between target fish biomass and the number of boating facilities per moku ($r_s = -0.46$, $p < 0.01$; Figure 21C-D). Target fish biomass was highest in mokus with northern and easterly exposures. Mokus with southern and westerly exposures have less severe sea conditions and these patterns

likely result from greater accessibility and therefore heavier fishing pressure in these locations (Figure 21E-F).

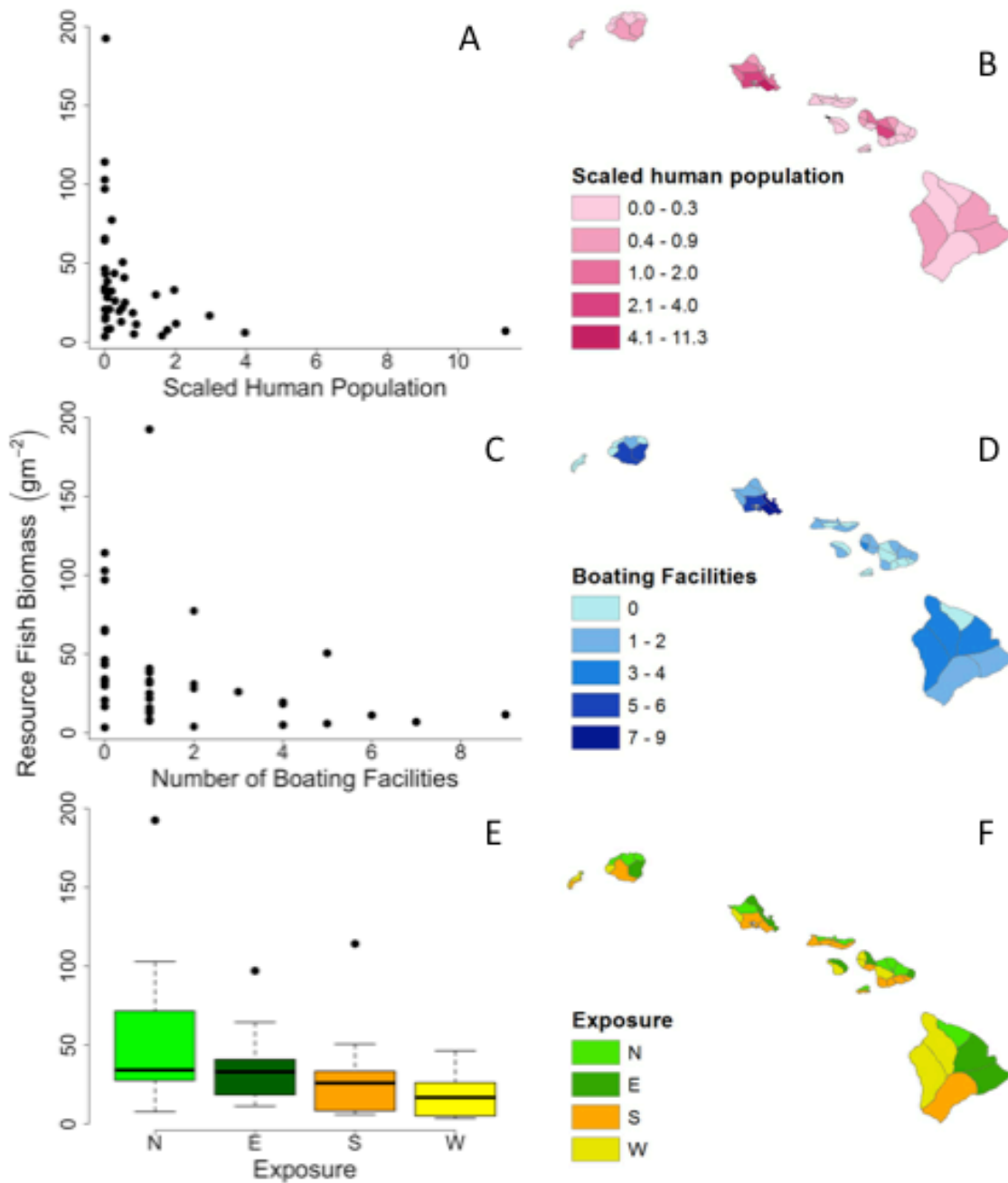


Figure 21. Relationship and spatial representation of resource fish biomass as a function of attributes by moku for (A-B) scaled human population (total human population/length of shoreline), (C-D) number of boating facilities, (E-F) exposure to physical conditions (North, East, South, West).

Comparison of Marine Managed Areas in Main Hawaiian Islands

Hawaii has a variety of marine managed areas (MMAs) throughout the state that vary greatly in size and shape, and offer various levels of protection from fishing. With the robust dataset compiled here, we evaluated the relative status of MMAs by comparing the level of resource fish biomass among these them.

Marine managed areas in Hawai'i exhibit a large variety of regulations, mostly related to gear type. For this reason, regulations were standardized to general categories. These included full protection (no fishing or collecting), partial protection (certain gear restricted), restricted access (military areas, Volcano National Park, etc.), and open (no restrictions). Each site was attributed with management "status" according to its location.

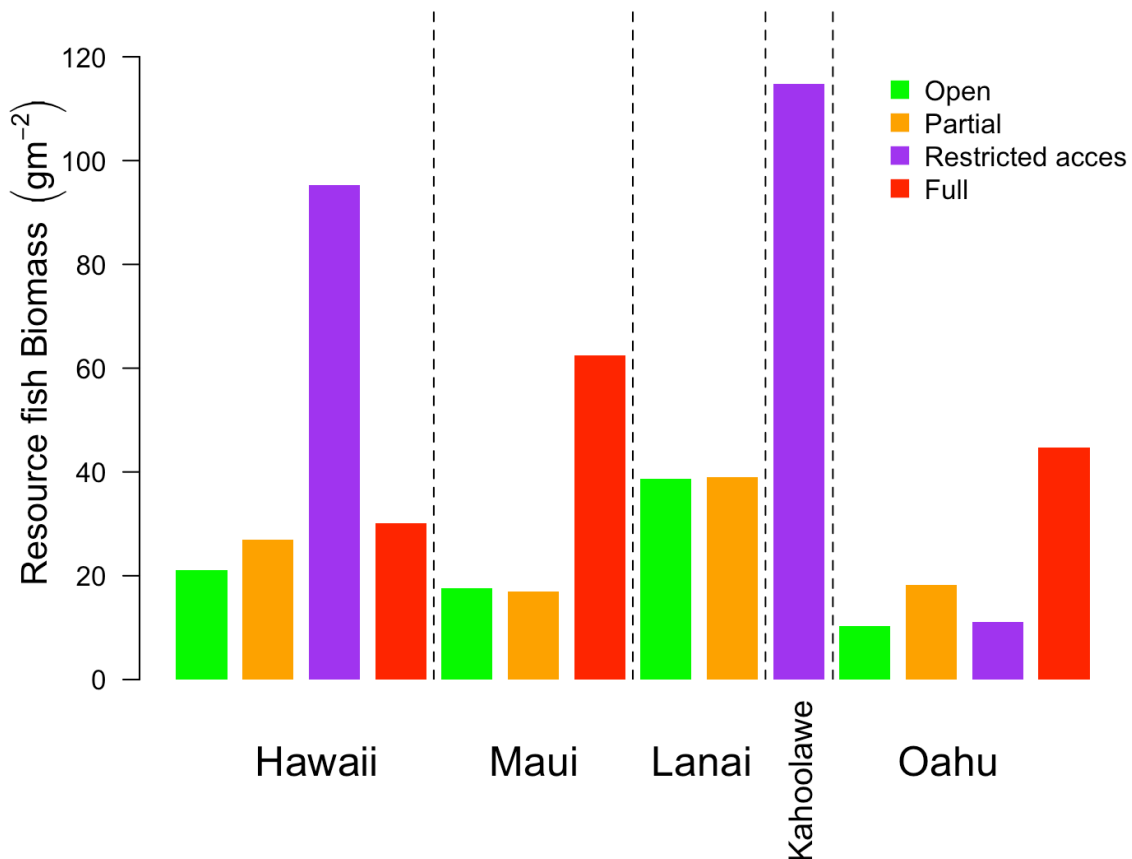


Figure 22. Resource fish biomass by island for 3 levels of spatial protection compared to open areas.

Fully protected MMAs were much more effective than partially protected ones (Figure 22). This was particularly true on Oahu, and to a lesser extent Maui, where fishing pressure is very high outside no-take areas. On Hawaii Island, restricted areas (e.g., Volcano National Park) have biomass equal to or greater

than fully protected areas. However, partially protected areas also afford much lower protection on Hawaii Island.

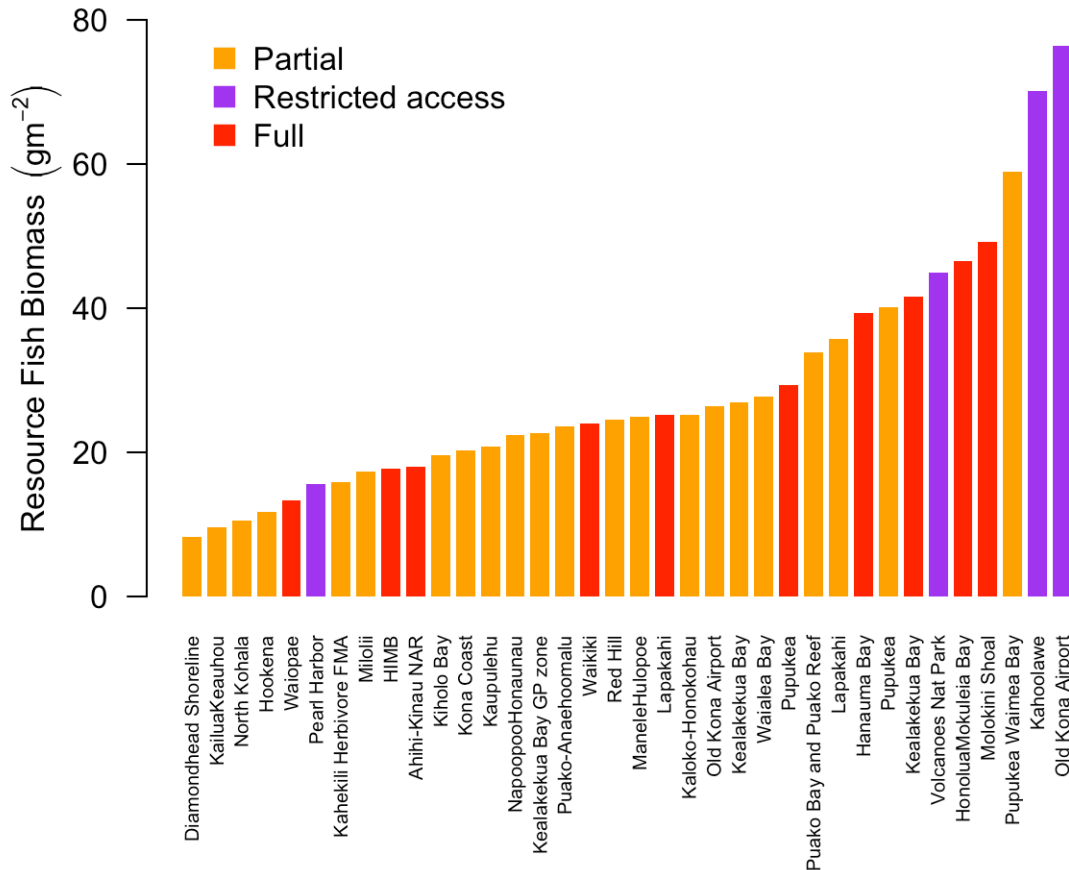


Figure 23. Bar plot of MPAs ordered by resource fish biomass. Colors denote protection level of MPAs

When comparing resource fish biomass by individual managed areas, in some cases restricted access infers the same benefits as full protection (Figure 23). For example, Old Kona airport, on Hawai'i Island, has the highest average resource fish biomass. This location has dual benefits of protection from both shoreline and boat access. It is also a highly productive area oceanographically, with a steep drop off and strong currents enhancing primary productivity and coral cover. Kaho'olawe is another example of high biomass and is effectively the state's largest marine protected area outside the NWHI. Many factors besides level of protection enter into the ability of an MMA to protect and produce high levels of resource fish biomass, including but not limited to MMA total area, area of hard-bottom habitat, age of MMA, and compliance (e.g., amount of poaching).

Another useful way to compare MMA effectiveness is to calculate total standing biomass of resource fishes (Figure 24). This is a function of average biomass and total area of hard-bottom habitat. Thus, MMAs with comparatively low

average biomass may support a large standing stock due to a large area of suitable habitat. This is important because a large standing stock of resource fishes protects genetic and species diversity, and enhances adult and larval spillover in adjacent and “downstream” areas, thereby supporting fisheries (McClanahan and Mangi 2000, Palumbi 2004, Sladek Nowlis and Friedlander 2005). When compared in this way, Ahihi-Kinau Natural Area Reserve in southwest Maui is by far the most effective MMA (Figure 25).

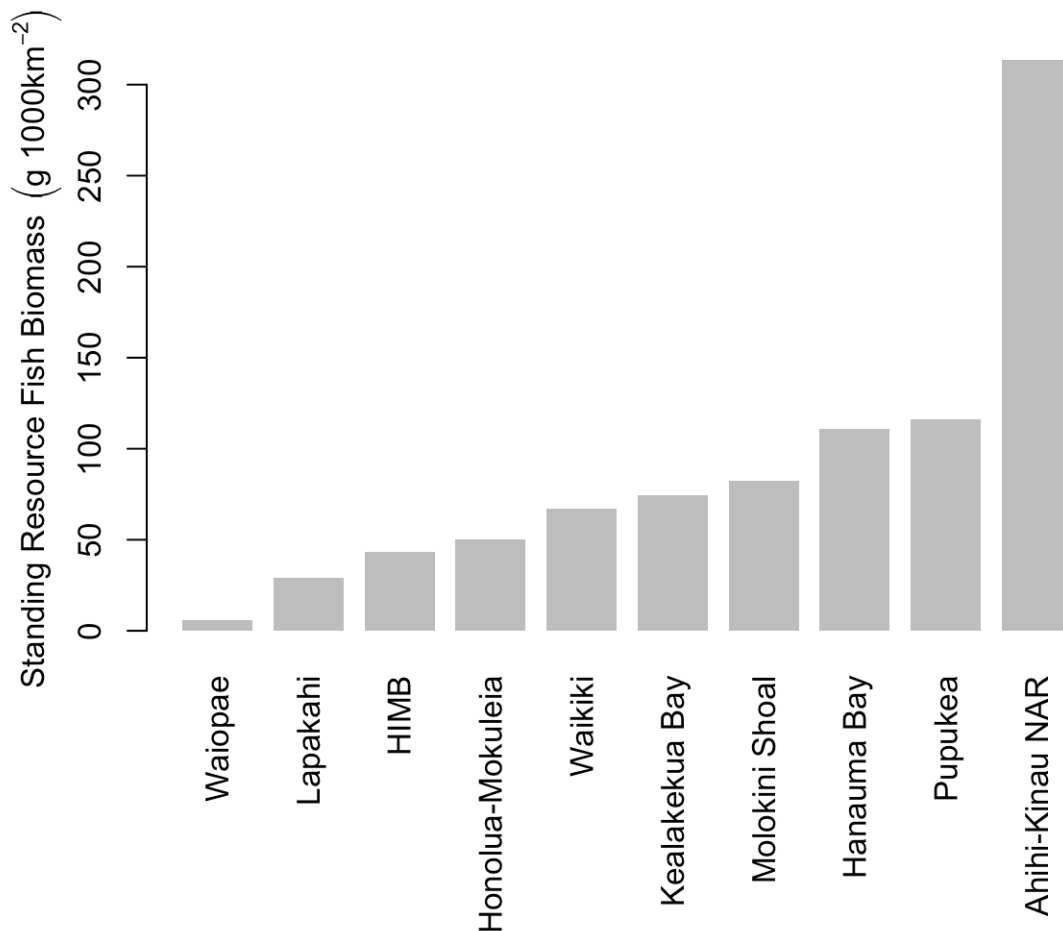


Figure 24. Bar plot of fully protected areas ordered by total resource fish biomass – average transect values multiplied by area of hard-bottom habitat.

MMA age is a primary factor determining effectiveness in producing high biomass of resource fishes. Many reef fish are relatively long-lived so the effects of protection from fishing are delayed but cumulative. This is illustrated by Figure 25, which shows the relationship between MMA age and resource fish biomass. A linear model provided a good fit to this data ($R^2=0.3$, $p<0.01$), though it appears that after about 15 years resource fish biomass begins to increase at a faster rate. This explains why the oldest MPAs in Hawai'i are among the most effective. Hanauma Bay was the first marine protected area in the state, established in 1967. This was followed in short order by Kealakekua Bay (1969) and Ahihi-Kinau NAR (1970).

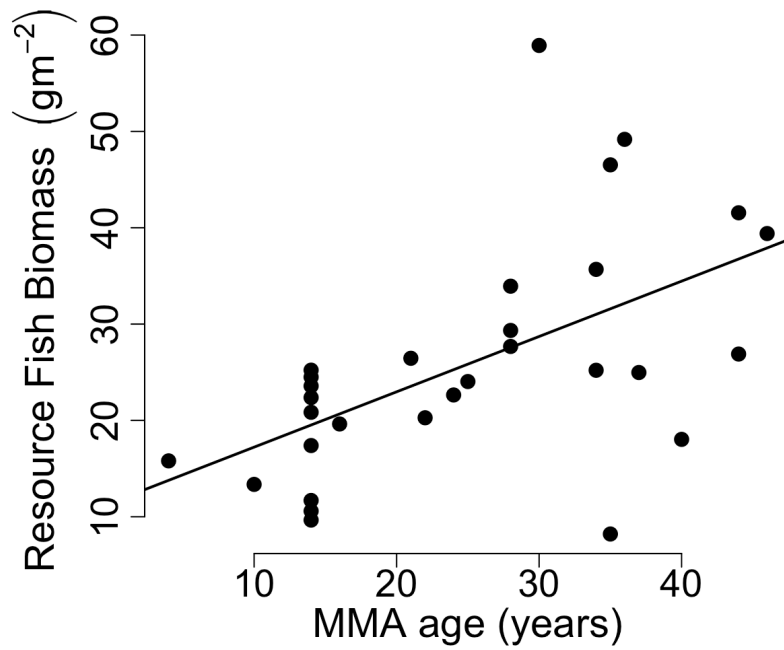


Figure 25. Resource fish biomass vs MMA age in years ($R^2=0.3$, $p<0.01$)



Bigscale Soldierfish -'ū'ū (*Myripristis berndti*) Northwestern Hawaiian Islands. Photo: Ryan Okano

Discussion

One of the main requirements of effective management of coral reef fisheries is accurate information on fish populations at spatial scales that correspond to these resource uses. This information is crucial to developing sustainable fisheries management strategies, improving current management approaches such as marine protected areas, informing design of future MMA networks, and aiding in the development of coastal and marine spatial planning (CMSP). There are a number of data sets of visual surveys of reef fishes from around the Hawaiian Islands, representing the work of both government and non-government organizations (eg. NOAA CRED, NOAA Biogeography, DLNR DAR, UH CRAMP, TNC, UH Fisheries Ecology Research Lab). However, no single data set is spatially comprehensive enough to enable a full understanding of the natural and anthropogenic processes that affect the distribution, abundance, and size of reef fish throughout the state. **This research effort has, for the first time, synthesized all of these datasets into a single spatially comprehensive database encompassing the entire Hawaiian archipelago.**

We compiled 25 datasets, representing more than 25,000 individual fish surveys from throughout the island chain since the year 2000. These data were rigorously error checked and integrated into a master database with a standardized structure. A key component of this database is a fish species table containing the most current and up to date information on the life history and ecology (e.g., length-weight parameters, trophic position, movement, and feeding ecology) for each fish species observed on surveys in the Hawaiian Islands. This information is imperative to the accurate assessment, monitoring, and management of coral reef fishes in Hawai'i and will be made available to the scientific and resource management communities.

With this extensive dataset we developed the first ever bioregionalization of the Hawaiian Archipelago based on the abundance and biomass of reef fishes. Results show clear separation between the Main Hawaiian Islands and the Northwestern Hawaiian Islands, but there are also a number of additional faunal breaks that are driven primarily by the relative abundance of endemic species. Fish species endemic to Hawai'i (found exclusively in the Hawaiian Archipelago) are much more common at the northern end of the chain and showed a strong and statistically significant correlation with latitude. Higher abundance of endemics at higher-latitude reefs may be related to better growth and survivorship after settlement onto reefs, higher levels of within-reef and regional self-recruitment at higher latitudes, or other factors (DeMartini and Friedlander 2004). These bioregions have important implications for management of reef fisheries at an archipelagic scale, and they further our understanding of the macroecology of reef fishes and their spatial distribution at large spatial scales.

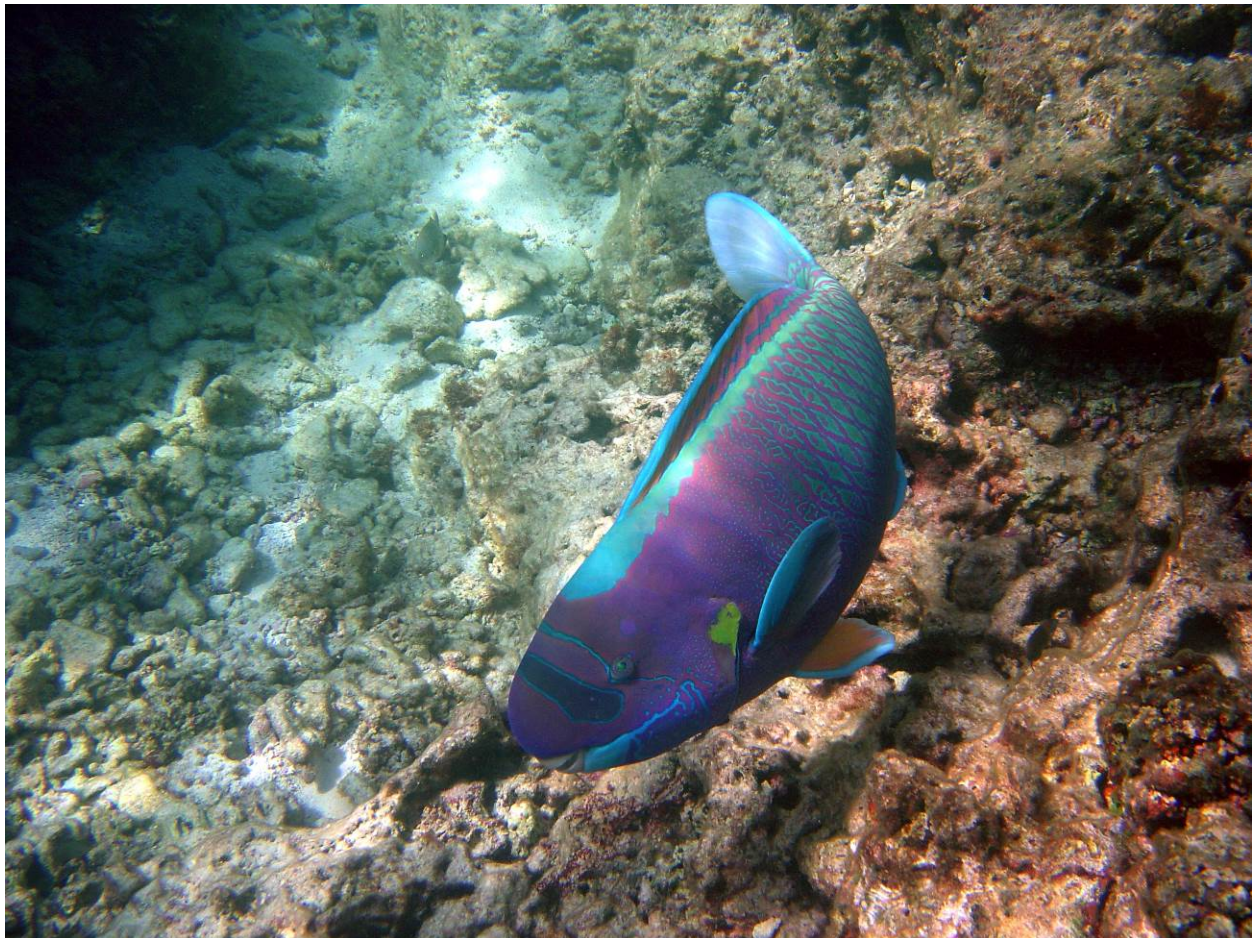
The traditional Hawaiian district or moku was used as a unit of spatial stratification in the Main Hawaiian Islands. Mokus correspond to major

biophysical attributes of island ecosystems and were the basic unit of marine resource management and harvesting in ancient Hawai'i. We attributed biological, physical, and human demographic information to each moku for analytical purposes and much of the variability in fish assemblage characteristics was explained by moku. We used human population per moku divided by shoreline length as an index of human population pressures. Biomass of fisheries resource species was negatively correlated with human population density among mokus with high biomass occurring in areas with low population pressure. Results highlight that reef fish populations in many areas in Hawaii have been negatively impacted by human population pressure. However, we also found a number of locations in the MHI that have high levels of fish biomass, suggesting that these areas could help replenish more heavily impacted areas if effective management is implemented.

Effectiveness of marine protected areas in Hawai'i were compared in terms of resource fish biomass. Hawaiian MMAs were categorized into 3 major categories of resource protection: full, partial, open (no protections), and a fourth category was included to represent restricted access areas that function as de-facto MMAs. Results showed that two of these restricted access areas, Old Kona Airport (Hawai'i Island) and Kaho'olawe Island, had the highest resource fish biomass per unit area compared with all other MMAs. MMA effectiveness varied due to a number of factors other than level of protection. By comparing total biomass of resource fishes by area of hard-bottom habitat, we found that Ahihi-Kinau Natural Area Reserve in southwestern Maui was by far the most effective MMA. A primary factor determining MMA effectiveness is MMA age or time since establishment. Many reef fishes are long lived so the effects of protection may be delayed as a result. We showed a strong positive relationship between MMA age and resource fish biomass, with older MMAs having higher resource fish biomass. MMAs around the populated areas of O'ahu and Maui showed higher biomass relative to fished areas. However, overall biomass in these protected areas was lower than MMAs on Hawai'i Island and Lāna'i, where overall human pressure is lower.

This report is the first ever synthesis of reef fish data in Hawaii and is an important contribution to our understanding of reef fish ecology and the effects of human impacts on reef fishes in the archipelago. These data are unprecedented in scope and provide the clearest picture of the status of reef fish populations across the entire Hawaiian Archipelago. We definitively show that humans are having a significant negative impact on reef fish populations in Hawaii and urgent management is necessary. MPAs have been shown to be effective, particularly in more populated areas. Community managed areas have also been shown to be effective in less populated areas where strong community values still exist. Owing to the failures of conventional marine management in the Hawaiian Islands, there is a growing interest in exploring new approaches to conserve marine ecosystems and coastal resources for future generations (Friedlander et al. 2013). Such approaches include shifts towards ecosystem-based

management, increasing local understanding of marine resources, and integrating traditional ecological knowledge and customary management practices into contemporary marine management. Collectively these measures can lead to sustainable resource use for generations into the future.



Spectacled Parrotfish – uhu uliuli (*Chlorurus perspicillatus*) Northwestern Hawaiian Islands. Photo: K. Stamoulis

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Appendix I. List of fish species encountered on underwater visual surveys and attributes used in this study including: **Zoogeographical category** describing the species distribution following Randall's definitions where 1- circumglobal, 2- wide-ranging Indo-Pacific, 3- Eastern tropical Pacific, 4- Japan to Hawaii, 5- antitropical, 6- Central Pacific, 7- waif, and 8- endemic; **Trophic 9** with trophic levels broken into 9 categories where Z- zooplanktivore, Hgd- herbivore grazer/detritivore, Hscex- herbivore scraper/excavator, Hbrow- herbivore browser, Hother- other herbivores, C- corallivore, D- detritivore, MI- mobile invertivore, SI- sessile invertivore, and P- piscivore; **Trophic 5** with trophic levels broken into 5 levels where APEX- apex predator, P- piscivore, S- secondary consumer, H- herbivore, Z- zooplanktivore; **Endemic** breaks species into 3 groups where E- endemic, I- not endemic, and X- invasive; **Mobility** are categorized following Friedlander (1998); **Resource species** include those targeted in commercial and recreational catches not including aquarium targets; **Harvested species** are resource species plus aquarium targets.

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource Species	HarvestedSpecies
Pomacentridae	<i>Abudefduf abdominalis</i>	8	Z	Z	E	S1	TRUE	TRUE
Pomacentridae	<i>Abudefduf sordidus</i>	2	Hother	H	I	S1	FALSE	FALSE
Pomacentridae	<i>Abudefduf vaigiensis</i>	2	Z	Z	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus achilles</i>	2	Hgd	H	I	S1	TRUE	TRUE
Acanthuridae	<i>Acanthurus blochii</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus dussumieri</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus guttatus</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus leucopareius</i>	5	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus lineatus</i>	2	Hother	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus maculiceps</i>	2	Hother	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus nigricans</i>	2	Hgd	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus nigrofuscus</i>	2	Hgd	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus nigroris</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus olivaceus</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus species</i>	2	Hother	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus thompsoni</i>	2	Z	Z	I	S1	FALSE	FALSE
Acanthuridae	<i>Acanthurus triostegus</i>	2	Hgd	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Acanthurus xanthopterus</i>	2	Hgd	H	I	S2	TRUE	TRUE
Mobulidae	<i>Aetobatus narinari</i>	1	MI	S	I	T	FALSE	FALSE
Albulidae	<i>Albula glossodonta</i>	2	MI	S	I	T	TRUE	TRUE
Carangidae	<i>Alectis ciliaris</i>	1	P	APEX	I	T	TRUE	TRUE
Monacanthidae	<i>Aluterus scriptus</i>	1	Hother	H	I	S2	TRUE	TRUE
Cirrhitidae	<i>Amblycirrhitis bimacula</i>	2	MI	S	I	R	FALSE	FALSE
Ammodytidae	<i>Ammodytoides pylei</i>	8	SI	S	E	S2	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Labridae	<i>Anampses chrysocephalus</i>	8	MI	S	E	S1	FALSE	FALSE
Labridae	<i>Anampses cuvier</i>	8	MI	S	E	S1	TRUE	TRUE
Labridae	<i>Anampses species</i>	8	MI	S	E	S1	FALSE	FALSE
Antennariidae	<i>Antennarius commersoni</i>	2	P	P	I	R	FALSE	FALSE
Antennariidae	<i>Antennarius drombus</i>	8	P	P	E	R	FALSE	FALSE
Anthias (Serranid)	<i>Anthias species</i>	8	Z	Z	E	S1	FALSE	FALSE
Lutjanidae	<i>Aphareus furca</i>	2	P	P	I	T	TRUE	TRUE
Apogonidae	<i>Apogon erythrinus</i>	8	MI	S	E	R	FALSE	FALSE
Apogonidae	<i>Apogon kallopterus</i>	2	MI	S	I	R	FALSE	FALSE
Apogonidae	<i>Apogon maculiferus</i>	8	MI	S	E	R	FALSE	FALSE
Apogonidae	<i>Apogon species</i>	2	MI	S	I	R	FALSE	FALSE
Apogonidae	<i>Apogonichthys perdix</i>	2	MI	S	I	R	FALSE	FALSE
Pomacanthidae	<i>Apothemichthys arcuatus</i>	8	SI	S	E	S1	FALSE	FALSE
Lutjanidae	<i>Aprion virescens</i>	2	P	APEX	I	T	TRUE	TRUE
Congridae	<i>Ariosoma fasciatum</i>	2	P	S	I	R	FALSE	FALSE
Tetraodontidae	<i>Arothron hispidus</i>	2	MI	S	I	S1	FALSE	FALSE
Tetraodontidae	<i>Arothron meleagris</i>	2	C	S	I	S1	FALSE	FALSE
Gobiidae	<i>Asterropteryx semipunctatus</i>	2	SI	S	I	S1	FALSE	FALSE
Atherinidae	<i>Atherinomorus insularum</i>	8	Z	Z	E	T	FALSE	FALSE
Aulostomidae	<i>Aulostomus chinensis</i>	2	P	P	I	S2	FALSE	FALSE
Balistidae	<i>Balistes polylepis</i>	7	MI	S	I	T	FALSE	FALSE
Balistidae	<i>Balistes species</i>	2	MI	S	I	S2	FALSE	FALSE
Gobiidae	<i>Bathygobius cocosensis</i>	2	SI	S	I	R	FALSE	FALSE
Belonidae	<i>Belonidae species</i>	2	P	P	I	T	FALSE	FALSE
Blenniidae	<i>Blenniella gibbifrons</i>	2	Hother	H	I	R	FALSE	FALSE
Blenniidae	<i>Blenniidae species</i>	2	Hother	H	I	R	FALSE	FALSE
Labridae	<i>Bodianus albotaeniatus</i>	8	MI	S	E	S2	TRUE	TRUE
Bothidae	<i>Bothus mancus</i>	2	MI	S	I	S1	FALSE	FALSE
Bothidae	<i>Bothus pantherinus</i>	2	MI	S	I	S1	FALSE	FALSE
Bothidae	<i>Bothus species</i>	2	MI	S	I	S1	FALSE	FALSE
Ophidiidae	<i>Brotula multibarbata</i>	2	MI	S	I	S1	FALSE	FALSE
Callionymidae	<i>Callionymus comptus</i>	8	MI	S	E	S1	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Callionymidae	<i>Callionymus decoratus</i>	8	MI	S	E	S1	FALSE	FALSE
Scaridae	<i>Calotomus species</i>	2	Hother	H	I	S2	TRUE	TRUE
Scaridae	<i>Calotomus carolinus</i>	2	Hbrow	H	I	S2	TRUE	TRUE
Scaridae	<i>Calotomus zonarchus</i>	8	Hbrow	H	E	S2	TRUE	TRUE
Monacanthidae	<i>Cantherhines dumerilii</i>	2	C	S	I	S1	FALSE	FALSE
Monacanthidae	<i>Cantherhines sandwichiensis</i>	8	Hother	H	E	S1	FALSE	FALSE
Monacanthidae	<i>Cantherhines verecundus</i>	8	Hother	H	E	S1	FALSE	FALSE
Balistidae	<i>Canthidermis maculatus</i>	1	Z	Z	I	H	FALSE	FALSE
Tetraodontidae	<i>Canthigaster amboinensis</i>	2	Hother	H	I	S1	FALSE	FALSE
Tetraodontidae	<i>Canthigaster coronata</i>	2	SI	S	I	S1	FALSE	FALSE
Tetraodontidae	<i>Canthigaster epilampra</i>	2	MI	S	I	S1	FALSE	FALSE
Tetraodontidae	<i>Canthigaster jactator</i>	8	Hother	H	E	S1	FALSE	TRUE
Tetraodontidae	<i>Canthigaster rivulata</i>	2	Hother	H	I	S1	FALSE	FALSE
Tetraodontidae	<i>Canthigaster solandri</i>	2	Hother	H	I	S1	FALSE	FALSE
Tetraodontidae	<i>Canthigaster species</i>	2	Hother	H	I	S1	FALSE	FALSE
Caracanthidae	<i>Caracanthus typicus</i>	8	MI	S	E	R	FALSE	FALSE
Carangidae	<i>Carangoides ferdau</i>	2	MI	APEX	I	T	TRUE	TRUE
Carangidae	<i>Carangoides orthogrammus</i>	2	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Caranx ignobilis</i>	2	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Caranx lugubris</i>	1	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Caranx melampygus</i>	2	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Caranx sexfasciatus</i>	2	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Caranx species</i>	2	P	APEX	I	T	TRUE	TRUE
Carcharhinidae	<i>Carcharhinus amblyrhynchos</i>	2	P	APEX	I	T	FALSE	FALSE
Carcharhinidae	<i>Carcharhinus galapagensis</i>	1	P	APEX	I	T	FALSE	FALSE
Carcharhinidae	<i>Carcharhinus melanopterus</i>	2	P	APEX	I	T	FALSE	FALSE
Pomacanthidae	<i>Centropyge fisheri</i>	2	Hother	H	I	S1	FALSE	TRUE
Pomacanthidae	<i>Centropyge flavissima</i>	7	Hother	H	X	R	FALSE	FALSE
Pomacanthidae	<i>Centropyge interrupta</i>	4	Hother	H	I	R	FALSE	FALSE
Pomacanthidae	<i>Centropyge loriculus</i>	2	Hother	H	I	R	FALSE	FALSE
Pomacanthidae	<i>Centropyge potteri</i>	8	Hother	H	E	R	FALSE	TRUE
Serranidae	<i>Cephalopholis argus</i>	2	P	P	X	S1	TRUE	TRUE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Chaetodontidae	<i>Chaetodon auriga</i>	2	SI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon citrinellus</i>	2	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon ephippium</i>	2	MI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon fremblii</i>	8	SI	S	E	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon kleinii</i>	2	Z	Z	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon lineolatus</i>	2	SI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon lunula</i>	2	SI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon lunulatus</i>	2	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon miliaris</i>	8	Z	Z	E	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon multicinctus</i>	8	C	S	E	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon ornatissimus</i>	2	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon quadrimaculatus</i>	5	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon reticulatus</i>	2	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon tinker</i>	6	SI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon trifascialis</i>	2	C	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Chaetodon unimaculatus</i>	2	C	S	I	S1	FALSE	TRUE
Chanidae	<i>Chanos chanos</i>	2	Hother	H	I	T	TRUE	TRUE
Labridae	<i>Cheilio inermis</i>	2	MI	S	I	S2	FALSE	FALSE
Cheilodactylidae	<i>Goniistius vittatus</i>	8	SI	S	E	S2	FALSE	FALSE
Scaridae	<i>Chlorurus perspicillatus</i>	8	Hscex	H	E	S2	TRUE	TRUE
Scaridae	<i>Chlorurus species</i>	2	Hother	H	I	S2	TRUE	TRUE
Scaridae	<i>Chlorurus spilurus</i>	2	Hscex	H	I	S2	TRUE	TRUE
Pomacentridae	<i>Chromis acares</i>	2	Z	Z	I	R	FALSE	FALSE
Pomacentridae	<i>Chromis agilis</i>	2	Z	Z	I	R	FALSE	FALSE
Pomacentridae	<i>Chromis hanui</i>	8	Z	Z	E	R	FALSE	FALSE
Pomacentridae	<i>Chromis leucura</i>	2	Z	Z	I	R	FALSE	FALSE
Pomacentridae	<i>Chromis ovalis</i>	8	Z	Z	E	R	FALSE	FALSE
Pomacentridae	<i>Chromis vanderbilti</i>	2	Z	Z	I	R	FALSE	FALSE
Pomacentridae	<i>Chromis verater</i>	8	Z	Z	E	R	FALSE	FALSE
Labridae	<i>Cirrhitlabrus jordani</i>	8	Z	Z	E	S1	FALSE	FALSE
Cirrhitidae	<i>Cirrhitops fasciatus</i>	5	MI	S	I	R	FALSE	FALSE
Cirrhitidae	<i>Cirrhitus pinnulatus</i>	2	MI	S	I	S1	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Blenniidae	<i>Cirripectes obscurus</i>	8	Hother	H	E	R	FALSE	FALSE
Blenniidae	<i>Cirripectes species</i>	8	Hother	H	I	R	FALSE	FALSE
Blenniidae	<i>Cirripectes vanderbilti</i>	8	Hother	H	E	R	FALSE	FALSE
Congridae	<i>Conger cinereus marginatus</i>	8	P	P	I	R	FALSE	FALSE
Congridae	<i>Conger species</i>	8	P	S	I	R	FALSE	FALSE
Labridae	<i>Coris ballieui</i>	8	MI	S	E	S1	FALSE	FALSE
Labridae	<i>Coris flavovittata</i>	8	MI	S	E	S2	TRUE	TRUE
Labridae	<i>Coris gaimard</i>	2	MI	S	I	S1	FALSE	TRUE
Labridae	<i>Coris venusta</i>	8	MI	S	E	S1	FALSE	FALSE
Gobiidae	<i>Coryphopterus duospilus</i>	2	Hother	H	I	S1	FALSE	FALSE
Gobiidae	<i>Coryphopterus species</i>	2	Hother	H	I	S1	FALSE	FALSE
Acanthuridae	<i>Ctenochaetus hawaiiensis</i>	2	D	S	I	S1	TRUE	TRUE
Acanthuridae	<i>Ctenochaetus strigosus</i>	8	D	S	I	S1	TRUE	TRUE
Labridae	<i>Cymolutes lecluse</i>	8	MI	S	E	S1	FALSE	FALSE
Labridae	<i>Cymolutes praetextatus</i>	2	MI	S	I	S1	FALSE	FALSE
Dactylopteridae	<i>Dactyloptena orientalis</i>	2	MI	S	I	T	FALSE	FALSE
Pomacentridae	<i>Dascyllus albisella</i>	8	Z	Z	E	S1	FALSE	TRUE
Dasyatidae	<i>Dasyatis lata</i>	8	MI	S	E	T	FALSE	FALSE
Carangidae	<i>Decapterus macarellus</i>	1	Z	Z	I	T	TRUE	TRUE
Carangidae	<i>Decapterus species</i>	1	Z	Z	I	T	TRUE	FALSE
Scorpaenidae	<i>Dendrochirus barberi</i>	8	MI	S	E	R	FALSE	FALSE
Diodontidae	<i>Diodon holocanthus</i>	1	MI	S	I	S1	FALSE	FALSE
Diodontidae	<i>Diodon hystrix</i>	1	MI	S	I	S1	FALSE	FALSE
Syngnathidae	<i>Doryrhamphus excisus</i>	2	Z	Z	I	S1	FALSE	FALSE
Echeneidae	<i>Echeneis naucrates</i>	1	Z	S	I	T	FALSE	FALSE
Muraenidae	<i>Echidna nebulosa</i>	2	MI	S	I	S1	FALSE	FALSE
Carangidae	<i>Elagatis bipinnulata</i>	1	P	APEX	I	T	TRUE	TRUE
Elopidae	<i>Elops hawaiiensis</i>	1	MI	S	I	T	TRUE	FALSE
Muraenidae	<i>Enchelycore pardalis</i>	2	P	S	I	R	FALSE	FALSE
Muraenidae	<i>Enchelynassa canina</i>	2	P	P	I	R	FALSE	FALSE
Engraulidae	<i>Encrasicholina purpurea</i>	8	Z	Z	E	T	FALSE	FALSE
Tripterygiidae	<i>Enneapterygius atriceps</i>	8	Hother	H	E	S1	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Blenniidae	<i>Entomacrodus marmoratus</i>	8	Hother	H	E	R	FALSE	FALSE
Labridae	<i>Epibulus insidiator</i>	2	MI	S	I	S2	FALSE	FALSE
Serranidae	<i>Epinephelus quernus</i>	8	P	APEX	E	S1	TRUE	TRUE
Scombridae	<i>Euthynnus affinis</i>	2	P	APEX	I	T	TRUE	TRUE
Gobiidae	<i>Eviota epiphanes</i>	2	Hother	H	I	S1	FALSE	FALSE
Pentacerotidae	<i>Evistias acutirostris</i>	5	MI	S	I	T	FALSE	FALSE
Blenniidae	<i>Exallias brevis</i>	2	C	S	I	R	FALSE	FALSE
Fistulariidae	<i>Fistularia commersonii</i>	2	P	P	I	S2	TRUE	TRUE
Apogonidae	<i>Foa brachygramma</i>	8	MI	S	I	R	FALSE	FALSE
Chaetodontidae	<i>Forcipiger flavissimus</i>	2	SI	S	I	S1	FALSE	TRUE
Chaetodontidae	<i>Forcipiger longirostris</i>	2	MI	S	I	S1	FALSE	FALSE
Pomacanthidae	<i>Genicanthus personatus</i>	8	Z	Z	E	S1	FALSE	FALSE
Carangidae	<i>Gnathanodon speciosus</i>	2	MI	S	I	T	TRUE	TRUE
Gobiidae	<i>Gnatholepis anjerensis</i>	2	Hother	H	I	S1	FALSE	FALSE
Gobiidae	<i>Gnatholepis caurensis hawaiiensis</i>	8	Hother	H	E	S1	FALSE	FALSE
Gobiidae	<i>Gobiidae species</i>	2	SI	S	I	S1	FALSE	FALSE
Labridae	<i>Gomphosus varius</i>	2	MI	S	I	S1	FALSE	FALSE
Microdesmidae	<i>Gunnellichthys curiosus</i>	2	Z	Z	I	S1	FALSE	FALSE
Muraenidae	<i>Gymnomuraena zebra</i>	2	MI	S	I	R	FALSE	TRUE
Muraenidae	<i>Gymnothorax eurostus</i>	5	MI	S	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax flavimarginatus</i>	2	P	P	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax javanicus</i>	2	P	S	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax melatremus</i>	2	MI	S	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax meleagris</i>	2	P	P	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax nudivomer</i>	2	P	P	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax pictus</i>	2	P	S	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax rueppelliae</i>	2	MI	S	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax species</i>	2	P	P	I	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax steindachneri</i>	8	P	P	E	R	FALSE	FALSE
Muraenidae	<i>Gymnothorax undulatus</i>	2	P	P	I	R	FALSE	FALSE
Labridae	<i>Halichoeres ornatissimus</i>	2	MI	S	I	S1	FALSE	TRUE
Hemiramphidae	<i>Hemiramphus depauperatus</i>	6	Hother	H	I	T	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Hemiramphidae	<i>Hemiramphus species</i>	6	Hother	H	I	T	FALSE	FALSE
Chaetodontidae	<i>Hemitaurchthys polylepis</i>	2	Z	Z	I	S1	FALSE	FALSE
Chaetodontidae	<i>Hemitaurchthys thompsoni</i>	5	Z	Z	I	S1	FALSE	FALSE
Chaetodontidae	<i>Heniochus diphreutes</i>	2	Z	Z	I	S1	FALSE	FALSE
Priacanthidae	<i>Heteropriacanthus cruentatus</i>	1	Z	Z	I	R	TRUE	TRUE
Syngnathidae	<i>Hippocampus fisheri</i>	8	Z	Z	I	S1	FALSE	FALSE
Syngnathidae	<i>Hippocampus kuda</i>	2	Z	Z	I	S1	FALSE	FALSE
Holocentridae	<i>Holocentridae species</i>	2	MI	S	I	R	TRUE	TRUE
Hemiramphidae	<i>Hyporhamphus acutus</i>	6	Hother	H	I	T	FALSE	FALSE
Labridae	<i>Iniistius aneitensis</i>	2	MI	S	I	R	TRUE	TRUE
Labridae	<i>Iniistius baldwini</i>	4	MI	S	I	R	TRUE	TRUE
Labridae	<i>Iniistius niveilatus</i>	2	MI	S	I	R	TRUE	TRUE
Labridae	<i>Iniistius pavo</i>	2	MI	S	I	R	TRUE	TRUE
Labridae	<i>Iniistius species</i>	2	MI	S	I	R	TRUE	TRUE
Labridae	<i>Iniistius umbrilatus</i>	8	MI	S	E	R	TRUE	TRUE
Scorpaenidae	<i>Iracundus signifer</i>	2	MI	S	I	R	FALSE	FALSE
Blenniidae	<i>Istiblennius zebra</i>	8	Hother	H	E	R	FALSE	FALSE
Scombridae	<i>Katsuwonus pelamis</i>	1	P	APEX	I	T	TRUE	TRUE
Kuhliidae	<i>Kuhlia sandvicensis</i>	6	Z	Z	I	R	TRUE	TRUE
Kyphosidae	<i>Kyphosus bigibbus</i>	5	Hbrow	H	I	S2	TRUE	TRUE
Kyphosidae	<i>Kyphosus cinerascens</i>	2	Hbrow	H	I	S2	TRUE	TRUE
Kyphosidae	<i>Kyphosus hawaiiensis</i>	8	Hother	H	E	S2	TRUE	TRUE
Kyphosidae	<i>Kyphosus sandwicensis</i>	8	Hother	H	E	S2	TRUE	TRUE
Kyphosidae	<i>Kyphosus species</i>	2	Hother	H	I	S2	TRUE	TRUE
Kyphosidae	<i>Kyphosus vaigiensis</i>	2	Hbrow	H	I	S2	TRUE	TRUE
Labridae	<i>Labridae species</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Labroides phthirophagus</i>	8	P	S	E	R	FALSE	TRUE
Ostraciidae	<i>Lactoria fornasini</i>	2	SI	S	I	S1	FALSE	FALSE
Lutjanidae	<i>Lutjanus fulvus</i>	2	MI	S	X	S1	TRUE	TRUE
Lutjanidae	<i>Lutjanus kasmira</i>	2	MI	S	X	S2	TRUE	TRUE
Labridae	<i>Macropharyngodon geoffroy</i>	8	MI	S	E	S1	FALSE	FALSE
Malacanthidae	<i>Malacanthus brevirostris</i>	2	MI	S	I	S1	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Mobulidae	<i>Manta alfredi</i>	2	Z	Z	I	T	FALSE	FALSE
Mobulidae	<i>Manta birostris</i>	2	Z	Z	I	T	FALSE	FALSE
Balistidae	<i>Melichthys niger</i>	1	Hother	H	I	S1	FALSE	TRUE
Balistidae	<i>Melichthys vidua</i>	2	Hother	H	I	S1	FALSE	TRUE
Scorpididae	<i>Microcanthus strigatus</i>	5	MI	S	I	S1	TRUE	FALSE
Monacanthidae	<i>Monacanthidae species</i>	2	Hother	H	I	S1	FALSE	FALSE
Lethrinidae	<i>Monotaxis grandoculis</i>	2	MI	S	I	S2	TRUE	TRUE
Mugilidae	<i>Mugil cephalus</i>	1	D	S	I	T	TRUE	TRUE
Mullidae	<i>Mullidae species</i>	2	MI	S	I	S2	TRUE	TRUE
Mullidae	<i>Mulloidichthys flavolineatus</i>	2	MI	S	I	S1	TRUE	TRUE
Mullidae	<i>Mulloidichthys mimicus</i>	6	MI	S	I	S2	TRUE	TRUE
Mullidae	<i>Mulloidichthys pflugeri</i>	2	P	P	I	S2	TRUE	TRUE
Mullidae	<i>Mulloidichthys vanicolensis</i>	2	MI	S	I	S1	TRUE	TRUE
Muraenidae	<i>Muraenidae species</i>	2	P	S	I	R	FALSE	FALSE
Ophichthidae	<i>Myrichthys magnificus</i>	8	MI	S	E	S1	FALSE	FALSE
Holocentridae	<i>Myripristis amaena</i>	6	Z	Z	I	R	TRUE	TRUE
Holocentridae	<i>Myripristis berndti</i>	2	Z	Z	I	R	TRUE	TRUE
Holocentridae	<i>Myripristis chryseres</i>	2	Z	Z	I	R	TRUE	TRUE
Holocentridae	<i>Myripristis kuntee</i>	2	Z	Z	I	R	TRUE	TRUE
Holocentridae	<i>Myripristis species</i>	2	Z	Z	I	R	TRUE	TRUE
Holocentridae	<i>Myripristis vittata</i>	2	Z	Z	I	R	TRUE	TRUE
Acanthuridae	<i>Naso annulatus</i>	2	Z	Z	I	T	TRUE	TRUE
Acanthuridae	<i>Naso brevirostris</i>	2	Z	Z	I	T	TRUE	TRUE
Acanthuridae	<i>Naso caesius</i>	2	Z	Z	I	T	TRUE	TRUE
Acanthuridae	<i>Naso hexacanthus</i>	2	Z	Z	I	S1	TRUE	TRUE
Acanthuridae	<i>Naso lituratus</i>	2	Hbrow	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Naso maculatus</i>	5	Z	Z	I	T	TRUE	FALSE
Acanthuridae	<i>Naso species</i>	2	Hother	H	I	S2	TRUE	TRUE
Acanthuridae	<i>Naso unicornis</i>	2	Hbrow	H	I	S2	TRUE	TRUE
Microdesmidae	<i>Nemateleotris magnifica</i>	2	Z	Z	I	S1	FALSE	FALSE
Mugilidae	<i>Neomyxus leuciscus</i>	6	D	S	I	T	TRUE	TRUE
Holocentridae	<i>Neoniphon aurolineatus</i>	2	MI	S	I	S1	TRUE	TRUE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Holocentridae	<i>Neoniphon sammara</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Neoniphon species</i>	2	MI	S	I	R	TRUE	TRUE
Labridae	<i>Novaculichthys taeniourus</i>	2	MI	S	I	S1	FALSE	TRUE
Blenniidae	<i>Omobranchus rotundiceps</i>	2	Hother	H	I	R	FALSE	FALSE
Oplegnathidae	<i>Oplegnathus fasciatus</i>	4	MI	S	I	T	FALSE	FALSE
Oplegnathidae	<i>Oplegnathus punctatus</i>	4	MI	S	I	T	TRUE	TRUE
Gobiidae	<i>Opua nephodes</i>	8	Hother	H	I	S1	FALSE	FALSE
Apogonidae	<i>Ostorhinchus maculiferus</i>	8	MI	S	E	R	FALSE	FALSE
Ostraciidae	<i>Ostracion meleagris</i>	2	SI	S	I	S1	FALSE	TRUE
Ostraciidae	<i>Ostracion whitleyi</i>	6	SI	S	I	S1	FALSE	FALSE
Labridae	<i>Oxycheilinus bimaculatus</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Oxycheilinus unifasciatus</i>	2	P	P	I	S1	TRUE	TRUE
Cirrhitidae	<i>Oxycirrhites typus</i>	2	Z	Z	I	S1	FALSE	FALSE
Blenniidae	<i>Parablennius thysanius</i>	2	Hother	H	X	R	FALSE	FALSE
Cirrhitidae	<i>Paracirrhites arcatus</i>	2	MI	S	I	R	FALSE	FALSE
Cirrhitidae	<i>Paracirrhites forsteri</i>	2	P	P	I	R	FALSE	FALSE
Pinguipedidae	<i>Parapercis schauinslandi</i>	2	MI	S	I	S1	FALSE	FALSE
Pinguipedidae	<i>Parapercis species</i>	2	MI	S	I	S1	FALSE	FALSE
Mullidae	<i>Parupeneus chrysonemus</i>	8	MI	S	E	S2	TRUE	TRUE
Mullidae	<i>Parupeneus cyclostomus</i>	2	P	P	I	S2	TRUE	TRUE
Mullidae	<i>Parupeneus insularis</i>	3	MI	S	I	S1	TRUE	TRUE
Mullidae	<i>Parupeneus multifasciatus</i>	2	MI	S	I	S1	TRUE	TRUE
Mullidae	<i>Parupeneus pleurostigma</i>	2	MI	S	I	S1	TRUE	TRUE
Mullidae	<i>Parupeneus porphyreus</i>	8	MI	S	E	S1	TRUE	TRUE
Monacanthidae	<i>Pervagor aspricaudus</i>	2	Hother	H	I	S1	FALSE	FALSE
Monacanthidae	<i>Pervagor spilosoma</i>	8	Hother	H	E	S1	FALSE	FALSE
Blenniidae	<i>Plagiotremus ewaensis</i>	8	P	P	E	R	FALSE	FALSE
Blenniidae	<i>Plagiotremus goslinei</i>	8	P	P	E	R	FALSE	FALSE
Belonidae	<i>Platybelone argalus</i>	1	P	P	I	T	FALSE	FALSE
Pomacentridae	<i>Plectroglyphidodon imparipennis</i>	2	MI	S	I	R	FALSE	FALSE
Pomacentridae	<i>Plectroglyphidodon johnstonianus</i>	2	C	S	I	R	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Pomacentridae	<i>Plectroglyphidodon sindonis</i>	8	Hother	H	E	R	FALSE	FALSE
Gobiidae	<i>Pleurosicya micheli</i>	2	C	S	I	R	FALSE	FALSE
Polynemidae	<i>Polydactylus sexfilis</i>	2	MI	S	I	S2	TRUE	TRUE
Priacanthidae	<i>Priacanthus meeki</i>	8	Z	Z	E	R	TRUE	TRUE
Priacanthidae	<i>Priacanthus species</i>	8	Z	Z	I	R	TRUE	TRUE
Gobiidae	<i>Priolepis aureoviridis</i>	6	Hother	H	I	S1	FALSE	FALSE
Gobiidae	<i>Priolepis eugenius</i>	8	SI	S	E	R	FALSE	FALSE
Apogonidae	<i>Pristiapogon kallopterus</i>	2	MI	S	I	R	FALSE	FALSE
Apogonidae	<i>Pristiapogon taeniopterus</i>	2	MI	S	I	R	FALSE	FALSE
Holocentridae	<i>Pristilepis oligolepis</i>	5	Z	Z	I	R	TRUE	FALSE
Anthias (Serranid)	<i>Pseudanthias bicolor</i>	2	Z	Z	I	S1	FALSE	FALSE
Anthias (Serranid)	<i>Pseudanthias hawaiiensis</i>	8	Z	Z	E	S1	FALSE	FALSE
Anthias (Serranid)	<i>Pseudanthias thompsoni</i>	8	Z	Z	E	S1	FALSE	FALSE
Carangidae	<i>Pseudocaranx cheilio</i>	8	P	APEX	I	T	TRUE	TRUE
Labridae	<i>Pseudocheilinus evanidus</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Pseudocheilinus octotaenia</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Pseudocheilinus tetrataenia</i>	5	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Pseudojuloides cerasinus</i>	2	MI	S	I	S1	FALSE	FALSE
Gobiidae	<i>Psilogobius mainlandi</i>	8	SI	S	E	R	FALSE	FALSE
Microdesmidae	<i>Ptereleotris heteroptera</i>	2	Z	Z	I	S1	FALSE	FALSE
Scorpaenidae	<i>Pterois sphex</i>	8	P	P	E	R	FALSE	FALSE
Balistidae	<i>Rhinecanthus aculeatus</i>	2	MI	S	I	S1	FALSE	FALSE
Balistidae	<i>Rhinecanthus rectangulus</i>	2	MI	S	I	S1	FALSE	FALSE
Holocentridae	<i>Sargocentron diadema</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron ensifer</i>	5	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron punctatissimum</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron species</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron spiniferum</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron tiere</i>	2	MI	S	I	R	TRUE	TRUE
Holocentridae	<i>Sargocentron xantherythrum</i>	8	MI	S	E	R	TRUE	TRUE
Synodontidae	<i>Saurida flamma</i>	5	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Saurida gracilis</i>	2	P	P	I	S2	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Synodontidae	<i>Saurida species</i>	2	P	S	I	S2	FALSE	FALSE
Scaridae	<i>Scarus dubius</i>	8	Hscex	H	E	S2	TRUE	TRUE
Scaridae	<i>Scarus psittacus</i>	2	Hscex	H	I	S2	TRUE	TRUE
Scaridae	<i>Scarus rubroviolaceus</i>	2	Hscex	H	I	S2	TRUE	TRUE
Scaridae	<i>Scarus species</i>	2	Hother	H	I	S2	TRUE	TRUE
Carangidae	<i>Scomberoides lysan</i>	2	P	APEX	I	T	TRUE	TRUE
Scorpaenidae	<i>Scorpaenodes kelloggi</i>	2	MI	S	I	R	FALSE	FALSE
Scorpaenidae	<i>Scorpaenodes parvipinnis</i>	2	MI	S	I	R	FALSE	FALSE
Scorpaenidae	<i>Scorpaenopsis brevifrons</i>	8	P	S	E	R	FALSE	FALSE
Scorpaenidae	<i>Scorpaenopsis cacopsis</i>	8	P	P	E	R	FALSE	FALSE
Scorpaenidae	<i>Scorpaenopsis diabolus</i>	2	P	P	I	R	FALSE	FALSE
Scorpaenidae	<i>Scorpaenopsis species</i>	2	P	S	I	R	FALSE	FALSE
Muraenidae	<i>Scuticaria okinawae</i>	2	P	S	I	R	FALSE	FALSE
Muraenidae	<i>Scuticaria tigrinus</i>	2	P	P	I	R	FALSE	FALSE
Scorpaenidae	<i>Sebastapistes ballieui</i>	8	MI	S	E	R	FALSE	FALSE
Scorpaenidae	<i>Sebastapistes coniota</i>	6	MI	S	I	R	FALSE	FALSE
Scorpaenidae	<i>Sebastapistes species</i>	6	MI	S	I	R	FALSE	FALSE
Carangidae	<i>Selar crumenophthalmus</i>	1	Z	Z	I	T	TRUE	TRUE
Carangidae	<i>Seriola dumerili</i>	1	P	APEX	I	T	TRUE	TRUE
Carangidae	<i>Seriola rivoliana</i>	1	P	APEX	I	T	TRUE	TRUE
Sphyraenidae	<i>Sphyraena barracuda</i>	1	P	APEX	I	T	TRUE	TRUE
Sphyraenidae	<i>Sphyraena helleri</i>	2	P	APEX	I	T	TRUE	TRUE
Sphyrnidae	<i>Sphyrna lewini</i>	1	P	APEX	I	T	FALSE	FALSE
Clupeidae	<i>Spratelloides delicatulus</i>	2	Z	Z	I	T	FALSE	FALSE
Pomacentridae	<i>Stegastes marginatus</i>	8	Hother	H	I	R	FALSE	FALSE
Labridae	<i>Stethojulis balteata</i>	8	MI	S	E	S1	FALSE	FALSE
Balistidae	<i>Sufflamen bursa</i>	2	MI	S	I	S1	FALSE	FALSE
Balistidae	<i>Sufflamen fraenatus</i>	2	MI	S	I	S2	FALSE	FALSE
Syngnathidae	<i>Syngnathidae species</i>	2	Z	Z	I	S1	FALSE	FALSE
Synodontidae	<i>Synodus binotatus</i>	2	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Synodus dermatogenys</i>	2	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Synodus lobeli</i>	4	P	P	I	S2	FALSE	FALSE

Family	Species	Zoogeog	Trophic 9	Trophic 5	Endemic	Mobility	Resource	
							Species	HarvestedSpecies
Synodontidae	<i>Synodus species</i>	2	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Synodus ulae</i>	4	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Synodus variegatus</i>	2	P	P	I	S2	FALSE	FALSE
Synodontidae	<i>Synodontidae species</i>	2	P	S	I	S2	FALSE	FALSE
Scorpaenidae	<i>Taenianotus triacanthus</i>	2	P	P	I	R	FALSE	FALSE
Tetraodontidae	<i>Tetraodontidae species</i>	2	Hother	S	I	S1	FALSE	FALSE
Labridae	<i>Thalassoma ballieui</i>	8	MI	S	E	S2	TRUE	TRUE
Labridae	<i>Thalassoma duperrey</i>	8	MI	S	E	S1	FALSE	TRUE
Labridae	<i>Thalassoma lutescens</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Thalassoma purpureum</i>	2	MI	S	I	S1	TRUE	TRUE
Labridae	<i>Thalassoma quinquevittatum</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Thalassoma species</i>	2	MI	S	I	S1	FALSE	FALSE
Labridae	<i>Thalassoma trilobatum</i>	2	MI	S	I	S2	FALSE	FALSE
Synodontidae	<i>Trachinocephalus myops</i>	1	P	P	I	S2	FALSE	FALSE
Carcharhinidae	<i>Triaenodon obesus</i>	2	P	APEX	I	T	FALSE	FALSE
Gobiidae	<i>Trimma taylori</i>	2	SI	S	I	R	FALSE	FALSE
Belonidae	<i>Tylosurus crocodilus</i>	1	P	APEX	I	T	TRUE	TRUE
Mullidae	<i>Upeneus arge</i>	2	MI	S	I	S2	TRUE	TRUE
Labridae	<i>Wetmorella albofasciata</i>	2	MI	S	I	R	FALSE	FALSE
Balistidae	<i>Xanthichthys auromarginatus</i>	2	Z	Z	I	S1	FALSE	FALSE
Balistidae	<i>Xanthichthys mento</i>	5	Z	Z	I	S1	FALSE	FALSE
Labridae	<i>Xyrichtys woodi</i>	8	MI	S	E	R	FALSE	FALSE
Zanclidae	<i>Zanclus cornutus</i>	2	SI	S	I	S1	FALSE	TRUE
Acanthuridae	<i>Zebrasoma flavescens</i>	2	Hgd	H	I	S1	FALSE	TRUE
Acanthuridae	<i>Zebrasoma veliferum</i>	2	Hgd	H	I	S1	TRUE	TRUE

Appendix II. Results of analysis of fish length and weight for 109 species.

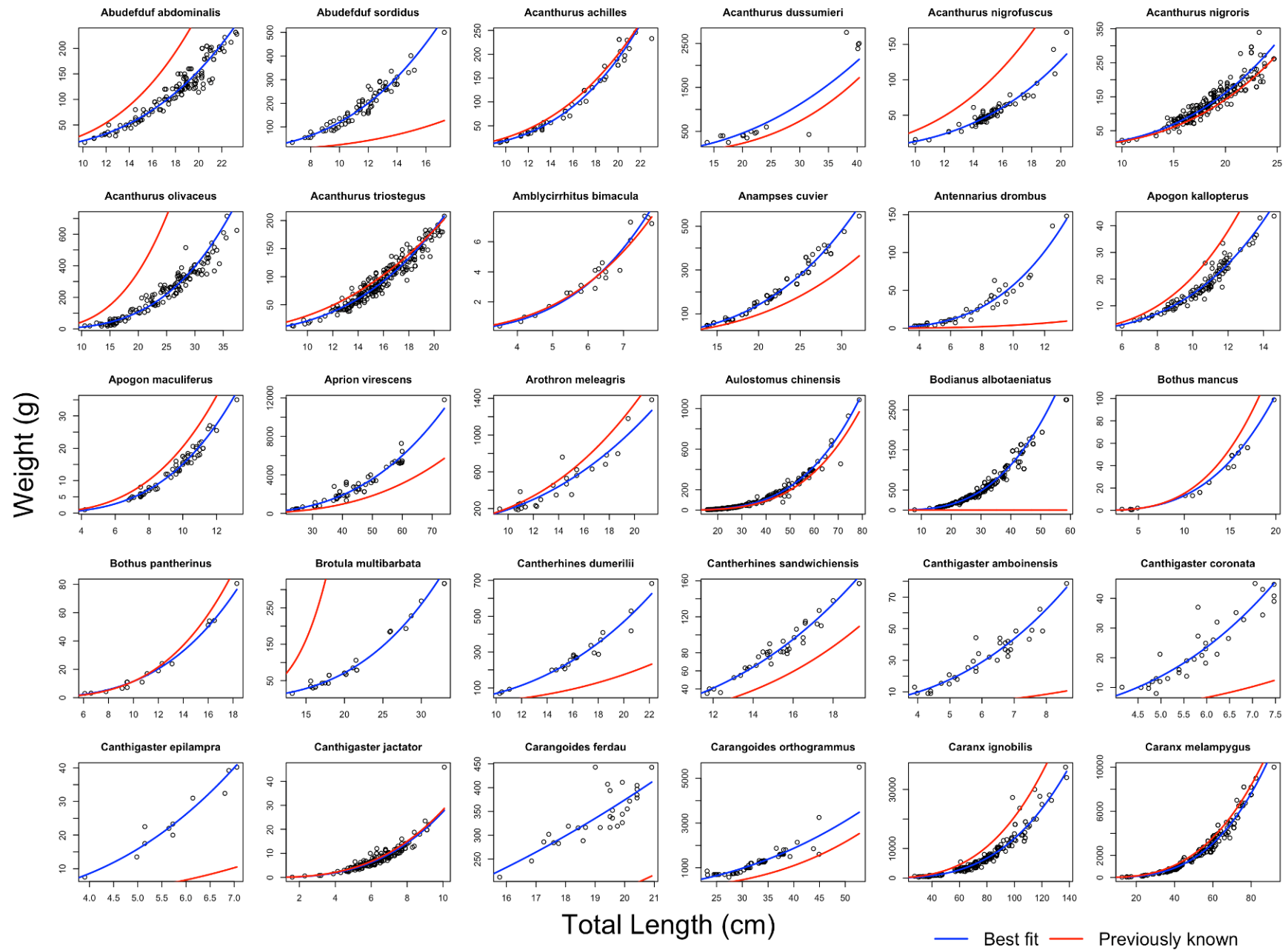
Family	Species	N	log(<i>a</i>)	SE log(<i>a</i>)	SE <i>b</i>	R ²	<i>p</i>	<i>a</i>	<i>b</i>
Pomacentridae	<i>Abudefduf abdominalis</i>	147	-4.061	0.169	0.058	0.95	<0.001	0.017	3.039
Pomacentridae	<i>Abudefduf sordidus</i>	74	-1.760	0.200	0.082	0.94	<0.001	0.174	2.838
Acanthuridae	<i>Acanthurus achilles</i>	54	-4.741	0.140	0.051	0.99	<0.001	0.009	3.335
Acanthuridae	<i>Acanthurus dussumieri</i>	16	-0.488	0.850	0.266	0.83	<0.001	0.656	2.187
Acanthuridae	<i>Acanthurus nigrofusus</i>	85	-5.082	0.268	0.099	0.93	<0.001	0.006	3.314
Acanthuridae	<i>Acanthurus nigroris</i>	234	-3.757	0.184	0.063	0.90	<0.001	0.024	2.948
Acanthuridae	<i>Acanthurus olivaceus</i>	151	-4.966	0.207	0.066	0.94	<0.001	0.007	3.211
Acanthuridae	<i>Acanthurus triostegus</i>	231	-4.084	0.147	0.053	0.94	<0.001	0.017	3.102
Cirrhitidae	<i>Amblycirrhitis bimacula</i>	22	-5.281	0.238	0.133	0.97	<0.001	0.005	3.593
Labridae	<i>Anampses cuvier</i>	161	-4.112	0.096	0.032	0.98	<0.001	0.016	3.024
Antennariidae	<i>Antennarius drombus</i>	44	-3.280	0.198	0.102	0.96	<0.001	0.039	3.168
Apogonidae	<i>Apogon kallopterus</i>	114	-4.630	0.153	0.065	0.95	<0.001	0.010	3.168
Apogonidae	<i>Apogon maculiferus</i>	66	-4.828	0.140	0.063	0.98	<0.001	0.008	3.274
Lutjanidae	<i>Aprion virescens</i>	75	-2.918	0.281	0.075	0.95	<0.001	0.055	2.834
Tetraodontidae	<i>Arothron meleagris</i>	27	-0.546	0.498	0.191	0.87	<0.001	0.593	2.505
Aulostomidae	<i>Aulostomus chinensis</i>	230	-7.936	0.089	0.025	0.99	<0.001	0.000	3.417
Labridae	<i>Bodianus albotaeeniatus</i>	464	-3.883	0.053	0.016	0.99	<0.001	0.021	2.955
Bothidae	<i>Bothus mancus</i>	31	-4.301	0.235	0.093	0.97	<0.001	0.014	2.974
Bothidae	<i>Bothus pantherinus</i>	18	-4.791	0.298	0.124	0.98	<0.001	0.008	3.135
Ophidiidae	<i>Brotula multibarbata</i>	29	-5.270	0.337	0.112	0.97	<0.001	0.005	3.181
Monacanthidae	<i>Cantherhines dumerilii</i>	22	-2.149	0.266	0.096	0.98	<0.001	0.117	2.770
Monacanthidae	<i>Cantherhines sandwichiensis</i>	38	-3.600	0.310	0.114	0.95	<0.001	0.027	2.940
Tetraodontidae	<i>Canthigaster amboinensis</i>	33	-1.418	0.280	0.156	0.90	<0.001	0.246	2.660
Tetraodontidae	<i>Canthigaster coronata</i>	33	-2.145	0.399	0.227	0.85	<0.001	0.120	2.950
Tetraodontidae	<i>Canthigaster epilampra</i>	11	-1.668	0.409	0.235	0.94	<0.001	0.190	2.749
Tetraodontidae	<i>Canthigaster jactator</i>	185	-3.379	0.102	0.055	0.94	<0.001	0.035	2.898
Carangidae	<i>Carangoides ferdau</i>	29	-0.470	0.753	0.255	0.72	<0.001	0.627	2.133
Carangidae	<i>Carangoides orthogrammus</i>	59	-0.797	0.389	0.112	0.88	<0.001	0.456	2.255
Carangidae	<i>Caranx ignobilis</i>	229	-4.673	0.156	0.037	0.97	<0.001	0.009	3.075
Carangidae	<i>Caranx melampygus</i>	265	-4.807	0.089	0.023	0.99	<0.001	0.008	3.135
Pomacanthidae	<i>Centropyge potteri</i>	62	-2.565	0.311	0.136	0.86	<0.001	0.078	2.622
Serranidae	<i>Cephalopholis argus</i>	1201	-4.464	0.063	0.018	0.96	<0.001	0.012	3.140

Family	Species	N	log(<i>a</i>)	SE log(<i>a</i>)	SE <i>b</i>	R ²	<i>p</i>	<i>a</i>	<i>b</i>
Chaetodontidae	<i>Chaetodon auriga</i>	23	-4.052	0.503	0.179	0.94	<0.001	0.017	3.159
Chaetodontidae	<i>Chaetodon fremblii</i>	128	-4.279	0.264	0.106	0.88	<0.001	0.014	3.221
Chaetodontidae	<i>Chaetodon lunulatus</i>	66	-3.452	0.337	0.131	0.89	<0.001	0.032	2.977
Chaetodontidae	<i>Chaetodon miliaris</i>	98	-4.895	0.160	0.065	0.97	<0.001	0.008	3.495
Chaetodontidae	<i>Chaetodon multicinctus</i>	31	-4.073	0.158	0.069	0.99	<0.001	0.017	3.230
Chaetodontidae	<i>Chaetodon ornatissimus</i>	20	-3.688	0.310	0.113	0.98	<0.001	0.025	3.144
Scaridae	<i>Chlorurus perspicillatus</i>	51	-3.928	0.111	0.034	0.99	<0.001	0.020	3.039
Scaridae	<i>Chlorurus spilurus</i>	33	-4.888	0.143	0.050	0.99	<0.001	0.008	3.352
Pomacentridae	<i>Chromis ovalis</i>	116	-2.409	0.177	0.066	0.92	<0.001	0.091	2.413
Cirrhitidae	<i>Cirrhitops fasciatus</i>	101	-4.158	0.271	0.122	0.87	<0.001	0.016	3.090
Cirrhitidae	<i>Cirrhitus pinnulatus</i>	273	-4.851	0.131	0.043	0.96	<0.001	0.008	3.361
Blenniidae	<i>Cirripectes vanderbilti</i>	22	-5.236	0.210	0.126	0.98	<0.001	0.005	3.559
Labridae	<i>Coris flavovittata</i>	296	-5.338	0.031	0.009	1.00	<0.001	0.005	3.347
Labridae	<i>Coris venusta</i>	225	-4.993	0.122	0.048	0.95	<0.001	0.007	3.245
Acanthuridae	<i>Ctenochaetus strigosus</i>	442	-3.646	0.080	0.031	0.95	<0.001	0.026	2.939
Labridae	<i>Cymolutes lecluse</i>	24	-4.676	0.353	0.129	0.96	<0.001	0.009	3.129
Pomacentridae	<i>Dascyllus albisella</i>	170	-4.129	0.079	0.035	0.98	<0.001	0.016	3.284
Scorpaenidae	<i>Dendrochirus barberi</i>	55	-4.200	0.275	0.129	0.91	<0.001	0.016	3.037
Tripterygiidae	<i>Enneapterygius atriceps</i>	58	-5.203	0.082	0.096	0.96	<0.001	0.006	3.659
Labridae	<i>Epibulus insidiator</i>	61	-3.157	0.184	0.060	0.97	<0.001	0.043	2.733
Gobiidae	<i>Eviota epiphanes</i>	144	2.591	0.043	0.091	0.86	<0.001	0.135	2.692
Fistulariidae	<i>Fistularia commersonii</i>	51	-11.122	0.489	0.115	0.96	<0.001	0.000	3.804
Chaetodontidae	<i>Forcipiger flavissimus</i>	60	-5.742	0.276	0.105	0.95	<0.001	0.003	3.538
Labridae	<i>Gomphosus varius</i>	92	-3.967	0.131	0.048	0.97	<0.001	0.019	2.785
Cheilodactylidae	<i>Goniistius vittatus</i>	368	-5.498	0.131	0.048	0.99	<0.001	0.004	3.363
Muraenidae	<i>Gymnothorax eurostus</i>	138	-6.970	0.167	0.049	0.97	<0.001	0.001	3.277
Muraenidae	<i>Gymnothorax flavimarginatus</i>	18	-5.738	1.175	0.268	0.88	<0.001	0.003	2.941
Labridae	<i>Halichoeres ornatissimus</i>	83	-3.024	0.168	0.083	0.94	<0.001	0.049	2.914
Priacanthidae	<i>Heteropriacanthus cruentatus</i>	32	-3.886	0.245	0.078	0.98	<0.001	0.021	2.897
Labridae	<i>Iiniistius pavo</i>	137	-0.611	0.355	0.115	0.72	<0.001	0.556	2.165
Kyphosidae	<i>Kyphosus bigibbus</i>	42	-5.431	0.368	0.110	0.96	<0.001	0.004	3.405
Lutjanidae	<i>Lutjanus kasmira</i>	273	-4.194	0.119	0.040	0.95	<0.001	0.015	2.985
Labridae	<i>Macropharyngodon geoffroy</i>	43	-3.958	0.223	0.093	0.96	<0.001	0.019	3.015

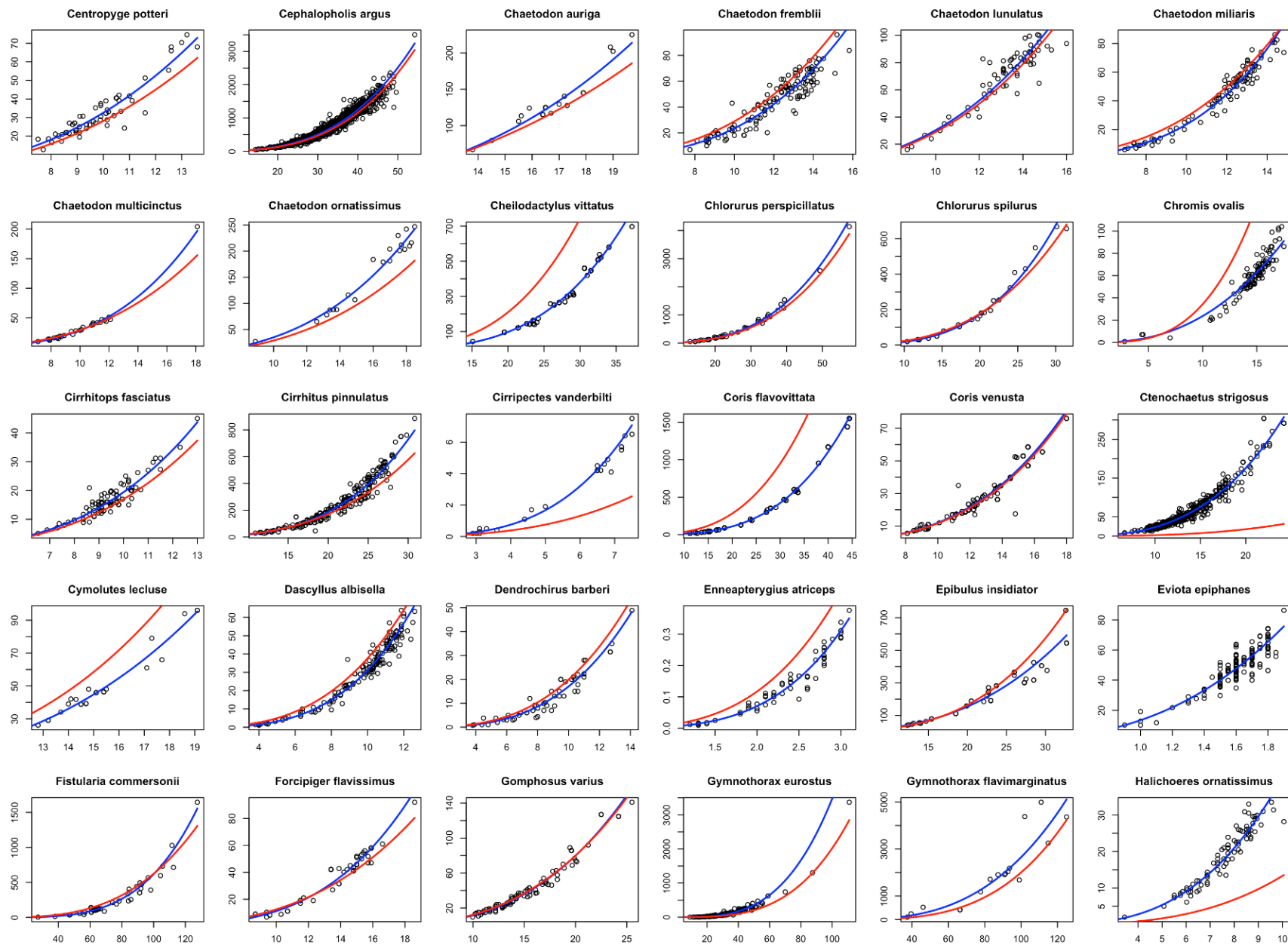
Family	Species	N	log(<i>a</i>)	SE log(<i>a</i>)	SE <i>b</i>	R ²	<i>p</i>	<i>a</i>	<i>b</i>
Balistidae	<i>Melichthys niger</i>	149	-4.439	0.115	0.036	0.98	<0.001	0.012	3.175
Balistidae	<i>Melichthys vidua</i>	107	-4.242	0.204	0.064	0.96	<0.001	0.014	3.203
Mullidae	<i>Mulloidichthys flavolineatus</i>	762	-5.033	0.071	0.022	0.96	<0.001	0.007	3.146
Mullidae	<i>Mulloidichthys vanicolensis</i>	556	-5.088	0.063	0.020	0.98	<0.001	0.006	3.199
Ophichthidae	<i>Myrichthys magnificus</i>	11	-9.796	0.719	0.196	0.97	<0.001	0.000	3.573
Holocentridae	<i>Myripristis amaena</i>	58	-4.859	0.415	0.129	0.92	<0.001	0.008	3.274
Holocentridae	<i>Myripristis berndti</i>	96	-1.206	0.305	0.113	0.83	<0.001	0.302	2.415
Holocentridae	<i>Myripristis kuntzei</i>	17	-4.342	0.300	0.102	0.98	<0.001	0.013	3.093
Acanthuridae	<i>Naso lituratus</i>	105	-0.974	0.184	0.057	0.92	<0.001	0.386	1.990
Acanthuridae	<i>Naso unicornis</i>	67	-2.927	0.100	0.031	0.99	<0.001	0.054	2.635
Holocentridae	<i>Neoniphon sammara</i>	188	-4.040	0.099	0.034	0.97	<0.001	0.018	2.924
Labridae	<i>Oxycheilinus unifasciatus</i>	110	-3.494	0.080	0.032	0.99	<0.001	0.031	3.167
Cirrhitidae	<i>Paracirrhites arcatus</i>	106	-4.100	0.171	0.073	0.94	<0.001	0.017	3.060
Cirrhitidae	<i>Paracirrhites forsteri</i>	220	-4.190	0.085	0.031	0.98	<0.001	0.015	3.091
Mullidae	<i>Parupeneus cyclostomus</i>	129	-4.881	0.080	0.025	0.99	<0.001	0.008	3.160
Mullidae	<i>Parupeneus insularis</i>	59	-5.009	0.246	0.079	0.97	<0.001	0.007	3.247
Mullidae	<i>Parupeneus multifasciatus</i>	983	-4.690	0.076	0.025	0.94	<0.001	0.009	3.121
Mullidae	<i>Parupeneus pleurostigma</i>	350	-4.596	0.053	0.017	0.99	<0.001	0.010	3.088
Mullidae	<i>Parupeneus porphyreus</i>	181	-4.625	0.094	0.028	0.99	<0.001	0.010	3.143
Monacanthidae	<i>Pervagor spilosoma</i>	96	-4.198	0.169	0.071	0.95	<0.001	0.015	3.089
Pomacentridae	<i>Plectroglyphidodon johnstonianus</i>	13	-4.328	0.384	0.189	0.96	<0.001	0.013	3.295
Priacanthidae	<i>Priacanthus meeki</i>	225	-4.359	0.092	0.030	0.98	<0.001	0.013	3.045
Holocentridae	<i>Sargocentron diadema</i>	169	-4.455	0.089	0.034	0.98	<0.001	0.012	3.106
Holocentridae	<i>Sargocentron spiniferum</i>	73	-3.303	0.548	0.154	0.83	<0.001	0.037	2.851
Holocentridae	<i>Sargocentron tiere</i>	38	-1.672	0.241	0.072	0.97	<0.001	0.189	2.321
Holocentridae	<i>Sargocentron xantherythrum</i>	64	-3.850	0.289	0.116	0.91	<0.001	0.021	2.904
Synodontidae	<i>Saurida gracilis</i>	138	-5.110	0.145	0.050	0.97	<0.001	0.006	3.122
Scaridae	<i>Scarus dubius</i>	40	-4.154	0.171	0.059	0.99	<0.001	0.016	3.097
Scorpaenidae	<i>Scorpaenodes kelloggi</i>	28	-4.530	0.228	0.202	0.91	<0.001	0.011	3.256
Scorpaenidae	<i>Scorpaenopsis cacopsis</i>	31	-4.176	0.073	0.025	1.00	<0.001	0.015	3.136
Scorpaenidae	<i>Scorpaenopsis diabolus</i>	101	-4.437	0.171	0.060	0.97	<0.001	0.012	3.321
Scorpaenidae	<i>Sebastapistes ballieui</i>	154	-4.694	0.134	0.067	0.94	<0.001	0.009	3.418
Scorpaenidae	<i>Sebastapistes coniota</i>	49	-3.984	0.189	0.099	0.95	<0.001	0.019	3.115

Family	Species	N	log(<i>a</i>)	SE log(<i>a</i>)	SE <i>b</i>	R ²	<i>p</i>	<i>a</i>	<i>b</i>
Pomacentridae	<i>Stegastes marginatus</i>	20	-4.815	0.436	0.189	0.95	<0.001	0.008	3.431
Labridae	<i>Stethojulis balteata</i>	148	-4.430	0.163	0.066	0.94	<0.001	0.012	3.152
Balistidae	<i>Sufflamen bursa</i>	166	-3.449	0.089	0.032	0.98	<0.001	0.032	2.893
Synodontidae	<i>Synodus binotatus</i>	13	-3.879	0.361	0.166	0.97	<0.001	0.021	3.071
Synodontidae	<i>Synodus ulae</i>	10	-5.311	0.491	0.204	0.98	<0.001	0.005	3.616
Scorpaenidae	<i>Taenianotus triacanthus</i>	20	-3.625	0.479	0.230	0.90	<0.001	0.028	2.880
Labridae	<i>Thalassoma ballieui</i>	836	-4.140	0.037	0.012	0.99	<0.001	0.016	2.993
Labridae	<i>Thalassoma duperrey</i>	367	-3.631	0.068	0.026	0.97	<0.001	0.027	2.693
Labridae	<i>Thalassoma purpureum</i>	66	-5.106	0.210	0.065	0.98	<0.001	0.006	3.325
Zanclidae	<i>Zanclus cornutus</i>	55	-3.751	0.253	0.102	0.94	<0.001	0.024	3.060
Acanthuridae	<i>Zebrasoma flavescens</i>	556	-3.282	0.058	0.021	0.97	<0.001	0.038	2.860

Appendix III.



Weight (g)



Total Length (cm)

— Best fit — Previously known

