Data Review and Management Brief for the West Hawai‘i Commercial Aquarium Fishery

A Report to the State of Hawai‘i Board of Land and Natural Resources

March 2024
(updated July 2024)

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Executive Summary

This report has been prepared to inform the Board of Land and Natural Resources prior to future decision-making on whether to issue seven commercial aquarium fish permits for the West Hawaiʻi Regional Fishery Management Area (WHRFMA). Seven applicants have complied with the state of Hawaiʻi's environmental review process pursuant to the Hawaiʻi Environmental Policy Act (HEPA). As part of the HEPA process, the seven applicants have proposed annual Total Allowable Catch (TAC) limits for eight fish species.

The Division of Aquatic Resources (DAR) reviewed two monitoring data sets and commercial aquarium fisheries information from West Hawaiʻi, as well as relevant management measures. With no formal stock assessment for examining the sustainability of the eight "revised White List" species, DAR focused on assessing risk according to three key factors: population impact, ecosystem impact, and manageability (the ability to mitigate risk with realistic management measures and oversight). DAR limited this simple risk assessment to two classifications of risk: high and low. A high-risk fishery, for example, would be one in which the available datasets suggest significant negative population and ecological impacts are likely and management measures are unable to mitigate risks. Conversely, a low-risk fishery will have little to no evidence to suggest significant negative population or ecosystem impacts are likely and management measures are appropriate for mitigating risk.

The review of monitoring data suggests that although commercial aquarium fishing affects target species populations, the commercial aquarium fishery may not be a primary driver of fish density and abundance. The data suggest that populations of the eight fish species are relatively stable over time, and there is no strong evidence to suggest that overfishing was occurring. Comparison of the proposed TACs to estimated population sizes suggest that the fishery will remove a small percentage of each species within West Hawaiʻi and is not likely to threaten the viability of each population over time.

The management review suggests that existing and proposed management measures provide significant safeguards against threats to populations of the eight target species as well as threats to the ecosystem. Most notably, closure of approximately 47.7% of the West Hawaiʻi Coast where the fishery operates establishes a level of protection rarely seen in other fisheries. Along with statewide and fishery-specific regulations, multiple licensing requirements, total limits on catch, and annual monitoring, the West Hawaiʻi Aquarium Fishery is the most heavily State-managed fishery in Hawaiʻi.

After review, DAR finds there is low risk of major population or ecosystem degradation as a result of resuming this fishery as proposed.

1. Introduction

The inshore waters of West Hawai‘i are among the most intensively monitored and studied marine areas in the state. An ongoing point of contention in the region dating back to the early 1980’s has been the West Hawai‘i commercial aquarium fishery.[1] Despite extensive nearshore monitoring, five mandated legislative status reports, active management of the fishery, and a completed environmental review, stakeholder perceptions regarding the condition of both targeted aquarium fish populations and the overall health of the marine ecosystem in the West Hawai‘i Regional Fishery Management Area (WHRFMA) remain wildly variable.

The wide-ranging stakeholder viewpoints on the status of aquarium fish populations in West Hawai‘i are partially the result of confusion and/or ambiguity about fisheries sustainability. While the general concept of sustainability is easy to understand, setting it as a goal in a fisheries management context can be challenging especially in the absence of clear definitions. To date, sustainability definitions from a fisheries management standpoint (i.e., via stock assessment) have not been established for the West Hawai‘i Aquarium fishery. Without sustainability reference points, the fishery can still be managed via risk management, or using available data to assess risk of population and/or ecosystem decline resulting from fishing activity. Indicators of fish population status such as species density, density stability over time, trends in benthic communities, as well as management measures regulating a fishery can all provide valuable information regarding the overall health of a resource and potential future impacts. Though qualitative risk assessment is not as precise or detailed as more complex approaches to fisheries assessments, relatively simple review of available data and management can provide valuable insight for assessing resource status and evaluating future risks.

Currently, the commercial aquarium fishery in West Hawai‘i is closed pending issuance of permits by the Board of Land and Natural Resources (BLNR). On January 30, 2023 the Hawai‘i Environmental Court indicated that the environmental review process pursuant to the Hawai‘i Environmental Policy Act (HEPA) had been satisfied for the West Hawai‘i fishery and subsequently lifted the long-standing injunction prohibiting the Department of Land and Natural Resources (DLNR) from issuing aquarium collection permits within the WHRFMA. The preferred alternative proposed by the seven applicants in the Revised Final Environmental Impact Statement (RFEIS) outlined two major changes to the management of the West Hawai‘i aquarium fishery: a revised list of fish species which can be collected and annual Total Allowable Catch (TAC)[2] limits. The proposed “revised white list” reduced the number of fish species that could be collected from forty to eight fish species. The eight species and associated TACs include: yellow tang (*Zebrasoma flavescens*; TAC: 200,000), kole (*Ctenochaetus strigosus*; TAC: 30,000), orangespine unicornfish (*Naso lituratus*; TAC: 5,872), black surgeonfish (*Ctenochaetus hawaiiensis*; TAC: 3,152), Potter’s angelfish (*Centropyge potteri*; TAC: 4,376), brown surgeonfish (*Acanthurus nigrofuscus*; TAC: 800), bird wrasse (*Gomphosus varius*; TAC: 344), and Thompson’s surgeonfish (*Acanthurus thompsoni*; TAC: 2,016)[3].

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[1] See Appendix A – History of the West Hawai‘i Commercial Aquarium Fishery for more information.

[2] The total number of fish per species that can be taken within a year. Once met, all commercial catch of the species will cease till the following year.

[3] Species names used in this document were chosen to be consistent with those used in the RFEIS. See Appendix B – Species Profiles for Hawaiian names and other common names.

In this document, the Division of Aquatic Resources (DAR) provides a review of fisheries data to assess risks of the proposed TACs for the eight revised white list fish species in the WHRFMA. The data review is comprised of five main components:

- Overview of the available fishery-independent[4] data sets including a description of six indicators of fish population and ecosystem status
- Overview of the fishery-dependent monitoring and commercial harvest
- Evaluation of the proposed TACs
- Review of existing management and concerns specific to the West Hawai‘i aquarium fishery
- Summary of findings and conclusion

While performing the data review DAR asked the following questions:

1) Does the data examined suggest that the proposed take will result in population[5]-level declines that would affect the long-term viability of the population?

2) Does the data examined suggest that the proposed take will result in impacts to the ecosystem that would result in measurable declines in ecosystem health or the ability of the ecosystem to sustain itself?

3) Do current management measures mitigate potential negative effects of the fishery or provide safeguards against unforeseen changes?

These questions address three key facets relevant to assessing the risk of this fishery: population decline, ecosystem decline, and manageability (ability to mitigate risk with realistic management measures and oversight). DAR limited this simple risk assessment to two classifications of risk: high and low. A high-risk fishery, for example, would be one in which the available datasets suggest significant negative population and ecological impacts are likely and management measures are unable to mitigate risks. Conversely, a low-risk fishery will have little to no evidence to suggest significant negative population or ecosystem impacts are likely and management measures are appropriate for mitigating risk. DAR recognizes that uncertainty associated with this assessment is present, both relative to data quality and uncertainty about future changes due to non-fishing impacts. Such uncertainty is present in all Hawai‘i nearshore fisheries and their continued existence requires some acceptance of risk.

DAR also recognizes that there is substantial opposition to this fishery based on ethical and/or cultural values which may hold that any amount of take for commercial aquarium purposes should be prohibited regardless of management or resource condition. In this document DAR will not attempt to support nor challenge those beliefs nor will it focus on or provide recommendations based on economic impacts. Though DAR believes that ethical and cultural concerns are an important part of the decision-making process, providing a comprehensive discussion of these factors is beyond the scope of this document. This document is solely intended to provide BLNR members with a data and management review relevant to the status of the resource.

[4] The term “fishery-independent” means that there is no reliance on commercial or non-commercial fishery catch data. Conversely, the term “fishery-dependent” indicates reliance on commercial or non-commercial fishery catch data.

[5] Here population refers to the local population of juvenile and adult fish that reside within the WHRFMA. This does not consider any connectivity with East Hawaii or other regions known to be connected to fish populations in the WHRMA via larval dispersal.

2. Overview of Fishery-Independent Monitoring

There are two main fishery-independent datasets relevant to the discussion regarding the future of the West Hawaiʻi Aquarium Fishery. They include:

1) DAR West Hawaiʻi Aquarium Project (WHAP) Surveys

   and

2) Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) Surveys

Though both datasets are derived from Underwater Visual Surveys (UVS), there are some key differences between the two monitoring programs as their intended goals and survey designs differ greatly. In this section we will provide an overview of WHAP and PIFSC-ESD datasets including their strengths, weaknesses, and most appropriate uses.

2.1 WHAP

WHAP was designed to answer two main questions related directly to the creation of the system of Fish Replenishment Areas (FRAs) within the West Hawaiʻi Regional Fishery Management Area (WHRFMA; DAR 2019):

1) How effective is the network of FRAs for increasing the abundance of fish species targeted by the aquarium fishery within FRAs?

   and

2) How will the FRA network (reduction of areas open to fishing) influence the abundance of fish species targeted by the aquarium fishery in remaining areas open to fishing?

WHAP attempts to answer these two questions by tracking and comparing fish abundance in areas open to aquarium fishing and those closed to aquarium fishing. Sites tracked for comparison belong to one of three management area types: FRAs (aquarium fishing prohibited in 2000), sites open to aquarium fish collection (OPEN), and long-term protected areas (LTPs; marine managed areas in West Hawaiʻi that had been closed to aquarium collecting since at least 1991). Fish communities at each site were surveyed between three and seven times each year from 1999 to 2021, mostly between the months of May and December (exception - only 1 survey was conducted at each site in 2020, due to the global pandemic). Starting in 2022, each site is now surveyed once annually, typically in July. Today, the WHAP data set includes over twenty years of fish abundance data across 23 permanent sites along the West Hawaiʻi coastline (Figure 1).

Because factors other than fishing can affect fish abundance, WHAP utilized a survey design known as Before-After-Control-Impact (BACI) to control for non-fishing factors that may differ between sites. The BACI survey design used by WHAP is comprised of two components:

1) Before-after: WHAP surveys began in 1999, one year before the establishment of the FRA network.

   and

2) Control-impact: FRA compared to adjacent LTP as well as OPEN compared to adjacent LTP.

The Before-After component allows researchers to define the degree of change occurring between the pre-implementation and post-implementation periods. The Control-Impact component allows researchers to determine what degree of that change can be attributed to the management action alone by comparison to the unchanged environment (control sites).

Because WHAP focused specifically on the impacts of the FRAs in mitigating the effects of the commercial aquarium fishery, sites were selected in the 10-18 m depth range in areas of abundant finger coral (*Porites compressa*) where the fishery and its primary target species (yellow tang) mainly occur. It's important to note that this excludes shallow water (< 10 m), deep water (> 18 m), and non-finger coral dominated reefs in the 10-18 m depth range where species targeted by the commercial aquarium fishery may also occur.

WHAP fish counts were performed as belt transects, or surveys in which divers made observations while swimming along a straight path along the seafloor (Walsh et al. 2013). Each site consists of four transects, arrayed in an “H” pattern with two transects oriented shallower and two oriented deeper. The transects used by WHAP are 25 m in length and in fixed locations, i.e., they did not change for the life of the survey. A pair of divers surveyed each 25 m long permanent transect making two passes and counting different portions of the fish community within 2 m of the transect on each pass. On the outward pass, larger planktivores and wide-ranging fishes within 4 m of the bottom were recorded. On the return pass, fish closely associated with the bottom, new recruits, and fishes hiding in cracks and crevices were recorded. Fish were recorded at the species level, but sizing of fish did not begin until 2003 when surveyors began using 5 cm size classes. Prior to 2002, fish were recorded as recruits, juveniles, adults, and terminal adults.

In addition to the fish surveys, WHAP incorporated benthic surveys starting in 2003 in order to track changes in coral cover (Walsh et al. 2013). These surveys were completed once every three to four years, however an extra survey was completed in 2016 following the 2015 mass coral bleaching event experienced in West Hawai‘i. Divers photographed the seafloor at one-meter intervals along each transect at all WHAP sites. Photos were taken at a fixed distance from the bottom to standardize the total area imaged. These images were then analyzed on land using standardized image analysis processes where 20 randomized points are overlaid on each image. An analyst then records the organism or other space occupier underneath each point. Data are then summarized by site as the percent of total points occupied by each species/group.

2.1.1 Best Use of the Dataset and Caveats

Given its design, the best use of the WHAP dataset is to track and compare site-level changes within permanently marked areas. Additionally, WHAP is a valuable dataset for monitoring ecosystem health. WHAP’s long time series at permanent transects can offer important insight on temporal change of benthic and fish communities. The spatial scale of WHAP sites (four 25 meter transect) is relatively small, however, and trends at WHAP sites may not reflect fish or benthic patterns within respective FRAs, LTPs, or proximate open areas due to the high spatial heterogeneity inherent in coral reef ecosystems. Because WHAP surveys are spatially limited, and habitat type specific, caution should be used when inferring that trends observed in the WHAP dataset are indicative of the entire population. The WHAP dataset should not be used to create population-level estimates of abundance because the narrow proportion of habitat sampled may not be adequately representative of West Hawai‘i reefs broadly and may exclude the preferred habitat for certain species or life stages.

Another consideration regarding the use of WHAP data relates to the BACI survey design. The original objective of WHAP was to compare site-level trends in FRAs and open areas with adjacent LTP control sites. Research questions change and WHAP data have commonly been used to compare WHRFMA-wide mean trends by management area type. Mean trends by management area type may overlook site-level variability which the original BACI survey design attempted to control for. Caution should be taken when inferring that mean trends are representative of all sites. For this reason, whenever management status means are presented in this report, site-level trends are also included.

Figure 1. West Hawai'i Aquarium Project (WHAP) survey sites.

2.2 PIFSC-ESD

Unlike WHAP, PIFSC-ESD surveys are not designed to provide detailed information about how a particular site changes over time. Rather, the objective of PIFSC-ESD surveys is to describe overall fish abundances over large spatial scales. Because PIFSC-ESD surveys are used to describe "population level" patterns, the survey design covers a wide range of depths and habitat types.

PIFSC-ESD surveys in the Main Hawaiian Islands (MHI) are based on a stratified random sampling design. The PIFSC-ESD survey design targets hard-bottom (not sand) habitat in water shallower than 30 m. This area is further divided into depth categories called strata (0-6m, 6-18m, 18-30m). The areas surveyed in the main Hawaiian Islands are all considered 'forereef',[6] and are further stratified into sectors per island that reflect broad differences in oceanographic exposure, reef structure, and local human population density. Survey sites are randomly selected within each stratum allowing data summaries such as density and abundance to be calculated for each strata as well as the entire island. While the survey design's primary intent is to summarize data at the island scale, finer spatial scale summaries, for example density and abundance estimates for West Hawaiʻi, may be informative with appropriate data review.

Instead of belt transects (as used by WHAP), PIFSC-ESD uses stationary point counts (SPC). In this method, surveys are paired along a 30-m transect with two divers counting in adjacent, 7.5-m radius cylinders. Surveys begin with a five-minute species enumeration period in which divers list all species within their cylinders. Counts and sizes are not taken in the first five minutes with the exception of rare or highly mobile species (those that may not remain in the cylinder till the count and sizing period occurs). After five minutes the divers begin sizing and counting fish, systematically working through the species on their list and recording the number and size of each fish. Fishes are sized to the nearest cm in total length. To the extent possible, divers remain at the center of their cylinders throughout the count; however, to survey cryptic species, the divers swim through their plots to search for these fish at the end of their survey (Ayotte et al. 2011).

The benthic survey component is conducted after the SPC survey. Both divers visually survey their respective cylinders estimating slope, benthic cover, habitat type, and habitat complexity. The visual benthic survey is accompanied by photoquadrats taken along the 30 m transect line. Photos are taken at 1-m intervals at a fixed height of 1 m above the sea floor (Ayotte et al. 2011).

2.2.1 Best Use of the Dataset and Caveats

PIFSC-ESD data are best used to provide insight into population-level abundance across broad geographic areas and habitat types. Because the survey encounters multiple fish species, population-level data for rare species or species with patchy distributions can be highly uncertain. Population estimates only reflect the 0-30 m depth range, and do not account for fish that may live deeper. PIFSC-ESD surveys are not annual, occurring once every three or more years. While all surveys were conducted between June and October, the nature of ship-based research also presents logistical constraints that may impact survey coverage in certain years. For analysis purposes, MHI data from years 2010 and 2012, as well as data from 2013 and 2015 were pooled[7] because logistical constraints required sampling effort to be split over multiple years (Figure 2).

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[6] Islands/atolls in the Northwest Hawaiʻian Islands include additional strata for backreef and lagoon zones.

[7] All West Hawaiʻi surveys were completed in 2010

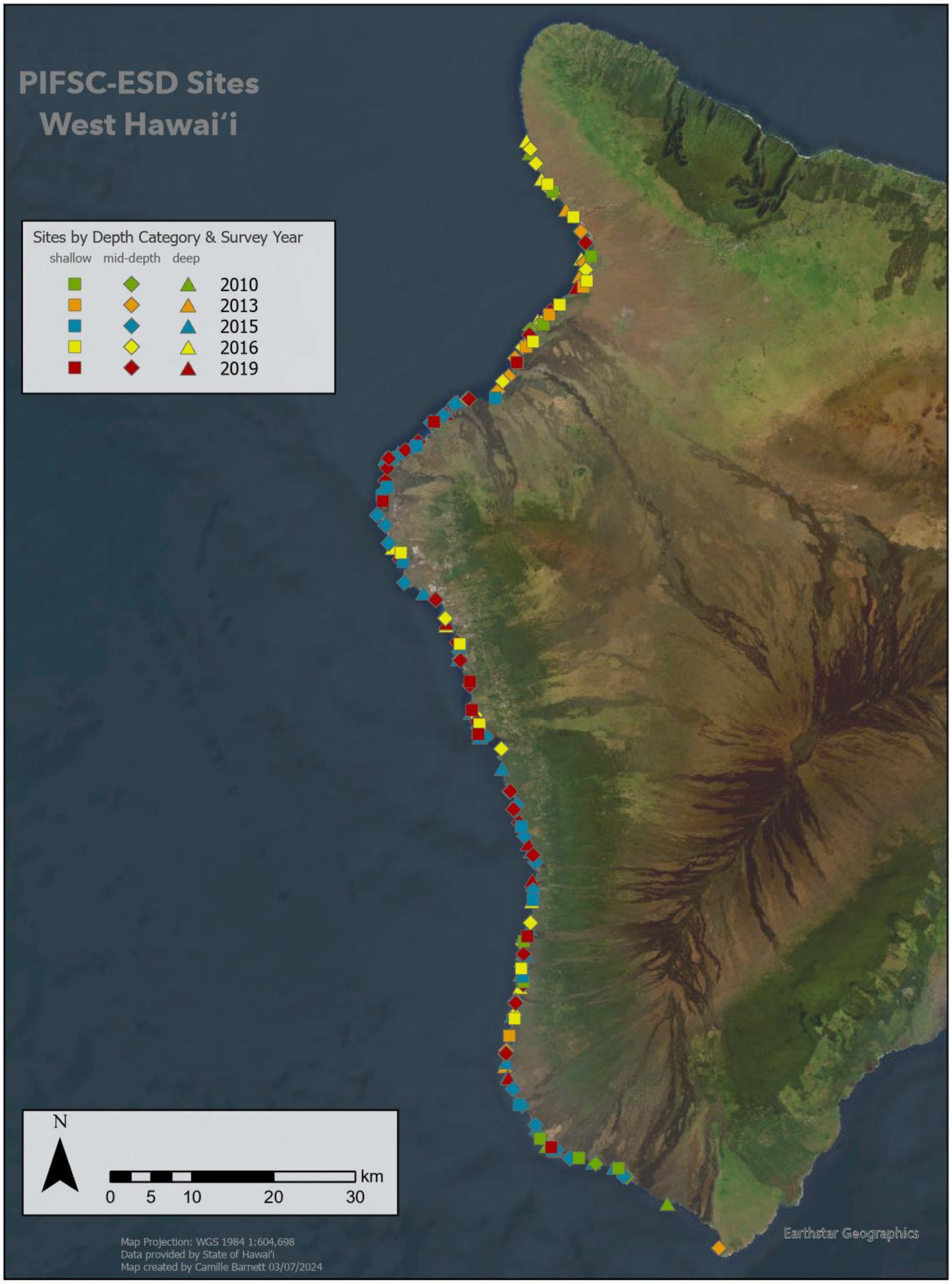


Figure 2. Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) survey sites.

3. Indicators of Fish Population & Ecosystem Status

3.1 Assessing Uncertainty of the PIFSC-ESD Population Estimates

The PIFSC-ESD data set can be used to describe density and abundance[8] for multiple species but the uncertainty of species-specific abundance information can be quite variable. Low sample sizes, or high spatial patchiness of species presence/absence can affect how well PIFSC-ESD data capture the "true" abundance of a species. The coefficient of variation (CV) provides insight into the uncertainty or data quality of species-specific abundance estimates. A CV less than 0.2 indicates good data quality, a CV between 0.2-0.3 indicates acceptable data quality, a CV between 0.3-0.5 indicates marginal data quality, and CV's greater than 0.5 indicates poor data quality.

For combined PIFSC-ESD data between 2010-2019, all species excluding Thompson's surgeonfish had CV values less than 0.2 (Figure 3). Four species including yellow tang, kole, brown surgeonfish, and orangespine unicornfish, had CV value less than 0.1. The CV for Thompson's surgeonfish fell between 0.2-0.3 suggesting an acceptable, but not great data quality. Species CVs for individual survey years reflect more variability and higher values as sample sizes decreased. At the individual year level, yellow tang, kole, orangespine unicornfish, Potter's angelfish, brown surgeonfish, and bird wrasse all fell between 0-0.3 or within the range of good to acceptable data quality (Figure 4). CVs for black surgeonfish were mainly below 0.3 (good to acceptable data quality), with a single year falling in the 0.3-0.5 range (marginal data quality). For Thompson's surgeonfish, two CVs were withing the 0.3-0.5 range (marginal data quality) and two CVs were greater than 0.5 (poor data quality).

[8] Details on density and abundance calculations are provided in multiple publications and reports by PIFSC-ESD.

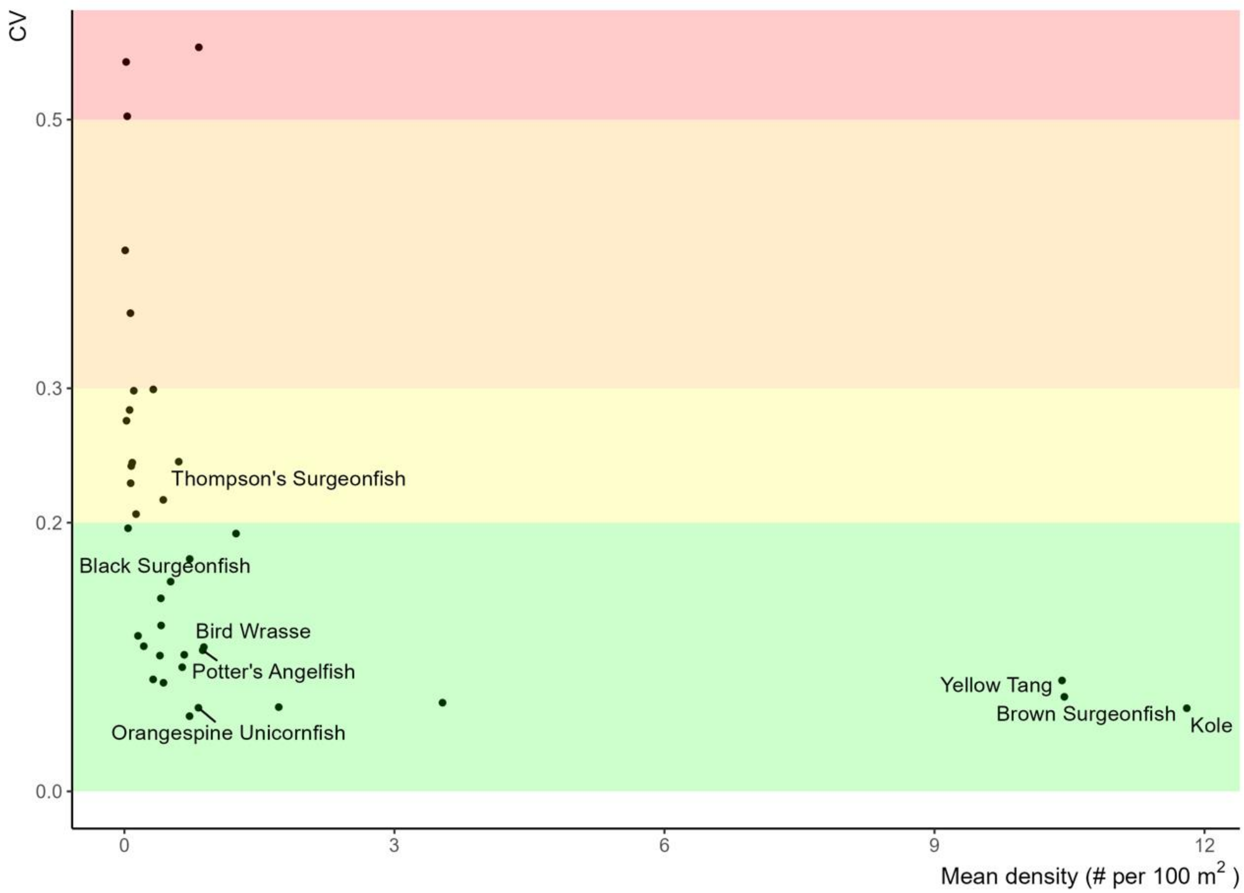


Figure 3. Coefficient of Variation (CV) and density (# per 100 m^2) for the 40 original white list species within the West Hawaiʻi Regional Fishery Management Area (WHRFMA), Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) data combined for years 2010-2019.

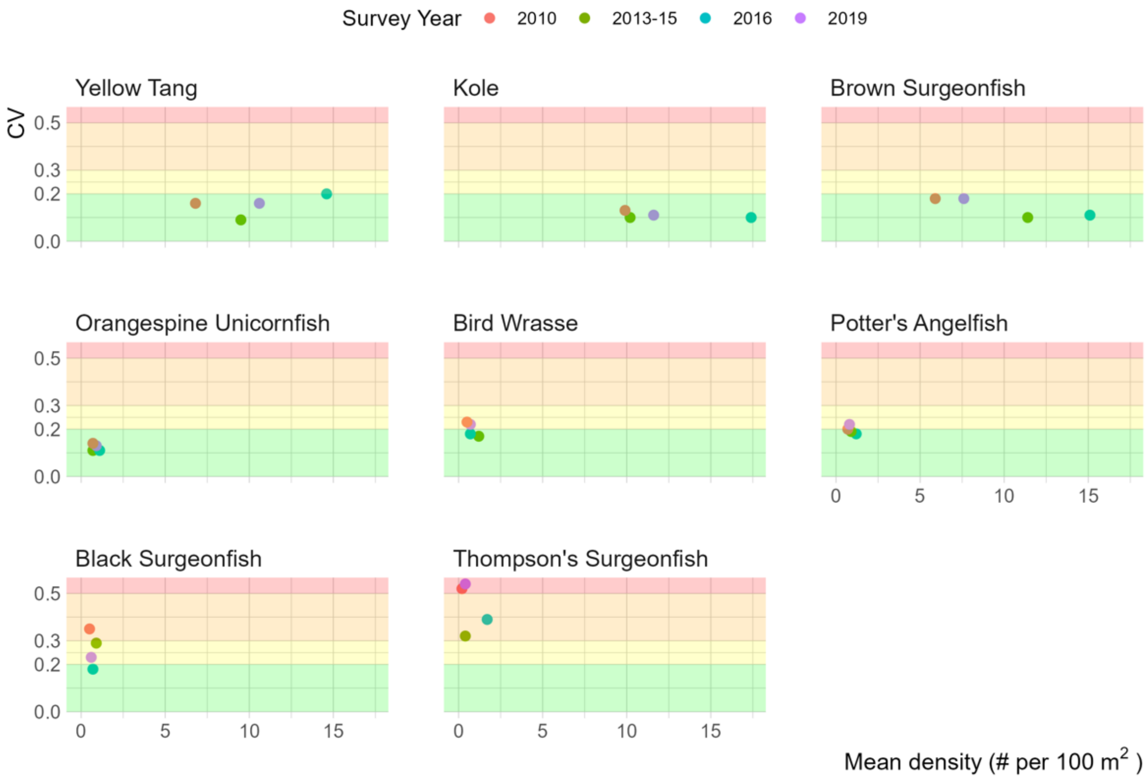
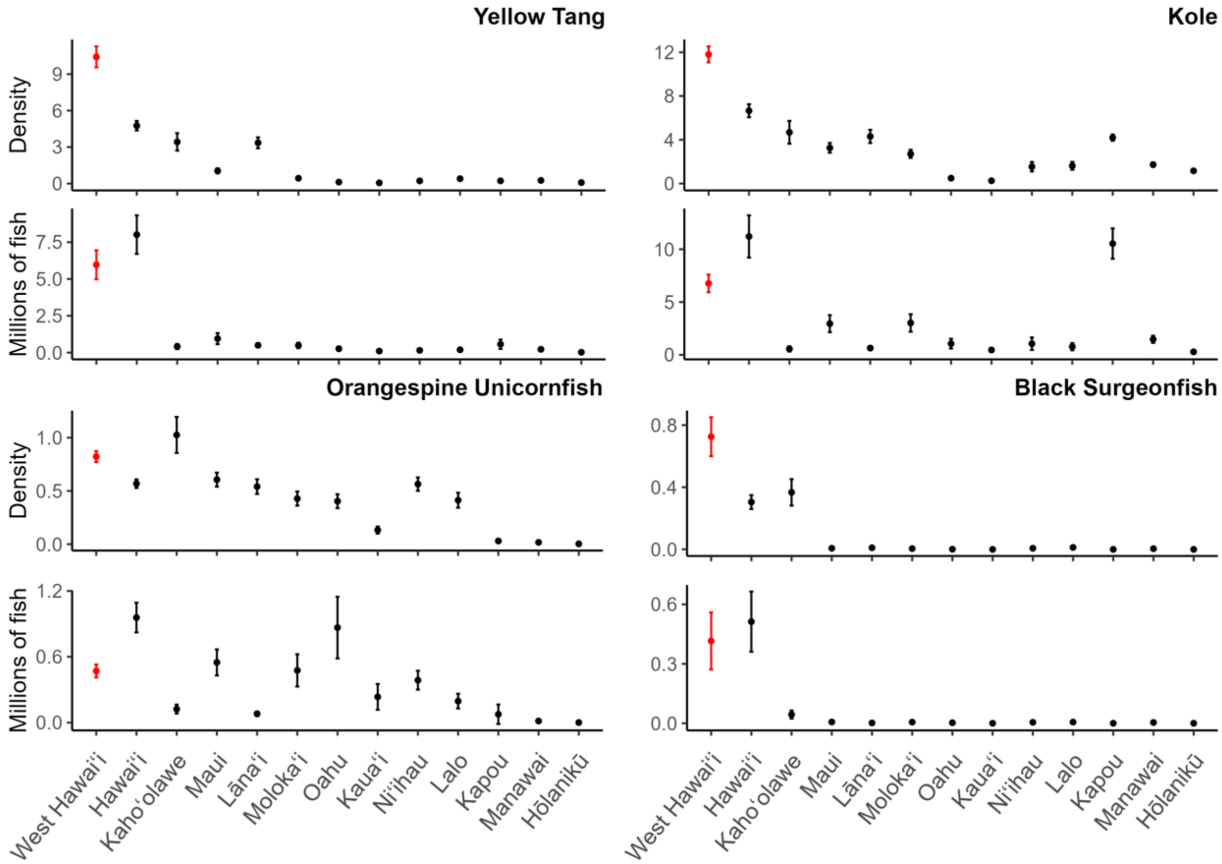


Figure 4. Coefficient of Variation (CV) and density (# per 100 m^2) for each of the 8 revised white list species. Points represent the four time periods used for estimating mean density within the West Hawai'i Regional Fishery Management Area (WHRFMA) between 2010-2019.

3.2 Density and Abundance Across the Hawaiʻian Archipelago (PIFSC-ESD)

WHRFMA density and population estimates for the eight species were compared to the rest of the Hawaiʻian archipelago to evaluate whether fish abundances in West Hawaiʻi are unique. Fishing pressure and other human impacts on these species vary greatly across the archipelago. So too do the oceanographic and other environmental conditions that may influence habitat suitability and populations size. Comparison across this diverse area provides insight into factors that influence fish density and population size.

Densities and abundances of the eight species within the WHRFMA were generally high relative to the rest of the archipelago (Figure 5). Species density was generally highest in the southern end of the archipelago (Hawaiʻi Island) becoming progressively less with northward movement up the island chain. Abundance followed this same general pattern for most of the species though with more variability as spatial extent of the reef area (inhabitable reef area) varied by island. The exception, the Potter's angelfish, was unique in its distribution with the WHRFMA population showing high mean density and abundance relative to other areas of the MHI, but below mean density and abundance in the Northwest Hawaiʻian Islands (NWHI). At the scale of the Hawaiʻian archipelago, these data suggest that low mean density and abundance of these species is not necessarily indicative of increased fishing pressure, particularly that of the commercial aquarium fishery. For seven of the eight species considered, WHRFMA populations exceeded those of the NWHI, where all fishing is prohibited.



Yellow Tang
Kole
Orangespine Unicornfish
Black Surgeonfish
Density
Millions of fish
West Hawai'i
Hawai'i
Kaho'olawe
Maui
Lāna'i
Moloka'i
Oahu
Kaua'i
Ni'ihau
Lalo
Kapou
Manawai
Hōlanikū

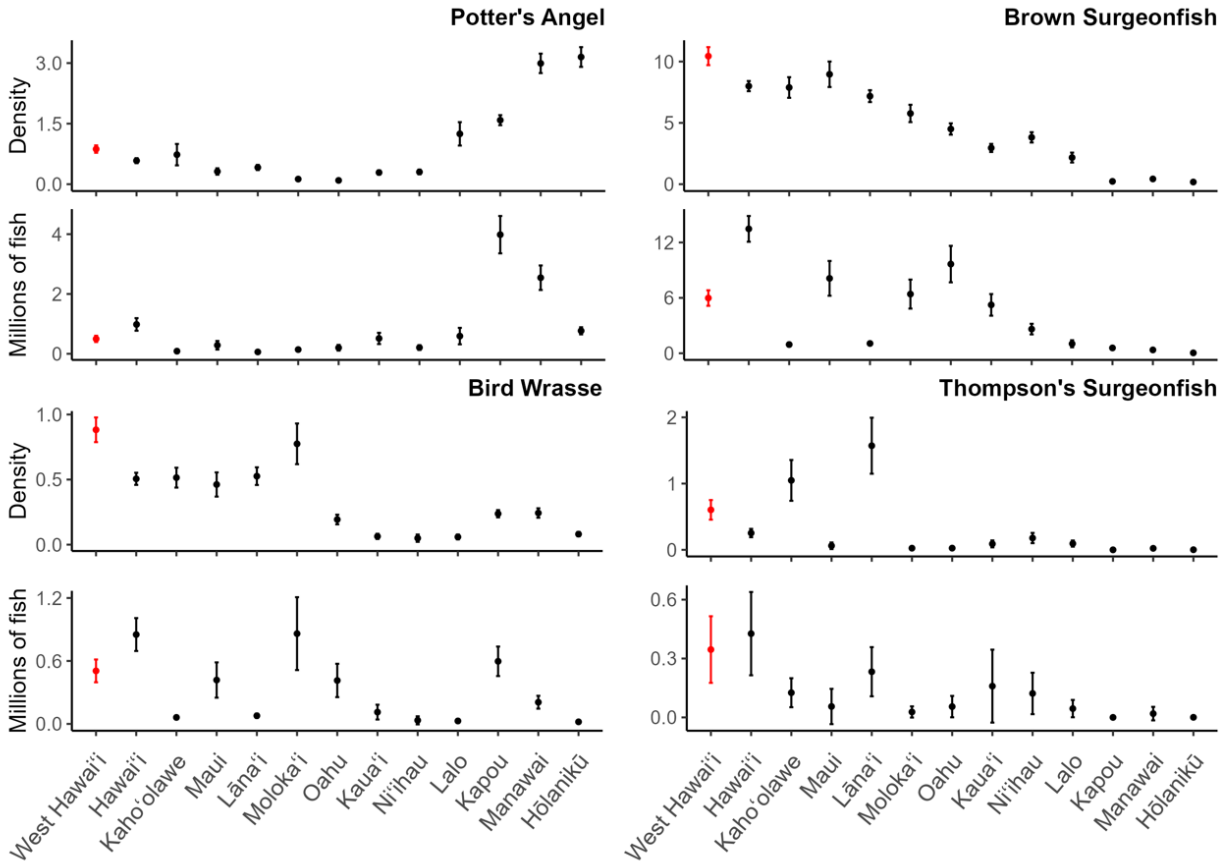
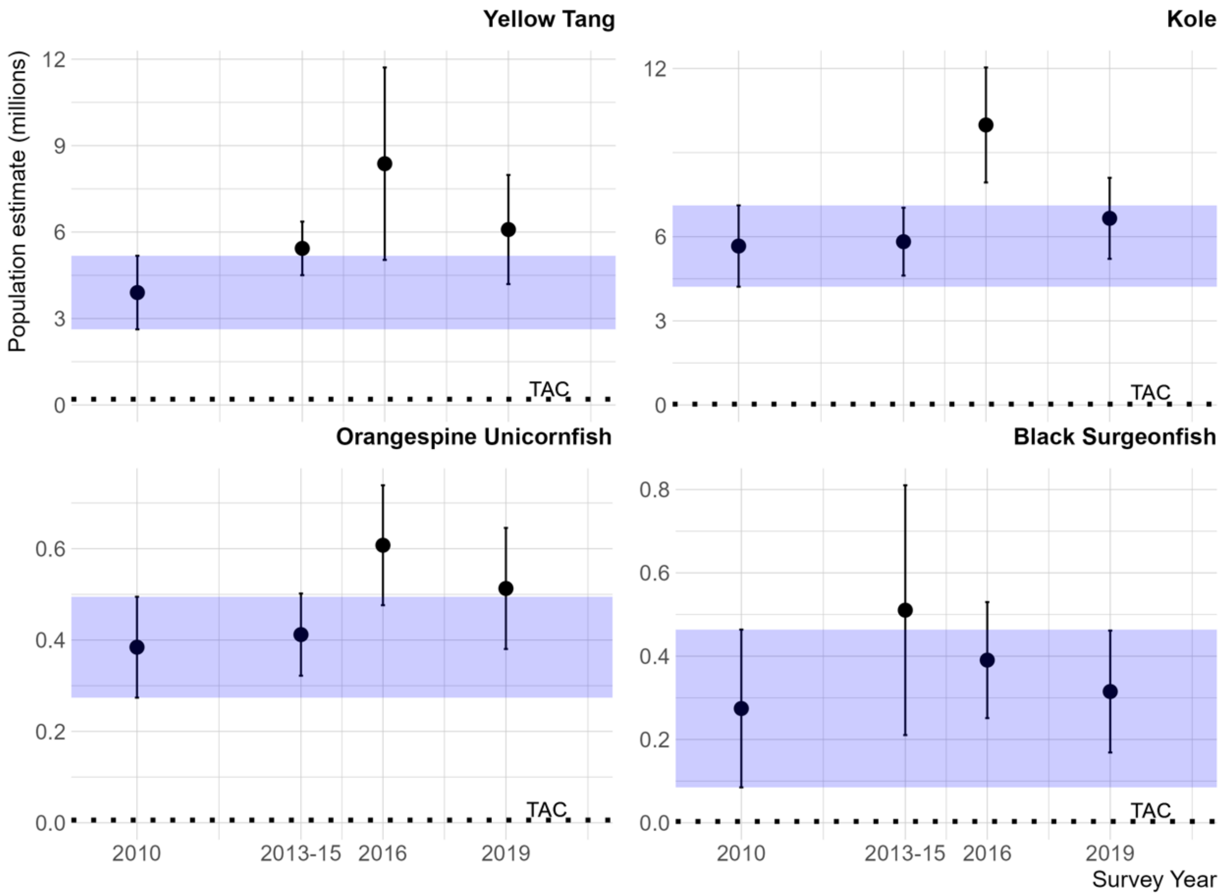


Figure 5. Mean density and abundance for West Hawaiʻi and islands of the Hawaiʻian archipelago, from Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) data 2010-2019.

3.3 West Hawaiʻi Population Data (PIFSC-ESD)

PIFSC-ESD WHRFMA population estimates for the eight species were examined to determine if there were any signs of persistent population decline over time. The uncertainty range of population estimates from the 2010 survey were compared to subsequent years as a crude gauge of population stability. Population estimates from 2010 do not represent a true "baseline" or unfished state but rather provide a conservative measure of whether abundance increased or decreased during the years covered by PIFSC-ESD surveys.

Abundance for the eight species within the WHRFMA were generally stable between 2010 and 2019 (Figure 6). Most of the species showed some indication of population increase coinciding around the large marine heatwave in 2015, though only statistically significant in three species (kole, brown surgeonfish, and bird wrasse). Stable population trends for the two main aquarium fishery targets (yellow tang and kole) during a time when aquarium harvest in the WHRFMA was reported to be high relative to the fishery's history is not consistent with population trends one would expect if overfishing was occurring.


Yellow Tang
Kole
Orangespine Unicornfish
Black Surgeonfish
Population estimate (millions)
12
9
6
3
0
TAC
0.8
0.6
0.4
0.2
0.0
2010
2013-15
2016
2019
Survey Year

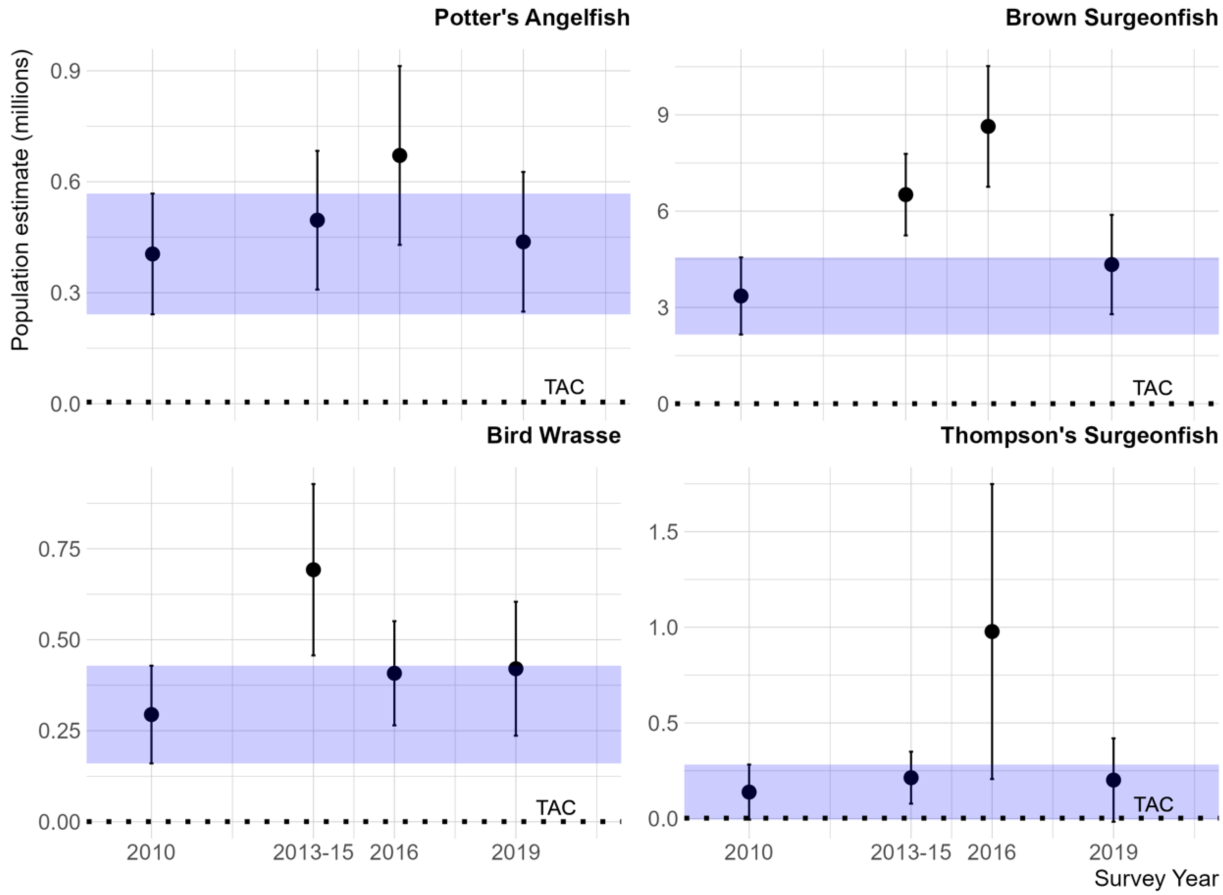


Figure 6. Estimated abundance within the West Hawai'i Regional Fishery Management Area (WHRFMA) in the 0-30 m depth range, Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) data 2010-2019. Note blue band denotes the confidence interval for year-1 (2010), the dotted line denotes the proposed Total Allowable Catch (TAC).*

3.4 Recruit Trend (WHAP)

Recruit[9] density at WHAP sites was examined as a coarse indicator of the input of new fish in the WHRFMA. Fish recruits will settle on reefs at multiple times throughout the year and is the net result of reproductive output by mature fish and a myriad of factors. Environmental factors such as ocean currents can sweep larvae offshore or lead to increased local retention, while ecological factors such as high rates of mortality due to predation affect both pelagic larvae and newly settled recruits. While WHAP surveys are simple “snapshot” estimates in time and do not tell the complete story of fish recruitment in the WHRFMA, looking at mean recruit density over time, though coarse, can be used to identify decline in recruit production that may warrant concern.

Recruit densities were aggregated across all sites because review of data indicated no differences between management status types. For species whose recruits were commonly encountered during WHAP surveys (yellow tang, kole, black surgeonfish, Potter’s angelfish, and brown surgeonfish), mean annual densities appeared to be stable or increasing in comparison to their 20-year mean estimates (Figure 7). Recruit trends were not informative for orangespine unicornfish, bird wrasse, and Thompson’s surgeonfish. The

[9] In this review, recruits are defined as juvenile fish 0-5 cm in length.

consistent low densities of recruits of these species in WHAP surveys could be related to multiple factors including recruit habitat preferences that do not align with the highly selective habitat surveyed by WHAP (mid-depth, abundant finger coral).

Large pulses in recruits prior to the 2015 marine heatwave were apparent for yellow tang, kole and black surgeonfish. Overall, recruit densities were highly variable both temporally and spatially. Trends in annual mean recruit densities as WHAP sites indicate that some sites/regions consistently produced more recruits than others (Figure 8). Patchy site-level recruit trends, especially for Potter’s angelfish and black surgeonfish highlight the importance of environmental factors for fish recruitment in the WHRFMA.

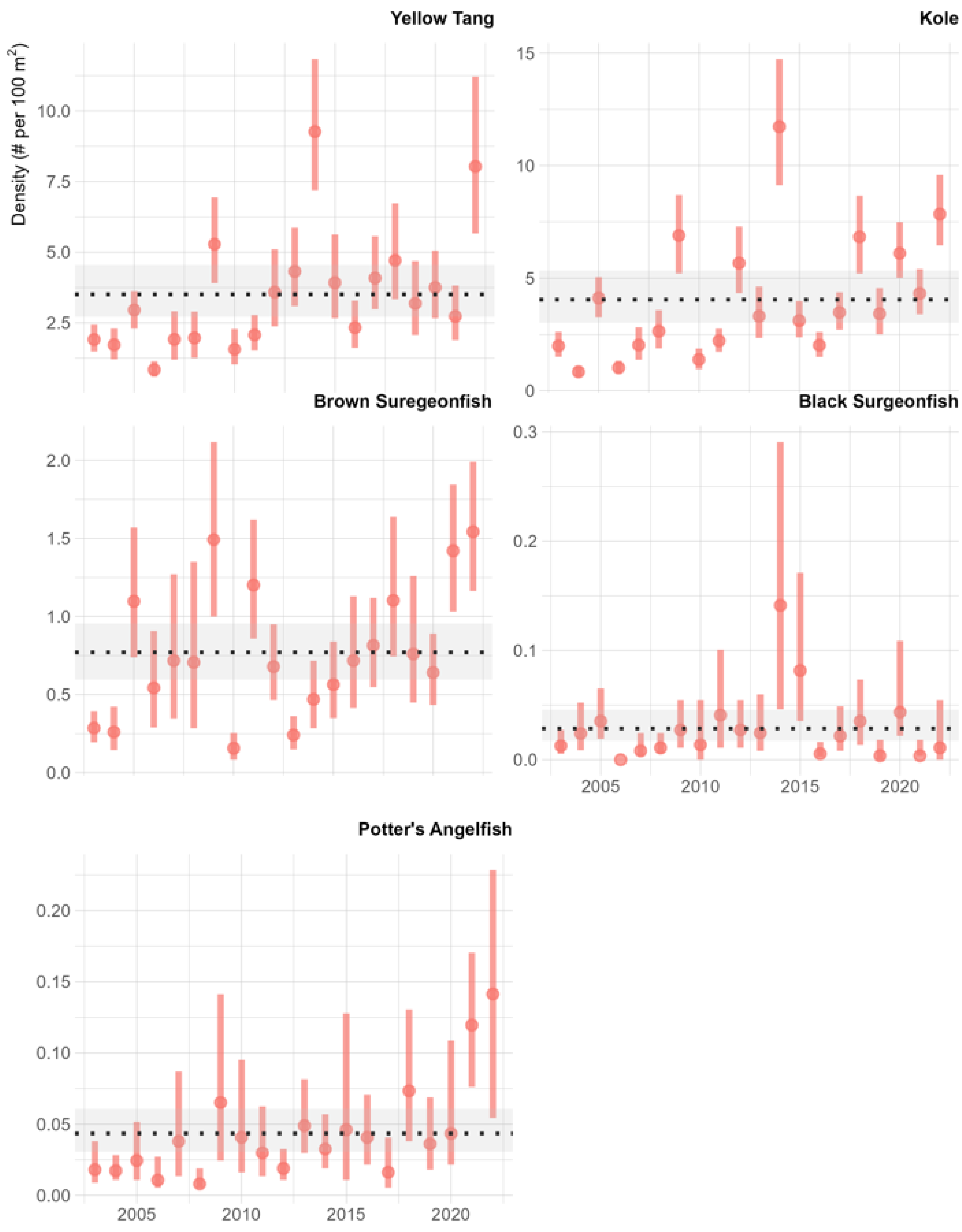


Figure 7. Mean annual recruit density within the West Hawai'i Regional Fishery Management Area (WHRFMA) in the 0-30 m depth range, West Hawai'i Aquarium Project (WHAP) data 2003-2022. Note vertical bars denote 90th percent confidence interval, dotted line denotes total mean with grey shading denoting its 90th percent confidence interval.*

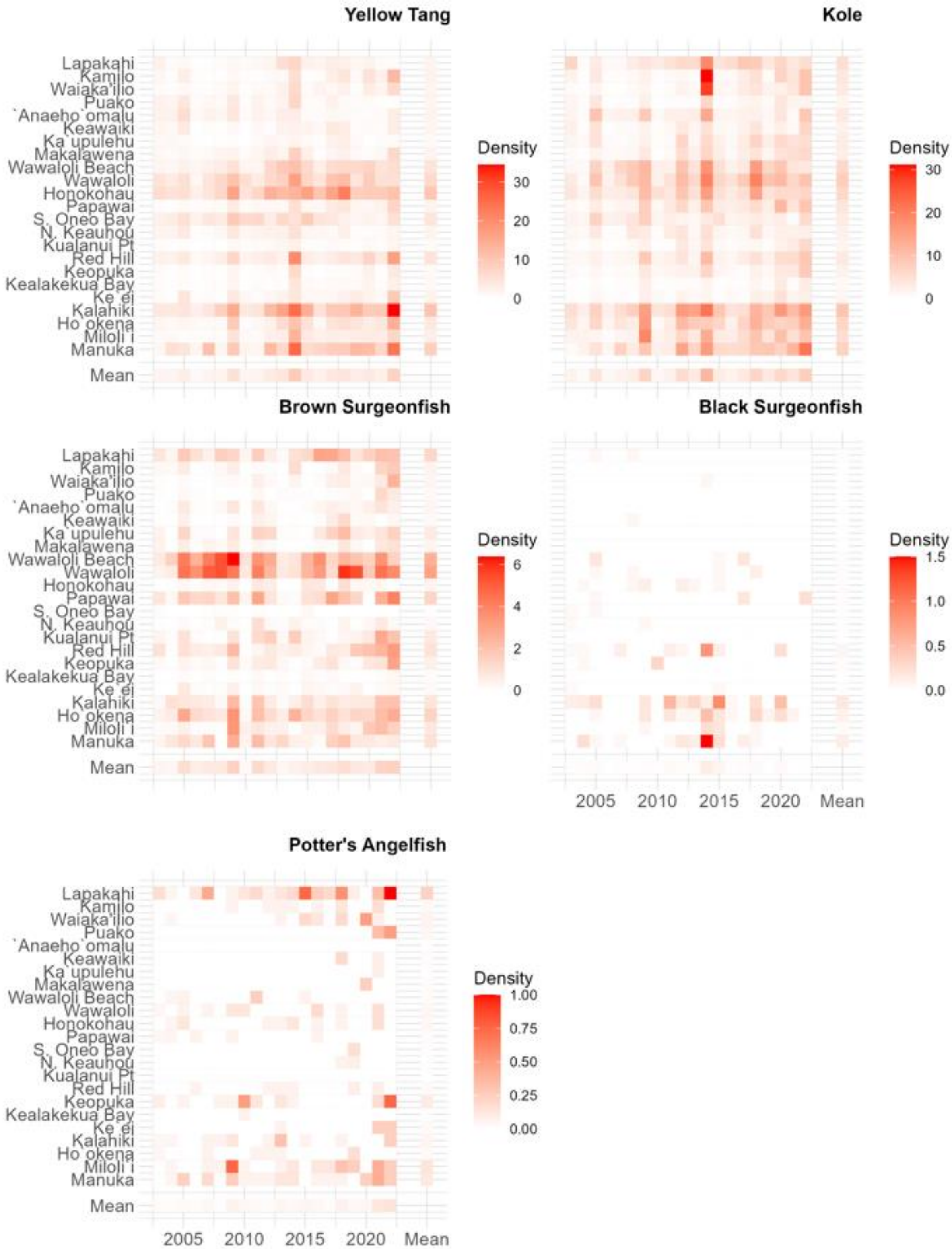


Figure 8. Heat map of recruit density by year and survey location in the West Hawai'i Regional Fishery Management Area (WHRFMA) in the 0-30 m depth range, West Hawai'i Aquarium Project (WHAP) data 2003-2022.

3.5 Juvenile Trend (WHAP)

Juvenile[10] density can be a valuable indicator of fishing impact given that it focuses on the smaller body sizes preferred by the aquarium fishery and therefore subject to the most intense levels of harvest. Mean juvenile density by management area type was compared for each species to determine if there were any apparent differences between areas open and closed to aquarium harvest. Consistently lower density and smaller/absent reactions following recruitment events in open versus closed areas may suggest that the fishery is having a measurable impact on the population. Additionally, site level trends were compared to these mean management area type values to determine their variability, i.e., how well the mean captured the overall trend. A high level of variability within management area types would suggest that density varies greatly even in areas with uniform protections, potentially due to factors including non-aquarium fishing impacts. High variability across management area types, i.e., open and closed areas, may again suggest that factors other than aquarium harvest are influencing density.

The relationship between management area type and mean juvenile fish density varied by species (Figure 9). For the most intensively harvested species, yellow tang and kole, lower density in the open areas was apparent in the annual mean density trend, yet for the other six species annual mean density was similar between the open and closed areas or even greater in the open areas in comparison to one or both of the closed area types. For all species, there was considerable variation within the site level trends contributing to mean density values. Overlap in site densities in the three management area types may suggest that the fishery is not so widespread or intensive that densities as a rule are always lower where commercial aquarium fishing occurs. Instances of lower densities in the FRA's and LTP's in comparison to the open areas may also suggest that aquarium fish catch is not the only factor determining abundance within an area. Natural non-uniform distribution of fish across the WHRFMA and non-fishing impacts on habitat also likely influence these densities. Management area type does not necessarily appear to always be a good predictor of target species density.

The generally similar shapes of mean juvenile density trends for each species suggests that primary factors driving juvenile abundance are similar across management area types, i.e., drivers of juvenile density trends appear spread across management area types, not unique to them. This in part is likely due to larval distribution being widespread across the WHRFMA, and not contained in certain areas. Additionally, the trends suggest that there are potential factors affecting most of the species similarly as shown in the peak in juvenile density occurring near the 2015 marine heatwave. There are exceptions to this however, and not all sites followed closely with mean values. For yellow tangs, there were sites in both the FRA and open sites that showed little or no association with the mean trend and pulses in juvenile density. This may suggest that within each management area type, not all sites are equal in their reaction to widespread pulses in recruitment, i.e., factors external to fishing may be limiting fish density.

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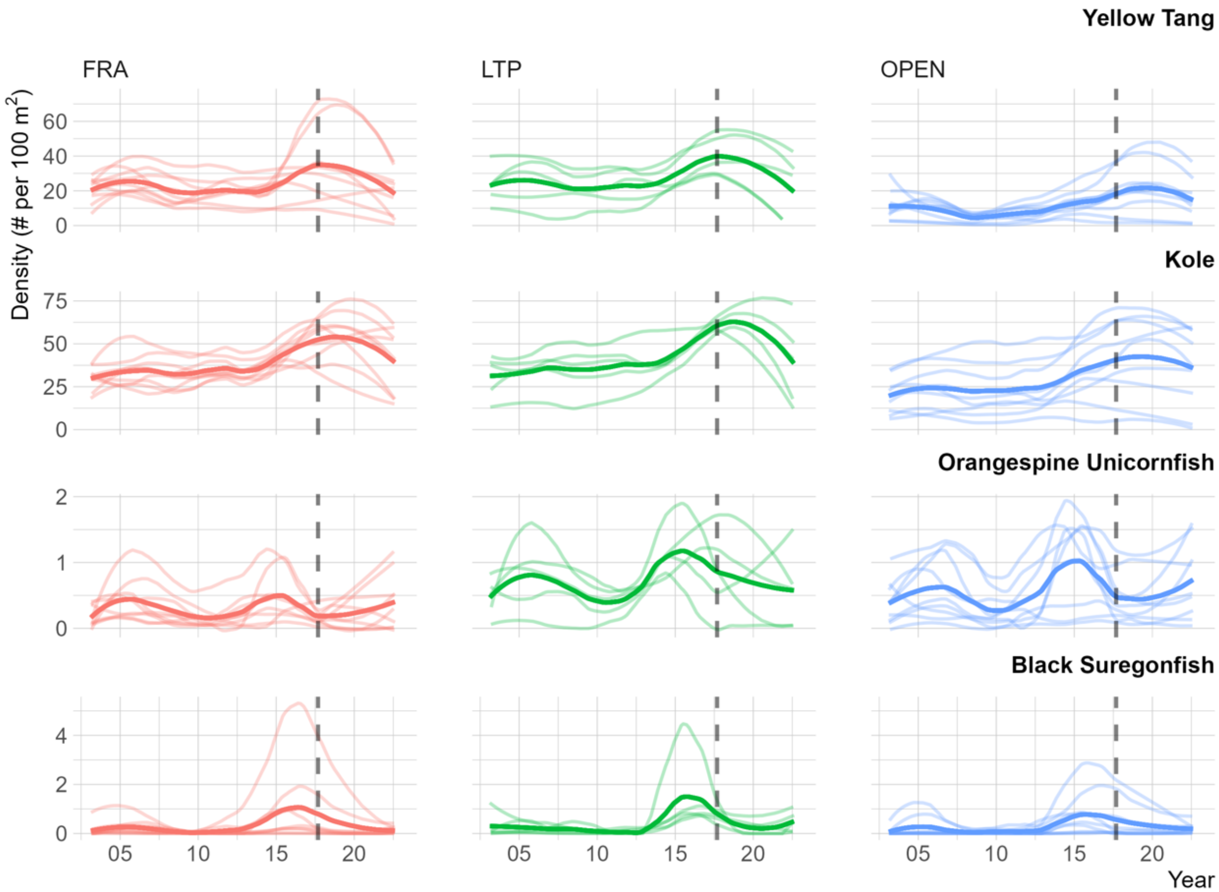
[10] In this review, juveniles are defined as juvenile fish 5-15 cm in length.


Yellow Tang
Kole
Orangespine Unicornfish
Black Suregonfish
FRA
LTP
OPEN
Density (# per 100 m2)
60
40
20
0
75
50
25
2
1
4
05
10
15
20
Year

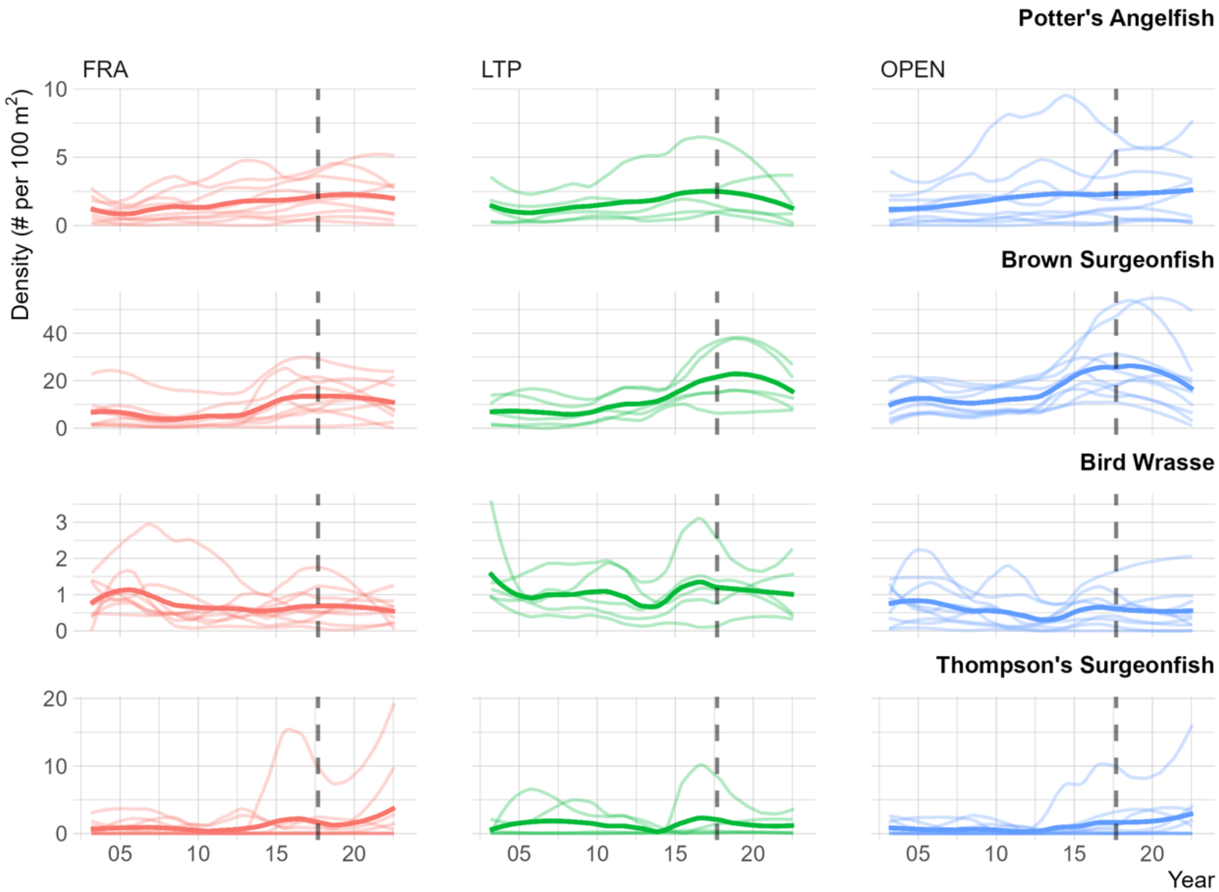


Figure 9. Annual mean density by management area (bold lines) and annual site-specific mean density (light lines) in the West Hawai'i Regional Fishery Management Area (WHRFMA) in the 0-30 m depth range, West Hawai'i Aquarium Project (WHAP) data 2003-2022. Note horizontal dashed line represents the closure of the fishery in 2017.*

3.6 Ecosystem Trend (WHAP)

Recent marine heatwaves, subsequent coral bleaching events, and forecasting of larger/more frequent coral bleaching events into the future have placed a spotlight on the role of herbivorous reef fishes in maintaining coral reef health and resilience to disturbance. Herbivorous coral reef fish species have been shown to offer an array of ecosystem services including maintaining coral health by limiting macro, and turf algae growth on or near live corals (Baggini et al. 2015, Hixon 2015). Of the eight species on the revised white list, four are herbivores including yellow tang (grazer), brown surgeonfish (grazer), Potter's angelfish (grazer), and orangespine unicornfish (browser; Hobson 1974, Tebbett et el. 2021). Of the other surgeonfish species, black surgeonfish and kole are detritivores and Thompson's surgeonfish is a planktivore (Tebbett et el. 2021). Bird wrasse is an invertivore (Randall et al. 1990). Analyzing grazing potential is difficult because of the diverse herbivore community, and other factors that can impact coral health. Though there has been a recent study that has attempted to quantify an adequate number of herbivores to satisfy ecosystem service needs (Donovan et al. 2023), determining the ecological impact of harvest at the herbivore species level is largely unstudied in Hawai'i. We can however look at existing monitoring data to explore whether areas of lower aquarium collection exhibit different indicators of coral reef health or react differently to bleaching events. This at minimum provides some insight into how areas protected from aquarium collection react differently to the open areas and what we may expect should collection resume. Here, the WHAP dataset is useful as it includes monitoring before, during, and after the large marine heatwave of 2015. Mean percent coral cover by management area, mean percent coral cover at the site level, and absolute change in percent coral cover were examined to determine if WHAP data showed any differences in the habitat characteristics of the three management area types and their reactions to and following a significant bleaching event. Significant differences wherein the open areas showed a markedly lower percent coral cover, greater impact of a bleaching event, or greater latent impacts of the bleaching even would suggest that removal of herbivores by the aquarium fishery may have negatively impacted ecosystem health.

By first comparing mean percent coral cover by management area type, we see that the three track closely between 2003 and 2020 (Figure 10, upper plot). While in certain years there is separation between the three management area types, when accounting for uncertainty these differences are not statistically significant, i.e., we cannot conclude those differences in mean percent coral cover are actually an accurate reflection of different habitat condition. These data do suggest however that all three management area types follow the same general trend over time, and that mean percent coral cover does not differ greatly between the fished and unfished sites.

Like fish density, site level percent coral cover trends varied within and across management area types, so site level and mean trends were plotted together to determine the level of variability (Figure 10, lower plots). Though the lowest values were observed in some of the open areas, there was a substantial amount of overlap within and across management area types. While low coral cover at open sites may suggest that commercial aquarium collection has an impact on percent coral cover, site-level coral cover at WHAP sites in 1999 indicate that open sites had slightly lower coral cover than FRA sites despite all sites being open to fishing prior to 1999 (Tissot & Hallacher, 2003). Additionally, the WHAP site with the lowest coral cover, Lapakai, was originally an LTP site and later reclassified as an open site. Overall, management area type does not necessarily appear to be a good predictor of percent coral cover.

Mean absolute change in percent coral cover before, during, and after the marine heatwave of 2015 showed little significant difference between management area types (Figure 11, upper plot). The only significant difference was between 2016 and 2020, where the LTP sites showed a greater decrease in percent coral cover compared to the FRA and open sites. There appears to be little apparent connection between the management area types and change in percent coral cover before, during, and after disturbance.

Again, site level trends were examined to understand variability in the mean absolute change values. Site-level trends were plotted before, during, and after the 2015 marine heatwave (Figure 11, lower plot). We see that there is a considerable amount of overlap in the pre-heatwave, heatwave, and post-heatwave periods, though lowest percent coral cover values did fall in open areas. It's important to note that between 2018 and 2020 there was no aquarium collection, so there is some uncertainty how percent coral cover in the open areas would have reacted post-heatwave. The lack of clearly defined separation between the pre-heatwave, heatwave, and post-heatwave site level trends suggest that aquarium collection alone may not be a significant factor in dictating percent coral cover, buffering against bleaching, or resilience.

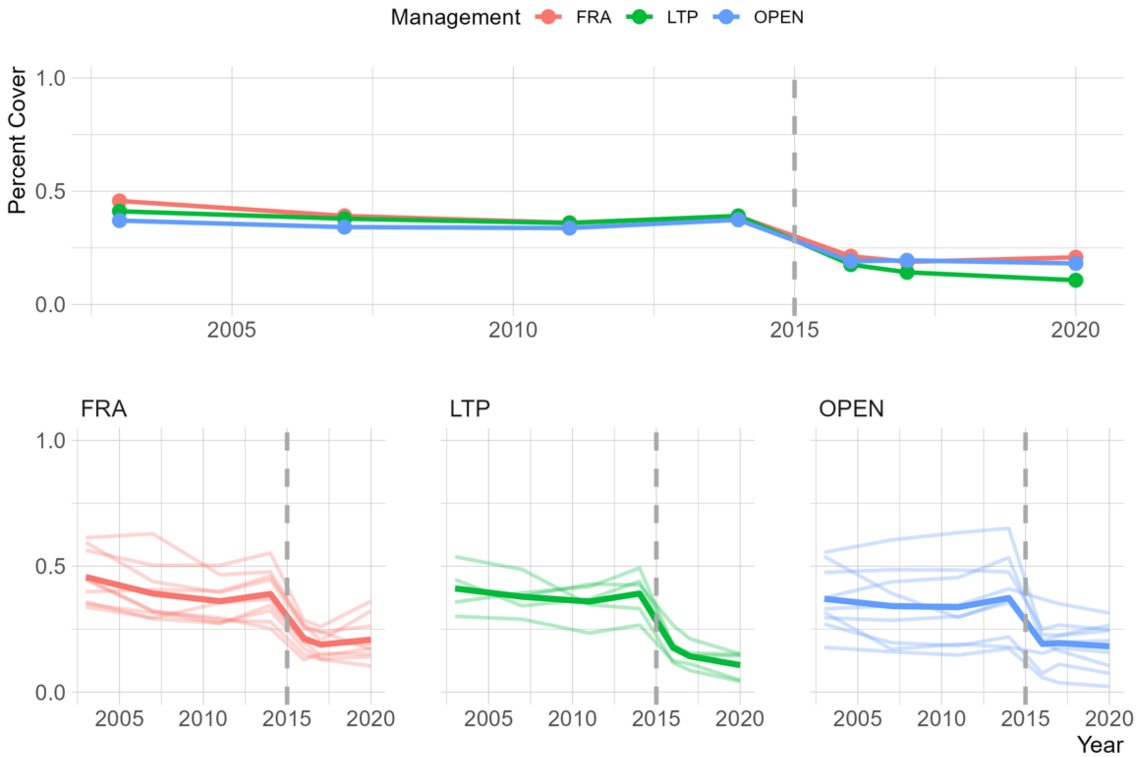


Figure 10. Annual mean percent coral cover by management area type (above) and annual mean percent coral cover (bold lines) with site-site specific annual mean percent coral cover (light lines), West Hawai'i Aquarium Project (WHAP) data 2003-2020 (below). Note dashed line represents marine heatwave.*

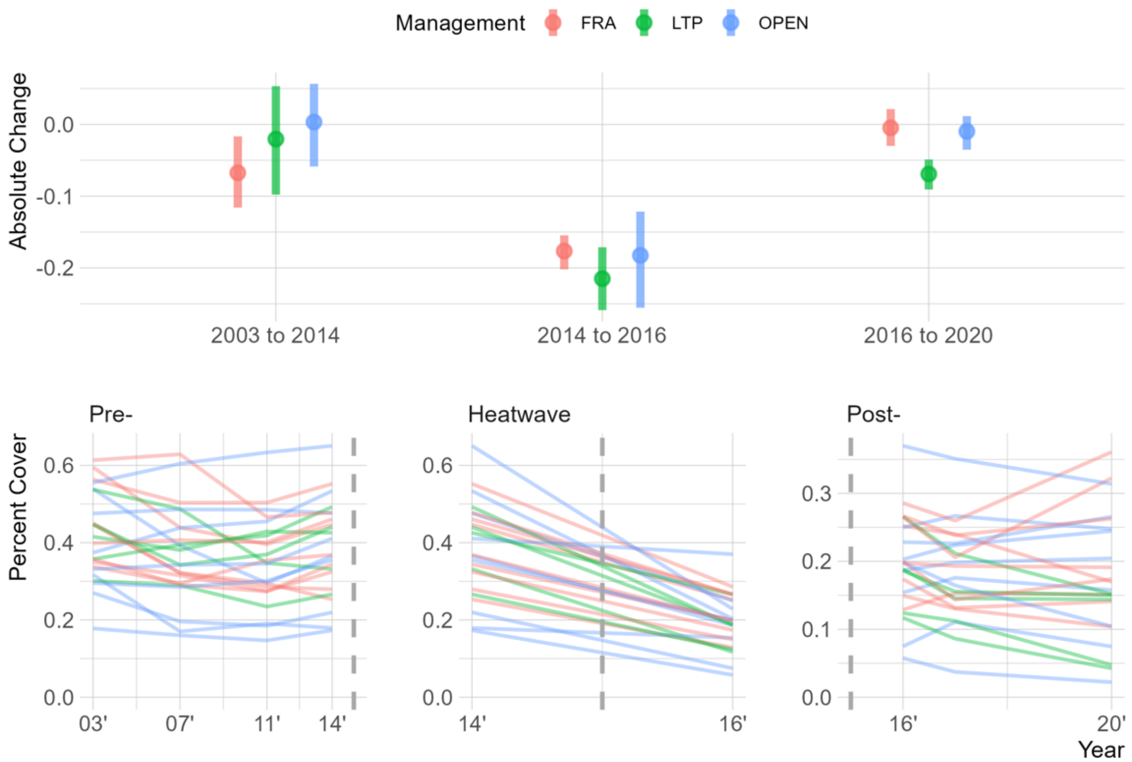


Figure 11. Absolute change in percent coral cover by management area type in the West Hawai'i Regional Fishery Management Area (WHRFMA) (above) and site-specific mean percent coral cover before, during, and after the 2014/2015 marine heatwave (below), West Hawai'i Aquarium Project (WHAP) data 2003-2020. Note dashed line represents marine heatwave.*

4. Overview of Fishery-Dependent Monitoring

All Commercial Marine License (CML) holders are required to submit catch reports to DAR pursuant to HAR §13-74-20. Aquarium fishers fill out a unique form specific to the fishery and submit on a fixed monthly basis. Critical information collected in these reports include date fished, area fished, and number caught by species. Area fished is based on a modified DAR commercial reporting grid in which the West Hawaiʻi coastline is subdivided into smaller nearshore reporting areas (Figure 12). Reports may be submitted by a single individual on a multi-person trip to eliminate the chance of double reporting, or they may be submitted per person.

Additionally, commercial marine dealers (businesses that receive marine life directly from fishers for sale to the public) must report weekly pursuant to HAR §13-74-46. Dealer reports include fisher information so catch and sales reports may be linked, providing an important tool to "double check" catch reports. Wholesale price or "ex-vessel value" is also recorded by species providing an important metric for tracking economic value of the fishery and price trends by species. Fishers can also legally sell their catch directly to aquarists via a Cash Sales Report. Cash Sales Reports are submitted monthly along with catch reports.

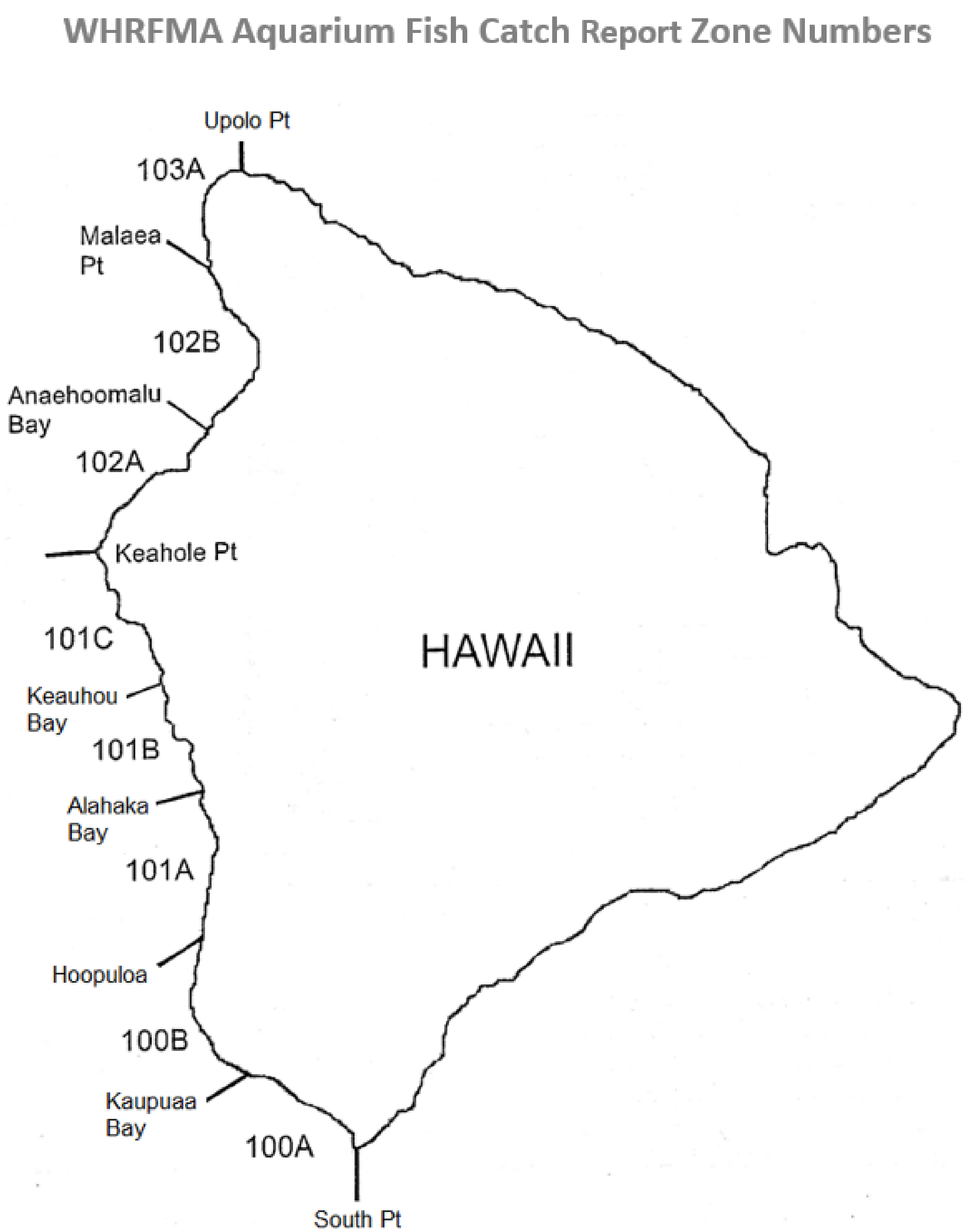


Figure 12. Reporting grid areas for the West Hawai'i commercial aquarium fishery.

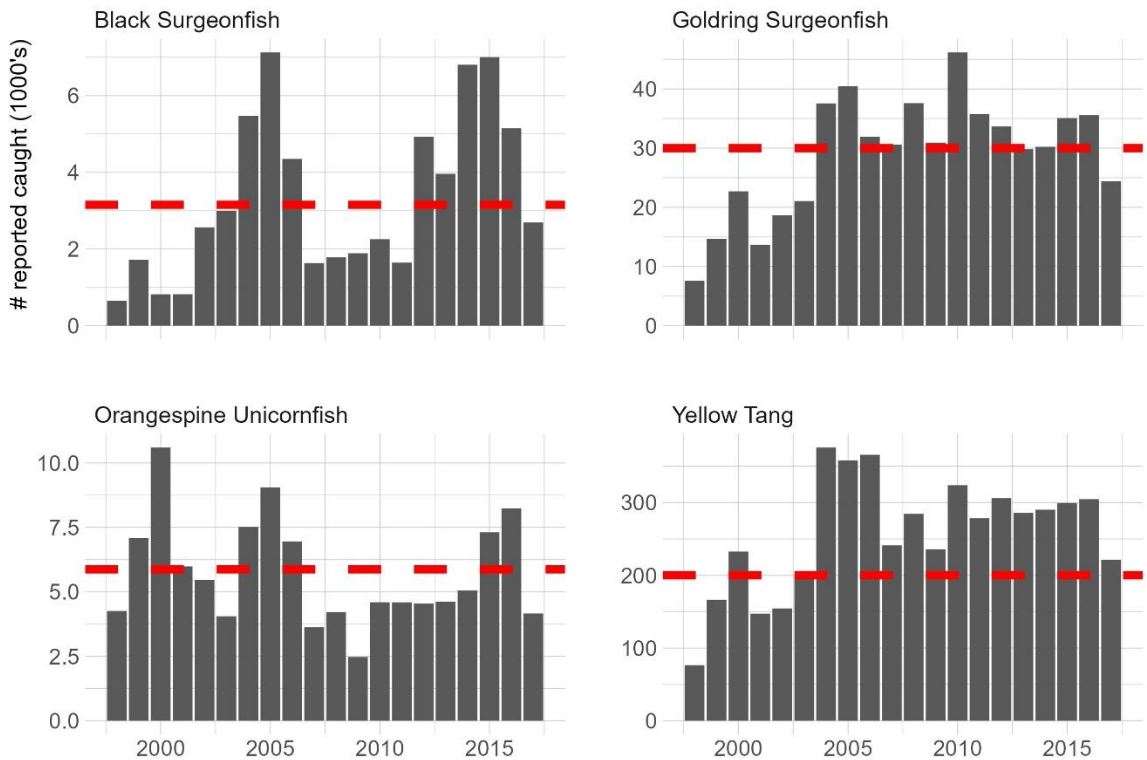
5. Commercial Harvest

WHAP and PIFSC-ESD data can be informative regarding the effects of the commercial aquarium fishery, though they do not necessarily offer insight into how fish populations and the ecosystem will react should the fishery exceed previous levels of take. An understanding of previous commercial aquarium harvest rates in comparison to the proposed TACs is critical in predicting the effects of the fishery should it resume.

The proposed TACs for goldring surgeonfish, naso tang, black surgeonfish, and bird wrasse are within ± 6% of their twenty-year mean annual catch for the West Hawaiʻi aquarium fishery. For these species, proposed TACs represent relatively status quo harvest. The proposed TAC for yellow tang is approximately 22% less than its twenty-year mean catch, while the proposed TAC for brown surgeonfish is approximately 25% more than its twenty-year mean catch. For all six of these species, their proposed TACs are less than their maximum annual catch for the same twenty-year period, i.e., the proposed TACs would not exceed previously recorded maximum catch. The proposed TAC for Potter's angelfish is 273% more (3.7 times greater) than its twenty-year mean catch, and the proposed TAC for Thompson's surgeonfish is 1,274% more (13.7 times greater) than its twenty-year mean catch. Both these proposed TACs exceed maximum annual catch reported in the same twenty-year period. High TACs in comparison to their previously reported catch for these two species is due to the applicants basing their proposed TACs on a fixed percentage of the estimated population and not previous catch[11]. Potter's angelfish and Thompson's surgeonfish were not primary target species of the WHRFMA fishery, so the population estimate-based TACs exceeded the catch-based TACs.

Poor resource condition or dwindling abundance can contribute to lower landings as fishers struggle to maintain catch. One obvious indication of severe depletion could be progressively lower landings over time relative to fishery participation and effort, i.e., the fishery's effort stays the same but catch declines suggesting that fishers are operating normally but catching less. Another indication would be steady catch, but disproportionally large increases in effort, i.e., catch stays the same but effort increases suggesting that fishers need to work harder to maintain their landings. Both scenarios would be evidenced by a declining catch per unit effort (CPUE). CPUE can be useful in fisheries where factors contributing to effort (e.g., techniques, methods, etc.) are relatively standardized across the fishery over time. In the commercial aquarium fishery, technique vary between collectors and evolve over time making analysis of CPUE difficult without standardization (See APPENDIX B - History of the West Hawaiʻi Aquarium Fishery). However, what is evident in the commercial reports is that landings did not progressively decrease over time in light of assumed steady or increasing market demand, which would be a significant warning that resources may be in peril.

[11] In the RFEIS, the applicants set their TACs based on one of two criteria: either the twenty-year historic average catch from the entire WHRFMA fishery (during which the populations have all been increasing or stable), or 1% of the 2019 PIFSC-ESD WHRFMA population estimate.



Black Surgeonfish
Goldring Surgeonfish
Orangespine Unicornfish
Yellow Tang
reported caught (1000's)
0
2
4
6
10
20
30
40
0.0
2.5
5.0
7.5
10.0
100
200
300
2000
2005
2010
2015

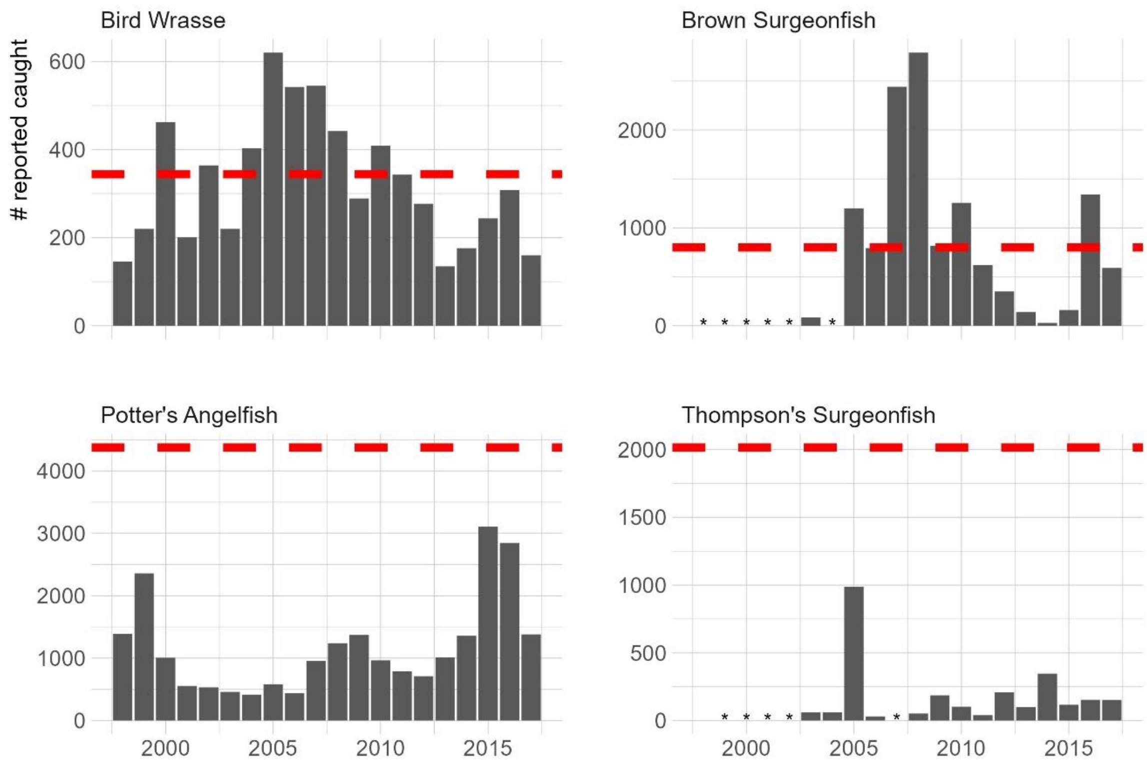


Figure 13. Annual reported landings for the West Hawai'i aquarium fishery (bars) and proposed Total Allowable Catch Limits (dashed red line) for the eight revised whitelist species, 1998-2017.

6. Evaluation of Proposed TACs (PIFSC-ESD)

The permit applicants identified in their RFEIS a preferred alternative that narrowed the existing white list down from 40 to 8 species. The preferred alternative assigned an annual TAC to each species, which would be divided equally among the seven applicants. A straightforward way to gauge the impact of these TACs is to compare them to the estimated sizes of the populations that they will draw from, i.e., what percent of the population will these fishers take per year if the TACs are fulfilled? It should be noted that we do not know what percentage of each species can be taken to maintain sustainability and sustainable harvest levels likely vary by species depending on life-history traits. While the RFEIS referenced a 2006 paper by Ochavillo and Hodgson that stated a broad range of 5%-25% ensures sustainability, this range represents a general guideline and should not be used to determine directly the sustainability of harvest in any of these species.

6.1 Evaluation of TACs in Relation to Estimated WHRFMA Populations

Given the relative uncertainty and variation among inter-annual survey trends, DAR compared the eight proposed TACs to two intentionally conservative population estimates of each species within the WHRFMA. They included: 1) the lowest mean abundance estimates among recent PIFSC-ESD data (2010-2012, 2013-2015, 2016, 2019) and 2) the low end of each estimate's 95% confidence interval to represent the "worst case scenario" in terms of possible population size during the sampling period. Note that DAR is using these lower-end values to be intentionally conservative, not due to any belief that the PIFSC-ESD derived estimates are overestimating population size. DAR has reason to believe that these estimates may be biased low (discussed below).

The TACs when compared to the lowest PIFSC-ESD estimates in terms of the percent of the population that would be harvested ranged between 0.02% (brown surgeonfish) and 5.13% (yellow tang; Table 1). Harvest estimates in relation to the lower end of those minimum estimate confidence intervals ranged between 0.04% (brown surgeonfish) and 7.62% (yellow tang). Other than the estimates for yellow tang, none of the other species had a harvest rate exceeding 5% under the proposed TACs.

DAR notes that these estimated harvest rates relative to the entire population are quite low, and there is justification to believe actual rates would be even lower. First, as "snapshots" of fish abundance, the PIFSC-ESD derived estimates are reflections of what was seen by surveyors during a relatively short window of time. PIFSC-ESD surveys therefore do not estimate the entirety of a fish population, but rather what is referred to as the "standing stock," or the population of fish observed at the time of survey. Certain life stages such as newly "dropped" juveniles (recruiting to the benthos from their pelagic larval stage) may have been under-represented in survey counts as replication was not performed to capture recruitment events over time. Second, the population estimates were just for the 0-30 m depth range, not the entire range of these species. Though there may be limited use of depths in excess of 30 m for these species, there are likely fish unaccounted for. Lastly, these estimates were again based on the "worst case scenario," or absolute low end of the population estimate range of likely abundances. Basing these percent harvest rates on combined-year mean abundance estimates for example would result in a lower harvest rate.

DAR does not find that there is justification to conclude that the proposed TACs would dramatically impact the populations of these eight species within the WHRFMA. While there is no doubt that harvest would have some impact, it seems unlikely that these species within the WHRFMA would be threatened at the population level by this proposed action.

Table 1. Comparison of proposed Total Allowable Catch (TAC) limits and reported catch with Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) abundance estimates and % harvest rates.

Common Name	Min caught	Mean caught	Max caught	EIS TAC	Min Pop Estimate[1]	Pop Lower[2]	% Min[3]	% Lower[4]
Yellow Tang	76,479	265,975	375,656	200,000	3,900,975	2,625,567	5.13%	7.62%
Goldring Surgeonfish	7,579	29,204	46,157	30,000	5,666,597	4,217,609	0.53%	0.71%
Orangespine Unicornfish	2,472	6,069	10,598	5,872	384,298	273,915	1.53%	2.14%
Black Surgeonfish	652	3,788	9,932	3,152	274,335	84,975	1.15%	3.71%
Potter's Angelfish	416	1,307	3,367	4,376	404,743	241,562	1.08%	1.81%
Brown Surgeonfish	4	632	2,790	800	3,357,250	2,156,384	0.02%	0.04%
Bird Wrasse	146	351	620	344	294,521	160,293	0.12%	0.21%
Thompson's Surgeon	1	147	987	2,016	213,565	77,690	0.94%	2.59%

[1] Lowest annual WHRFMA (0-30 m depth) mean population estimate, PIFSC-ESD data 2010-2019.
[2] WHRFMA (0-30 m depth) population estimate representing the low end of the above estimate's 95th confidence interval, PIFSC-ESD data 2010-2019.
[3] Percent of the "Min Pop Estimate" represented by the associated TAC.
[4] Percent of the "Pop Lower" estimate represented by the associated TAC.

6.2 Evaluating the Yellow Tang TAC in Relations to Target Size Class in Open Area

DAR further evaluated the potential impact of the yellow tang TAC. Yellow tang are the main target of the fishery and had the highest estimated "fishing pressure" in the previous analysis relative to the other species (although still very low). Almost half (47.7%) of the 0-30m habitat in the WHRFMA is closed to fishing. Multiplying the estimate of the yellow tang in the WHRFMA by the proportion of habitat open to the fishery (53.3%) provides a coarse estimate of the portion of yellow tang available to the fishery. Additionally, the aquarium fishery targets yellow tang within a narrow size range and there is also a slot-limit (no person shall possess more than five yellow tang larger than 4.5 inches in total length, or possess more than five yellow tang smaller than two inches in total length). To account for these factors the proposed TAC was applied not to the entire population of the species across West Hawai‘i, but to an estimate of the population that would be available to the fishery. The goal was to gauge the TAC's impact on the actual segment of the WHRFMA population that will be targeted.

DAR used PIFSC-ESD from 2010-2012, 2013-2015, 2016, and 2019 survey dataset to estimate the number of yellow tang in the 5-10 cm size class in the open area of the WHRFMA. Again, to acknowledge the uncertainty in population estimates, DAR used mean as well as lower and upper estimates to compare to the proposed harvest of 200,000 fish per year. Note that the 2010-2016 population estimates incorporate fishing mortality because the West Hawai‘i Aquarium fishery was allowed during this time. Estimated percent harvest ranged between 16% and 31% for the low population estimate, between 8% and 18% for the mean population estimate, and between 5% to 15% for the upper population estimate (Table 2). Varying harvest rates among estimates suggests the likely reality that the number of fish available to the fishery is not constant through time due to variable recruitment. It's also important to reiterate that these percentages reflect just the percent of the 5-10 cm size class in the open area taken, not the entire population. As previously noted, we suspect that PIFSC-ESD may be underestimating true abundance though to an unknown degree.

The ideal means to assess the impacts of the TAC on yellow tang or any of the other species would be via a population model, i.e., a stock assessment. Without one however, a simple comparison like this which estimates percent removal or “fishing pressure” can still provide helpful insight. This analysis suggests that a TAC of 200,000 fish will result in 5% to 31% of 5-10 cm yellow tang in the open area taken per year, or between 69% and 95% of the target 5-10 cm size class “escaping” the fishery annually. This is in light of existing regulations limiting the daily take of yellow tang less than 2 in (5.08 cm) and greater than 4.5 in (11.43 cm), protecting both newly settled recruits and the larger breeding population. All size classes, including the entirety of the adult breeding population will have complete protection in approximately 47.7% of the WHRFMA’s waters in depths of 0-30 m. Considering this, DAR finds little support for a scenario where a TAC of 200,000 yellow tang would present a substantial threat to the WHRFMA population.

Table 2. Yellow tang juvenile (5-10 cm) population estimates in West Hawaiʻi Regional Fishery Management Area (WHRFMA) open areas in the 0-30m depth range and percent of estimates represented by the 200,000 fish Total Allowable Catch (TAC), Pacific Islands Fishery Science Center - Ecosystem Sciences Division (PIFSC-ESD) data 2010-2019.

Estimate Type	2010-12		2013-15		2016		2019	
	Estimate	% Caught	Estimate	% Caught	Estimate	% Caught	Estimate	% Caught
Lower	653,738	31%	859,053	23%	1,242,991	16%	993,916	20%
Mean	1,175,056	17%	1,107,988	18%	2,539,884	8%	1,684,128	12%
Upper	1,696,374	12%	1,356,924	15%	3,836,776	5%	2,374,340	8%

7. Review of Existing Management

The West Hawaiʻi aquarium fishery today (though not active) is the most regulated fishery occurring in Hawaiʻi State waters[12]. Rules and regulations pertaining to the fishery include both statewide measures, fishery-specific measures, and those pertaining just to the WHRFMA. The following is an overview of management measures currently in place.

7.1 Input Controls

Input controls are management measures pertaining to who can fish and how fishing occurs. Permitting requirements for the West Hawaiʻi Aquarium fishery include the Hawaiʻi State CML pursuant to HAR §13-74-20, the West Hawaiʻi Aquarium Permit pursuant to HAR §13-60.4-7(a), and the general Aquarium Permit pursuant to HRS §188-31. At present, the aquarium fishery is also the only fishery in the State of Hawaiʻi in which fishers must first conduct an environmental review pursuant to the Hawaiʻi Environmental Policy Act (HEPA) before entry.

Additionally, the following gear/vessel-based restrictions and requirements are relevant to the West Hawaiʻi aquarium fishery:

HAR §13-60.4 WEST HAWAIʻI REGIONAL FISHERY MANAGEMENT AREA, HAWAIʻI

- §13-60.4-4 – No person shall possess aquarium collecting gear, or take or possess any specimen of aquatic life for aquarium purposes:
    - Between sunset and sunrise, provided that collecting gear or collected aquatic life may be possessed after sunset or before sunrise if notification by phone is made to the Division of Aquatic Resources West Hawaiʻi (DAR-Kona) office prior to sunset. The notification shall include the names of individuals who plan to possess the gear or aquatic life and the location where the possession will take place.
    - Without holding a valid West Hawaiʻi aquarium permit issued pursuant to section 13-60.4-7(a)
    - In violation of the terms and conditions of a West Hawaiʻi aquarium permit issued to that person
    - While occupying any vessel that does not conform to the registration and marking requirements of section 13- 60.4-7(d)
- §13-60.4-4 – No person shall Possess or use any net or container employed underwater to capture or hold aquatic life alive for aquarium purposes, that is not labeled with the commercial marine license number or numbers of the person or persons owning, possessing or using the equipment.
- §13-60.4-7(c)(1-5) - Aquarium collecting vessel registration and marking requirements. All aquarium collecting vessels shall:
    - Be registered every year with the Division of Aquatic Resources West Hawaiʻi (DAR-Kona) office to take aquatic life for aquarium purposes within the West Hawaiʻi regional fishery management area. Each registration shall be valid for one year from the date of registration. The current vessel identification number issued by either the department or the United States Coast Guard shall serve as the registration number for each vessel.

[12] See Appendix C – Summary of Current and Proposed Management Measures for the West Hawaiʻi Commercial Aquarium Fishery

- Clearly display the capital letters "AQ" permanently affixed to both sides of the vessel, either near the top of the gunwales or on the superstructure. Unless otherwise specified, the "AQ" letters shall be no less than six inches high and three inches wide in either black or a color that contrasts with the background.
- Fly a "stiffened" flag or pennant from the vessel with the letter "A" as specified by the department. The flag or pennant shall be provided at cost to aquarium permittees as specified by the department. The flag or pennant shall be displayed and clearly visible from both sides of the vessel at all times while aquarium collecting gear or collected aquarium marine life or both are onboard.
- Display a dive flag at all times when divers are in the water.
- In the event an aquarium collecting vessel becomes inoperable, the operator of the vessel shall immediately notify the department's division of conservation and resources enforcement or United States Coast Guard or both by VHF radio or by cellular phone or both.

7.2 Output Controls

Output controls are management measures pertaining to what can be caught, including bag limits, size limits, and species restrictions. Statewide fishing rules and regulations apply to this fishery along with those pertaining to both the statewide aquarium fishery and the WHRFMA aquarium fishery specifically. The following species-based restrictions are relevant to the West Hawai‘i aquarium fishery:

HAR §13-60.4 WEST HAWAI‘I REGIONAL FISHERY MANAGEMENT AREA, HAWAI‘I

- HAR §13-60.4-7(b) - Commercial aquarium take in the WHRFMA limited to 40 “white list” species.
- HAR §13-60.4-4(2) – No person shall possess more than five *Zebrasoma flavescens* (yellow tang) larger than 4.5 inches in total length, or possess more than five *Zebrasoma flavescens* smaller than two inches in total length.
- HAR §13-60.4-7(b)(2) - No more than five *Ctenochaetus strigosus* (goldring surgeonfish or kole) larger than four inches in total length may be taken per day or possessed at any time. Note* pursuant to HAR §13-95-25, statewide minimum kole size is five inches (see below).
- HAR §13-60.4-7(b)(3) - No more than ten *Acanthurus achilles* (Achilles tang) may be taken per day, or possessed at any time. Note* currently prohibited under HAR §13-60.41-2(b) (see below).

HAR §13-95 RULES REGULATING THE TAKING AND SELLING OF CERTAIN MARINE RESOURCES

- HAR §13-95-25 - It is unlawful to take, possess, or sell any kole less than five inches in length.

HAR §13-60.41 WEST HAWAI‘I PĀKU‘IKU‘I REPLENISHMENT

- HAR §13-60.41-2 (b) - Within the West Hawai‘i regional fishery management area, it is unlawful to take or possess any pāku‘iku‘i. Note* this rule is in effect until December 19, 2024.

7.3 Spatial Controls

State waters along the West Hawaiʻi coastline include several area designations that exclude aquarium collection including the FRAs, the Miloliʻi Community-Based Subsistence Fishing Areas (CBSFA), Marine Life Conservation Districts (MLCDs), and Fisheries Management Areas (FMAs). Altogether, aquarium fishing is prohibited in approximately 47.7% of the waters off West Hawaiʻi in the 0-30 m depth range (Figure 14).

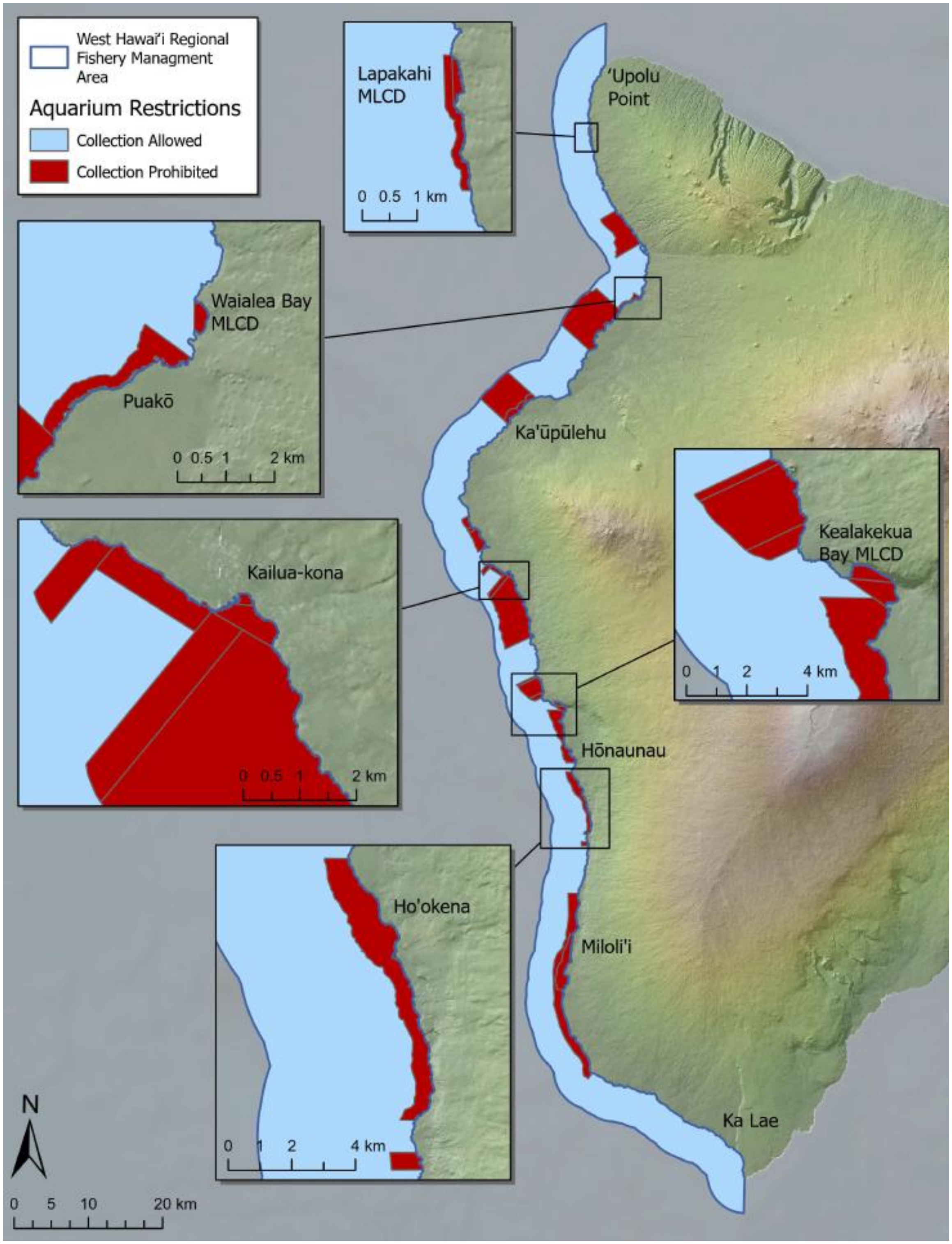


Figure 14. Map of the West Hawai'i Regional Fishery Management Area (WHRFMA) with areas open (blue) and closed (red) to commercial aquarium fishing.

7.4 Monitoring

Fishery-specific monitoring is in place by both fishery-dependent (monitoring the fishery itself) and fishery-independent (monitoring the effects of the fishery) means. Fishery dependent monitoring includes mandatory catch and dealer reports for commercial aquarium fishers and dealers. Fishery-independent monitoring is performed via annual WHAP surveys, which are specific to monitoring the West Hawaiʻi aquarium fishery. Additional ongoing monitoring activities providing insight into the health of marine resources within the WHRFMA include PIFSC-ESD, DAR Fish and Habitat Utilization (FAHU) surveys, and DAR Shallow Water Resource Fish (SWRF) surveys.

8. Other Considerations

The following are additional considerations that may be relevant to assessing the potential impact or risk of this proposed take.

8.1 Physical Impacts of the West Hawaiʻi Aquarium Fishery

Nearly all ocean activities impact the marine environment from directly removing and destroying marine life to simply disturbing organisms in their natural state. A criticism of the West Hawaiʻi aquarium fishery is that the fishery itself is especially impactful in terms of negative effect on corals. As previously shown, we did not see significant differences in percent coral coverage between the FRA, LTP, and Open area sites that would suggest that the aquarium fishery was actively destroying corals to the extent that it would cause clear signals in the data. It's important to recognize though that WHAP surveys were not designed specifically to determine physical impact of the aquarium fishery. While WHAP surveys can define large-scale or widespread differences in habitat, the ability to pick up small-scale or localized impacts is likely beyond the capability of the survey. DAR recognizes that the fishery does likely have some physical impact on the reef whether measurable via ongoing monitoring methods or not. The following sections will discuss two different alleged impacts of the West Hawaiʻi aquarium fishery on habitat including anchoring and the collection process itself.

8.1.1 Physical Impacts Via Anchoring

Anchoring on live corals is prohibited statewide pursuant to HAR §13-257-4. The West Hawaiʻi aquarium fishery, which is primarily boat-based and occurs almost exclusively in areas of high coral cover, does yield the potential of anchoring impacts if responsible anchoring guidelines noted in HAR §13-257-4 are not followed. DAR does not actively track anchoring sites and techniques of the West Hawaiʻi aquarium fishery, though the Division, in cooperation with the Division of Ocean Conservation and Resource Enforcement (DOCARE), will respond in cases of observed infraction or coral destruction. DAR recognizes that instances of coral destruction via anchoring in the West Hawaiʻi aquarium fishery has been previously cited by those in opposition to the fishery. Conversely, fishery participants have stated that it is not a defining characteristic of the fishery and that responsible collectors are able to utilize suitable anchoring points that do not damage coral. Ultimately, DAR is hesitant to assume that the West Hawaiʻi aquarium fishery poses a greater threat via anchoring than other ocean uses that also anchor on or near hard-bottom habitats. Aside from anecdotal information and input from fishery participants, we simply do not know at what rate illegal anchoring by the fishery occurs and if these seven applicants will exhibit this illegal behavior. DAR finds it reasonable however, to conclude that as a boat-based fishery operating often in coral-rich habitats, some risk of coral damage via anchoring (whether intentional or not) is present.

8.1.2 Physical Impacts During Collection

Damage to stony corals in any form is prohibited pursuant to HAR §13-95-70. Additionally, causing damage to corals while retrieving lay nets (the barrier net most aquarium collectors use is considered a fine-mesh lay net) is prohibited pursuant to both §13-75-12.4 and §13-60.4-6. Concerns raised during the Hawaiʻi Environmental Policy Act (HEPA) review process included both that collectors regularly set their panel barrier nets on or near live corals posing a risk of breakage and that to collect fish hidden within corals, collectors will break them open. DAR recognizes that there have been reported instances of both live corals being broken by fishing gear and collectors themselves intentionally. Though there has been testimony on the use of destructive practices by some collectors in the past, the applicants have also provided video evidence of collection techniques to catch coral-associated species without coral harm. DAR is once again hesitant to state that aquarium collection is inherently associated with coral damage or to make the broad assumption that the seven applicants will use techniques that intentionally damage corals. DAR does recognize, however, that any fishery that comes in close contact with live corals does pose some level of risk to them.

8.2 Black Market and Illegal Activity

Should the seven applicants be allowed re-entry into the fishery, they will have a significant incentive to proceed in a lawful manner, or face loss of their permits or closure of the fishery. Threat of permit loss may be especially significant given the time and resources invested in reinstating their permits and the financial gain they would stand to lose. In terms of illegal activity, the more likely threat is in the form of unpermitted individuals attempting to collect and export fish under the cover of the active lawful fishery. A legal pipeline in any fishery poses an opportunity for unscrupulous unlicensed fishers to sell and move their catch under the guise of legal activity. It should be noted that though the high value of live aquarium fish may make a black market more lucrative to law breakers, illegal or unreported sales are not unique to the commercial aquarium fishery.

Safeguards against the illegal black market include the relatively small size of the fishery. The seven applicants have been publicly named and are well-known to DAR, the Division of Conservation and Resource Enforcement (DOCARE), and the broader West Hawaiʻi community. Vessel marking requirements pursuant to HAR §13-60.4-7 (c)(1-5) means that all permitted aquarium fishers will be easily distinguishable from the general public, a facet not present in all commercial fisheries of the State. In short, a small pool of known, easily identifiable individuals will make the unlawful collectors easier to identify and investigate. Additionally, the seven applicants have voiced their intent to work exclusively with a limited number of commercial dealers to receive and export their catch, thereby limiting the potential legal avenues through which fish and money can lawfully move. Though this is not dictated by a requirement of their permit at this time, narrowing the pool of identified legal fishers and dealers increases the ability to identify illegal activity by simplifying chain of custody.

8.3 Accurate Reporting and Tracking TAC limits

Any fishery being managed under TAC limits is dependent on accurate and timely reporting. Monthly catch reports would be used to track this fishery including cumulative catch of individual species. Ideally, as with the MHI Deep-7 fishery, the fishery would be tracked on a per-trip basis. DAR does not have the authority to require more frequent reporting by aquarium fishers. Participants may however report weekly on a voluntary basis, which would both improve our tracking and provide them with a more up-to-date accounting of their catch over time. Identification of late reports is simplified both by the small size of the fishery and the automated Civil Resource Violation System (CRVS) which automatically assigns violations to those who fail to report in a timely manner. Note that monthly reporting is a requirement of the CML, and repeated failure to do so can constitute grounds for revocation.

Tracking of the fishery is also crucial for management under TAC limits. Cumulative catch for each species would need to be tracked over time to ensure that limits are not surpassed, and that fishery participants are notified of fishery status changes. Plots as shown in Figure 15 can be updated monthly to provide a visual of fishery performance. Catch by individual collector cannot be made public as it is confidential, though DAR would have the ability to do so and share with fishery participants.

8.4 Assistance by Unpermitted Individuals

Should permits be issued, the seven applicants would be the only individuals permitted to take part in commercial aquarium fishing trips. All individuals participating in aquarium fishing trips, including those handling/possessing aquarium collection gear or operating vessels, would by law need to possess both a State Aquarium Permit and a West Hawai‘i Aquarium Permit. Only the seven individuals named thus far as applicants are eligible to receive such permits at this time. DAR recognizes that aquarium collection, especially when boat-based, is typically not an individual activity for multiple reasons including diver safety. However, fishery participants would be limited to the pool of seven, and permittees would need to work together if a team of two or more is needed.

8.5 Overlap with Food Fish Fisheries

Commercial food fish reports from West Hawai‘i[13] over the past 20 years include limited catch of kole (average annual catch 206 lbs. per year), orangespine unicornfish (average annual catch 91 lbs. per year), black surgeonfish (average annual catch 32 lbs. per year), and brown surgeonfish (confidential[14]). All four species are relatively small components of both the West Hawai‘i and Statewide commercial inshore reef fish fisheries. Because West Hawai‘i lacks a network of full-time fish markets capable of receiving and selling large amounts of reef fish like O‘ahu, it is likely that a large portion of the commercial sales of reef fish occurring are relatively small scale and direct to consumer. Though DAR recognizes that a portion of these sales may be unreported due to the closed communities and networks within which they occur, it is unlikely that commercial catch of these species is occurring to the extent that it rivals non-commercial catch. Due to the low and sporadic reported commercial catch of these four species, using average catch or CPUE over time to determine the impact of the commercial aquarium fishery is unfeasible.

The Hawai‘i Marine Recreational Fishing Survey (HMRFS) is a statewide creel survey targeting fishers at boat launches and common fishing access points. HMRFS is the most expansive creel survey effort in the state and the primary means to measure non-commercial fishing catch over a wide geographic area. Survey results within the WHRFMA over the past 20 years reflect similar results as the commercial reports, with limited intercepts (angler interviews) for kole (85 intercepts), orangespine unicornfish (25 intercepts), black surgeonfish (6 intercepts), and brown surgeonfish (8 intercepts). HMRFS surveyors did not encounter any anglers possessing yellow tang, Potter’s angelfish, bird wrasse, or Thompson’s surgeonfish during the 20-year period. While HMRFS surveys do provide confirmation that kole, orangespine unicornfish, black surgeonfish, and brown surgeonfish are caught for non-commercial purposes, low sample sizes may not be an accurate representation of how much effort or overall take is occurring. Factors contributing to low HMRFS sample sizes for these species include both the expansive

[13] DAR commercial reporting grid areas 100-103.
[14] Fewer than three fishers reporting 2004-2023.

and rugged coastline of West Hawai‘i and the fact that the primary group targeting most of these species are spearfishers, which are particularly hard to intercept. Due to the paucity of HMRFS intercepts of these four species, using average catch or CPUE over time to determine the impact of the commercial aquarium fishery is unfeasible. Catch expansion using The NOAA’s Marine Recreational Information Program (MRIP) effort surveys is possible, though again low sample sizes will likely prevent accurate estimation of total catch at the annual level.

DAR is unable to accurately quantify the total WHRFMA harvest of these species for consumptive purposes. Based on available commercial and HMRFS data, we see that the highest overlap is with kole followed to a lesser extent by orangespine unicornfish, black surgeonfish, and brown surgeonfish. Knowing that limited take of yellow tang for consumption does occur (though not commonly captured in fishery dependent data), the aquarium fishery likely has some small degree overlap with the food fish fishery for the species. Fishery overlap with food fish take of bird wrasse, potter’s angelfish, or Thompson’s surgeonfish is likely negligible or non-existent in the present day.

8.6 Safeguarding Against Unexpected Impacts or Other Changes

Whether management decisions are guided by formal stock assessment or based on available data alone, uncertainty is always present. Assessments, no matter how complex, are only as good as the data upon which they are based and the assumptions made. Accepting that there is some chance of being “wrong” is an ever-present facet of fishery management. Aside from incorrect assumptions, there are also numerous factors external to the fishery that can lead to concern for finfish populations and ecosystems. Disease, additional marine heatwaves, and shifting oceanographic conditions can all change the setting in which a fishery takes place and warrant re-evaluation regarding whether or not the populations targeted and their habitat can continue to sustain a fishery. This is objectively true for all fisheries regardless of disposition.

Uncertainty and the threat of unforeseen changes can be mitigated via regular monitoring of both the populations targeted and their ecosystems. DAR has emergency rulemaking authority under HRS §91-3(b) should the need to enact swift rule changes arise. Emergency rules with adequate justification may proceed without public notice or hearing and be adopted for a period no longer than 120 days without renewal. Similarly, DAR also maintains the ability to adopt, amend, or repeal an existing rule as a means of adaptive management under HRS §187A-5(b)(1). Adaptive management must go through the full public notice and hearing process, but changes are in place for a period of no longer than two years without renewal.

9. Summary of Findings

Regarding the three questions posed in Section 1, DAR finds the following:

1) *Does the data examined suggest that the proposed take will result in population-level declines that would affect the long-term viability of the population?*

No, DAR did not see clear evidence in WHAP or PIFSC-ESD data to suggest that the proposed take will result in population-level declines that would affect the long-term viability of the population.

WHAP and PIFSC-ESD data suggest that the commercial aquarium fishery in West Hawaiʻi, while undoubtedly responsible for removal of fish off the reef, may not be the largest factor influencing population trends, recruit density, and juvenile abundance. The WHRFMA populations of these species are generally robust in comparison to the rest of the MHI, and generally stable over time including when the fishery was active. High density and abundance where the fishery was active and comparatively lower density and abundances where the fishery was small or non-existent suggests that the commercial aquarium fishery may not be a primary factor driving population status across the archipelago. Recruitment of juveniles for five of the eight species including yellow tang and kole was (though highly variable) stable or increasing over time including when the fishery was active. Increasing recruit trends even during a period when catch was relatively high suggests that the populations were not unable to sustain themselves. Recruit density also appeared to be associated with certain areas of the WHRFMA suggesting a spatial component to where recruits tend to settle.

The exploration of WHAP data showed that describing the impact of the FRAs in terms of singular mean trends overlooks site-level variability. Overlap in site-level juvenile fish densities were apparent not only within the three management area types, but also across them. While consistently lower mean juvenile densities in the open areas for some species suggest that the fishery may be having a clearly defined impact, overlap between open and closed areas suggests that factors other than commercial aquarium fishing are likely also influencing juvenile density. Comparison of juvenile density trends across management area types also showed that for each species, the FRA, LTP, and open sites often displayed similar responses to recruitment pulses even prior to the fishery closure. That is, the open areas did not show a clear indication that that they were less able to sustain juvenile densities during ongoing collection.

Comparison of the proposed TACs to PIFSC-ESD population estimates suggested that the proposed level of take would remove a relatively small percentage of the entire WHRFMA populations of the eight species. A deeper look into the impact of proposed harvest on yellow tangs which focused on the proportion of the population estimated to be available to the fishery (accounting for the percent of the WHRFMA open to fishing and the fishery's preferred size class: 5-10 cm) also did not raise major concerns. While estimates of juvenile yellow tang harvest rates were between 5% and 31% of the targeted population open to the fishery, risk to the population was assessed as low. The rationale for the low risk is that the TAC will have far less impact on fish in the open area outside of the targeted size range, and no impact on fish in the 47.7% of the WHRFMA closed to commercial aquarium harvest should provide adequate reproductive output to sustain the WHRFMA yellow tang population.

2) *Does the data examined suggest that the proposed take will result in impacts to the ecosystem that would result in measurable declines in ecosystem health or the ability of the ecosystem to sustain itself?*

No, DAR did not see clear evidence in WHAP data to suggest that the proposed take would result in measurable declines in ecosystem health or the ability of the ecosystem to sustain itself.

The relationship between management area type and percent coral cover was not apparent. There was considerable site-level variability within and across the FRAs, LTPs, and open sites. Differences in percent coral cover before, during, and after the bleaching event of 2015 was not apparent suggesting that commercial aquarium collection may not have a measurable impact on habitat. The four herbivorous fish species included in the revised white list certainly contribute to total herbivory. The data suggests however that removal of a portion of these populations by the commercial aquarium fishery may not have a strong influence on percent coral cover.

3) *Do current management measures mitigate potential negative effects of the fishery or provide safeguards against unforeseen changes?*

Yes, after review of existing and proposed management measures, DAR finds that they would likely mitigate potential negative effects of the fishery and provide safeguards against unforeseen changes.

DAR finds that the amount of management and oversight on the West Hawai‘i aquarium fishery surpasses that of any other State-managed fishery with the majority of management measures being unique to the fishery itself. The combination of input controls, output controls, spatial controls, monitoring, and capability of managers to make regulatory changes in emergency situations provides DAR with powerful tools to mitigate and address population decline both resulting from commercial collection and otherwise.

Potentially the most significant management measure in place is the closure of approximately 47.7% of the WHRFMA to commercial aquarium collection, a degree of protection seen in few other fisheries. Coupled with size restrictions for the two most intensely harvested species (yellow tang and kole) in the open areas, a substantial proportion of the total WHRFMA populations of theses eight species will be protected. This is significant as larvae are not confined to their management area type. A high level of spatial protection and protections on the adults of the two most intensely harvest species ensures continuous larval distribution across the entire WHRFMA including the open areas.

The introduction of TACs provides a solution to the uncertainty of a fishery once without limits on total catch. For yellow tang, goldring surgeonfish, naso tang, bird wrasse, and black surgeonfish, proposed TACs are near or below the twenty-year mean annual take for the fishery ensuring that that catch would not go beyond levels previously recorded. For brown surgeonfish, Potter’s angelfish, and Thompson’s surgeonfish (the three species in which the proposed TAC’s greatly exceed the twenty-year mean annual catch), it is important to note that prior mean harvest rates of these species relative to their most conservative WHRFMA population estimates (from Table 1) were less than 1 percent (0.03%, 0.5%, and 0.2%, respectively). The proposed TACs on these species, while exceeding low historical harvest rates would remove less than 3% of the most conservative population estimates for any of these species in the WHRFMA (last column in Table 1). Along with limiting the fishery to eight species and limiting total catch, the West Hawai‘i aquarium fishery would be further confined by the number of participants who can legally collect. A known number of individuals with vessel marking requirements would make this a highly visible and easily identifiable fishery not only providing ease in identifying who can legally collect, but also who cannot.

Lastly, WHAP surveys, as a fishery specific monitoring survey, serves as a powerful mitigation measure against unforeseen population changes. Along with other large-scale and regional monitoring efforts such as FAHU and SWRF surveys, DAR has the ability to track resource conditions annually and make adjustments to management should they be warranted. Science is imperfect, and risk of unforeseen circumstances is ever-present. The ability to track the fishery on an annual basis provides the managers with a “safety net” to ensure that significant negative change does not go unnoticed.

10. Conclusion

After review, DAR does not find clear evidence to suggest that commercial aquarium take in West Hawai‘i, as proposed by the seven applicants, will result in major declines in WHRFMA populations of the eight species to the extent that they would be threatened at a population level. DAR also did not find clear evidence to suggest the proposed commercial aquarium take in West Hawai‘i would result in impacts to coral environments of the WHRFMA to the extent that percent coral cover, resistance to bleaching, or resilience following a bleaching event would be significantly compromised. Additionally, DAR finds that existing and proposed management measures, most notably substantial spatial closures which prohibit aquarium fishing in almost half of the prime fishing depths in the WHRFMA, effectively help to mitigate potential negative effects of the fishery and provide safeguards against unforeseen changes. DAR does not find that the level of uncertainty or risk in the proposed West Hawai‘i aquarium fishery are greater than that of any other nearshore fishery in the State. Based on these findings, DAR assesses the direct risk of significant population and habitat impacts as low.

11. References

Ayotte, P., K. McCoy, I. Williams, and J. Zamzow. 2011. Coral Reef Ecosystem Division standard operating procedures: data collection for Rapid Ecological Assessment fish surveys. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-11-08

Baggini, C., Y. Issaris, M. Salomidi & J. Hall-Spencer. 2015. Herbivore diversity improves benthic community resilience to ocean acidification. *Journal of Experimental Marine Biology and Ecology* 469, 98–104

DAR 2019. Report to the Thirtieth Legislature 2020 Regular Session on a report on the Findings and Recommendations of Effectiveness of the West Hawai'i Regional Fishery Management Area (WHRFMA). State of Hawai'i. November 2019.

Donovan MK, C.W.W. Counsell, M.J. Donahue, J. Lecky, L. Gajdzik, S.D. Marcoux, R. Sparks, C. Teague. 2023. Evidence for managing herbivores for reef resilience. Proc. R. Soc. B290: 20232101.https://doi.org/10.1098/rspb.2023.2101

Hixon, M. A. 2015. Reef fishes, seaweeds, and corals. in *Coral reefs in the Anthropocene* 195–215 Springer.

Hobson, E.S., 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72(4):915-1031.

Ochavillo, D. and G. Hodgson. 2006. MAQTRAC marine aquarium trade coral reef monitoring protocol data analysis and interpretation manual. Reef Check Foundation. California, USA.

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

Tebbett, S.B., A.C. Siqueira, & D.R Bellwood. 2002. The functional roles of surgeonfishes on coral reefs: past, present and future. *Rev Fish Biol Fisheries* **32**, 387–439. https://doi.org/10.1007/s11160-021-09692-6

Walsh W., S. Cotton, C. Barnett, C. Couch, L. Preskitt, B. Tissot and K. Osada-D'Avella. 2013. Long-Term Monitoring of Coral Reefs of the Main Hawaiian Island. Final Report 2009 NOAA Coral Reef Conservation Program.

APPENDIX A: History of the West Hawai‘i Aquarium Fishery

History of the West Hawai‘i Commercial Aquarium Fishery

A Report to the State of Hawai‘i Board of Land and Natural Resources

March 2024

Hawaii Division of Aquatic Resources

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Introduction

Collection of marine life for aquarium purposes has been occurring in Hawai‘i since at least the 1950’s. Since the 1990’s the majority of commercial aquarium catch in the state has come from the waters off the west coast of Hawai‘i Island. The West Hawai‘i aquarium fishery quickly grew to be one of the most economically valuable nearshore fisheries in the State of Hawai‘i. The expansion of the West Hawai‘i aquarium fishery, however, has a long history of conflict with other ocean user-groups, residential communities, and special interest groups. Persistent public concerns about the aquarium fishery have resulted in multiple legislative and Board of Land and Natural Resources (BLNR) hearings, court cases, and ultimately more aquarium-specific management and monitoring than any other nearshore commercial fishery in the state.

The history of the West Hawai‘i aquarium fishery and associated management measures provides important context to the current state of the fishery (closed) and considerations for the future of commercial aquarium fishing in West Hawai‘i. Agencies tasked with managing resources do not manage the resource itself; rather, they manage the humans that may or may not harvest a resource. Understanding the motivations and dynamics of the humans participating in resource harvest is critical to resource management. Exploring economic or market factors that influence fisher decisions, therefore, provides important context for evaluating the West Hawai‘i aquarium fishery.

The purpose of this report is to provide members of the Board of Land and Natural Resources with a historical review of the West Hawai‘i commercial aquarium fishery from the perspective of State fishery managers. This review begins with a brief history of the main driver of demand for West Hawai‘i aquarium fish – the marine aquarium hobby. Next, trends in commercial aquarium fishing effort and catch in West Hawai‘i are described according to three time periods in the fisheries expansion: pre-1986, 1987-1999, 2000-2017. Throughout the report, an attempt was made to relate trends in aquarium fishing effort and catch to general changes in the marine aquarium hobby. Pertinent management measures relevant to the West Hawai‘i aquarium fishery are also noted including a brief review of the court rulings and timeline related to the aquarium fishery closure.

The Evolution of the Marine Aquarium Hobby

The marine aquarium hobby, where individuals keep fish and other marine organisms in contained environments for enjoyment and educational purposes, drives the demand that created Hawai'i's aquarium fishery. Since the emergence of the modern aviation industry made it easier to move live fish from source to market, the marine aquarium hobby has grown and changed considerably. In the early years of the hobby, focus was on the maintenance of fishes with an emphasis on aesthetics. Two of the most popular fish families in the hobby during this time were *Chaetodontidae*, more commonly known as butterflyfish and *Pomacanthidae*, more commonly known as angelfish. Growing concerns throughout the 1980's that butterflyfish and angelfish could not be properly cared for in captivity spurred a gradual shift in the marine aquarium hobby away from maintaining "fish-only" aquariums to replicating coral reef settings with both fish and benthic organisms.

Modern reef aquaria surged in popularity over the next three decades fueling demand for colorful fish like the yellow tang (*Zebrasoma flavescens*), that are also "reef safe"[1]. As knowledge about aquarium husbandry improved, hobbyist's appreciation for the wellbeing and sustainable capture of aquarium fishes also increased. The hobby began to desire both younger/smaller fishes that are better suited for adapting to the home aquarium and for fish collected with better care and handling. Some methods for aquarium fish collecting were more selective and resulted in less stress and injuries to animals. As such, selective demand by the marine aquarium hobby put pressure on many aquarium fisheries to not only shift what species they target, but also improve fishing practices.

[1] Reef safe fish is the marine aquarium hobby are fish that do not readily consume corals and other benthic invertebrates.

History and the Expansion of the West Hawai‘i Aquarium Fishery

The aquarium fishery in Hawai‘i targets multiple species of fish. Temporal trends in total catch, species composition of catch, participation, and effort tell the story of the fishery's expansion[2]. To aid interpretation of West Hawai‘i aquarium fishery trends, the fishery was divided into three phases of development (Figure 1). Phase timelines were based on changes in observed trends and changes to the management of the fishery. As such, the classification of fishery development phases is somewhat subjective. However, the phases help contextualize changes in the fishery and allow for deeper explorations of factors that contributed to the expansion of the West Hawai‘i aquarium fishery.

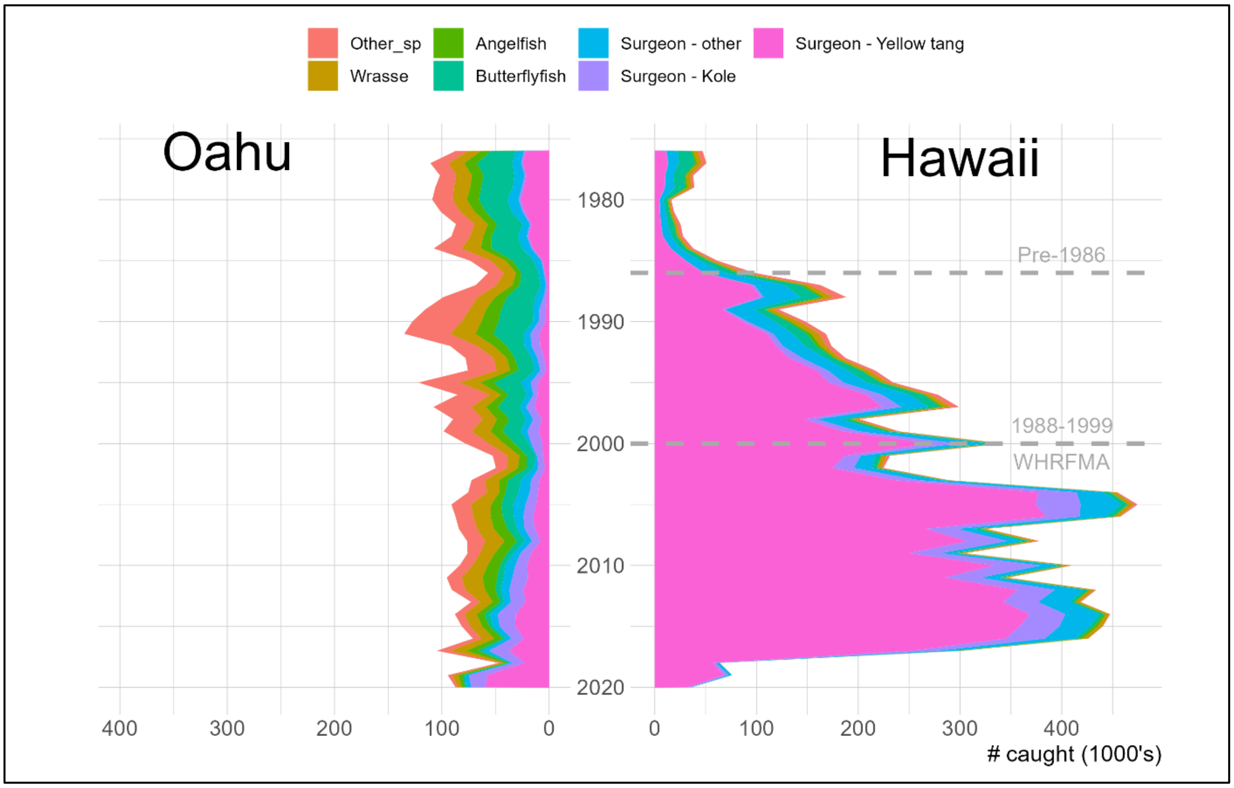

Figure 1. Total catch and composition of main species and/or aquarium fish families for O'ahu and Hawai'i Island. The three phases of West Hawai'i Aquarium fishery development are highlighted. Note: results reflect catch for all of Hawai'i Island.

Pre-1986

Prior to 1986, O‘ahu was the main island for commercial aquarium collecting. O‘ahu accounted for 73% of the total reported commercial aquarium catch with wrasses, butterflyfish, and angelfish comprising

[2] Aquarium catch and effort data comes from the state of Hawai‘i's commercial fish reporting system. In 1973, the state implemented the C-6 aquarium fish catch report. Only catch and effort information from 1976 on were considered in this report due to early problems with C-6 report. Commercial aquarium catch is self-reported by fishers. The accuracy of the information is dependent on the sincerity of those submitting the reports and no system existed for verifying information. Therefore, information of catch and effort information should be regarded as minimum and not absolute values and caution is advised when interpreting trends.

over 50% of the catch (Figure 1). The yellow tang was also an important component of O‘ahu commercial catch. However, a series of hurricanes in the early 1980s caused extensive damage to coral reefs across leeward O‘ahu (Walsh et. al., 2003). Yellow tang catch declined over 75% from a high of ~26,400 fish in 1980 to ~6,200 fish in 1985. Meanwhile, catch of yellow tang on Hawai‘i island nearly tripled. By 1985, yellow tang catch on Hawai‘i island exceeded the highest catch previously reported on O‘ahu. According to commercial aquarium catch reports, participation in the West Hawai‘i commercial aquarium fishery was stable at around 10 collectors between 1980 and 1985. Therefore, the increase in reported catch was most likely the result of increased fishing effort and/or capture efficiency (Figure 2).

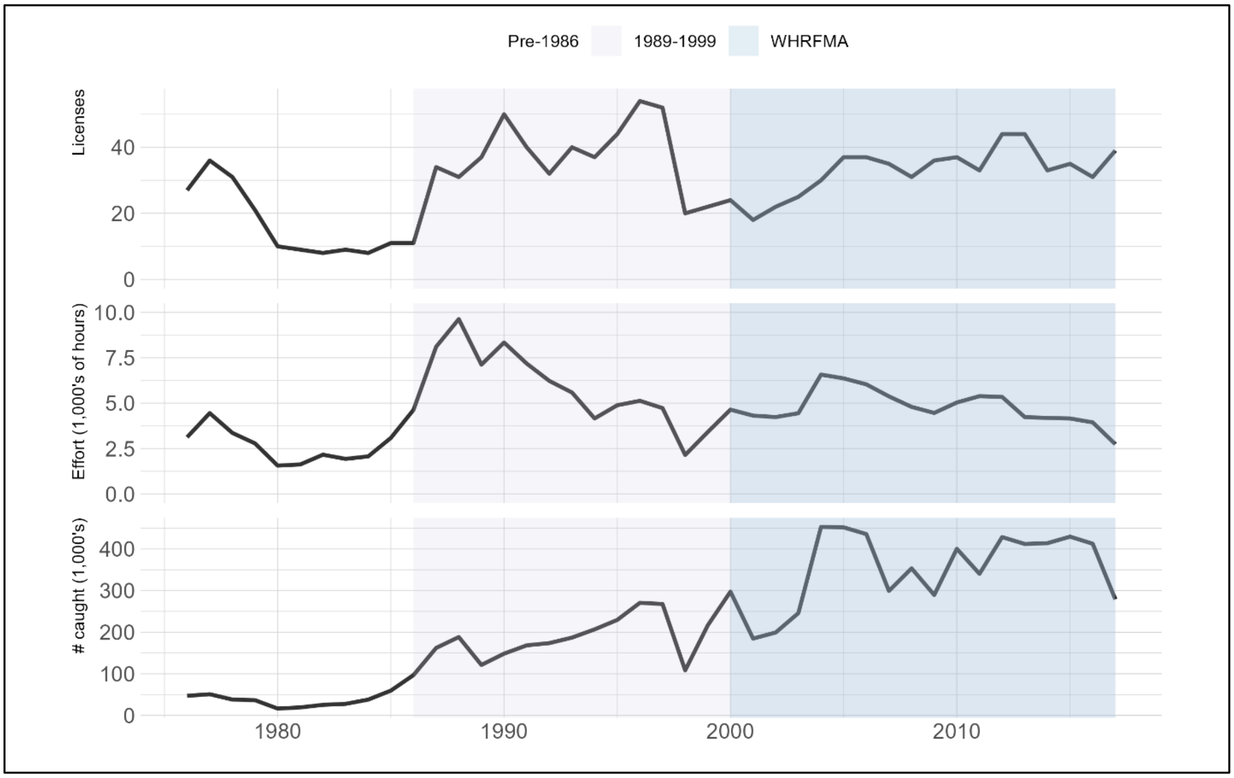

Figure 2. Trends in reporting licenses (top), effort (middle), and total reported catch (bottom) for the West Hawai'i Commercial Aquarium Fishery. Shaded regions reflect the three phases of fisheries development.

The decrease in West Hawai‘i aquarium licenses reporting catch prior to the 1980’s is worth noting. Walsh et al. (2003) attributed the decline to worldwide oil and fuel shortages that contributed to economic recession. The marine aquarium hobby is a luxury activity and as such, demand for aquarium fish is connected to the state of the economy. Another consideration when interpreting trends in commercial fisheries reports, especially prior to 2000, is reporting accuracy. Recordkeeping for commercial fishing licenses was suspect until 1999 and accurate aquarium fish catch reporting has been a challenge in Hawai‘i as well as other small-scale fisheries throughout the world.

1986-1999

The West Hawai‘i aquarium fishery expanded rapidly following the mid 1980’s. By 1990, five-times as many commercial licenses were reporting aquarium catch compared to the early 1980’s. Reported catch of yellow tang, which never exceeded 30k fish annually on O‘ahu, surpassed 100k fish from West Hawai‘i in 1988. The high reported catches of yellow tang partly reflect the high abundance of this species along the Kona coast compared to other regions/islands across the Hawaiian archipelago. In hindsight, the timing of the geographic shift in Hawai‘i’s aquarium fishery to the Kona coast of Hawai‘i where the bright and colorful yellow tang were plentiful aligned with growth of the marine aquarium hobby. Abundant yellow tang and high demand for these fish by marine aquarium hobbyists contributed to the rapid expansion of West Hawai‘i’s aquarium fishery. The net result was a shift in the composition of reported West Hawai‘i aquarium catch with yellow tang and other surgeonfish becoming the main targets of the fishery (Figure 3).

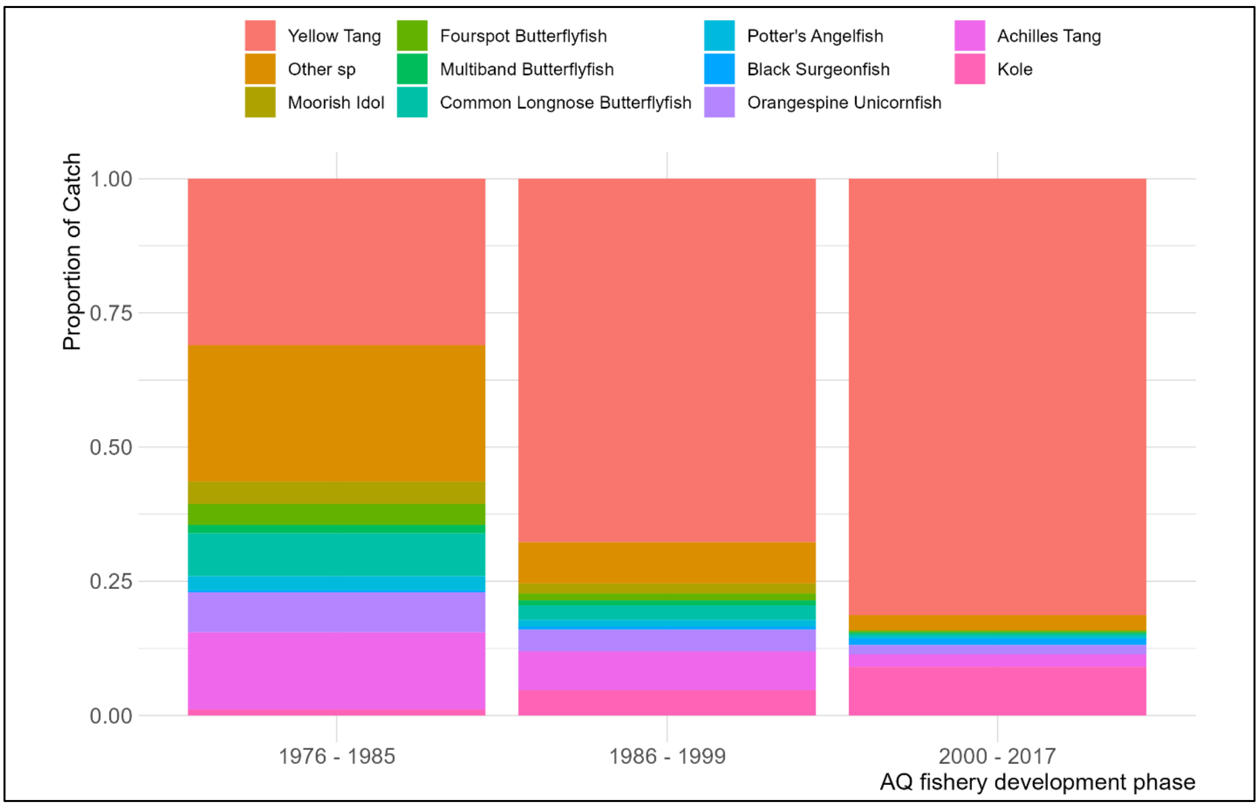

Figure 3. Average species composition of reported aquarium catch in West Hawai‘i across three time periods reflecting general phases of the West Hawai‘i aquarium fishery.

The rapid growth of the West Hawai‘i aquarium fishery in the mid to late 1980’s spurred conflict with other ocean users mainly snorkel and dive tour operators) off the Kona coast. The majority of reported aquarium catch prior to 1990 occurred in catch grid 101 (Figure 4). Catch area 101 comprises the area from Keāhole Pt. south to the traditional fishing village of Miloli‘i (Figure 5). This area includes the two major harbors and boat launches for the Kona coast and therefore most ocean related businesses operate in the same vicinity. To minimize future conflicts, aquarium collectors and tour operators formed a

“Gentlepersons” agreement in 1987 whereby no aquarium collection would occur in specific stretches of the West Hawaiʻi coastline. In 1991, these four areas were incorporated into the Kona Coast Fishery Management Area, which spanned approximately four miles of coast. In 1992, an additional 1.3 miles of coastline was protected via the “Old Kona Airport” Marine Life Conservation District (MLCD). These spatial prohibitions on aquarium fishing represent the early stages of management of the West Hawaiʻi aquarium fishery.

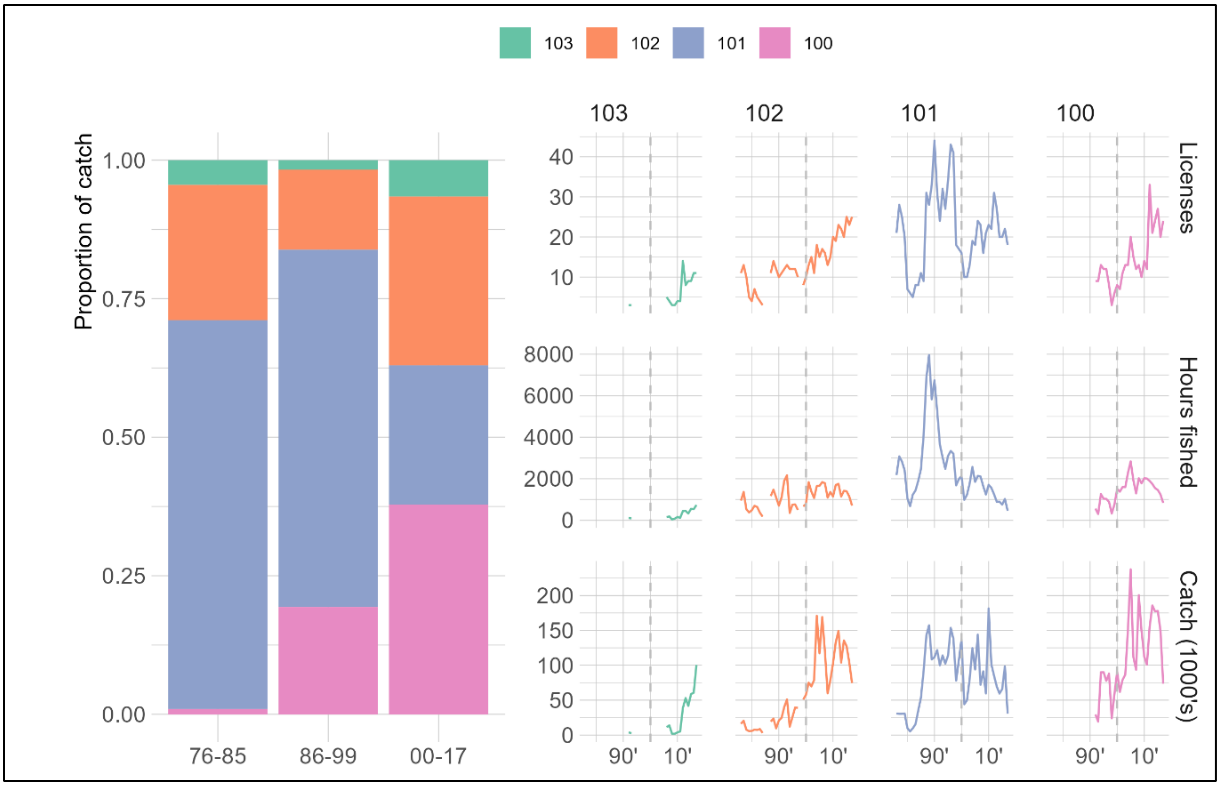

Figure 4. Proportion of catch in each catch area during each phase of the West Hawaiʻi aquarium fishery (left) and trends in reporting licenses (right-top), effort (right-middle), and total reported catch (right-bottom) for each area. Confidential data (less than three reporting licenses were removed from trends. Catch areas are arranged North-South (103-100). The vertical dashed line indicated the establishment of the Fish Replenishment Area (FRA) network.

The creation of spatial prohibitions on aquarium collection in West Hawaiʻi did not eliminate concerns of all stakeholders in West Hawaiʻi and questions about the sustainability of the aquarium fishery continued throughout the 1990’s. Multiple stakeholder groups sought additional management and/or the complete ban of the aquarium fishery. Meanwhile, the number of aquarium fishers reporting catch declined by more than 60% between 1997 and 1998. Tracking individual fishers in the state’s commercial aquarium fishery database prior to 1999 is currently not possible. Without knowledge of what fishers stopped reporting, it is difficult to determine if the decrease in reporting licenses reflects an actual drop in participation. While it seems reasonable that the aquarium fishery’s conflict with the public may have caused some collectors to exit the fishery, other plausible explanations for the decline in participation include: some fishers stopped reporting but continued fishing or low recruitment (the number of new fish that enter a population each year) of aquarium fish species caused some part-time fishers to drop out.

Either way, the decline in reporting licenses in 1998 resulted in less reported aquarium fish catch which dropped below 110k for the first time since 1986. The decline in catch was just temporary, however, as catch was back over 200k fish in 1999 despite a similar number of reporting fishers in both 1998 and 1999 (Figure 4).

Acknowledging the lack of clear scientific evidence of overfishing, the Division of Aquatic Resources (DAR) collaborated with the University of Hawaiʻi (UH) at Hilo in the mid-1990s to assess the effects of aquarium collection on the coral reefs offshore of Kona. Results indicated that aquarium fishing significantly reduced the abundance of some fish species targeted by the West Hawaiʻi aquarium fishery including the yellow tang whose abundance in areas open to fishing was roughly half of abundance in areas closed to fishing (Tissot & Hallacher, 2003)[3]. The findings of lower fish abundances in areas open to fishing by Tissot & Hallacher (2003) supported the need for additional management of aquarium fishing in West Hawaiʻi.

In 1998, the Hawaiʻi State Legislature passed Act 306, which established the West Hawaiʻi Regional Fisheries Management Area (WHRFMA). The WHRFMA encompassed the entirety of the West Hawaiʻi coastline (147 miles from ʻUpolu Pt. to Ka Lae). The overall purpose of the WHRFMA was to ensure the sustainability of the State's nearshore ocean resources, effectively manage fishery activities, enhance nearshore resources, and minimize conflicts of use. Act 306 instructed The Department of Land and Natural Resources (DLNR) to designate a minimum of thirty percent of coastal waters in the WHRFMA as fish replenishment areas (FRAs) where aquarium fish collection would be prohibited. Act 306 also contained instructions for non-aquarium fishing related actions (establishment of day-use moorings, designation of gill net and reef-dwelling fishing prohibitions). Additionally, the act called for "substantive involvement of the community in resource management decisions".

Act 306's "substantive involvement of the community" directive encouraged DAR to engage and consult with stakeholders in an active and continuous effort as opposed to the typical late-stage public hearing process for compiling stakeholder input. DAR, in conjunction with UH Sea Grant, facilitated the creation of the West Hawaiʻi Fishery Council (WHFC). The WHFC was comprised of 24 voting members and 6 ex-officio agency representatives (DAR, DOBOR, DOCARE, UH Sea Grant, Governor's office). Voting members represented the diverse communities and stakeholder groups in West Hawaiʻi and included: 3 aquarium collectors, 1 aquarium shop owner, 3 commercial dive tour operators, 1 hotelier, at least 10 fishers (commercial and recreational), shoreline gatherers, recreational divers, as well as several community representatives. The WHFC worked with stakeholders to develop a plan for a network of Fish Replenishment Areas (FRAs) along the West Hawaiʻi coast. The FRAs were intended to reduce both user conflict and localized resource depletion. The intent of Act 306 was to sustainably manage the aquarium fishery and other activities in the WHRFMA, not to dismantle or shut the aquarium fishery down completely (Walsh et. al., 2005). Considerable emphasis was placed on reviewing the best available information on marine protected areas, community-based resource management and scientific understanding of Hawaiʻi's coral reefs and aquarium fish species. Conflict "hotspots" were centered on near shore areas surrounding residential communities as well as popular diving and tourist areas. The final WHFC plan consisted of a network of 9 FRAs which, combined with existing protected areas, would prohibit aquarium fishing along 35.2% of the WHRFMA's coastline.

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[3] The limited spatial scope (two reef areas) investigated by Tissot & Hallacher (2003) means that study conclusions are most appropriate for describing the potential for aquarium fish collection to result in localized depletion. Localized depletion should not be confused with the "status" of a fishery being sustainable or overfished. The status of a fishery is more appropriately investigated at a spatial-scale commensurate with a fish population.

The “FRA Rule” went into effect in 1999 as HAR 13-60.3. The public hearing on the FRA Rule was and still is the largest public hearing ever conducted by DAR. At least 860 members of the public attended and the plan received overwhelming support (93.5% of 876 testimonies). The support across a wide range of stakeholder groups was a testament to the dedicated efforts to involve stakeholders at the beginning as opposed to the end of the process. The FRA network became effective on December 31st, 1999.

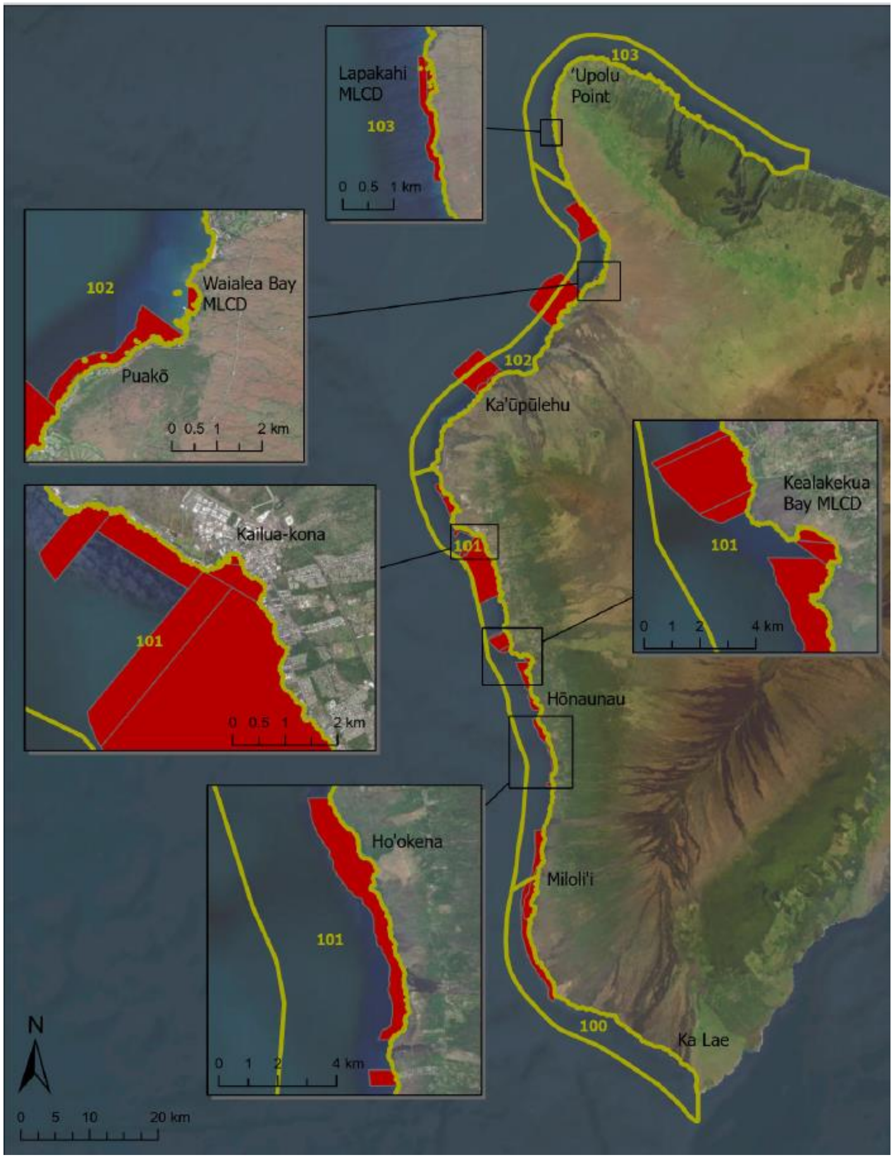

Figure 5. Map of commercial fish catch areas with areas where aquarium fishing is prohibited in red.

WHRFMA

One of the goals of Act 306 and the creation of a network of FRAs was to reduce conflict between aquarium fishers and stakeholder groups such as dive and snorkel tour operators. Multiple FRAs were placed in catch area 101 which is close to major tourist infrastructure and ocean access points used by both tour operators and aquarium fishers. After FRA closures, there was a general decline in commercial aquarium fishing effort within area 101 and considerable catch increases in areas 100 and 102 (Figure 4). Both areas 100 and 102 are not main destinations of Kona based ocean tour operators due to large distances from the main boat harbors. As such, catch areas 100 and 102 had both lower potential conflict between fishers and other ocean users and more area open to aquarium fishing compared to area 101.

The eventual increase in aquarium catch following FRA closures does not simply reflect spatial reallocation of fishing effort into more productive and/or underexploited areas. The price of yellow tang (adjusted for inflation) was relatively stable around $3/fish prior to 2000, then increased to over $5/fish in 2008 (Figure 6). The relatively sudden change in price is consistent with increased demand by the marine aquarium hobby that outpaced the increasing supply of yellow tang. The increased demand for aquarium fish encompasses not only the expansion of the marine aquarium hobby (more consumers) but also a shift in consumer preference for purchasing healthy fish with better survival probabilities. Some aquarium fishers in West Hawaiʻi modified or developed new fishing methods and targeting techniques that resulted in higher quality fish with regards to health (no injuries) and size (smaller or younger fish may adapt to captivity better than older/larger fish).

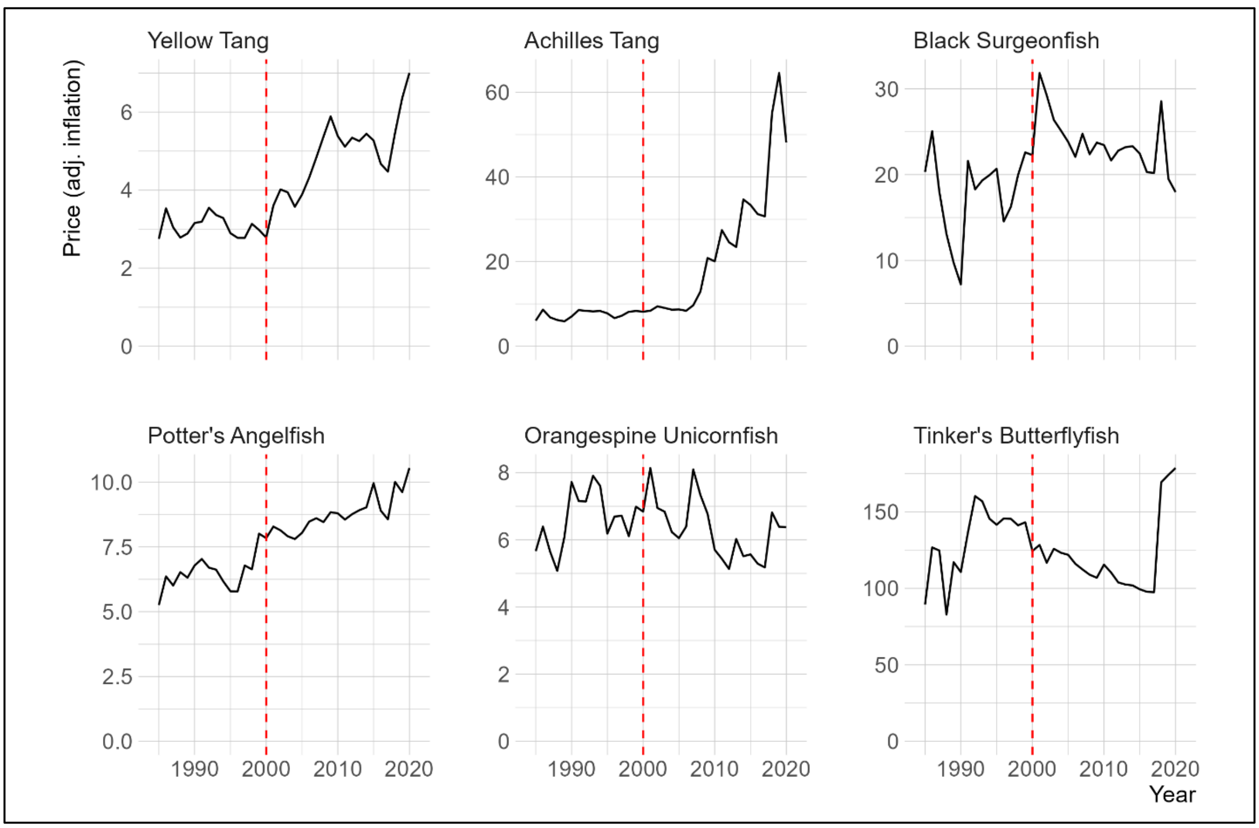

Figure 6. Price trends in 2022 dollars for six select aquarium fishery species. Price reflects sales information from all islands (not just West Hawaiʻi). The vertical dashed line indicated the establishment of the Fish Replenishment Area (FRA) network.

To meet demand for more fish, fishers can either harvest more frequently/longer, harvest more efficiently, or harvest in more productive areas. Reported effort was relatively stable after the mid 1990's (Figure 2), while nominal catch per unit effort (CPUE)[4] of yellow tang generally increased (Figure 7). Spatial patterns of yellow tang CPUE indicated that fishers became more efficient at catching yellow tang in addition to discovering more productive fishing grounds (Figures 7 & 8). Stevenson et al. (2011) reported several technological improvements that may have increased catch productivity. Some aquarium fishers began using underwater scooters to scout fishing areas while others modified gear configurations and/or deployment methods to increase catch. Additionally, some fishers worked in teams which was shown to increase catch rates per person[5].

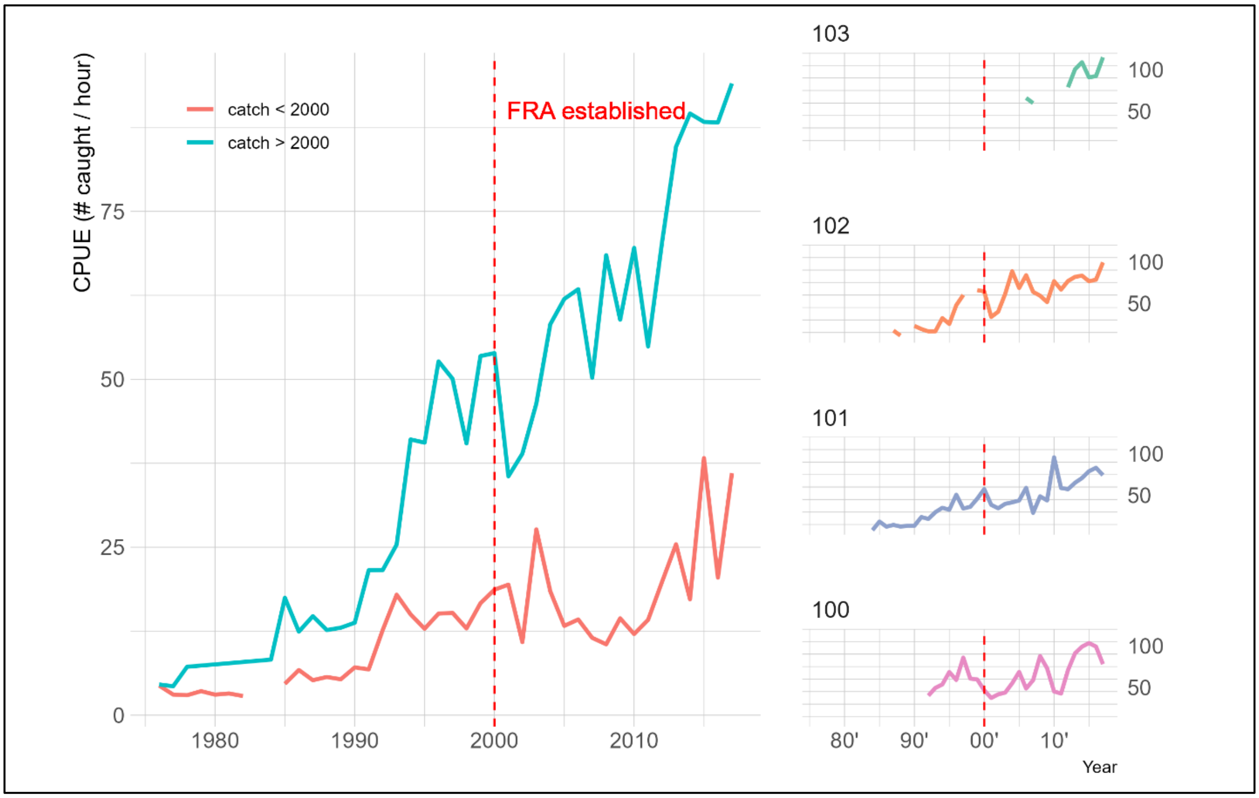

Figure 7. Trends in yellow tang catch per unit effort across the West Hawai'i Regional Fishery Management Area (WHRFMA) (left) and the four catch areas arranged from North to South (right). Separate Catch Per Unit Effort (CPUE) trends were calculated dependent on whether fishers caught more or less than 2,000 yellow tangs in a year. CPUE trends for each catch area are presented only for fishers catching more than 2,000 yellow tang. Confidential data when less than three reporting licenses were removed from trends. The vertical dashed line indicated the establishment of the Fish Replenishment Area (FRA) network.

To meet a change in demand regarding the health/condition of fish, some fishers modified their capture methods. Aquarium fish catch reports prior to 2012 contain limited information regarding specific method details. However, those involved in the fishery/trade note that some aquarium fishers started to use

[4] CPUE information is highly dependent upon accurate reporting of catch and effort. Prior to CPUE calculations, outlier values (i.e. catches of more than 500 yellow tang in 1 hour) were removed. Additionally, CPUE trends were calculated separately for "part-time" and "frequent collectors". Histogram plots of annual catch by fisher indicated a natural break at a catch of 2,000 yellow tang which was used as an arbitrary cutoff for classifying aquarium fishers.
[5] The number of crew participating on a fishing trip was not reported until 2012 when monthly reporting switched to a trip-based report format.

smaller barrier nets in the early 1990's. The use of smaller nets may allow fishers to be more selective in targeting specific groups of fish and thus reduce the number of non-targeted fishes caught. Smaller nets are also more amenable to "bleeding" which is the practice of opening a net to let undesired (either wrong species or wrong size) fish pass by without being captured. As such, aquarium fishers that were more selective in their methods to collect fish, may spend less time removing unwanted catch from their nets. Other behavioral changes related to improving the quality or health of aquarium catches relate to differential targeting and treatment of "hard" versus "soft-bodied" fish. Surgeonfish are considered "hardier" than "soft-bodied" fish such as some butterflyfish and angelfish. To further reduce potential stress and injuries to fish following harvest, some aquarium fishers would collect and store "soft-bodied" fish separately from hardier species.

In the early 2000's there was also a shift in the size of fish targeted by the West Hawai'i aquarium fishery. Large fish require more water volume for shipping which increases freight cost. Additionally, larger/older fish may not adapt to captivity as well as smaller/younger fish. However, recently settled fish are not as "hardy" as fish that have grown for a few months and thus young fish do not survive as well throughout the supply-chain process from collector to consumer. Some West Hawai'i aquarium fishers began to target fish in very specific size/age range to match market demand. For yellow tang, aquarium fishers preferentially target fish that are at least 3 months old and generally no bigger than 10 cm (Stevenson et al., 2011). Behavioral shifts by aquarium fishers that were motivated by market dynamics resulted in an even more specialized fishery for yellow tang (Figure 8)[6]. The evolution of aquarium capture methods and species targeting by West Hawai'i aquarium fishers likely reduced the fisheries impact of the aquarium fishery compared to earlier years.

[6] All aquarium fish catch reports were classified based on species-specific relative percentages. When yellow tang comprised more than 85% of catch, the trip was classified as "specialized"; "main target" trips were defined as trips with yellow tang comprising between 50% and 85% of catch; "minor targeting" was defined as trips with yellow tang comprising between 25% and 50% of catch; and trips where yellow tang comprised less than 25% of catch were classified as "secondary". Prior to 2012, reporting was monthly (ie max # of trips reported by a fisher would be 12), after which reporting was trip based.

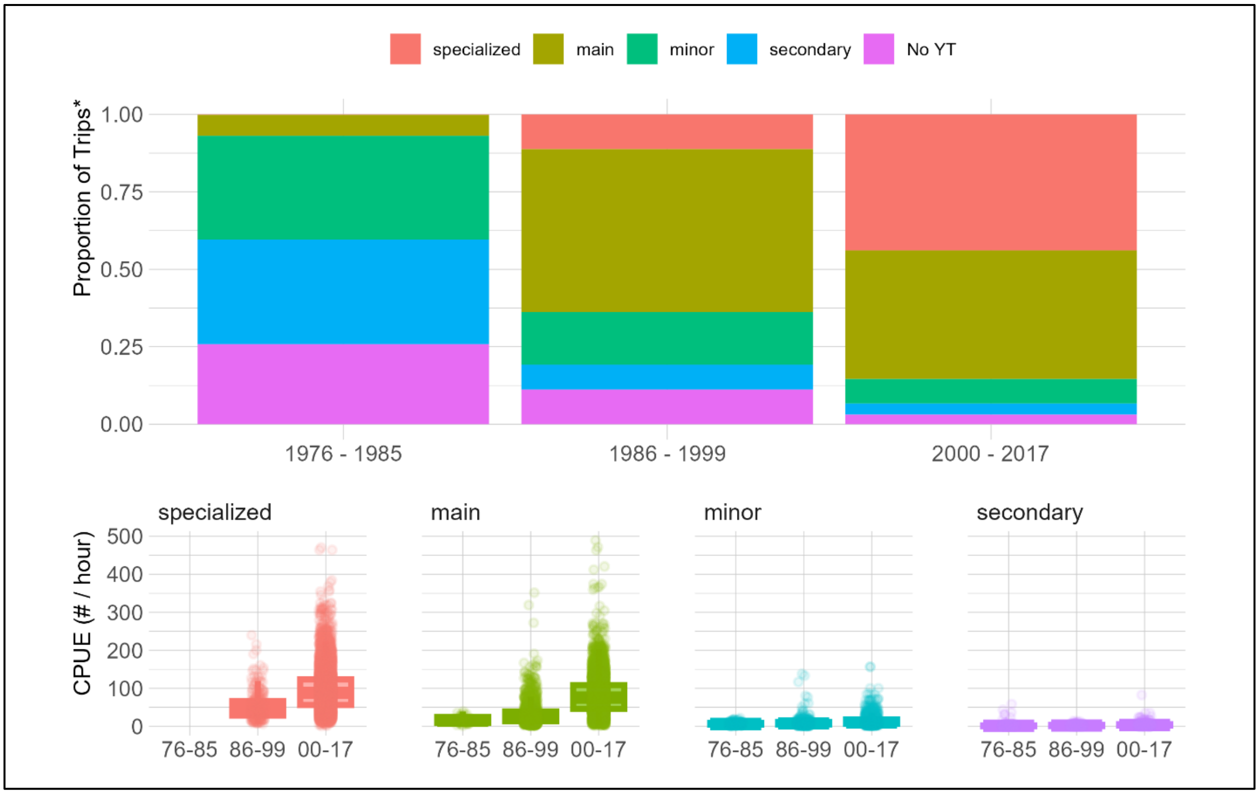

Figure 8. Change in yellow tang targeting across three time periods in the West Hawai'i aquarium fishery (top) and differences in yellow tang Catch Per Unit Effort (CPUE) between the targeting classifications and across time periods (bottom).

Following the establishment of FRA's, spatial re-allocation of aquarium fishing effort in the WHRFMA, and subsequent changes to catch methods and harvest efficiencies, reported total catch increased to a high of more than 450,000 fish caught in 2004 (Figure 2). Despite the prohibition of aquarium fishing in almost half of the shallower than 30 m reef habitat in the WHRFMA, public concerns regarding the sustainability of the aquarium fishery continued. The WHFC continued to work with DAR, aquarium collectors, and stakeholder groups to ensure resource sustainability. Without traditional fisheries management reference points for sustainability, the WHFC supported management based on precautionary principles. The WHFC recommended prohibitions on the collection of fish species that were rare, potentially overfished and/or not suitable for home aquariums ("Whitelist" of 40 species which could be taken by aquarium fishers). The WHFC also recommended size and/or bag limits to some frequently caught species. To help maintain breeding populations of yellow tang, the WHFC recommended protecting fish > 4.5" Total Length (TL) as well as very small/young fish (<2" TL) because they do not survive transport and handling well. Kole (*Ctenochaetus strigosus*) and pāku'iku'i (*Acanthurus achilles*) are both important food fish as well as aquarium fishery targets in West Hawai'i. The WHFC recommended a size-specific bag limit of 5 kole larger than 4.5" TL/aquarium collector/day and a bag limit of 10 pāku'iku'i/aquarium collector/day.

Additionally, the WHFC continued working with community groups on spatial-use conflicts. The WHFC drafted recommendations for creating a new FRA at Ka'ohe Bay (Pebble Beach) following a request by the South Kona community to prohibiting aquarium fishing in proximate nearshore waters. The WHFC recommendation included lifting aquarium prohibitions in a similarly sized section of another FRA not proximate to a residential area. However, the aquarium fishers were okay with the additional prohibited area without the re-opening of any previously established FRAs.

In December 2013, HAR 13-60.3 was amended to create restrictions on the species of fish and invertebrates that could be caught for aquarium purposes within the WHRFMA. As previously described, many of the experienced aquarium fishers in West Hawaiʻi had already shifted their fishing behaviors and size specific targeting of yellow tang and kole prior to new regulations due to market forces from the marine aquarium hobby. Therefore, the size-specific amendments may have been most applicable to "newer", or part-time fishers.

Reported commercial aquarium catch in West Hawaiʻi largely remained above 300,000 fish/year following peak reported catch in the mid-2000's until the end of 2017 when the fishery closed. Nominal CPUE trends for yellow tang[7] by spatial catch area are not consistent with patterns that would suggest declining populations (Figure 7). Caution is warranted when interpreting non-standardized CPUE trends and any potential relationship with population abundance. However, the large conservation benefit of the network of spatial closures (fishing mortality reduced to 0 in almost half of the main depths targeted by aquarium fishers) coupled with the highly selective targeting of juvenile fish likely contribute safeguards to overfishing the population of yellow tang in the WHRFMA.

[7] Yellow tang are the focal species of the West Hawaiʻi aquarium fishery comprising 82% of total catch since 1999.

Continued Conflict & the Closure of the West Hawaiʻi Aquarium Fishery

Conflict between the aquarium fishery in West Hawaiʻi and the public continued even with efforts to reduce direct conflict between user groups through spatial closures and stakeholder involvement. Isolated incidents such as the discovery of 610 dead aquarium fish in a dumpster at Honokōhau Harbor in 2010, were highly publicized and shed light on some of the unfortunate realities related to fisher experience levels in the West Hawaiʻi aquarium fishery. Most of dead fish were yellow tang with nearly half of the fish being recruits (very small fish that recently settled on the reef). While equipment failure was identified as a factor that could have resulted in the death of these fish, the large number of recruits would be consistent with collection behavior of an inexperienced collector.

In 2010, the DAR had been aware for many years that there was considerable variability in fisher skill levels, compliance with licensing/reporting, and effort within the West Hawaiʻi aquarium fishery. With minimal oversight on issuing permits and the potential for large profits, the aquarium fishery attracted many different types of fishers some of whom did not report their catch, fished illegally, and/or employed destructive fishing practices. The WHFC and DAR had previously recommended limiting West Hawaiʻi aquarium fishers to ensure a level of professionalism, skill, and provide economic incentive for fishers to promote good stewardship. However, a limited entry system was never implemented as DLNR was not authorized to do so. As such, the West Hawaiʻi aquarium fishery was comprised of many types of fishers, including skilled fishers that employed what has been described globally as the “standard” of sustainable aquarium collecting methods, as well as illegal fishers that not only did not report catch but may have also employed destructive and/or irresponsible fishing practices.

Non-reporting and/or illegal aquarium fishers may explain reports of aquarium catches of 1,000’s of yellow tangs for which there is minimal evidence in aquarium catch reports since trip-based reporting began in 2012 (only 6 trips with more than 900 yellow tang). For aquarium fishers hoping to sell fish and maintain good professional reputation with fish buyers, there are limitations to the number of fish that an aquarium fisher can catch in a single trip without risking damage to fish health due to overcrowding. Aquarium fishing vessels are outfitted with livewells which provide fresh seawater to help keep fish alive during transport. Overcrowding fish in livewells results in injuries and stress that can lead to mortalities and reduce profits. There is a considerable learning curve to becoming an efficient and successful aquarium fish collector in West Hawaiʻi. Market forces such as low prices or refusal to buy poor quality fish would eventually limit new or novice collectors from continuing in the fishery. However, market forces/feedback would not prevent poor collecting practices by new fishers.

Meanwhile, a new stakeholder group in the aquarium fishing debate emerged in the late 2000’s. Animal welfare advocates from Maui attempted to ban or severely restrict the aquarium fishery through the introduction of multiple state legislative bills, which were ultimately unsuccessful. This group of stakeholders, which generally believes that wild-caught fish should not be kept in captivity, found common ground with Native Hawaiʻian practitioners who found the commercial aquarium fishery to be a violation of cultural values deeply rooted in the connection between humans and the environment. Both groups have been critical of the aquarium fishery for ethical and cultural reasons in addition to claiming scientific and management shortcomings

A series of court proceedings that began in 2012 culminated in the September 6, 2017 decision by the Hawaiʻi State Supreme Court that commercial aquarium collection pursuant to permits issued under Hawaiʻi Revised Statute (HRS) §188-31 was subject to environmental review procedures laid out by the

Hawaiʻi Environmental Policy Act (HEPA; HRS 343). On January 5, 2018, DLNR announced that all collection of aquatic life for commercial aquarium purposes was prohibited in the WHRFMA until an environmental review was completed. On January 30, 2023 the Hawaiʻi State Supreme Court indicated that the environmental review process pursuant to HEPA had been satisfied for the West Hawaiʻi fishery and subsequently lifted the long-standing injunction prohibiting the DLNR from issuing aquarium collection permits within the WHRFMA. A brief summary of court proceedings related to the West Hawaiʻi aquarium fishery can be found in Figure 9.

TIMELINE

Court Rulings on West Hawai'i Aquarium Fishery Closure

2012

Oct 24: Plaintiffs sue DLNR for failing to complete an environmental review before approving aquarium permits.

2013

June 24: Circuit Court determines issuance of aquarium permits is not subject to review under Hawai'i Environmental Policy Act (HEPA).

July 18: Plaintiffs appeal to the Intermediate Court of Appeals (ICA).

2016

Aug 31: The ICA upholds Circuit Court ruling, affirming that aquarium permits are not subject to environmental review.

2017

Sept 6: Hawaii Supreme Court rules that commercial aquarium permits are subject to Hawai'i environmental review.

Sept 7: DLNR stops issuing new commercial aquarium permits or renewing existing ones.

Oct 27: Based on the Supreme Court decision, all existing aquarium permits for use of fine mesh nets/traps to catch aquatic life for aquarium purposes now illegal and invalid pending a full review of the fishery under HEPA. Aquarium collecting is still allowed if fine mesh nets/traps are not used.

2018

Jan 5: DLNR announces no aquatic life may be taken for commercial aquarium purposes in waters off West Hawai'i until an environmental review is completed.

April 8: The Pet Industry Joint Advisory Council (PIJAC), submits Environmental Assessments (EA) to DLNR for the islands of Hawai'i and O'ahu, maintaining that issuing of commercial permits would not have significant environmental impact.

April 12: Judge Crabtree rules all unexpired recreational permits allowing collection with fine-mesh nets void pending environmental review.

July 26: DLNR rejects aquarium Environmental Assessments, requiring a more rigorous Environmental Impact Statement (EIS).

2020

Nov 30: Environmental review required for new or renewed commercial marine licenses (CMLs) used for aquarium collection. This is an addition to the 2017 ruling on fine mesh nets. DLNR not issuing or renewing permits without environmental review stipulation. No injunction issued on current licenses due to economic hardship during pandemic.

2021

January 12: commercial aquarium fishing banned in the State of Hawai'i until Chapter 343 environmental review process completed.

June 25: BLNR reaches tie vote for acceptance or rejection of revised final EIS. No additional actions taken by deadline and revised EIS accepted. This decision did not allow aquarium collection to resume.

2023

January 30: Injunction on aquarium fishing in West Hawai'i Island lifted. Aquarium collectors cannot resume until DAR issues permits. Commercial aquarium fishing is still not allowed anywhere else in Hawai'i.

Figure 9. Summary of court proceedings for the West Hawai'i commercial aquarium fishery

Conclusion

The association between demand from the marine aquarium hobby and trends in catch and species targeting by the West Hawai'i aquarium fishery is clear. Experienced aquarium fishers in West Hawai'i shifted their behavior to target species and size classes that were valued by marine aquarium hobbyists. Catch and value declined for species with decreased demand by the hobby such as Moorish idols (*Zanclus cornutus*) and Longnose butterflyfish (*Forcipiger flavissimus*) (Figure 10). Declines in catch for species that do not survive well in aquaria illustrates how market forces can contribute to improving fishing practices even in the absence of management.

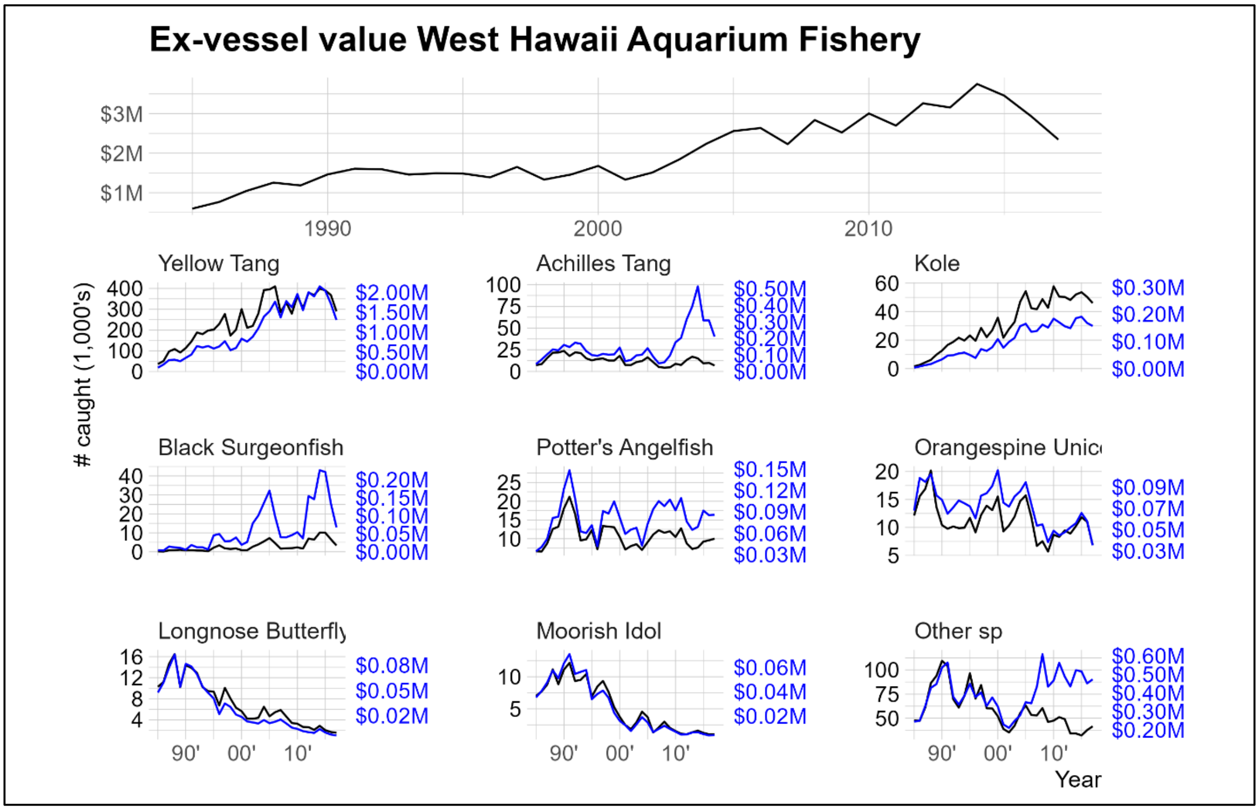

Figure 10. Ex-vessel value (in 2022 dollars) of the West Hawai'i aquarium fishery (top) and species-specific trends (bottom) of catch (black line and left axes) and ex-vessel value (blue line and right axes).

In addition to market forces, management measures such as spatial closures also influenced West Hawai'i aquarium fisher behavior. Aquarium fishers reallocated effort to regions of the WHRFMA with less conflict with ocean user groups and residential communities. Spatial prohibitions on aquarium fishing reduced direct conflict between stakeholders and reduced fishing mortality for fish species targeted by aquarium collectors to zero in more than a third of the shallower than 30m reef habitat in the WHRFMA. The FRA network, therefore, not only prevented localized depletion in areas frequented by ocean users, but prohibiting aquarium fishing in such a large area reduced much of the potential for the aquarium fishery to harvest an amount of an aquarium fish species that would result in the WHRFMA being overfished.

Historical efforts to involve stakeholders, conduct fisheries-independent monitoring of aquarium fish, and enact management measures to prevent overfishing of aquarium resources in the WHRFMA are unparalleled in other near shore fisheries in Hawaiʻi. Despite many management measures that illustrate progressive efforts to prevent overfishing by the West Hawaiʻi aquarium fishery (spatial closures - gear restrictions - species prohibitions - size restrictions - bag limits - moratorium), stakeholder views on the status of aquarium fish species in the WHRMA remain divided.

References

Walsh W.J., Cotton S.P., Dierking, J and I.D. Williams. 2003. The Commercial Marine Aquarium Fishery in Hawai'i 1976-2003. In: Friedlander A.M. (ed.) Status of Hawai`i' s Coastal Fisheries in the New Millennium. Proceedings of a Symposium sponsored by the American Fisheries Society, Hawai`i Chapter. pp. 132-159.

Walsh, W.J., B.N. Tissot, and L.E. Hallacher. 2005. A report on the findings and recommendations of effectiveness of the West Hawai`i regional Fishery management area. Report to the Twenty-Third Hawai`i Legislature Regular Session of 2005. 38 pp.

Stevenson, T.C., B.N. Tissot, and J. Dierking. 2011. Fisher behavior influences catch productivity and selectivity in West Hawaii's aquarium fishery. ICES Journal of Marine Science. 68(5): 813–822.

Tissot, B. N., and Hallacher, L. E. 2003. Effects of aquarium collectors on coral reef fishes in Kona, Hawaii. Conservation Biology, 17: 1759–1768.

APPENDIX B: Species Profiles

Species Profiles for the West Hawaiʻi Commercial Aquarium Fishery

A Report to the State of Hawaiʻi Board of Land and Natural Resources

March 2024

Hawaii Division of Aquatic Resources

Zebrasoma flavescens (yellow tang)

Names: yellow tang, lauʻīpala, lāʻī pala
Mating/ Reproduction: Broadcast spawners
IUCN Status: Species of Least Concern

Description and Ecology

The yellow tang (*Zebrasoma flavescens)* is a species of herbivorous surgeonfish indigenous to the tropical North Pacific, ranging from the Hawaiʻian archipelago and Johnston Island to the Marshall, Mariana, and Ryukyu islands south of Japan (Randall 2007). Yellow tang are also known as, *lauʻī pala* or *lāʻī pala* in Hawaiʻian, meaning "yellowed ti leaf." Yellow tang are common in the Hawaiʻian Islands, particularly along the leeward coast of Hawaiʻi Island. They are almost always a solid, bright yellow with a white tail spine (Fig. 1), attain a maximum size of 20 cm, and can live for more than 40 years (Randall 2007, Claisse et al. 2009).

Figure 1. Yellow tang (lauʻīpala, Zebrasoma flavescens). Photo credit: Keoki Stender.

This species is a broadcast spawner and has an approximately 50-day pelagic larval stage. Following larval settlement, juveniles prefer finger coral (*Porites compressa)*-rich mid-depth reef habitats, ranging in depth from 10 to 25 m). Adults generally inhabit shallower and more topographically complex reefs with abundant turf algae (Walsh 1984, Claisse et al. 2009). Yellow tangs are common within depths of 1 to 40 m and have been observed as deep as 81 m (Randall 2001).

Ctenochaetus strigosus (kole)

Names: Goldring Surgeonfish, kole tang, kole makaonaona, ukole, pākole, yelloweye kole
Mating/ Reproduction: Broadcast spawners
IUCN: Species of Least Concern

Description and Ecology

Kole *(Ctenochaetus strigosus)* are endemic to the Hawaiʻian Islands and Johnston Atoll. *Kole*, meaning "raw" or "red" in Hawaiʻian, is also known as *ukole* or *pākole* (Pukui and Elbert 1986). Kole are brown in color with light blue to yellow horizontal stripes along their body, becoming spots towards the face (Fig 2). They are also characterized by having a distinctive yellow-gold ring surrounding their eye. Juveniles are golden-yellow, darkening as they gradually develop stripes. This relatively common species reaches a maximum size of 24 cm.

Kole tend to be solitary and are typically found on shallow, topographically complex reefs, although they have been recorded at depths greater than 110 m. While kole are commonly grouped with herbivorous fishes, they belong to a genus of surgeonfishes that evolved to selectively target and remove particulate materials from within algal turfs (Bellwood et al. 2014). All members of the genus *Ctenochaetus* have elongated brush-like teeth (cteno – comb, chaeta – bristle). *Ctenochaetus* avoid dense algal turfs and their feeding mode, referred to as "brushing", does not appear effective for removing attached algae (Tebbet et al. 2022). Gut contents of *Ctenochaetus* fishes generally contain >90% of particulate matter (organic detritus and inorganic sediments) including diatoms, cyanobacteria, and other microalgae and microbes.

Figure 2. Kole (Goldring surgeonfish, Ctenochaetus strigosus). Photo credit: Keoki Stender.

Kole are broadcast spawners and typically spawn in pairs (Froese and Pauly 2000). While there is some variability in the seasonal timing of spawning events, Kole typically have 2 peak spawning events: late winter and early summer. These events are often followed by waves of juvenile recruitment onto the reef, depending on local currents and seasonal conditions (Walsh 1987).

Naso lituratus (naso tang)

Names: Orangespine Unicornfish, Clown tang, Naso tang, umaumalei, kala umaumalei
Indigenous/ Endemic/ Introduced: Indigenous
Mating/ Reproduction: Broadcast spawners
IUCN: Species of Least Concern

Description and Ecology

Orangespine unicornfish (*Naso lituratus*) typically inhabit coral-rich, rocky, and rubble-dominant reefs from 5 to 30 m depth (Randall 2007). Orangespine unicornfish reach a maximum size of 46 cm and are herbivorous, preferring leafy brown algae (Randall and Clements 2001, Randall 2007, Hoover 2008). Adult orangespine unicornfish have a solid black dorsal fin, with the black coloration continuing along the dorsal body, and a pale blue line along the base of the dorsal fin (Hoover 2008; Fig 3). They have bright orange and yellow anal and caudal fins, and in contrast to other *Naso* species they lack a distinctive horn on the forehead. The caudal peduncle bears two forward-directed spines, and the caudal fin of the adult male has trailing filaments (Randall and Clements 2001, Randall 2007). Juveniles have similar markings, with slightly dulled coloration compared to adults (Hoover 2008). During breeding, orangespine unicornfish form distinct pairs for broadcast spawning activities (Randall and Clements 2001).

Figure 3. Orangespine unicornfish (umauma lei, Naso literatus). Photo credit: Keoki Stender.

The name *umaumalei* refers to the bright orange coloration of the *ʻūlei* or Hawaiʻian rose (*Osteomeles anthyllidifolia*) and literally translates to "chest lei" (Pukui and Elbert 1986), while the name *kala umaumalei* refers to the use of this species to treat illness. *Kala* means "to loosen, free, release," referring to the treated person being freed or cured of an illness (Gutmanis 1976).

Ctenochaetus hawaiiensis (chevron tang)

Names: Black Surgeonfish, Chevron tang, ukole, pākole, king kole, black-eye kole
Mating/ Reproduction: Broadcast spawner
IUCN: Species of Least Concern

Description and Ecology

Black surgeonfish (*Ctenochaetus hawaiiensis*) are widespread throughout the tropical Pacific Ocean, including the Pitcairn Islands, the islands of Micronesia, and the Hawaiʻian Islands (Randall and Clements 2001, Randall 2007). Adults are olive-green/ black in color with gray, fine horizontal stripes while juveniles are bright orange-red with blue and purple chevron patterning, inspiring the common name, Chevron tang (Fig. 4).

Figure 4. Black surgeonfish (pākole, Ctenochaetus hawaiiensis). Photo credit: Keoki Stender.

Adults inhabit high energy shallow surge zones, while juveniles prefer deeper reef areas (Hoover 2008). Surgeonfish in the *Ctenochaetus* genus have elongate brush-like teeth (cteno – comb, chaeta – bristle) and these fishes have evolved to selectively target and remove particulate materials from within algal turfs (Bellwood et al. 2014). Gut contents of *Ctenochaetus* fishes generally contain >90% of particulate matter (organic detritus and inorganic sediments) including diatoms, cyanobacteria, and other microalgae and microbes. *Ctenochaetus* avoid dense algal turfs and their feeding mode, referred to as "brushing", does not appear effective for removing attached algae (Tebbet et al. 2022).

The reproductive ecology of black surgeonfish is not well understood, however broadcast spawning has been documented (Breder and Rosen 1966, Froese and Pauly 2019).

Centropyge potteri (Potter's angelfish)

Names: No additional names known
Mating/ Reproduction: Oviparous
IUCN: Least Concern

Description and Ecology

The Potter's angelfish (*Centropyge potteri*) is endemic to Hawaiʻi and Johnston Atoll (Lobel 2003, Randall 2007). This bright orange fish is characterized by a thin, vertical striping and a bright blue margin along its rear dorsal, caudal and anal fins (Fig 5). It has a slender, rounded body and is considered a 'pygmy' angelfish within the family *Pomacanthidae* due to its small maximum size (13 cm). The Potter's angelfish prefers a finger-coral (*Porites compressa*) dominated habitat but can occur in a variety of habitats at depths ranging from 5 to 138 m. Individuals have a relatively small range once established.

Figure 5. Potter's angelfish (Centropyge potteri). Photo credit: Keoki Stender.

The Potter's angelfish is omnivorous, feeding mostly on algae and detritus on dead coral surfaces (Hobson 1974). This species is oviparous and frequently forms a harem with one male and up to seven females. If a male is removed from the harem, a female will change sex to male (protogynous hermaphroditism; Lutnesky 1996). Peak reproductive activity occurs from December to May (Lobel 1978, Thresher 1984, Whiteman and Cōté 2004, Randall 2007).

Acanthurus nigrofuscus (brown surgeonfish)

Names: Brown Surgeonfish, Lavender tang, Forktail tang, māʻiʻiʻi, māʻiʻi
Mating/ Reproduction: Broadcast spawner
IUCN: Least Concern

Description and Ecology

The brown surgeonfish (*Acanthurus nigrofuscus*) is common throughout Hawaiʻi, the Indo-Pacific and Eastern Africa (Randall 2007). This light brown to pale lavender fish has fine, bluish gray vertical stripes along its body becoming light orange facial spots, and is characterized by two prominent black spots at the posterior base of the dorsal and anal fins (Fig. 6). Attaining a maximum size of 21 cm, the brown surgeonfish inhabits coral reefs ranging from 2 to 25 m depth. It's diet consists primarily of filamentous algae, and this species often forms large, grazing schools on shallow to mid-depth reefs. During the spawning season, brown surgeonfish will form large mating aggregations (Domeier and Colin 1997, Randall 2007).

Figure 6. Brown Surgeonfish (māʻīʻīʻī, Acanthurus nigrofuscus). Photo credit: Keoki Stender.

The Hawaiʻian name for this species, *māʻiʻi*, means "tiny" and also refers to a taro variety (*Colocasia* spp.) (Pukui and Elbert 1986). Traditionally a preferred subsistence fish, the *māʻiʻi* could be eaten both raw or broiled (Titcomb 1972).

Gomphosus varius (bird wrasse)

Names: Bird Wrasse, hīnālea ʻiʻiwi, hīnālea nukuiwi,
Mating/ Reproduction: Broadcast spawner
IUCN: Least Concern

Description and Ecology

The bird wrasse (*Gomphosus* varius) is widespread throughout the Western Pacific including Southern Japan, the Great Barrier Reef, the Eastern Indian Ocean and the Hawaiʻian Islands (Randall 2007). The preferred habitat of this active, omnivorous fish includes shallow lagoons, coral-rich reefs, and reef slopes at depths of 2 to 30 m (Hoover 2008). The Hawaiʻian names, *hīnālea ʻiʻiwi*, and *hīnālea nukuiwi*, refer the long beak of an endemic forest bird, the ʻ*iʻiwi or* Scarlet Honeycreeper (*Drepanis coccinea*). Terminal males of this species are easy to recognize, having a bright blue, elongated body with an extended beak-like snout (Fig. 7). On males, blue-green body scales are lined with a pink stripe, and a distinctive yellow bar extends dorsally from the pectoral fin. Initial/ female phase individuals have an orange snout and gray head, tapering into a dark gray mid body and caudal region. Juveniles have a smaller snout, and are easily confused with juveniles of the species, *Thallasoma dupperey*. At maximum size, bird wrasse can reach 32 cm. The Bird Wrasse is a sequential hermaphrodite, meaning that adult females can become males under driving environmental conditions (e.g. removal of a male in the area; Randall et al 1990).

Figure 7. Bird Wrasse (hīnālea ʻiʻiwi, Gomphosus varius). Photo credit: Keoki Stender.

Acanthurus thompsoni (Thompson's surgeonfish)

Names: Thompson's Surgeonfish, no other names documented
Mating/Reproduction: Broadcast spawner
IUCN: Least Concern

Description and Ecology

The Thompson's surgeonfish (*Acanthurus thompsoni*) ranges in color from a uniform dark brown to a pale gray-blue and can rapidly change color from one to the other (Randall 2007) (Fig. 8). This species has a wide distribution throughout the Pacific, including the Hawai'ian Islands, and prefers schooling along the outer reef slope (at 5 to 70 m depth) where it actively feeds on plankton including zooplankton, pelagic cnidarians, fish eggs and larval crustaceans (Froese and Pauly 2000). The reproductive biology of the Thompson's surgeonfish is not well understood, however they are known to be broadcast spawners. The Thompson's surgeonfish reaches a maximum size of 27 cm.

Figure 8. Thompson's Surgeonfish (Acanthurus thompsoni). Photo credit: Keoki Stender.

References

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

Bellwood DR, A.S. Hoey, O. Bellwood, and C.H.R. Goatley. 2014. Evolution of long-toothed fishes and the changing nature of fish–benthos interactions on coral reefs. Nat Commun 5:3144

Claisse J.T., M. Kienzle, M.E. Bushnell, D.J. Shafer, and J.D. Parrish. 2009. Habitat- and sex-specific life history patterns of Yellow Tang Zebrasoma flavescens in Hawai'i, USA. Marine Ecology Progress Series. 389:245-255.

Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning and aggregations: defined and reviewed. Bull. Mar. Sci. 60(3): 698-726.

Froese, R. and D. Pauly, Editors. 2000. FishBase 2000: concepts, design and data sources. ICLARM, Los Baños, Laguna, Philippines. 344 p.

Froese, R. & D. Pauly (Editors). 2019. FishBase. World Wide Web electronic publication. version (02/2019). - via World Register of Marine Species

Gutmanis, J. 1976. Hawaiian Herbal Medicine: Kahuna La'au Lapa'au. Island Heritage Publications. 144 pp.

Hobson, E.S., 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72(4):915-1031.

Hoover, J. P. 2008. Ultimate Guide to Hawaiian Reef Fishes: Sea Turtles, Dolphins, Whales, and Seals. Mutual Publishing. 388 pp.

Lobel. P. S. 1978. Diel, lunar, and seasonal periodicity in the reproductive behavior of the pomacanthid fish, Centropyge potteri, and some other reef fishes in Hawai'i. Pac. Sci. 32(2): 193-207.

Lutnesky, M. M. F. 1996. Size-dependent rate of protogynous sex change in the pomacanthid angefish, Centropyge potteri. Copeia 1: 210-212.

Pukui, M.K. and S.H. Elbert. 1986. Hawaiian Dictionary: Hawaiian-English, English-Hawaiian. University of Hawaii Press, Honolulu. 572 pp.

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

Randall J. E. 2001. Surgeonfishes of Hawai'i and the World. Mutual Publishing and Bishop Museum, Honolulu. Hawai'i. 125 pp.

Randall, J.E. and K. D. Clements. 2001. Second Revision of the Surgeonfish Genus Ctenochaetus (Perciformes: Acanthuridae), with Descriptions of Two New Species. Indo-Pacific Fish. 32: 1-33

Randall J. E. 2007. Reef and Shore Fishes of the Hawaiian Islands. University of Hawaiʻi Sea Grant College Program, Honolulu. 560 pp.

Tebbett, S.B., A.C. Siqueira, & D.R Bellwood. 2002. The functional roles of surgeonfishes on coral reefs: past, present and future. *Rev Fish Biol Fisheries* **32**, 387–439. https://doi.org/10.1007/s11160-021-09692-6

Thresher, R.E., 1984. Reproduction in reef fishes. T.F.H. Publications, Inc. Ltd., Neptune City, New Jersey. 399 p.

Titcomb, M. 1972. Native Use of Fish in Hawaii. University of Hawaii Press, Honolulu. 175 p.

Walsh W.J. 1984. Aspects of nocturnal shelter, habitat space, and juvenile recruitment in Hawaiian coral reef fishes. Ph. D. Dissertation. University of Hawaiʻi, Honolulu. pp. 1–475

Walsh W.J. 1987. Patterns of recruitment and spawning in Hawaiian reef fishes. Environmental Biology of Fishes 18(4): 257-276

Whiteman, E.A. and I.M. Cōté, 2004. Monogamy in marine fishes. Biol. Rev. 79: 351-375.

APPENDIX C: Summary of Current and Proposed Management Measures for the West Hawai‘i Commercial Aquarium Fishery

Management Measure	Scale	Status
Input Controls		
Commercial Marine License (CML) requirement	Statewide	Current
Aquarium permit requirement	Statewide	Current
West Hawai‘i Regional Fishery Management Area (WHRFMA) aquarium permit requirement	WHRFMA	Current
Gear restrictions	Statewide & WHRFMA	Current
Hawai‘i Environmental Policy Act (HEPA) review requirement	Statewide	Current
Vessel marking requirement	WHRFMA	Current
Output Controls		
West Hawai‘i commercial aquarium fishery specific size & bag limits	WHRFMA	Current
Kole size limit	Statewide	Current
White list[1] (40 species)	WHRFMA	Current
Revised white list (8 species)	WHRFMA	Proposed in FEIS
Total Allowable Catch (TAC)[2] for revised whitelist species	WHRFMA	Proposed in FEIS
Spatial Controls[3]		
Marine Life Conservation Districts (MLCDs) & Fishery Management Areas (FMAs)	WHRFMA	Current
Fish Replenishment Areas (FRAs)	WHRFMA	Current
Miloli‘i Community-Based Subsistence Fishing Area (CBSFA)	WHRFMA	Current
Monitoring		
Commercial logbook – catch report	Statewide	Current
Commercial logbook - dealer report	Statewide	Current
West Hawai‘i Aquarium Project (WHAP) surveys	WHRFMA	Current

[1] The term “white list” refers to the list of species allowed for collection by the West Hawai‘i commercial aquarium fishery. Species excluded from the list are prohibited for take by the fishery.
[2] Annual limit on the total take of each species by the West Hawai‘i commercial aquarium fishery. Once met, collection for the species will cease till the following year.
[3] All commercial aquarium collection currently prohibited.