Report to the Thirty-Third Legislature
2025 Regular Session

Report on Findings and Recommendations Regarding the Population Status of Individual Species and Families of Coral Reef Herbivores Around the Island of O‘ahu

Prepared by the

State of Hawaii
Department of Land and Natural Resources
Division of Aquatic Resources

In response to Senate Resolution 104 (2024)

December 2024

I. Introduction

In Hawai'i, herbivorous reef fish play an important role in the health of coral reef ecosystems. They are also an important resource for cultural, recreational, subsistence, and commercial fishers. It is the responsibility of the Department of Land and Natural Resources (Department) to effectively manage coral reef herbivores, striking a balance between ecosystem health and continued access to sustainable fisheries.

In response to mounting scientific evidence and community concerns regarding the sustainability of many herbivorous reef fish, the Department's Division of Aquatic Resources (DAR) led a multi-year statewide stakeholder engagement process to develop management measures for these important species. As a result of this process, in February 2024, the Department amended its statewide herbivore rules, including new size limits for uhu, manini, and kole, new bag limits for kala and uhu, and limits on commercial kala and uhu take. In conjunction with this rulemaking effort, DAR developed a statewide Sustainable Herbivore Management plan to guide ongoing and future management of these important coral reef species.

Senate Resolution 104 (2024) requested the Department, with support from the National Oceanic and Atmospheric Administration Pacific Islands Fisheries Science Center (NOAA-PIFSC) and other experts, to conduct a study on the population status of individual species and families of coral reef herbivores around the island of O'ahu, prioritizing uhu and kala populations, and to conduct an analysis of alternative policies for substantially replenishing populations of coral reef herbivores around the island of O'ahu within the decade. The Department was requested to submit a report of its findings and recommendations, including any proposed legislation, to the Legislature no later than December 1, 2024.

II. Report

The attached Sustainable Herbivore Management plan provides detailed information on coral reef herbivore species and strategies to effectively manage them to support healthy ecosystems and sustainable use.

III. Plans for next year

In the next year, DAR will continue to conduct statewide fishery independent and dependent monitoring efforts, including fish and habitat-focused underwater visual surveys (UVS), the Hawaii Marine Recreational Fishing Survey (HMRFS), commercial logbook reporting, and commercial dealer reporting. NOAA is also working on completing its own round of statewide underwater visual surveys, which have not been conducted since 2019. These data sources, along with others, will be analyzed to in part compare herbivore populations across the archipelago and habitat types. DAR will also partner with the NOAA-PIFSC Stock Assessment Program to perform length-based stock assessments for select reef fish species (including select large-bodied herbivores) based on methodology used in 2016 by NOAA-PIFSC scientist Marc Nadon. This effort will include the hiring of a full-time NOAA stock assessment scientist to assist DAR personnel. Funding for this position is being provided by DAR. NOAA-PIFSC is also hiring a full-time life history scientist position to help gather and analyze reef fish life history data to support these stock assessments.

DAR will continue to refine the community and place-based management process through the efforts of the Holomua Marine Initiative. Though the island-based rulemaking process will not begin in Oʻahu in the coming year, it provides an additional avenue through which regional fishing regulations can be implemented. Ongoing efforts to further manage herbivore populations on Oʻahu via place-based regulations include the proposed establishment of the Maunalua Bay Fisheries Management Area (FMA). This community-led initiative seeks, among other regulations, to ban night spearfishing in an expansive area along Oʻahu's South shore (Portlock to Diamondhead). This proposed regulation seeks to offer additional regional protections for species commonly targeted by spearfishers at night (including uhu and kala) where the practice is commonplace.

Lastly, DAR will continue to monitor and evaluate the efficacy of the statewide herbivore rules implemented in February 2024. This includes working with the Division of Conservation and Resources Enforcement (DOCARE), commercial and non-commercial fishers, and the general public to ensure that all rules are enforced, understood, and adhered to. The herbivore rules include strict commercial regulations for uhu and kala, including the establishment of statewide Annual Catch Limits (ACLs) and new permitting requirements for both uhu and kala. DAR will continue to monitor commercial uhu and kala catch to ensure landings remain within specified limits and work with DOCARE, fishers, and dealers to promote compliance.

Holomua Marine Initiative

Sustainable Herbivore Management

State of Hawai'i Department of Land and Natural Resources (DLNR)

Division of Aquatic Resources (DAR)

November 2021/ Revised May 2024

Letter from the Administrator

The mission of the Department of Land and Natural Resources (DLNR) Division of Aquatic Resources (DAR) is *to work with the people of Hawai'i to manage, conserve, and restore the state's unique aquatic resources and ecosystems for present and future generations*. Our kuleana (responsibility) is to sustain and replenish our marine resources through preventative and restorative management activities.

Warming oceans due to global climate change are a growing concern for the health of our nearshore marine ecosystems. Coral bleaching events in 2014 and 2015, resulting in 50% coral mortality in West Hawai'i and 20-30% in Maui, left Hawai'i's reefs vulnerable to potential macroalgae overgrowth and smothering. Poor water quality also exacerbates reef health and recovery potential. The reef has natural defenses against such overgrowth: herbivorous fish and invertebrates graze down algae and provide these ecosystems with greater resiliency. For these reasons, herbivore management is crucial to the future of Hawai'i's reefs.

Regulations will reflect pono (doing what is right) fishing practices and provide clear standards and instructions reflecting what can and cannot be done in marine spaces to address the challenges facing our nearshore reefs today. Implementing regulations on marine herbivores is part of a multipronged effort to sustainably manage Hawai'i's aquatic resources and address local and global concerns for the health of nearshore marine ecosystems with the impacts of climate change.

The people of Hawai'i share a collective kuleana for the ocean. Statewide herbivore regulations will ensure that reefs remain healthy to sustain future generations of fish and urchins, and thereby, future generations of Hawai'i's people, culture, and nearshore waters. We all have an impact on nearshore waters and must accept our role within these ecosystems. This management plan outlines how we can better steward our marine resources, so that we may enjoy our coastal waters, support our livelihoods, and feed our families for years to come.

Mahalo,
Brian Neilson
DAR Administrator

Executive Summary

Healthy coral reefs are important to the people of Hawai‘i for many reasons. Coral reefs protect Hawai‘i's shorelines and infrastructure during storms from high wave impacts and erosion and provide jobs to thousands of residents. Reefs also provide habitat for many fish species providing food security to thousands of people. Fishing is intertwined within Hawaiian culture as an activity where fishers can provide for their community, continue traditional practices, and teach the next generation about the local relationship to the ocean. Within the nearshore environment, Hawai‘i's commercial and non-commercial fisheries are valued between $10-$16 million annually. In addition to the monetary value, the non-commercial near-shore fishery provides more than 5 million meals a year to the people of Hawai‘i.[1]

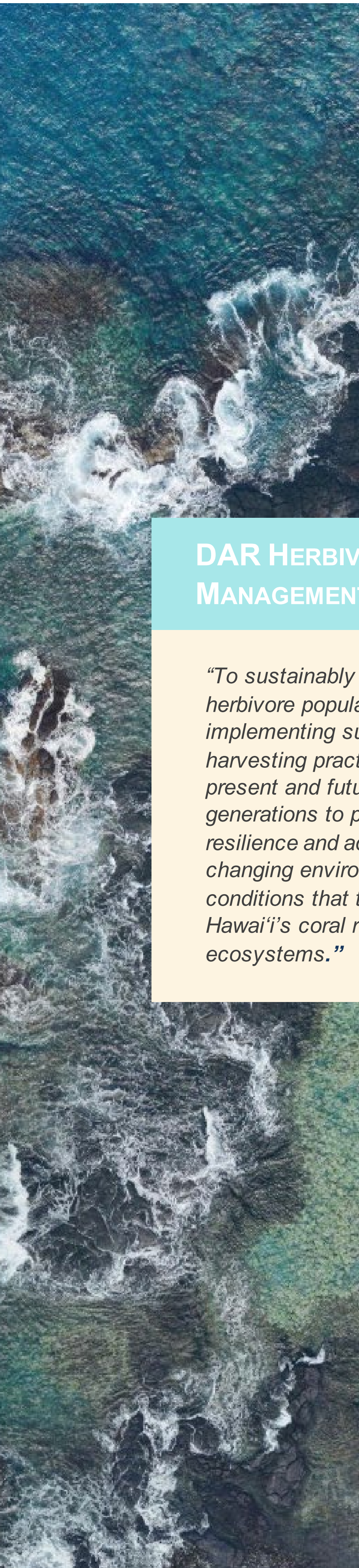
Coral reefs are intricate ecosystems that face numerous challenges at both global and local scales. Threats to Hawai‘i's coral reef ecosystems include poor water quality resulting from land-based sources of pollution, excess nutrient runoff, physical damage from ocean activities, invasive species, marine debris, unsustainable fishing practices, climate change, and ocean acidification. Globally, climate change is intensifying and causing coral bleaching worldwide. A global bleaching event from 2014-2017 was one of the most devastating bleaching events on record for Hawai‘i.[2–4] These events are predicted to become more frequent, and in some locations, severe bleaching will occur annually by 2034.[5]

The future of coral reefs will depend on reef resilience in the face of climate change impacts. There are well-documented linkages between herbivores and coral habitat, but these relationships are complex, varying greatly in both space and time, and interact with multiple environmental and human drivers. **Maintaining adequate levels of herbivore biomass is essential for maintaining healthy corals and, where the condition of corals has declined, improvements in herbivore biomass can aid recovery.**

The Division of Aquatic Resources' (**DAR**) goal for herbivore management is to sustainably manage herbivore populations by implementing sustainable harvesting practices for present and future generations to promote resilience and address rapidly changing environmental conditions that threaten Hawai‘i's coral reef ecosystems. Management objectives are rooted in the Holomua Marine Initiative's four pillars: place-based planning, pono practices, monitoring and restoration. The success of this management plan relies on a multi-faceted approach, mauka to makai, and community engagement. Key actions include implementing both place-based and statewide regulations to promote sustainable fishing practices, enhancing monitoring efforts to track changes and evaluate effectiveness, and collaborating with partners to better address land-based impacts. This plan will be reviewed and adapted, as necessary, every five years to ensure management actions are effective, and objectives and sustainability targets are adjusted to meet rapidly changing environmental and human impacts affecting coral reefs and herbivores.

Contents

This management plan was developed and revised by DLNR, Division of Aquatic Resources' Holomua Marine Initiative team (Luna Kekoa, Stacia Marcoux, Anita Tsang, Casey Ching, Amy Markel and Bert Weeks), leadership (Brian Neilson, David Sakoda, Ryan Okano and Brian Kanenaka), and staff (Kirsten Moy and Amber Meadows). It was developed in consultation with DAR Aquatic Biologists with expertise in fisheries, monitoring, fisheries management and coral reef ecology. It was externally reviewed and revised by Cassandra Pardee, Poseidon Fisheries Research. Funding and technical assistance was also provided by the National Marine Fisheries Service Pacific Islands Regional Office. It was also externally reviewed by Dr. Mark Hixon, Dr. Ed DeMartini and Dr. Alan Friedlander, recognized experts in coral reef ecology and fisheries in Hawai'i.



Our Kuleana

The mission of the Department of Land and Natural Resources (**DLNR**) is to "*enhance, protect, conserve and manage Hawai'i's unique and limited natural, cultural and historic resources held in public trust for current and future generations of the people of Hawai'i nei, and its visitors, in partnership with others from the public and private sectors.*" DAR, one of many within DLNR, manages the state's aquatic resources and ecosystems through programs in ecosystem management, fisheries management, and place-based management. DAR currently works to improve conditions in the state's aquatic environments by using tools including fishing regulations, permits, marine management areas, education, environmental response, invasive species control, and restoration.

DAR Herbivore Management Goal:

"To sustainably manage herbivore populations by implementing sustainable harvesting practices for present and future generations to promote resilience and address rapidly changing environmental conditions that threaten Hawai'i's coral reef ecosystems."

Box 1

On September 1, 2016, at the International Union for Conservation of Nature World Conservation Congress in Hawai'i, Governor David Ige announced the Sustainable Hawai'i Initiative. DAR's kuleana (responsibility) within this statewide initiative is **Holomua Marine Initiative**. This initiative aims to focus on a broad range of marine management measures to sustain, conserve, and enhance our marine resources and ecosystems for present and future generations.

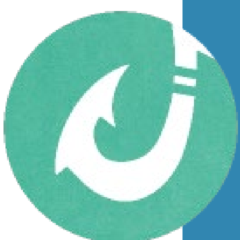
Effective management will be assessed by measuring progress towards ecological, social, and cultural sustainability goals. Ultimate success, however, relies on the actions of individuals and communities. Working together —informed by local knowledge and the best readily available science — management can respond to climate change threats, restore our fisheries, and ensure the health and services of nearshore ecosystems. *Holomua Marine Initiative* outlines how DAR plans to work in partnership with communities to operationalize the four pillars to achieve shared nearshore management goals. The four pillars: Place-Based Planning, Pono Practices, Monitoring, and Restoration are key aspects of this management plan. The four pillars have been adapted to fit the overall goal of this management plan (Box 1). Each pillar has a specific objective that will work towards the overarching goal (Box 2).

Photo: PICES/Gov of Japan/DLNR

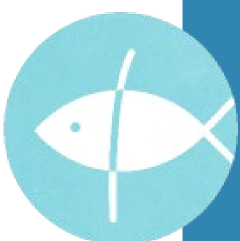
Holomua Marine Initiative Four Pillars

The four pillars of the Holomua Marine Initiative plan have been adapted to support the over-arching goal. DAR has developed specific objectives that fall under each of the four pillars.

Place-Based Planning integrates the recognized differences in species diversity, abundance and harvesting practices into management planning. This pillar aims to partner with communities and stakeholders to build cohesive, ecologically connected management strategies, including MMAs to address concerns unique to a specific area. **Objective:** Work with local communities and stakeholders to develop and implement place-based Marine Management Areas (MMA) that increase herbivorous fishes and invertebrate biomass and promote reef resilience at the local scale through improved marine management.



Pono Practices encourages responsible behavior guided by Hawaiian values and perspectives through education and outreach, statewide rules, strengthened enforcement, and local partnerships to encourage sustainable behaviors and practices in nearshore waters. This pillar is a call to action for resource users to interact with nearshore resources in a pono way. **Objective:** Develop and implement statewide herbivore management measures that increase herbivorous fishes and invertebrate diversity, abundance and biomass to promote both ecological complementarity and functional redundancy as well as reinforce pono practices through balancing scientific understanding with traditional ecological knowledge to promote sustainable use and stewardship of natural resources.



Monitoring is an essential component that measures and documents current conditions, tracks herbivore response following implementation of new management approaches, and uses data to identify areas where management actions need to be further adapted. Monitoring provides a way to measure the changes occurring and if implemented actions are effective. **Objective:** Evaluate and review the effectiveness of pertinent management measures every five years and implement adaptive strategies which account for changes in environmental conditions, habitat, herbivore population dynamics, and resource uses.

Restoration is a multi-faceted approach to manage for improved reef restoration and resilience, including both resistance to and recovery from disturbance. The restoration pillar builds on existing strategies to prevent damage to fragile nearshore ecosystems from invasive species, disease, and climate driven events. This pillar expands efforts to restore and enhance impacted areas, by strengthening and supporting collaborations with mauka initiatives and organizations to reduce land-based threats to nearshore ecosystems. **Objective:** By 2022, begin collaborating with other agencies and communities to mitigate environmental and human impacts that affect nearshore environments. By 2030, expand efforts to improve resilience and enhance restoration.

Box 2. Aligning Herbivore Management with the four pillars of Holomua Marine Initiative


Photo: Jeff Milisen

Introduction

The health of coral reefs is important for people in Hawai‘i for many reasons. While many people recognize the importance of healthy reefs for healthy fish communities and fisheries, coral reefs also protect Hawai‘i’s shorelines and infrastructure during storms from high wave impacts and erosion and provide jobs to thousands of residents. In 2017, ocean tourism and recreation in Hawai‘i employed more than 100,000 people and generated $8 billion (gross domestic product) according to NOAA’s Office for Coastal Management.

The future of coral reefs will depend on their resilience in the face of climate change impacts. Herbivory has been identified as a key component of the ecosystem that allows corals to both withstand and recover from disturbances such as heat waves.[6–8] Therefore, it is important to understand status and trends of both the benthos (organisms living on the ocean floor) and herbivores. Herbivore biomass along with natural physical factors like sea surface temperature and wave energy have been shown as predictors of a whether an area is likely to be coral or algae dominated. [9]

Threats to Coral Reefs

Coral reefs are intricate ecosystems that face numerous challenges at both global and local scales. Threats to Hawai'i's coral reef ecosystems include sedimentation and pollution from coastal development; excessive nutrient runoff; physical damage from ocean activities; invasive species; marine debris, unsustainable fishing practices, climate change, and ocean acidification.[10]

Globally, climate change is intensifying and causing coral bleaching worldwide. **Bleaching** is the process that occurs when corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues, causing them to turn completely white.[11] The likelihood of coral mortality from bleaching is dependent on the intensity and duration of heat stress.[12] There is a higher likelihood of coral mortality when ocean temperatures stay warmer than usual for extended time periods. A global bleaching event from 2014 to 2017 was the longest, most widespread and most destructive on record, with 75% of the world's corals bleaching and with 30% dying.[3] Hawai'i experienced a subsequent bleaching event in 2019. [13] These events are predicted to occur more frequently in the future, and in some locations, severe bleaching will occur annually by 2034.[5]

The period between severe bleaching events is narrowing, with the window for recovery between severe bleaching events dropping from 25-30 years in the 1980s down to less than 6 years as of 2016.[14] Up to 90% of reefs around the world are projected to experience severe annual bleaching by 2055.[15]

In addition to warming, global oceans are also becoming more acidic, compromising the calcification and growth of reef structures.[16] Since the industrial revolution, carbon dioxide (CO_2) levels have been rising. The increasing amount of CO_2 dissolving into the ocean causes waters to become more acidic.

When CO_2 from the atmosphere dissolves into the ocean, it produced an acid that inhibits the ability of corals and shelled organisms to grow their skeletons. If pH continues to decline, these shells and skeletons can even begin to dissolve.

Ocean acidification will also lead to increases in algal growth and diversity and decreases in reef complexity and growth. **Crustose coralline algae** (CCA) play an important role in the growth and stabilization of coral reefs by creating "coral glue" for coral polyp settlement and growth. The combined effects of warming and acidification, particularly compounded with other local stressors, serve to lower the capacity for resilience of coral reefs.[17] Human population growth, water quality, and unsustainable fishing practices also impact coral reef communities. Globally, populated areas that are accessible to fishing are often overexploited and have lower fish biomass than unpopulated inaccessible areas.[8] Recent studies show a direct correlation between increasing human population density and declines of targeted coral reef species; the same correlation was not observed in non-targeted species.[7,8]

Role of Herbivory in Reef Resilience

Resilience, with respect to coral reefs, means the ability to resist and recover from disturbances and maintain ecosystem functions.[18,19] Promoting resilience has become even more important to meet the challenges our reefs face and ensure their existence into the future. Protecting herbivore abundance and diversity can help maintain ecological balance and improve resilience to coral reef threats. Different herbivore species target different types of algae and work together to prevent macroalgae overgrowth that smothers coral reefs.[20,21]

Herbivore is a broad term that includes a wide range of species; and not all species play the same role in the resilience mechanism. Some species graze on larger macroalgae that can overgrow and displace corals, while others scrape away algal turfs to clear space for new corals to settle and grow. These distinctive and complementary functions of each species highlight the need for herbivores to be managed collectively for a resilience-oriented approach.[22]

Herbivorous reef fish are categorized into functional groups: browsers, grazers, scrapers, and excavators.[23] **Browsers** (e.g. kala and nenue), feed primarily on macroalgae overgrowth. **Grazers** (e.g. manini, kole, palani) tend to graze on algal turfs to keep macroalgae cropped low, and may also act as detritivores feeding on sediments and animal material. **Detritivores** serve an important role in facilitating herbivory by cleaning filaments and turfs of algae so that other species can more easily feed on them. They also promote growth of CCA by cleaning off surfaces for settlement. **Scrapers** and **excavators** also graze on algal turfs, but scrape the underlying reef surface to varying degrees. Scrapers (e.g. small-bodied uhu) remove less underlying reef material than excavators (e.g. large-bodied uhu), who act as bioeroders that remove dead coral and dig deeper into the reef matrix while feeding.

Each of these roles is crucial in maintaining ecosystem balance of reef systems. It is important to manage for both diversity and redundancy of these roles, as disturbance can cause detrimental phase shifts in the benthic (bottom surface of the ocean) community as well as reef fish communities.[24,25] A coral-algal **phase shift** refers to coral reef areas shifting from being dominated by corals (high coral cover) to having unusually low levels of coral cover with persistent states of high fleshy macroalgae cover. Once the surface of the bottom is covered with algae, coral can no longer settle and grow there. Hawai‘i’s herbivores have been shown to exhibit both complementary and redundant roles,[26] and having a diverse community of herbivores that complement and reinforce one another’s roles optimizes reef resilience.[27]

Herbivores play a critical role in controlling algae levels on reefs. Coral mortality from bleaching events opens more space for algal settlement and growth. Herbivores can quickly react to this situation and help keep the newly opened space from becoming overgrown with algae. In fact, herbivores can set the stage on this new space for the successful settlement and growth of new corals. Herbivores help to maintain a crucial balance to a reef’s algae “budget” [28] throughout disturbance events to prevent coral-dominated communities from shifting to algae-dominated communities.[29]

By reducing competition from aggressive algae growth, coral reefs have more energy to recover from other stressors such as bleaching, storm events, and invasive species outbreaks. One example of corals ability to recover from other detrimental effects was during a Crown-of-thorns outbreak in the Natural Area Reserve, ‘Āhihi-Kīna‘u on Maui, which prohibits the take of fishes or marine organisms in the reserve. Crown-of-thorns are voracious corallivores, and rapidly decreased the coral cover in ‘Āhihi-Kīna‘u from 23-6% at Kanahena Point from 1999 to 2006.[30] Once the Crown-of-thorns vacated the area, herbivores in the reserve were able to keep algal growth to a minimum which assisted in allowing the coral to recover quickly with coverage returning back to over 30% cover by 2015. Fishing practices that protect key herbivores statewide, when combined with other place-based approaches, will help to achieve reef resilience.[31]

It is important to understand that there is a balance between the level of herbivory and the amount of nutrients that enter the coral reef ecosystem, which can influence the growth of coral or algae (Figure 1). Even if land-based pollution (a frequent source of excess nutrients) were to decrease, with low herbivory, the reef ecosystem will likely still be dominated by turf algae. Turf algae can be especially problematic for reefs because it can grow quickly. This is particularly true in Hawai‘i since these high islands with steep and narrow watersheds and abundant rainfall have high baseline nutrient levels compared with other low-lying reef systems.

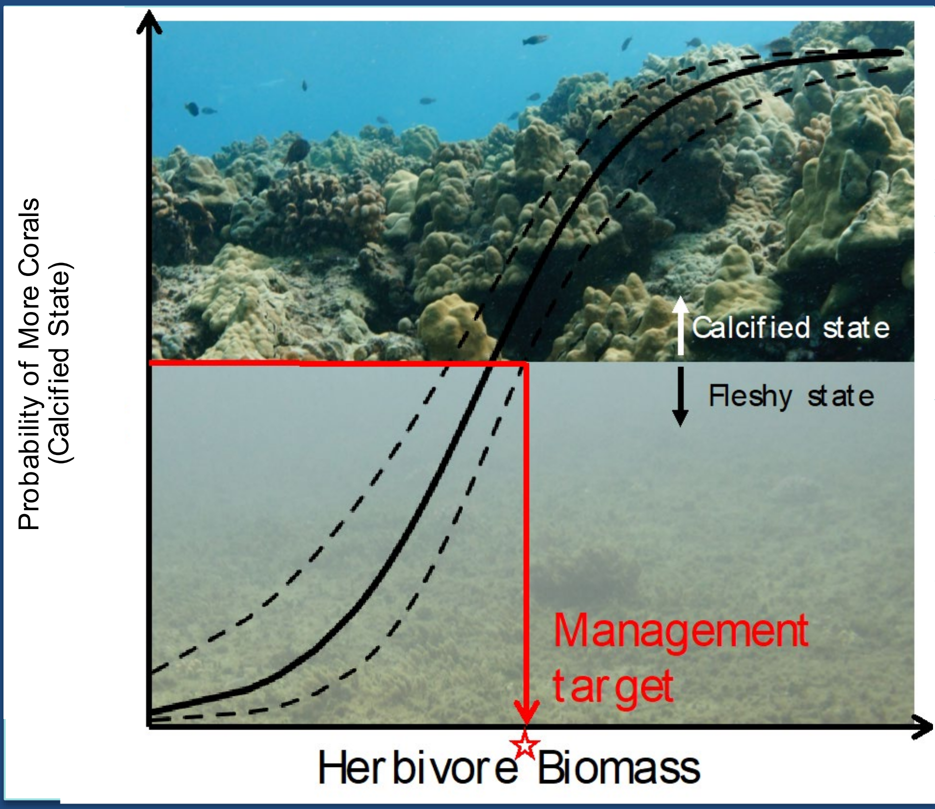


Figure 1: Hypothesized non-linear relationship between herbivory and probability of a calcified benthic state. Generally, when there are more herbivores, there is less algae and more room for corals to settle and grow. Once corals die, that space is either recolonized by corals or by algae. Herbivores help to ensure that there is plenty of space for corals to settle before algae takes over the reef.

Due to their role in controlling algae, improved management of herbivorous reef fishes has been identified as a top strategy to help promote reef resilience.[32] Successful nearshore management requires a combination of sustained herbivory protection and reduced nutrient pollution. Increasing the herbivore population is key to promoting coral-dominated ecosystems. Coral-dominated ecosystems are important because they are habitat to a greater diversity and are more productive than algae-dominated systems. They also provide more ecological and cultural **ecosystem services** (benefits to people from ecosystems) like food, income, lifestyle, and cultural connection. There are several management strategies that may be implemented to increase herbivores on the reef, including measures to ensure that as many fish in the population as possible reproduce and contribute to the next generation.

Fishing in Hawaiʻi

Fishing is intricately entwined within Hawaiʻi's culture as an activity where fishers can provide for their community, continue traditional practices, and teach the next generation about the local relationship to the ocean. Indigenous Hawaiians relied heavily on fishing as a main source of protein and developed associated cultural practices that have been passed down for generations. Today, up to one third of people in Hawaiʻi go fishing and it remains a significant way that people interact with the ocean. Many fish are shared or given away to family members, elders, neighbors, and friends; a physical representation of aloha, showing love for and taking care of one another. Fishing can represent a connection to something larger than oneself through fishing in the same way or area that your ancestors did, and by maintaining the same relationship between fishers, ocean, and community that sustained local people for hundreds of years.

Within the nearshore environment, Hawaiʻi's commercial and non-commercial fisheries are valued between $10-$16 million annually.[1] Although small, the nearshore commercial fishery provides specific types of fishes that would not otherwise be available in markets and is therefore especially important for certain cultures in Hawaiʻi.[1] Aside from the monetary value, Hawaiʻi's nearshore coral reef fishery is an essential component of food security and regional cuisine for many families and communities. 90% of adults in Hawaiʻi consume fish every month, with the highest consumption occurring in Native Hawaiian and Filipino communities.[33]

Seafood consumption in Hawaiʻi is more than double the national average. The non-commercial fishery provides more than 5 million meals a year.[1] Of the total reef fishes catch statewide, prior to 2014 an estimated 84% was non-commercial, but variations in this percentage occurred by island.[34] There is no reporting requirement for non-commercial catch in Hawaiʻi, so these values are estimated. For example, on Molokaʻi, 95% of the catch is non-commercial, whereas 77% is non-commercial on Oʻahu.[35] Herbivores make up 21% of the total meals the non-commercial fishery provides.[1] Given the significance of the nearshore coral reef fishery, active and **adaptive management** focused on sustainability is imperative.

Current Status

Hawai‘i’s Benthic Communities

Coral cover is spatially variable around Hawai‘i[36–39] (Figure 2). Few areas are characterized by high percent coral cover (greater than 60% coral cover). These are key areas to consider for additional conservation measures. The percent of live coral cover in the state is found on O‘ahu (23.4%), Hawai‘i Island (18.5%), and Maui (17.1%), and there are also large reef tracts in Southern Moloka‘i, West Maui, and West Hawai‘i[36,39] (Figure 2). In addition to coral cover, the ratio of calcified cover (such as coral) to fleshy cover (such as algae) is another useful indicator of benthic condition, where a higher value indicates more coral than algae. The ratio of calcified to fleshy cover also varies greatly across Hawai‘i, with the lowest values on O‘ahu (Figure 2). The differences in coral cover can be attributed to various natural drivers including oceanography (such as wave energy and currents), protection from persistent extreme temperatures (in some cases, there is higher percent coral cover in locations with access to cold groundwater outflows and in deeper reefs), and human impact drivers including pollution, urbanization, and fishing[36].

The global bleaching event from 2014 to 2017 was one of the most devastating bleaching events on record for Hawai‘i. Surveys on O‘ahu and Kaua‘i during 2014 revealed signs of bleaching in up to 95% of coral colonies in some areas, with severe bleaching and mortality observed at many sites.[40] Hawai‘i Island’s Kona coast, saw coral losses of nearly 50% due to bleaching regardless of management type[4,41] (Figure 3). In areas affected by other stressors, such as Kāne‘ohe Bay, which was previously inundated with freshwater floods, coral mortality rates were high, and few corals recovered.[42] Even marine protected areas like Hanauma Bay experienced bleaching and mortality in 2015.[43] For place-based information on benthic cover and bleaching in the Hawaiian Islands, please visit the interactive map at: https://allencoralatlas.org/atlas/#6.63/20.3272/-158.21074

Not all coral species are equal in the face of bleaching and some are particularly susceptible and likely to die. Complex branching corals such as *Acropora*[44] (rare in Hawai‘i) and commonly found species such as *Pocillopora*[45] are expected to decline more rapidly than mounding coral species, which are expected to be more resilient to climate change. However, there are also many examples of massive lobe corals (*Porities* species) suffering significant mortality as well. In West Hawai‘i, from 2014-2016 mounding coral *Porites evermanni* lost 92.5%, *P. lobata* 55.7% and *P. compressa* 32.9% of live coral cover.[4,46]

Photo: Jeff Milisen

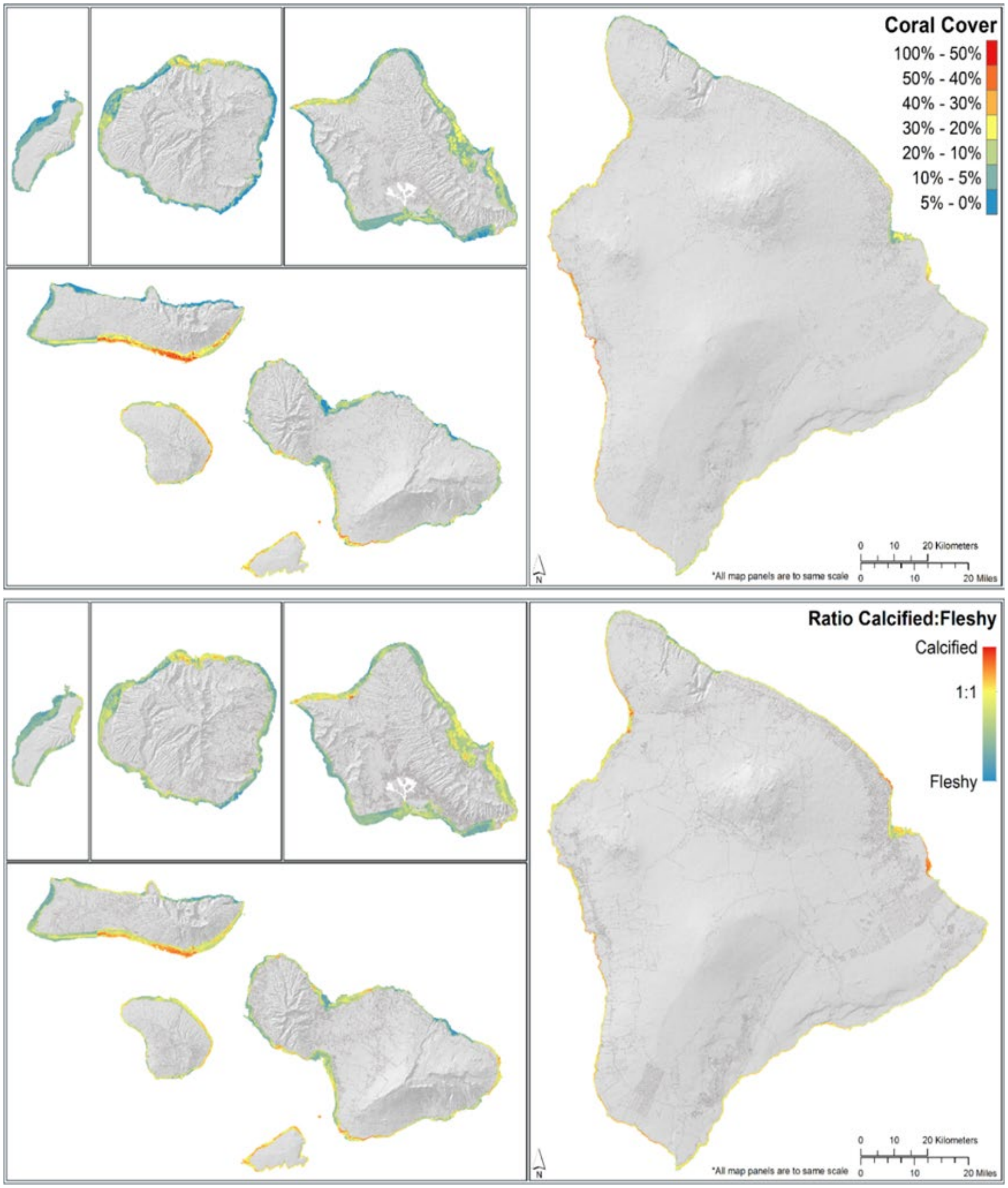


Figure 2: Maps from HIMARC (Donovan et al. 2020) data from 2004-2014, at a 100m resolution of percent coral cover (top) and the ratio of calcified to fleshy benthic cover (bottom). Areas in red are where coral cover is the highest and areas in blue are where it is the lowest. For the ratio of calcified to fleshy benthic cover, areas in red are where the ratio is the highest (more coral, less algae) and areas in blue are where it is the lowest (more algae, less coral).

Hawai'i's Herbivores

Herbivore biomass, like coral cover, is also spatially variable due to a range of factors, including habitat, physical/oceanographic drivers, and human impacts. Negative human impacts affecting herbivore biomass are urban runoff, cesspool effluent, and fishing pressure.[36] Herbivore biomass is generally lower on O'ahu than everywhere else (Figure 4), which is likely related to the compounding effects of land-based sources of pollution, urbanization and overfishing. Herbivore biomass is higher in Marine Life Conservation Districts (MLCD) like Hanauma Bay-O'ahu, Molokini Crater-Maui and Kealakekua Bay-Hawai'i Island, where fishing is prohibited or highly restricted and in the most remote places where there are low levels of urbanization and limited human access such as Hamakua and Kaho'olawe.

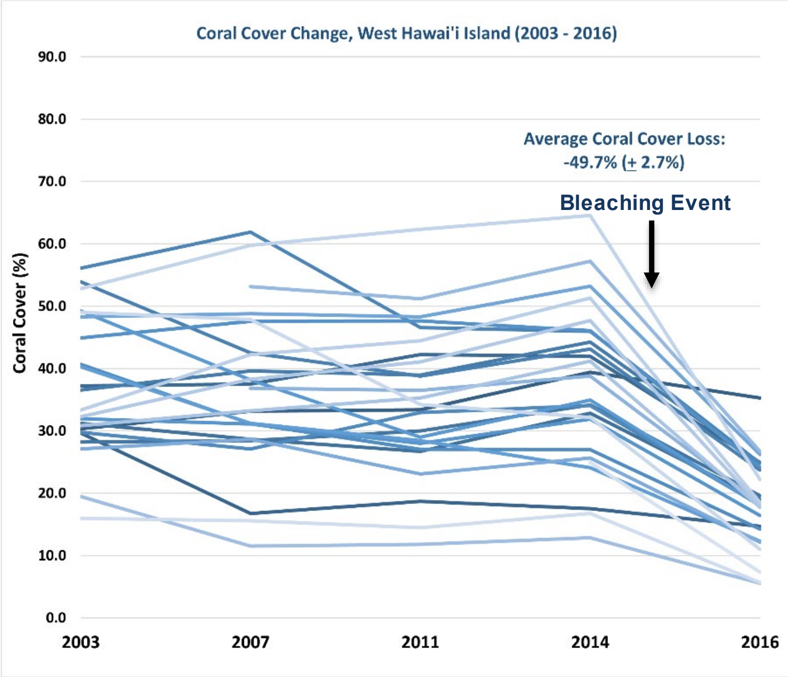


Figure 3: Change in coral cover (%) across the 25 DAR Kona fixed monitoring sites from 2003-2017. A global-scale coral bleaching event cause catastrophic declines in coral cover in the fall of 2015. Figure taken from Walsh et al. 2019. Despite these large declines, it is likely too soon to detect a response by the fish communities to changes in the benthos.

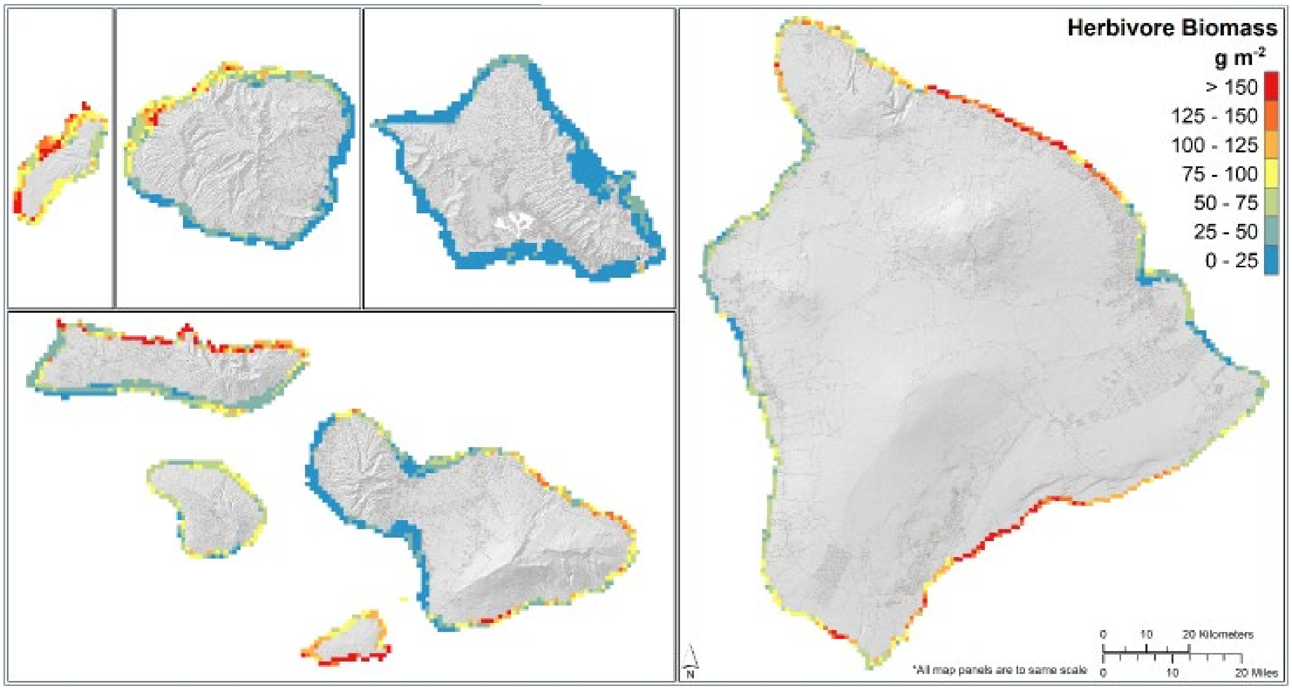


Figure 4: Map from HIMARC (Donovan et al. 2020) showing the herbivore biomass statewide at a one-kilometer resolution, with data from 2004-2014. Areas in red are where herbivore biomass is the highest and areas in blue are where herbivore biomass is the lowest.

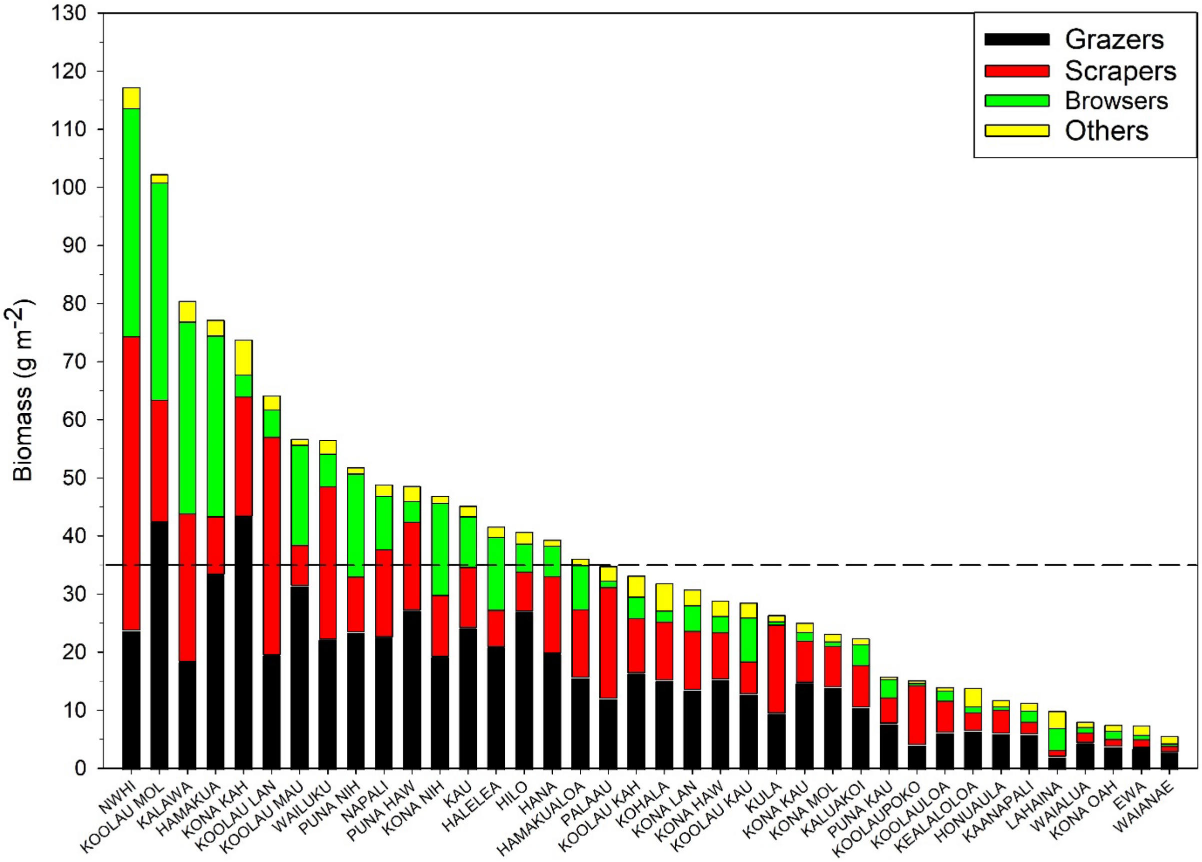


Figure 5: Figure from Friedlander et al. 2015 showing herbivore biomass by moku with the Northwestern Hawaiian Islands as a reference. The line at ~35 g/m2 is equivalent to 30% of virgin stock biomass in NWHI. 57% (n=21) of these moku fall below this level.

When compared to the Northwestern Hawaiian Islands (NWHI) as a reference, herbivore biomass by moku is much lower in the main Hawaiian Islands (MHI), with 57% of all moku being having less than 30% of the biomass found in the NWHI (Figure 20).[47] This clearly illustrates the depletion of MHI stocks and, given the difference in fishing pressure and other human impacts between the NWHI and the MHI, highlights the need for management action to replenish these stocks.

Commercial Herbivore Catch 2003 - 2020

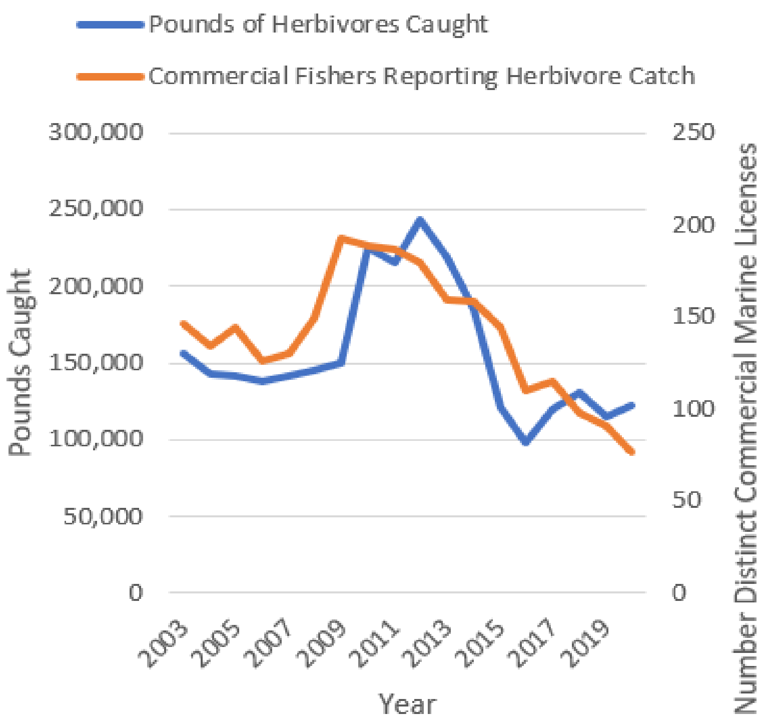


Figure 6: Decade of annual commercial catch of herbivorous fishes

Many locations with high herbivore biomass (Figure 4 - orange and red on the map) are in areas with high wave energy, which is an important physical factor for both coral cover and herbivore biomass.[36] High wave energy can also act as a pseudo-fishing reserve by limiting human accessibility to fishing due to the challenging water conditions.

In the last 10 years, there has been a decrease in the yearly commercial catch of herbivorous fishes from approximately 221,000 pounds of fish caught in 2011 to approximately 115,000 pounds in 2020 (Figure 5). Catch spiked in 2010, which could represent both a return to baseline conditions following the recession as well as overfishing.

Photo: Jeff Milisen

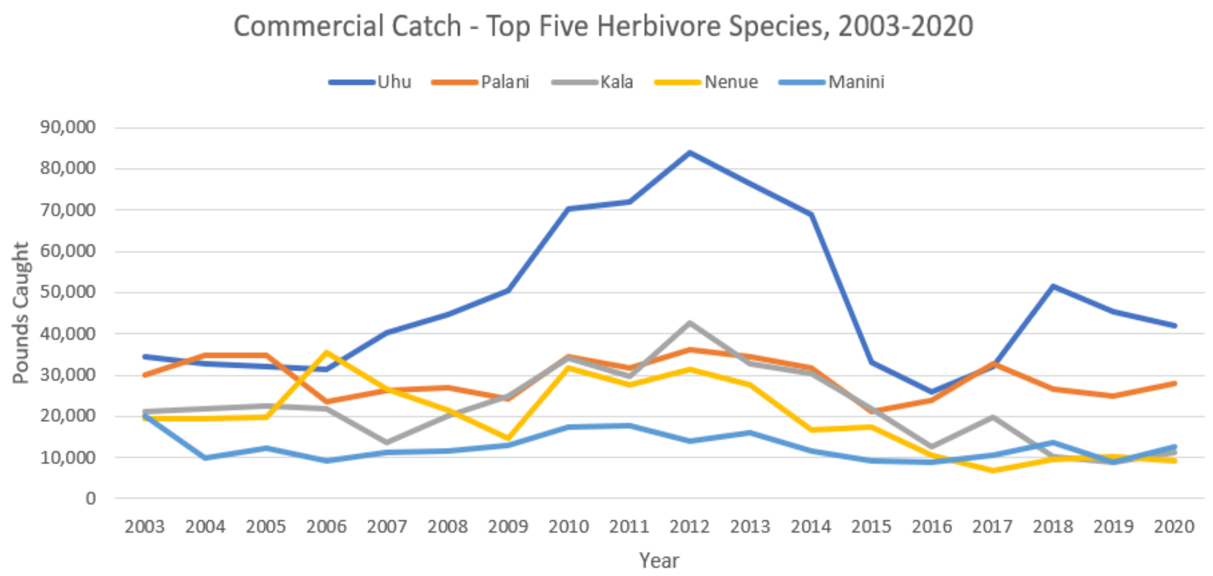


Figure 7: Commercial catch (in pounds) of the top five species of herbivores from the Commercial Marine License dataset from 2011 to 2020.

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This coincides with a decrease in number of commercial fishers reporting catch for herbivores over the same time, from 207 fishers in 2011 to 88 in 2020. The top five species caught (Figure 6) were Uhu (all species of parrotfishes), Palani/Pualu (Eyestriped Surgeonfish, Ringtail Surgeonfish, and Yellowfin Surgeonfish), Kala (Unicornfish), Nenue (Chubs), and Manini (Convict Tang).

For more information and studies on the status of Hawai'i's reef communities and herbivore fish populations, see ***Appendix: Status and Trends***.

Defining sustainable ecosystems

There are well-documented linkages between herbivores and coral habitat, but these relationships are complex, varying greatly in both space and time, and interact with multiple environmental and human drivers. Further, the increasing threat of climate change to coral reef ecosystems needs to be considered when defining and tracking sustainability targets for coral reef habitat as it relates to herbivory.

Maintaining adequate levels of herbivore diversity and biomass is essential for maintaining healthy corals, and in areas where the condition of corals has declined, improvements in herbivore biomass can aid recovery. Studies elsewhere have suggested targets for levels of herbivore biomass that are more likely to lead to a calcified-dominated condition (more corals) as opposed to a fleshy (more macro-algae) dominated condition.[48–50] These target levels have not yet been assessed for Hawai'i's reefs. Hawai'i's coral reefs are dominated by slower-growing coral species, which differ from other places around the world, therefore, the herbivore biomass threshold may be unique to Hawai'i.

DAR is working collaboratively with subject-matter experts to look at these questions: how many herbivores is enough to maintain and/or bolster reef resilience in Hawai'i; and how conservative should management plans be to create a buffer for future climate scenarios (i.e. how many more herbivores may be needed to fulfill the same function as the threats from climate change increase)? By 2024, upon completion of this study, and more Hawai'i specific information becomes available, an ecosystem sustainability metric will be incorporated into this Herbivore Management Plan. This information may also be used in future evaluations and management strategies included as part of the plan action items.

The recent coral losses from the global bleaching event and the impending threat of continued impacts paint a dire picture for the long-term persistence of Hawai'i's reefs and highlight the urgent need for local management strategies that can boost the reef's ability to overcome these challenges. From mauka to makai, Hawai'i's resource managers are working to incorporate the best readily available science into management approaches aimed at resilience. On land, watershed management initiatives such as the "30 by 30 Watershed Forests Target" seek to protect and restore priority watersheds throughout the state, contributing to healthier ecosystems both up and downstream through decreased erosion and land-based sources of pollution.[51] At sea, fisheries management plans such as this one seek to protect key species and places that allow our island way of life to persist. DAR aims to maximize herbivore biodiversity and biomass given the habitat availability to optimize reef resilience.

Photo: Jeff Milisen

Herbivore Management Strategy

Knowing the importance of herbivory for healthy reefs, DLNR-DAR has determined it is necessary to implement an Herbivore Management Plan, with fishing regulations for select species and species groups. This plan will enhance management measures for species fulfilling key functional roles in coral reef ecosystems. Implementation is critical in the face of unprecedented, global-scale threats. The **Herbivore Management Goal** is that DAR aims to sustainably manage herbivore populations by implementing sustainable harvesting practices for present and future generations to promote resilience and address rapidly changing environmental conditions that threaten Hawai'i's coral reef ecosystems. DAR has developed the following objectives and action items that fall within the four pillars of Holomua to help achieve the herbivore management goal.

PLACE-BASED PLANNING integrates the recognized differences in species diversity, abundance and harvesting practices into management planning. This pillar aims to partner with communities and stakeholders to build cohesive, ecologically connected management strategies, including MMAs to address concerns unique to a specific area.

Objective: Work with local communities and stakeholders to develop and implement place-based MMAs that increase herbivorous fish and invertebrate biomass and promote reef resilience at the local scale through improved marine management.

<u>Actions within this pillar will focus on implementing MMAs with rules, activities and community engagement that reflect specific needs and concerns of each place</u>.

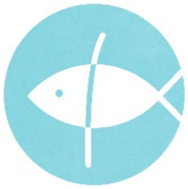
- *Action PB.1* By 2025, engage local community and stakeholders to determine specific needs and concerns for each place proposed for new and/or revised MMAs.
- *Action PB.2* By 2030, implement new and/or revised Marine Management Areas that promote place-based management and sustainable harvesting practices of herbivorous species.

PONO PRACTICES encourages responsible behavior guided by Hawaiian values and perspectives through education and outreach, statewide rules, strengthened enforcement, and local partnerships to encourage sustainable behaviors and practices in nearshore waters. This pillar of Holomua is a call to action for resource users to interact with nearshore resources in a pono way.

Objective: Develop and implement statewide herbivore management measures that increase herbivorous fish and invertebrate diversity, abundance and biomass to promote both ecological complementarity and functional redundancy as well as reinforce pono practices through balancing scientific understanding with traditional ecological knowledge to promote sustainable use and stewardship of natural resources.

Actions within this pillar will encourage ocean resource users to behave responsibly. DAR and DOCARE will work together with community members to increase stewardship and compliance.

- *Action PP.1* Implement new and/or revised rules that promote sustainable harvesting practices of herbivorous species, by 2023 at the Statewide level and by 2030 at the place-based level.
- *Action PP.2* Support and enhance DOCARE's enforcement efforts statewide to strengthen enforcement of resource violations.
- *Action PP.3* By 2022 continuing as appropriate in the future, create outreach and education materials to increase compliance of herbivore management strategies.
- *Action PP.4* By 2023, integrate traditional Hawaiian knowledge with more modern scientific information about fish size at maturity and other life history information to create a comprehensive document to share life history information of nearshore species with the public.



MONITORING is an essential component that measures and documents current conditions, tracks herbivore response following implementation of new management approaches, and uses data to identify areas where management actions need to be further adapted. Monitoring provides a way to measure the changes occurring and if implemented actions are effective.

Objective: Evaluate and review the effectiveness of pertinent management measures every five years and implement adaptive strategies which account for changes in environmental conditions, habitat, herbivore population dynamics, and resource uses. Actions within this pillar will track progress of herbivores, evaluate management effectiveness, identify data gaps, and determine areas where the plan may need to be adapted.

- *Action M.1* Analyze and interpret fishery dependent and independent data to evaluate ecological and socio-cultural responses to targeted management strategies.
- *Action M.2* By 2030, create a core team of permanent civil service staff in each district to collect and analyze fisheries independent and dependent data.
- *Action M.3* Collaborate with other sources (federal and academic) of fisheries independent and dependent data to bolster and fill in data gaps (i.e., HIMARC, CRAMP, MHI-RAMP, etc.).
- *Action M.4* By 2025, review and amend current regulations and Marine Management Areas as needed to support fishery and coral reef health.
- *Action M.5* By 2025, evaluate existing MMA for effectiveness in promoting sustainable fishing practices of herbivorous fish.

RESTORATION Herbivore management is only part of a multi-faceted approach to manage for improved reef restoration and resilience, including both resistance to and recovery from disturbance. Restoration builds on existing strategies to prevent damage to fragile nearshore ecosystems from invasive species, disease, and climate driven events. This pillar expands efforts to restore and enhance impacted areas, by strengthening and supporting collaborations with mauka initiatives and organizations to reduce land-based threats to nearshore ecosystems.

Objective: By 2022, begin collaborating with other agencies and communities to mitigate environmental and human impacts that affect nearshore environments. By 2030, expand efforts to improve resilience and enhance restoration. Actions within this pillar will expand efforts to restore and improve nearshore areas, and work with other agencies to reduce land-based threats to nearshore ecosystems.

- *Action PR.1* By 2025, identify key management areas to address land-based sources of pollution and sedimentation that adversely affect nearshore habitat and herbivore populations.
- *Action PR.2* By 2025, prioritize key watersheds with highest potential to recover herbivores and habitat.
- *Action PR.3* Work with regional and local partners to implement efforts that support restoration.
- *Action PR.4* Build on existing work to enhance native sea urchin stocks (Hāwaʻe Maoli), raised in DAR's urchin hatchery, on specific reefs to reduce invasive algae.

Strategy Summary

The overall success and implementation of these action items and objectives will rely heavily on community engagement and support of this plan. With proper outreach, education, engagement, and support of each part of the plan, it can be easily implemented and maintained. However, if community support is lacking, much of the implementation and maintenance of the plan will be difficult.

Table 1:List of objectives and action items with the relative ease of implementation (easy, moderate, difficult) and ease of maintenance (easy, moderate, difficult, as determined by

Objective		Ease of Implementation	Ease of Maintenance
Place-based planning		Moderate	**Easy**
	Action PB.1	Moderate	Moderate
	Action PB.2	Moderate	Easy
Pono Practices		**Moderate**	**Easy**
	Action PP.1	Moderate	Easy
	Action PP.2	Moderate	Moderate
	Action PP.3	Easy	Easy
	Action PP.4	Moderate	Easy
Monitoring		**Moderate**	**Moderate**
	Action M.1	Moderate	Moderate
	Action M.2	Difficult	Moderate
	Action M.3	Easy	Easy
	Action M.4	Moderate	Moderate
	Action M.5	Moderate	Easy
Restoration		**Moderate**	**Easy**
	Action PR.1	Moderate	Easy
	Action PR.2	Moderate	Easy
	Action PR.3	Moderate	Easy
	Action PR.4	Easy	Easy

Place-based Planning

Place Based Planning integrates the recognized differences in species diversity, abundance and harvesting practices into management planning. Actions within this pillar identify and develop management strategies for improved marine management in partnership with communities and stakeholders at local to regional scales.

Objective: Work with local communities and stakeholders to develop and implement place-based MMAs that increase herbivorous fish and invertebrate biomass and promote reef resilience at the local scale through improved marine management.

Actions within this pillar will focus on implementing MMAs with rules, activities and community engagement that reflect specific needs and concerns of each place.

- *Action PB.1* By 2024, engage local community and stakeholders to determine specific needs and concerns for each place proposed for new and/or revised MMAs.
- *Action PB.2* By 2030, implement new and/or revised MMAs that promote place-based management and sustainable harvesting practices of herbivorous species.

Current Marine Management Areas

There are currently 58 MMAs in existence in Hawai‘i, encompassing 6% of nearshore waters. Within the nearshore (50-meter/ 164-foot depth), 5% of the MMAs offer specific protections for herbivores (Figure 7). Approximately 2% of nearshore waters are designated with MMAs that offer full protection to herbivores (green: no-take, or take is heavily restricted), 3% offer partial protection (yellow: some take permitted, but with regulations limiting the take of herbivores or certain species of herbivores) and 1% includes MMAs where restrictions do not explicitly prevent the take of herbivores (red).

Within the next three years (by 2024) DAR plans to engage with local communities and stakeholders to determine specific needs and concerns for each area proposed for a new or revised MMA. Through working with local communities, DAR plans on implementing new and revised MMAs by 2030 that will promote the sustainable management and harvesting of herbivorous species at a place-based scale throughout the main Hawaiian Islands.

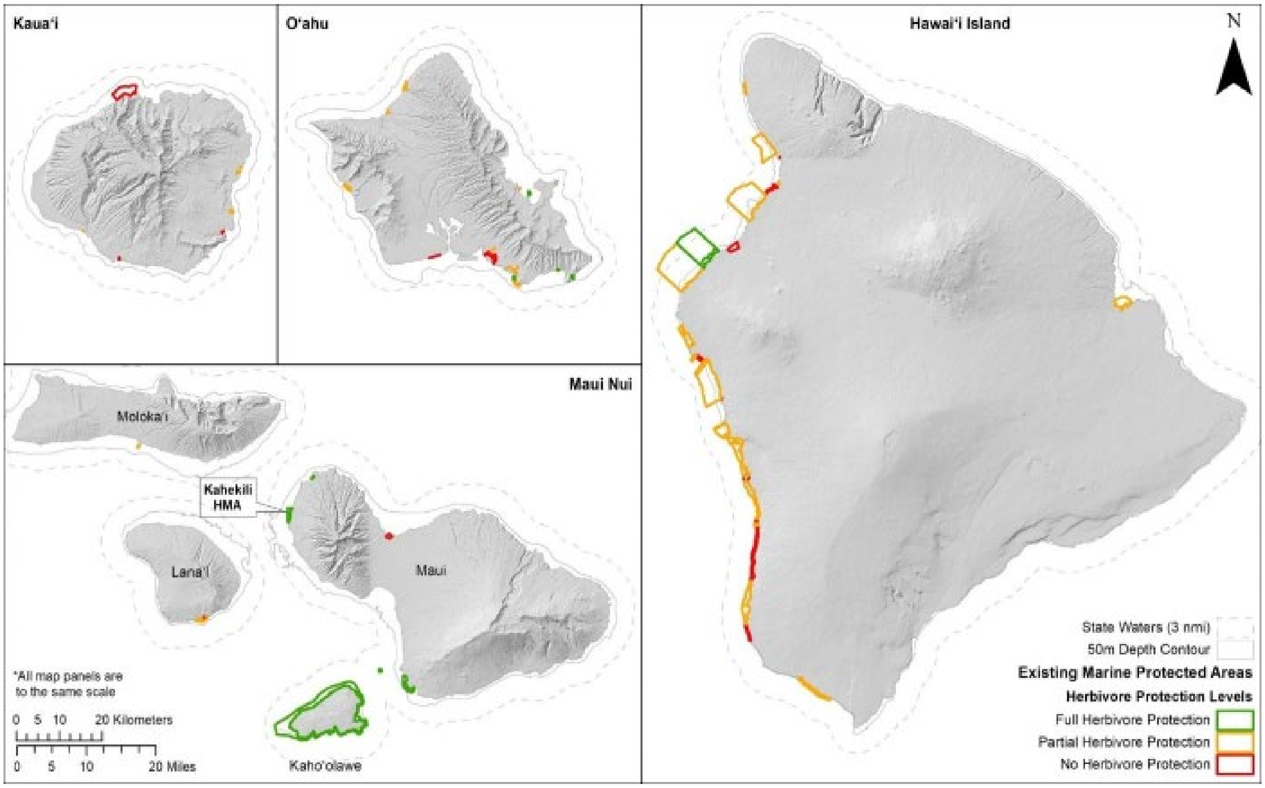


Figure 8: Map of existing Marine Management Areas in Hawai'i and the level of herbivore protection for each place, based on existing rules

Management Actions and Their Effects

The following two case studies demonstrate the positive effects of MMAs on site-specific herbivore biomass and benthic cover.

Kahekili Herbivore Management Area

The Kahekili Herbivore Fisheries Management Area (KHFMA) was established on Maui in 2009 along an approximately two-mile section of the north Kāʻanapali coastline in West Maui. Rules established in this area prohibited the take of herbivores, including both fishes (chubs, surgeonfishes and parrotfishes) and urchins. This area is the first place in Hawaiʻi where fish stocks were being managed for the specific goal of improving the health and resilience of the coral reef itself – not just the fishes.

West Maui, including the Kahekili area, has been impacted from issues relating to high nutrient loads for decades. Much of this originated from legacy agriculture of sugarcane and pineapple plantations, both of which decreased significantly from the 1970s to late 1990s. Sugarcane production ceased in 1999 and pineapple production ceased in 2009[52]. More recently, wastewater effluent and urban development, including the expansion of golf courses and resorts, has been the dominant source of high nutrient levels in nearshore waters. In 1996, 94% of phosphorous and 57% of nitrogen in the area was due to the injection wells[53] A direct link between the wastewater injection wells discharge from the Lahaina Wastewater Reclamation Facility and water quality on West Maui reefs has been documented[54].

Leading up to the establishment of the KHFMA, state monitoring results showed that coral cover in the reefs along this section of coastline had declined dramatically and that reefs were periodically overgrown by blooms of seaweed. The condition of the reef was particularly concerning in 2005 and 2006, when dense summer blooms of the alien seaweed *Acanthophora spicifera* appeared to be accelerating the ongoing declines in coral cover. Survey data from this time also showed that the herbivore fish biomass within this area was low compared to similar habitats around other parts of Maui.

Management actions within the KHFMA focused on protecting important herbivorous fishes and invertebrates form harvest, while continuing to allow all other forms of fishing. Regulations prohibited the killing or harvesting of all sea urchins along with all parrotfishes, surgeonfishes, and chubs. Taken together, these regulations protected all important reef herbivores from harvest and stopped the long-term practice of fish feeding (a practice that alters fish composition, behavior and normal grazing practices). Routine fish and habitat surveys were conducted on the reefs in the KHFMA along with other similar reefs around Maui.

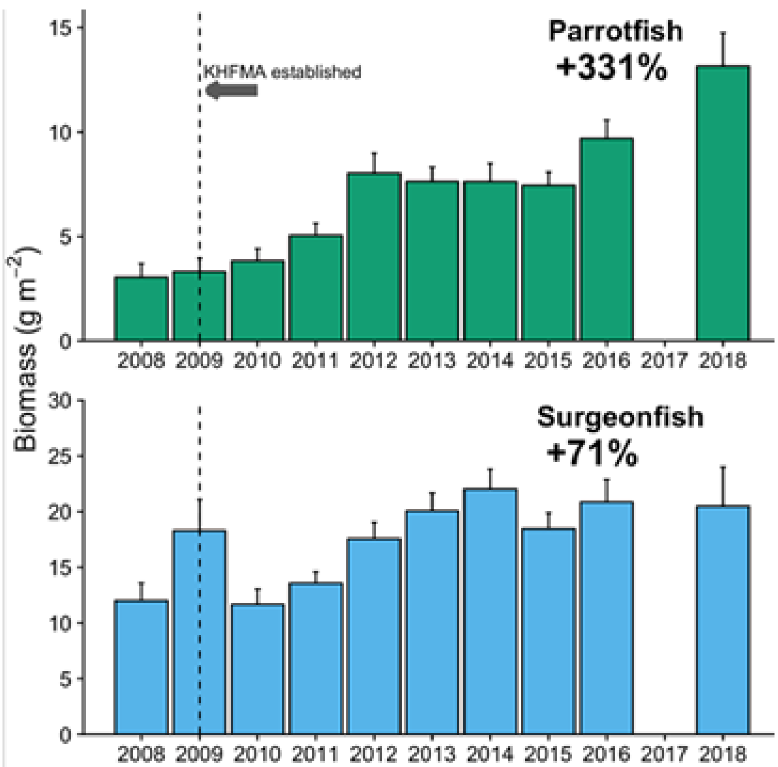


Figure 9: Change in biomass of parrotfishes (top) and surgeonfish (bottom) by species from 2008-2018 at Kahekili Herbivore Management Area. Figure from DAR 2018 results brief. These results were updated from the published findings in Williams et al 2016.

Nine years after the rules were implemented, average parrotfish biomass increased by 331% and average surgeonfish biomass increased by 71%[55] (Figure 8). The change in urchin density varied by species, with some staying relatively stable and some declining (Figure 9). This suggests that they weren't heavily targeted/harvested prior to the new rules and also could be a result of the reduction in their food source, macroalgae.

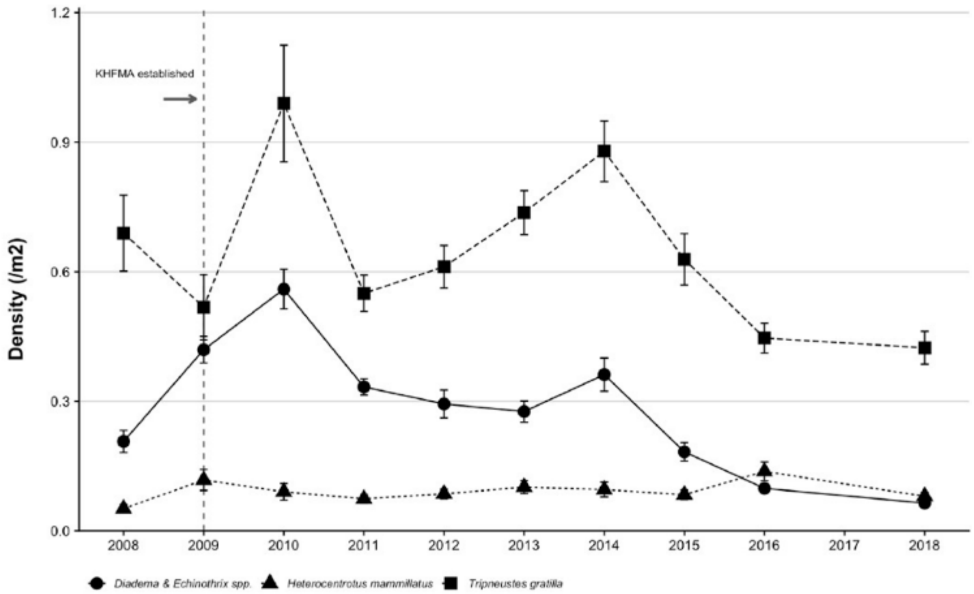


Figure 10: Density of three species of sea urchins from 10-years of monitoring at Kahekili (2008-2018). Figure from October 16, 2019 NOAA Fisheries Report.[52]

Improving and sustaining conditions that support coral cover over the long-term is especially important in Hawai'i because the majority of our coral species (*Porites* spp.) are slow-growing (only 1-3 cm/ year) and have very low recruitment rates. Coral cover declines in the KHFMA stabilized in 2012 and appeared to slowly increase through 2014. Unfortunately, the mass bleaching event in 2015 impacted some of these corals, driving coral cover further downward through 2018. However, the study found that CCA, a foundational building block for coral recruitment and growth, increased more than 11% and macroalgae cover remained low[55,56] (Figure 10).

These changes in benthic composition along with the initial increases in herbivore biomass are positive signs that the reef is becoming a more suitable environment for coral settlement and growth. Despite the initial increase in parrotfishes and surgeonfishes, preliminary results show significant declines in parrotfish and surgeonfish biomass, coral cover and crustose coralline algae (DAR/NOAA in prep) between 2018 and 2021. The driver of these changes is unknown, but given the rapid and significant response to herbivore populations and the reef after the rules were initially implemented in 2009, it is clear that continued compliance is critical to maintain the high levels of herbivores and positive trends in reef condition overtime. Overall, positive changes in CCA and relatively low macroalgae should help the corals in this area become more resilient to disturbances and hopefully better persist into the future.

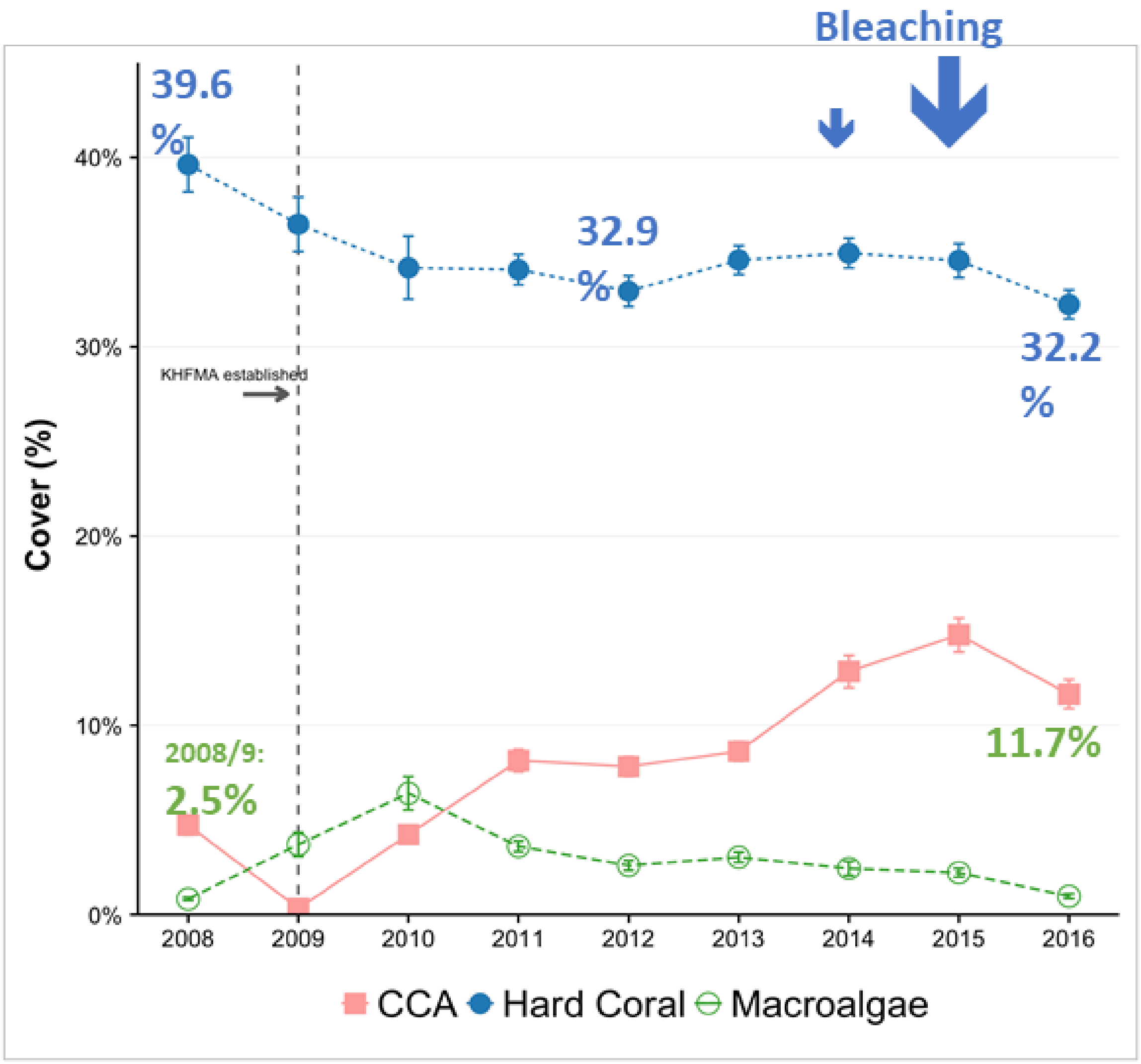


Figure 11: Plot of change in benthic cover (crustose coralline algae, hard coral, macroalgae and turf algae) from 2008-2018. Figure from DAR report 2018.

West Hawai'i Regional Fishery Management Area

In West Hawai'i, herbivore biomass increased by 30.8% from 2003 to 2017 in MPAs (defined as MLCDs and reserves) and biomass was almost 70% greater in these areas than both open areas and fishery replenishment areas[41,57] (Figure 11). There was no change over the same time period for open and fish replenishment management regimes at the same mid-depth ranges. This increase in herbivore biomass coincided with a large fish recruitment event in 2014, as well as a heatwave that caused coral bleaching and subsequently large declines in coral and increases in macroalgae. While these patterns are associated with each other in time, the ultimate effects of increased herbivore biomass on benthic status will be determined over longer time scales.

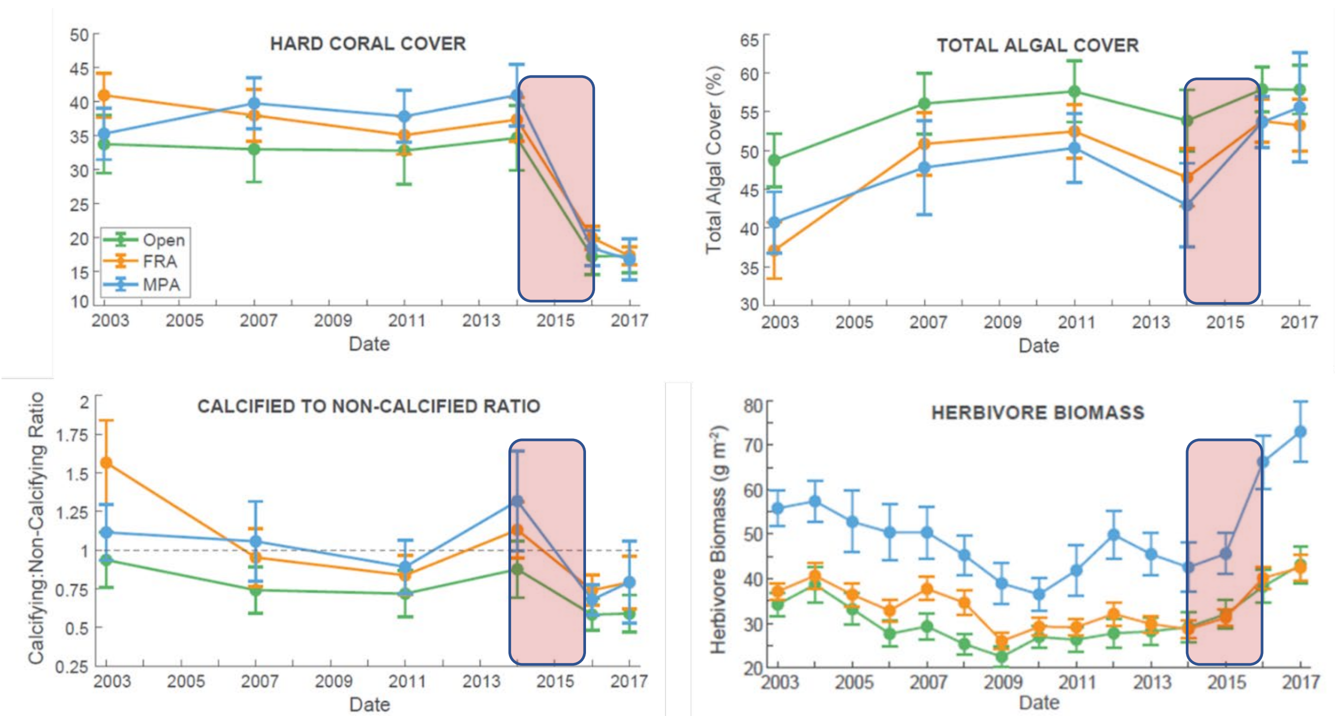


Figure 12: Hard coral cover, total algal cover, calcified to non-calcified ratio and herbivore biomass from 2003-2017 in West Hawai'i. Indicators are grouped by management status (blue line = marine protected area (MPA); orange line = fish replenishment area (FRA); green line = open to fishing). Error bars represent +/- 1 standard error. Data source: DAR's West Hawai'i Aquarium Project (WHAP). Figures from Gove et al. 2019. Red shaded area added to illustrate the bleaching event from 2014-2016.

Pono Practices

Mālama i ke kai, a mālama ke kai ia ʻoe.

Care for the ocean, and the ocean will care for you

Pono Practices encourages responsible behavior guided by Hawaiian values and perspectives through education and outreach, statewide rules, strengthened enforcement, and local partnerships to encourage sustainable behaviors and practices in nearshore waters. This pillar is a call to action for resource users to interact with nearshore resources in a pono way. Actions within this pillar will encourage ocean resource users to behave responsibly. DAR and DOCARE will work together with community members to increase stewardship and compliance.

Objective: Develop and implement statewide herbivore management measures that increase herbivorous fish and invertebrate diversity, abundance and biomass to promote both ecological complementarity and functional redundancy as well as reinforce pono practices through balancing scientific understanding with traditional ecological knowledge to promote sustainable use and stewardship of natural resources.

<u>Actions within this pillar will encourage ocean resource users to behave responsibly. DAR and DOCARE will work together with community members to increase stewardship and compliance.</u>

- *Action PP.1* Implement new and/or revised rules that promote sustainable harvesting practices of herbivorous species, by 2023 at the Statewide level[a] and by 2030 at the place-based level.
- *Action PP.2* Support and enhance DOCARE's enforcement efforts statewide to strengthen enforcement of resource violations.
- *Action PP.3* By 2022 continuing as appropriate in the future, create outreach and education materials to increase compliance of herbivore management strategies.
- *Action PP.4* By 2023, integrate traditional Hawaiian knowledge with more modern scientific information about fish size at maturity and other life history information to create a comprehensive document to share life history information of nearshore species with the public.

The Needs of Commercial and Non-Commercial Fishing

Rules proposed for herbivores as part of this management plan will be applied to all types of fishing, both commercial and non-commercial. A 1998 DLNR policy lays out the hierarchy of priorities that DLNR must abide by when making management decisions:

- The policy prioritizes the protection of the resource first
- Public use second, without undue damage to the resource
- Commercial use third, only if commercial use does not conflict or interfere with public use and resource protection.

[a] In February 2024, amended statewide regulations for uhu, kala, manini and kole were implemented.

As a large portion of the nearshore fishery is non-commercial, management action as outlined in this plan will apply to both commercial and non-commercial fishing, to follow the guidance of this policy.

Traditional and Contemporary Management Options and Benefits

Traditional Hawaiian Fishery Management

Historically Hawaiʻi had several management regimes. At the ahupuaʻa (traditional land divisions based on watersheds) level, konohiki (resource managers) [58] coordinated with the people of the land, local elders, and expert fishermen to determine when it was appropriate to place kapu (ban/taboo) on different fish species. Kapu represented a type of **closure** that was usually based on spawning seasons of certain species to protect resource replenishment.[59] Adherence to the closure was motivated by shared cultural, social, and spiritual values,[60] as well as a potential penalty of death.[61] If there was balance and harmony between the ahupuaʻa residents and konohiki, the land and sea would be abundant.[58]

In the 1839 Declaration of Rights and the Constitution of 1840, konohiki fishing rights were given written recognition, designating fishing grounds for the konohiki and the people of that ahupuaʻa.[62] In 1845, it was documented that the privilege of the konohiki putting kapu exclusively on one kind of fish was exchangeable for the right of kapu over all fish within a konohiki's fishing ground for a certain length of time.[60] In 1850, the Kuleana Act granted fee simple titles for kuleana lands to ahupuaʻa residents upon proving two-year occupancy of the land, providing two corroborating witnesses who "knew" the land, and acquiring approval of the konohiki.[63] In 1859, the laws were codified, but the written acknowledgement of the kapu now only included the season "for the protection of such fishing grounds the minister of the interior may taboo the taking of fish thereon at certain seasons of the year."[64]

Another important aspect of historical regulations and distribution of catch was the practice of giving and sharing. A fisher's catch was typically shared with the kūpuna and kahuna (elders), the konohiki, and the broader community.[60] It was easier for all to see the amount that was being taken out of the ocean because it was shared by the community. In fact, it was illegal in the kanawai (laws) to deny a hungry person a fish from your pile.[60,61,65]

Contemporary Fishery Management

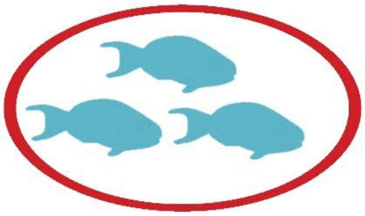
Regulations can be implemented to limit unsustainable harvest, ultimately providing better fishing opportunities for the future. The most commonly used regulations for recreational fisheries management worldwide are **bag limits**, which limits the total catch per person per day, and **size limits**, which limits the minimum or maximum size needed for a fish to be legally harvested.[66]

The Division of Aquatic Resources, DLNR, has the authority to regulate fisheries. HRS section 187 A-5 gives DLNR the authority to make the following kinds of regulations concerning aquatic life:

- Bag limits
- Size limits
- Seasonal closures
- Area restrictions
- Gear restrictions

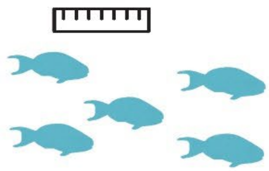
Activities related to boating, recreation, and other human activities in state waters are regulated by the Division of Boating and Ocean Recreation, DLNR (HAR 234), and regulations on water quality are set by the Department of Health (HAR 11-54).

The Division of Aquatic Resources has the authority to make fishing rules to ensure sustainable harvest. These rules are based on the following principles:



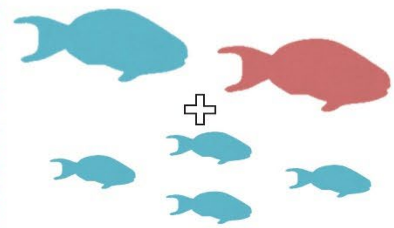
Take only what you need

Type of Rule:
Bag Limit
the number of fish that **one** person is a allowed to take in a single day.



Let the keiki grow

Type of Rule:
Size Limit
minimum size required to catch (allows fish to reproduce)

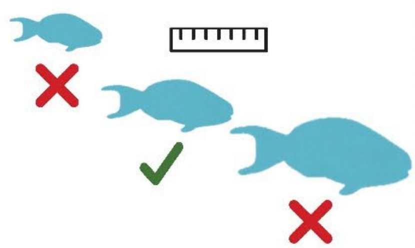


Let the fish reproduce

Type of Rule:
Closed Season
during the time of year a fish species typically is spawning or reproducing

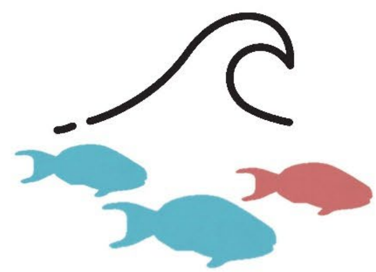
Use the right gear

Type of Rule:
Gear Regulations
limits on type of gear that is allowed, such as: hook and line, spearfishing, nets and traps



The sweet spot: catch medium fish

Type of Rule:
Slot Limit
no fish smaller/larger than a certain size are allowed - smaller fish have not had a chance to spawn, larger fish create more offspring



Respect Local Rules

Type of Rule:
Place-based Regulations
many places in Hawai'i have extra rules that are specific to a specific area/place

Bag Limits

A bag limit is one management method that reduces the amount of fish harvested by limiting the total number of fish caught per person per day. Bag limits are helpful in situations where fish are being removed from the population faster than they can be replaced by the next generation. Bag limits generally allow for fishers to use any legal gear type, making this form of regulation more inclusive as it does not exclude select fishers from being able to harvest a particular species. From an ecological point of view, bag limits are more effective at reducing post-release mortality by eliminating the extra time and handling needed to measure fish due to a size restriction.[66] Bag limits also allow for the harvest of the species at all times of the year by any gear type. Sustainable results can be increased further when combining bag limits with another type of regulation such as size limits or gear restrictions.[67]

Size Limits

Size limits set size requirements for the harvest of a species and may be set for a minimum or maximum size, or both. Minimum size limits aim to protect the juvenile fish population until they've reached a size of maturity where they can reproduce at least once. Size at maturity is typically used to set minimum size limits to give fish the opportunity to reproduce. Since every individual is a little different, size at maturity is often estimated and described as the L_{50} value (the length at which at least half of the population is able to reproduce). A maximum size limit aims to protect the bigger fish and ensure that the population has large spawners, which can produce exponentially more offspring than a newly mature fish.[68] Fishing pressure tends to target the larger and older individuals, however 70% of egg production comes from the top 10% of size classes. Big old fecund female fish (BOFFFs) produce many more, often larger (higher quality) eggs, disproportionately contributing to standing stock biomass and spawning potential of the population.[68] Minimum and maximum sizes can also be combined to create a slot limit, which means that only the size in between the minimum and maximum size limit may be caught. Both minimum and maximum size limits aim to address inappropriate harvest by protecting the reproductive potential on either sides of the size spectrum for a single species. For multi-species fisheries, either size limits for multiple species or area restrictions can help to support the reproductive potential in the population.

> *Definition of Size/Length at Maturity:*
> The size/length or age at which individuals are reproductively active and producing[69]
>
> *Definition of L_{50}:*
> The size/length at which at least 50% of the individuals in a population are reproductively active and producing[69]

Some fishers prefer size limits to bag limits because they are still allowed to catch as many fish as they want if it is within a certain size. Size limits may have less of a socioeconomic impact compared to bag limits by encouraging more fisher participation. Size limits also allow fishers to continue fishing, making sure that food is on the table, traditions continue being passed on, and the connection of community are maintained through sharing of fish.[70,71]

While bag limits may only affect the most efficient fishers, size limits can reduce the impacts of all fishers.[66] Size limits are popular for the dual goal of limiting overfishing and improving the fishing quality.[72]

Size limits can also help fishing communities attain optimal yields, even under high fishing pressure.[73] For most fishes, the size at which optimum yield is achieved can be simply approximated by multiplying a species' length at maturity (L_{50}) by a factor of 1.2. [74]

Seasonal and Area Closures

Seasonal closures refer to prohibiting the harvest of certain species during certain times of the year, usually based on spawning seasons. Closures can be variable depending on location and species. In general, these regulations are most appropriate if certain species of fish aggregate when spawning, making them easier to target.

Area regulations are regulations that are specific to a place and may include seasonal closures, gear restrictions, or certain size and bag limits that may be more restrictive than statewide regulations.

Although kapu and seasonal closures were used regularly in ancient Hawaiian times, they were done at ahupuaʻa and moku (island) levels, and as such, are not applicable for statewide regulations. Because there can be variation in spawning seasons between places, seasonal closures for certain species corresponding with their spawning season are a consideration for place-based management in the future.

Gear Regulations

There are many different fishing gear types used in Hawaiʻi's nearshore fishery, and some types are more effective at catching large numbers of fishes or other aquatic species quickly. Therefore, regulations on specific gear and methods of fishing can help to minimize higher catch rates and may even limit or eliminate the harvest of particular species or life stages. For example, there are regulations in Hawaiʻi that prohibit smaller mesh nets, as larger mesh sizes allow smaller juvenile fishes to escape, giving them a chance to reach maturity.

Many existing MMAs, have gear regulations and there are also statewide gear regulations. Current gear regulations can be found here: https://dlnr.Hawaiʻi.gov/dar/fishing/fishing-regulations/gear-restrictions/. Gear regulations in varying strictness are often used to rank the level of protection of marine protected areas.[64]

Table 2: Fishing gear type with associated ease of enforceability (easy, moderate, difficult) and likelihood for wanton waste (low, moderate, high).

Gear Type	Enforceability	Likelihood for Wanton Waste
Spearfishing	Moderate	Moderate
Throw Net	Easy	Moderate
Lay Net	Difficult	High
Traps	Moderate	Moderate
Hook and Line	Easy	Low

Addressing Overly Efficient Gear (SCUBA and Nighttime Spearfishing)

Across the board there are certain gear types or fishing methods that are overly efficient in comparison to other gear types. SCUBA spearfishing and nighttime spearfishing are two examples of gear/fishing types that are particularly effective at taking herbivorous fishes.

Most Pacific Island countries ban the use of SCUBA while spearfishing.[75] Banning nighttime spearfishing or SCUBA spearfishing is a significant way to control fishing pressure.[76] SCUBA spearfishing is banned in American Samoa and this regulation has relatively high compliance.[76] In American Samoa, there was a documented 15 fold increase in catch of parrotfishes with the introduction of SCUBA in 1994, leading to a harvest of 18.7% of the standing stock.[77] This was the basis for the country's ban of SCUBA spearfishing through Executive Order.[77]

Some fishers in Hawaiʻi feel that SCUBA spearfishing is too efficient, and that nighttime spearfishing is unfair because sleeping fishes are defenseless, and other fishes are easily disoriented with a night divers light.[78] If SCUBA spearfishing were allowed, recognizing that some individuals may have difficulty freediving, a compromise of no SCUBA spearfishing at night would be helpful.[78] SCUBA spearfishing was banned within the West Hawai‘i Regional Fishery Management Area (WHRFMA) boundaries from ‘Upolu Point to Ka Lae (South Point) on Hawai‘i Island in December of 2013.

Fishing regulations help to ensure sustainable harvest.

	Benefits	Drawbacks
Bag Limits	• Reduces excessive take • Reduces fishing pressure • Allows all gear types • Promotes sustainable catch Adjustable • based on resource health and fisher need	• Different bag limits for different species may be difficult to remember • Targets gear types which catch large amounts of fish very easily • Statewide bag limits are difficult to determine because of variability between places
Size Limits	• Immature fish are allowed to reach spawning size • Does not limit number caught Allows • most gear types	• Fish size can be difficult to estimate while underwater • Different size limits for different species may be difficult to remember • Catch and release for undersized fish is not practical for some gear types like a spear or some nets

Closed Season	• If during spawning season, protects reproductive individuals
	• Reduces fishing pressure
	  • Reproductive fish are less stressed
	  • Chance to rest and grow larger
		• Spawning seasons are highly variable by place
		• Life history could change with changing conditions
		• Reduces access at certain times

Gear Regulations	• Allows for a variety of species to still be caught • Can limit take of certain life stages or types of fish while still allowing fishing	• Excludes fishers who prefer specific gear types, if that gear is regulated
Slot Limits	• Minimizes take of the population that haven't yet reproduced • Minimizes take of large very reproductive individuals • Older fish reproduce in much larger amounts than smaller fish • Allows for most gear types	• Can be difficult to estimate in water • Different size limits for different species may be difficult to remember • May limit catch of a desired size range
Place-based Regulations	• Incorporates traditional knowledge at local scales into management actions • Aligns regulations with unique characteristics of a place • Protects entire local ecosystem • Ensures broad size range of herbivores • Can replenish nearby fished areas via spillover of adult fish and seeding by larvae.	• Fisherman can have a hard time remembering the rules for each place • May increase pressure in non-regulated areas • May limit access to preferred local fishing areas

Table 3: Different regulation options and their ability to monitor (easy, moderate, difficult); ease of enforceability (easy moderate, difficult); and likelihood to produce waste (low, moderate, high).

Regulation options	Ability to Monitor Change	Enforceability	Likelihood for wanton waste
Size Limits	Easy to Moderate- at the group level (family or herbivores) Difficult- at species level on large scales (island or statewide scale)	**Easy**	**Moderate**
Bag Limits	Moderate to Difficult	**Easy**	**Low**
Seasonal Closure	Easy at place-based scale	**Easy**	**Low**
Time Area Closure	Easy at place-based scale	**Easy**	**Low**

Determining Sustainable Fishing Levels

With a limited amount of catch data, one way to look at the effectiveness of fishing regulations is to determine if the level of fishing pressure is sustainable. In fisheries with limited catch data one way to estimate a sustainable fishing level is looking at the **Spawning Potential Ratio** (SPR). A SPR of 100% (or ratio of 1) means that there is no fishing pressure, and all individual fish can reproduce. A SPR of 0% (or ratio of 0) means that every fish is harvested prior to reproducing. A SPR of greater than 30% is traditionally considered a sustainable yield. When assessing the sustainability of a fishery, we want an SPR value above 0.30.

> *Definition of Spawning Potential Ratio (SPR)*
> The percentage of the population that has been able to effectively create eggs to reproduce, or a measure of current egg production relative to egg production when a stock is not fished.[79]

Aside from looking at the number of fishes taken out of a fishery, managers also consider the amount of effort being used to fish. The level of fishing effort is referred to as **fishing rates** (F). A sustainable fishing rate (F_{30}) is the amount of fishing that will result in an SPR of 30%. For a sustainable fishery, we want an F/F_{30} below 1, meaning a fishing rate below the rate that equals 30% SPR.

Finally, fishery managers determine **overfishing limits** (OFL) that corresponds to a 50% risk of overfishing. When reporting the current status for the species under consideration we will give three statuses:

- **SUSTAINABLE:** This means SPR >0.30 and F/F_{30} is < 1.
- **INSUFFICIENT DATA:** A stock assessment has not yet been completed for this species to categorize the stock as sustainable or unsustainable, management must be based on the best available data, and then adapted once better data is available.
- **UNSUSTAINABLE:** This means SPR <0.30 and F/F_{30} is > 1.

SPR and F/F_{30} values are from a 2017 stock assessment of Hawai'i's coral reef fishes and is the best available science to date.[80] For species grouped together for management, the most vulnerable species is listed for stock status.

When reporting management considerations, if the data are available, we will report the OFL for total catch weight as well as a more conservative catch limit equaling 40% overfishing probability. We will also report the minimum size considerations that would equal OFL and 40% overfishing probability.

Species and/or Species Groups Under Consideration

DAR has selected several species and species groups to be considered for additional management. These species or species groups are being considered because of their functional role in coral reef resilience. Proposed management actions will consider the species' life history, fishing pressure, traditional and contemporary use, and input from the public.

	Hawaiian Name	Common Name	Scientific Name
Chubs	Nenue	Highfin Chub	*Kyphosus cinerascens*
	Nenue	Pacific Chub	*Kyphosus elegans*
	Nenue	Hawaiian Chub	*Kyphosus hawaiiensis*
	Nenue	Lowfin Chub	*Kyphosus vaigiensis*
	N/A	Bermuda Chub	*Kyphosus sectatrix*
Surgeonfish	Palani	Whitespine Surgeonfish	*Acanthurus dussumieri*
	Pualu	Ringtail Surgeonfish	*Acanthurus blochii*
	Pualu	Yellowfin Surgeonfish	*Acanthurus xanthopterus*
	Umaumalei	Orangespine Unicorfish	*Naso lituratus*
	Kala	Bluespine Unicornfish	*Naso unicornis*
	Manini	Convict Tang	*Acanthurus triostegus/sandvicensis*
	Na'ena'e	Orangeband Surgeonfish	*Acanthurus olivaceus*
	Pāku'iku'i	Achilles Tang	*Acanthurus achilles*
	Kole	Goldring Surgeonfish	*Ctenochaetus strigosus*
	Black or King Kole	Chevron Tang, Black Surgeonfish, or Hawaiian Bristletooth	*Ctenochaetus hawaiiensis*
Parrotfish	Uhu 'ele'ele (male) or Pālukaluka (female)	Redlip Parrotfish	*Scarus rubroviolaceus*
	Uhu uliuli (male) or 'Ahu'ula (female)	Spectacled Parrotfish	*Chlorurus perspicillatus*
	Pōnuhunuhu	Star-eye Parrotfish	*Calotomus carolinus*
	Uhu	Yellowbar Parrotfish	*Calotomus zonarchus*
	Uhu	Bullethead Parrotfish	*Chlorurus spilurus*
	Lauia	Regal Parrotfish	*Scarus dubius*
	Uhu	Palenose Parrotfish	*Scarus psittacus*
Urchins	Wana	Blue-black urchin	*Echinothrix diadema*
	Wana	Banded urchin	*Echinothrix calamaris*
	Wana hālula	Long-spined urchin	*Diadema paucispinum*
	Hā'uke'uke 'ula'ula	Red or Slate pencil urchin	*Heterocentrotus mammillatus*
	Wana	Rough-spined urchin	*Chondrocidaris giganteae*
	Ha'ue'ue	Ten-lined urchin	*Eucidaris metularia*
	'Ina kea	Pale rock boring urchin	*Echinometra mathaei*
	'Ina	Black rock boring or Oblong urchin	*Echinometra oblonga*
	Hāwa'e maoli	Collector urchin	*Tripneustes gratilla*

The following section aims to highlight some of the background of these considerations. Commercial catch data are based on the Commercial Marine License database, which is the largest and oldest DLNR fisheries dataset, dating back to 1948, and based on mandatory reporting of commercial catch. Hawai'i does not require a recreational fishing license or mandatory reporting like many other places, and thus it can be challenging to get accurate information on the extent of recreational or subsistence catch. The Hawai'i Marine Recreational Fishing Survey (HMRFS) compiles information from both non-commercial shoreline and private boat fishers through a voluntary, in-person creel survey. Information is captured directly from fishers about their catch, but the number of interviews is constrained by logistics and a limited number of personnel. Management considerations are based on a suite of information and factors to consider, including input from a public scoping process.

Urchins:

For the purposes of this management plan, we are focused on urchin species that live on the reef habitat. Due to the variability of urchins both in presence and in harvesting practices, urchins will likely be part of place-based management by island, region, or specific MMA, as opposed to statewide. **All reef species (no intertidal or sand dwelling species)** are being considered including the following; Hawaiian names for these species include four broad categories[81,82]:

Wana (those with long slender spines): Typically found on reef habitat

- Blue-black Urchin (*Echinothrix diadema*) is more common in shallow habitat below 15 ft.[81]
- Banded Urchin (*Echinothrix calamaris*) is the most common long-spined urchin in Hawai‘i.[81]
- Long-Spined Urchin (*Diadema paucispinum*) is the least common species of wana here in Hawai‘i but is from the important genus *Diadema,* which has been shown to control macroalgae in the Caribbean.[83]

Hā ‘uke‘uke (thick, flattened, or stubby spines):

- Hāuke‘uke ‘ula‘ula/ Slate Pencil Urchin (*Heterocentrotus mammillatus*) is a large reef species that has limited predator defenses and utilizes habitat and nocturnal behavior to eat macroalgae.[84]
- Rough Spined Urchins (*Chondrocidaris giganteae*) and Ten-Lined Urchins (*Eucidaris metularia*) both lack the skin of living tissue present on the spines of other urchins, so their blunt spines are usually covered with a layer of algae and detritus.[81]

‘Ina (medium length spines):

- Rock Boring Urchin (*Echinometra mathaeil*) and Black Rock-Boring Urchin (*Echinometra oblonga*) as their common name suggests, bore into rock while eating algae to create habitat for themselves.[81]

Hāwa‘e (short slender spines):

- Hāwa‘e maoli/ Collector Urchin (*Tripneustes gratilla*) has been cultivated in aquaculture facilities and used extensively in Kāne‘ohe to help control invasive algae.[85] It’s been noted that this species often aren’t eaten by native Hawaiians,[81] but is highly targeted by other Pacific Islander cultures and for palu, or bait. When eaten, they are targeted during the days they have eggs like most other harvested urchin species.

<u>Status:</u> INSUFFICIENT DATA

There are some marked declines in place-based monitoring, such as in Hā‘ena, Kaua‘i from their Long-term Monitoring and Assessment of the Hā‘ena, Kaua‘i Community Based Subsistence Fishing Area Report.[86] There’s some speculation that local species may be vulnerable to viruses, and could use the extra protection.[83] There were documented mortalities of Collector Urchins (*Tripneustes gratilla*) in Hawai‘i, Kaua‘i, and most recently in coastal waters along O‘ahu and Maui.[87]

Current regulations:
Maui: Kahekili Herbivore Fisheries Management Area (FMA): No take of sea urchins in the FMA
Kauaʻi: Hāʻena Community-Based Subsistence Fishing Area (CBSFA): Limit of five per species per day
Hawaiʻi Island: Old Kona Airport Marine Life Conservation District (MLCD): Collection of wana, wana halula, and hāʻukeʻuke is permitted, with hand tool, and without use of SCUBA gear, from June 1 to October 1.

Management Considerations: Seasonal restrictions are not currently being considered since urchins are generally targeted for food when they are reproducing (i.e. gonads are what is harvested), meaning that seasonal restrictions timed with reproduction would inadvertently result in restricting all harvest. Bag limits with pieces/individuals are likely to be easier to enforce than a volume-based limit.

In Old Kona Airport MLCD in West Hawaiʻi, a 2005 rule passed to allow for the harvesting of sea urchins, where harvesting was previously prohibited. Based on input from urchin harvesters and the community, the West Hawaiʻi Fisheries Council developed a proposal which permits non-commercial harvesting from June 1 to October 1.[59]

Figure 13: Hawaiian woman collecting wana *(sea urchins). Courtesy of Bernice P. Bishop Museum.)*

Commercial Harvest: Commercial catches of sea urchins for both consumption and aquarium purposes are tracked by DAR via mandatory commercial fishing reports. Over the past 20 years (2001 to 2020) an average of 901 sea urchins were caught statewide annually for commercial purposes. Of the total catch during that period, 95% were collected for the commercial aquarium trade. The local market for Hawaiʻi-caught sea urchins as food is relatively limited as the species are not competitive with imports preferred by sushi and other high-end restaurant markets. Additionally, local commercial demand for home consumption is limited as many locals do not commonly consume Hawaiʻi sea urchin species, and those who do mainly collect their own non-commercially. Commercial take of all species for aquarium purposes including invertebrates has been banned statewide since January 2021.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (Pcs.)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs.)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch (Pcs.)	% Change in Price/Pc.
Urchins	Handpick	Confidential[1]	Confidential[1]	36	Confidential[1]	NA	NA

[1]Data withheld to preserve fisher/dealer confidentiality.

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Urchins	2,363	$2.82	137	$2.53	-94.2%	-11.8%

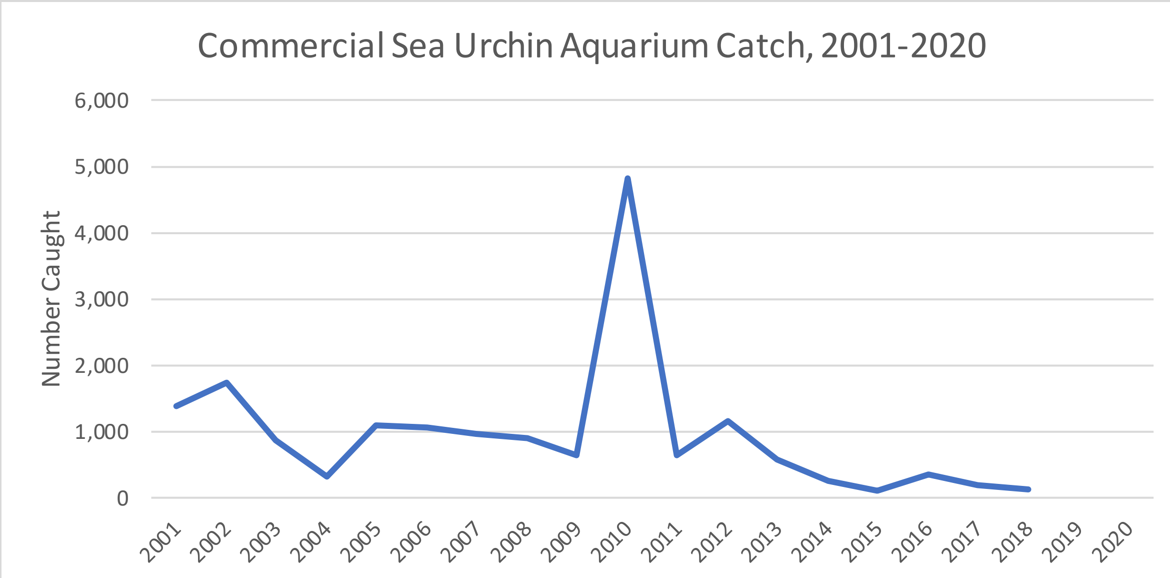


Figure 14: Commercial aquarium catch data for urchins is confidential for the years not plotted and does not mean recorded catch was zero.

Non-commercial Harvest: The majority of sea urchins harvested in Hawaiʻi is non-commercial for subsistence.

Historical Take and Cultural/Traditional Use: Sometimes a sauce is made of ʻina by breaking the tests into large pieces, adding water and salt, and draining the water after several hours. This liquid is called kai ʻina (a reddish lavender like the color) and is eaten with raw fish.[88] Wana spines are removed for eating, and the five orange-colored gonads (elelo) are scooped out. The fluid (kai) inside the body is used, too.[82] The kai and elelo are mixed and used as a relish eaten with sweet po tato and poi. Hāʻukeʻukeʻulaʻula or punohu spines were used potentially as ki, or carved ʻaumakua, found on Kahoʻolawe.[82] *Eucidaris metularia* - sometimes called hāʼueʼue (Hawaiʻi island name) or peni (Maui name), was too small and not eaten.[82] All kinds of urchins were used as bait for paeaeae fishing for uhu.[89] In the story of Kalamainuʼu we learn how Hinalea were caught using a mix of wana and ʻōhiki (ghost crabs) in a hinaʼi or basket trap.[61] Urchins were mentioned in the Kumulipo and were also referenced in ʻōlelo noʼeau. Today many still consider the gonads of urchins a delicacy, eating them raw, cooked, or dried, and preparing sauces using the urchin's liquids.[81]

The area fronting the Queen Liliʻuokalani's royal compound Hamohamo in Waikīkī Kai, Oʻahu included ʻIna sea urchins and hāʻukeʻuke sea urchins. The Queen had them propagated and some were brought from Hilo, some from Lāhainā, some from Molokaʻi and from Kauaʻi, and from Waialua, Oʻahu.[90,91]

Background/Ecology/Behavior: Urchins are considered **grazers** and sometimes bioeroders on the reef.[92] Urchins graze on turf and macroalgae, but their unusual five-part mouth (Aristotle's Lantern) is capable of devouring dead fishes, tube worms, mollusks, and even other urchins.[81]

Role for Reef Resilience: Sea urchins are effective grazers preventing macroalgal dominance on reefs. However, they are not a replacement for herbivorous fishes as some species bio-erode the reef and can scrape even Crustose Coralline Algae.[92] Recent work in Oʻahu suggests that urchins accounted for 32-88% of herbivore biomass, depending on the site.[93] Urchins have been documented as the largest percentage of herbivore biomass and algae control in the Kaloko Honokōhau area of Hawaiʻi Island.[94]

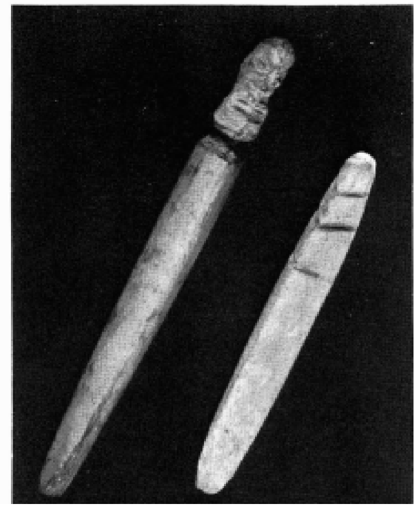
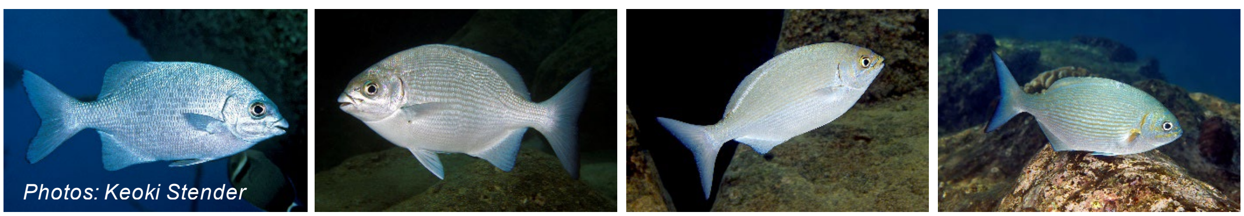


Figure 15: Hawaiian woman collecting wana *(sea urchins). Courtesy of Bernice P. Bishop Museum.)*

Life History: Urchins are generally highly nocturnal, and most are active in large groups at night. Echinoderms, including sea urchins, have "boom and bust" patterns of density, leading to big increases and decreases in their population.[95] Once a population decline has been initiated, losses are common, and recovery is extremely slow.[95] Overharvesting can lead to a downward cascade of urchin populations. Other reasons for population decline can include viruses which infect sea urchins leading to mass die-offs,[83] and terrestrial runoff impacting fertilization and other reproductive functions.[96] Multiple pressures from overharvest, viruses, and terrestrial input could be devastating and recovery could be challenging.

Nenue/Enenue *(Kyphosus cinerascens, Kyphosus elegans, Kyphosus hawaiiensis, Kyphosus sectatrix, Kyphosus vaigiensis)*



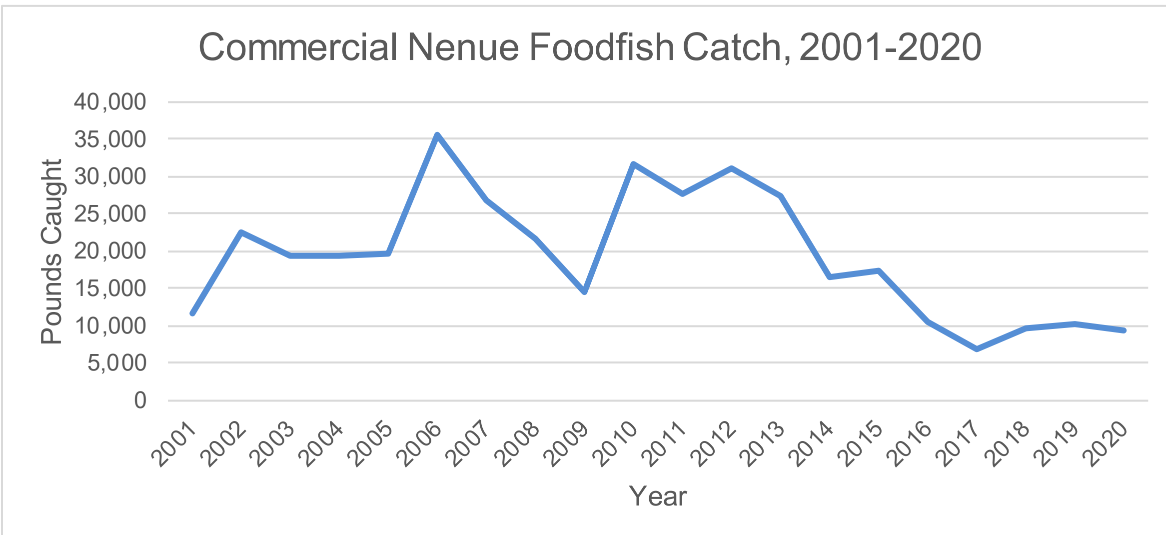
Current Status: INSUFFICIENT DATA

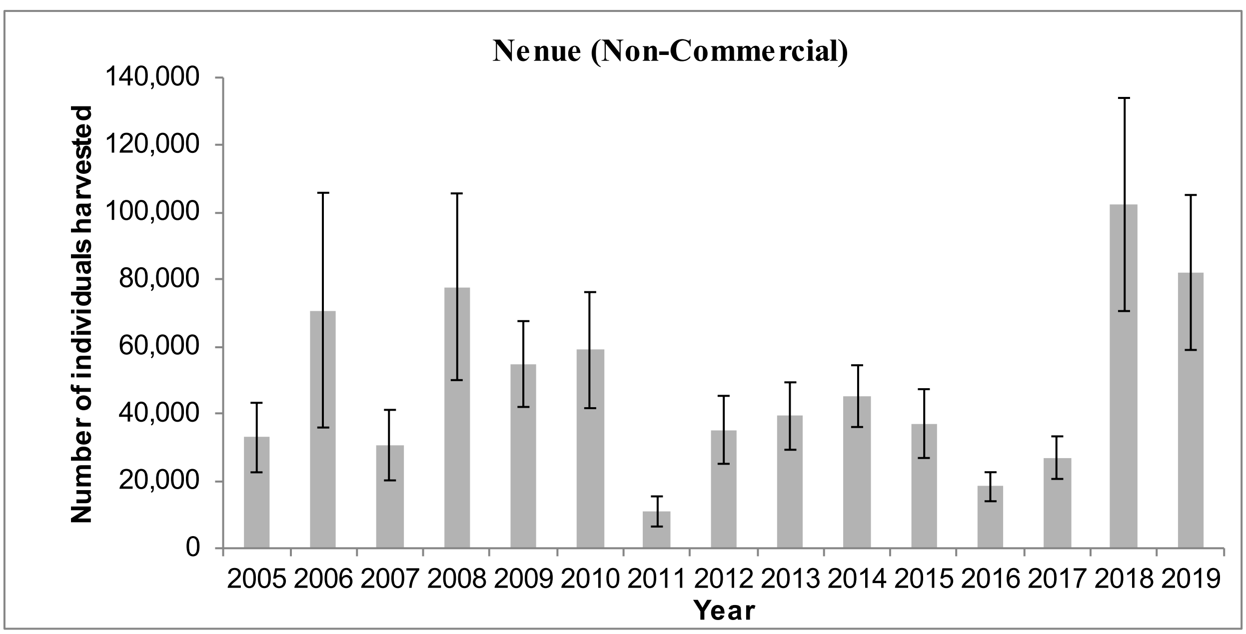
Current Regulations: No current regulations

Management Considerations: Data are limited on length at maturity for most species, so a size limit would be difficult to estimate. However, life history studies in Hawaiʻi are in progress, which will better inform tailored management decisions**.** A bag limit would support pono practices and is more likely to be supported by subsistence fishers.

Commercial Harvest: Though nenue are not preferred by some local consumers due to their strong flavor, commercial catch for the species group is relatively high with 167,126 pounds caught between 2011 and 2020. Commercial harvest of nenue is primarily by nets; 40.2% for surround net and 26.9% by gillnet. They are also taken by spear (16.4%). Large shoals of nenue allow surround nets to efficiently harvest large quantities all at once. While market price has increased, there has been a decrease in nenue catch from 2011 to 2020, which may reflect the amount of effort in the fishery rather than an indication of population status. Under rare circumstances (e.g., fulfillment of a specific aquarist's request), nenue are collected by commercial aquarium collectors. They are otherwise not considered to be a species targeted by the fishery with less than ten fish typically collected per year.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Nenue	Surround net (40.2%), Gillnet (26.9%), Spear (16.4%)	12,144.2	$2.07	9,316.2	$2.20	-23.3%	6.3%





Non-Commercial Harvest: Nenue is a common fish targeted by non-commercial fishers, but due to its strong taste, it is not a preferred food fish by everyone. It is most often caught using rod and reel, but also targeted by spear and throw net fishers. In the HMRFS data set, the median catch of nenue is two fish per person, but they are sometimes caught in larger numbers depending on the gear type. Nenue catch varies per year as shown in the chart below. They are very popular bait for the ulua fishing method called slide baiting, due to the fish being hardy and able to stay alive for a long time.

Historical Take and Cultural/Traditional Use: There are many different variations of names people use for chubs regardless of species. In Kāneʿohe, the community refers to the juveniles as nenue and the adults as Enenue.[60] In the moʿolelo of Punia, "The Boy Punia and the King of the Sharks", the same fish are called Ananue.[61] Some references are mauka related such as within the Kumulipo where enenue are known for being guarded and having a connection to the lauhue, a type of poisonous gourd, that grew in the forest.[97] The mele, "Aloha Ka Manini" written by Israel Kamakawiwo'ole also references the enenue.

Historically, there were two ways of catching nenue, either with a net or a hook. They were caught similarly to kala with papa nets if they were schooling, with long paloa nets in shallow waters, or with hoʿomoemoe nets at night. If they were being fished using a hook, nenue were said to be fed similar to tamed hogs. The most famous fisher of nenue by hook was the judge of Hana in the areas known as Kaʿuiki and Alaʿau.[89]

Nenue are used in poke preparation. Their stomachs, full of limu nanue and limu kala, are eaten or used in the mixing of the poke for their strong taste. For these reasons they are also good for palu. While it is best eaten raw according to some, others prefer it wrapped in ti leaves and broiled.[60]

Background/Ecology/Behavior: Nenue/enenue are found in rough and turbulent waters along rocky coastlines and coral reef habitats.[88] They have a long digestive tract and use bacterial fermentation to get nutrition from the seaweed they eat.[98] Nenue species can be difficult to tell apart visually, as species look very similar. Occasionally, individuals are yellow, white, or multicolored.[98] In old Hawaiʻi, a yellow nenue was regarded as queen of the school, but these color variations are not documented to have any social or behavioral significance. However, when aroused from either mating or browsing, nenue will occasionally turn very dark with white spots.[98]

Certain species will slightly vary in diet and habitat depending on the marine environment they occupy. The Cortez Chub (*Kyphosus elegans*) is a common species and frequently observed in schools on reefs or rocky substrate and feed on benthic algae (*Sargassum, Ulva, Zonaria, Gelidium, Amansia, Polysiphonia, Herposiphonia, Gelidiella, Griffithsia, Hypnea*, and *Turbinaria)*.[99] Brassy Chub/Lowfin Chub (*Kyphosus vaigiensis*) is found to aggregate over hard, algal-coated bottoms, of surf-swept reefs, as well as rocky areas[100] and have surprising movement patterns between estuarine and coastal habitats indicating they are unlike most nearshore fishes that stay close to home coral reefs.[101] Highfin Chub (*Kyphosus cinerascens*) is typically found in aggregations over hard, algal-coated bottoms of exposed, surf-swept outer reef flats to a depth of at least 24 meters[102] and are known for eating macroalgae as well as associated invertebrates.[103] Hawaiian Chub (*Kyphosus hawaiiensis*) is endemic to Hawaiʻi and typically occupy shallow water, in the surge zone near coral and rocky reefs.[104]

Role for Reef Resilience: All species of nenue fill the role of **browsers**, frequent shallow parts of the reef and selectively feed on larger seaweeds (macroalgae). Like pulling weeds from a garden, browsers remove the larger leafy seaweeds making room for grazers and scrapers to remove the underlying turf algae. These large herbivores are drivers of ecosystem resilience of coral reefs by browsing on macroalgae and providing space for coral growth.[101]

Life History: Some species reach lengths to at least 24 inches and weigh 6 pounds with a record of one unspecified nenue reaching over 12 pounds according to Hawai'i Fishing News. Poseidon Fisheries Research and NOAA Fisheries are currently studying their life history in Hawai'i.

Surgeonfish (will be managed separately by species):

Palani and Pualu (*Acanthurus dussumieri, Acanthurus blochii, Acanthurus xanthopterus*)

Current Status: UNSUSTAINABLE

Acanthurus blochii **SPR: 0.12 F/F_{30}: 2.3 (unsustainable)**
Acanthurus dussumieri **SPR: 0.36 F/F_{30}: 0.8 (sustainable)**
Acanthurus xanthopterus **(insufficient data)**

Current Regulations: None

Management Considerations: A minimum size limit could increase reproductive potential and sustainability for these species.

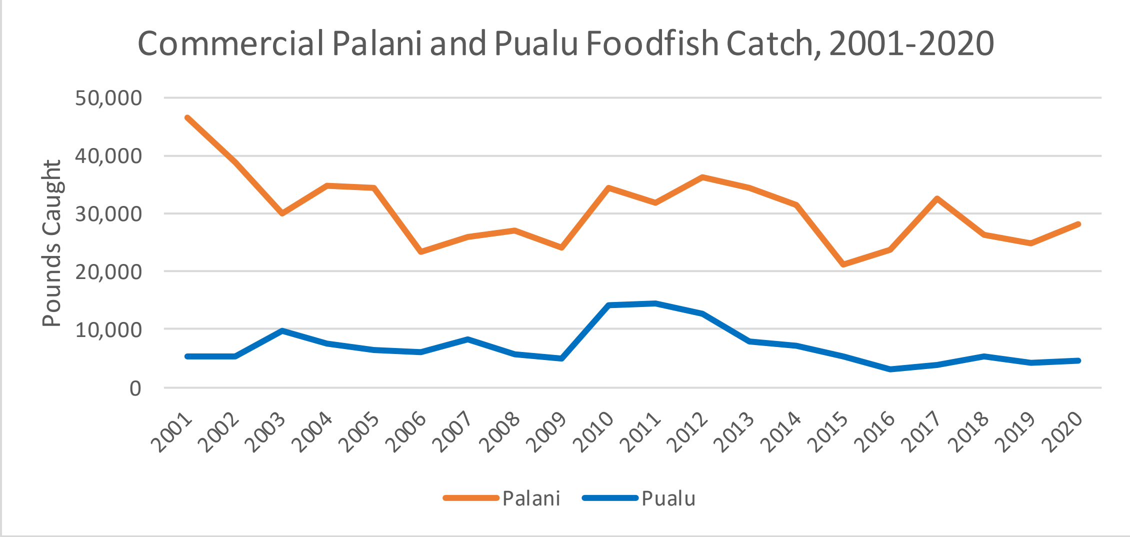
Minimum Size limit: 11.4 inches (OFL) 12 inches (40% probability of overfishing)

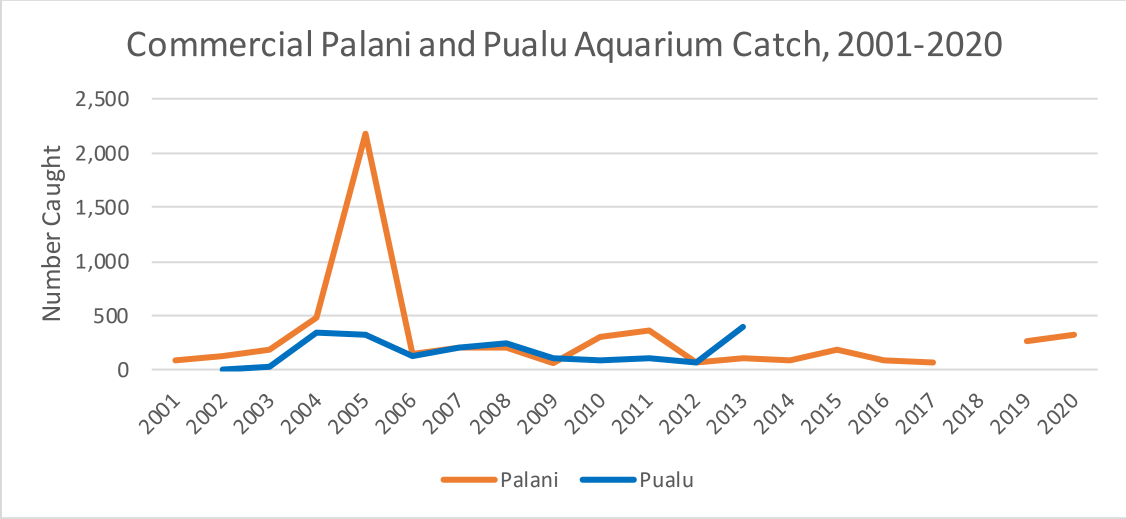
Catch limits: 84,437 lbs (OFL) 79,807 lbs (40% probability of overfishing)

Commercial Harvest: The commercial reporting groups "palani" and "pualu" includes three of the large-bodied surgeonfish Ringtail Surgeonfish (*Acanthurus blochii*), Eyestripe Surgeonfish (*Acanthurus dussumieri*), and Yellowfin Surgeonfish (*Acanthurus xanthopterus*) which represent the highest commercial landings of surgeonfish (40%) with 360,897 pounds of fish landed between 2011 and 2020. They are primarily caught with spear, seine net, and gillnet. Palani and pualu are collected by commercial aquarium collectors, though infrequently. Large tank requirement (recommended by one online retailer as over 300 gallons) to house these large-bodied surgeonfishes likely contributes to the low demand.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Palani	Spear (39.0%), Seine Net (31.3%), Fish Trap (11.0%)	35,010.0	$1.94	27,228.7	$1.89	-22.2%	-2.8%
Pualu	Spear (30.8%), Gill Net (25.4%), Fish Trap (17.6%)	6,182.2	$2.02	4,326.2	$1.84	-30.0%	-8.7%

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Palani	398	$2.28	148	$4.95	-62.8%	117.0%
Pualu	27	$3.59	71	$3.25	163.7%	-9.5%





Non-Commercial Harvest: Palani and pualu are the larger surgeonfish species and are considered fair eating fishes. There are not any non-commercial catch estimates for any of the large-bodied surgeonfish of due to limited samples in the HMRFS data set.

Historical Take and Cultural/Traditional Use: Palani was kapu to men, but available to women. In many of the cultural texts, palani and pualu are mentioned for the strong odor of the skin and flesh. Ku'u i'a pā ka lani (my fish whose odor reaches heaven). In the story of Ke'emalu, Ke'emalu called to her ancestor Palaninuimahao'o and was soon on his back on the way to shore. As they traveled to shore she needed to urinate and couldn't control herself and urinated on her ancestor. Palani-nui-mahao'o became angry and left her out at sea. This is how the palani got its strong odor. In the story of Punia, he kills multitudes of ghosts and rolls them up in a fish net, which tainted the nets, and is how the palani got its odor.[60]

In the ʻŌlelo Noʻeau palani and puwalu (pualu) are mentioned twice as an insult:

- #495 Hauna ke kai o ka palani
  The Palani makes a strong-smelling soup
  - A person of unsavory reputation imparts it to all he does
- #940 He puwalu, ke kū nei ka lahea.
  It is a puwalu fish, for a strong odor is noticed
  - A rude remark about a person with strong body odor. Sometimes the palani fish is mentioned instead of pualu.

Background/Ecology/Behavior: Pualu/The Ringtail Surgeonfish (*Acanthurus blochii*), palani/Eyestripe Surgeonfish (*Acanthurus dussumieri*), and pualu/Yellowfin Surgeonfish (*Acanthurus xanthopterus*) are somewhat difficult to distinguish from one another.[105] All three are commonly referred to as palani within the markets. They can be found in bays and outer reef areas. They feed on primarily on filamentous algae and often ingest sand to assist in the digestion of the algae they also feed on diatoms and detritus. Usually seen in small groups.[106]

Role for Reef Resilience: Palani and pualu serve as **grazers** feeding on filamentous algae over both reefs and sandy bottoms. They also serve as **detritivores** cleaning the bottom of sediments and other decaying plant and animal material.

Life History: Palani and pualu are large-bodied surgeonfishes reaching lengths between 17 inches for Ringtail Surgeonfish to 24.5 inches for Yellowfin Surgeonfish.[106] These are long-lived species with a longevity over 25 years: 26 years for pualu/Ringtail Surgeonfish, 30 years for palani and 29 years for pualu/Yellowfin Surgeonfish. Females mature around 3 years of age. Length at maturity (L_{50}) for these species are 8.9 inches for pualu/Ringtail Surgeonfish, 10 inches for palani and 12.2 inches for pualu/Yellowfin Surgeonfish. Spawning seasons is highly variable between species with spawning activity occurring throughout the year.[107]


Photo: Keoki Stender

Umaumalei (*Naso lituratus*)

Current Status: **UNSUSTAINABLE** **SPR: 0.25 F/F_{30}: 1.3**

Current Regulations: Oʻahu AQ Rules (HAR 13-77; applicable only when using fine mesh nets): Bag Limit of 50, West Hawaiʻi White List Species.

Umaumalei are on the West Hawaiʻi White List established in 2013 identifying fishes that could be legally taken for aquarium purposes. Aquarium take on Oʻahu was addressed by implementing a bag limit of 50. To comply with a current court order, aquarium fishes harvesting is no longer allowed statewide, while the industry prepares an Environmental Impact Statement (EIS). If the fishery is allowed to continue in the future, this EIS process will likely result in new regulations on future harvest.

Management Considerations: Given the recorded mean historical catch, a reasonable bag limit would ensure that typical recreational catch of umaumalei is not hindered. In addition, a bag limit will provide protection against excessive take in the future. Generally, a larger minimum size limit increases the reproductive potential, yielding many more fish in the nearshore fishery.[68]

Minimum Size limit: 8.5 inches (OFL); 9.3 inches (40% probability of overfishing)

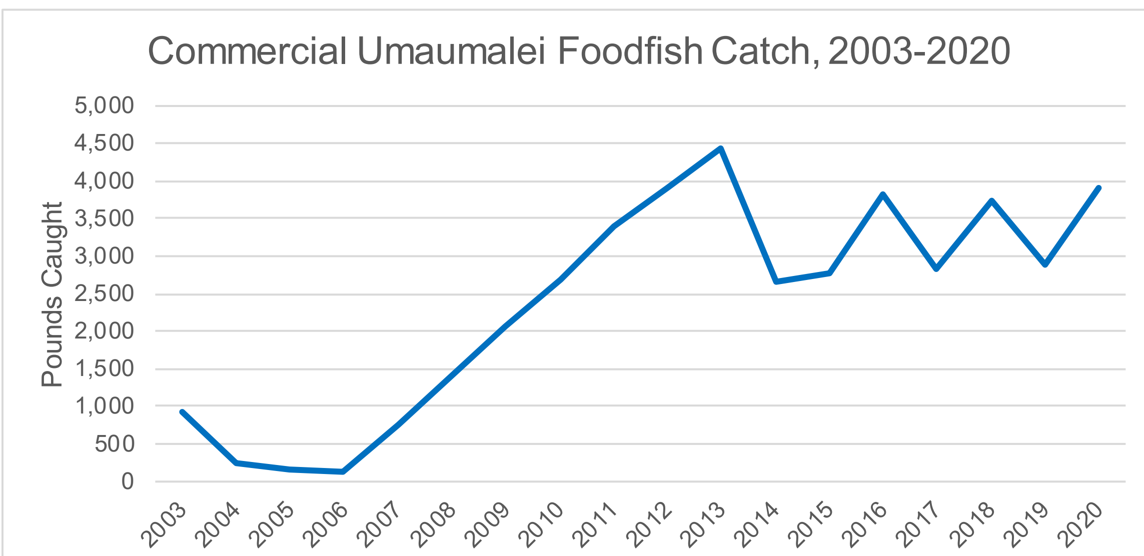
Catch limits: 9,678 lbs (OFL); 7,385 lbs (40% probability of overfishing)

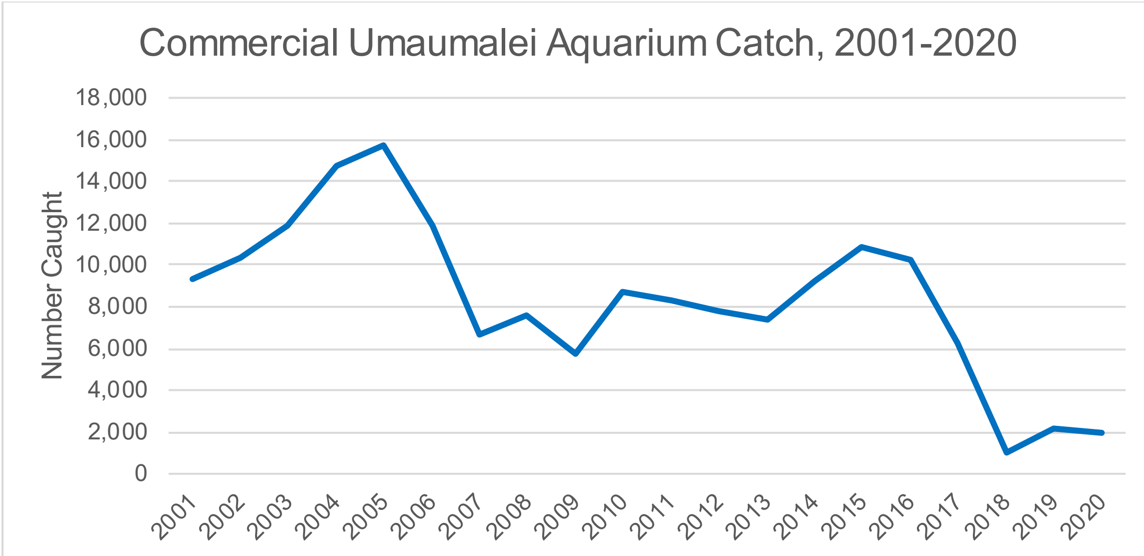
Commercial Harvest: Commercial foodfishes harvest of umaumalei is relatively low with 34,378 pounds caught from 2011 to 2020. They are primarily harvested using spear, though also caught with surround nets or fish traps. Umaumalei generally has a limited presence in local fish markets due both to being considered only of fair eating quality, and limited direct targeting by commercial fishers. However, their bright and bold markings across their bodies make them highly desirable for the aquarium trade. Umaumalei are the fourth most caught finfish of the commercial aquarium fishery and considered a targeted species. Between 2011 and 2020, 65,168 umaumalei were collected by commercial collectors.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Umaumalei	Spear (93.7%), Surround Net (3.7%), Fish Trap (1.2%)	Unavailable[1]	Unavailable[1]	3,435.1	$2.25	NA	NA

[1]*Foodfish reporting code for umaumalei not offered until October 2002.*

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Umaumalei	12,774	$6.20	4,317	$6.01	-66.2%	-3.1%





Non-commercial Harvest: Compared to other fishes, umaumalei are considered only fair eating quality, but they are regularly harvested by some fishers despite not being a typically a sought-after food. The species is regularly targeted, but only by a portion of non-commercial fishers. The median historical, recreational catch is two fish per person (HMRFS). Non-commercially they are selectively taken typically by spear or throw net.

Historical Take and Cultural/Traditional Use: Umaumalei was referenced as the chief of fish in a fisherman's prayer.[60] In the Kumulipo, the umaumalei is guarded and connected to the ulei that grows in the forest.[97]

Background/Ecology/Behavior: Umaumalei are a type of unicornfish within the surgeonfish family that lacks the characteristic "horn" that most other unicornfish possess. Their brightly accented yellow and blue coloration causes them to stand out on the reef. They are one of the larger surgeonfishes found in Hawaiʻi. They are typically seen in small aggregations mixed with other surgeonfishes of similar size or solitarily swimming around nearshore reefs.

Role for Reef Resilience: As **browsers**, they frequent shallow parts of the reef and selectively feed on larger seaweeds (macroalgae).[99] Browsers remove the larger leafy seaweeds making room for grazers and scrapers to remove the underlying turf algae.[9,23]

Life History: Umaumalei can grow to a maximum of almost 18 inches[80] and live more than 25 years,[80,108] but reach maturity around 8.4 inches in fork length.[80] Little is known about their L_{50} specific to Hawaiʻi, but in American Samoa, their L_{50} is 6.9 inches fork length[109] and in Guam, 5.9 inches for females and 7.1 inches for males.[110]

Kala (*Naso unicornis*)

Current Status: **UNSUSTAINABLE** **SPR 0.03 F/F_{30}: 6.0**

Current Regulations:
State (HAR 13-95) Minimum size 14 inches, Bag limit 4
Commercial fishers may take and sell more than 4 kala per day with a permit.[b]

Management Considerations: To address the already low predicted SPR[80] and low productivity,[110] a bag limit in addition to the size limit may support replenishment of the stock.

Minimum Size limit: 18 inches (OFL) 18.5 inches (40% probability of overfishing)

Catch limits: 73,193 lbs (OFL) 69,005 lbs (40% probability of overfishing)

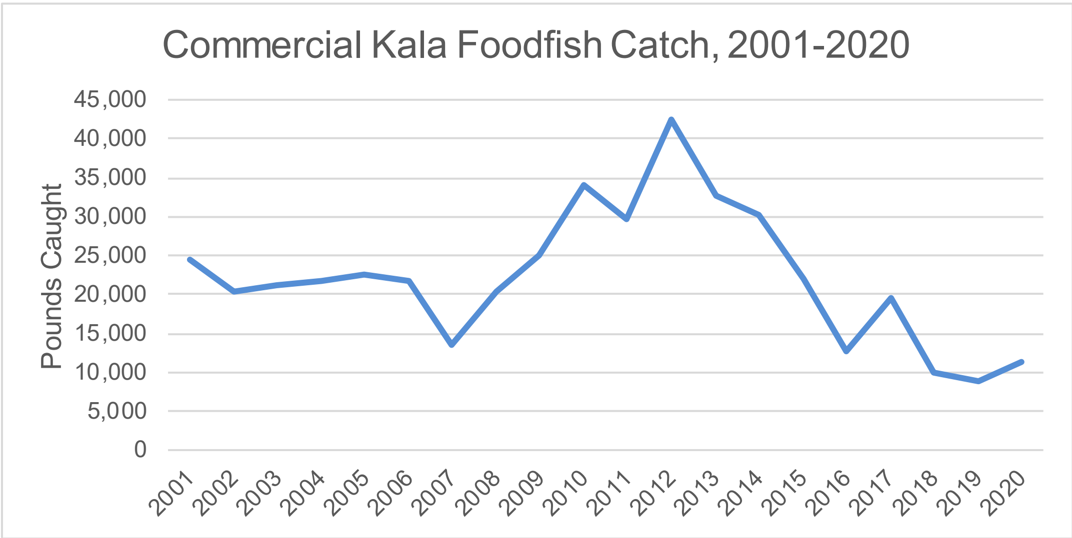
Commercial Harvest: The commercial "kala" reporting group includes Bluespine Unicornfish (*N. unicornis*) as well as the lesser-caught Shortnose Unicornfish (*Naso brevirostris*) and Whitemargin Unicornfish (*Naso annulatus*) has the third highest commercial landings of herbivorous fishes with 219,403 pounds of fish landed between 2011 and 2020. Other species in this genus, besides kala, feed mainly on zooplankton and are not primarily herbivores. Kala can be caught via multiple methods but are mostly caught with gillnet or spear. Kala is caught occasionally by commercial aquarium collectors, but collection is infrequent and like nenue, likely driven by sporadic requests by specific aquarists and suppliers. Commercial aquarium collection in recent years (2011-2020) is typically less that ten fish per year.

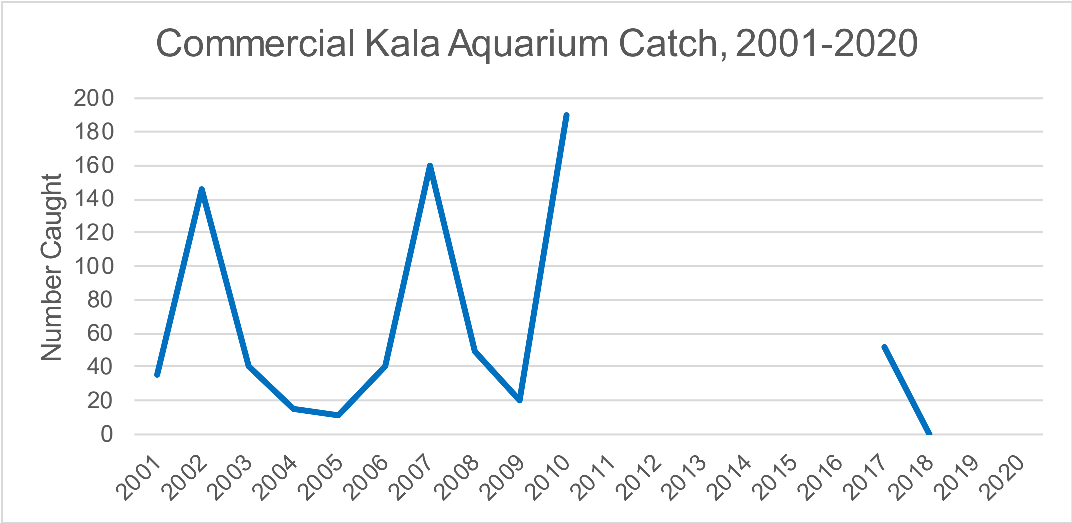
Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Kala	140	$5.88	12	$8.55	-91.2%	45.4%

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Kala	Gillnet (39.5%), Spear (35.7%), Surround Net (15.2%)	15,566.4	$1.73	12,501.0	$2.17	-19.7	25.4%

[b] Bag limit and additional commercial fishing requirements were implemented in February 2024.

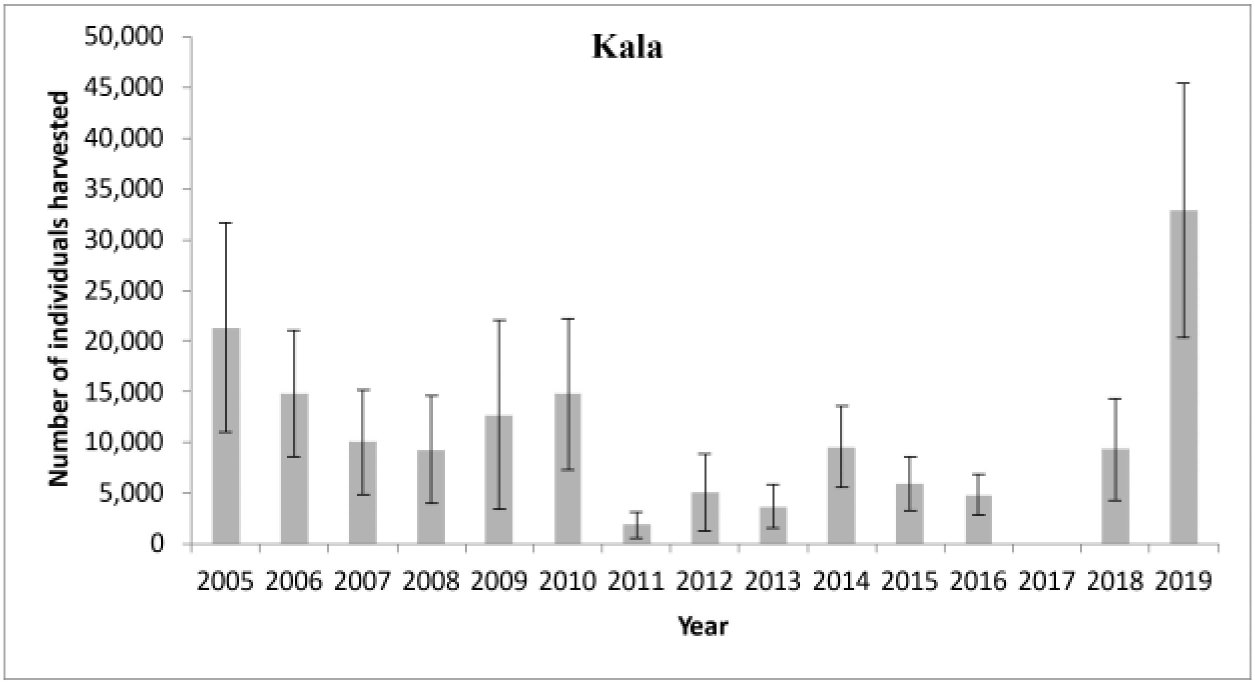
Non-commercial Harvest: Kala, as one of the larger surgeonfish species, are considered a good eating fish and a desired target for spearfishers. According to HMRFS data, spearfishing is the most common method of take, followed by rod and reel, but kala is also taken with various forms of net fishing. As one of the larger reef species, fishers don't often take many, reflected in a median historical take of only one fish per person. However, this is highly dependent upon gear type, as throw nets or gill nets typically take





Commercial aquarium catch data for kala is confidential for the years not plotted and does not mean recorded catch was zero.

more than the median. Resource users have witnessed massive amounts of kala being taken by throw nets cast over entire schools. Despite high variability between years in the amount of kala taken, it ranks highly as one of the most harvested herbivorous fish species in the recreational survey compared to other fish of comparable size.



Historical Take and Cultural/Traditional Use: Historically, kala has always been a popular fish because it was easier to find and catch. This is demonstrated in many cultural aspects through name, practice, and use. Kala is mentioned in the Kumulipo,[97] in the story of Punia[89] and in the story of Lonoikamakahiki.[60] There are also ʻōlelo no’eau referencing kala. The mele “Aloha Ka Manini” written by Israel Kamakawiwo’ole also references kala. Kala skin was used for pūniu drums, typically used for hula. They were usually broiled for consumptive purposes and occasionally eaten raw, dried, or used for baking. The softer parts of the fish are good as bait.[60]

In Kāneʿohe, they refer to kala as the larger fish of that species, pakalakala (pakala, pakalaka) is the younger individuals, and kala oheno represents the sizes in-between. The odor of the fish is known to vary depending on the area it inhabits and an associated cultural protocol like palani and pualu was used to get rid of the odors.[60]

Specialized fishing methods were developed to catch kala. Kahaʻulelio describes kala ku, a type of fishing done in both deep and shallow seas during low tide. Kala was often seen eating limu kala, and when spotted, were quickly surrounded by net with meshes the width for 2-3 fingers. The net was laid by canoes or by swimming.[89] Hinaʿi pai kala fishing used a lifted, plaited basket at as a net. It included kala being fed limu kala, kalo, and ipu pu through a basket with food that was lowered into the water until the fish became fat and accustomed to receiving food. Once tamed, a net was then lowered to catch the kala. The largest baskets were known as the ʿie kala and used limu kala as bait.

Background/Ecology/Behavior: Kala, derives its common name from the distinctive blue line across its back, the unicorn-like horn on its face, and the brightly-colored blue spines near its tail. These spines near the tail are a signature feature for surgeonfishes and how they get their names, as they are said to be as sharp as a surgeon’s scalpel, though they are different in color and number for different species. kala are typically found in shallow nearshore reef habitats and near rocky shores in schools, but larger adults may be spotted alone.[88]

Role for Reef Resilience: Like umaumalei, kala are **browsers** and selectively graze on leafy macroalgae such as limu kala and other large frondose algae.[88,111]

Life History: Kala are long-lived fish and can reach up to 50 years in age or older.[111–113] If undisturbed, kala have the potential to grow to 27 inches long and weigh up to 12 lbs.[88] Compared to other regions, Hawaiʻi's kala mature later and grow larger.[111] They reach maturity at 13.97 inches fork length[80] but it takes them conservatively about 8 years to reach reproductive maturity.[112] Males will mature around 4.5 years in age and females will mature around 7.5 years.[113] They have a spawning period during the spring and summer months from May to June.[113]


Photo: Keoki Stender

Manini (*Acanthurus triostegus,* subspecies *sandvicensis*)

Current Status: **INSUFFICIENT DATA**

Manini are frequently fished in Hawaiʻi for food consumption. Despite fishing pressure, they continue to be the most abundant surgeonfish on nearshore shallow reefs.[88]

Current Regulations:
State (HAR 13-95) Minimum Size 6 inches[c]

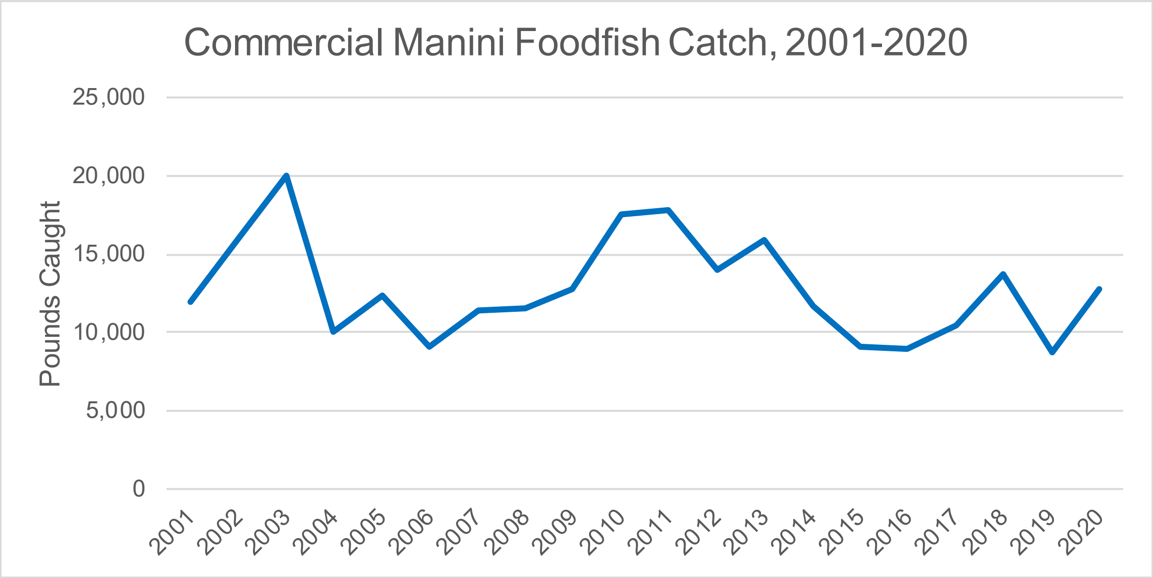
Management Considerations: Manini has a high productivity, low susceptibility, and low vulnerability.[110] A bag limit would accommodate various gear types that target the species and the associated needs for take - whether it be home consumption or large events/gatherings. Implementing a bag limit would also limit excessive take into the future. Though manini is still considered an abundant fish stock, it is unknown if the species is abundant enough to ensure both a sustainable fishery and robust ecological function. Adapting existing regulations on manini would ensure they remain sustainable for generations to come and continue to be the prized lawnmowers of our reefs.

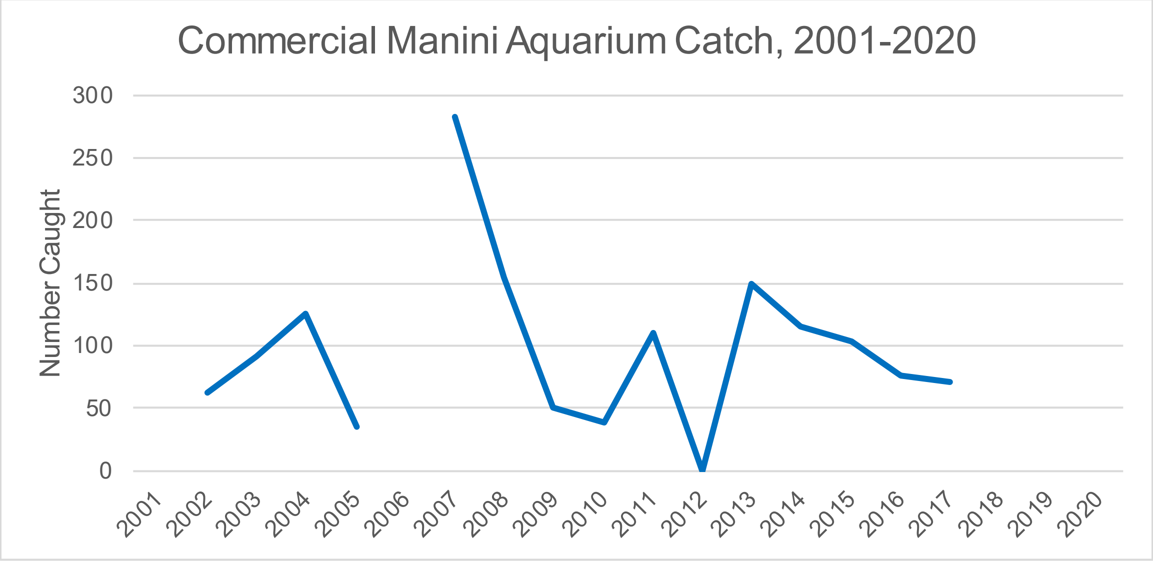
Commercial Harvest: Manini is one of the most recognizable and popular food fish in Hawaiʻi with 123,118 pounds commercially caught between 2011 and 2020. Although commercial catch by weight ranks behind other herbivorous fishes such as kala, many more individual fish are caught based on the smaller size of manini when compared to larger surgeonfishes. They are mostly caught using spear but surround nets and throw nets are also used. manini are occasionally caught by commercial aquarium collectors though not considered a commonly targeted species. Commercial aquarium catch in recent years (2011-2020) is typically low at approximately 100 fish or less collected per year.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Manini	Spear (51.7%), Surround Net (22.1%), Thrownet (10.3%)	14,688.8	$3.80	10,935.4	$3.37	-25.6%	-11.3%

[c] Amended to 6 inches in February 2024

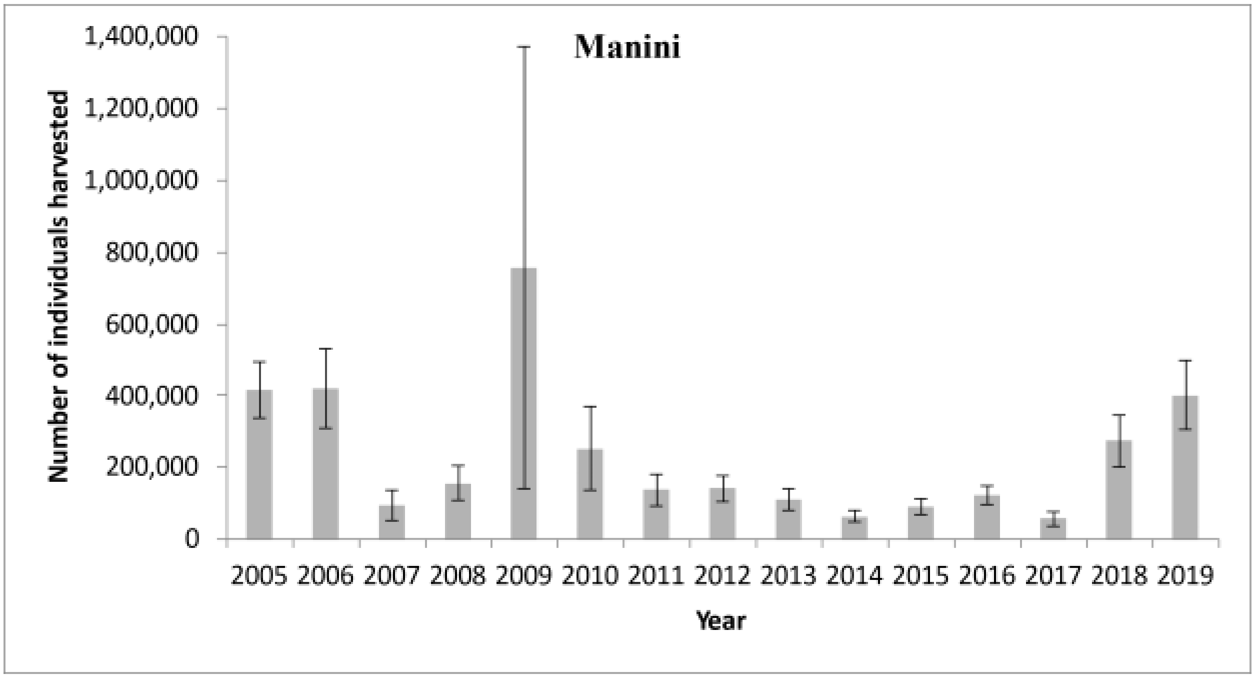
Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Manini	262	$3.32	72	$6.88	-72.4%	113.2%





Commercial aquarium catch data for manini is confidential for the years not plotted and does not mean recorded catch was zero.

Non-commercial Harvest: Manini are a very common food fish and are often targeted by non-commercial fishers who enjoy them fried or grilled. They are a common target for skilled throw net fishermen who target large schools resulting in sizable catches from a single throw. They are also a common target for spearfishers due to their abundance, size and ease in capture; Manini are often the first fish that beginner spearfishers will catch. Most fishers are partial to the smaller ones, that cook more seamlessly than the larger sizes. According to HMRFS, the median take is 16 fish per person but is dependent on gear type. They are the most common herbivorous fish caught in surveys, but yearly catch is variable, as shown below.



Historical Take and Cultural/Traditional Use: As a popular fish, manini was prepared raw, dried, and broiled and well-liked by chiefs and commoners alike. When eaten raw, manini were usually salted. There were stories of the ʿōhua, young individuals, being mixed with salt and scattered to dry on the lava rocks.[60] Their stages of growth are ʿōhua liko, ʿōhua kaniʿo, ʿōhua pala pohaku, kakala manini (half grown), and manini (adult stage).[60]

Their frequent consumption led to their presence in historical fishponds. Moʿolelo speak of the prayers of Kahuna causing some of the fishes, such as manini, that were not accustomed to living in Loko Kuapa, a type of Hawaiian fishpond, to come in.[114] In addition to being raised in fishponds, they were caught with upena holahola, a net used with poison, where a fish hole is surrounded and ʿauhuhu is diffused into the water. The fish then float into the net.[89]

Manini was referenced in fishers prayers as being “stripe skinned.”[60] There are also ʻōlelo noʿeau that reference manini. Mele “Aloha Ka Manini” written by Israel Kamakawiwo’ole speaks of the manini.

They are frequently caught by spear and net, depending on the need for take. A spearfisher catching for his family or to be shared with close friends may only catch a relatively small amount, but manini are also known to be served at large gatherings or for special occasions.

Background/Ecology/Behavior: Manini are one of the most common fish found in Hawai'i's reefs. Endemic to Hawai'i, their Hawaiian name means small or stingy, referring to a mo'olelo referring to the small size of the manini as being inadequate for hosting a meal. Their black vertical bars down their bodies are similar to the jail bars or black and white striped clothing you may associate with their common name, the Convict Tang. They are found schooling in most reef areas from shore to depths of about 90 ft.[88]

Role for Reef Resilience: As **grazers**, they intensely feed on low lying turf seaweeds and keep them cropped down, similar to mowing the lawn. This prevents turf algae from overgrowing space where Crustose Coralline Algae could settle and facilitate coral growth.[23]

Life History: Manini can reach lengths up to 12 inches and can weigh close to two pounds.[88] They form large spawning aggregations once they reach their length at maturity of 5- 6.1 inches.[98]

Na'ena'e (*Acanthurus olivaceus*)

Current Status: INSUFFICIENT DATA

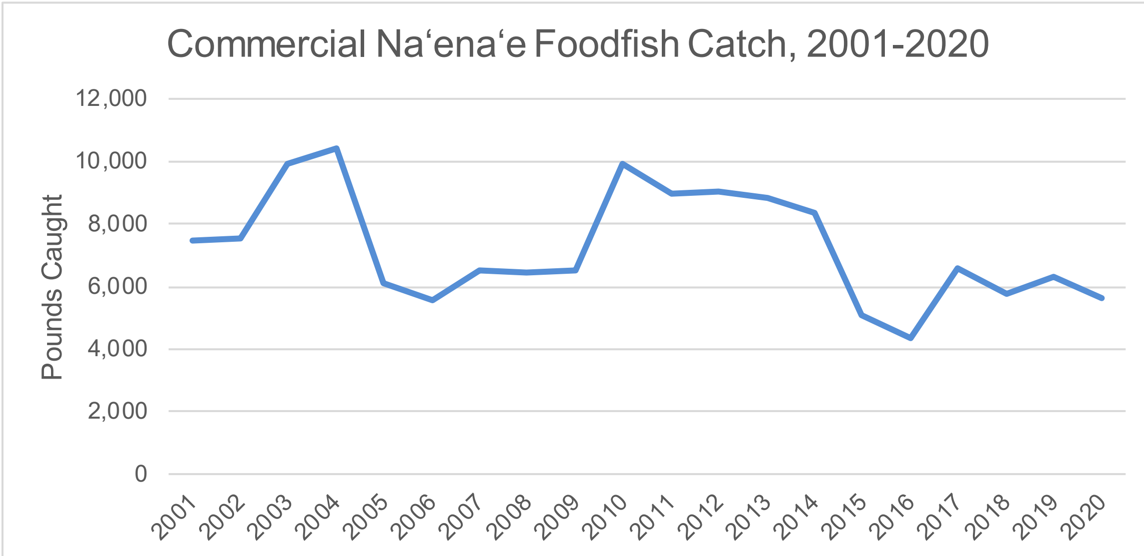
Current Regulations: None

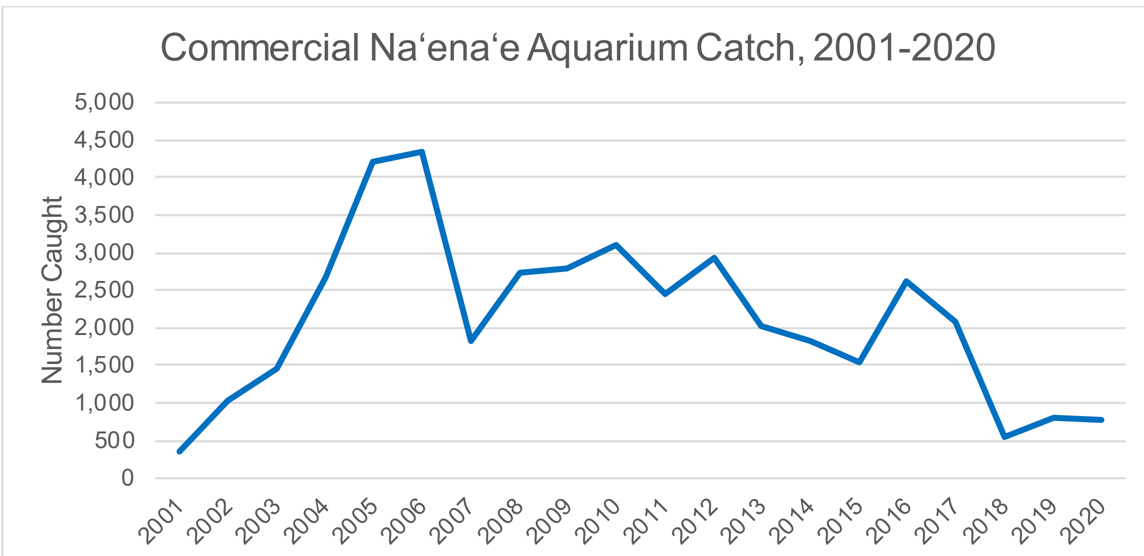
Management Considerations: A minimum size limit could increase reproductive potential and sustainability for this species. L_{50} for the species is 6.6 inches,[107] so a minimum size larger than this would ensure that many individuals would have a chance to reproduce.

Commercial Harvest: A total of 68,925 pounds of na'ena'e were caught by commercial foodfishes fishers between 2011 and 2020. Na'ena'e, like palani, pualu, and nenue, are preferred by some individuals, while others tend to avoid them in favor of more mild-flavored species. They can often be found in fish markets alongside other large-bodied surgeonfishes such as pualu and palani that are targeted concurrently. Primary gears used to catch na'ena'e for the foodfish market are fish traps, spears, and seine nets. Na'ena'e are collected by commercial aquarium collectors, though in relatively low number compared to more targeted species such as Yellow Tangs and kole. Large tank requirement due to their large adult size and less vibrant coloring (in comparison to other collected species) when mature may contribute to the comparatively low demand.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Na'ena'e	Fish Trap (35.4%), Spear (33.6%), Seine Net (20.4%)	6,580.6	$1.46	5,733.8	$1.60	-12.9%	9.6%

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Na'ena'e	1,216	$3.36	1,371	$4.04	12.7%	20.3%





Non-Commercial Harvest: Na‘ena‘e are targeted by non-commercial fishers as a food fish, similar to other surgeonfishes of similar size like kole or manini. They are caught mostly with spears and sometimes throw net. There are limited samples in the HMRFS data set.

Historical Take and Cultural/Traditional Use: Not much is known about how na‘ena‘e were used historically and culturally, but resource users acknowledge they are good to eat, always cooked, and excellent broiled.[60] In Hawaiian culture, many ocean species have a terrestrial counterpart. Though not specifically listed in the Kumulipo,[97] the na‘ena‘e fish has a terrestrial counterpart with the same name, a shrub in the daisy family with a fragrant bloom.[115]

Background/Ecology/Behavior: The horizontal orange band make this species easy to identify. Na‘ena‘e live on the outer reef where the waves are active and the water is deeper.[105] Adults occur singly or in schools.

Role for Reef Resilience: Na'ena'e serve as **detritivores** feeding on surface film of detritus diatoms, and filamentous algae covering sand and bare rock.[116]
Life History: Na'ena'e can reach lengths up to 14 inches.[106] In Hawai'i they have been found to reach 14 years of age. However, in Australia max age is recorded at 33 years. Size at maturity is 7 inches for females and 6 inches for males. They reach maturity quickly around 1 year. Spawning occurs year-round.


Photo: Keoki Stender

Paku'iku'i (*Acanthurus achilles*)

Current Status: INSUFFICIENT DATA

In shallow water habitats, observations of the species in West Hawai'i have declined by 90% since 2008.[57] Commercial catch data suggests that the population may be declining statewide. Monitoring across the state has not seen the same declines due to this species' patchy distribution and abundance, but targeted catch size for these fish is generally small with large individuals rarely seen.

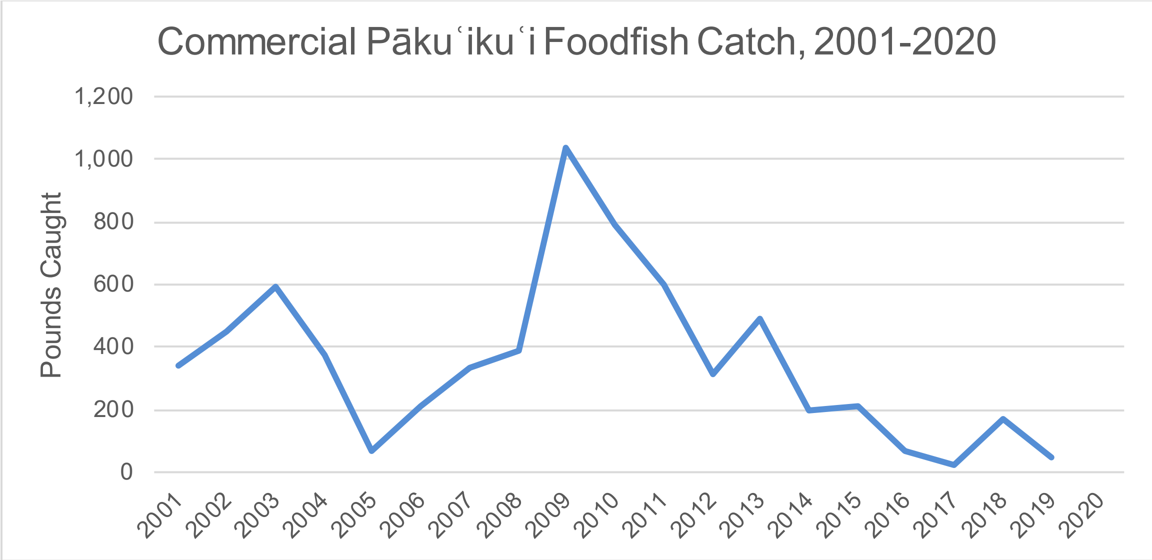
Current Regulations: Aquarium Rules (HAR 13-77; applicable only when using fine mesh): Bag Limit of 10, West Hawai'i White List[d]

Management Considerations: A conservative bag limit and size minimum would limit take to help pāku'iku'i stocks recover so they can be further harvested, studied and better managed in the future.

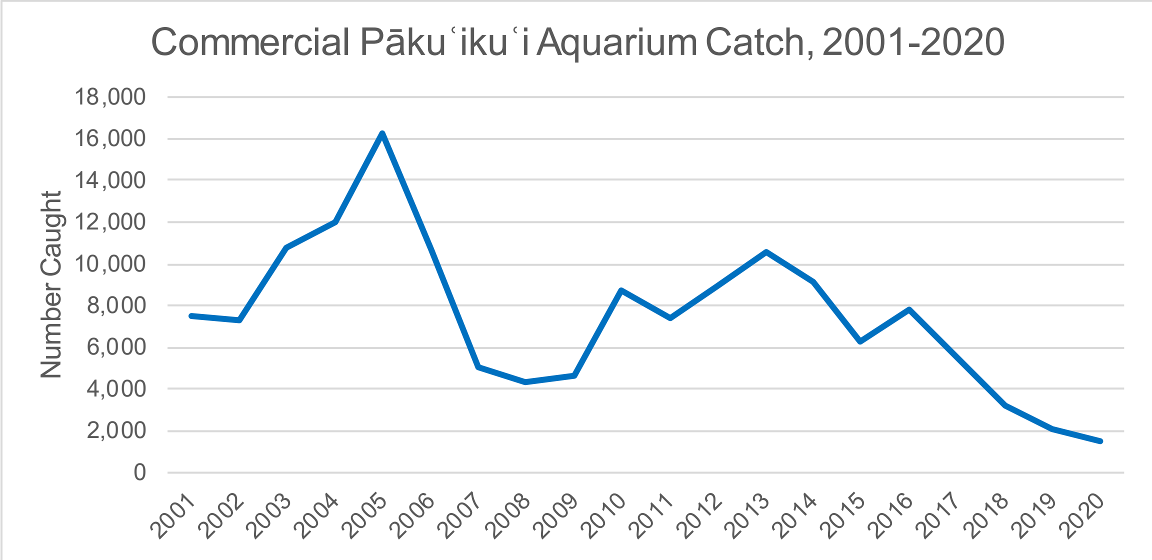
Commercial Harvest: Pāku'iku'i are highly valued by commercial aquarium collectors, with 62,535 fish collected between 2011 and 2020. Though demand for the species remains high, recent catch has decreased dramatically compared to 1996-2000 landings. Price per piece has conversely increased dramatically. Though there are many factors influencing the catch, demand, and pricing within the commercial aquarium fishery, the occurrence of decreasing catch with greatly increasing price may suggest increased scarcity and an inability to meet demand. While this species is highly targeted for the aquarium trade, it is rarely targeted as a food fish by commercial fishers with only 2,195 pounds landed from 2011 to 2020. When caught, it is almost always with a spear.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Pāku'iku'i	Spear (97.5%), Gillnet (0.6%), Inshore Handline (0.6%)	517.0	$2.66	77.3	$1.91	-85.0%	-28.2%

[d] As of December 2022, harvest of pāku'iku'i within the West Hawai'i Regional Fishery Management Area is temporarily banned (two years, with possibility to extend) through the State's adaptive management rulemaking authority.



Commercial foodfish catch data for pākuʿikuʿi in 2020 is confidential and does not mean recorded catch was zero.



Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Pākuʻikuʻi	14,446	$7.31	4,035	$45.12	-72.1%	517.0%

Commercial aquarium catch data for pākuʿikuʿi in 2020 is confidential and does not mean recorded catch was zero.

Non-commercial Harvest: Pākuʻikuʻi are targeted by non-commercial fishers as a food fish, similar to other surgeonfishes of similar size like kole or manini. As an uncommon fish, they are not often reported within the HMRFS data set but when present, they are caught mostly with spears and sometimes throw net. The median take of these few occurrences is four fish per person.

Historical take and Cultural/Traditional Use: Not much is known about how pāku'iku'i were used historically and culturally, but resource users acknowledge they are good to eat, always cooked, and excellent broiled.[60] In the Kumulipo, the pāku'iku'i were guarded and connected to the kukui in the forests.[97]

Background/Ecology/Behavior: Pākuʻikuʻi, also known as the Achilles Tang, is named after the greek legend of Achilles due to the distinctive orange coloration on the fish's "heel" along the side of their bodies. Pākuʻikuʻi refers to the splashing or beating of water and a common method of fishing where fish were chased into a net by beating the surface of the water.[99] The species is found in small aggregations within surge zones and shallow rocky shoreline habitats.[117] They are aggressive and territorial fish and have been observed driving other fish out of their territory while feeding.[99,118]

Role for Reef Resilience: Like manini, they are **grazers** and the lawnmowers of the reef, cropping down turf algae but not removing it completely.[119]

Life History: Catch is so limited that life history studies have not been possible. Pākuʻikuʻi are thought to be long-lived fish reaching 27 years old,[120] but very little is known about their life history. Monogamous mating is observed.[121] Most available information is based on information known about similar species within the family - length at maturity is estimated to be 7.7 inches based on the maximum size from FishBase.org[117] and an estimation relationship modeled after similar species.[122]

Kole (*Ctenochaetus strigosus*)

Current Status: **INSUFFICIENT DATA**

Kole is one of the most abundant reef fishes in Hawaiʻi. Despite fishing pressure, West Hawaiʻi shows an increasing trend of kole.[57] This species is generally considered abundant, though there is no stock assessment available.

Current Regulations: Minimum Size Limit of 5 inches[e]. Oʻahu Aquarium Rules (HAR 13-77; applicable only when using fine mesh): Bag Limit of 75, and 6 maximum of individuals over 5 inches, West Hawaiʻi White List

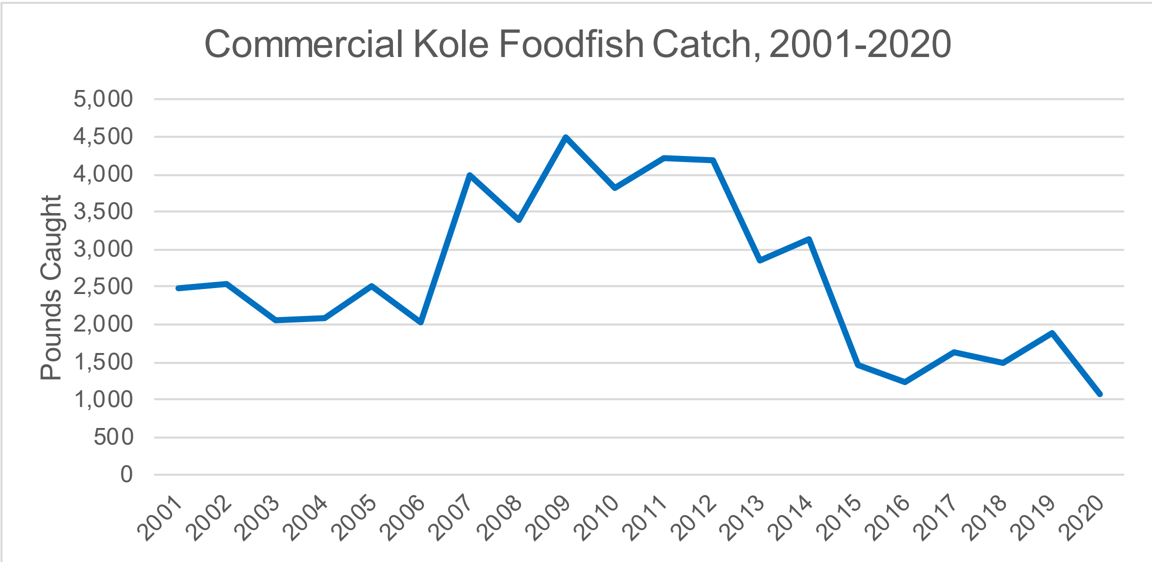
Management Considerations: The distinct size differences in the length of maturities (3.3 inches for females and 3.9 inches for males)[123] present an ideal opportunity to effectively manage the reproductive output of the species with an appropriately set minimum size limit. A bag limit would limit excessive take but still allow for a family to feed itself and for enough to be caught for large gatherings with minor adjustments and planning ahead.

Commercial Harvest: Despite being widely considered one of the best-eating nearshore species, kole are not as commonly caught by commercial fishers compared to other herbivores with only 23,156 pounds landed from 2011 to 2020. However, like manini, due to their small size, this catch weight represents many more individuals than the comparative catch weight of larger surgeonfishes, such as palani. Kole are almost always caught with a spear. They are the second most harvested finfish species

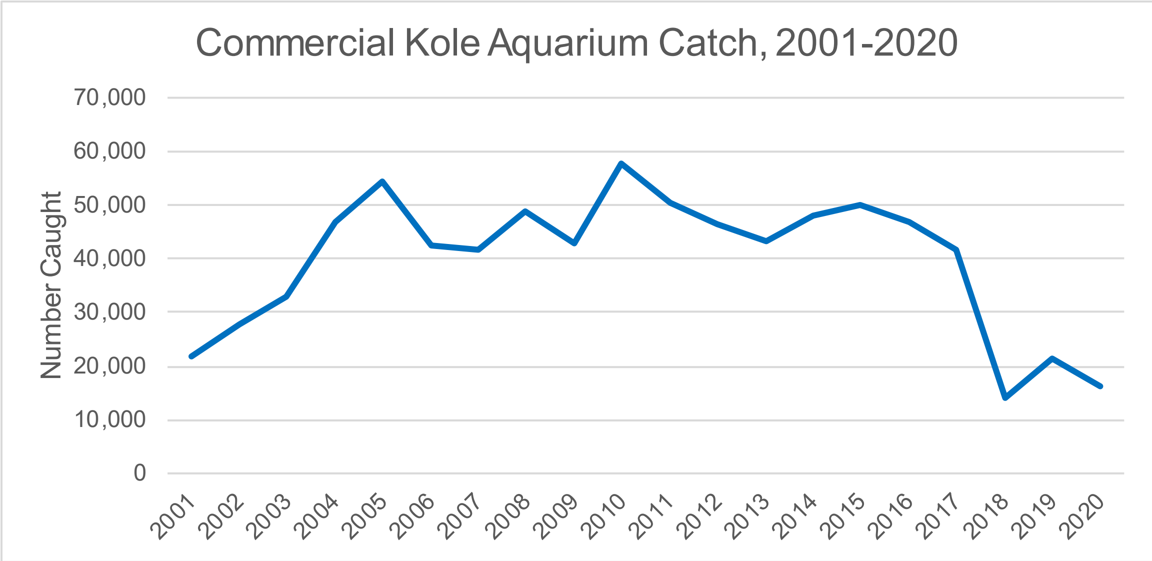
[e] Minimum size limit was established in February 2024.

in Hawai‘i’s commercial aquarium fishery with 378,436 fish collected between 2011 and 2020.

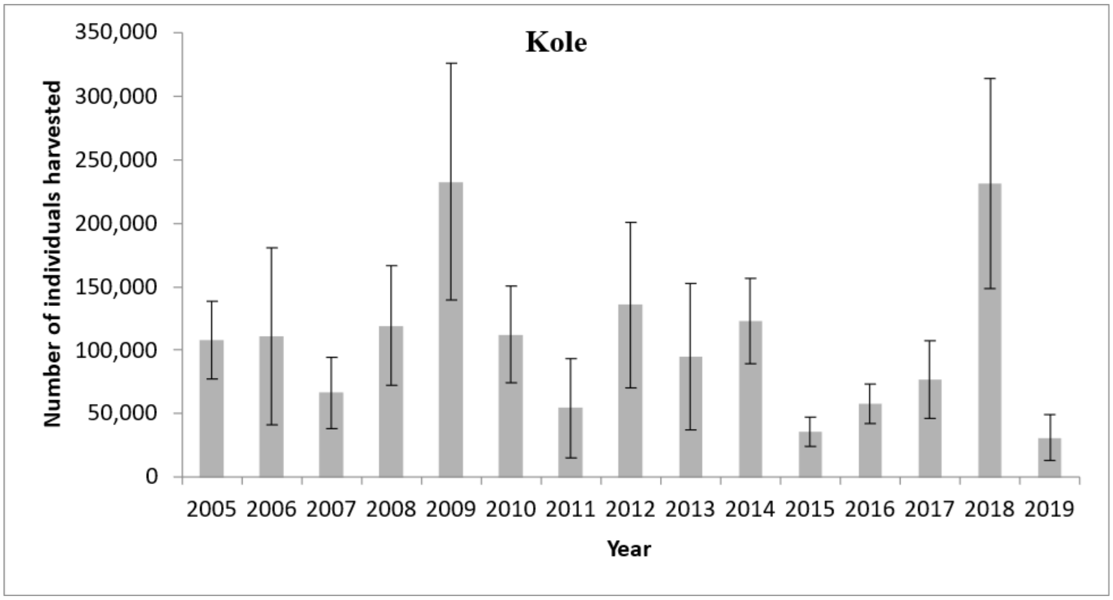
Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Kole	Spear (97.3%), Misc. Net (1.1%), Gillnet (0.9%)	3,144.4	$3.31	1,465.9	$4.02	-53.4%	21.5%



Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Kole	26,596	$2.74	28,060	$4.31	5.5%	57.0%



Non-commercial Harvest: Kole are very commonly targeted by non-commercial fishers and represent the second most harvested herbivorous fish behind manini, despite ciguatera concerns. They are most commonly harvested via spear and are an easy target for even novice spearfishers due to their territorial behavior which keeps them within close boundaries and makes them easy targets compared to other fish species. The median catch recorded in HMRFS is 10 fish per person, but as they are sometimes served fried at large events and luaus, there are multiple occurrences of over 200 hundred fish harvested per trip. Kole harvest per year is highly variable as shown below.



Historical take and Cultural/Traditional Use: Kole was mentioned in a fisher's prayer as the "bright eye" kole that dwells in holes."[60] Kole maka onaona was a poetic name for kole, known to never be cooked, but eaten raw and usually seen schooling with pākuʻikuʻi. In a house building tradition, a kole was put in the ground where house posts facing the east were planned to be put in. If a Kahuna were to enter and predict trouble for the householders, he would die."[60] Kole is commonly caught for subsistence and known to be served at large events and gatherings as a favorite local food.

Background/Ecology/Behavior: Kole are endemic to Hawai'i, and an abundant surgeonfish on Hawai'i's reefs distinguished by its bright yellow eye, associated with its common name as the Goldring Surgeonfish. They occupy nearshore reef habitats from the shoreline up to depths of 150 ft and are usually solitary or among other surgeonfishes of similar size.[88] Kole can be very territorial and tend to stay close to their home boundaries. Their ability to occupy a wide variety of reef habitats in shallow nearshore waters bolsters their prevalence.[88,124]

Role for Reef Resilience: Kole are **detritivores**. They feed around the seaweed and turf algae picking off and cleaning the bottom of sediments and other decaying plant and animal material.[119] Their role is to prevent sediment and detritus from covering coral as well as create space for crustose coralline algae to grow and promote coral recruitment.

Life History: Kole generally grow to about 10 inches and weigh up to one pound.[88] They can live up to 18 years.[123] The females and males have distinct size differences with females reaching maturity at 3.3

inches fork length around 9 months old and males at 3.9 inches fork length around 15 months old.[123] Kole usually spawn in aggregations, however, pair spawning also occasionally occurs.[125] Their spawning season extends over two monthly ranges from March to June and February to May.[123,124]

Black Kole (King Kole) (*Ctenochaetus hawaiiensis*)

Current Status: **INSUFFICIENT DATA**

The species is most abundant in West Hawai'i and has a patchy and uncommon distribution across the rest of the main Hawaiian Islands.

Current Regulations: None

Management Considerations: The limited life history data, low frequency of catch, and uncommon presence across the state suggests a place-based approach to the management of this species may be the best option.

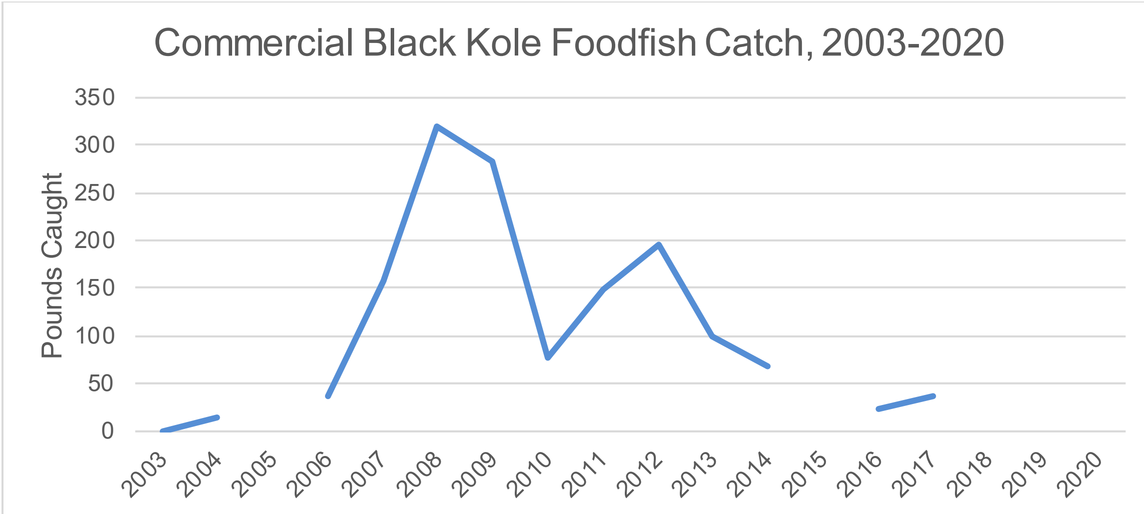
Commercial Harvest: Black Kole are very rarely caught by commercial foodfishers (typically <100 pounds per year). Though commercial aquarium catch is relatively low, they are considered a prized aquarium species due to their vibrant orange color as juveniles, and intricate markings as adults. Between 2011 and 2020, 33,758 Black Kole were collected by the commercial aquarium collectors.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Black Kole	Spear (99.8%), Confidential[1], Confidential[1]	Unavailable[2]	Unavailable[2]	23.2	$3.67	NA	NA

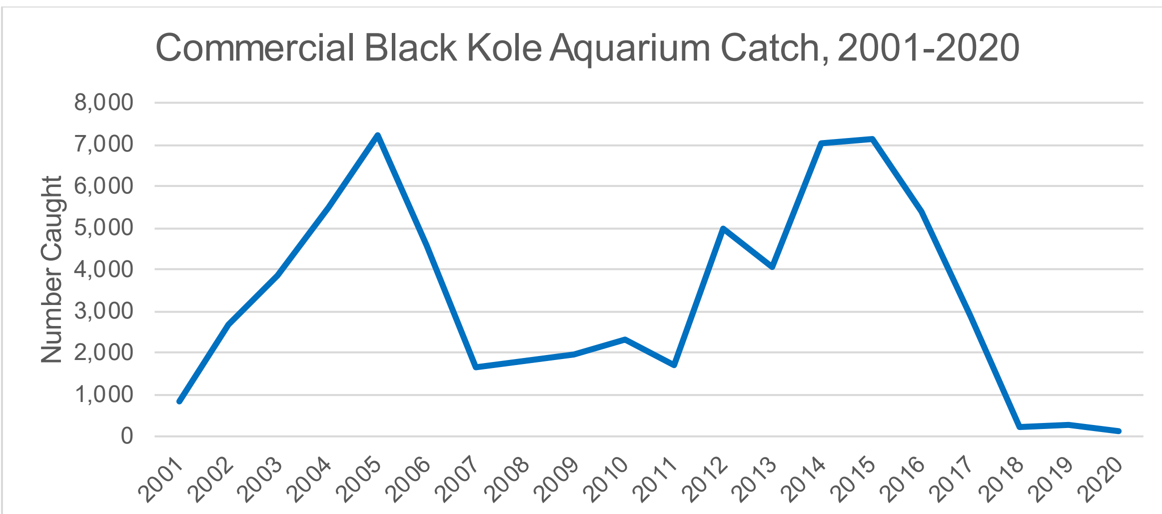
[1]*Data withheld to preserve fisher confidentiality.*
[2]*Foodfish reporting code for Black Kole not offered until October 2002.*

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Black Kole	1,862	$16.00	1,784	$21.42	-4.2%	33.9%

Non-commercial Harvest: Black Kole are a target in areas that they are abundant, similar to other small surgeonfishes like kole or manini. In the HMRFS data, they are almost always harvested by spear and occasionally by throw net but are not as commonly caught as other surgeonfishes with significantly fewer catch reports in the survey. When caught, the median catch was four fish per person. They are usually caught on the larger side, near their maximum size.



Commercial foodfish catch data for Black Kole is confidential for the years not plotted and does not mean recorded catch was zero.



Historical take and Cultural/Traditional Use: For cultural and traditional use information for this species, please see the section above on kole (*Ctenochaetus strigosus*).

Background/Ecology/Behavior: The less popular Black Kole is less frequently seen in nearshore reef habitats and rocky shorelines as their relative, the kole, but they do share many similar characteristics and habitat preferences. They are less common across Hawai'i's reefs and are slightly bigger than kole.

Role for Reef Resilience: Black Kole are **detritivores** and feed on sediments and other decaying plant and animal material.

Life History: Black Kole reach a maximum size of 9.8 inches.[117] Length at maturity is estimated to be 7.8 inches in fork length based on a model that estimates this parameter from the life history of other surgeonfishes.[122] Currently, there is a lack of studies done regarding their life history and reproduction.

Uhu *(Parrotfishes, will be managed by group as large-bodied and small-bodied)*

Large-bodied Parrotfishes (*Scarus rubroviolaceus, Chlorurus perspicillatus*)

Current Status: UNSUSTAINABLE

Red-lipped Parrotfish (*Scarus rubroviolaceus*) **SPR: 0.26 F/F_{30}: 1.2 (unsustainable)**

Spectacled Parrotfish (*Chlorurus perspicillatus*) **SPR 0.54 F/F_{30} 0.5 (sustainable)**

Current Regulations:
State (HAR 13-95) Minimum size 14 inches, Bag limit 2 total all uhu species, Commercial fishers may take and sell more than 2 ulu ʻeleʻele with a permit.[f]

Maui (HAR 13-95.1) Minimum size 14 inches for these large-bodied species of parrotfishes, Bag limit 2 total, regardless of species, No take of blue terminal-phase male individuals of the large-bodied species.

"Uhu" means any fish belonging to the family Scaridae or any recognized synonyms.

Management Considerations: Length at maturity (L_{50}) for these species are 13.8 inches for Red-lipped Parrotfish (*Scarus rubroviolaceus*) and 13.6 inches for the Spectacled Parrotfish (*Chlorurus perspicillatus*).[126] Given that they are heavily targeted and play a key role in creating space for coral recruitment, they are a critically important component of the nearshore fishery and promoting reef resilience.

Minimum Size limit: 12.7 inches (OFL); 13.3 inches (40% probability of overfishing)
Current Maui rules= 26% probability of overfishing

Catch limits: 181,881 lbs (OFL); 175,047 lbs (40% probability of overfishing)

Given the social dynamics of uhu (sex changing from female to male and the establishment of harems-please see background/ecology/behavior section below), there are several important considerations in regard to management options that optimize the reproductive potential of the population. The largest female in a group may not change sex if the combined reproductive potential (how many eggs they can produce) of all the other females in the group is less than her current reproductive potential.[127] However, when a terminal blue uhu is removed (through fishing or other mortality), if the largest female in a harem changes into a terminal phase male, it effectively removes her female reproductive potential from the population.
Surveys have revealed that parrotfish populations on Oʻahu are dominated in abundance by the smaller uhu species, which may be indicative of fishing pressure targeted towards the larger bodied uhu species or terminal phase males.[128] Two of the most abundant parrotfishes found were the smaller, less favorable species by fishers (*Chlorurus spilurus* or Bullethead parrotfish and *Scarus Psittacus* or Palenose parrotfish), while the three larger bodied, heavily targeted fishery species (uhu ʻeleʻele or pālukaluka; uhu

[f] Minimum size limit was amended to 14 inches (was previously 12 inches) and bag limit was implemented in February 2024.

uliuli or ʻahuʻula; and pōnuhunuhu) comprised only a small portion of the overall parrotfish community.[128] This suggests that there is some level of fishing pressure skewed towards the larger sizes and possibly terminal phase males.[129–132] In other words, smaller fish are found in areas with higher fishing pressure, or a decline in larger sized fishes is seen with increasing fishing pressure.

Research has shown a high percentage of initial phase, sneaker males on Oʻahu compared to the blue terminal males, which is slightly unusual compared to the amount of blue male terminal phase parrotfishes in other areas of the world. The percentage of terminal males contributing to a population have been found to range from 10 – 50% elsewhere, compared to <14 % as seen on Oʻahu reefs, and this was observed in both highly targeted large-bodied species and less commonly targeted small-bodied species.[128] While many studies support the phenomenon of strongly skewed sex ratios (towards initial phases) indicating heavy fishing pressure, it is important to note that generally, even in unfished areas, the proportion of initial phase fishes are always higher than terminal phase males.[129,133–136] Additional factors that complicate and affect the variability of sex ratios among and in between species include the age or length at transition, longevity between sexes, growth differences, location, and social factors.[126,136,137] Ultimately, however, fishing pressure targeted towards larger and/or terminal phase uhu may lead to a selective preference for reproduction via the smaller sneaker males over terminal phase males.[126] Because sneaker males have a similar appearance to females, they are able to sneak into a terminal male spawning event and release their spawn with the territorial male's.[138] However, this reproductive strategy is not optimal as smaller sized fish have weaker reproductive potential, which can lead to overall population declines in abundance and/or size.[139,140]

Current fishing pressure tends to target the largest fishes and may disproportionately end up targeting terminal phase blue males and also removing the reproductive potential of the largest females (as they are either targeted by the fishery or likely to transition to terminal male, if the terminal male is removed from the harem). Over time, this can decrease the overall size of uhu and terminal phase males in the population, shifting evolutionary pressure towards smaller reproductive strategies. Hence protecting the terminal phase males and largest females through either a slot limit (minimum and maximum size limit) or banning the take of blue uhu will likely increase reproductive output and result in more and larger fishes.

A complete ban on the taking of all parrotfish species have been enacted in several areas around the world, including Bermuda, Belize, Bonaire, and St. Lucia, either through specific regulations prohibiting the take of all parrotfish or the creation of marine reserves.[129,141,142] While full protection of targeted species is generally the most common solution for conservation purposes, and significant increases in parrotfish biomass and size have been reported as a result of this management strategy, [129,143] it is recognized that completely prohibiting the take of uhu may not be the best solution for economic, social, and cultural purposes here in Hawaiʻi. Management strategies working to support sustainable fisheries should explore options that address ecological, economic, social, and cultural issues that will make the present situation better, even though it may not necessarily be the most optimal for improving ecological conditions.[133]

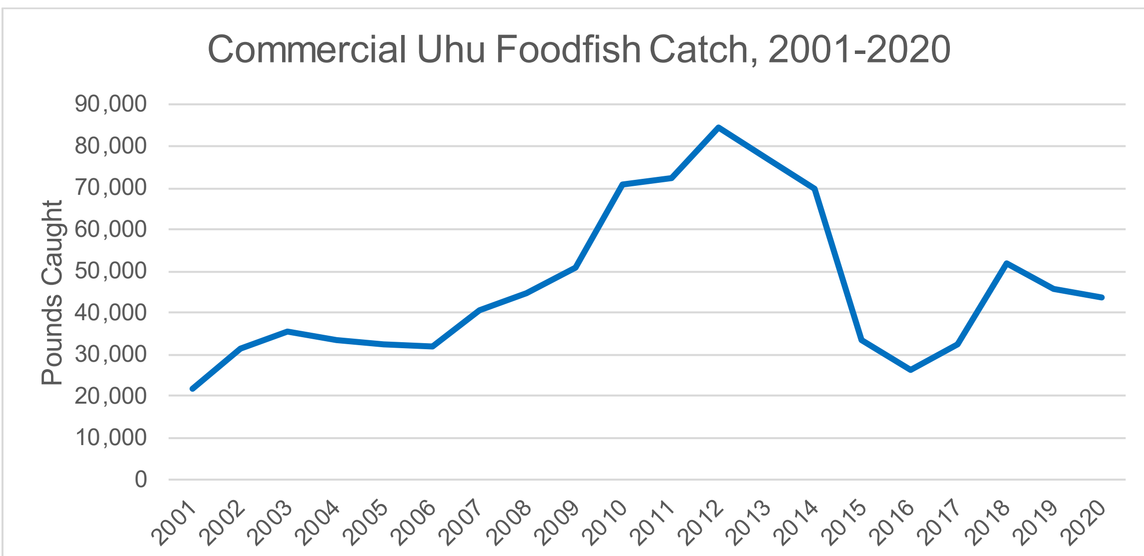
Commercial Harvest: Uhu as a group are the most commonly caught herbivore by commercial fishers with 537,076 pounds landed between 2011 and 2020 and one of the most commonly seen reef fishes in many fish markets and restaurants. They are most often caught using spears but are also targeted with seine nets and fish traps. Due to their behavior of sleeping at night, they are easily harvested in large numbers through night diving, especially on SCUBA.[144] Uhu are occasionally caught by commercial aquarium collectors, but they are not considered regular targets of the fishery. Only 26 uhu have been reported as collected by commercial aquarium collectors over the past ten years.

Food Fishery	Top Commercial Gear Type (20-Yr. average)	1996-2000 Average Catch (lbs.)	1996-2000 Average Price/Lb. (Adjusted)	2016-2020 Average Catch (lbs.)	2016-2020 Average Price/Lb. (Adjusted)	% Change In Catch (lbs.)	% Change in Price/Lb.
Uhu[1]	Spear (72.6%), Seine Net (14.2%), Fish Trap (9.1%)	34,306.4	$3.69	39,977.4	$5.02	16.5%	36.0%

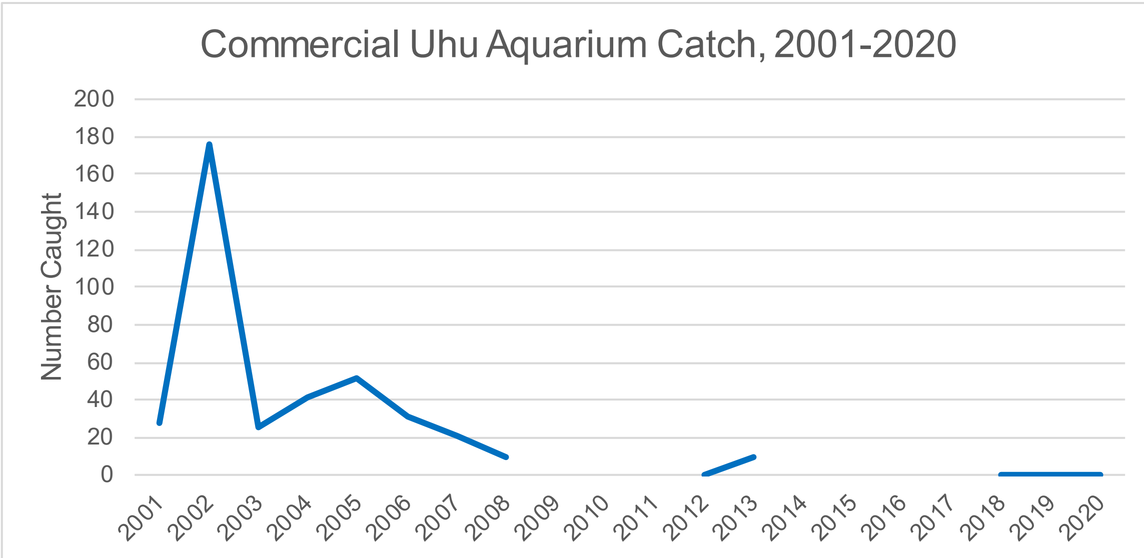
[1]Includes large- and small-bodied species

Aquarium Fishery	1996-2000 Average Catch (Pcs)	1996-2000 Average Price/Pc. (Adjusted)	2016-2020 Average Catch (Pcs)	2016-2020 Average Price/Pc. (Adjusted)	% Change In Catch	% Change in Price/Pc.
Uhu[1]	98	$11.37	Confidential[2]	Confidential[2]	NA	NA

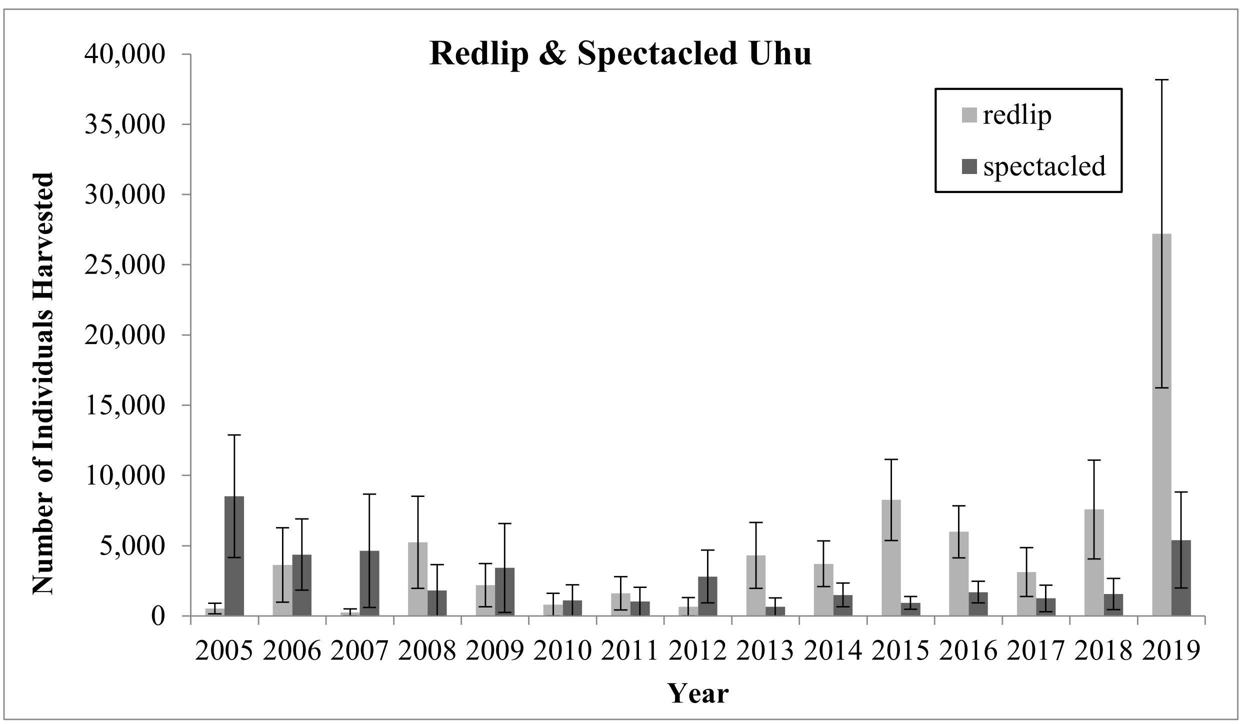
[1]Includes large- and small-bodied species
[2]Data withheld to preserve fisher confidentiality



Non-commercial Harvest: Uhu are a very common fish for non-commercial fishers, primarily by spearfishers but also occasionally by throw net or rod and reel fishers. In the HMRFS data, the median take was one fish per person, with most fishers taking fewer than five. The highest reported catch was of 20 fish. Of the two large-bodied uhu, the Red-Lipped is more commonly caught than the Spectacled Parrotfish, but the catch trends have been variable yearly.



Commercial aquarium catch data for uhu is confidential for the years not plotted and does not mean recorded catch was zero.



Historical take and Cultural/Traditional Use: Uhu in ancient days was the most telltale of all fish as they revealed what sort of behavior was going on at the fishers' home.[60] Uhu was a favorite fish with the Hawaiians, sometimes eaten dried, or broiled, but usually raw and prepared with pieces of the fat liver.[60] It was such a highly desirable fish that it was part of the Kahuna prayers to call fish into the Loko Kuapa, Hawaiian fishponds.[114] In a fisherman's prayer, the uhu was referred to as "gumless uhu" at sea. The stages of growth are: ohua (spawn) pōnuhunuhu or pānuhunuhu."[60]

There are many specialized fishing methods for uhu, so much so that a mele was written for uhu fishing on Lanaʿi. This method entails a decoy known as a pula, pakahi, or uhu pakahi, to lure other uhu in. Once caught, the fisher would secure the decoy by line causing other uhu to rush in where he would lower the net and pull the net to bag the uhu once they came close, sometimes catching two or three."[89] When catching by hook and line, the 'alaʿala (ink bag) of the he'e (octopus) was used. The ink bag was rubbed over the hook and the smell would attract the uhu. If a miss was made merely injuring the fish and not catching, the fishing was over for the day as no more uhu would bite.[61] Upena ohua palemo or a net for catching young uhu was also used. It was one fathom and requires 10 men to work the net.[61] When uhu traveled in single file fashion it was known as uhu holo or uhu makaʿikaʿi and a special trap called an ahu was built for a channel in the reef where uhu would habitually file through known as a kuʿuna. There were two gates called ohiʿa. During the months of May, June, and July, the outer gate was opened allowing the leader to come in with his followers. The gate was then shut and the other gate opened as soon as enough uhu had been taken for use.[60]

There are also many 'ōlelo no'eau and moʿolelo that reference the uhu. In the story of Puniakaia, he catches a small uhu (pauhuuhu) and takes him home to care for him. The uhu grows to be a very large fish and given the name Uhumakaʿikaʿi, this was the parent of all fishes. Puniakaia returns the uhu to the ocean and, when there is a call for everyone to go fishing, Puniakaia calls upon his pet uhu to bring the fish and Uhumakaʿika'i obeys providing enough fish for everyone including the pigs and dogs.[145]

Background/Ecology/Behavior:

Uhu have three morphological stages: the juvenile stage, initial phase, and terminal phase (commonly referred to as a blue uhu). The juvenile phase includes immature individuals with stripes that have not yet sexually matured. The initial phase includes mature females and males (also called sneaker males) which generally display a coloration of drab colors ranging from reddish browns to gray. In the larger terminal phase, their body color changes to bright blues and greens, and this phase is comprised of sex-changed males that were previously female. Terminal phase males are territorial and have a harem of females. If there is no terminal male in a harem, the largest female of the harem can change sex and become a new terminal male, or a neighboring terminal male can also expand his territory to include the territory of a removed terminal phase male.[128,138,146]

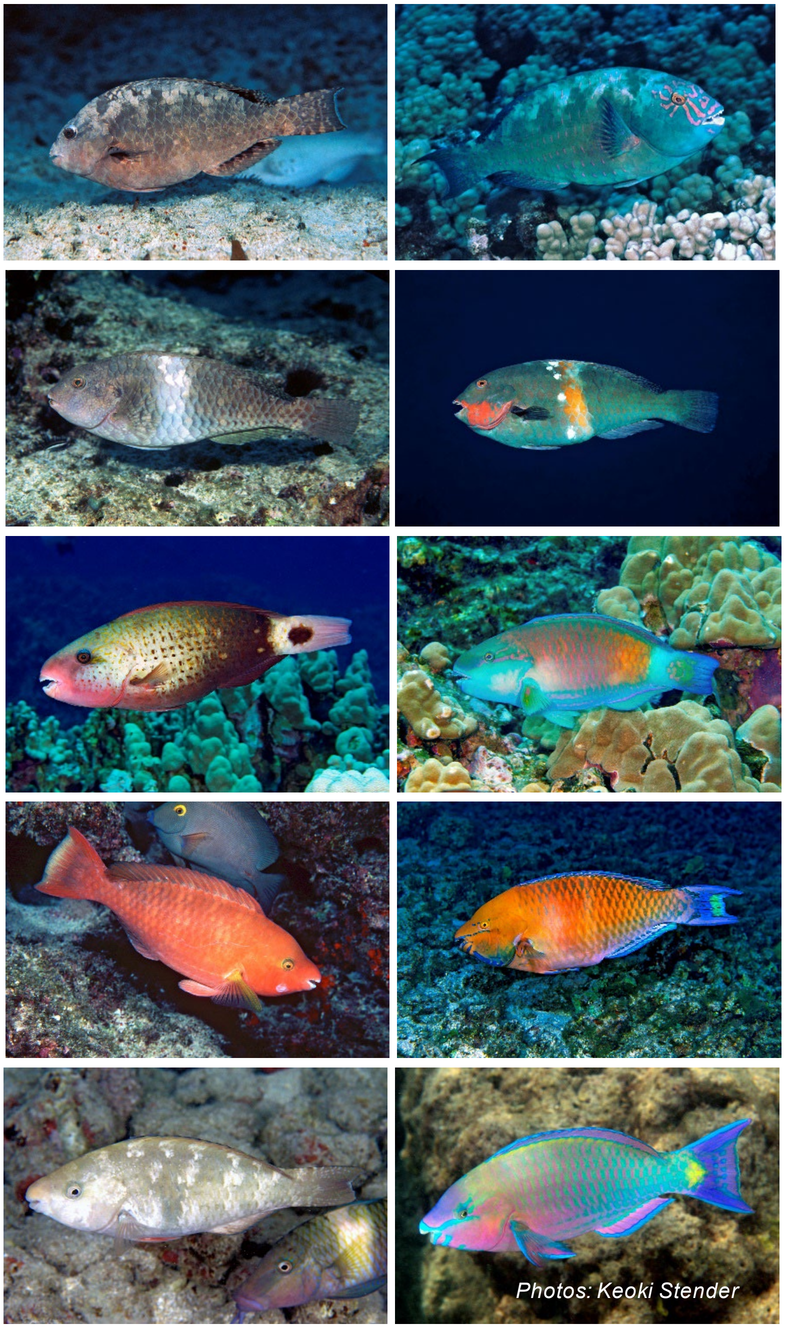
Uhu palukalua (female), uhu 'ele'ele (blue green male), Red-lipped Parrotfish (*Scarus rubroviolaceus*): These uhu are typically found on shallow reefs where they feed upon turf algae, coralline algae, etc. They occur solitarily or in pairs, but can occur in large schools.[147] Large adults usually occur on upper parts of deep slopes[148] or within 2 feet of water on shallow reef flats. Their distribution is highly influenced by fishing pressure.

Uhu 'ahu'ula (female), uhu uliuli (blue male), Spectacled Parrotfish (*Chlorurus perspicillatus*): This is an endemic species to the Hawaiian Islands. These uhu are found on shallow reefs and clear lagoon and seaward reefs, from the intertidal to at least 150 feet,[117] where they feed upon turf algae, coralline algae, etc.

Role for Reef Resilience: The large-bodied uhu are **excavators**, removing top and bottom layers of turf algae and coralline algae, and exposing the reef substrate for new crustose coralline algae to settle and grow, which then provides the foundation for new coral larvae to easily settle.[149,150] In addition to creating new settlement areas for coral larvae, the grazing both reduces coral's competition with algae for space, but also helps to remove sediment that was trapped in turf algae.[150] Turf and crustose algae make up 98% of the large-bodied uhu's diet.[151] Grazing rates of both the Red-lipped Parrotfish and Spectacled Parrotfish increase with increasing size[151] and smaller individuals may act as grazers and scrapers. Although a few species of uhu in other parts of the world may eat living coral, live coral makes up less than 2% of the diet of these large-bodied uhu in Hawai'i.[151]

Life History: These are long-lived species with a longevity of at least 20 years. They are mature at about 3-4 years. Length at maturity (L_{50}) for these species are 13.8 inches for Red-lipped Parrotfish 13.6 inches for Spectacled Parrotfish.[126] Parrotfishes begin life as female and can subsequently change sex to male around at 5 - 7 years. [126,127] Their peak spawning season is from April – July.[128]

Small-bodied Uhu (*Calotomus carolinus, Calotomus zonarchus, Chlorurus spilurus, Scarus dubius, Scarus psittacus*)



Photos: Keoki Stender

Status: **UNSUSTAINABLE**

Pānuhunuhu/Star-eyed Parrotfish (*Calotomus carolinus*) **SPR 0.13 F/F_{30} 2.2 (unsustainable)**

Bullethead Parrotfish (*Chlorurus spilurus*) **SPR 0.23 F/F_{30} 1.14 (unsustainable)**

Lauia, Regal Parrotfish (*Scarus dubuis*) **SPR 0.45 F/F_{30} 0.6 (sustainable)**

Pānūnū/ Palenose Parrotfish (*Scarus psittacus*) **SPR 0.41 F/F_{30} 0.7 (sustainable)**

Yellownose Parrotfish (*Calotomus zonarchus*) (**insufficient data**)

Current Regulations: State (HAR 13-95) Minimum size 10 inches, Bag limit 2 total all uhu species[g]

Maui (HAR 13-95.1) Minimum size 10 inches
"uhu" means any fish belonging to the family Scaridae or any recognized synonyms.

Management Considerations:
These species are heavily targeted though less heavily than large-bodied species. A minimum size limit would be appropriate for each of these species, given that they are heavily targeted and given their importance to reef resilience. A bag limit combined with minimum size limits would reduce fishing pressure and maximize reproductive output and have the best likelihood of maintaining sustainable population.

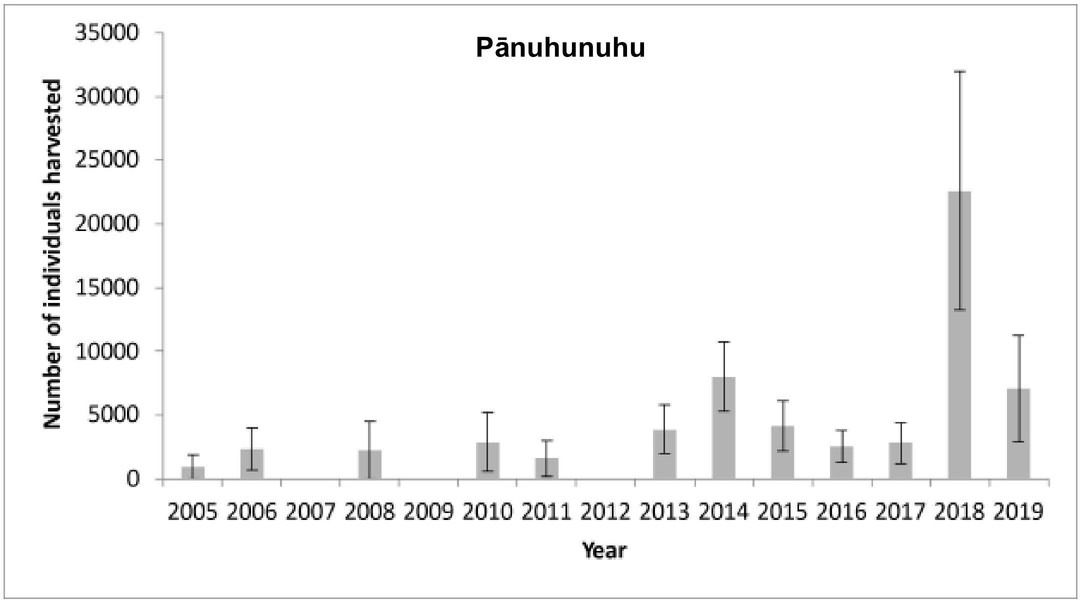
Minimum Size limit: 10.8 inches (OFL); 11.4 inches (40% probability of overfishing)

Catch limits: 18,585 lbs (OFL); 16,843 lbs (40% probability of overfishing)

[g] Minimum size limit was amended to 10 inches (was previously 12 inches), the addition of *Calotomus zonarchus* and *Calotomus carolinus* and bag limit was implemented in February 2024.

Commercial Harvest: (See previous section on large-bodied uhu for general uhu commercial harvest information)

Non-commercial Harvest: Pānuhunuhu is the most commonly caught of the small-bodied parrotfishes. In the HMRFS data, the median catch of pānuhunuhu is one fish per person. It is most commonly caught by spearfishers but also caught with rod and reel as well as throw nets. Catch per year for pānuhunuhu is varied as shown in the chart below.



Historical Take and Cultural/Traditional Use: (See previous section on large-bodied uhu for general uhu commercial harvest information)

Background/Ecology/Behavior: Uhu are important algae eaters as well as bioeroders. These smaller-bodied uhu are important **grazers**, cropping down larger macroalgae from our reefs. Very large individuals of these species can also be scrapers. Pānuhunuhu is found in coral, rubble, and weedy areas, singly or in small groups.[117] *Calotomus zonarchus* is also found in coral, rubble, and weedy areas, singly or in small groups.[117,152]

Pōnuhunuhu or pānuhunuhu, Star-eyed Parrotfish (*Calotomus carolinus*): This species is fairly common on shallow reefs where it feeds upon seaweed using rough jaws composed of fused, pebble-like teeth. It feeds on a variety of encrusting algae.[153]

Yellowbar Parrotfish (*Calotomus zonarchus*): This species is endemic to the Hawaiian Islands, rare in the main Hawaiian Islands, and common in the northwestern Hawaiian Islands. It occurs in areas of coral and coral rubble, from the surge zone to about 30 feet.[117]

Bullethead Parrotfish (*Chlorurus spilurus*): This species is very common on shallow reefs where it feeds upon coralline algae. *Chlorurus sordidus* was a previous synonym for this species, but a recent study indicates that *C. spilurus* is a distinct Pacific species from the *Chlorurus sordidus* in the Indian Ocean and Red Sea.[154]

Lauia, Regal Parrotfish (*Scarus dubius*): This species is endemic to the Hawaiian Islands. Males were formerly known as *Scarus lauia*.[155]

Pānūnū, Palenose Parrotfish (*Scarus psittacus*): This species is very common on reefs in small harems where it feeds upon benthic algae and *Halimeda*.[152] Females were formerly known as *Scarus forsteri*, males as *Scarus taeniurus*.[156]

<u>Role for Reef Resilience:</u> Large individuals of these smaller-bodied species are **scrapers**, scraping off turf algae, and coralline algae from the reef. Smaller individuals of these species are important **grazers**, cropping down larger macroalgae from our reefs.

<u>Life History:</u> Reproduction in the smaller-bodied species is more flexible and opportunist than the large-bodied parrotfishes.[126] Our endemic species Yellowbar Parrotfish and Regal Parrotfish, are lacking in life history information because they are rare in the Main Hawaiian Islands. Pānuhunuhu and Palenose Parrotfish live about 3 to 5 years, and Bullethead Parrotfish lives to be about 11 years. Size at maturity for these species is: Pānuhunuhu 9.6 inches, Bullethead Parrotfish 6.8 inches, and Palenose Parrotfish 5.5 inches.[126] Maximum size of these species are: Pānuhunuhu/Star-eyed Parrotfish 21 inches,[157,158] Bullethead Parrotfish 16 inches,[124,157] Pānūnū/ Palenose Parrotfish12 inches,[124,157] and our two endemic species, Yellowbar Parrotfish 13 inches,[99] and Regal Parrotfish 14 inches.[157]

Compliance and Enforcement

Promoting compliance and upholding conservation rules are essential to increase management effectiveness and improve the overall health of nearshore environments. The Division of Conservation and Resources Enforcement (DOCARE) is the law enforcement agency of DLNR. DOCARE is responsible for enforcing existing regulations and any new fisheries regulations that are implemented. Fisheries regulations serve to protect, conserve, and manage Hawai‘i's unique and limited natural, cultural, and historical resources. DAR works closely with DOCARE when developing and proposing new rules and, as part of Holomua Marine Initiative, DOCARE's capacity is growing. DOCARE is currently working to increase its enforcement capacity by filling officer vacancies through its Academy and Field Training Program. DOCARE is also providing updated training on marine rules, and ensuring it has enough vessels, vehicles, and equipment to carry out enforcement responsibilities. During this last legislative session, their inspection authority was expanded so that officers now have the authority to inspect catch when fishing or harvesting activity is believed to be occuring, allowing them to ensure that pono and legal fishing practices are followed. Knowing that officers cannot be everywhere all the time, the public can now report resource violations through the DLNR Tip App. Data reported on this app helps officers better address "hot spots" for violations and work more closely with concerned communities where problems are identified. Violations may incur criminal and civil penalties. These fees are assessed per violation. For example, if there are multiple fish caught below a minimum size limit, as set by the regulation, each fish caught could result in individual and separate penalties/fines. The tables below highlight the fee schedule for marine resource violations:

Table 4: Schedule of criminal and civil fines for marine resource violations. Fines increase if there is no response within 21 days. Fines are assessed per violation.

	1st Offense		2nd Offense		3rd Offense	
Violation	**Criminal Fine**	**Civil Fine**	**Criminal Fine**	**Civil Fine**	**Criminal Fine**	**Civil Fine**
Fishing within an MLCD	$250-$1,000	Up to $200	$500-$1,000	Up to $400	$1,000	Up to $600
Fishing in prohibited area	$100-$1,000	Up to $200	$200-$1,000	Up to $400	$500-$1,000	Up to $600
Gear restriction Violation	$100-$1,000	Up to $200	$200-$1,000	Up to $400	$500-$1,000	Up to $800
Size Limit Violation	$100-$1,000	Up to $200	$200-$1,000	Up to $400	$500-$1,000	Up to $800
Bag Limit Violation	$100-$1,000	Up to $200	$200-$1,000	Up to $400	$500-$1,000	Up to $800

DOCARE is also expanding its Makai Watch Program. Makai Watch is an educational program that empowers community leaders to take ownership in the protection of their local marine resources. Makai Watch partners with local communities to educate the public on pono behavior. The program trains community members to take active roles in managing their resources by teaching them how to: (1) spot unlawful uses of marine resources, (2) educate users regarding correct practices, and (3) contact enforcement authorities as appropriate. By enhancing outreach and education efforts, Makai Watch promotes compliance with existing rules and allows enforcement to focus on resource users who choose to evade proper regulations.

Monitoring

is an essential component of management that measures and documents current mauka-to-makai conditions Monitoring provides a way to measure the changes occurring, determine actions are effective, if implemented, and identify areas where management actions need to be adapted.

Objective: Evaluate and review the effectiveness of pertinent management measures every five years and implement adaptive strategies which account for changes in environmental conditions, habitat, herbivore population dynamics, and resource uses. Note: For some species, it may not be possible to detect change on such a short time scale. These will be monitored for change and assessed as prudent.

Actions within this pillar will track progress of herbivores, evaluate management effectiveness, identify data gaps, and determine areas where the plan may need to be adapted.

- *Action M.1* Analyze and interpret fishery dependent and independent data to evaluate ecological and socio-cultural responses to targeted management strategies.
- *Action M.2* By 2030, create a core team of permanent civil service staff in each district to collect and analyze fisheries independent and dependent data.
- *Action M.3* Collaborate with other sources (federal and academic) of fisheries independent and dependent data to bolster and fill in data gaps (i.e.. HIMARC, CRAMP, MHI-RAMP, etc.).
- *Action M.4* By 2025, review and amend current regulations and Marine Management Areas as needed to support fishery and coral reef health.
- *Action M.5* By 2025, evaluate existing MMA for effectiveness in promoting sustainable fishing practices of herbivorous fishes.

It is critical to adaptive management to implement management strategies to assess the productiveness of the Management Plan and various regulations to make informed decisions moving forward.

Monitoring

DAR has district teams that conduct regular monitoring for each district. This includes fish and benthic surveys performed on set transects (counting and measuring fishes and invertebrates on a specific line over a specific area) on SCUBA, as well as similar surveys conducted at sites with a random design. Additionally, DAR collaborates with many partners who also perform surveys so that management decisions can be informed on the best readily available science. DAR partners with the Hawaiʻi Monitoring and Reporting Collaborative (HIMARC) who combined, standardize, and calibrate data from the surveys of seven different organizations.

With the help of HIMARC, by 2023, we will compare a baseline assessment of herbivore biomass and benthic condition based on data from 2004-2014 with another assessment based on data from 2015-2020 data. This comparison will provide an initial assessment of spatial and temporal trends, as well as be used to determine gaps in data and spatial survey coverage to better develop a statewide monitoring plan as part of the broader Holomua Marine Initiative. The data will also be analyzed to look for changes between the two time periods and to better understand any drivers of change that could be addressed through future management actions. This will allow us to adjust the management plan as appropriate and necessary based on the latest data available.

Reviewing and Reporting on the Plan

Management strategies laid out in this plan will go through several public scoping sessions so that community members will be able to learn about the status of the environment and herbivorous fishes and make comments based on their own experiences and perceptions interacting with these resources.

Every five years the management plan will be reviewed to assess and adapt to changes in environmental conditions, habitat, herbivore populations, and resource uses. The overall goals, objectives, and action items will be reviewed to maintain the ecological functions of the habitat and herbivore communities into the future.

RESTORATION

Herbivore management is only part of a multi-faceted approach to manage for improved reef restoration and resilience, including both resistance to and recovery from disturbance. The restoration pillar builds on existing strategies to promote resilience and prevent damage to fragile nearshore ecosystems from human use, terrestrial threats, and biological stressors including climate change. This pillar expands efforts to protect, restore, and enhance cultural and biological resources by strengthening and supporting community and agency partnerships, programs, and projects.

Objective: By 2022, begin collaborating with other agencies and communities to mitigate environmental and human impacts that affect nearshore environments. By 2030, expand efforts to improve resilience and enhance restoration.

<u>Actions within this pillar will expand efforts to restore and improve nearshore areas, and work with other agencies to reduce land-based threats to nearshore ecosystems.</u>

- *Action PR.1* By 2025, identify key management areas to address land-based sources of pollution and sedimentation that adversely affect nearshore habitat and herbivore populations.
- *Action PR.2* By 2025, prioritize key watersheds with highest potential to recover herbivores and habitat.
- *Action PR.3* Work with regional and local partners to implement efforts that support restoration.
- *Action PR.4* Build on existing work to enhance native sea urchin stocks (Hāwaʻe maoli), raised in DAR's urchin hatchery, on specific reefs to reduce invasive algae.

Land use and Mitigation to minimize threats to nearshore habitats

Under Hawaiʻi's government structure, water quality, including land-based sources of pollution fall under the responsibility of the Department of Health (DOH). The DOH has created a Water Quality Plan with the goal to "Ensure the protection of human health and sensitive ecological systems by outlining a path to protect, restore, and enhance the quality of waters in the State." Specific objectives of the plan are to:

- Develop scientifically based water quality standards that meet federal requirements and protect state waters.
- Engage in new water quality monitoring initiatives to supply data for-developing water quality monitoring methodologies, prioritizing watersheds, and strategies to address identified pollutant sources.

- Develop Total Daily Loads that improve water quality and serve an integral role in watershed-based planning.
- Increase the amount of resources devoted to the control of non-point source water pollution.
- Collaborate with the Counties and State agencies to prioritize impaired watersheds for restoration efforts and support stakeholder stewardship of watershed resources.
- Regulate point source discharges through permitting and enforcement.
- Upgrade and replace cesspools.
- Continue to work with stakeholders to develop a long-range plan for cesspool conversions as required under Act 132 0f 2018.
- The entire DOH water quality plan can be found here: https://health.hawaii.gov/water/files/2019/03/FINAL-DOH-Water-Quality-Plan-2019.pdf

In addition to Hawai'i's Department of Health water quality plan, the US Coral Reef Task Force (USCRTF) has plans to develop water quality standards for coral reefs. The water quality standards developed through the USCRTF could be used to create scientifically based water quality standards to protect state waters to meet the objective from the DOH water quality plan.

DAR recognizes that protecting water quality requires coordination and cooperation with many different agencies and organizations and will support the effort of the DOH and other partners in reaching these water quality goals in order to lessen the impacts of land-based run off on nearshore ecosystems.

DAR Sea Urchin Hatchery

The DAR Sea Urchin Hatchery is key to invasive seaweed control and reef restoration in Kāne'ohe Bay. DAR cultivates hāwa'e maoli, (the native collector sea urchin) at Ānuenue Fisheries Research Center. The urchins are raised from on-site spawning and grown up to 15 mm in diameter, at which time they are released into Kāne'ohe Bay to control invasive, non-native seaweeds.[85]

The first hatchery raised urchins were released in 2011. Since then, the hatchery has outplanted over 500,000 of these urchins that eat invasive algae. Invasive seaweeds once smothered coral reefs in Kāne'ohe Bay. Urchins are used as a biological control agent. They can eat algae in the small spaces of the reef and reclaim important habitat for young fishes and other small organisms.

As a result of DAR's efforts, invasive seaweed in Kāne'ohe Bay has decreased significantly in the last five years. DAR habitat managers continue to strategically deploy urchins wherever invasive seaweed is found. This prevents a full-scale reinvasion from taking root again and preserves the integrity of coral reef habitat. DAR is now also out-planting these urchins at the Waikīkī MLCD and FMA to control invasive algae in that area.

COMMUNITY ENGAGEMENT

DAR will work collaboratively with the public and specific communities to fulfill objectives within this management plan. Any statewide rules will be proposed and scoped through a public participatory process and must go through the Chapter 91 rule-making process, which provides the public with an opportunity to provide public testimony, highlighting their input about the rules. Place-based and island-scale planning will include community participation to develop and draft any applicable rules. Communities will also be asked to contribute input regarding mauka to makai partnerships and identifying place-specific needs to be address as part of this broader plan, as is applicable to specific geographical places. There will be many opportunities for public engagement regarding objectives and actions of this Sustainable Herbivore Management Plan.

NEXT STEPS

- DAR will continue to move forward a statewide proposal for herbivore regulations by the end of 2021, with public scoping scheduled in December.[h]
- Starting from 2021 to 2026, DAR will extend and amplify community engagement opportunities for considering island-scale and place-based regulations for herbivores.
- From 2021 to 2024, DAR will be collaborating with the Hawai‘i Monitoring and Reporting Collaborative (HIMARC) to examine herbivory thresholds in relation to coral reef sustainability. Results from this project will be integrated into future versions of this Herbivore Management Plan and used to inform and adapt management actions as they relate to herbivory and benthic conditions.[i]
- Starting in 2021, DAR will convene a Nearshore Restoration hui to build relationships and expand collaborations with partners to help address land-based threats that impact the nearshore habitat and herbivore populations.
- This plan will be reviewed and updated every five years, responding to new information, changing conditions, and arising concerns/threats. Actions and priorities will also be reviewed and updated during this process. This review and update will be conducted with community engagement and feedback.

CLOSING MESSAGE

Given the unprecedented threats to our nearshore resources due to climate change, management action is urgently needed to ensure the sustainability of herbivores and coral reefs. Maintaining adequate levels of herbivore biomass is essential for maintaining healthy corals, and where the condition of corals has declined, improvements in herbivore biomass can aid recovery. The future of coral reefs will depend on their resilience in the face of climate change impacts and healthy herbivory can help strengthen this resilience. The goal, objectives and actions in this Sustainable Herbivore Management Plan will lead towards better stewardship of our marine resources, so that we may enjoy our coastal waters, support our livelihoods, and feed our families for generations to come.

[h] Statewide herbivore rule amendments (HAR 13-95) were signed by the Governor and took effect on February 22, 2024.

[i] In November 2023, HIMARC published a paper with the results of this analysis: Donovan, Mary K., Chelsie WW Counsell, Megan J. Donahue, Joey Lecky, Laura Gajdzik, Stacia D. Marcoux, Russell Sparks, and Christopher Teague. "Evidence for managing herbivores for reef resilience." *Proceedings of the Royal Society B* 290, no. 2012 (2023): 20232101.

Glossary

Adaptive management: a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.

Bag Limits: a management method that reduces the amount of fish harvested by limiting the total number of fish caught per person per day.

Benthic Community: the community of organisms that live on or in the seafloor.

Biodiversity: the variety of life, including diversity within species, between species, and among ecosystems.

Biomass: the total mass/weight of organisms in a given area.

Bleaching: The process that occurs when corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues, causing them to turn completely white.[11]

Browsers: Herbivorous functional group that feed primarily on macroalgae overgrowth.

Crustose Coralline Algae (CCA): algae of rock-hard calcium-carbonate structure that contribute to reef calcification and cementation.

Ecosystem functions: the interactions between organisms and physical environment, such as nutrient cycling, energy flow and productivity

Ecosystem: a dynamic complex of algae, animal and microorganism communities and their nonliving environment interacting as a functional unit.

Ecosystem Services: The benefits people derive from ecosystems.

Excavators: herbivorous functional group acting as bioeroders removing dead coral and digging deeper into the reef.

Fishing rate: a measure of the intensity with which a fish stock is being exploited.

Grazers: Herbivorous functional group eat algal turfs to keep macroalgae cropped low.

Herbivores/Herbivory: Fishes and invertebrates that eat plant and algal material. Herbivory is one of the most important processes in maintaining ecological balance on coral reefs.

Holomua Marine Initiative*:* a goal to effectively manage Hawai‘i’s nearshore waters, ensuring healthy reefs and abundant resources for future generations.

Length at Maturity (L_{50}): The size at which individuals are reproductively active and reproducing. Length of Maturity is usually defined as the point at which least 50% of the individuals in a population are reproductively active and producing L_{50}.

Marine Life Conservation Districts (MLCD): areas designed to conserve and replenish marine resources. MLCDs may allow only limited fishing and other consumptive uses or prohibit such uses entirely.

Marine Management Areas (MMA): specific geographic areas designated by statute or administrative rule for the purpose of managing a variety of marine, or estuarine resources and their use. The resources may include any type of marine life and their habitats. The goal of MMAs may also include preservation of cultural or historical resources.

Optimal Yield: The number of fish harvested that will provide the greatest overall benefit to the economy with respect to food production and recreational opportunities while also taking into account the protection of marine ecosystems.

Overfishing Limits (OFL): catch level that corresponds to the maximum catch that can be extracted from a fish population sustainably. In the context of this report OFL refers to 40% probability of overfishing

Phase Shift: a change in the ecosystem state in response to a persistent change in external environmental conditions. Coral-algal phase shift refers to coral reef areas shifting to unusually low levels of coral cover with persistent states of high fleshy macroalgae cover.

Resilience: the ability to resist and recover from disturbances and maintain ecosystem functions

Scrapers: herbivorous functional group that scrape the underlying reef surface while grazing on algal turfs.

Seasonal closures: a management method that prohibits the harvest of certain species during certain times of the year, usually based on spawning seasons

Size Limits: a management method that set size requirements for the harvest of a species and may be set for a minimum size, maximum size, or both.

Spawning Potential Ratio (SPR): The percentage of the population that has been able to effectively create eggs to reproduce, or a measure of current egg production relative to egg production when a stock is not fished.[69]

Stock: ecologically isolated fish population that is the focus of fishery management.

Sustainability: the balance between resource use and replenishment allowing current and future generations to meet their needs. It is achieved through responsible and respectful practices that encourage replenishment and preservation of natural resources for subsistence, cultural, and economic purposes.

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Abbreviations

AQ	Aquarium Fishery
BLNR	Board of Land and Natural Resources
CBSFA	Community-Based Subsistence Fishing Area
CI	Conservation International
DAR	Division of Aquatic Resources
DLNR	Department of Land and Natural Resources
DOCARE	Division of Conservation and Resources Enforcement
FMA	Fisheries Management Area
HAR	Hawai‘i Administrative Rules
HMA	Herbivore Management Area
HIMARC	Hawai‘i Monitoring and Reporting Collaborative
HMRFS	Hawai‘i Marine Recreational Fishing Survey
IUCN	International Union for Conservation of Nature
MLCD	Marine Life Conservation District
MMA	Marine Management Area
NOAA	National Oceanic and Atmospheric Administration
NRA	Netting Restricted Area
NPS	National Park Service
SBRRB	Small Business Regulatory Review Board
SPR	Spawning Potential Ratio
TNC	The Nature Conservancy
WHAQ	West Hawai‘i Aquarium Fisher

APPENDIX: STATUS AND TRENDS

There are multiple agencies and studies that have attempted to help quantify the status of corals and herbivores across Hawai'i. The following section gives some information from these various studies. Key takeaways from this section are below:

- Hawai'i's herbivores have a positive effect on the ratio of calcified (coral) to fleshy (algae) cover and coral cover (Figure 15).[36] An increase in herbivore biomass has shown a positive increase in calcified cover over algae cover in sites across the Hawaiian Islands (Figure 15).
- Physical drivers such as wave energy and rugosity have a positive effect on both coral cover and herbivore biomass (Figures 15 and 16). Fishing and water quality issues (urban runoff and cesspool effluent) had negative impact on herbivore biomass (Figure 16).[36,159]
- Due to differences in physical, oceanographic, environmental, and human effects, coral cover is spatially variable across the Hawaiian Islands and across locations within each island (Figures 17-24).[36,39,42]
- Herbivore biomass also varied spatially across islands and throughout time (Figures 25-29).

Corals and Herbivores are Linked

The Hawai'i Monitoring and Reporting Collaborative (HIMARC) works closely with partners from seven different agencies: DAR, NOAA Fisheries, NOAA Fish Habitat Utilization Surveys, National Park Service (NPS), Coral Reef Assessment and Monitoring Program (CRAMP), and The Nature Conservancy to combine and standardize monitoring data.

Using these data, patterns of coral and algal cover were investigated throughout Hawai'i.[36] Both coral cover and the ratio of calcified to fleshy benthic cover (a measurement representing the relative amount of coral (calcified) to algae (fleshy) cover throughout a reef area) were strongly predicted by herbivore biomass (Figure 15).[36] The effect of herbivore biomass was the strongest among the 27 other predictors also examined. Despite place-based differences, the positive relationship between coral-dominated areas and larger herbivore biomass was consistent across all locations in Hawai'i.[8,36] A different study in the Caribbean, demonstrated a similar nonlinear relationship between herbivore biomass and higher percent coral cover to fleshy benthic cover.[49] These studies indicate that herbivores play an important role in maintaining the reef.

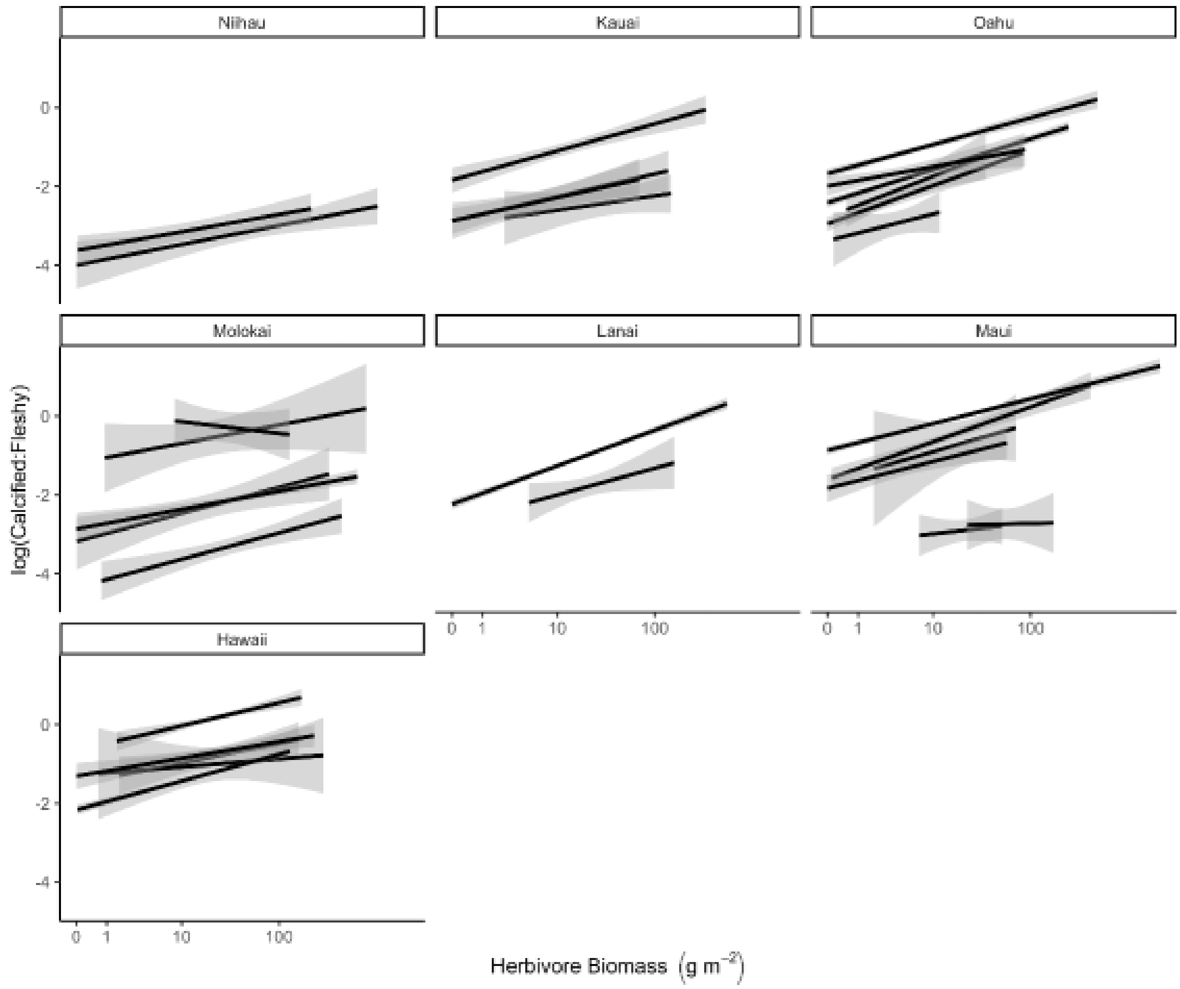

Figure 16: Plot from HIMARC of the ratio of calcified to fleshy benthic cover and herbivore biomass. This relationship plotted using the HIMARC dataset, shows that herbivorous fishes are important for the balance between coral and algae, and thus the reef condition. Where there were more herbivores, there were more corals and less algae.

Drivers of Benthic Communities and Herbivore Biomass

Coral and algal cover can easily change, both from place to place and over time depending on various physical, oceanographic, environmental, and human drivers. A major factor in the proportion of coral cover on a reef is wave energy and exposure.[37,38,160–162] Other important physical factors of benthic communities (bottom type e.g. coral, algae, rubble, sand) include substrate type,[38] island age,[37,38] depth, [37,161] and subsurface water temperature.[162] Benthic communities do not respond uniformly to these physical drivers that constantly change, which can result in spatial clustering of various bottom types.[162,163]

In addition to the physical factors, there are also biological factors (e.g., herbivore biomass) and human factors (e.g. land-based sources of pollution, sedimentation, and high human population) that affect the benthic communities[38] (Figure 15). The human impacts to benthic communities are also not uniform throughout Hawai‘i, with urbanization and fishing being greatest on O‘ahu, while sediment and nitrogen influx are high on Maui and Hawai‘i Island.[164]

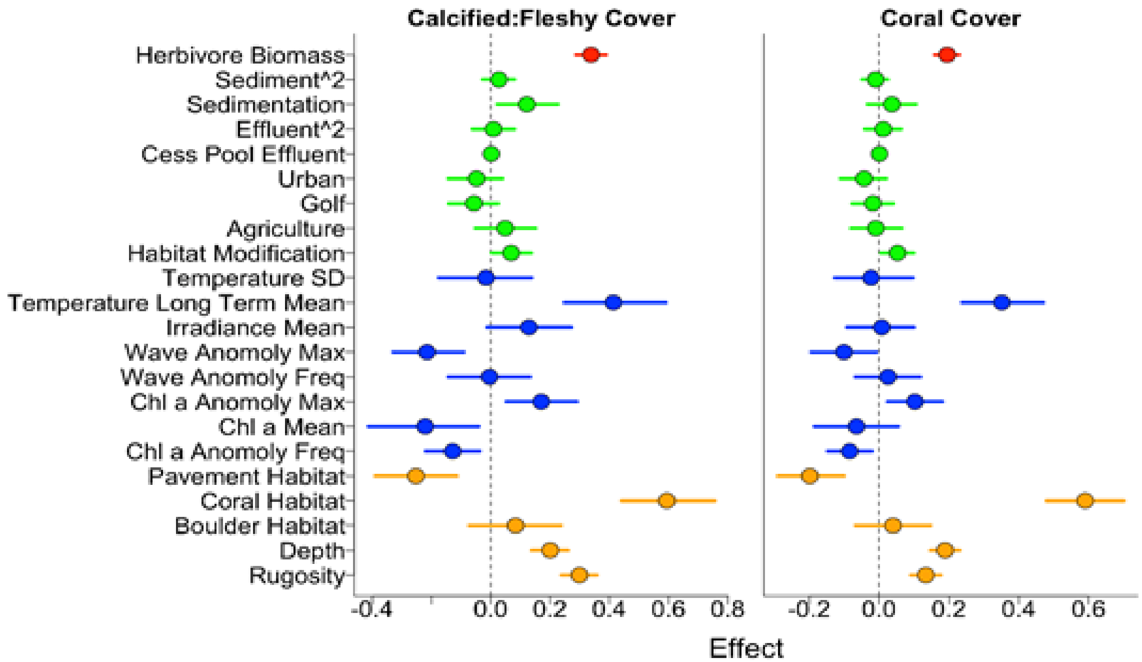

Figure 17: From Donovan et al. (2020)- Effects for each predictor on the ratio of calcified (coral) to fleshy (algae) benthic cover (left) and percent coral cover (right), from Bayesian hierarchical models and the HIMARC dataset that accounted for spatial and temporal structure in the data. Drivers (y-axis) are colored to correspond with fishing variables (red), land-based pollution variables (green), oceanographic variables (blue), and habitat variables (orange). Points are median of posterior estimates and horizontal lines are 95% Bayesian intervals; vertical dashed line represents zero effect. Intervals that do not cross the zero line represent a negative (to the left of zero line) or positive (to the right of zero line)

Herbivore biomass, like coral cover, is also spatially variable due to a range of factors, including habitat, physical/ oceanographic drivers, and human impacts (Figure 16). Some of the strongest positive effects from habitat and oceanography include presence of coral reef habitat, rugosity (how much structure the reef has), and maximum wave energy (more herbivores where these influences are high).[36] Cesspool effluent, unsustainable fishing, and reef pavement (lack of reef structure) had the strongest negative effects on herbivore biomass (fewer herbivores where these influences are high).[36] Similar results were found in an analysis of resource fishes in shallow waters in West Hawai‘i.[159]

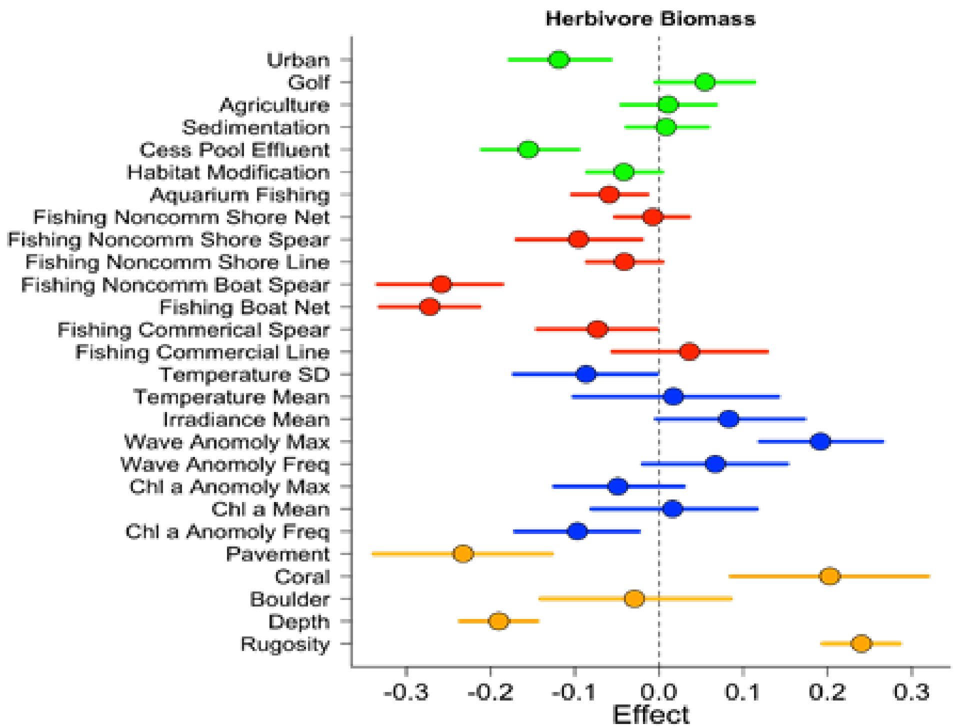

Figure 18: From Donovan et al. (2020)- Effects for each predictor on the ratio of herbivore biomass, from Bayesian hierarchical models and the HIMARC dataset that accounted for spatial and temporal structure in the data. Effects (y-axis) are colored to correspond with land-based pollution variables (green), fishing variables (red), oceanographic variables (blue), and habitat variables (orange). Points are median of posterior estimates and horizontal lines are 95% Bayesian intervals; vertical dashed line represents zero effect. Intervals that do not cross the zero line represent a negative (to the left of zero line) or positive (to the right of zero line) effect on indicator condition.

Unsustainable fishing impacts can reduce the likelihood of herbivore biomass reaching its fullest potential, given the capacity of the habitat to support such fish populations. Examining the effect of fishing pressure on herbivore biomass, a global study showed more than double the average herbivore biomass in areas that were not accessible to fishing.[9] The same study found a 33% lower biomass for scrapers (small parrotfishes), greater than 50% lower biomass for grazers/detritivores (surgeonfishes) and a more than 80% lower biomass for browsers (unicornfish and chubs) in fishing-accessible areas versus areas not accessible for fishing, despite large site-specific differences. Fishing variables were also significant drivers of herbivore biomass in Hawai‘i[36] (Figure 16), which highlights the need for additional fishing regulations in order to best manage herbivore populations so that they can fulfill critical roles in promoting coral reef health and persistence in the face of global environmental changes.

Changes in Benthic Habitat over time

CRAMP has monitored coral cover since 1998 to understand change in percent coral cover over the past 20 years. Because coral cover varies across locations, it is difficult to assess the change in coral cover in Hawai‘i as a whole. Figures 21-23 show variable changes at different locations and depths. A few sites on Kauai also suffered significant losses from the coral bleaching event[42] (Figure 21). Other sites such as Papaula reef on Maui experienced a 46% coral loss from 1999-2015 (Figure 22). Some areas showed large increases of coral cover such as Hawai‘i Island, but was last surveyed in 2012, before the bleaching event (Figure 23).

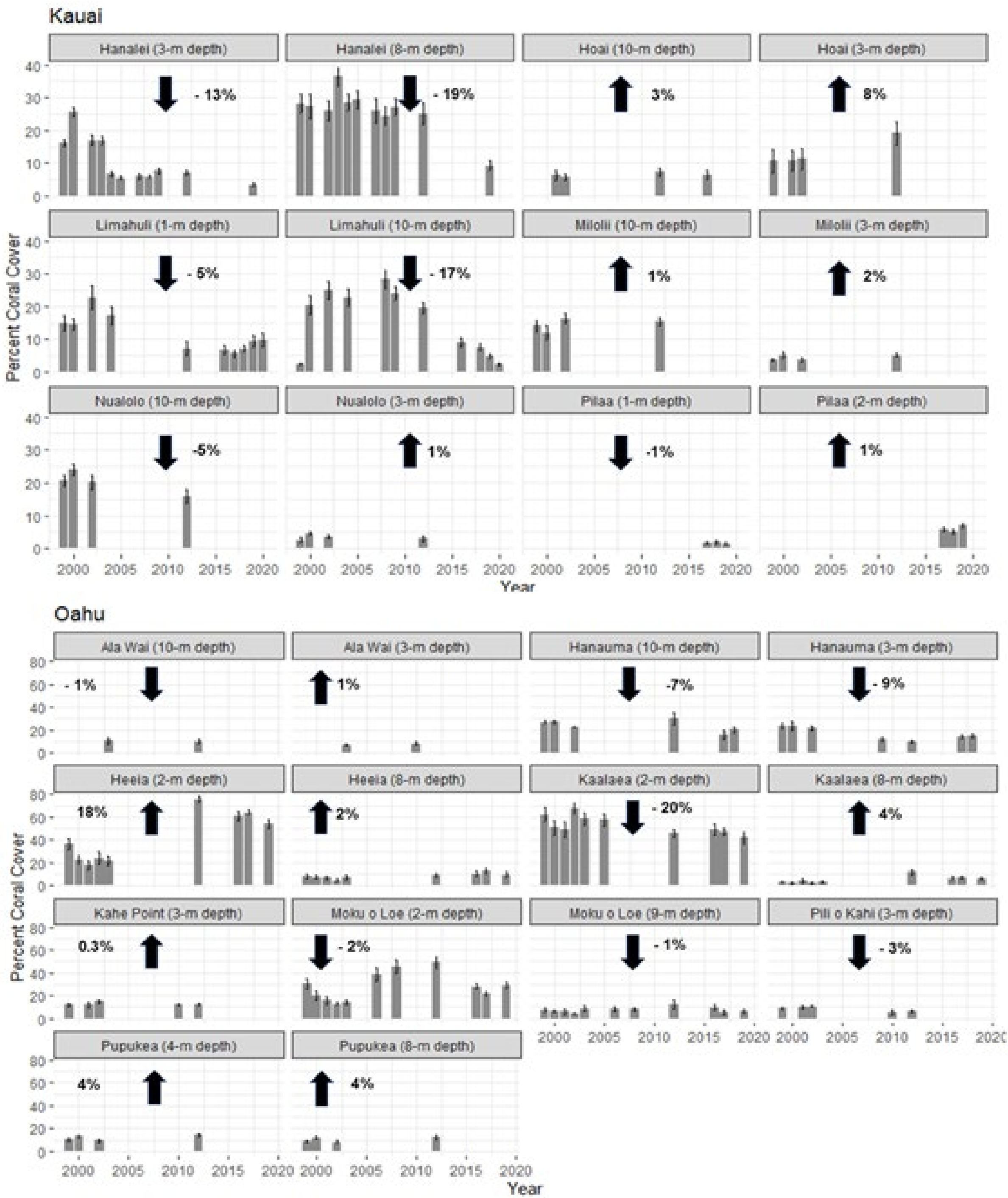

Figure 19: Percent coral cover (+/- standard error) from CRAMP monitoring transect data for Kauaʻi and Oʻahu from 1999-2020. Site name and depth of survey is indicated above each plot. Arrows and percent value in bold text indicate the increase or decrease and percent change of the mean across all transects within a given year from the first year sampled (i.e., 1999 in many cases) to the last year sampled (i.e., 2020 in some cases). Not all sites were surveyed each year.

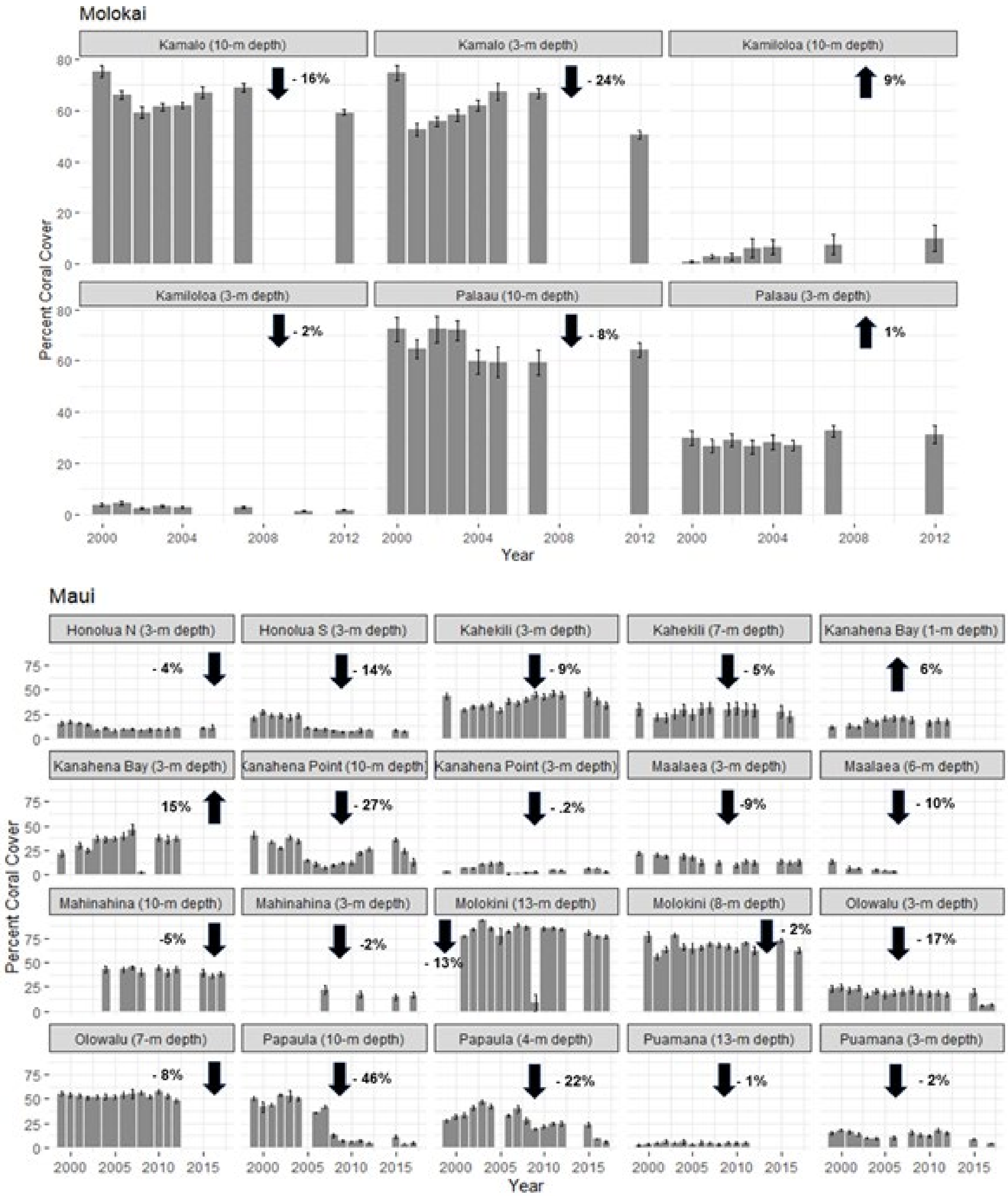

Figure 20: Percent coral cover (+/- standard error) from CRAMP monitoring transect data for Moloka'i (1999-2012) and Maui (1999-2017). Site name and depth of survey is indicated above each plot. Arrows and percent value in bold text indicate the increase or decrease and percent change of the mean across all transects within a given year from the first year sampled to the last year sampled. Not all sites were surveyed each year.

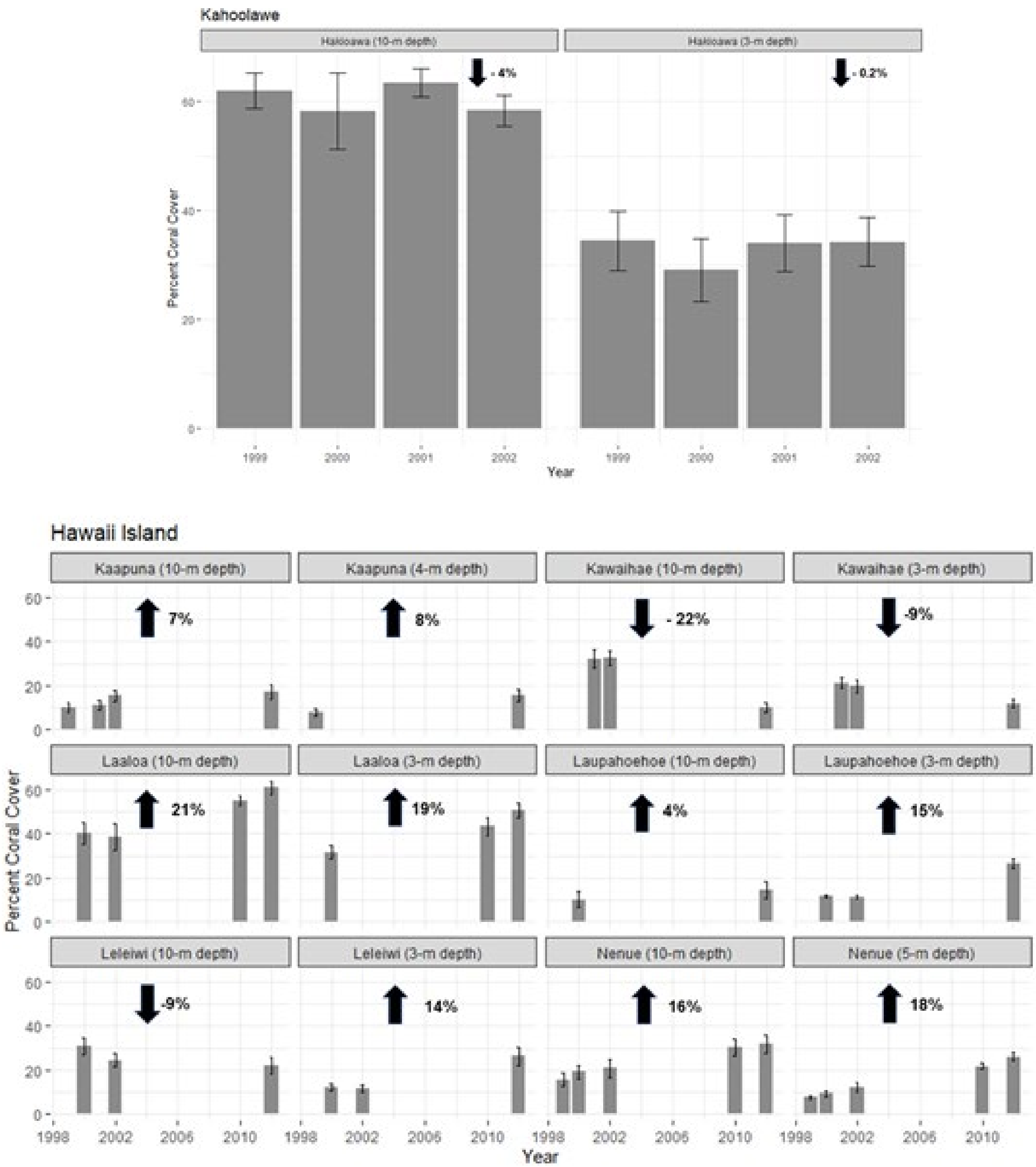

Figure 21: Percent coral cover (+/- standard error) from CRAMP monitoring transect data for Kaho'olawe (1999-2002) and Hawai'i Island (1999-2012). Site name and depth of survey is indicated above each plot. Arrows and percent value in bold text indicate the increase or decrease and percent change of the mean across all transects within a given year from the first year sampled to the last year sampled. Not all sites were surveyed each year.

NOAA's Ecosystem Sciences Division's Pacific Reef Assessment and Monitoring Program (Pacific RAMP) have also monitored benthic cover, assessing four time points between 2010-2019.[165] Despite best efforts to survey the same sites across the extent of the sector, it was not always possible, so there may be higher variability in some areas because surveys are from different areas within a sector. Also, some of the sectors had fairly low sample sizes. Even with these caveats, most locations had higher percent coral cover (orange and pink on the figures) than macroalgae (red and bright green) (Figures 24-28). Just like the last study, changes in coral cover varied between islands and between site specific locations (Figures 24-28). The most drastic losses in coral cover were on the Kona coast of Hawai'i (Figure 28), Kihei in Maui (Figure 26), and Ka'ena point on O'ahu (Figure 25).The north end of Lānaʻi exhibited an increase of coral cover (Figure 26).

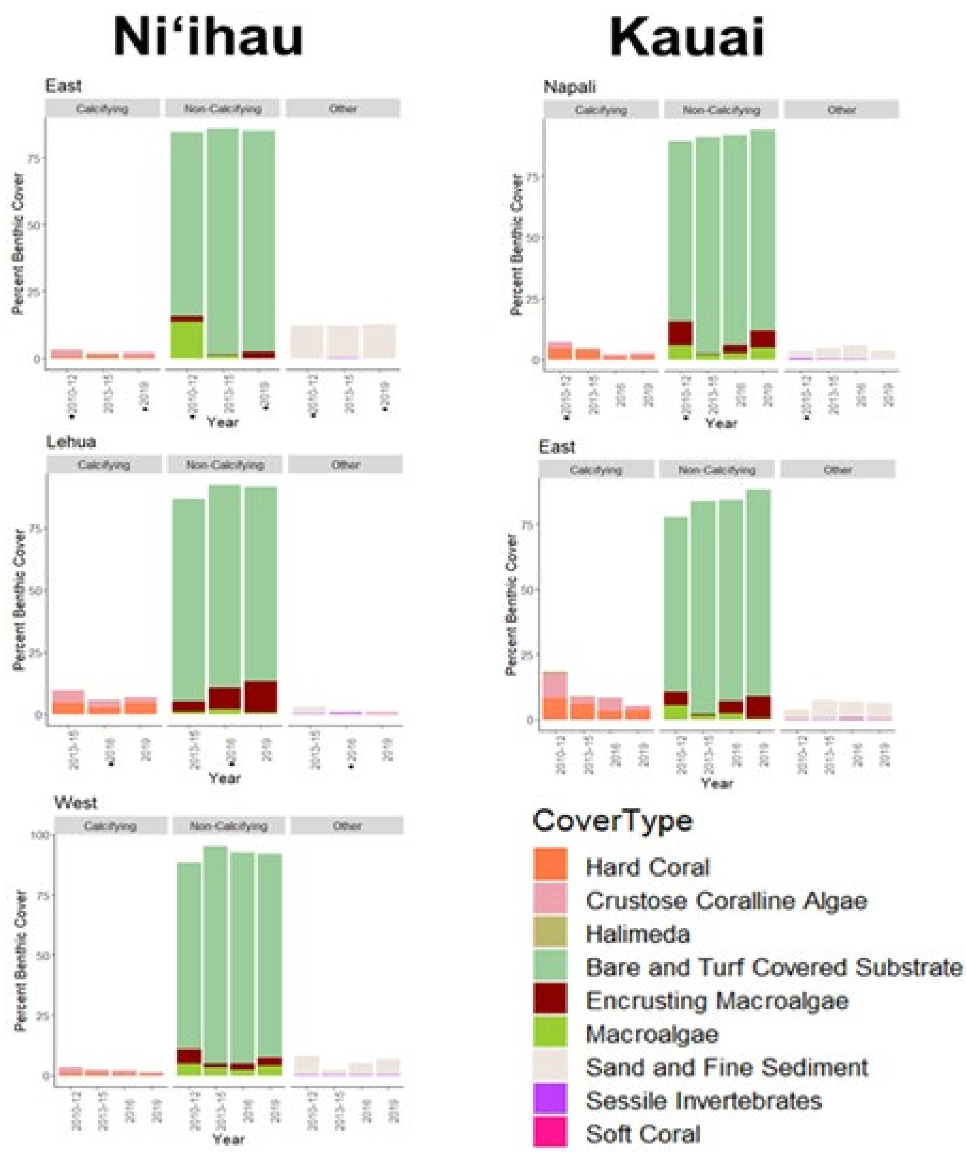

Figure 22: Percent by category of benthic cover observed for Ni'ihau and Kaua'i from Pacific Ramp from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data were generated from stratified random sites, not the same sites each year. Sectors with ≤5 survey sites are indicated with an asterisk (*)

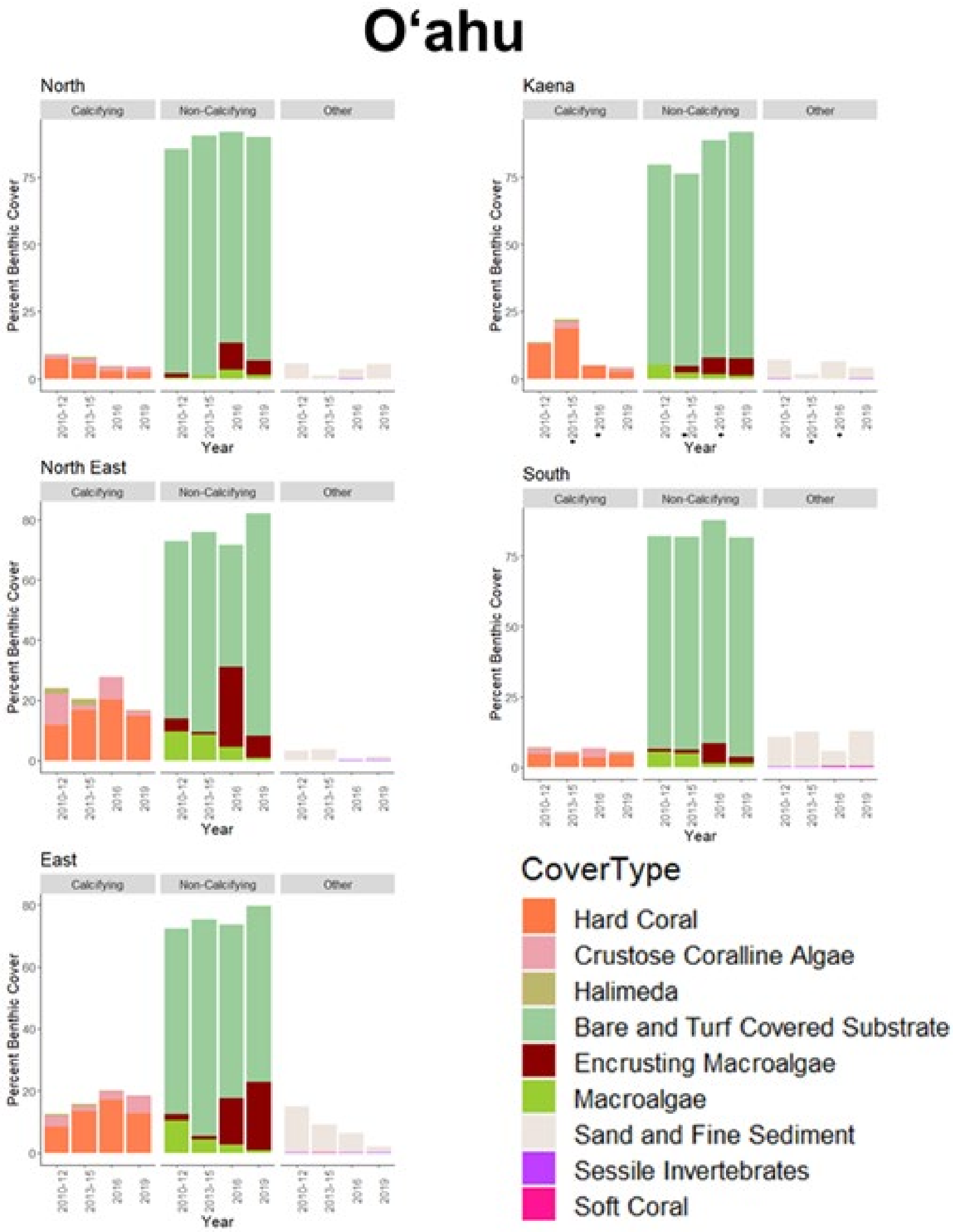

Figure 23: Percent by category of benthic cover observed for O'ahu from Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data were generated from stratified random sites, not the same sites each year. Sectors with ≤5 survey sites are indicated with an asterisk (*)

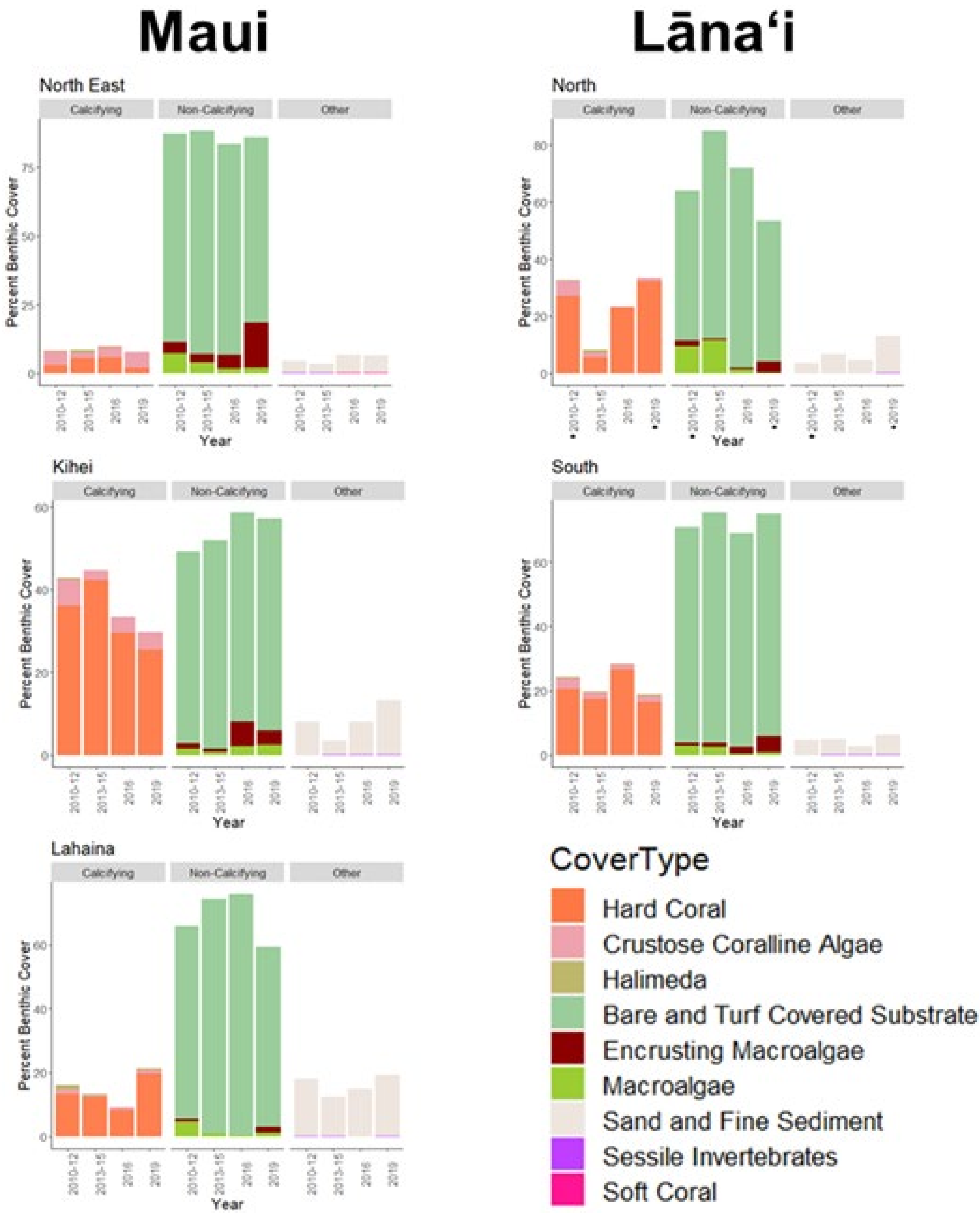

Figure 24: Percent by category of benthic cover observed for Maui and Lāna'i from Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data were generated from stratified random sites, not the same sites each year. Sectors with ≤5 survey sites are indicated with an asterisk (*)

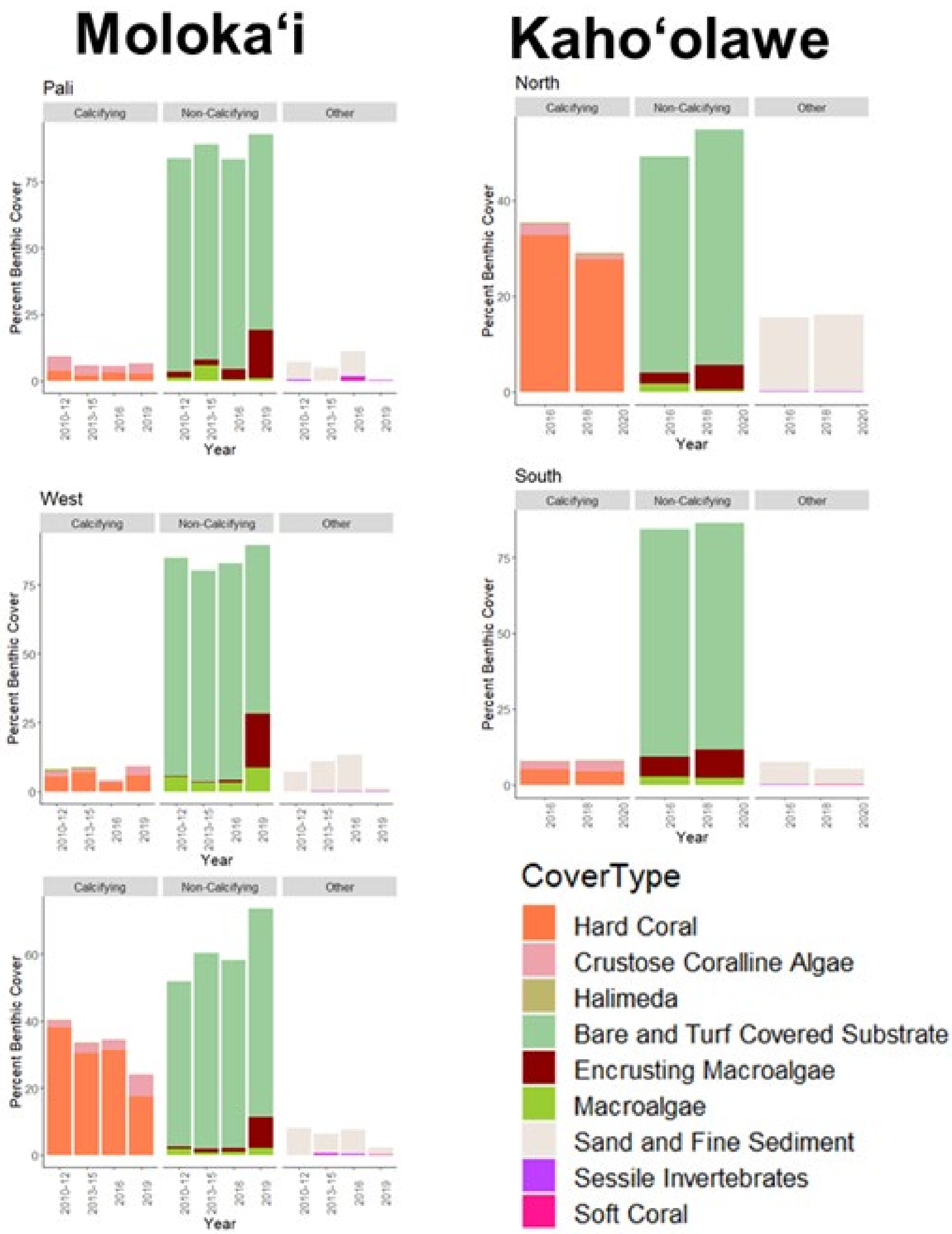

Figure 25: Percent by category of benthic cover observed for Moloka'i and Kaho'olawe from Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data were generated from stratified random sites, not the same sites each year. Sectors with ≤5 survey sites are indicated with an asterisk (*)

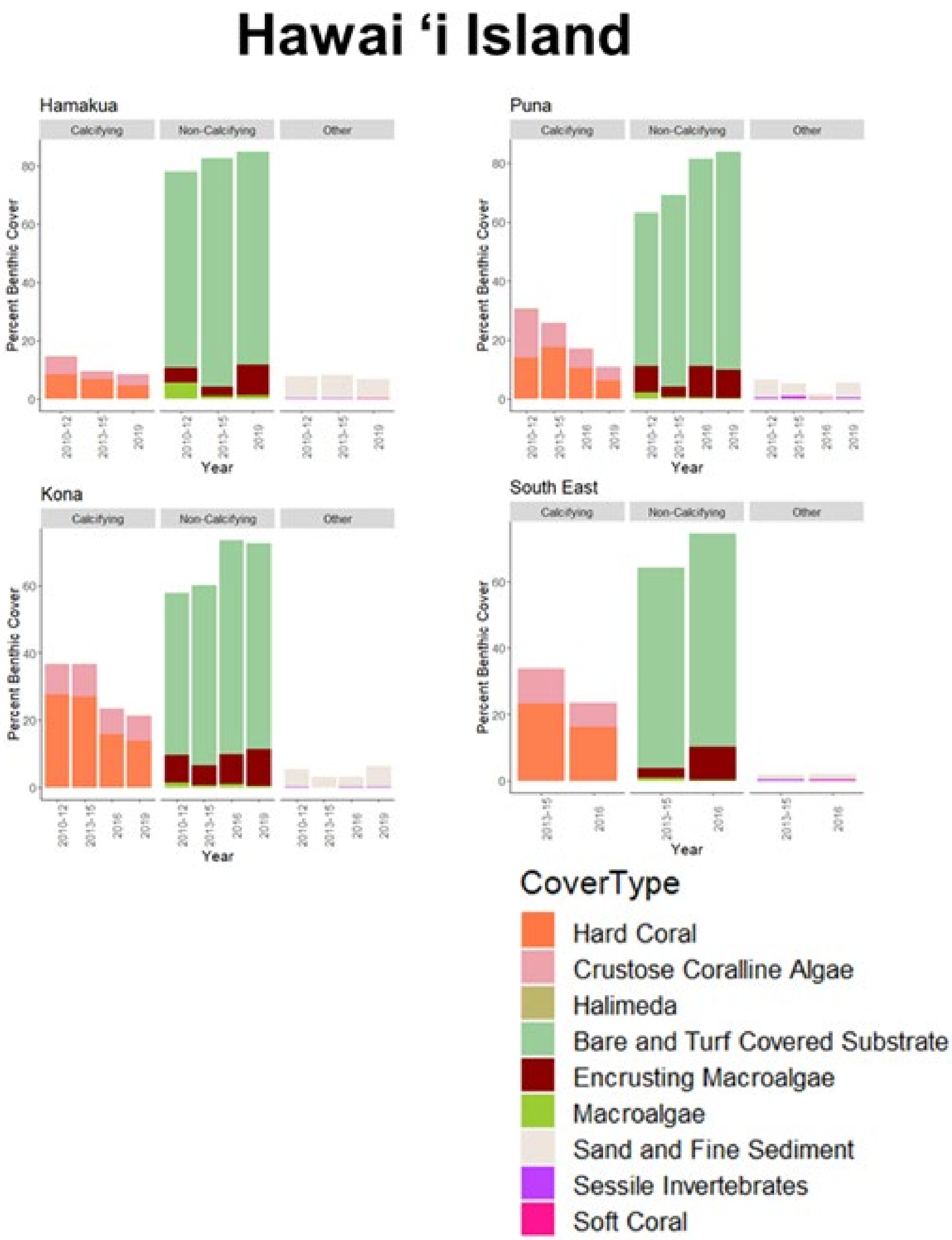

Figure 26: Percent by category of benthic cover observed for Hawaiʻi Island from Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data were generated from stratified random sites, not the same sites each year. Sectors with ≤5 survey sites are indicated with an asterisk (*).

Changes in Herbivore Biomass over time

Pacific RAMP has monitored fish biomass by trophic group (position within the food chain) from 2010- 2019 along with the benthic surveys described above. Along with benthic cover, herbivore biomass was variable across the main Hawaiian Islands[165] (Figure 29). Pacific RAMP also documented the mean biomass (grams/m^2) for each of the main herbivorous families: surgeonfishes (Acanthuridae), chubs (Kyphosidae), and parrotfishes (Scaridae) across each island sector (Figures 30-33). Fish surveys are difficult because the fish are moving and may avoid divers so the variability (error) between each year can be quite large.

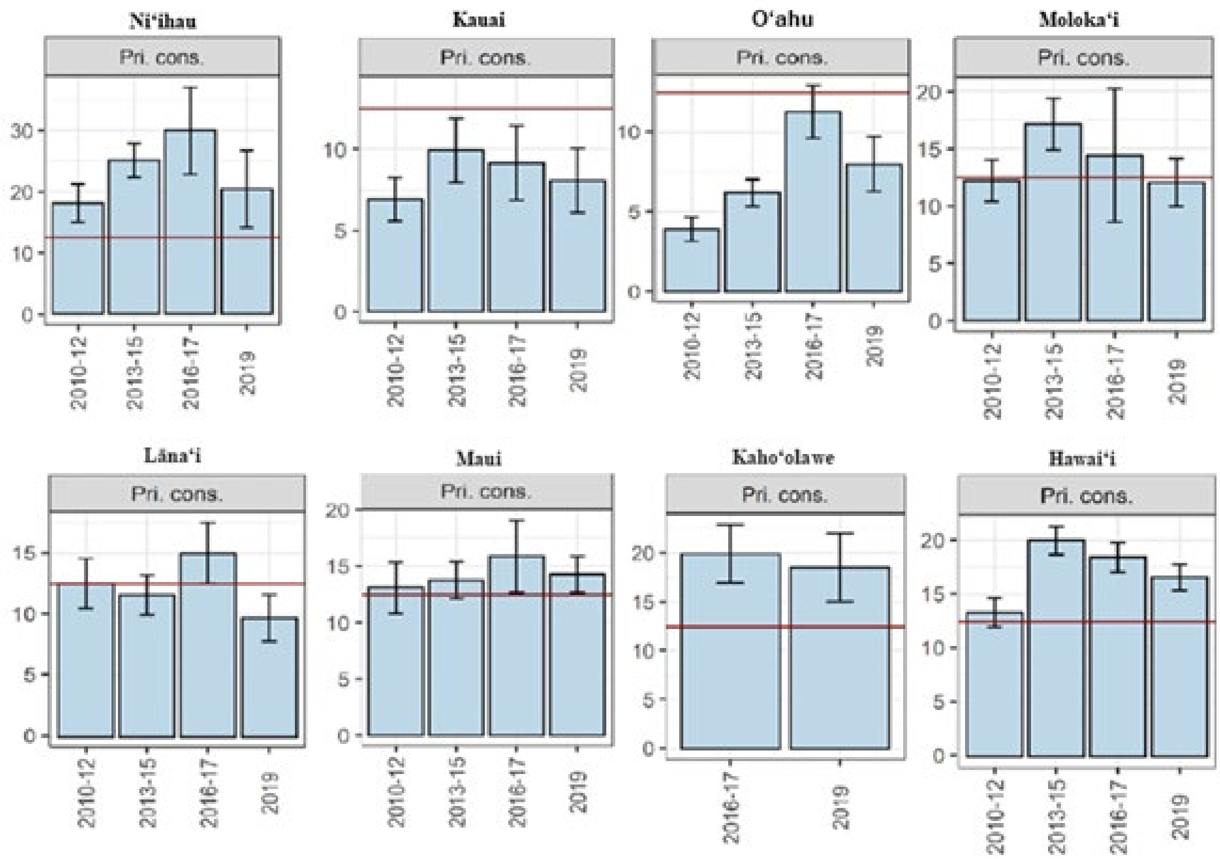

Figure 27: Mean biomass (g/ m² ± SE) of herbivores observed at each of the main Hawaiian Islands from Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. The MHI region mean estimates of fish biomass are plotted for reference (red line). Figures taken and compiled from McCoy et al. (2019).

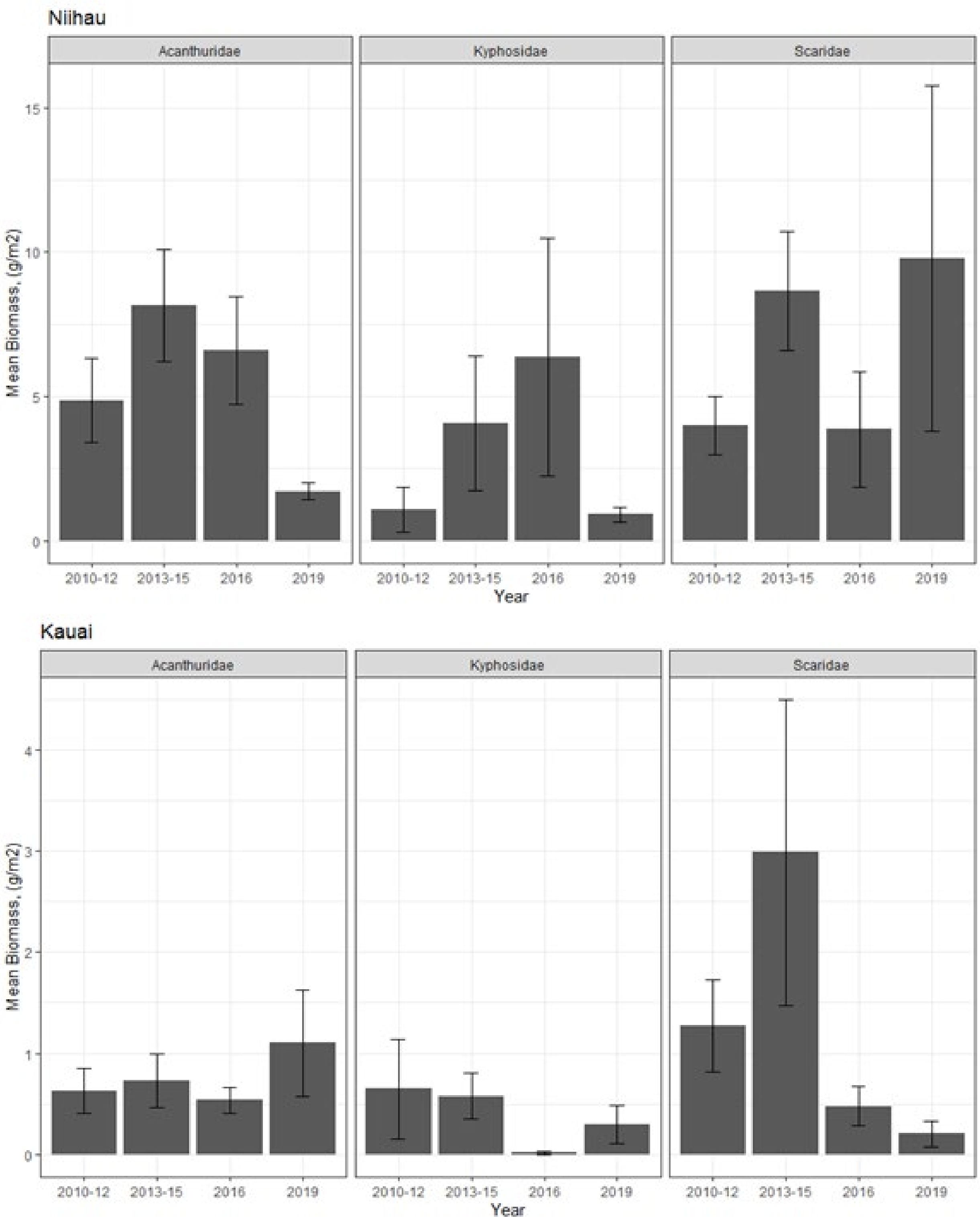

Figure 28: Mean biomass (g/ m² ± SE) of each of the main herbivorous fish families (Acanthuridae- surgeonfish, Kyphosidae- chubs, and Scaridae- parrotfish) observed at Ni'ihau and Kaua'i Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data source used with permission from Pacific RAMP.

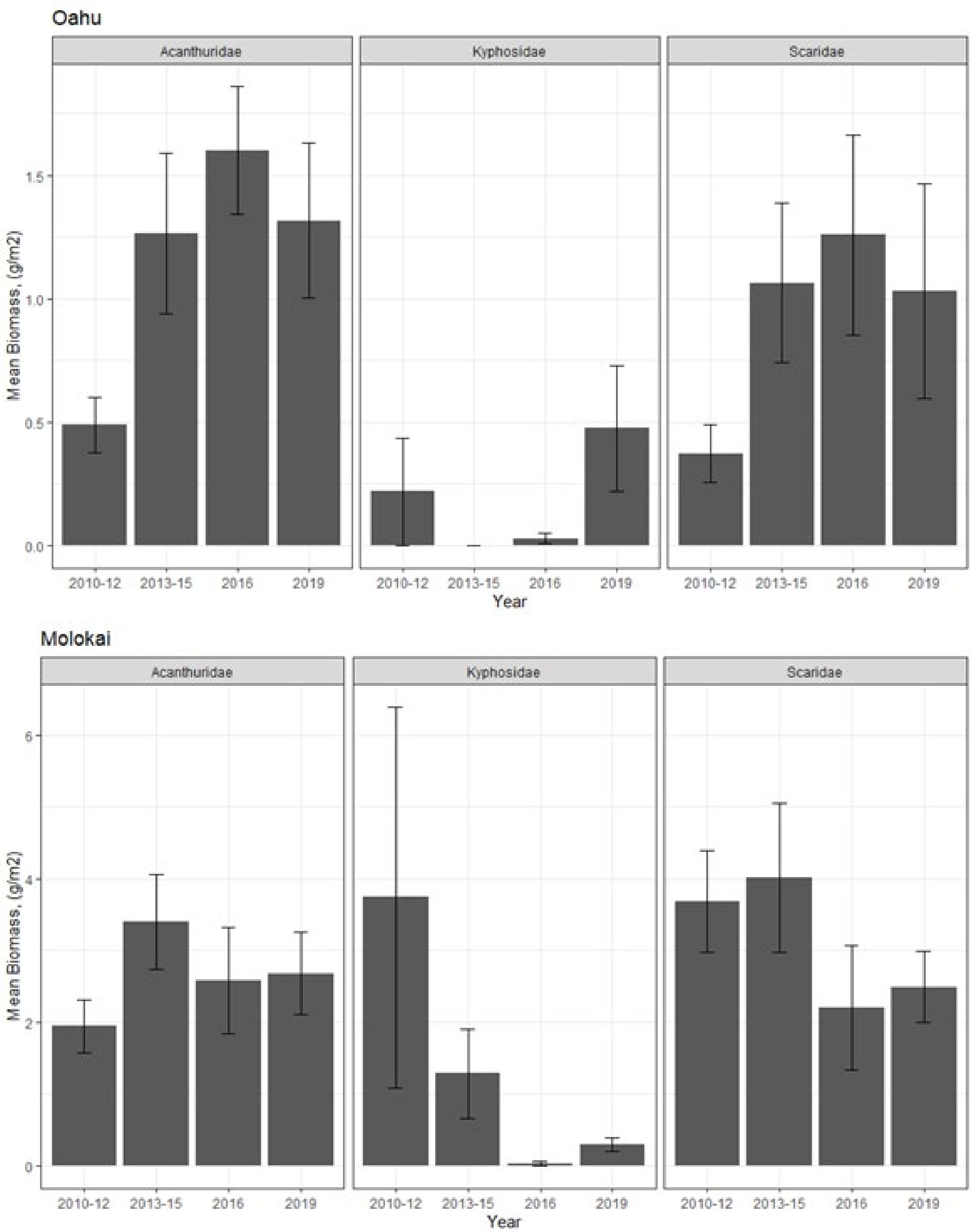

Figure 29: Mean biomass (g/ m² ± SE) of each of the main herbivorous fish families (Acanthuridae- surgeonfish, Kyphosidae- chubs, and Scaridae- parrotfish) observed at Oʻahu and Molokaʻi Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data source used with permission from Pacific RAMP.

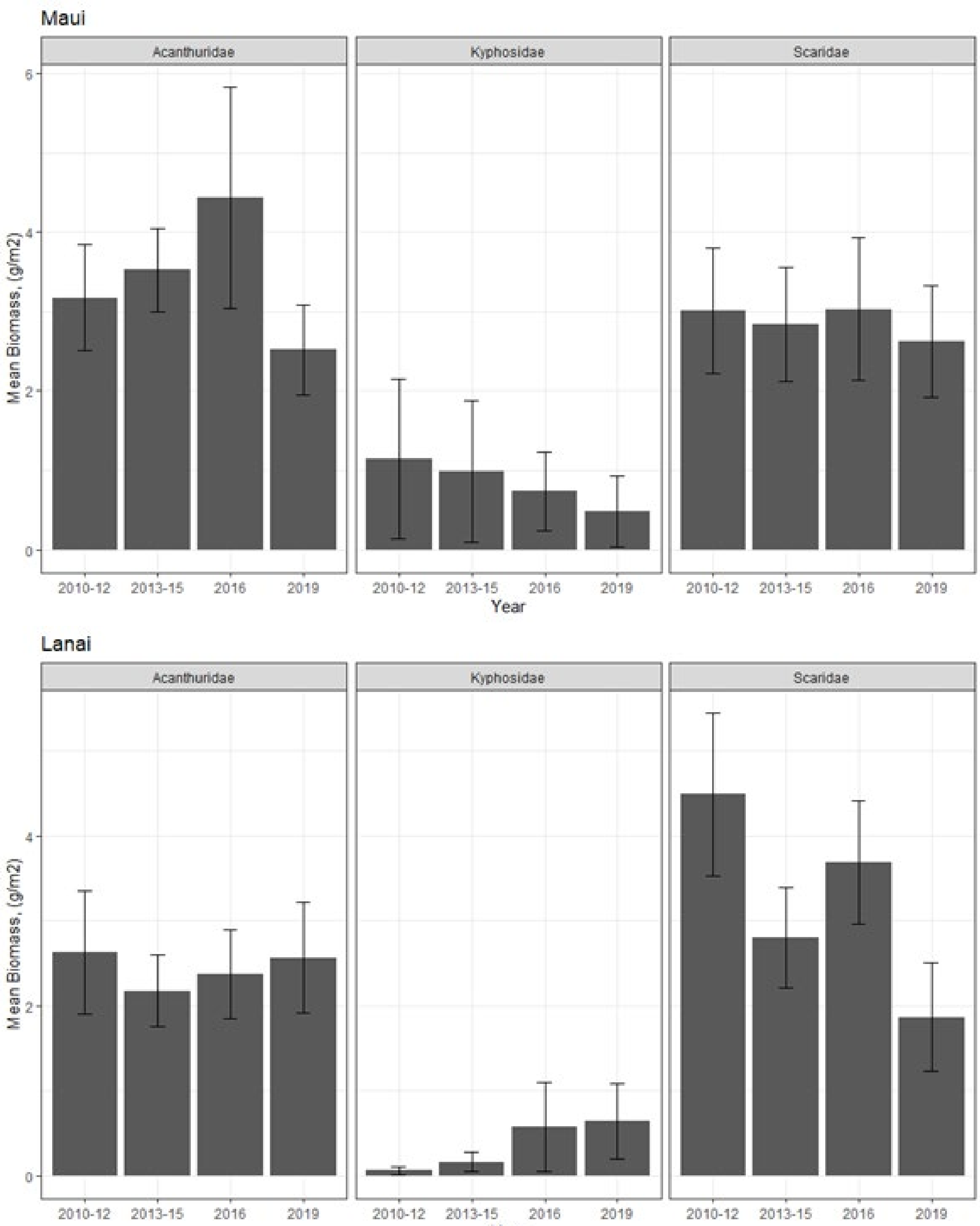

Figure 30: Mean biomass (g/ m² ± SE) of each of the main herbivorous fish families (Acanthuridae- surgeonfish, Kyphosidae- chubs, and Scaridae- parrotfish) observed at Maui and Lāna'i Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data source used with permission from Pacific RAMP.

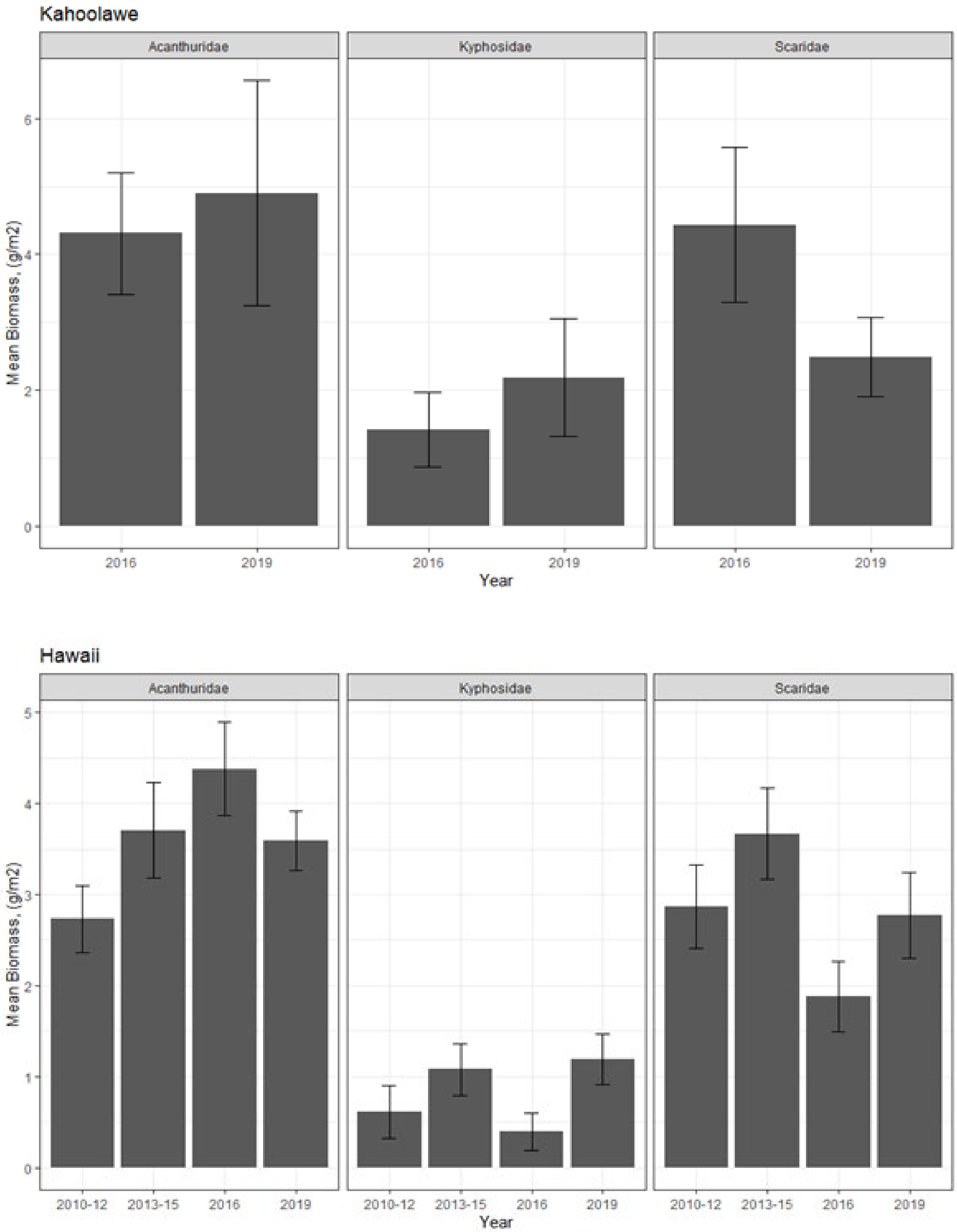

Figure 31: Mean biomass (g/ m² ± SE) of each of the main herbivorous fish families (Acanthuridae- surgeonfish, Kyphosidae- chubs, and Scaridae- parrotfish) observed at Kaho'olawe and Hawai'i Island Pacific RAMP from 2010-2019, binned as 2010-2012, 2013-2015, 2016-2017 and 2019. Data source used with permission from Pacific RAMP.