Holomua: Marine 30x30 Initiative

Sustainable Herbivore Management

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

Division of Aquatic Resources (DAR)

November 2021

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 Hawaiʻi 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 Hawaiʻi and 20-30% in Maui, left reefs in Hawaiʻi vulnerable to potential macroalgae overgrowth and smothering. Poor water quality also negatively affects reef health and recovery potential of corals. The reef has natural defenses against such overgrowth: herbivorous fishes and invertebrates graze down algae and support the resilience of these ecosystems. In addition, herbivores are an important food source in Hawaiʻi for residents. For these reasons, adaptive and effective herbivore management is crucial to the future of the reefs.

Regulations should reflect pono (doing what is right) fishing practices and provide clear standards and instructions as to 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 aquatic resources of Hawaiʻi and address local and global concerns for the health of nearshore marine ecosystems with the impacts of climate change.

The people of Hawaiʻi 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 the people, culture, and nearshore waters of Hawaiʻi. As an island State, we carry a responsibility to take care of our ocean. 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 Hawaiʻi for many reasons and they are in peril. Coral reefs protect shorelines in Hawaiʻi 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, commercial and non-commercial fisheries in Hawaiʻi are valued between $10-$16 million annually. In addition to the monetary value, the non-commercial nearshore fishery provides more than 5 million meals a year to the people of Hawaiʻi.[1]

Coral reefs are intricate ecosystems that face numerous challenges at both global and local scales. Threats to Hawaiʻi's coral reef ecosystems include climate change, ocean acidification, poor water quality resulting from land-based sources of pollution, excess nutrient runoff, physical damage from ocean activities, invasive species, marine debris, and unsustainable fishing practices. 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 Hawaiʻi.[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. 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 Hawaiʻi's coral reef ecosystems. Management objectives are rooted in the Holomua: Marine 30x30 four pillars: place-based planning, pono practices, monitoring, and protection and restoration. The success of this management plan relies on a multi-faceted approach, mai uka a hiki i kai, from the mountains to the ocean, 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.

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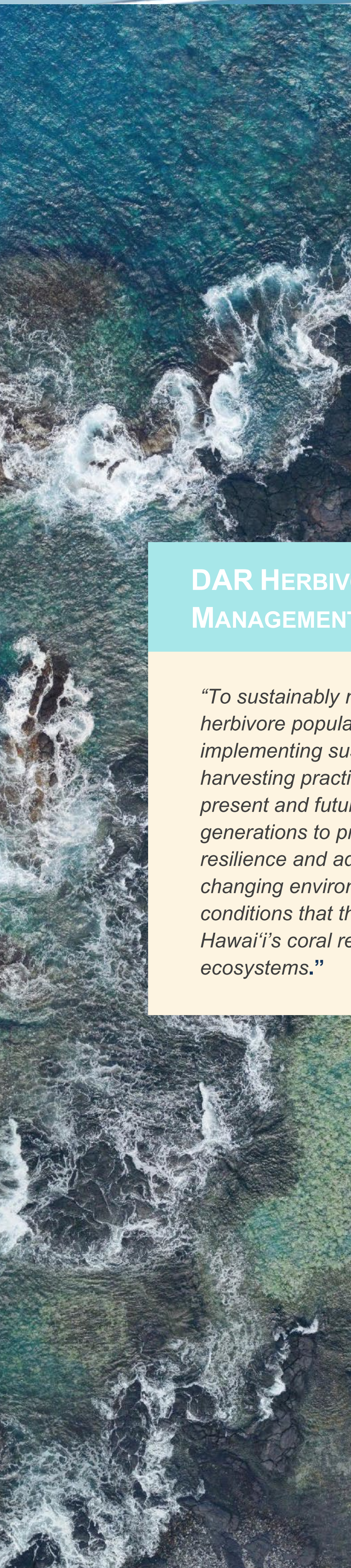
This management plan was developed and revised by DLNR, Division of Aquatic Resources' Holomua Marine 30x30 team (Luna Kekoa, Stacia Marcoux, Casey Ching, Amy Markel, Bert Weeks, and Anita Tsang), leadership (Brian Neilson, David Sakoda, Ryan Okano and Brian Kanenaka), and staff (Kirsten Moy and Amber 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 provided by the National Marine Fisheries Service Pacific Islands Regional Office. It was also externally reviewed by Dr. Ed DeMartini, Dr. Mary Donovan, Dr. Alan Friedlander, and Dr. Mark Hixon, recognized experts in coral reef ecology and fisheries in Hawai‘i. Species-specific images in the Pono Practices section were provided by and used with permission by Keoki Stender.

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 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 30x30**, a goal *to effectively manage Hawai'i's nearshore waters, with at least 30% established as marine management areas by 2030*. 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. The *Holomua: Marine 30x30* Roadmap (https://dlnr.hawaii.gov/dar/files/2020/12/HolomuaMarine30x30_Roadmap_web.pdf) outlines how DAR plans to work in partnership with communities to operationalize the four pillars to achieve shared nearshore management goals. The four pillars introduced in the Roadmap are Place-Based Planning, Pono Practices, Monitoring, and Protection and Restoration. This management plan is organized and presented within the framework of the four pillars (Box 2). Each pillar has a specific objective that will work towards the overarching goal (Box 1).

Photo: PICES/Gov of Japan/DLNR

Holomua: Marine 30x30 Four Pillars

This management plan is organized and presented within the framework of the four pillars of Holomua 30x30. 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 focuses on community partnerships to build a cohesive, ecologically connected network of areas for improved marine management that will make up 30% of nearshore waters, within the 50-meter (164-foot) depth contour, by island. **Herbivore-Specific 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. The Pono Practices pillar is a call to action for resource users to interact with nearshore resources in a pono way. **Herbivore- Specific 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 ecological 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. **Herbivore-Specific 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.

PROTECTION AND RESTORATION is a multi-faceted approach to manage for improved reef restoration and resilience, including both resistance to and recovery from disturbance. Protection and restoration build 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. **Herbivore-Specific 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 scale-up restoration efforts.

Box 2. Aligning Herbivore Management with the four pillars of Holomua: Marine 30x30

INTRODUCTION

The health of coral reefs is important for people in Hawai‘i for many reasons and reefs are in peril. While many people recognize the importance of healthy reefs for productive fish communities and fisheries, coral reefs in Hawai‘i also protect shorelines and infrastructure (valued at $836 million per year of flooding protection[6]) during storms from high wave impacts and erosion and provide jobs to thousands of residents. Considering only economic factors, in 2002, nearshore reefs in Hawai‘i generated about $800 million annually in gross revenues with $364 million of that representing value added specifically from reefs.[7]

What is an herbivore?

A marine herbivore is a fish or invertebrate that mainly eats plant and algal material.

Box 3

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.[8–10] 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. [11]

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.[12]

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, that lead them to expel the symbiotic algae living in their tissues, often causing them to turn completely white.[13] The likelihood of coral death from bleaching is dependent on the intensity and duration of heat stress.[14] There is a higher likelihood of coral's dying when ocean temperatures remain 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. [15] These events are predicted to occur more frequently in the future, and in some locations, severe bleaching will occur annually by 2034.[5] Up to 90% of reefs around the world are projected to experience severe annual bleaching by 2055.[16]

In addition to warming, global oceans are also becoming more acidic, compromising the calcification and growth of reef structures.[17] 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. **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. They produce a calcified substance that provides this structural support for reefs, that can be weakened or reduced in acidic conditions. Ocean acidification will also lead to increases in algal growth and diversity and decreases in reef complexity 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.[18] Human population growth, water quality, and unsustainable fishing practices also impact coral reef communities. Populated areas that are accessible to fishing are often overexploited and have lower fish biomass than unpopulated inaccessible areas.[10] 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.[9,10]

Role of Herbivory in Reef Resilience

Resilience, with respect to coral reefs, is the ability to resist and recover from disturbances and maintain ecosystem functions.[19,20] 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 (in both species and size) 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 can smother coral reefs without enough grazing pressure.[21,22] Juvenile urchins (and fishes) are able to get into the small places of the reef that larger-bodied fishes are not able to reach. Sea turtles are also important grazers, preventing overgrowth of macroalgae on reefs in Hawai'i.[23]

Herbivore is a broad term that includes a wide range of species; and not all species play the same role in reef resilience. Some species graze on larger macroalgae that can overgrow and displace corals, while others scrape away algal turfs (dense threadlike algae covering surfaces on the bottom of the ocean, like rocks and reefs) 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.[24]

Herbivorous reef fish are categorized into functional groups: browsers, grazers, scrapers, and excavators.[25] **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.[26,27] 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,[28] and having a diverse community of herbivores that complement and reinforce one another’s roles, optimizes reef resilience.[29]

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” [30] throughout disturbance events to prevent coral-dominated communities from shifting to algae-dominated communities.[31]

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 a detrimental event was 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.[32] 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.[33]

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.

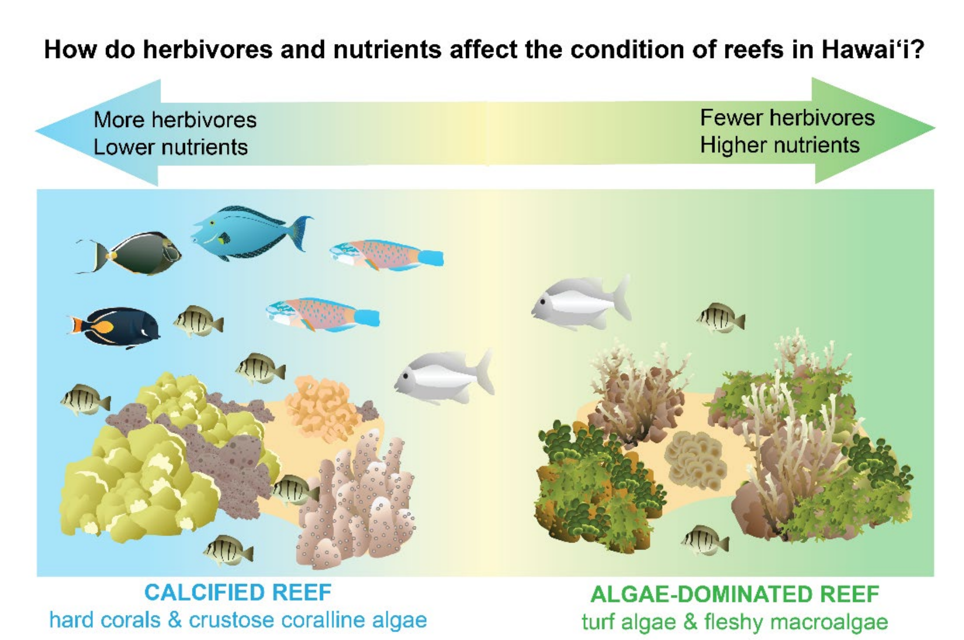


Figure 1: Illustration showing the key role of herbivore fishes as gardeners of the reef. They can regulate algae levels, cleaning space for corals and coralline algae to grow and build the reef. When herbivores are abundant and nutrient levels are low (blue), the reef can remain in a calcified status with a lot of crustose coralline algae. When nutrient levels are high and/or there are not enough herbivores (green), algae can overgrow and smother corals, resulting in an algae-dominated reef. The infographic was created by DAR (Laura Gajdzik and the Holomua: Marine 30x30 team using Vecta) in collaboration with HIMARC (Ellie S. Jones).

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.[34] 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 of organisms 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 Hawai‘i

Fishing is intricately entwined within culture in Hawai‘i 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 Hawai‘i 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 in Hawai‘i, 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 Hawai‘i.[1] Aside from the monetary value, the nearshore coral reef fishery in Hawai‘i is an essential component of food security and regional cuisine for many families and communities. 90% of adults in Hawai‘i consume fish every month, with the highest consumption occurring in Native Hawaiian and Filipino communities.[35]

Seafood consumption in Hawai‘i is more than double the national average. The nearshore fishery provides more than 7 million meals a year, with 5 million provided by the non-commercial fishery alone.[1] Of the total reef fishes catch statewide, an estimated 84% is non-commercial, but variations in this percentage occur by island.[36] There is no reporting requirement for non-commercial catch in Hawai‘i, so these values are estimated. For example, on Moloka‘i, 95% of the catch is non-commercial, whereas 77% is non-commercial on O‘ahu.[37] Herbivores make up 21% of the total meals the non-commercial fishery provides.[1] Given the significance of the nearshore coral reef fishery and DAR’s kuleana to manage, conserve and restore the State’s aquatic resources, active and **adaptive management** focused on sustainability is imperative.

CURRENT STATUS

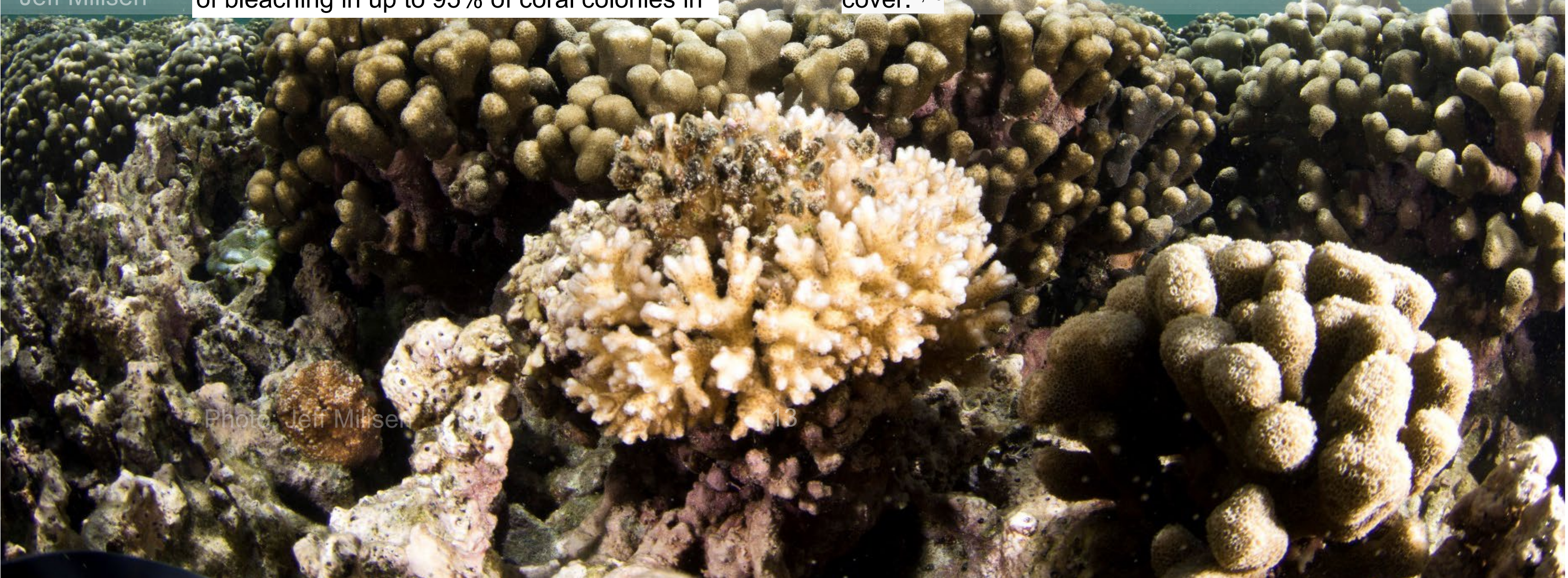
Benthic Communities in Hawai‘i

Coral cover is spatially variable around Hawai‘i[38–41] (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 greatest 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[38,41] (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).[38]

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.[38] 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.[42] Hawai‘i Island's Kona coast, saw coral losses of nearly 50% due to bleaching regardless of management type[4,43,44] (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.[45] Even marine protected areas like Hanauma Bay experienced bleaching and mortality in 2015.[46] 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*[47] (rare in Hawai‘i) and commonly found species such as *Pocillopora*[48] 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 (*Porites* 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.[4,49]

Photo: Jeff Milisen



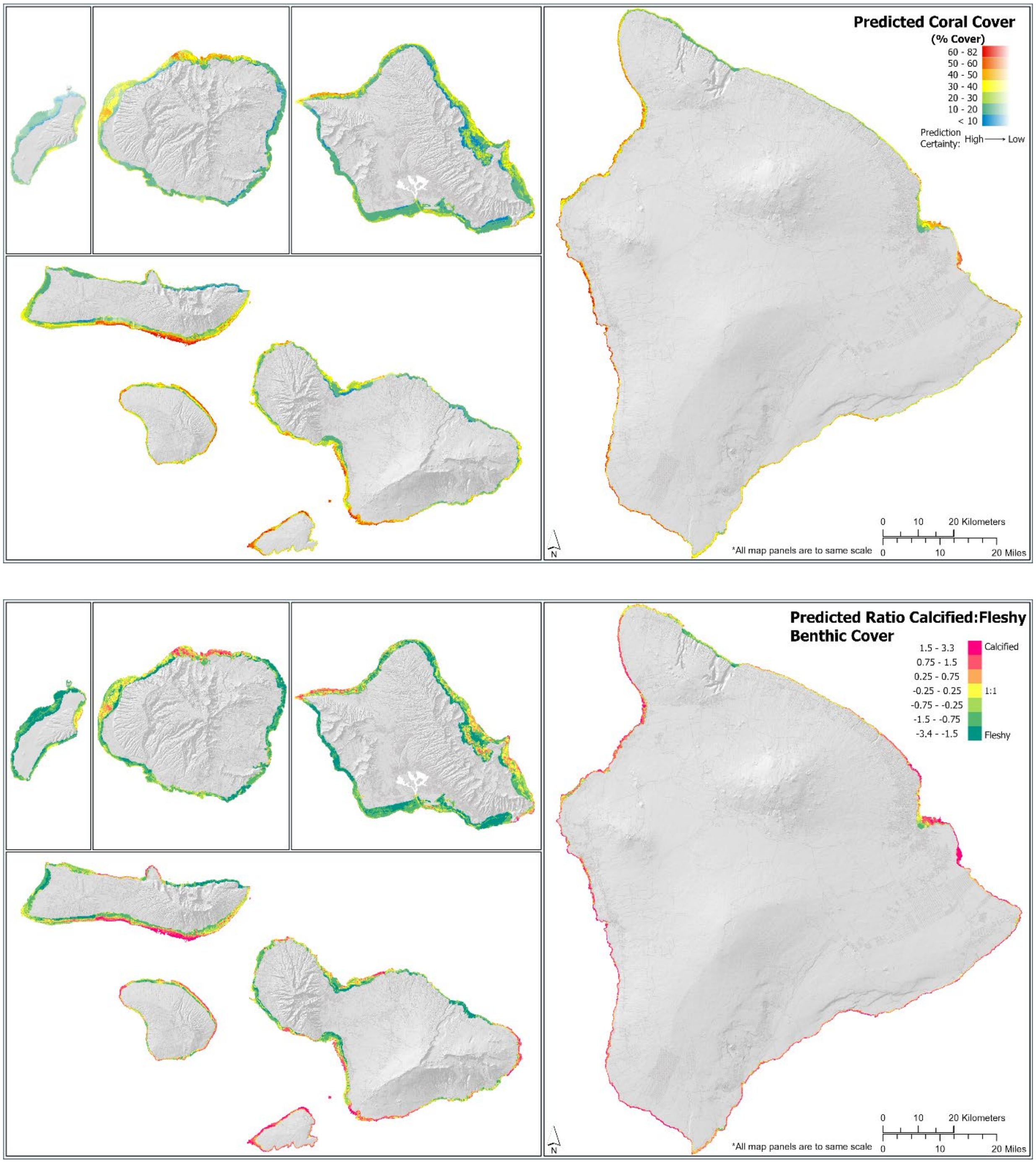


Figure 2: Predicted maps for hard bottom habitats 0-30 meters depth at a spatial resolution of 100m generated by the Hawai'i Monitoring and Reporting Collaborative (HIMARC)[36] using combined data from 2004-2014 from multiple statewide monitoring programs and comprehensive mapping of drivers in a Bayesian Hierarchical Model. (Top) Percent Coral Cover, with high cover in red and low cover in blue. (Bottom) Ratio of calcified to fleshy benthic cover, areas in red have high calcified cover (more coral, less algae) and areas in green have high fleshy cover (less coral, more algae)

Herbivores in Hawai‘i

Herbivore biomass, like coral cover, is also spatially variable due to a range of factors, including habitat, physical/oceanographic drivers, and human impacts. Human impacts negatively affecting herbivore biomass are urban runoff, cesspool effluent, and fishing pressure.[38,50] Many locations with high herbivore biomass (Figure 4 - orange and red on the map) are in areas that are relatively less accessible by humans, and with high wave energy, which is an important physical factor for both coral cover and herbivore biomass. High wave energy can also act as a pseudo-fishing reserve, when seas are rough, by limiting human accessibility to fishing when weather conditions are not favorable for fishing.

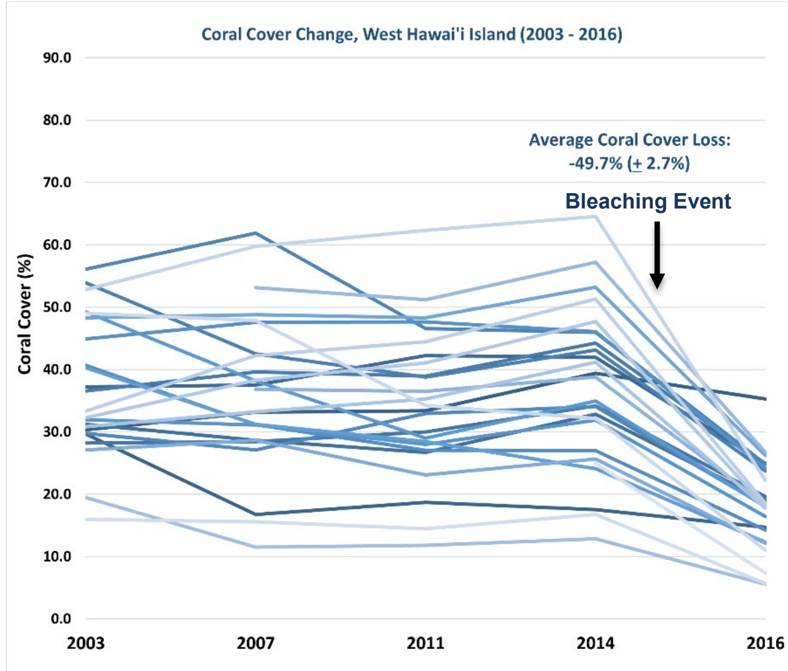


Figure 3: Change in coral cover (%) across the 25 DAR Kona fixed monitoring sites from 2003-2017. A global-scale coral bleaching event caused catastrophic declines in coral cover in the Fall of 2015. Figure taken from Walsh et al. 2019.

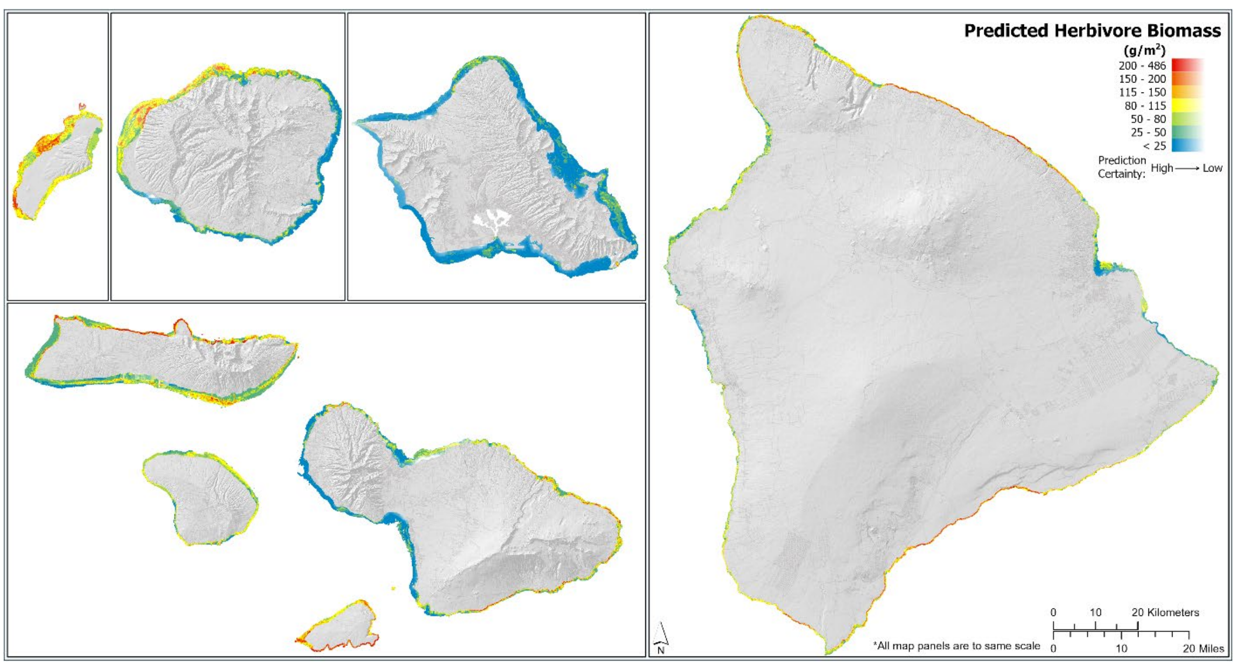


Figure 4: Predicted map of herbivore biomass for hard bottom habitats 0-30 meters depth at a spatial resolution of 100m generated by the Hawai‘i Monitoring and Reporting Collaborative (HIMARC)[36] using combined data from 2004-2014 from multiple statewide monitoring programs and comprehensive mapping of drivers in a Bayesian Hierarchical Model. Areas in red are where herbivore biomass is the highest and areas in blue are where herbivore biomass is the lowest.

Herbivore biomass is generally lower on O‘ahu than everywhere else (Figure 4, Figure 5), which is likely related to the compounding effects of land-based sources of pollution, urbanization and fishing pressure. Herbivore biomass for all six moku on O‘ahu was in the lowest quarter of values across all moku, with mean herbivore biomass ranging from 7.6 g/m^2 in O‘ahu Kona to 22.2 g/m^2 in Ko‘olauloa. Several moku on Maui were also among the lowest herbivore biomass including Lahaina and Kealaloloa.

Herbivore biomass was highest where fishing is prohibited or highly restricted and in the most remote places where there are low levels of urbanization and limited human access. Kona Kaho‘olawe had the highest mean biomass of 164.4 g/m^2, and other moku on Kaho‘olawe, Hawai‘i, Moloka‘i, and Ni‘ihau made up the highest quarter of all values across moku.

These areas had herbivore biomass comparable to that observed inside Marine Life Conservation Districts (MLCD), where fishing is prohibited or highly restricted (Figure 5, grey area). Only 11 of the 40 moku had mean herbivore biomass values within the range of estimated biomass for MLCDs (moku bars overlap grey box in Figure 5).

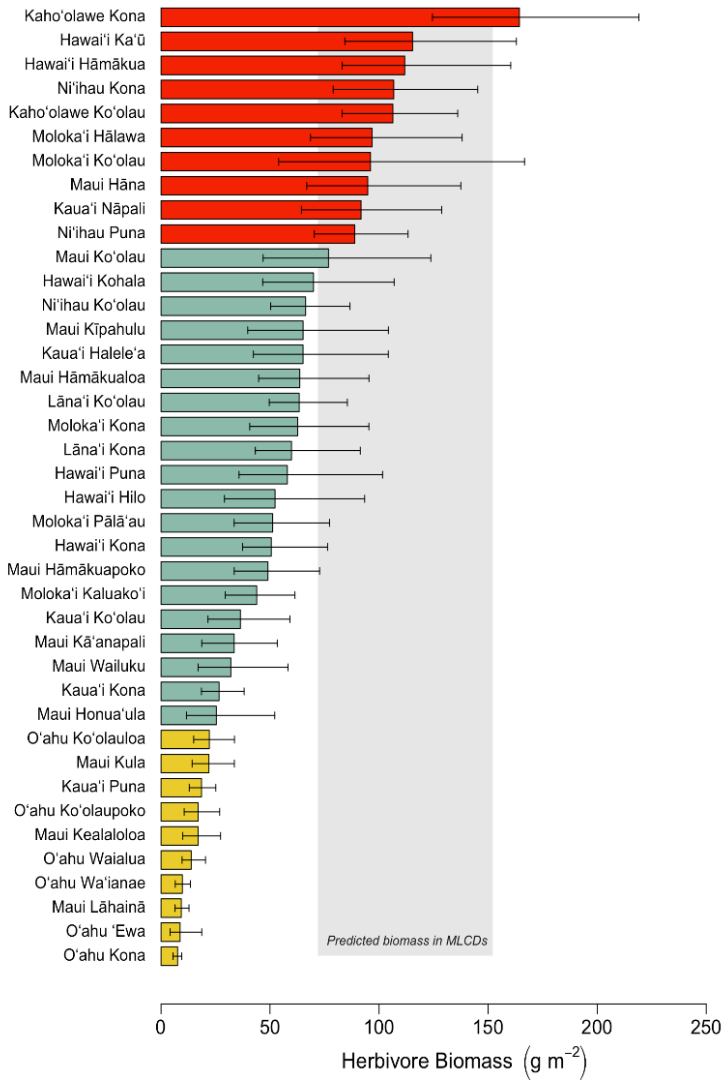


Figure 5: Predicted herbivore biomass summarized across moku based on predicted maps in Figure 4[36]. Bars are means of posterior predictions for all 100m pixels in a given moku, and thus represent estimates that account for the relative distribution of habitat and variation in other predictors in a given moku. Moku with median values in the upper quartile (top fourth) are colored red, and moku with median values in the lower quartile (bottom fourth) are colored yellow. Error bars correspond to 50% intervals of posteriors for all 100m pixels in a given moku. Grey shaded area corresponds to the 50% interval of posterior for all 100m pixels inside Marine Life Conservation Districts, which highly restrict fishing, and thus can serve as a no-take

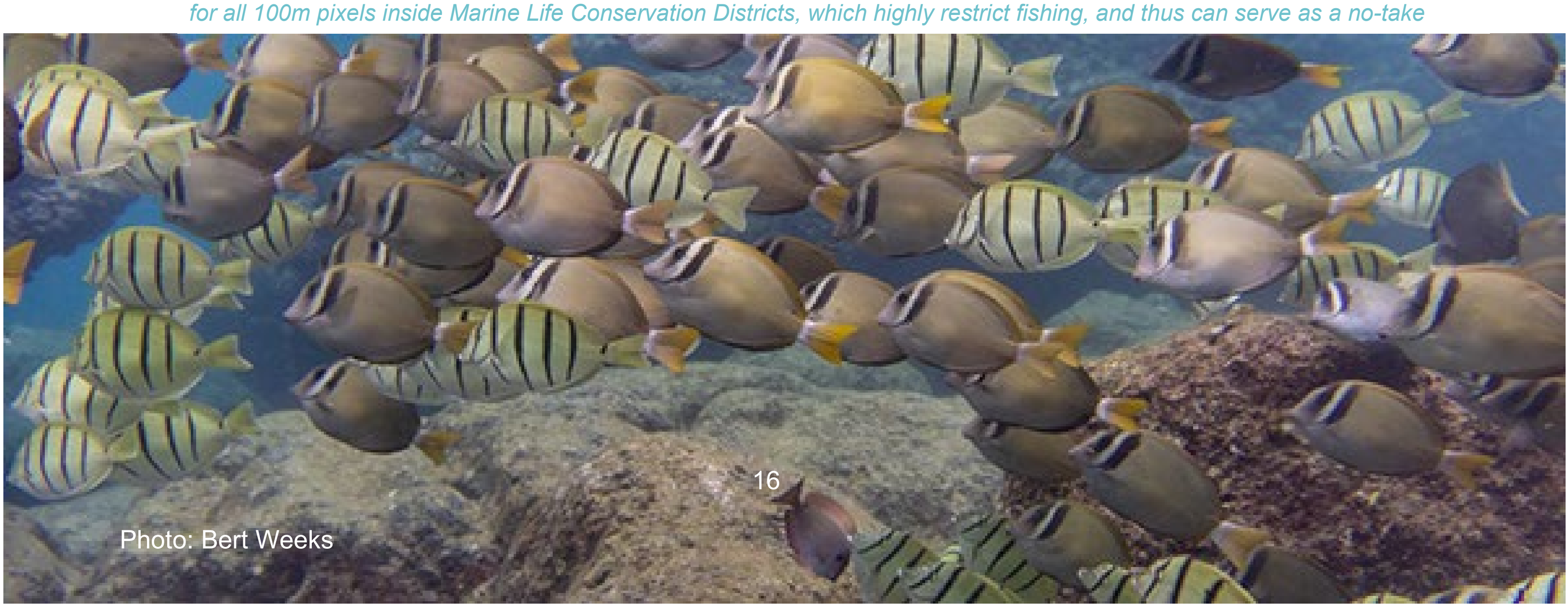


Photo: Bert Weeks

The large gradient in biomass and comparisons between fished and less fished areas illustrates the depletion of herbivore stocks and the need for management to both reduce stressors to recover depleted areas and maintain stocks in areas with high biomass. Similarly, when compared to the Northwestern Hawaiian Islands (NWHI) as a reference, herbivore biomass was four times lower in the main Hawaiian Islands (MHI), where herbivores accounted for 61% of total resource biomass (compared to 39% in the NWHI), further highlighting the level of reduced biomass in much of the MHI in the presence of human impacts.[10]

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 fishing pressure.

This coincides with a decrease in the 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 (Eyestripe Surgeonfish, Ringtail Surgeonfish, and Yellowfin Surgeonfish), Kala (Unicornfish), Nenue (Chubs), and Manini (Convict Tang).

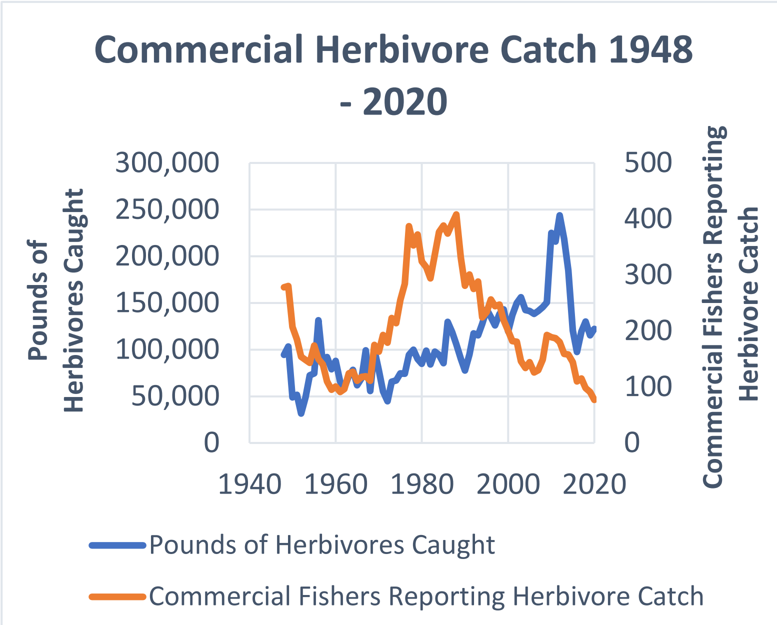


Figure 6: Annual reported commercial catch of herbivorous fishes and number of commercial fishers reporting from 1948 – 2020.

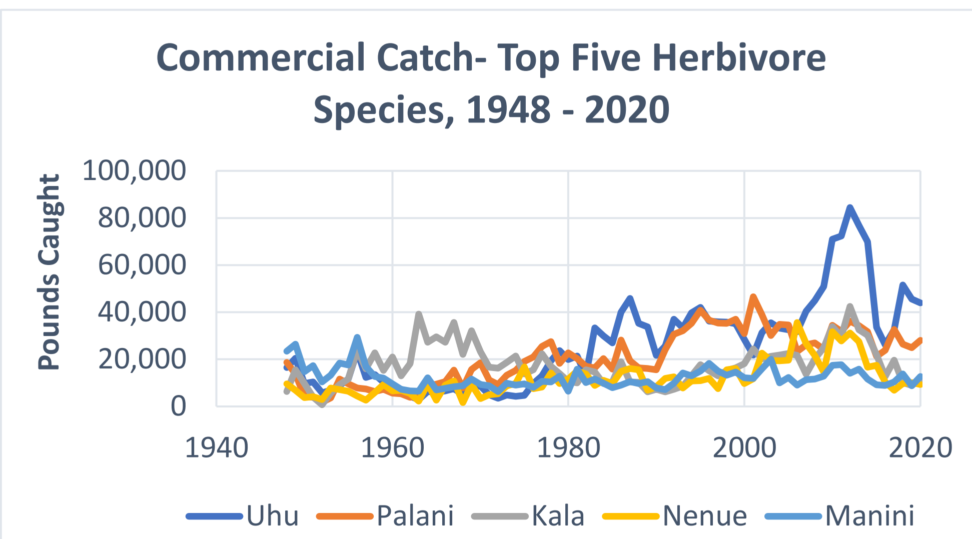


Figure 7: Annual reported commercial catch (in pounds) of the top five caught herbivorous fishes from 1948 – 2020.

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 algae) dominated condition.[51–53] These target levels have not yet been assessed for Hawai‘i’s reefs. Coral reefs in Hawai‘i 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’s 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. Resource managers in Hawai‘i 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 Protection” target, seek to protect and restore priority watersheds throughout the state, contributing to healthier ecosystems from ridge to reef through decreased erosion and land-based sources of pollution.[54] 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, abundance, and biomass to optimize reef resilience while balancing the needs of resource users.

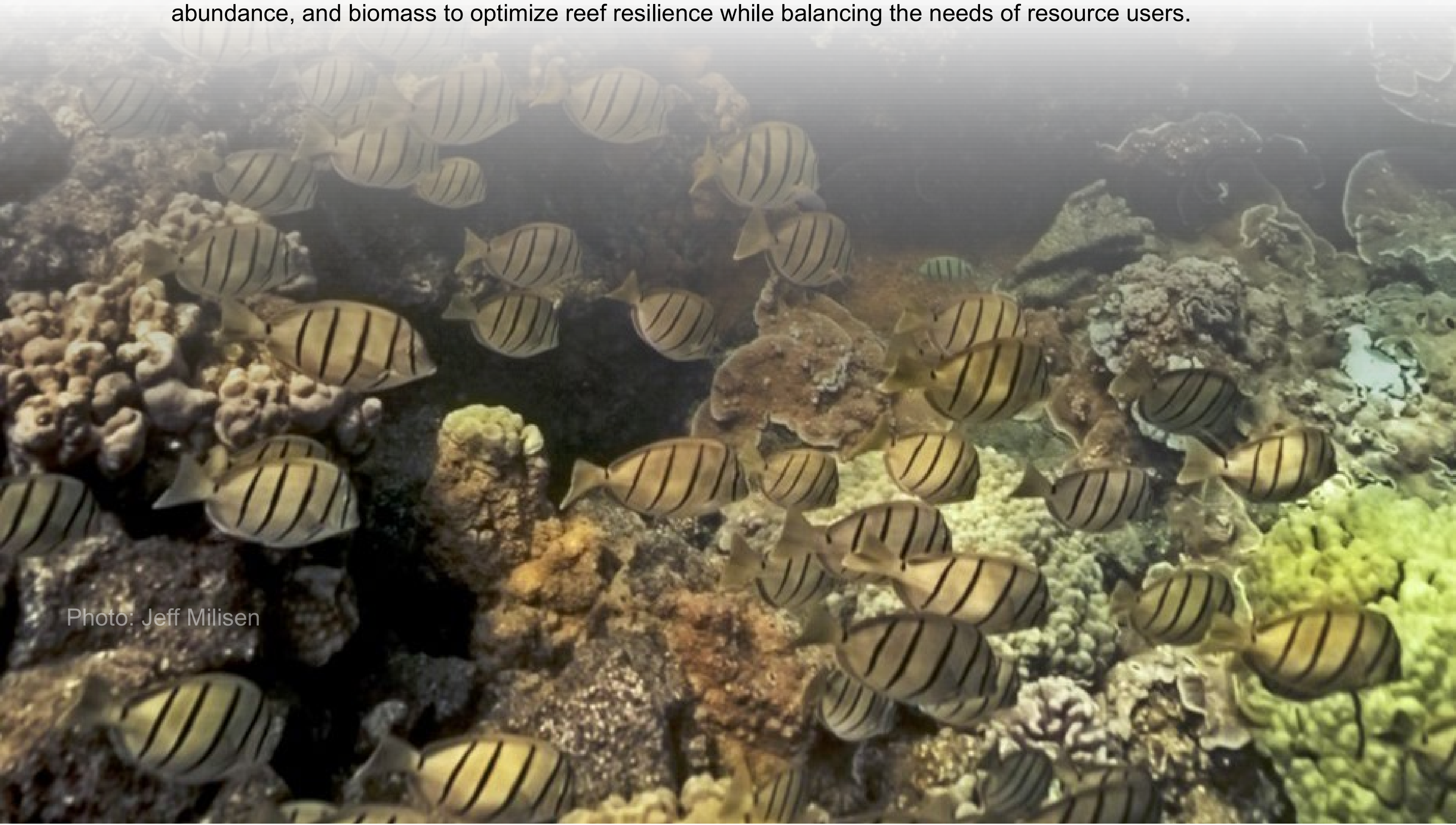


Photo: Jeff Milisen

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 harvest practices for present and future generations to promote resilience and address rapidly changing environmental conditions that threaten Hawaiʻi's coral reef ecosystems. DAR has developed the following objectives and action items that fall within the four pillars of Holomua: Marine 30x30 to help achieve the herbivore management goal.

PLACE-BASED PLANNING

Place-Based Planning integrates the recognized differences in species diversity, abundance, and harvesting practices into management planning. This pillar focuses on community partnerships to build a cohesive, ecologically connected network of areas for improved marine management that will make up 30% of nearshore waters, within the 50-meter (164-foot) depth contour, by island.

Herbivore-Specific 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.

Actions within this pillar will focus on activities and community engagement to implement MMAs that reflect specific needs and concerns of each place.

- ***Action PB.1*** By 2024, begin engaging 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 Hawai'i with boundaries overlapping the nearshore (50-meter/ 164-foot depth), encompassing 6% of nearshore waters (of the 30% goal). Within the nearshore, 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). Some of the areas labeled as "partial protection" may not have rules specifically established to address the take of herbivores and as such, may have limited conservation value.

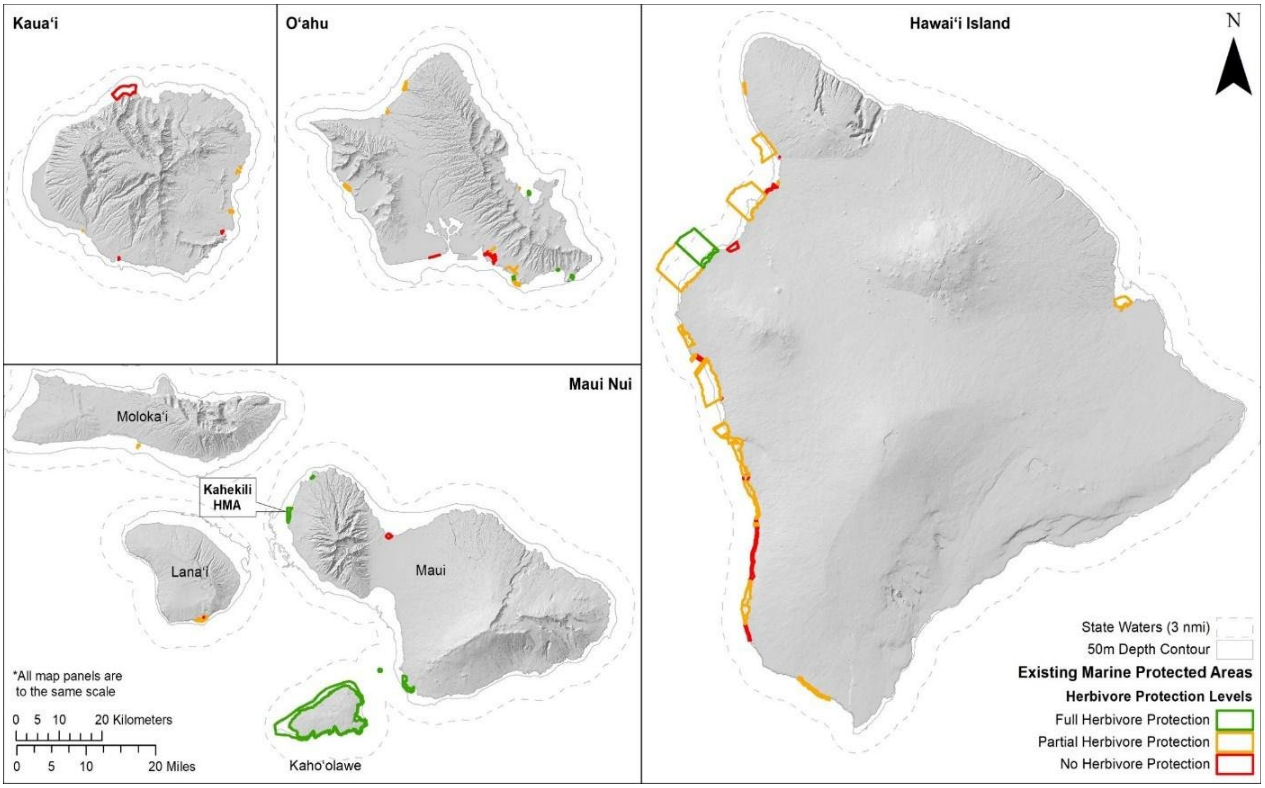


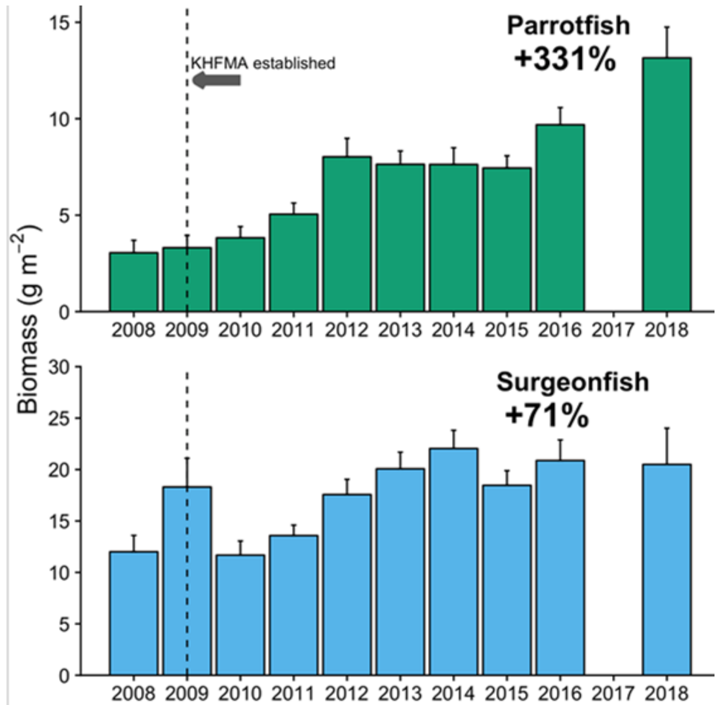
Figure 8: Map of existing Marine Management Areas in Hawai'i and the level of herbivore protection for each place, based on existing rules

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. Working with local communities, DAR plans to implement new and revised MMAs by 2030 that will promote the sustainable management and harvesting of herbivorous and other nearshore species at a place-based scale throughout each of the main Hawaiian Islands.

Management Actions and Their Effects

The following two case studies demonstrate the 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. Leading up to the establishment of the KHFMA, state monitoring results showed that coral cover along this section of coastline had declined dramatically and that reefs were periodically overgrown by blooms of algae. There were concerns about injection wells and the need to control high nutrient inputs in the area contributing to these algae blooms. The condition of the reef was particularly concerning in 2005 and 2006, when dense summer blooms of the alien algae *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.

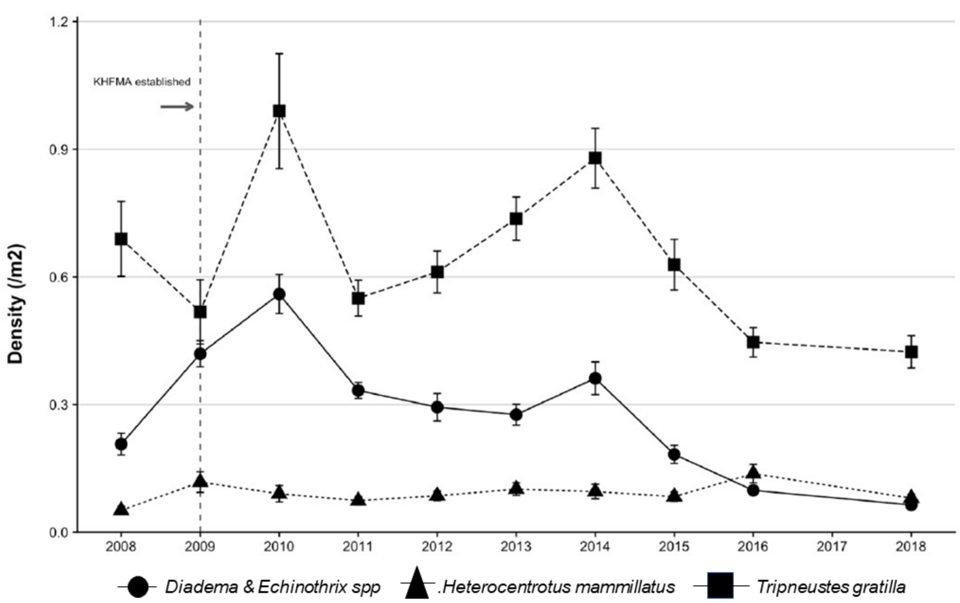


Figure 9 (Right): Change in biomass of Parrotfishes (top) and Surgeonfish (bottom) by species from 2008-2018 at Kahekili Herbivore Management Area. Figure from DAR 2018 results brief. These results were updated from the published findings in Williams et al 2016.

Figure 10 (Lower): 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]

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.

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.

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[56]) 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[55,57] (Figure 10).

These changes in benthic composition along with increasing herbivore biomass are positive signs that the reef is becoming a more suitable environment for coral settlement and growth. Overall, these changes should help the corals in this area become more resilient to disturbances and hopefully better persist into the future.

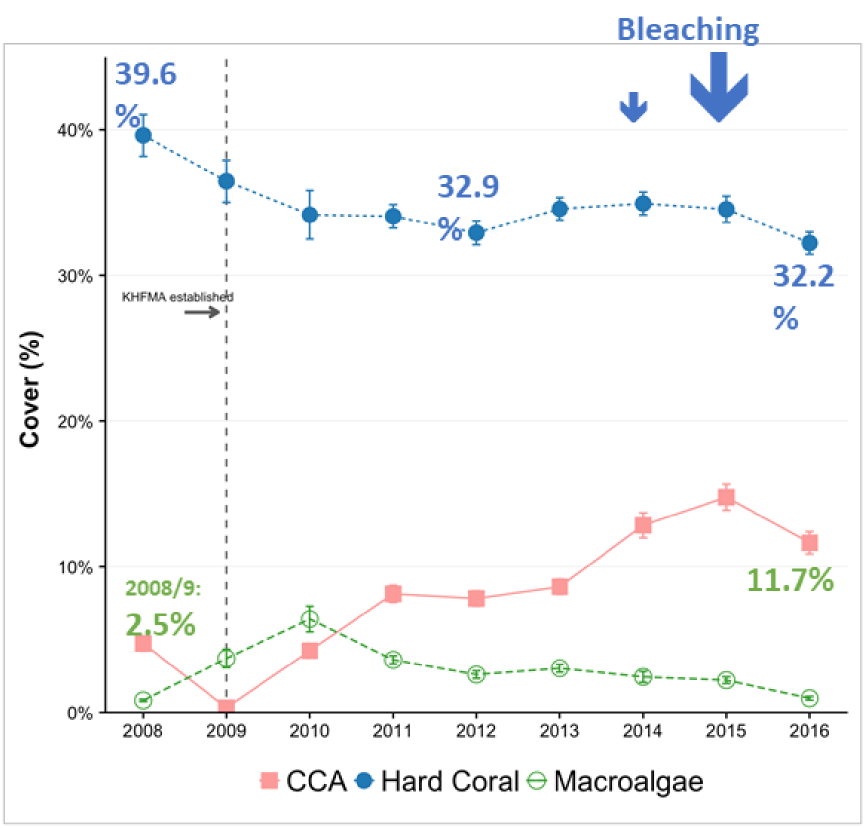


Figure 11: Change in benthic cover (crustose coralline algae, hard coral, macroalgae and turf algae) from 2008-2018. Figure from DAR report 2018.

West Hawai‘i Regional Fishery Management Area

In West Hawai‘i, herbivore biomass increased by 30.8% from 2003 to 2017 in MLCD (labelled MPA in the figure) and biomass was almost 70% greater in these areas than both open areas and fishery replenishment areas (FRA)[43,44] (Figure 11). There was no change over the same time period for these other management regimes (open areas and FRA) at 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.

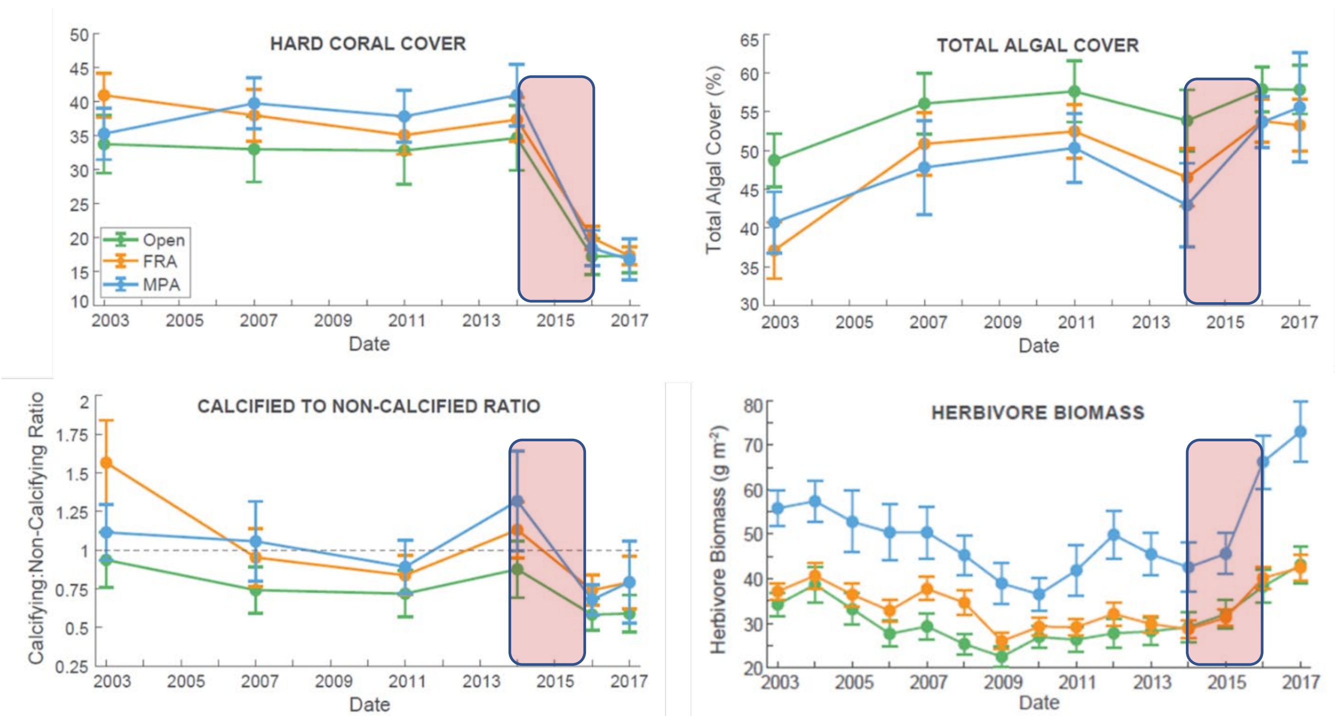


Figure 12: Hard coral cover, total algal cover, calcified to non-calcified ratio and herbivore biomass from 2003-2017 in West Hawai‘i. Indicators are grouped by management status (blue line = marine protected area (MPA); orange line = fish replenishment area (FRA); green line = open to fishing). Error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

In December 2013, DLNR amended the rules to the West Hawai‘i Regional Fishery Management Area (WHRFMA) to include a ban on SCUBA spearfishing anywhere within the WHRFMA boundaries from ‘Upolu Point to Ka Lae. The West Hawai‘i Aquarium Project (WHAP) surveys 25 permanent monitoring sites up to 4 times per year at depths from 30 to 60 feet. Two of these permanent sites are highly protected Marine Life Conservation Districts (MLCDs), and thus spearfishing is already banned entirely and had been prior to this rule amendment.

Prior to the SCUBA spearfishing ban, all parrotfish species showed declining trends (except for the small-bodied Bullethead Parrotfish with a 3% increase in biomass). However, after the SCUBA spearfishing ban, there was a significant increase in parrotfishes biomass across all 25 sites ($t = 9.628$, $df = 31.97$, $p < 0.0001$, Figure 13). Species-specific increases in biomass ranged from 47-364% from 2014 to 2019; with the largest percent increase for the highly targeted large-bodied, Red-Lipped Parrotfish.

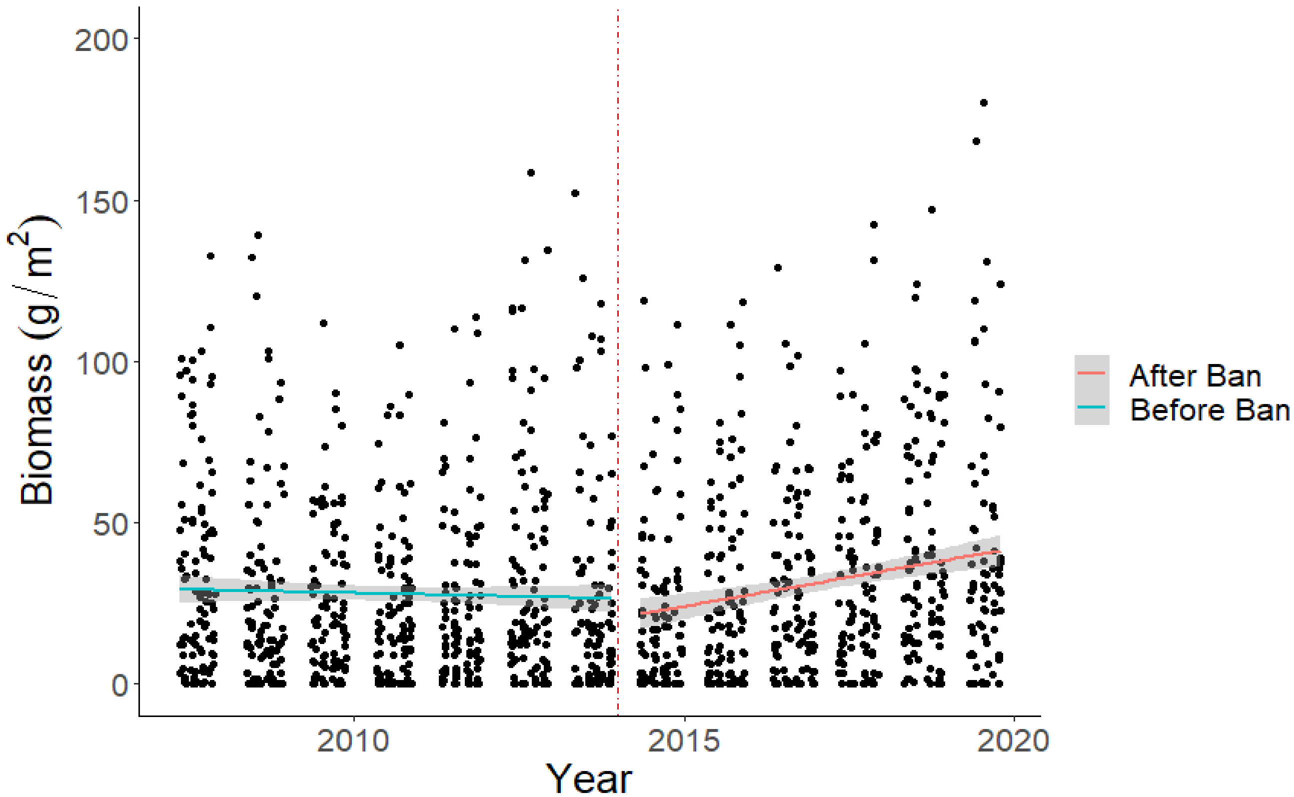


Figure 13: Parrotfish biomass (g/m²) from 2007-2019 at each of the 25 sites from each survey round (each site is surveyed 4 times per year, except 2019, where each site was surveyed 3 times).Trend line highlights the change in mean biomass per year both before and after the implementation of the SCUBA spearfishing ban in December 2013. The vertical red dotted line indicates the beginning of the ban.

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. The Pono Practices pillar is a call to action for resource users to interact with nearshore resources in a pono way.

Herbivore- Specific 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.

<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 and by 2030 at the place-based level.
- *Action PP.2* Support and enhance DOCARE's enforcement and outreach 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 with herbivore management strategies.
- *Action PP.4* By 2023, integrate traditional Hawaiian knowledge with additional 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.

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 Hawai'i had several management regimes. At the ahupua'a (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 **seasonal closure** 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 ahupua'a 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 ahupua'a.[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 over 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 ahupua'a 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

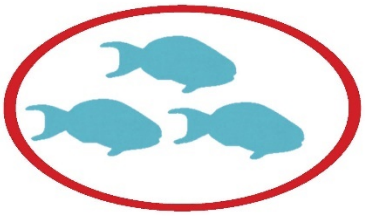
Regulations can be implemented to limit and/or prevent unsustainable harvest by a single person and maximize sustainable harvest overall, ultimately providing better fishing opportunities for the future. Regulations can be implemented proactively, to ensure sustainability, prior to observations of declines in a fishery. This promotes the maximum fishing opportunities by not waiting for the stock to be in peril before pursuing regulations and ensuring enough fish in the fishery before significant declines. 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] For additional information on coral reef fisheries management strategies, refer to "A perspective on the management of coral reef fisheries" in *Ecology of Fishes on Coral Reefs* by Alan Friedlander.[67]

The Division of Aquatic Resources, DLNR, has the authority to regulate fisheries. HRS section 187A-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

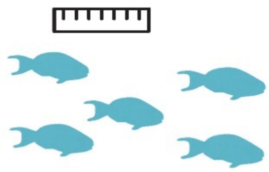
Activities related to boating, recreation, and other human activities in state waters are regulated by the Division of Boating and Ocean Recreation, DLNR (HAR 234), and regulations on water quality are set by the Department of Health (HAR 11-54).

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



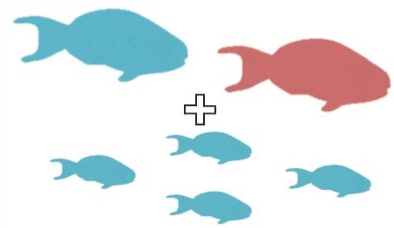
Take only what you need

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



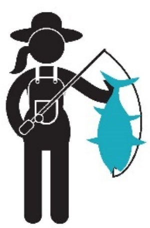
Let the keiki grow

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



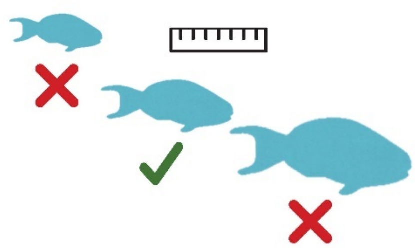
Let the fish reproduce

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



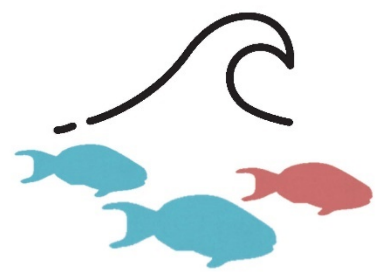
Use the right gear

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.[68]

Size Limits

Size limits set size requirements for the harvest of a species and may be set for a minimum size, 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 as the L_{50} (the length at which at least half of the population is able to reproduce). A maximum size limit aims to protect the biggest fish which can produce exponentially more offspring than a newly mature fish.[69] In some species, like uhu where the largest individuals are male, maximum size limits can ensure large male spawners. 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 conserve the reproductive potential on either side of the size spectrum.

> *Definition of Size/Length/Age at Maturity:*
> The size, length or age at which individuals are reproductively active and producing.[70]
>
> *Definition of L_{50}:*
> The size/length at which at least 50% of the individuals in a population are reproductively active and producing.[70]

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.[71,72]

While bag limits may only affect the most efficient fishers, size limits can help all fishers in reducing their impact on the fishery.[66] Size limits are popular for the dual goal of limiting overfishing and improving the fishing quality.[73]

Size limits can help fishing communities attain optimal yields, even under high fishing pressure.[74] 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.[75] There are limitations to the benefits of size limits in that size-restricted fish may experience stress, injury or even death when released if they are below or above the regulated size limit. Also, some gear types, like spearfishing, do not allow for catch and release so catch outside of the legal limit will likely be discarded and wasted.

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 when spawning behaviors make certain species of fish easier to target in large numbers (spawning aggregations, etc.). There are limitations to the benefits of seasonally restrictions in that seasonally restricted fish may experience stress, injury or even death when released if they are caught out of season.

Area regulations are regulations that are specific to a place and may be any one or a subset of regulations including 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) level, and as such, are not applicable for current statewide regulations. Because there can be variation in spawning seasons between places, seasonal closures for certain species corresponding with their spawning season will be considered for place-based management in the future. Seasonal closures may not always have a conservation benefit to the fishery if the area is too small or closure period is too short. This may lead to increased pressure in other areas or lead to a derby effect, with a lot of targeted pressure, just before or soon after the closure.

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 and other aquatic organisms quickly. Therefore, regulations on specific gears 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 small mesh nets. Larger mesh sizes allow smaller juvenile fishes to escape, allowing them to reach maturity.

Many existing MMAs have gear regulations, and there are also statewide gear regulations. These regulations can be found here: https://dlnr.Hawaiʻi.gov/dar/fishing/fishing-regulations/gear-restrictions/. MMAs are often ranked by their level of protection based on the restrictiveness of gear regulations in place.[64,76]

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.

Many Pacific Island countries ban the use of SCUBA while spearfishing.[77] Banning nighttime spearfishing or SCUBA spearfishing is a significant way to control fishing pressure.[78] SCUBA spearfishing is banned in American Samoa and this regulation has relatively high compliance.[78] 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.[79] This was the basis for the country's ban of SCUBA spearfishing through Executive Order.[79]

Fishers in Hawaiʻi have expressed that SCUBA spearfishing can be too efficient, and nighttime spearfishing may be considered unfair because sleeping fishes are defenseless, and other fishes are easily disoriented with a night divers light.[80] SCUBA spearfishing was banned on Hawaiʻi Island in December of 2013, anywhere within the West Hawaiʻi Regional Fishery Management Area (WHRFMA) boundaries from ʻUpolu Point to Ka Lae (South Point). Since the implementation of this ban, uhu have significantly increased.

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 of 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 can be 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 • Can replenish nearby fished areas via spillover of adult fish and seeding by larvae.	• Specifics of place-based rules can be hard to commit to memory • May increase pressure in non-regulated areas • May limit access to preferred local fishing areas

Table 1: Different regulation options and their ability to monitor (easy, moderate, difficult); difficulty of enforceability (easy moderate, difficult); and likelihood to produce waste/bycatch (low, moderate, high). For monitoring, level of difficulty was based on the ability to conduct a study to monitor changes and the ability to detect statistical change, given the scope of variables affecting the abundance and/or biomass of species. For enforceability, level was determined based on the difficulty of understanding and complying with a given regulation and the difficulty in determining whether a violation has occurred. Likelihood for waste (bycatch) level was determined based on the likelihood of incidental discard and/or survivability of the catch if outside of the allowable take (i.e., a fish too small with a minimum size limit, an out of season fish, or when there are more fish caught than allowed by a bag limit).

Regulation options	Ability to Monitor Change	Enforceability	Likelihood for waste
Size Limits	Easy to Moderate- at the group level (family of herbivores) Difficult- at species level on large scales (island or statewide scale)	**Moderate**	**Low** to **Moderate**, depending on gear type
Bag Limits	Moderate to Difficult	**Moderate**	**Low** to **Moderate**, depending on gear type
Seasonal Closure	Easy at place-based scale	**Easy** to **Moderate**	**Low** to **Moderate**, depending on gear type
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 1 means that there is no fishing pressure, and all individual fish can reproduce. A SPR of 0 means that every fish is harvested prior to reproducing. A SPR of greater than 0.30 is traditionally considered a sustainable yield. When assessing the sustainability of a fishery, managers consider a SPR value above 0.30 to be sustainable.

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.[81]

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 0.30. For a sustainable fishery, managers consider a F/F_{30} below 1 to be a sustainable fishing rate, meaning a fishing rate below the rate that equals 0.30 SPR.

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

- **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 based on the 2017 stock assessment of coral reef fishes in Hawai‘i.[82] DAR proposes to manage some closely-related species as a group based on having similar life history and/or being difficult to identify to the species level, due to similar size and appearance. For species grouped together for management, the most vulnerable species is listed for stock status.

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

Species and/or Species Groups Under Consideration

DAR selected several species and species groups to be considered for additional management. DAR considering these species or species groups because of their functional role in coral reef resilience. Any future management actions proposed as part of this plan 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 Unicornfish	*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 the background of these considerations. Commercial catch data are based on DAR's Commercial Marine License database, which is the largest and oldest DLNR fisheries dataset, dating back to 1948, and is based on mandatory reporting of commercial catch. Hawai‘i does not require a marine recreational fishing license or reporting for non-commercial catch. It can be challenging to get accurate information on the extent of non-commercial 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 focused on urchin species that live on the reef habitat. Sea urchins are important herbivores and, like fishes, graze macroalgae. They are particularly important because they can graze in small and tight spaces on the reef, clearing space in areas most fishes would not be able to access. 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[83,84]:

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.[83]
- Banded Urchin (*Echinothrix calamaris*) is the most common long-spined urchin in Hawaiʻi.[83]
- Long-Spined Urchin (*Diadema paucispinum*) is the least common species of wana here in Hawaiʻi but is from the important genus *Diadema,* which has been shown to control macroalgae in the Caribbean.[85]

Hāʻukeʻuke (thick, flattened, or stubby spines):

- Hāukeʻuke ʻulaʻula/ Slate Pencil Urchin (*Heterocentrotus mammillatus*) is a large reef species that has limited predator defenses and utilizes habitat and nocturnal behavior to eat macroalgae.[86]
- 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.[83]

ʻIna (medium length spines):

- Rock Boring Urchin (*Echinometra mathaei*) and Black Rock-Boring Urchin (*Echinometra oblonga*) as their common name suggests, bore into rock while eating algae to create habitat for themselves.[83]

Hāwaʻe (short slender spines):

- Hāwaʻe maoli/ Collector Urchin (*Tripneustes gratilla*) has been cultivated in aquaculture facilities and used extensively in Kāneʻohe to help control invasive algae.[87] It's been noted that this species often aren't eaten by native Hawaiians,[83] 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.

Status: **INSUFFICIENT DATA**

The most detailed urchin monitoring is conducted with place-based surveys, where data are analyzed for a specific place over time, as opposed to regionally or statewide. Some locations have documented marked declines, such as in Hāʻena, Kauaʻi from their Long-term Monitoring and Assessment of the

Hāʻena, Kauaʻi Community Based Subsistence Fishing Area Report.[88] There's some speculation that local urchin species may be vulnerable to viruses, and could use the extra protection.[85] There were documented mortalities of Collector Urchins (*Tripneustes gratilla*) in Hawaiʻi, Kauaʻi, and most recently in coastal waters along Oʻahu and Maui.[89]

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. There have been suggestions to protect urchins in areas that are particularly impacted by invasive macroalgae.

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]

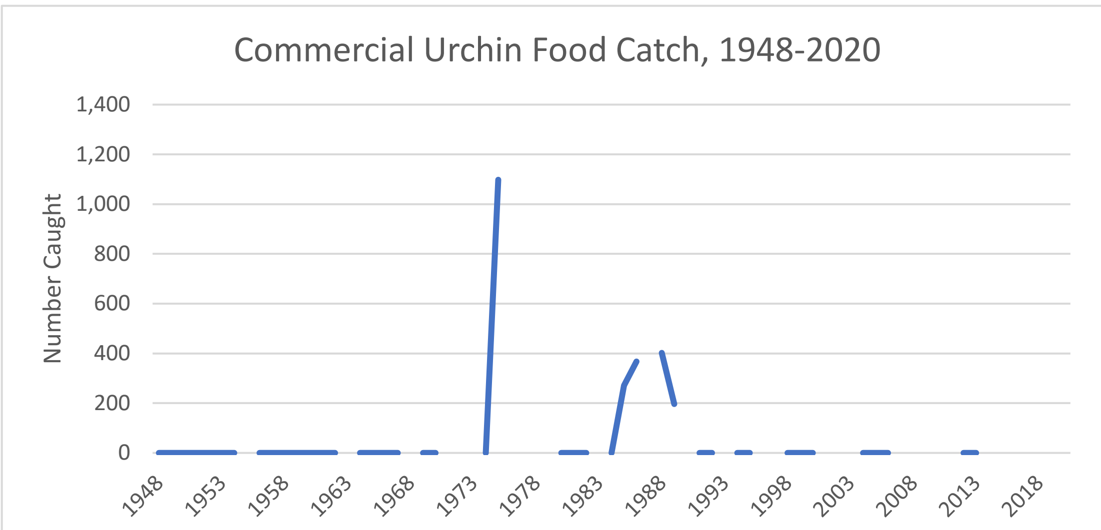
Figure 14. Hawaiian woman collecting wana (sea urchins). Courtesy of Bernice P. Bishop Museum.)

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 native 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, pending Hawaiʻi Environmental Policy Act (HEPA) review.

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%



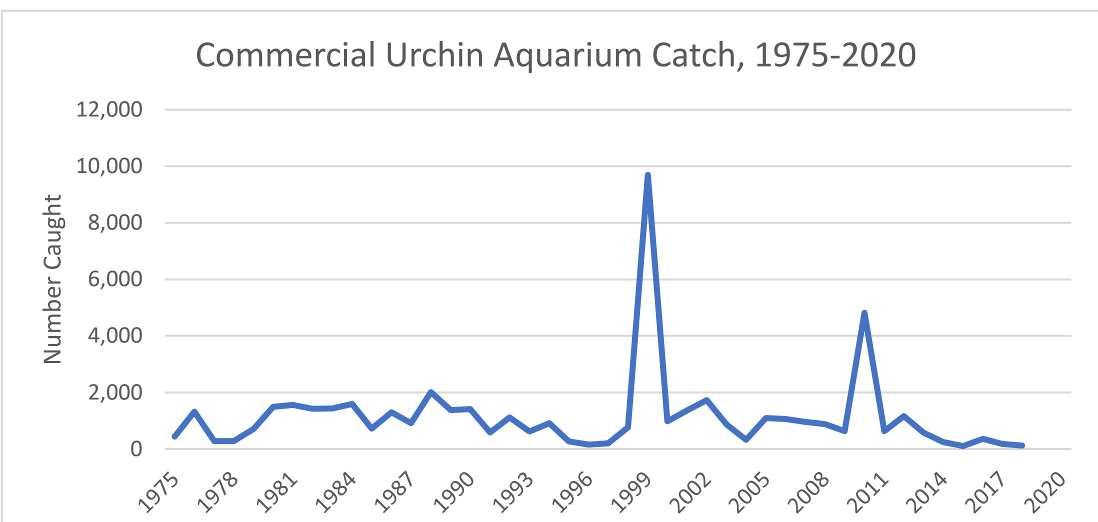


Figure 15: Number of urchins reported for commercial food catch from 1948 to 2020 (top) and commercial aquarium catch from 1975 to 2020. Commercial catch data for urchins is confidential for the years not plotted and does not mean recorded catch was zero.

Non-commercial Harvest: Most sea urchins harvested in Hawai‘i is non-commercial for subsistence.

Historical Take and Cultural/Traditional Use: Sometimes a sauce is made of ‘ina by breaking the tests into large pieces, adding water and salt, and draining the water after several hours. This liquid is called kai ‘ina (a reddish lavender like the color) and is eaten with raw fish.[90] 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.[84] The kai and elelo are mixed and used as a relish eaten with sweet potato and poi. Hā‘uke‘uke ula‘ula or Punohu spines were used potentially as ki, or carved ‘aumakua, found on Kaho‘olawe.[84] *Eucidaris metularia* - sometimes called Hā‘ue‘ue (Hawai‘i Island name) or Peni (Maui name), was too small and not eaten.[84] All kinds of urchins were used as bait for fishing for Uhu.[91] The story of Kalamainu‘u describes how Hinalea were caught using a mix of Wana and ‘Ohiki (ghost crabs) in a Hina‘i or basket trap.[61] Urchins were mentioned in the Kumulipo and were also referenced in ‘ōlelo no‘eau. Today many still consider the gonads of urchins a delicacy, eating them raw, cooked, or dried, and preparing sauces using the urchin’s liquids.[83]

The area fronting the Queen Lili‘uokalani’s royal compound Hamohamo in Waikīkī Kai, O‘ahu included ‘ina sea urchins and Hā‘uke‘uke sea urchins. The Queen had them propagated and some were brought from Hilo, some from Lāhainā, some from Moloka‘i and from Kaua‘i, and from Waialua, O‘ahu.[92,93]

Background/Ecology/Behavior: Urchins are considered **grazers** and sometimes bioeroders on the reef.[94] 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.[83]

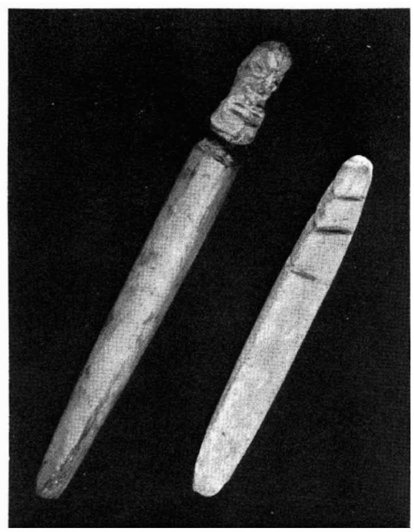
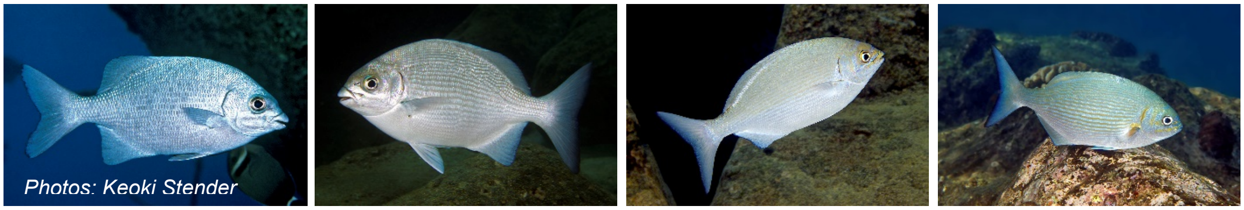


Figure 16.. Hawaiian woman collecting wana *(sea urchins). Courtesy of Bernice P. Bishop Museum.)*

Role for Reef Resilience: Sea urchins are effective grazers preventing macroalgal dominance on reefs. Recent work in O‘ahu suggests that urchins accounted for 32-88% of herbivore biomass, depending on the site.[95] Urchins have been documented as the largest percentage of herbivore biomass and algae control in the Kaloko Honokōhau area of Hawai‘i Island.[96]

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.[97] Once a population decline has been initiated, losses are common, and recovery is extremely slow.[97] 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,[85] and terrestrial runoff impacting fertilization and other reproductive functions.[98] 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)***


Photos: Keoki Stender

Current Status: **INSUFFICIENT DATA**

Current Regulations: No current regulations

Management Considerations: Data are limited on length at maturity for most species, therefore a size limit is difficult to estimate. However, life history studies in Hawaiʻi are in progress, which will better inform tailored management decisions**.**

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. Prior to aquarium harvest restrictions, (e.g., fulfillment of a specific aquarist's request), Nenue were collected by commercial aquarium collectors, though infrequently. 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%

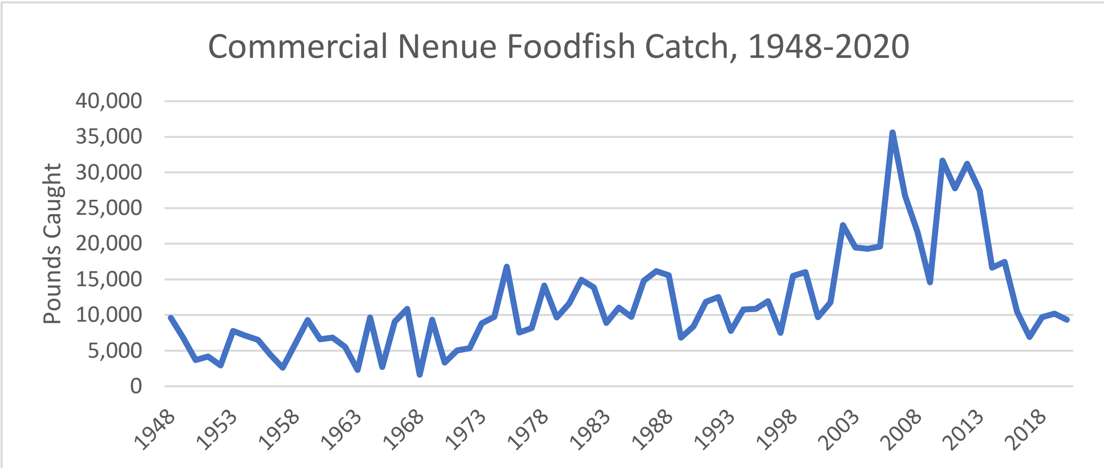
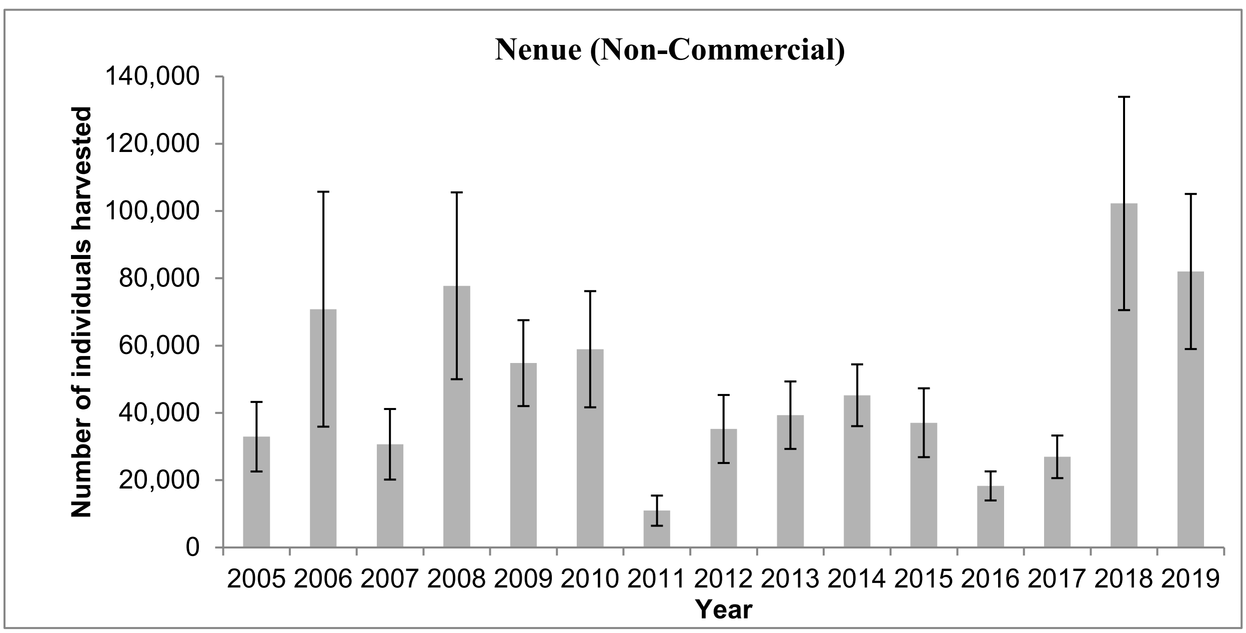


Figure 17: Commercial foodfish harvest of Nenue (in pounds) from 1948 to 2020.

Non-Commercial Harvest: Nenue is a common fish targeted by non-commercial fishers. 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 Kāneʻohe, the community refers to the juveniles as Nenue and the adults as Enenue.[60] In the mo῾olelo 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.[99] The mele, "Aloha Ka Manini" written by Israel Kamakawiwoʻole 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 hoʻomoemoe 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 Kaʻuiki and Alaʻau.[91]

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.[90] They have a long digestive tract and use bacterial fermentation to get nutrition from the seaweed they eat.[100] Nenue species can be difficult to tell apart visually, as species look very similar. Occasionally, individuals are yellow, white, or multicolored.[100] 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.[100]

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)*.[101] Brassy Chub/Lowfin Chub (*Kyphosus vaigiensis*) is found to aggregate over hard, algal-coated bottoms, of surf-swept reefs, as well as rocky areas[102] and have surprising movement patterns between estuarine and coastal habitats indicating they are unlike most nearshore fishes that stay close to home coral reefs.[103] 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[104] and are known for eating macroalgae as well as associated invertebrates.[105] Hawaiian Chub (*Kyphosus hawaiiensis*) is endemic to Hawaiʻi and typically occupy shallow water, in the surge zone near coral and rocky reefs.[106]

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.[103]

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 Hawaiʻi Fishing News. Poseidon Fisheries Research and NOAA Fisheries are currently studying their life history in Hawaiʻi.

Surgeonfish:

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.

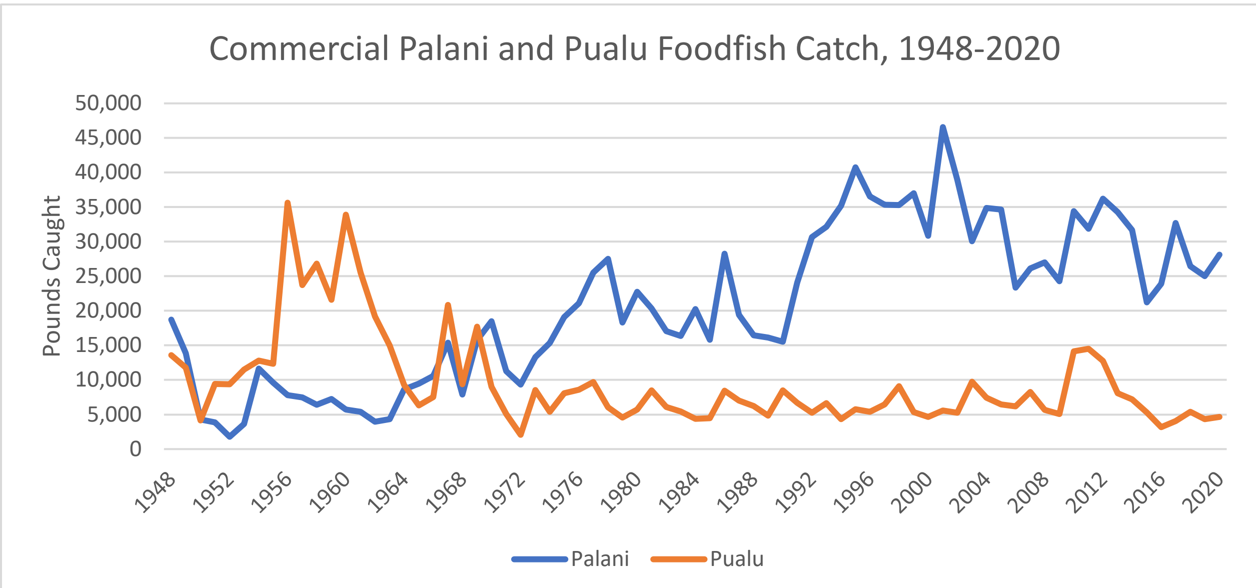
Minimum Size limit: 11.4 inches (OFL) 12 inches (40% probability of overfishing)

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. Prior to aquarium harvest restrictions, Palani and Pualu were 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%**



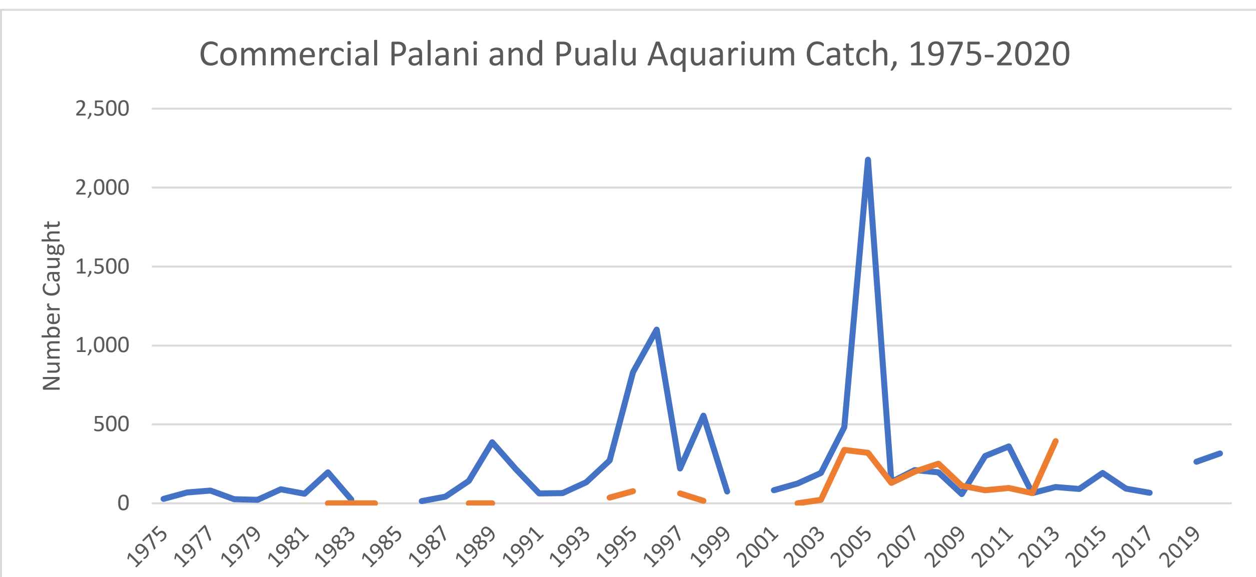


Figure 18: Commercial foodfish harvest of Palani and Pualu (in pounds) (top) from 1948 to 2020 and commercial aquarium catch (in number of individuals) (bottom) from 1975- 2020. Commercial catch data for Palani and Pualu is confidential for the years not plotted and does not mean recorded catch was zero.

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. Kuʻu iʻa pā ka lani (my fish whose odor reaches heaven). In the story of Keʻemalu, Keʻemalu called to her ancestor Palaninuimahaoʻo 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-mahaoʻo 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.[107] 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.[108]

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.[108] 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.[109]

Umaumalei (*Naso lituratus*)

<u>Current Status:</u> UNSUSTAINABLE SPR: 0.25 F/F_{30}: 1.3

<u>Current Regulations:</u> O‘ahu AQ Rules (HAR 13-77; applicable only when using fine mesh nets): Bag Limit of 50, West Hawai‘i White List Species.

Umaumalei are on the West Hawai‘i White List established in 2013 identifying fishes that could be legally taken for aquarium purposes. Aquarium take on O‘ahu 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.

<u>Management Considerations:</u> 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.[69]

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

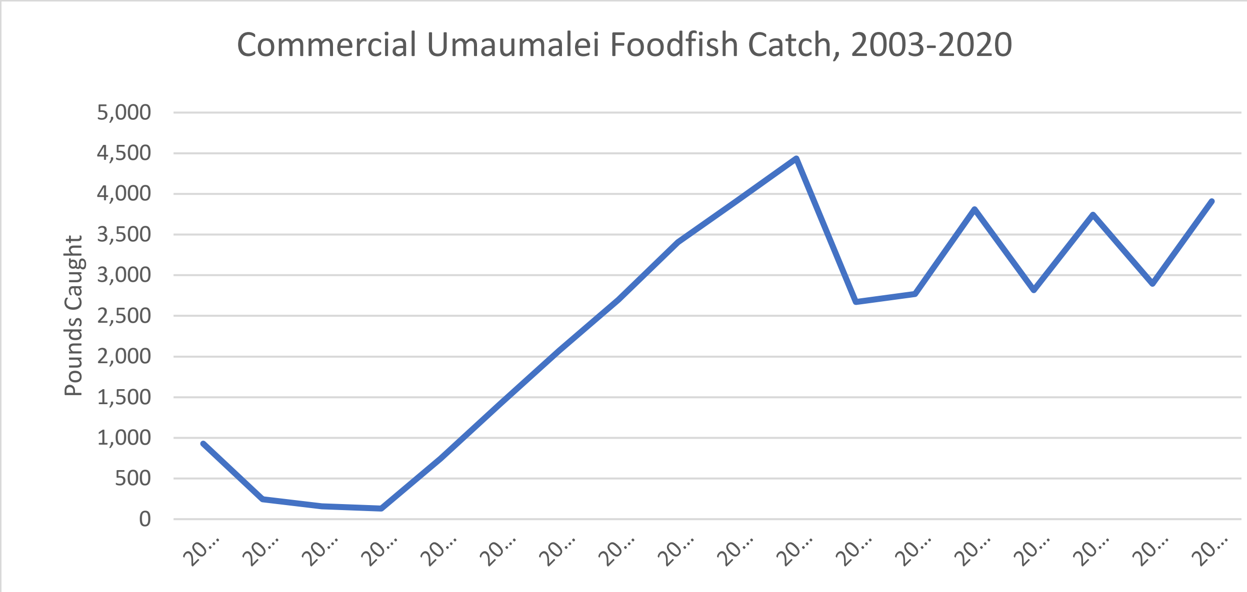
Catch limits: 9,678 lbs. (OFL); 7,385 lbs. (40% probability of overfishing)

<u>Commercial Harvest:</u> 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%**



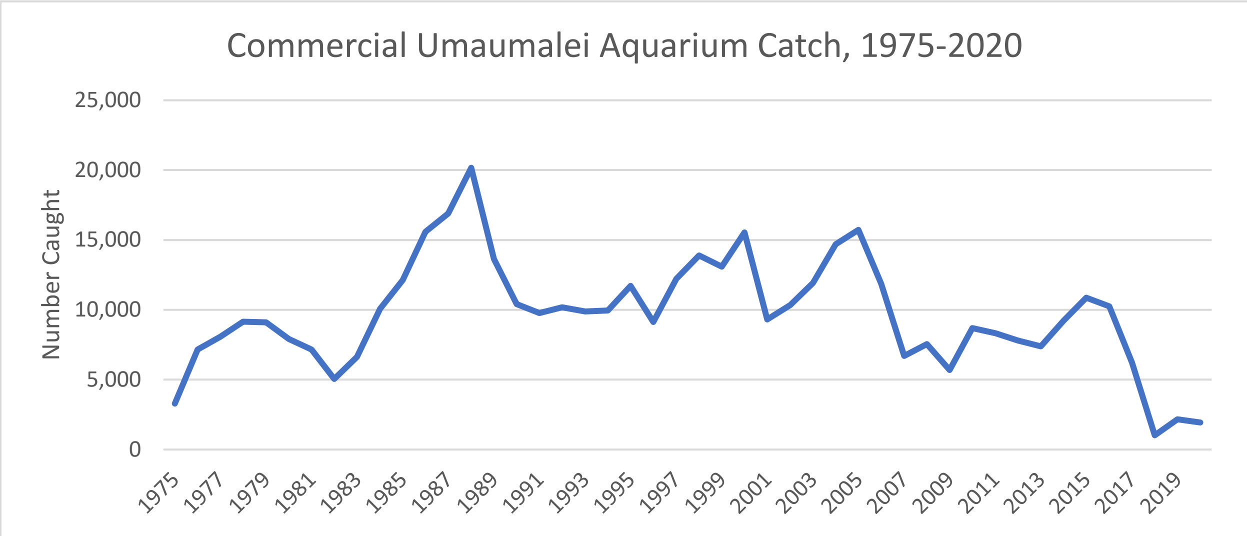


Figure 19: Commercial foodfish harvest of Umaumalei (in pounds) from 1948 to 2020 (top). Foodfish reporting code for Umaumalei not offered until October 2002 so 2003 was the first year species-specific commercial foodfish catch data is available. Commercial aquarium catch of Umaumalei (in number of individuals)) from 1975- 2020 (bottom).

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 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.[99]

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).[101] Browsers remove the larger leafy seaweeds making room for grazers and scrapers to remove the underlying turf algae.[11,25]

Life History: Umaumalei can grow to a maximum of almost 18 inches[82] and live more than 25 years,[82,110] but reach maturity around 8.4 inches in fork length.[82] Little is known about their L_{50} specific to Hawaiʻi, but in American Samoa, their L_{50} is 6.9 inches fork length[111] and in Guam, 5.9 inches for females and 7.1 inches for males.[112]

Kala (*Naso unicornis*)

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

Current Regulations:
State (HAR 13-95) Minimum size 14 inches

Management Considerations: To address the already low predicted SPR[82] and low productivity,[112] a bag limit in addition to the size limit would allow the stock to replenish.

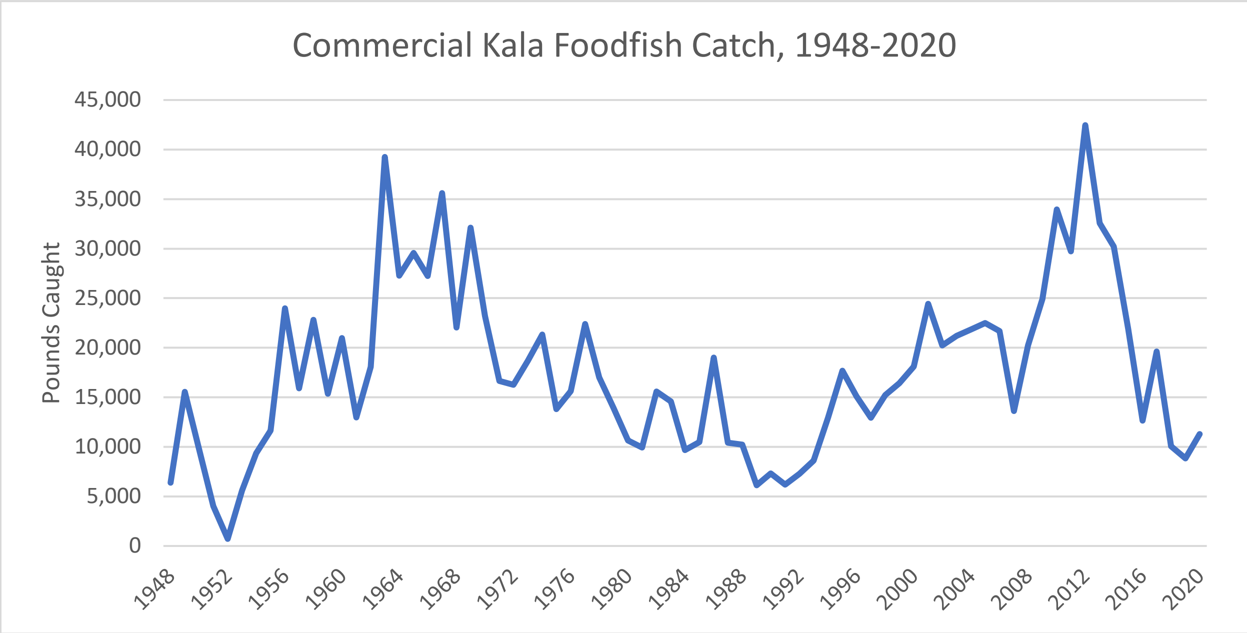
Minimum Size limit: 18 inches (OFL) 18.5 inches (40% probability of overfishing)

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

Commercial Harvest: The commercial foodfish fishery “Kala” reporting group includes Bluespine Unicornfish (*Naso unicornis*), as well as the lesser-caught Shortnose Unicornfish (*Naso brevirostris*) and Whitemargin Unicornfish (*Naso annulatus*). This group 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 are caught occasionally by commercial aquarium collectors, but collection is infrequent and, like Nenue, likely driven by sporadic requests by specific aquarists and suppliers. In commercial aquarium reporting, "Kala" refers specifically to *Naso unicornis*. Commercial aquarium collection in recent years (2011-2020) is typically less that ten fish 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.
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%

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%



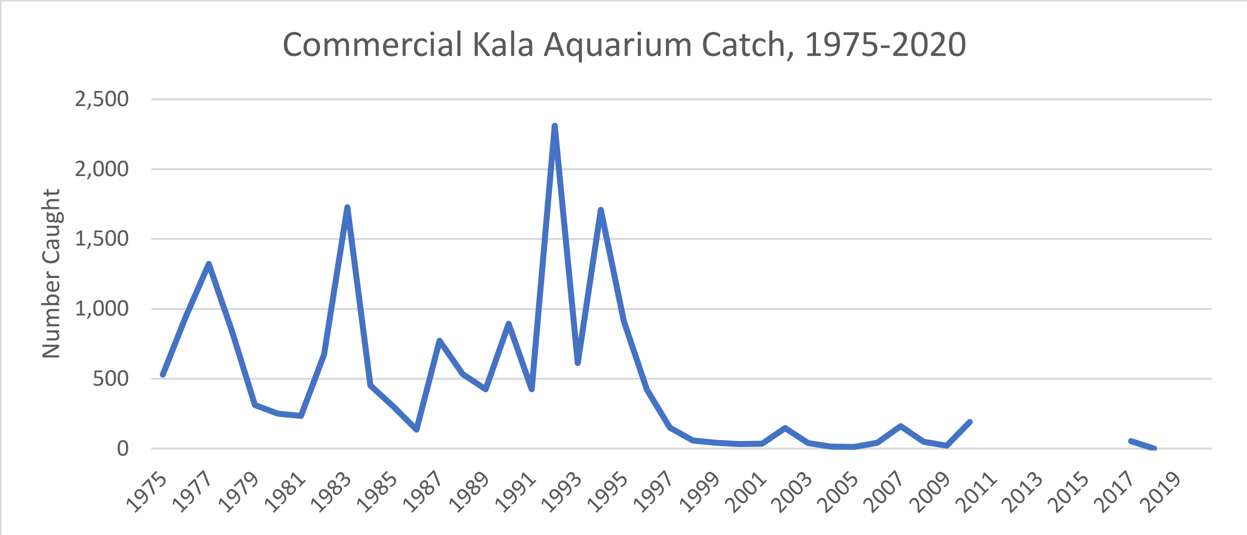
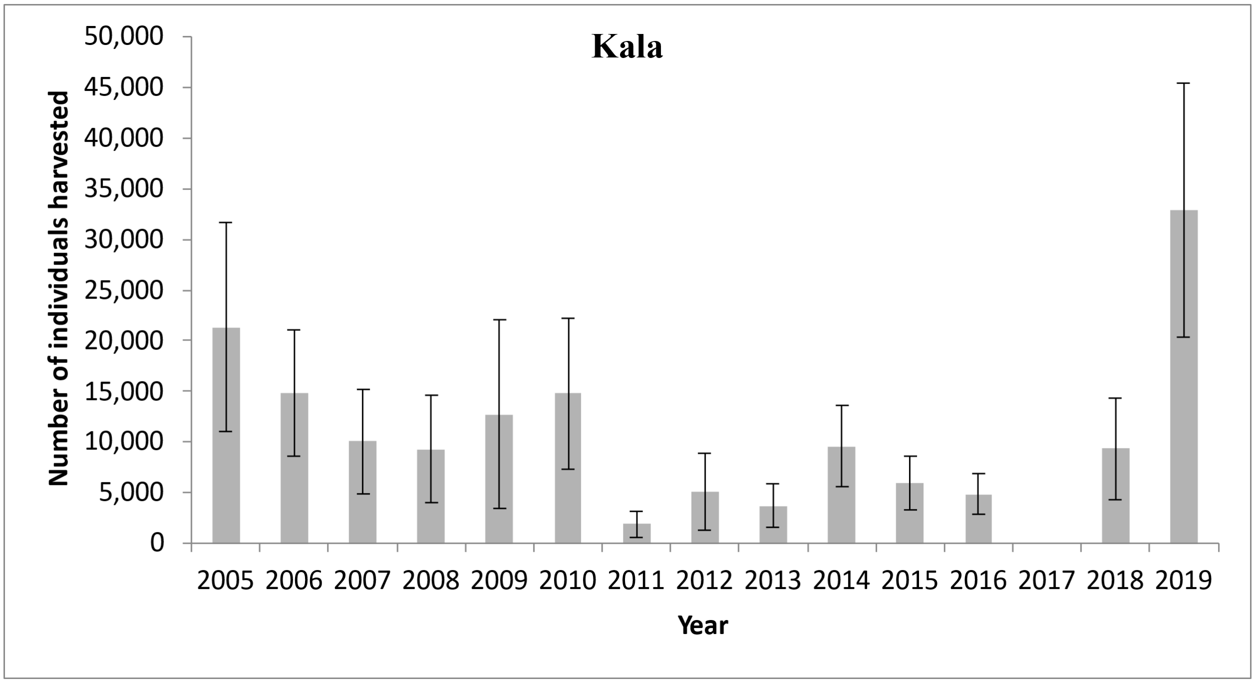


Figure 20: Commercial foodfish harvest (top) of Kala (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020. Commercial aquarium catch data for Kala is confidential for the years not plotted and does not mean recorded catch was zero.

Non-commercial Harvest: Kala, as one of the larger surgeonfish species, are considered a good eating fish and a desired target for spearfishers. The take of undersized kala, especially while night diving, is a common violation of the current regulations. 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 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 have always been a popular fish because they were easier to find and catch. This is demonstrated in many cultural aspects through name, practice, and use. Kala is mentioned in the Kumulipo,[99] in the story of Punia[91] 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 Kāneʻohe, 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.[91] Hinaʻi pai kala fishing used a lifted, plaited basket 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.[90]

Role for Reef Resilience: Like Umaumalei, Kala are **browsers** and selectively graze on leafy macroalgae such as Limu Kala and other large frondose algae.[90,113]

Life History: Kala are long-lived fish and can reach up to 50 years in age or older.[113–115] If undisturbed, Kala have the potential to grow to 27 inches long and weigh up to 12 lbs.[90] Compared to other regions, Hawaiʻi's Kala mature later and grow larger.[113] They reach maturity at 13.97 inches fork length[82] but it takes them conservatively about 8 years to reach reproductive maturity.[114] Males will mature around 4.5 years in age and females will mature around 7.5 years.[115] They have a spawning period during the spring and summer months from May to June.[115]


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.[90]

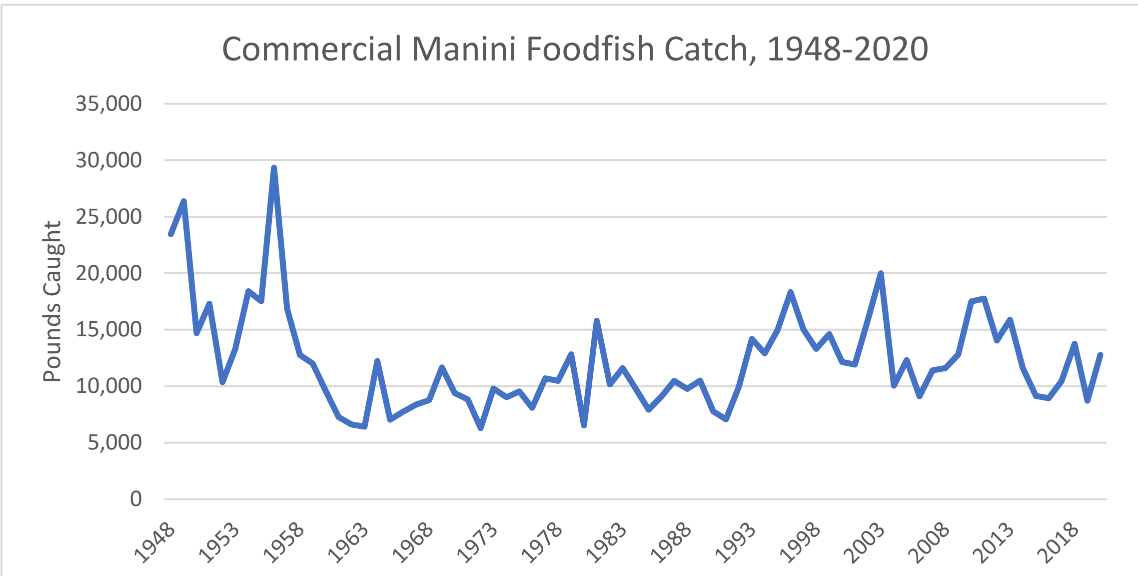
Current Regulations:
State (HAR 13-95) Minimum Size 5 inches

Management Considerations: Manini has a high productivity, low susceptibility, and low vulnerability to unsustainable harvest.[112] 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. Community-collected data suggests that the size at maturity is between 5-6.1-inches,[116] meaning many individuals are likely not mature before entering the fishery. 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%

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%



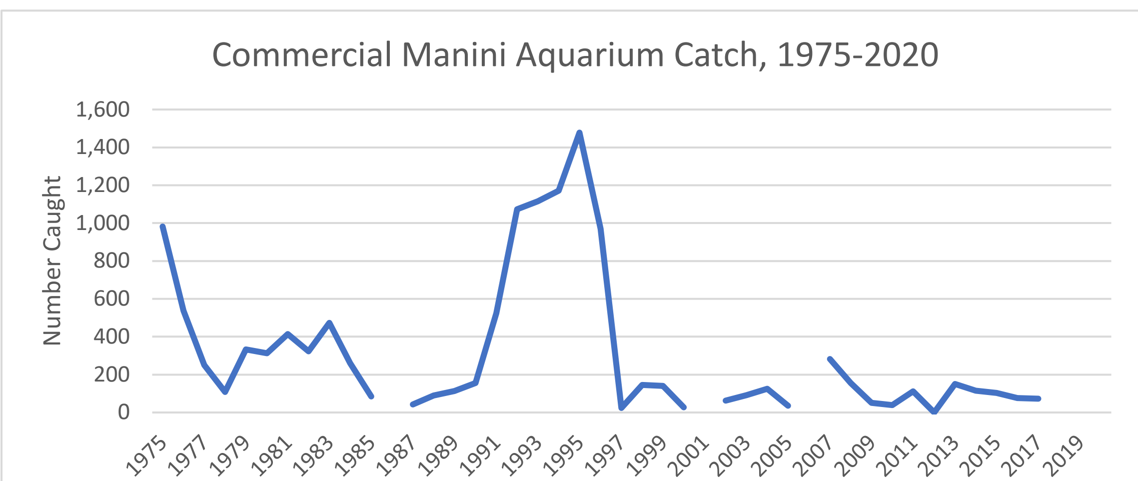
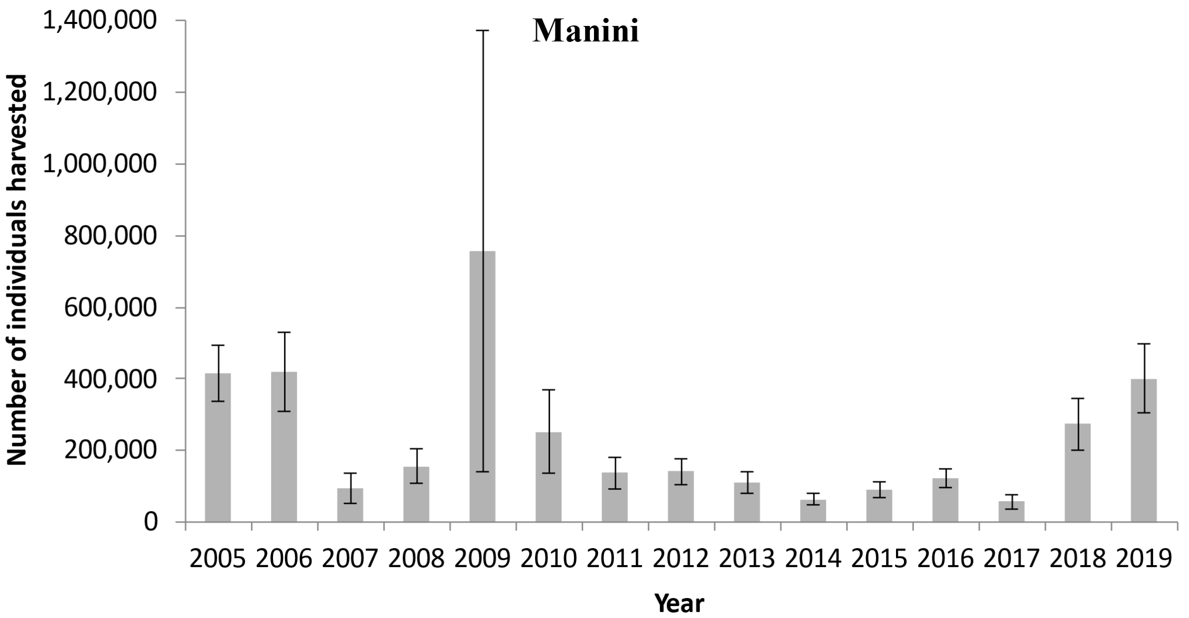


Figure 21: Commercial foodfish harvest (top) of Manini (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020. Commercial aquarium catch data for Manini is confidential for the years not plotted and does not mean recorded catch was zero.

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 ʻŌhua, young individuals, being mixed with salt and scattered to dry on the lava rocks.[60] Their stages of growth are ʻŌhua liko, ʻŌhua kaniʻo, ʻŌhua Pala Pohaku, Kakala Manini (half grown), and Manini (adult stage).[60]

Their frequent consumption led to their presence in historical fishponds. Moʻolelo 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.[117] 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 ʻauhuhu is diffused into the water. The fish then float into the net.[91]

Manini was referenced in fishers prayers as being “stripe skinned.”[60] There are also ʻōlelo noʻeau 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 Hawaiʻi’s reefs. Endemic to Hawaiʻi, their Hawaiian name means small or stingy, referring to a moʻolelo referring to the stingy nature of these fish. 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.[90]

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.[25]

Life History: Manini can reach lengths up to 12 inches and can weigh close to two pounds.[90] They form large spawning aggregations[101] once they reach their length at maturity of 5- 6.1 inches.[116]

Naʻenaʻe (*Acanthurus olivaceus*)

Current Status: INSUFFICIENT DATA

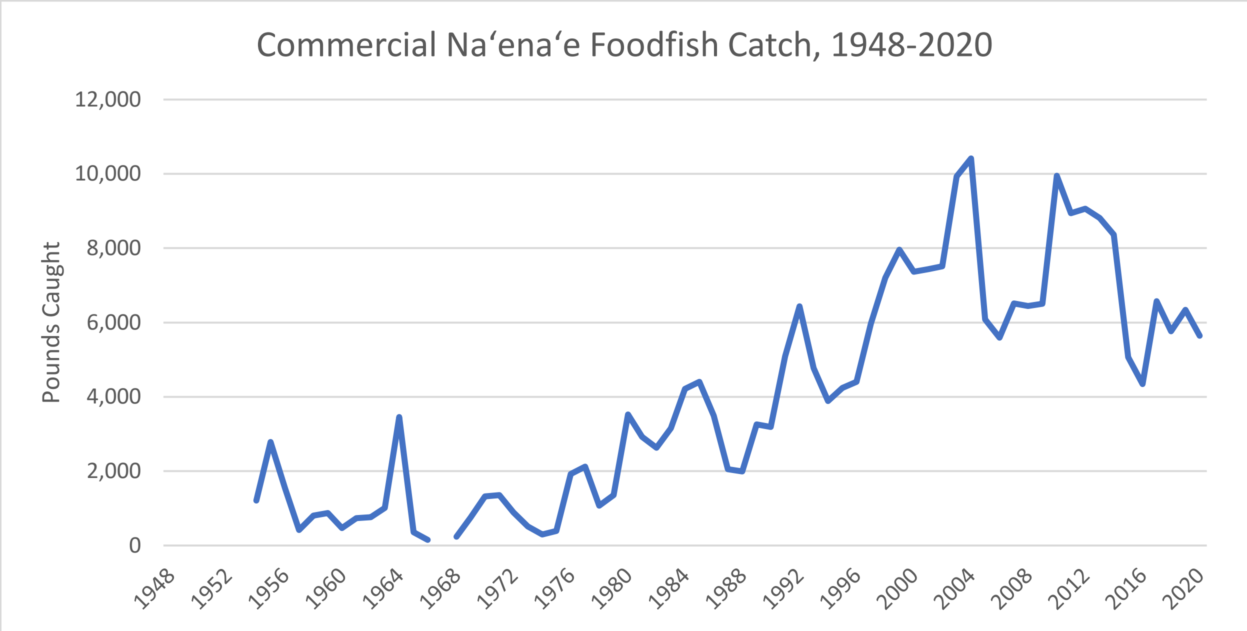
Current Regulations: None

Management Considerations: A minimum size limit could increase reproductive potential and sustainability for this species. L_{50} for the species is 6.6 inches,[109] therefore a minimum size larger than 6.6 inches would ensure that individuals have a chance to reach maturity and reproduce.

Commercial Harvest: A total of 68,925 pounds of Naʻenaʻe were caught by commercial fishers for foodfish between 2011 and 2020. Naʻenaʻe, 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 Naʻenaʻe for the foodfish market are fish traps, spears, and seine nets. Naʻenaʻe 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.
Naʻenaʻe	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.
Naʻenaʻe	1,216	$3.36	1,371	$4.04	12.7%	20.3%



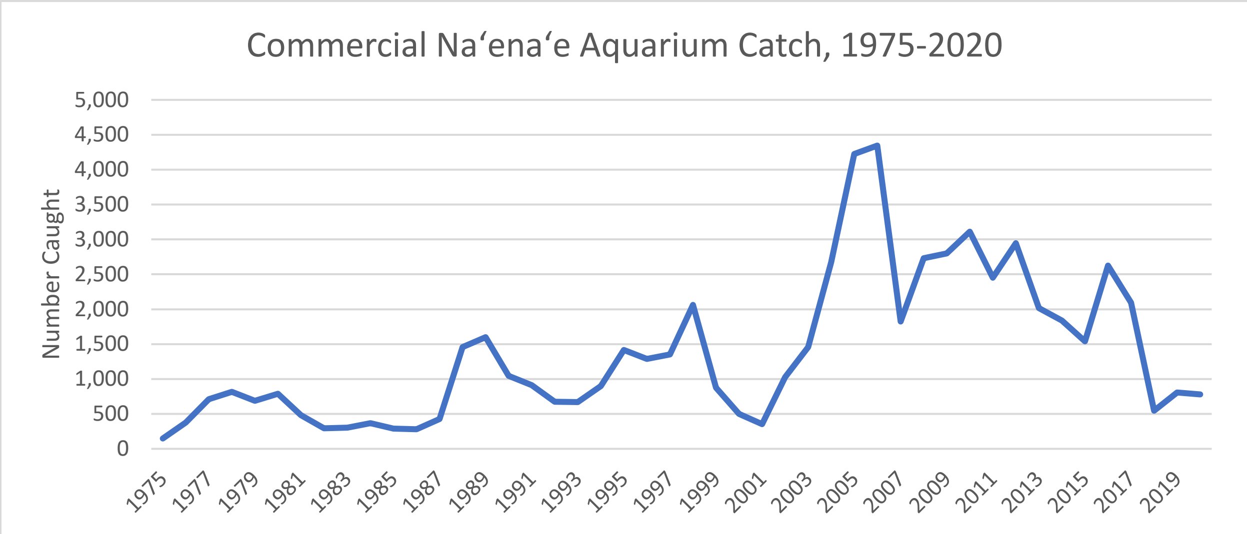


Figure 22: Commercial foodfish harvest (top) of Na‘ena‘e (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020.

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,[99] the Na‘ena‘e fish has a terrestrial counterpart with the same name, a shrub in the daisy family with a fragrant bloom.[118]

Background/Ecology/Behavior: The horizontal orange band make this species easy to identify. Naʻenaʻe live on the outer reef where the waves are active and the water is deeper.[107] Adults occur singly or in schools.

Role for Reef Resilience: Naʻenaʻe serve as **detritivores** feeding on surface film of detritus diatoms, and filamentous algae covering sand and bare rock.[119]

Life History: Naʻenaʻe can reach lengths up to 14 inches.[108] In Hawaiʻi 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

Pakuʻikuʻi (*Acanthurus achilles*)

Current Status: INSUFFICIENT DATA

In shallow water habitats, observations of the species in West Hawaiʻi have declined by 90% since 2008.[44] 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.

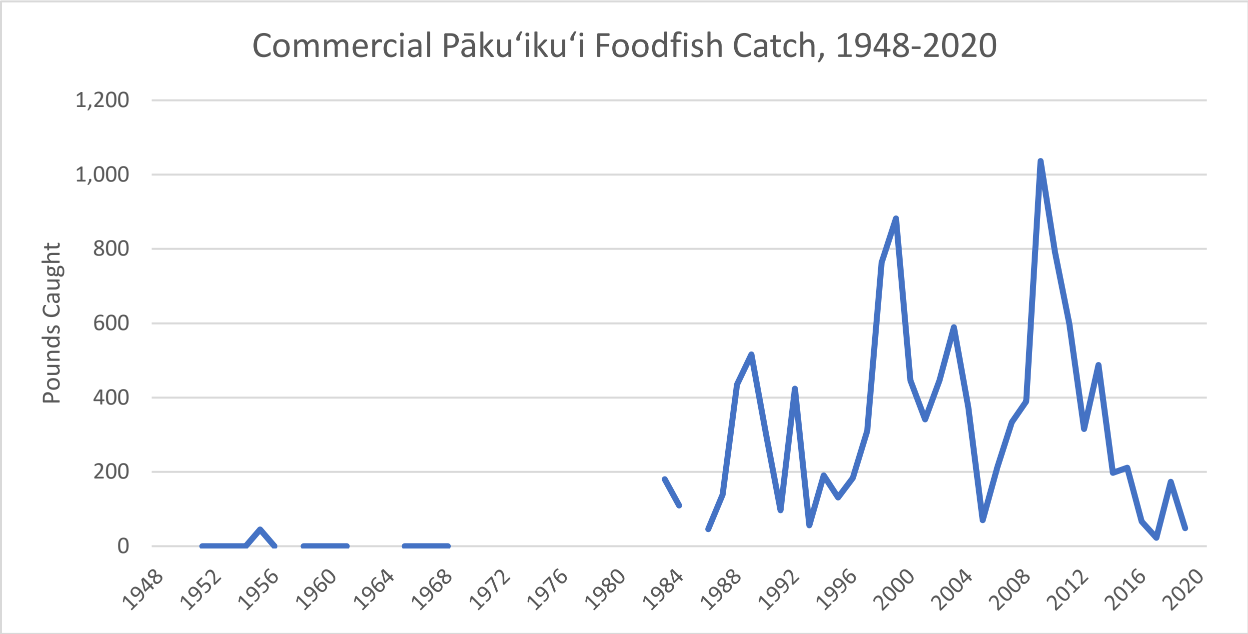
Current Regulations: Aquarium Rules (HAR 13-77; applicable only when using fine mesh): Bag Limit of 10, West Hawaiʻi White List

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

Commercial Harvest: Pākuʻikuʻi 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.
Pākuʻikuʻi	Spear (97.5%), Gillnet (0.6%), Inshore Handline (0.6%)	517.0	$2.66	77.3	$1.91	-85.0%	-28.2%

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%



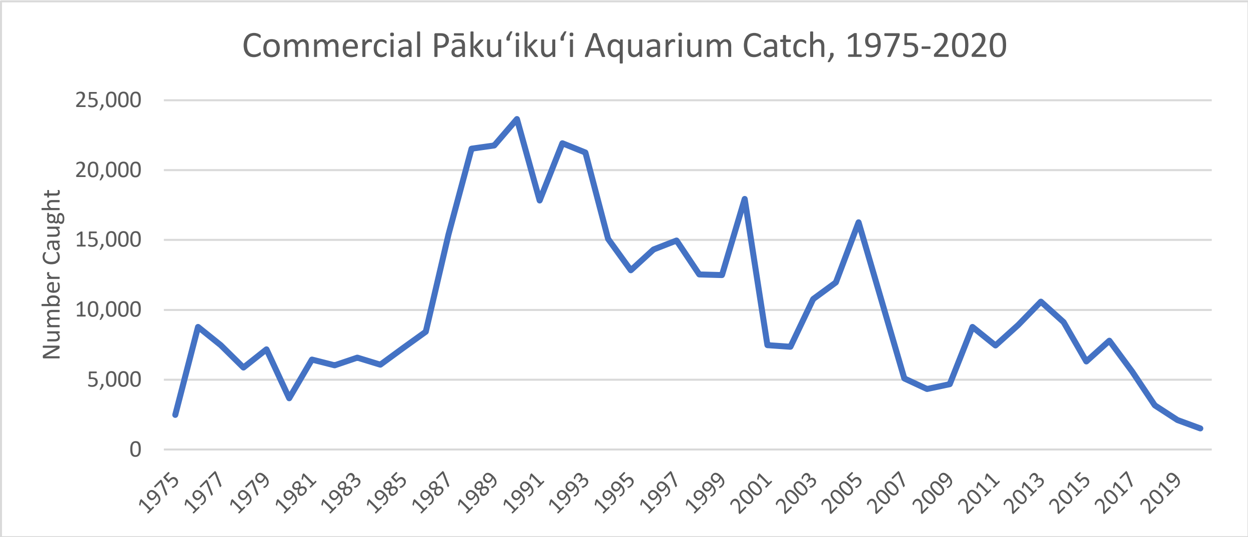


Figure 23: Commercial foodfish harvest (top) of Pākuʻikuʻi (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020. Commercial catch data for Pākuʻikuʻi is confidential for the years not plotted and does not mean recorded catch was zero.

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: Little has been documented 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.[99]

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.[101] The species is found in small aggregations within surge zones and shallow rocky shoreline habitats.[120] They are aggressive and territorial fish and have been observed driving other fish out of their territory while feeding.[101,121]

Role for Reef Resilience: Like manini, they are **grazers** and the lawnmowers of the reef, cropping down turf algae but not removing it completely.[122]

Life History: Catch is so limited that life history studies have been challenging. Pākuʻikuʻi are thought to be long-lived fish reaching 27 years old,[123] but very little is known about their life history. Monogamous mating is observed.[124] 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[120] and an estimation relationship modeled after similar species.[125]


Photo: Keoki Stender

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.[44] This species is generally considered abundant, though there is no stock assessment available.

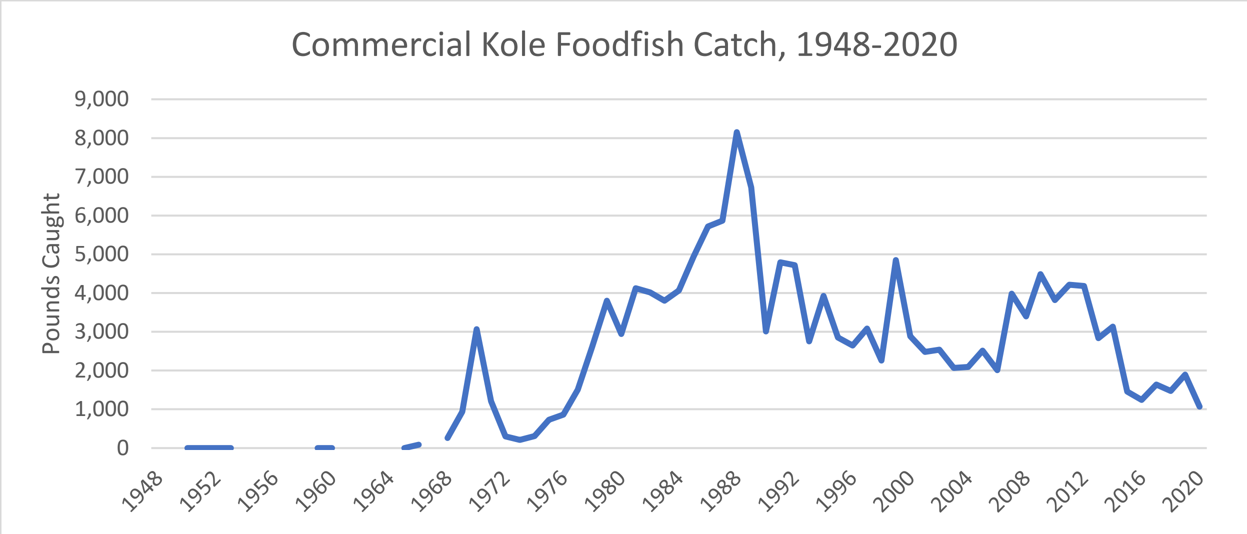
Current Regulations: Oʻahu Aquarium Rules (HAR 13-77; applicable only when using fine mesh): Bag Limit of 75, and 6 maximum of individuals over 5 inches, West Hawaiʻi White List

Management Considerations: The distinct size differences in the length of maturities (3.3 inches for females and 3.9 inches for males)[126] 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 in Hawaiʻi'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%



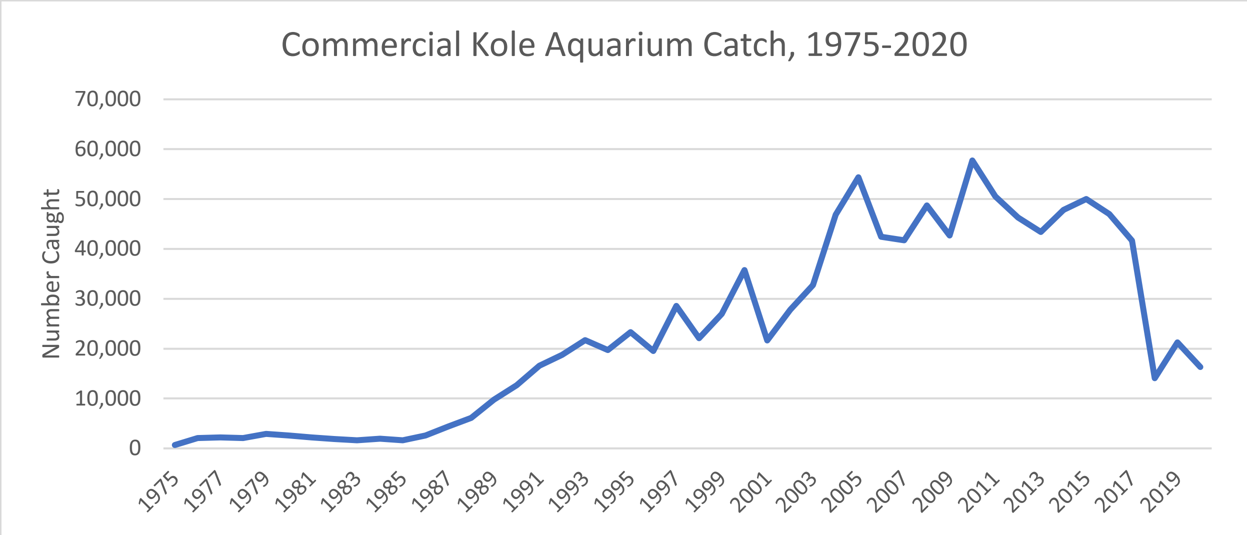
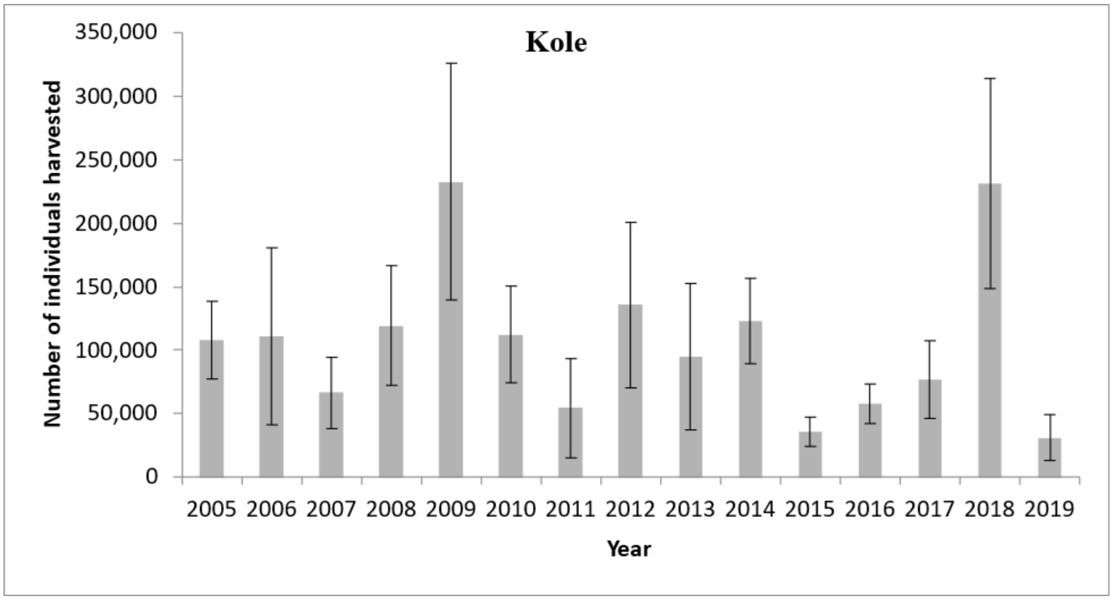


Figure 24: Commercial foodfish harvest (top) of Kole (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020. Commercial catch data for Kole is confidential for the years not plotted and does not mean recorded catch was zero.

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 pākuʿikuʿi. 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.[90] 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.[90,127]

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.[122] 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.[90] They can live up to 18 years.[126] 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.[126] Kole usually spawn in aggregations, however, pair spawning also occasionally occurs.[128] Their spawning season extends from February to June.[126,127]

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

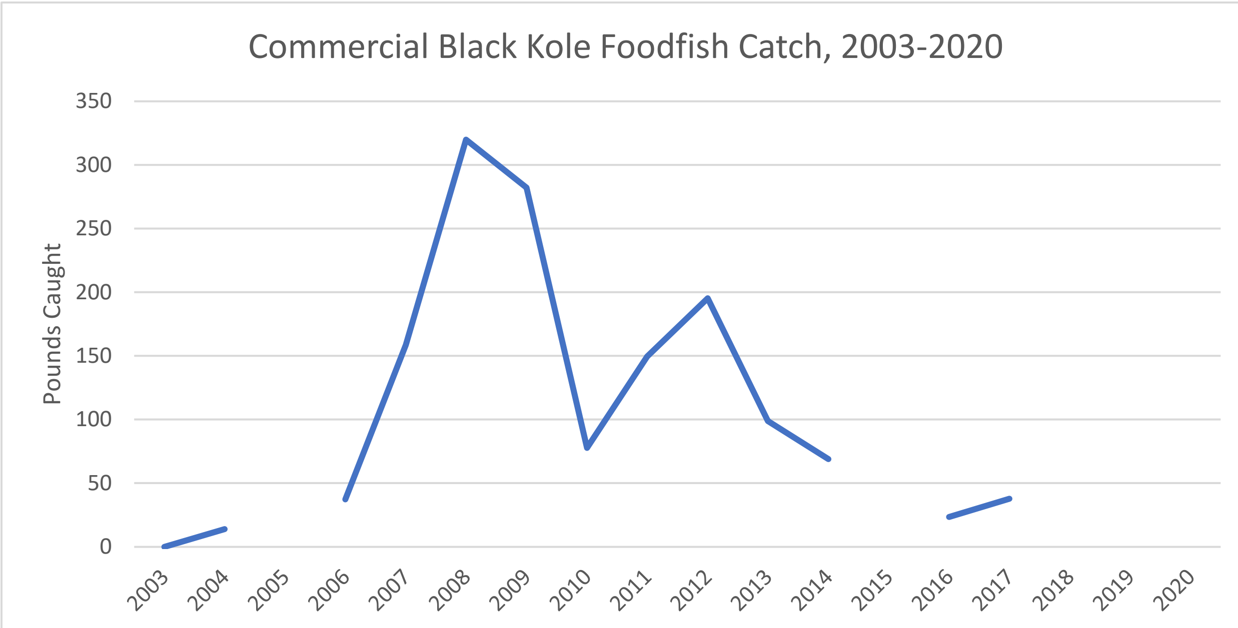
Management Considerations: The limited life history data, low frequency of catch, and uncommon presence across the state suggests a place-based approach to the management of this species may be the best option.

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%



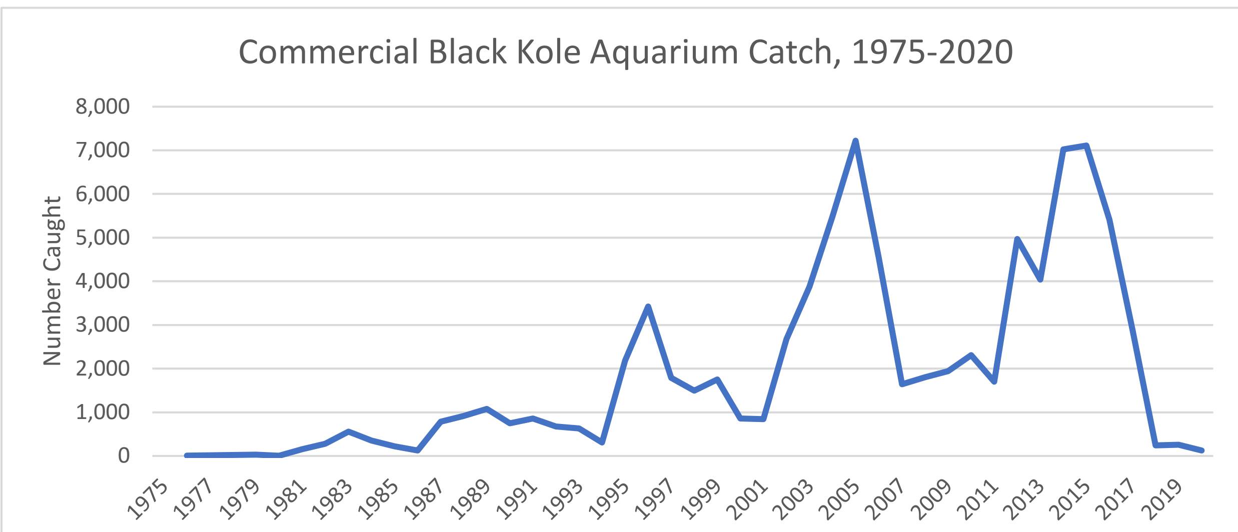


Figure 25: Commercial foodfish harvest (top) of Black Kole (in pounds) from 1948 to 2020 and commercial aquarium catch (bottom) (in number of individuals) from 1975- 2020. Commercial catch data for Black Kole is confidential for the years not plotted and does not mean recorded catch was zero. Foodfish reporting code for Black Kole not offered until October 2002 so 2003 was the first year species-specific commercial foodfish catch data is available for Black Kole.

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.

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 are documented to reach a maximum size of 9.8 inches,[120] but are known to grown larger. 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.[125] Currently, there is a lack of studies done regarding their life history and reproduction.

Uhu *(Parrotfishes, DAR proposes to manage by group as large-bodied and small-bodied)*


Photos: Keoki Stender

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)**

***** These SPR values seem questionable, given the proportional general abundance of each of these species in the MHI. DAR is working with fisheries scientists to update the stock assessment information for these species and others listed in this plan and the plan will be updated accordingly.

Current Regulations:
State (HAR 13-95) Minimum size 12 inches

"Uhu" means any fish known as *Scarus dubius, Scarus psittacus,* ***Scarus rubroviolaceus****, Chlorurus sordidus,* ***Chlorurus perspicillatus****,* or any recognized synonym.

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*).[129] 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)

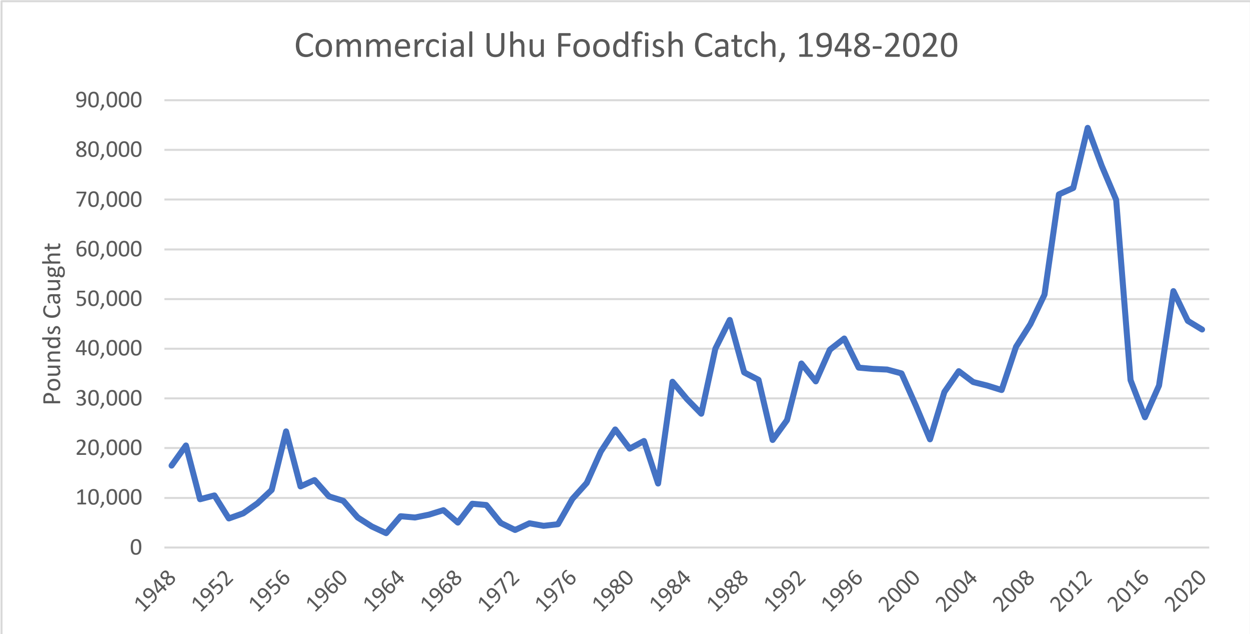
Commercial Harvest: Uhu as a group are the most commonly caught herbivore by commercial fishers with 537,076 pounds landed between 2011 and 2020 and one of the most commonly seen reef fishes in many fish markets and restaurants. They are most often caught using spears but are also targeted with seine 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.[130] It is important to note that there have been many changes historically in the Uhu fishery, including major shifts in the gear types over time. One example is the shift to SCUBA spearfishing, a much more efficient method. These shifts can greatly change the amount of catch at a given time. 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*



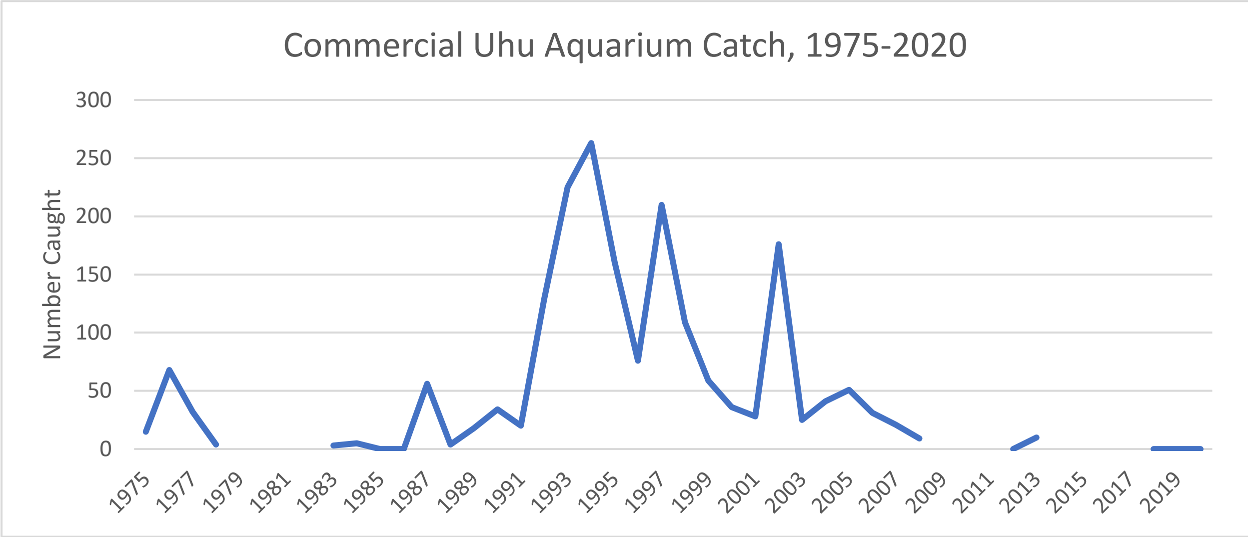
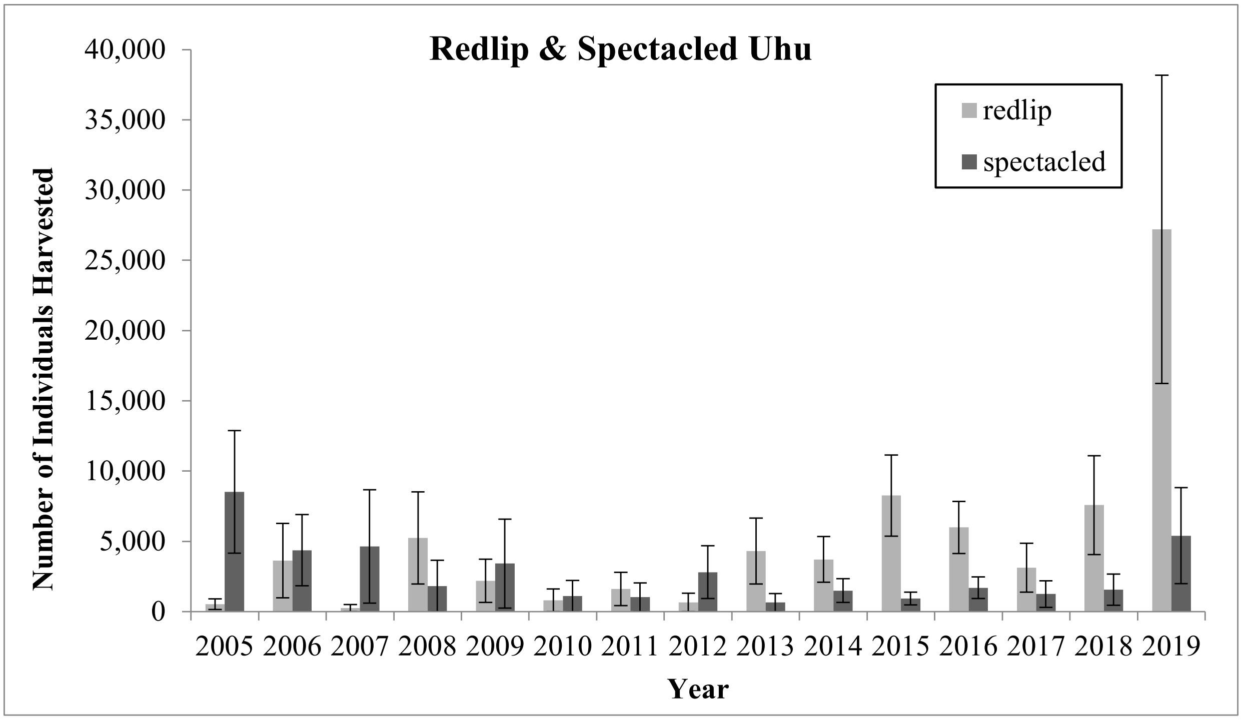


Figure 26: Commercial foodfish harvest Uhu (in pounds) from 1948 to 2020 (top) and commercial aquarium catch (in number of individuals) from 1975- 2020 (bottom). Commercial aquarium catch data for Uhu is confidential for the years not plotted and does not mean recorded catch was zero.

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.



<u>Historical take and Cultural/Traditional Use</u>: 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.[117] In a fisherman's prayer, the Uhu was referred to as "gumless Uhu" at sea. The stages of growth are: Ohua (spawn) Ponuhunuhu or Panuhunuhu."[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."[91] When catching by hook and line, the ʻalaʿala (ink bag) of the Heʻe (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 ʻōlelo 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.[131]

Background/Ecology/Behavior:
***Scarus rubroviolaceus,* Uhu Palukalua (female), Uhu ʻEleʻele (blue green male)**: 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.[132] Large adults usually occur on upper parts of deep slopes[133] or within 2 feet of water on shallow reef flats. Their distribution is highly influenced by fishing pressure.

***Chlorurus perspicillatus,* Uhu ʻAhuʼula (female), Uhu Uliuli (blue male):** 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,[120] 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.[134,135] 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.[135] Turf and crustose algae make up 98% of the large-bodied uhu's diet.[136] Grazing rates of both the Red-lipped Parrotfish and Spectacled Parrotfish increase with increasing size[136] 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 Hawaiʻi.[136]

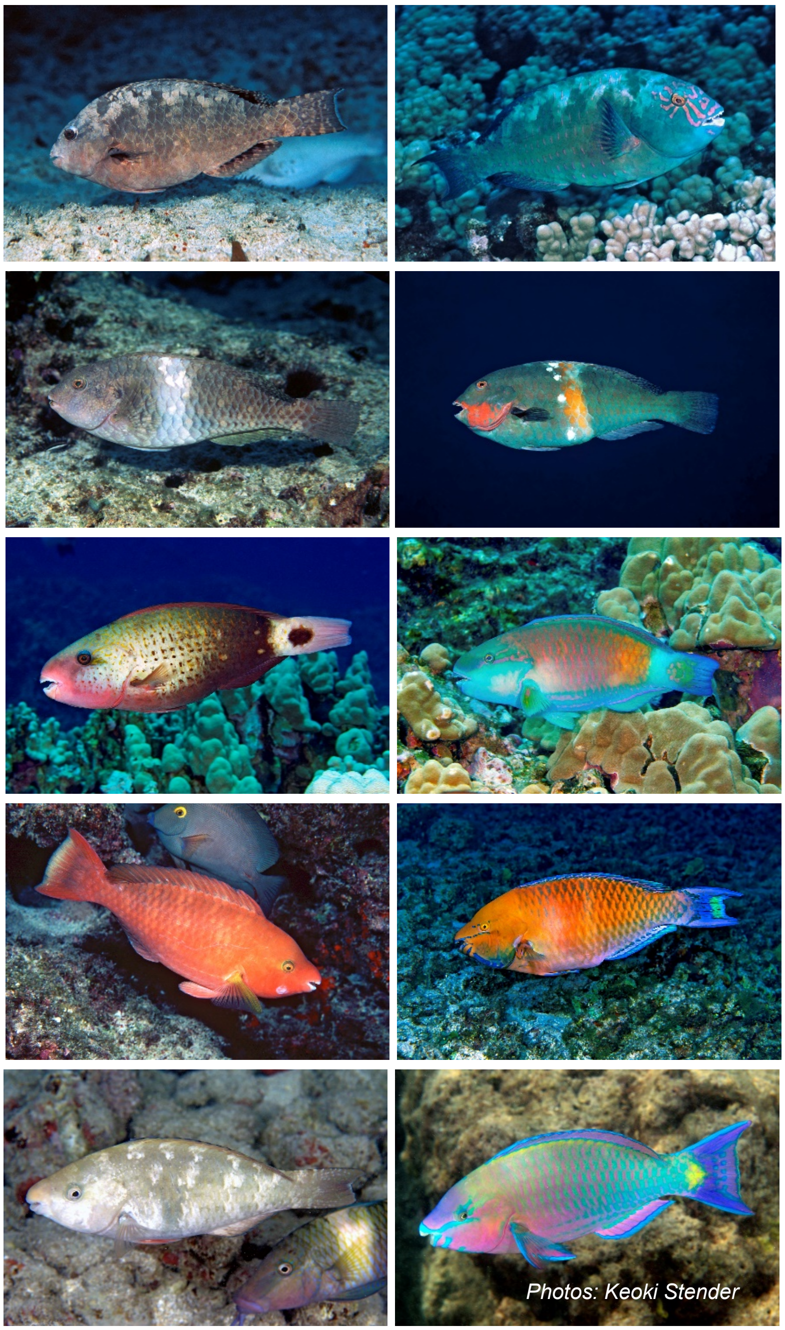
Life History: These are long-lived species with a longevity of at least 20 years. They are mature at about 3-4 years. Length at maturity (L_{50}) for these species are 13.8 inches for Red-lipped Parrotfish 13.6 inches for Spectacled Parrotfish.[129] Parrotfishes begin life as female and can subsequently change sex to male around at 5 - 7 years. [129,137] Their peak spawning season is from April – July.[138]

A special note on banning the take of blue Uhu:
Uhu have three morphological stages: the juvenile stage, initial phase, and terminal phase. The juvenile phase includes immature individuals with stripes that have not yet sexually matured. The initial phase includes mature females and males which have drab colors called sneaker males. The terminal phase changes their body color to bright blues and greens, comprised of sex-changed males that were previously female. Terminal phase males are territorial and have a harem of females. However, if there is no terminal male in a harem, the largest female of the harem can change sex and become a new terminal male.[139,140] However, 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.[137] A neighboring terminal male can also expand his territory to include the territory of a removed terminal phase male.[138]

Part of the issue of removing the blue Uhu is that if the largest of the females in the harem may change into a terminal phase male, that effectively removes her female reproductive potential from the population. In the larger-bodied species, there is a higher percentage of initial phase sneaker males compared to blue terminal phase males, which may be a result of fishing pressure for large blue Uhu.[138] The fishing pressure may be leading to a selective preference for reproduction via sneaker males over terminal phase males.[129] 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.[139] This high percentage of sneaker males compared to the blue terminal males, is unusual compared to the amount of blue male terminal phase parrotfishes in other areas of the world where the percentage of the population can be 10 - 50%, compared to 1 - 2 % as seen on Oʻahu reefs.[129] Decreases in the proportion of terminal phase blue males makes it more challenging for females to find a spawning partner.[141] If there is pressure from fishing to catch the largest size Uhu, including females, this will prevent individuals from growing large enough to change sex, and could result in lower reproductive output.[141]

In summary, current fishing pressure tends to target the largest fishes and disproportionately ends up targeting terminal phase blue males. Over time, this changes the proportion of terminal phase males in the population and shifts evolutionary pressure towards smaller reproductive strategies. Hence protecting the terminal phase males will increase reproductive output and result in larger fishes.

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



Photos: Keoki Stender

Status: **UNSUSTAINABLE**

Pananu/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)**

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

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 12 inches (excluding *Calotomus carolinus and Calotomus zonarchus*)

“Uhu” means any fish known as *Scarus dubius, Scarus psittacus, Scarus rubroviolaceus, Chlorurus sordidus, Chlorurus perspicillatus,* or any recognized synonym.

Maui (HAR 13-95.1) Minimum size 10 inches, Bag limit 2 for total regardless of species, “uhu” means any fish belonging to the family Scaridae or any recognized synonyms.

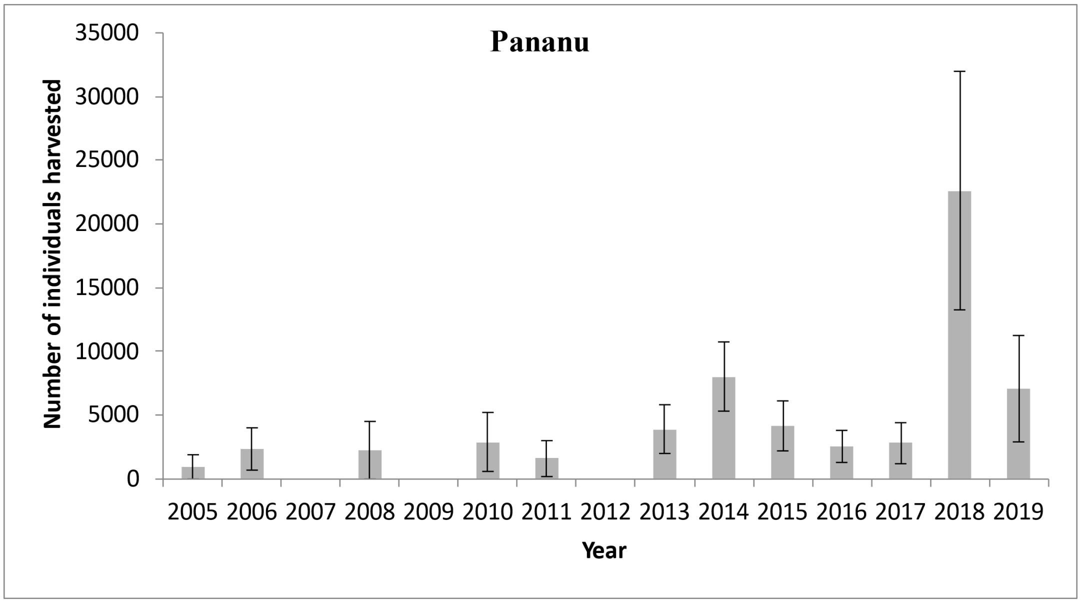
Management Considerations: These species are heavily targeted though less heavily than large-bodied species. A minimum size limit would be appropriate for each of these species, given that they are heavily targeted and given their importance to reef resilience. A bag limit combined with minimum size 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)

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

Non-commercial Harvest: Pananu is the most commonly caught of the small-bodied parrotfishes. In the HMRFS data, the median catch of Pananu 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 pananu 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. Pananu is found in coral, rubble, and weedy areas, singly or in small groups.[120] *Calotomus zonarchus* is also found in coral, rubble, and weedy areas, singly or in small groups.[120,142]

Pananu pōnuhunuhu, (*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.[143]

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.[120]

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.[144]

Regal Parrotfish (***Scarus dubius***)**:** This species is endemic to the Hawaiian Islands. Males were formerly known as *Scarus lauia*.[145]

Palenose Parrotfish (*Scarus psittacus*): This species is very common on reefs in small harems where it feeds upon benthic algae and *Halimeda*.[142] Females were formerly known as *Scarus forsteri*, males as *Scarus taeniurus*.[146]

<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.[129] Our endemic species Yellowbar Parrotfish and Regal Parrotfish, are lacking in life history information because they are rare in the Main Hawaiian Islands. Pananu 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: Pananu 9.6 inches, Bullethead Parrotfish 6.8 inches, and Palenose Parrotfish 5.5 inches.[129] Maximum size of these species are: Pananu 21 inches,[147,148] Bullethead Parrotfish 16 inches,[127,147] Palenose Parrotfish12 inches,[127,147] and our two endemic species, Yellowbar Parrotfish 13 inches,[101] and Regal Parrotfish14 inches.[147]

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 in Hawaiʻi serve to protect, conserve, and manage the 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 30x30, DOCARE's capacity is growing. DOCARE is working to increase its enforcement capacity by filling officer vacancies through its Academy and Field Training Program. It is also providing updated training on marine rules, and ensuring it has enough vessels, vehicles, and equipment to carry out enforcement responsibilities. In the 2021 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 occurring, 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 separate penalties and fine. The tables below highlight the fee schedule for marine resource violations:

Table 2: 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 the Makai Watch Program. Makai Watch is an educational program under DLNR Division of Conservation and Resources Enforcement. It empowers community leaders to take ownership in the protection of their local marine resources. Makai Watch partners with communities to educate the public on pono behavior. The program trains local communities 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

Monitoring is an essential component that measures and documents current conditions, tracks ecological 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.

Herbivore-Specific 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 response of herbivores and coral reef habitat, 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 (trends in benthic condition and herbivore diversity, abundance and biomass) and make this information publicly accessible.
- ***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 best available data and ecological conditions to assess current status of the fishery and coral reef condition. Consider amending current regulations as needed to support current conditions of the fishery and the reefs.
- ***Action M.5*** By 2025, evaluate existing MMA for effectiveness in promoting sustainable fishing practices of herbivorous fishes.

Monitoring

DAR employees conduct regular monitoring for each district, in partnership with federal agencies and universities. 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 randomly selected sites. Additionally, DAR collaborates with other partners, agencies, and groups who also conduct surveys. DAR, among six other agencies and organizations, partners with the Hawaiʻi Monitoring and Reporting Collaborative (HIMARC), which combines, standardizes, and calibrates data from the surveys of the different organizations.

With the help of HIMARC, by 2023, we will compare a baseline assessment of benthic condition and herbivore biomass based on data from 2004-2014 (Figure 2 and Figure 4) with another assessment based on data from 2015-2020. 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 30x30 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.

PROTECTION AND RESTORATION

Herbivore management is one component of a multi-faceted approach to manage for improved reef restoration and resilience, including both resistance to and recovery from disturbance. Protection and 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.

Herbivore-Specific 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 scale-up restoration efforts.

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, in coordination with partners, prioritize key watersheds with the highest potential to recover herbivores and nearshore habitat.
- *Action PR.3* Work with regional and local partners to implement restoration plans.
- *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.
- *Action PR.5* Build on existing work in coral restoration, out-planting coral modules grown at DAR's coral nursey, on specific reefs where restoration will enhance coral reef habitat.

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 DOH's 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 the DOH's water quality plan, the US Coral Reef Task Force (USCRTF) has plans to develop priority water quality standards for coral reefs. The water quality standards developed through the USCRTF. These standards could be used to recommend and revise scientifically based, water quality standards for aquatic life, in addition to human health, in the Environmental Protection Agency's (EPA) Water Quality Standards Handbook, supporting the objective from the DOH water quality plan. For more information on what the EPA is doing to protect coral reefs, please visit https://www.epa.gov/coral-reefs/what-epa-doing-protect-coral-reefs.

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

DAR Coral Nursery and Restoration

DAR has created a one-of-a-kind land-based Coral Restoration Nursery to fast-grow Hawaiian corals under strict biosecurity protocols. Through a suite of unique restoration tools and procedures, DAR can produce a couple hundred large coral colonies per year for outplanting to damaged or degraded reef areas. There are several sites with outplanted colonies on O'ahu and coral restoration projects are being planned for West Hawai'i.

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 3/5 inch (15 mm) in diameter, at which time they are released into Kāne'ohe Bay to control invasive, algae.[87]

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 outplanting these urchins at the Waikīkī MLCD and FMA to control invasive algae in that area.

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 successfully implemented and maintained. However, community support is critical to meeting these objectives.

Table 3: List of objectives and action items with the relative difficulty of implementation (easy, moderate, difficult) and difficulty of maintenance (easy, moderate, difficult, as determined by DAR). The first row is for the objective overall. Easy indicates objectives/actions where partnerships are already established, funding has been secured, or easily accessed, there is a high level of investment, and the action item is likely to have widespread support with little contention. Difficult indicates objectives/actions where funding may be difficult to secure, there is a low level of investment, and/or the action item is likely to have strong opposition by some resource users or much contention. Moderate is ranked in between Easy and Difficult. All rankings are a combination of several factors with these main considerations.

Objective	Difficulty of Implementation	Difficulty of Maintenance
Place-based planning	Difficult	Moderate
Action PB.1	Moderate	Moderate
Action PB.2	Difficult	Moderate
Pono Practices	Difficult	Difficult
Action PP.1	Difficult	Difficult
Action PP.2	Difficult	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
Protection and Restoration	Moderate	Easy
Action PR.1	Moderate	Easy
Action PR.2	Moderate	Easy
Action PR.3	Moderate	Easy
Action PR.4	Easy	Moderate
Action PR.5	Easy	Moderate

Reviewing and Reporting on the Plan

Management strategies laid out in this plan will go through several public scoping sessions where DAR can provide a status report on the condition of the coral reefs and herbivorous fishes, and communities can provide their own insight and comments based on their 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.

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 engagement process and must adhere to the Chapter 91 rule-making process, which provides the public with an opportunity to provide testimony on any rule proposal. Place-based and island-scale planning will include community participation to develop and draft any applicable rules. Communities will also be asked to help identify place-specific needs that can be addressed with support of watershed and coastal partnership, as part of this broader plan. DAR aims to provide many opportunities for the public to provide input on objectives and actions of this Sustainable Herbivore Management Plan.

NEXT STEPS

- DAR will continue to move forward with a statewide proposal for herbivore regulations by the end of 2021, with public scoping scheduled in December.
- Starting from 2021 to 2026, DAR will hold community engagement opportunities for considering island-scale and place-based regulations for herbivores.
- From 2021 to 2024, DAR will collaborate with the Hawaiʻi Monitoring and Reporting Collaborative (HIMARC) to examine herbivory thresholds in relation to coral reef sustainability. Results from this project will be integrated into future updates of this Herbivore Management Plan and used to inform and adapt management actions as they relate to herbivory and benthic conditions.
- Starting in 2021, DAR will convene a Nearshore Restoration hui to build and expand partnerships to help address land-based threats that impact nearshore habitats and herbivore populations.
- This plan will be reviewed and updated every five years, responding to new information, changing conditions, and arising concerns/threats. An evaluation of the success in meeting the goal, objectives, and actions of this plan will be completed. 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 persistence of coral reefs into the future. 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.


Photo: Bert Weeks

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.[13]

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 30x30*:* a goal to effectively manage Hawai‘i’s nearshore waters, with at least 30% established as marine management areas*.*

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 Area (MMA): specific geographic area designated by statute or administrative rule for the purpose of managing a variety of marine, or estuarine resources and its 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	Hawaiʻi Administrative Rules
HMA	Herbivore Management Area
HIMARC	Hawaiʻi Monitoring and Reporting Collaborative
HMRFS	Hawaiʻi 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 Hawaiʻi Aquarium Fishery