Honokoa Reef Assessment
2022

by

Dwayne Minton[1], Ryan Carr[2], Harry Lynch[2], Cecile Walsh[2]
and Eric Conklin[2]

[1]Dwayne Minton Consultants
7722 Hwy 3A.
Balfour, B.C. V0G 1C0
Canada

[2]The Nature Conservancy
923 Nu‘uanu Ave.
Honolulu, HI 96817

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Introduction

The west coast of Hawaiʻi Island has extensive nearshore coral reefs. This biologically diverse and productive ecosystem is economically and culturally important to the people of Hawaiʻi. Coral reefs in Hawaiʻi are under threat from a range of anthropogenic stressors, including sediment runoff resulting from human activity, overfishing, and wastewater pollution. These activities, along with environmental disturbances associated with climate change, disrupt natural ecological processes, decrease reef resilience, and impair the condition of many coral and fish species.

The reefs north of Kawaihae Harbor, from the Kawaihae Lighthouse to Kailapa are consistently impaired from sediment runoff due the degradation of the upland ahupuaʻa through over-grazing by feral goats, the proliferation of invasive plants, and wildfire. The Kailapa community has identified Honokoa gulch as a major source of sediment erosion and transport to the nearshore reefs and have initiated a restoration project with the goal of significantly reducing upland erosion and coastal sedimentation (DHHL 2024).

In 2022, TNC undertook a comprehensive coral reef survey centered around Honokoa gulch to document the current conditions of the benthic (coral) and fish assemblages. These data are intended to form a baseline condition assessment of the Honokoa reef for future assessments.

Geographic Setting

The survey area includes fringing coral reefs along approximately approximately 2.75 km of coastline between the Kawaihae Lighthouse and the Kailapa Department of Hawaiian Homelands (DHHL) community. For the purposes of this report, this reef area is referred to as the Honokoa reef. The southern edge of the survey area is adjacent to the entrance channel (~15 m) to Kawaihae Deep Draft Harbor, one of two main commercial ports for the island of Hawaiʻi. This area is within the West Hawaiʻi Regional Fishery Management Area (WHRFMA) and the North Kohala Fisheries Replenishment Area (FRA). Within the FRA, fishing for aquarium purposes is prohibited, although other forms of fishing are permitted. Other regulations for the WHRFMA, such as a prohibition on SCUBA spearfishing, are also enforced.

No permanent streams discharge into the coastal waters, but several intermittent streams can discharge large volumes following rain events. These discharge events carry considerable sediment into the nearshore waters. While most coastal residences have onsite sewage disposal systems, primarily cesspools (DHHL 2024), the low population density may limit their effect on coastal waters. Overall, water quality within the Honokoa survey area is likely to be generally good, but may be periodically compromised, especially during or following storm events.

In 2015, West Hawaiʻi experienced a prolonged period of elevated sea water temperatures that resulted in the onset of widespread coral bleaching (Kramer *et al.* 2016, Maynard *et al.* 2016). During this period, sea temperatures were above the bleaching threshold (Degree Heating Weeks = 4 °C-weeks) for two months (NOAA CRW 2016), a level of thermal stress unprecedented in Hawaiʻi. TNC documented severe, widespread bleaching in nearly all coral species and down to depths of at least 15 m on West Hawaiʻi reefs from Honokoa to Keauhou (Maynard *et al.* 2016). At the Kailapa site, coral cover at the shallow and deep sites declined by 59% and 42%, respectively following the bleaching (Minton *et al.* 2018) and showed no recovery over the next three years (Minton *et al.* 2020)

Survey Methods

TNC collected fish and benthic data at a total of 45 randomly-selected and two existing long-term monitoring sites[1] along the fringing reef fronting Honokoa Gulch between May 30, 2022 and June 3, 2022 (Figure 1). All sites were between 1 and 16 m depth on predominately hardbottom. Locational information (latitude/longitude) and other metadata for all survey sites have been compiled in Appendix A.

Survey teams navigated via a small, motorized boat to each pre-determined site using a Garmin GPS unit. Once on site, divers on scuba were deployed and descended directly to the bottom. At each site, fish surveyors established transect start-points. When two fish surveyors were present (19 sites, see Appendix A), start points were spaced approximately 10 m apart. From each start-point, divers deployed a 25-m transect line along a predetermined compass bearing, which at sites with two fish surveyors resulted in two transect lines running parallel to each other. If the pre-determined compass bearing resulted in a large change in depth, the bearing was altered such that the transect followed the contour at the depth of the start point. All data collection was conducted by trained divers who had been calibrated to reduce surveyor variability. Fish and benthic data were collected at all 47 sites, however, turbid conditions at one site (2022-HON-

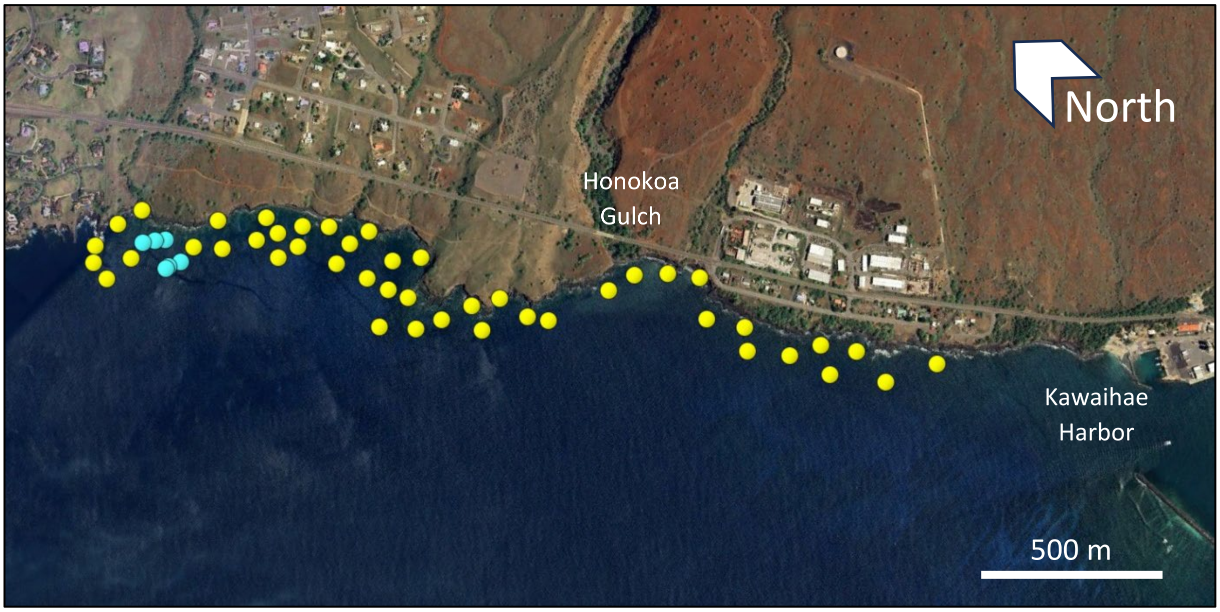

Figure 1. Honokoa survey sites (yellow) and long-term monitoring transects (blue) surveyed by TNC in 2022.

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[1] Data collection at the long-term monitoring sites was conducted following the methods described in Maynard *et al.* 2016. This resulted in three "sub-sites" for each of the two long-term sites that were not statistically independent. See the "Data Management and Analysis" section for more information on how the two long-term monitoring sites were incorporated into the analysis.

043) did not allow for the collection of benthic data that was of sufficient quality for use so this site was excluded from the benthic analysis. The specific survey methods for each type of data collection are discussed in detail below.

Benthic Cover

At each survey site, photographs of the bottom were taken every meter along one 25-m transect line using an Olympus Tough camera or equivalent mounted on a PVC monopod. The white-balance of the camera was adjusted prior to photographing each transect to improve color quality. This generated 25 images for each survey site, with each photo covering approximately 0.8 x 0.6 m of the bottom.

Twenty randomly-selected photographs from each transect were analyzed to estimate the percent cover of coral, algae, and other benthic categories. Photos were analyzed using CoralNet, an online repository and resource for benthic image analysis maintained by the University of California, San Diego (Beijbom *et al.* 2015). Thirty random points were overlaid on each digital photograph, and the benthic component under each point was classified into one of the following groups: coral (to species), macroalgae (to lowest possible taxonomic resolution), crustose coralline algae, turf, other biotic, and abiotic (to sand, rubble, pavement or recently dead coral). Once completed, the raw point data from each photograph was combined to calculate the percent cover of each benthic component for the survey site. As noted above, turbid water conditions precluded the collection of usable benthic data at one site.

Benthic Topography

The topographic complexity of the bottom at each site was measured using an index of rugosity calculated along the first 10 m of the same 25-m transect used for benthic imagery by dividing the length of brass chain necessary to contour the bottom by the 10-m transect length (McCormick 1994). For this index, a value of one represents a flat surface with no topographic relief, and increasing values represent more topographically complex substratum.

Coral Reef Fish Abundance and Biomass

While slowly deploying the 25-m transect lines, divers identified to species and sized to the nearest centimeter all fishes within and passing through a 5-m wide belt along the transect, extending from the seafloor to the surface. Divers took between 10 and 15 minutes to complete a single survey. Individual fish biomass (*i.e.*, wet weight) was calculated using fish length and size-to-weight conversion parameters from FishBase (Froese and Pauly 2010) or the USGS Hawaiʻi Cooperative Fisheries Research Unit (HCFRU). Some species, such as eels (Family Muraenidae), cannot be reliably sized using non-intrusive visual surveys, so these species were counted but excluded from biomass estimates.

Fish data were pooled into several groups: total fish, fish family, resource fish[2], including a selected non-resource group for comparison, prime spawners, and invasive fish. Resource fish refer to fishes desirable for food, commercial activity, and/or cultural practices in Hawaiʻi (see Williams *et al.* 2008), whereas the selected non-resource fish are species not routinely targeted by fishers in Hawaiʻi to a significant degree (Table 1). Several of the species included in the non-resource fish list are targeted in the aquarium fishery on Hawaiʻi Island, but none comprise a large component of the catch in that fishery, and take of juveniles as a percentage of the juvenile population has been estimated to be <8% for the most heavily fished species (*Acanthurus nigricans* [goldrim surgeonfish]) and <1% for most others (Walsh 2013). Given that the non-resource species list is used statewide by TNC for comparative purposes, no changes were made. Nearly all fish species are taken by some fishers at some time in Hawaiʻi, therefore designating a fish species as either "resource" or "non-resource" is oftentimes difficult. These two groupings—resource fish and non-resource fish—are intended to represent the high and low ends of the fishing pressure continuum in Hawaiʻi.

Prime spawners are large resource fishes (>70% their maximum size) generally prized by fishers and that tend to contribute disproportionately more to the total breeding potential of the population than smaller individuals. Prime spawners have greater egg and sperm production (*i.e.*, fecundity) and their larvae often have higher survivorship compared to smaller individuals (Williams *et al.* 2008). Prime spawner biomass is often a good indicator of fishing impacts (*e.g.*, prime spawner biomass often decreases as fishing pressure increases), while representing an important component of ecological function (*i.e.*, population breeding potential).

Invasive fishes included three species: *Cephalopholis argus* (peacock grouper or roi), *Lutjanus kasmira* (bluestriped snapper or taʻape), and *L. fulvus* (blacktail snapper or toʻau).

Data Management and Analysis

All fish and site data were entered into a custom Access database and checked for errors. All benthic data were compiled in Excel spreadsheets prior to analysis. All databases and spreadsheets support safeguards to ensure high data quality, and they reside on a secure, cloud-storage platform that is backed up regularly to protect against data loss. Raw point data for the benthic photographs are maintained online in CoralNet.

When the data from the long-term monitoring sites were analyzed with the data collected at the 45 randomly-selected sites, each of the six transects was treated as a “site.” This resulted in 51 survey sites for most analyses. Data were available for the two long-term monitoring sites (Kailapa Shallow and Kailapa Deep) from 2015, 2016, 2017, 2019, 2022 (this study), and 2023,

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[2] In other TNC reports, "resource fish" may be called "target fish." The species comprising these groups are identical (see Table 1).

Table 1. Fish species comprising the seven resource species groups and the non-resource group used in this report. Groups are modified from Williams *et al.* (2008).

Resource Groups

Surgeonfishes (Acanthuridae)
Acanthurus achilles
Acanthurus blochii
Acanthurus dussumieri
Acanthurus leucopareius
Acanthurus nigroris
Acanthurus olivaceus
Acanthurus triostegus
Acanthurus xanthopterus
Ctenochaetus spp.
Naso spp.

Wrasses (Labridae)
Bodianus albotaeniatus
Cheilio inermis
Coris flavovittata
Coris gaimard
Iniistius spp.
Oxycheilinus unifasciatus
Thalassoma ballieui
Thalassoma purpureum

Apex
Aphareus furca
Aprion virescens
All Carangidae (jacks)
All Priacanthidae (big-eyes)
All Sphyraenidae (barracuda)

Goatfishes (Mullidae)
All

Parrotfishes (Scaridae)
All

Soldier/Squirrelfishes(Holocentridae)
Myripristis spp.
Sargocentron spiniferum
Sargocentron tiere

Others
Chanos chanos
Cirrhitus pinnulatus
Monotaxis grandoculis

Non-resource Group

Acanthurus nigrofuscus
Acanthurus nigricans
Chaetodon multicinctus
Chaetodon ornatissimus
Chaetodon quadrimaculatus
Chaetodon unimaculatus
Plectroglyphidodon spp.
Stegastes spp.
All wrasses, except those listed above
All hawkfishes, except *Cirrhitus pinnulatus*
All triggerfishes, except planktivorous species

which allowed for examination of the changes in the benthic and fish assemblages at Honokoa over time at these two sites. For these analyses, the three transects at each site were averaged to obtain a single value for each site. All means are presented as the average ± the standard error of the mean (SEM) unless otherwise stated.

Results and discussion

Benthic Assemblage

The typical West Hawai‘i reef tends to be dominated by turf algae, coral and crustose coralline algae (Table 2; Minton *et al.* 2020). Among corals, *Porites lobata* (lobe coral) is the most common species, especially at shallower depths. Other coral species tend to increase in abundance with depth; *P. compressa* (finger coral) becomes more abundant, and *P. monticulosa* (plate and knob coral) can be locally dominant.

Unlike the typical benthic community on most West Hawai‘i reefs, crustose coralline algae (CCA) were especially common at Honokoa. While algal turfs were still the dominant benthic

Table 2. Average (±SEM) percent cover of benthic groups at Honokoa in 2022. West Hawai‘i data are from Minton *et al.* (2020)

	Honokoa	**West Hawai‘i**
Turf	60.2 ± 2.1	63.1 ± 1.5
Crustose Coralline Algae	17.9 ± 2.0	8.2 ± 1.0
Coral	14.7 ± 1.6	19.6 ± 1.6
Porites lobata	9.6 ± 0.6	15.2 ± 1.5
Porites compressa	2.7 ± 0.6	2.7 ± 0.6
Porites rus	1.7 ± 1.3	0.1 ± 0.1
Porites monticulosa	0.5 ± 0.3	0.9 ± 0.9
Montipora capitata	0.1 ± 0.1	0.2 ± 0.1
Pavona varians	0.1 ± 0.1	0.1 ± 0.1
Porites evermanni/lutea	<0.1	0.1 ± 0.1
Montipora patula	<0.1	0.1 ± 0.1
Pocillopora meandrina	<0.1	<0.1
Coral sp.	<0.1	-
Leptastrea sp.	Present[†]	0.1 ± 0.1
Macroalgae	0.1 ± 0.1	<0.1
Cyanobacteria	<0.1	0.2 ± 0.1
Other	<0.1	0.2 ± 0.1
Abiotic	7.2 ± 1.0	8.7 ± 1.1
Sand	6.6 ± 1.0	6.8 ± 0.9
Rubble	0.5 ± 0.1	1.9 ± 0.5
Pavement	0.1 ± 0.1	<0.1
Recently dead coral	<0.1	<0.1

[†] Species was observed in one or more benthic photos but was sufficiently rare that none of the random photo-points fell on it.

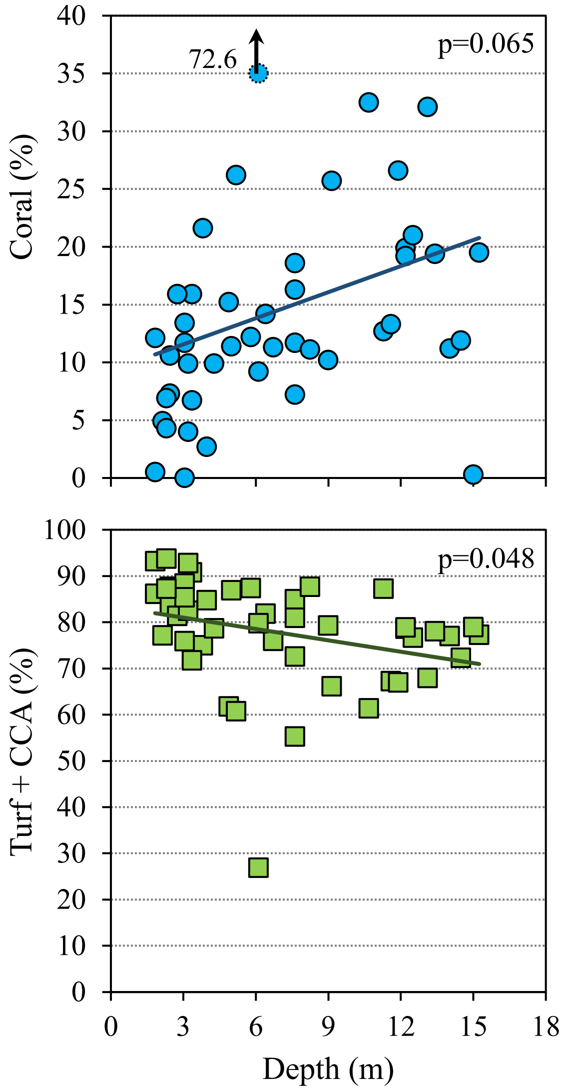

Figure 2. Percent cover vs. depth at Honokoa in 2022. A trendline is provided to aid in visualizing the change in coral cover with depth. P-values provided for the Pearson correlation. Note: The y-axis on the top graph is truncated to better visualize the data. One site had 72.6% coral cover.

type at Honokoa, CCA covered nearly 18% of the bottom, almost twice that found previously on other West Hawaiʻi reefs (Table 2). Coral cover was 14.7 ± 1.6%, which is lower than the regional average due primarily to the lower abundance of *P. lobtata* (Table 2). However, *P. lobata* was still the most abundant coral at Honokoa, but *P. compressa* and *Porites rus* (plate and pillar coral) were also relatively abundant, and *P. monticulosa* was abundant at a few survey sites.

Coral cover increased with depth (Figure 2), where deep sites had, on average, twice the cover of shallow ones. One notable exception was site 2022-HON-058, which was directly offshore of Honokoa gulch at 15 m depth and had <1% coral cover. The higher coral cover at depth was associated with decreases in cover of algal turf and CCA (Figure 2). While *P. lobata* was the dominant species at all depths at Honokoa, cover of other coral taxa increased considerably with depth, especially *P. compressa* (Figure 3). This increase in the cover of coral species other than *P. lobata* was the primary driver for the higher coral cover observed at deep compared to shallow sites at Honokoa.

The benthic assemblage also differed across the longshore extent of Honokoa reef. Notably, the amount of abiotic substratum was three times higher at the southern end compared to the northern end of the Honokoa survey area (Figure 4). This is likely associated with periodic sediment inputs via Honokoa Gulch and the proximity to Kawaihae Harbor, a major commercial port with a deep-dredge channel that abuts the southern end of the survey area. Several sites close to the gulch had visible plant and woody debris on the bottom (Figure 5), suggesting that sediment and other organic debris are at least periodically flushed from the gulch into the nearshores marine waters. As discussed above, site 58 (2022-HON-058) was a “deep” site with <1% coral cover and was instead dominated by woody debris, smooth stones reminiscent of river rocks, and dark sediment (Figure 5). Likewise, the one site whose photos could not be analyzed due to low water clarity (2022-HON-043) was also in this area. All of the

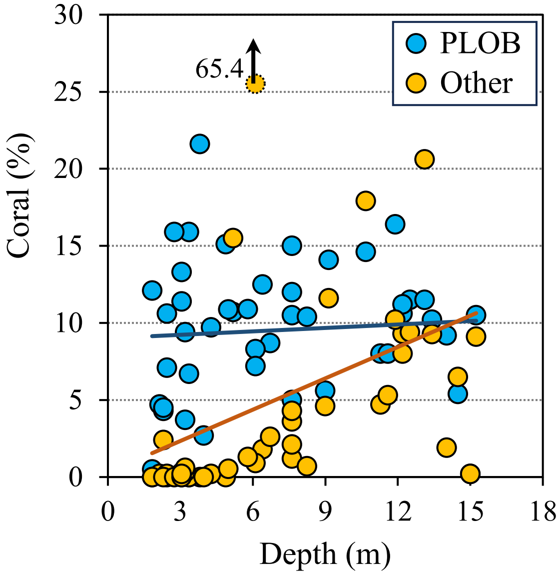

Figure 3. Cover of *Porites lobtata* (PLOB) and all other corals vs. depth at Honokoa in 2022. A trendline is provided to aid in visualizing the change in coral cover with depth. Note: The y-axis is truncated to better visualize the data and one site had 65.4% cover of other coral species.

sites with noticeably dark colored sediment (often a sign of terrestrial inputs) were located between Honokoa Gulch and Kawaihae Harbor. In contrast, sites towards the northern end of the survey area tended to have lighter colored sand (Figure 5), usually indicating it is composed primarily of calcium carbonate and has a predominantly marine origin.

The availability of more hardbottom at northerly sites presented opportunities for greater coral cover. However, coral cover changed relatively little across the extent of the Honokoa reef (Figure 4b). Instead, cover of CCA increased considerably at northern sites (Figure 4c), more than doubling that typically observed along the southern extent of the Honokoa reef (Figure 4). CCA cover at Honokoa was unexpectedly high compared to typical West Hawaiʻi reefs (Table 2), and across the state more generally. Reasons for the high CCA cover at Honokoa are unclear, but in Hawaiʻi, reefs exposed to both high nutrients and herbivory are capable of phase-shifting to CCA-dominated benthic communities (Smith *et al.* 2001), which may eventually prove beneficial to coral settlement (Evensen *et al.* 2021) and facilitate recovery from coral bleaching events, such as that which occurred in 2015.

Following the 2015 mass bleaching event, coral cover declined at the Kailapa Shallow site by 59% and by 42% at the Kailapa Deep site (Figure 6). The relative loss of coral at both depths at Kailapa was considerably higher than the average decline observed across West Hawaiʻi reefs (Minton *et al.* 2018). For many years following the 2015 bleaching event, coral cover remained low before increasing several years later. In contrast, CCA cover increased in the years immediately following the bleaching event, eventually exceeding the cover that had been present pre-bleaching at both Kailapa Shallow and Kailapa Deep sites. CCA cover remained high in 2022 as well as in a more recent survey conducted in 2023 (Figure 6).

The increase in CCA cover in the years following the bleaching event may have facilitated the increase in coral cover observed in later years (2019-2023). By 2022, coral cover at the Kailapa Deep had returned to pre-bleaching levels, whereas the coral cover at Kailapa Shallow, while

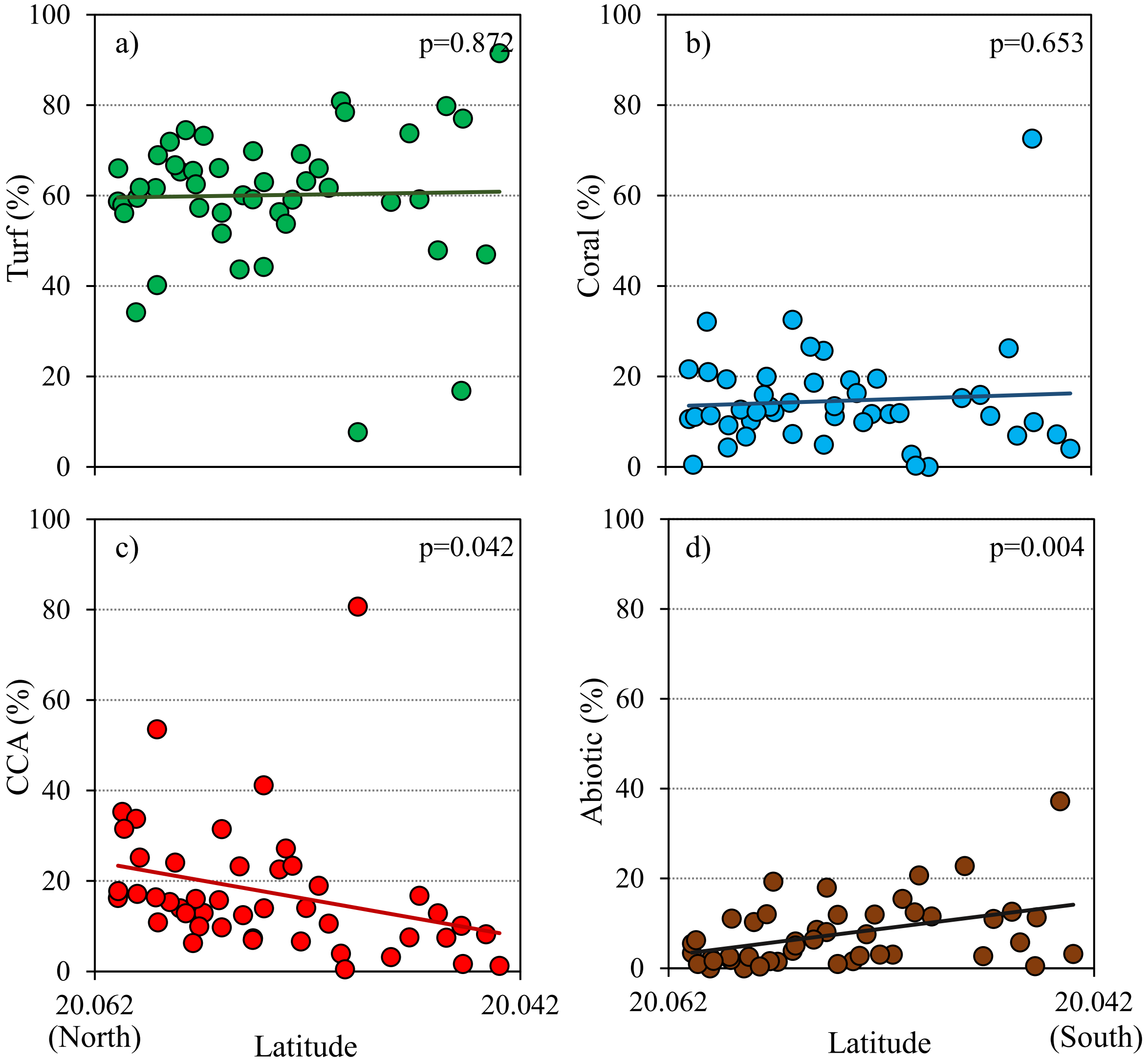

Figure 4. Percent cover of (a) turf, (b) coral, (c) CCA, and (d) abiotic substratum across the Honokoa reef area. A trendline is provided to aid in visualizing the change in cover with latitude. P-values provided for the Pearson correlation.

showing some recovery, has not returned to pre-bleaching levels. Reasons for this difference between the two depths are unclear, but it suggests CCA cover alone is not responsible for the increase in coral cover, and/or that shore-based stressors may be slowing or possibly inhibiting coral recovery in the shallow reef areas of Honokoa.

Coral Bleaching

Coral bleaching was observed at only 9 of the 49 (18%) sites with coral at Honokoa in 2022 and affected <1% of all coral tissue. Among *Porites* species, *P. compressa* had the highest percentage of bleached tissue (3.6 ± 3.5%) but this was heavily skewed by a single site where all observed *P. compressa* tissue was bleached. Removing this site from the analysis, none of the four species had coral tissue bleaching rates >0.3%, and two, *P. rus* and *P. monticulosa*, showed no tissue paling or bleaching. In contrast, *Montipora capitata* and *M. patula* had tissue bleaching rates >30% (Figure 7). Higher bleaching rates for these two montiporids compared to the aforementioned Porites species is not unusual, but given their relative rarity on the Honokoa reef, *M. capitata* and *M. patula* contribute little to the coral tissue bleaching rate across the greater Honokoa survey area. Coral tissue bleaching rates were too low to conduct a meaningful analysis of spatial and depth-related patterns.

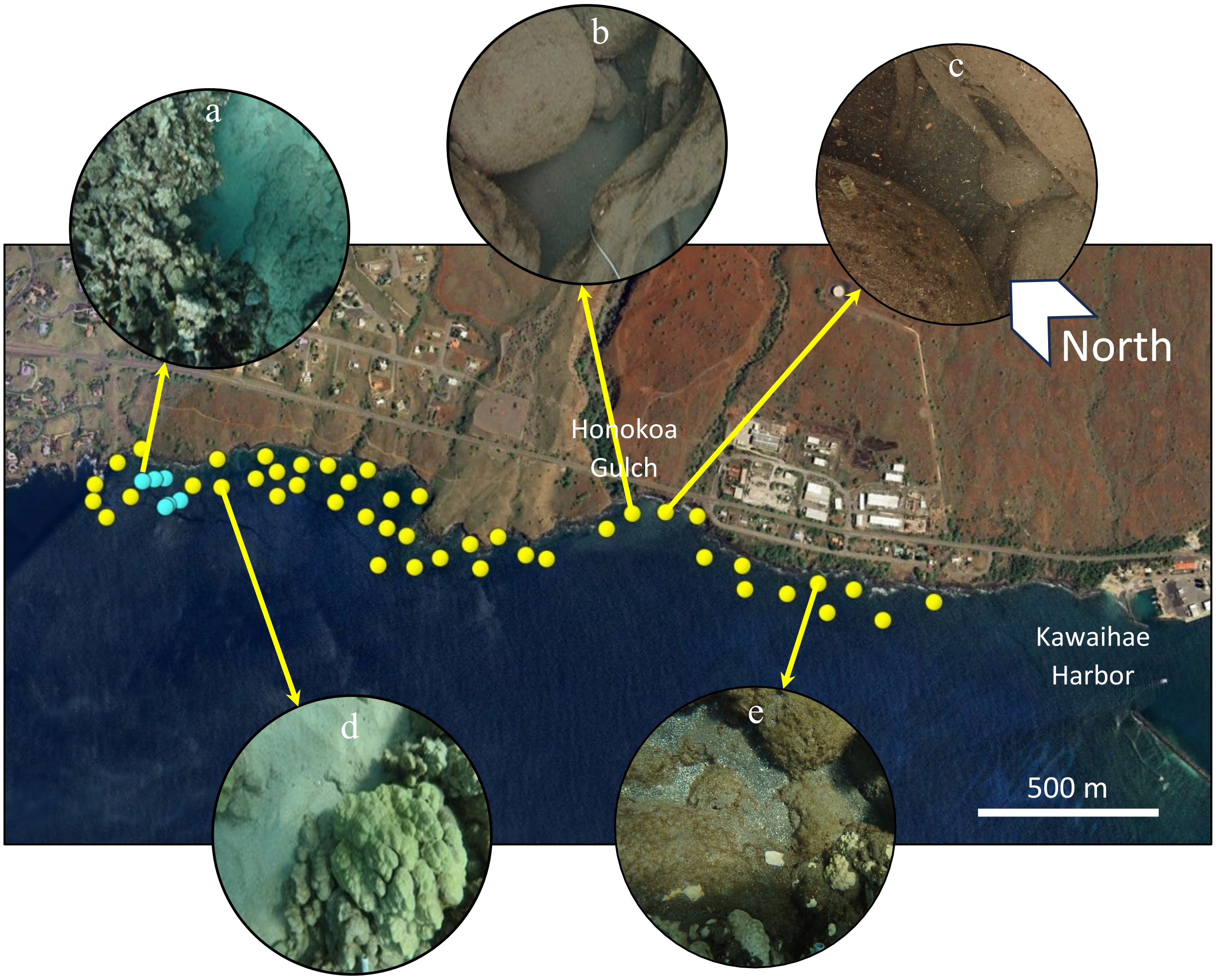

Figure 5. Five representative sites showing the change benthic composition and sediment color from north (left) to south (right). Sites include: (a) 2022-HON-RR2C, (b) 2022-HON-058, (c) 2022-HON-052, (d) 2022-HON-015, and (e) 2022-HON-042.

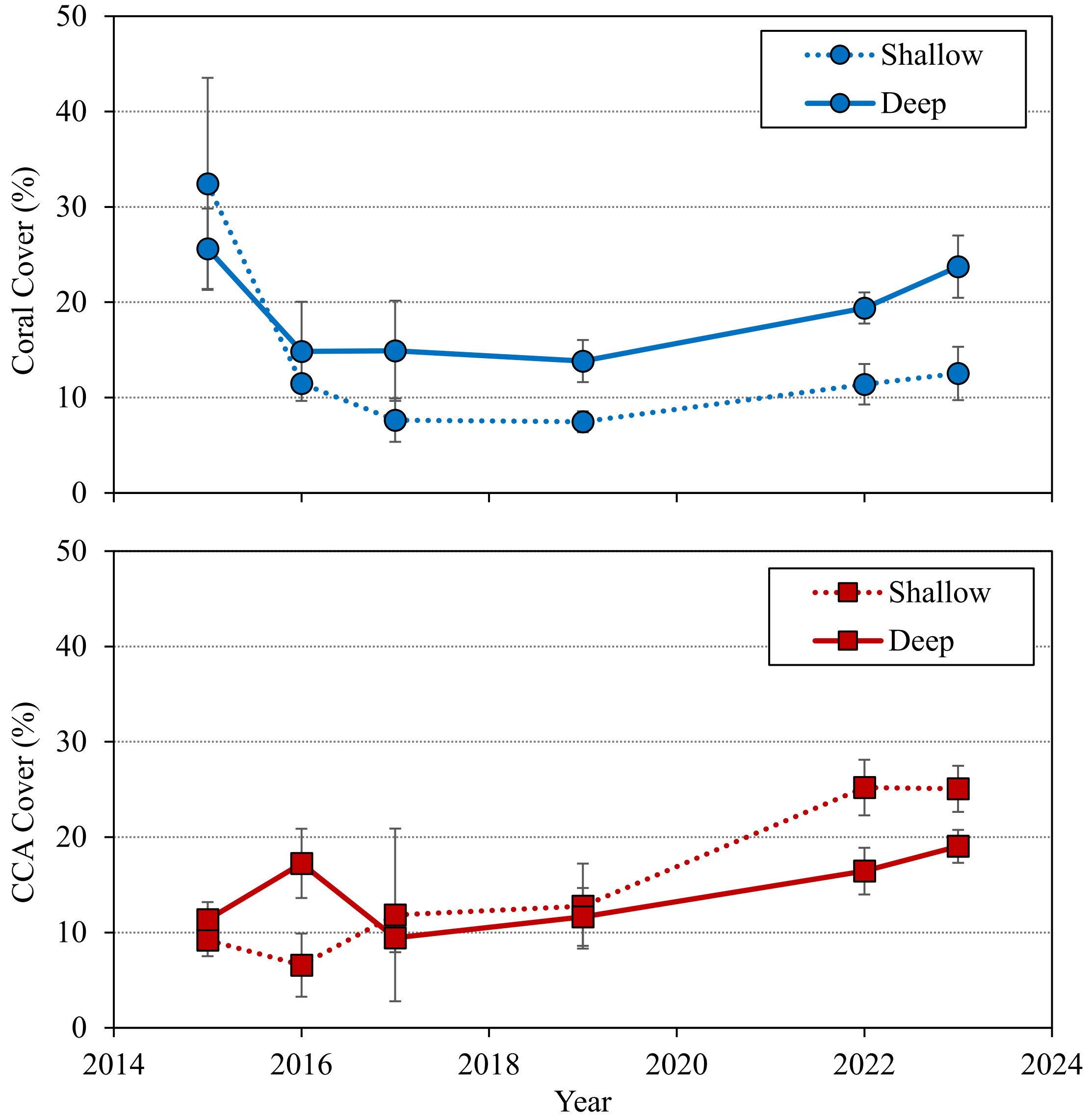

Figure 6. Cover of coral (top) and CCA (bottom) at the Kailapa Shallow and Kailapa Deep long-term monitoring sites. Data from 2022 are from this report. Data from 2015-2019 are from Minton *et al.* (Minton et al. 2020) and 2023 from TNC (unpublished). The 2015 surveys were conducted during the mass bleaching event at a time in which it is likely that some coral mortality had already occurred but before the bulk of the mortality. As such, the 2015 surveys likely represent a reasonable, albeit slightly conservative, estimate of pre-bleaching coral cover.

Fish Assemblage

One hundred and nine fish species representing 24 families were observed at Honokoa in 2022 (Table 4). Average total fish biomass was 48.4 ± 4.6 g/m^2, which was below average for West Hawai‘i reefs (60.8 ± 12.7 g/m^2; Figure 8). Acanthurids (surgeonfish) contributed the most to fish biomass at Honokoa, accounting for over 40% of the total fish biomass. They had nearly 4-times greater biomass than scarids (parrotfish), the next most common family. This dominance

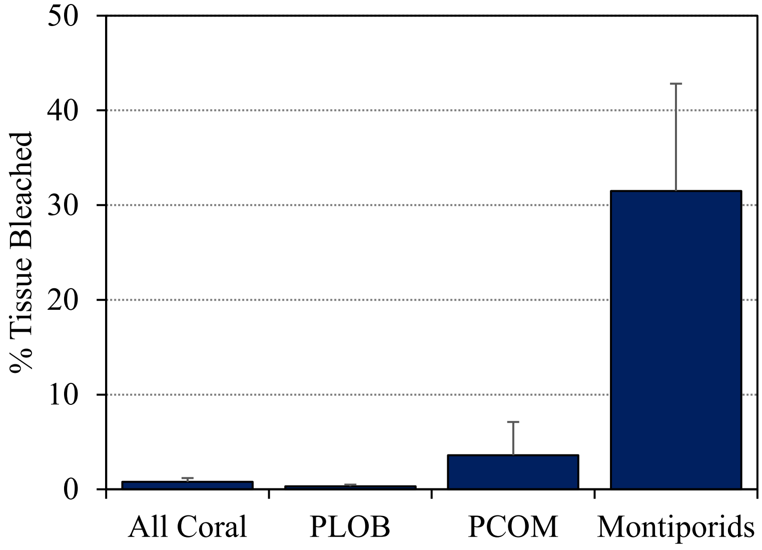

Figure 7. Percent of coral tissue bleached for all coral, *Porites lobata* (PLOB), *P. compressa* (PCOM) and two *Montipora* species (Montiporids).

of acanthurids to the total fish biomass is not unusual on Hawaiian reefs. Acanthurids, along with pomacentrids (damsel fish), were numerically dominant and together accounted for nearly 80% of the abundance with the Honokoa survey area (Table 4).
Total fish biomass showed no pattern with depth or across the Honokoa area (Figures 9a and b). Given the spatial differences observed in the benthic community, the lack of a spatial pattern in total fish biomass across the Honokoa area was surprising. No depth and/or spatial pattern in total fish biomass might suggest a homogenous fish assemblage, but further investigation suggests this is not the case. While total fish abundance also showed no differences across the Honokoa survey area, fish abundance significantly decreased with depth (Figures 9c and d). Theses patterns of total fish biomass and abundance suggests fewer but larger fish were present at deep compared to shallow sites, and at Honokoa was due to a shift in the species composition of the fish assemblage at depth to species with larger body size. For example, the group of non-resource fish (Table 1), which is composed of relatively small-bodied species (*e.g.*, small surgeonfish, butterflyfishes, etc.), were significantly more abundant at shallow than deep water sites (Pearson Correlation; r= -0.56, p<0.0001), whereas the abundance of resource fish groups either increased or did not vary with depth.

For this report, resource fish (Table 1) include fish desirable for food, commercial activity, or cultural practices that reside in the habitats and depth ranges surveyed by TNC divers. Total resource fish biomass was 29.3 ± 3.5 g/m^2, which represented almost 61% of the total fish biomass. All resource fish groups except holocentrids (redfish) were well represented. Acanthurids accounted for the largest percentage of the resource fish biomass (~42%), followed by scarids, which comprised over 18% (Figure 10). Labrids (wrasses), apex predators (*e.g.*, jacks), mullids (goatfish), and other resource fish (e.g., emperors, jobfish, etc.) each represented about 9% of the total resource fish biomass. This relatively even spread of biomass among the resource groups is unusual. On most Hawaiian reefs acanthurids and scarids tend to dominate the resource fish biomass, with the remaining groups being considerably less significant components. *Ctenochaetus strigosus* (goldring bristletooth or *kole*) were the most common resource fish species at Honokoa, followed by *Oxycheilinus unifasciatus* (ringtail wrasse or

Table 4. Fish biomass (g/m^2) and abundance (individuals/125 m^2) by fish family at Honokoa in 2022. Families are arranged by biomass. *Individuals were present, but biomass was not estimated for this family.

	Biomass	**Abundance**
Acanthuridae	19.8 ± 2.3	54.8 ± 3.7
Scaridae	5.4 ± 1.3	2.1 ± 0.4
Labridae	5.1 ± 1.0	10.2 ± 0.8
Lutjanidae	3.4 ± 2.1	2.0 ± 0.9
Balistidae	3.0 ± 0.5	2.2 ± 0.3
Mullidae	2.8 ± 0.6	4.5 ± 1.0
Lethrinidae	2.5 ± 0.6	1.0 ± 0.3
Chaetodontidae	1.5 ± 0.2	4.1 ± 0.3
Pomacentridae	1.3 ± 0.3	57.6 ± 10.5
Serranidae	1.0 ± 0.4	0.2 ± 0.1
Carangidae	0.9 ± 0.5	0.6 ± 0.4
Holocentridae	0.4 ± 0.2	0.4 ± 0.2
Zanclidae	0.2 ± 0.1	0.3 ± 0.1
Kyphosidae	0.2 ± 0.1	0.1 ± 0.1
Diodontidae	0.2 ± 0.1	<0.1
Monacanthidae	0.2 ± 0.2	0.1 ± 0.1
Pomacanthidae	0.1 ± 0.1	0.7 ± 0.2
Aulostomidae	0.1 ± 0.1	0.1 ± 0.1
Cirrhitidae	<0.1	0.3 ± 0.1
Tetraodontidae	<0.1	0.6 ± 0.2
Ostraciidae	<0.1	0.3 ± 0.1
Blenniidae	<0.1	0.5 ± 0.2
Synodontidae	<0.1	<0.1
Muraenidae	*	<0.1
Total Fish Biomass	48.4 ± 4.6	113.0 ± 11.6

po'ou). *Monotaxis grandoculis* (bigeye emperor or *mū*), *Naso literatus* (orangespine unicornfish or *umaumalwei*), and the *Chlorurus spilurus* (bullethead parrotfish or *uhu*) were also frequently observed at survey sites.

Prime spawners are large resource fishes (>70% their maximum size) generally prized by fishers, making them a good indicator of fishing impacts (*e.g.*, prime spawner biomass often decreases as fishing pressure increases). At Honokoa, the prime spawner biomass was 11.7 ± 2.4 g/m^2 and prime spawner abundance was 5.1 ± 1.0 individuals/125 m^2 (per survey site). Prime spawners were observed for 21 species, including representatives from all resource fish groups. Four species accounted for over 57 % of the total prime spawner biomass, including *Chlorurus spilurus* (16% of total prime spawner biomass) and *Scarus psittacus* (palenose parrotfish or *uhu*, 10%), *Acanthurus blochii* (ringtail surgeonfish or *pualu*, 16%), *Aprion virescens* (green jobfish

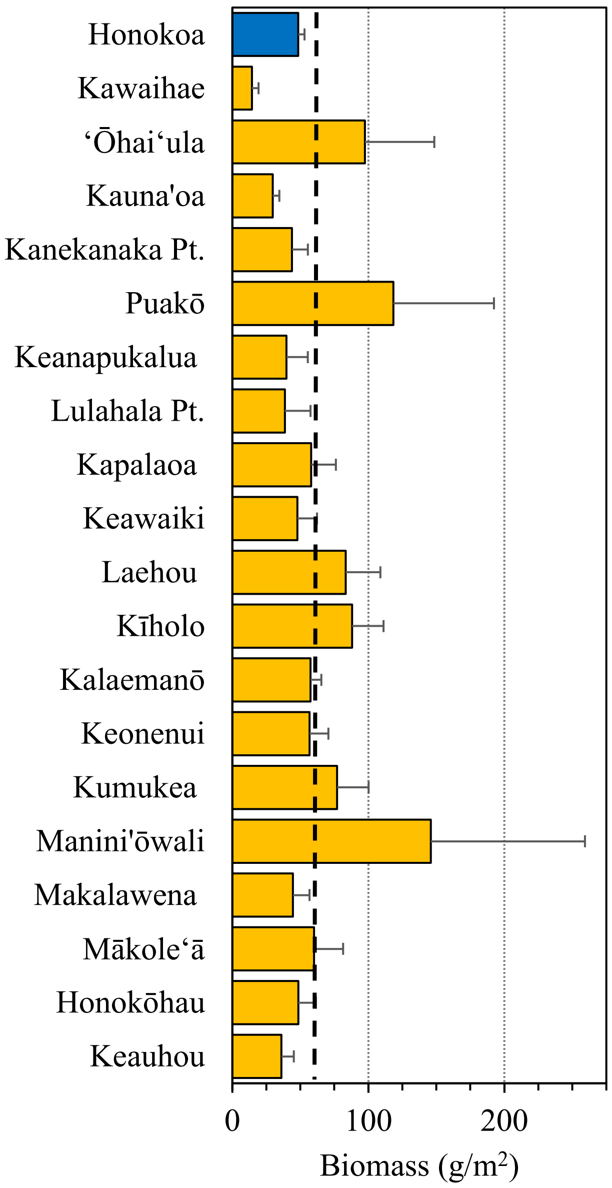

Figure 8. Average total fish biomass at Honokoa in 2022 (this report) compared to prior data from 19 other West Hawaiʻi locations (Minton *et al.* 2020). Sites are arranged from most northerly (Honokoa) to more southerly (Keahou). Dotted line represents the average total fish biomass (60.8 ± 12.7 g/m^2) for West Hawaiʻi.

or *uku*, 15%). *Acanthurus leucopareius* (whitebar surgeonfish or *maikoiko*) was by far the most abundant prime spawner at Honokoa, averaging 1.5 prime spawner individuals per survey site and 30% of all prime spawners observed at Honokoa. Other relatively abundant species included *A. triostegus* (convict tang or *manini*, 15%) and the *Parupeneus multifasciatus* (manybar goatfish or *moāno*, 11%).

Similar to total fish biomass, total resource fish (Figure 11) and prime spawner (Figure 12) biomass showed no depth or spatial patterns across the Honokoa area. However, total resource fish abundance increased significantly across the reef, with more resource fish at sites towards the north compared to survey sites in the south. This indicates resource fish are larger, on average, towards the southern end of the Honokoa reef tract because fewer fish accounting for the same biomass at southern sites means that the fish present in the south were on average larger than in the north. Prime spawner abundance did not differ (Figure 12), so larger individuals of a given species weren't more common at southern sites. Therefore, the composition of the resource fish assemblage must be different, with larger-bodied species, such as apex predators, comprising a greater percentage of the resource fish biomass at sites to the south. Indeed, all resource fish groups except apex predators were less abundant at more southerly sites within the Honokoa reef tract.

Cover of CCA was more than double the average for West Hawaiʻi reefs. One possible explanation is the reef is experiencing both nutrient inputs and high herbivory, which can

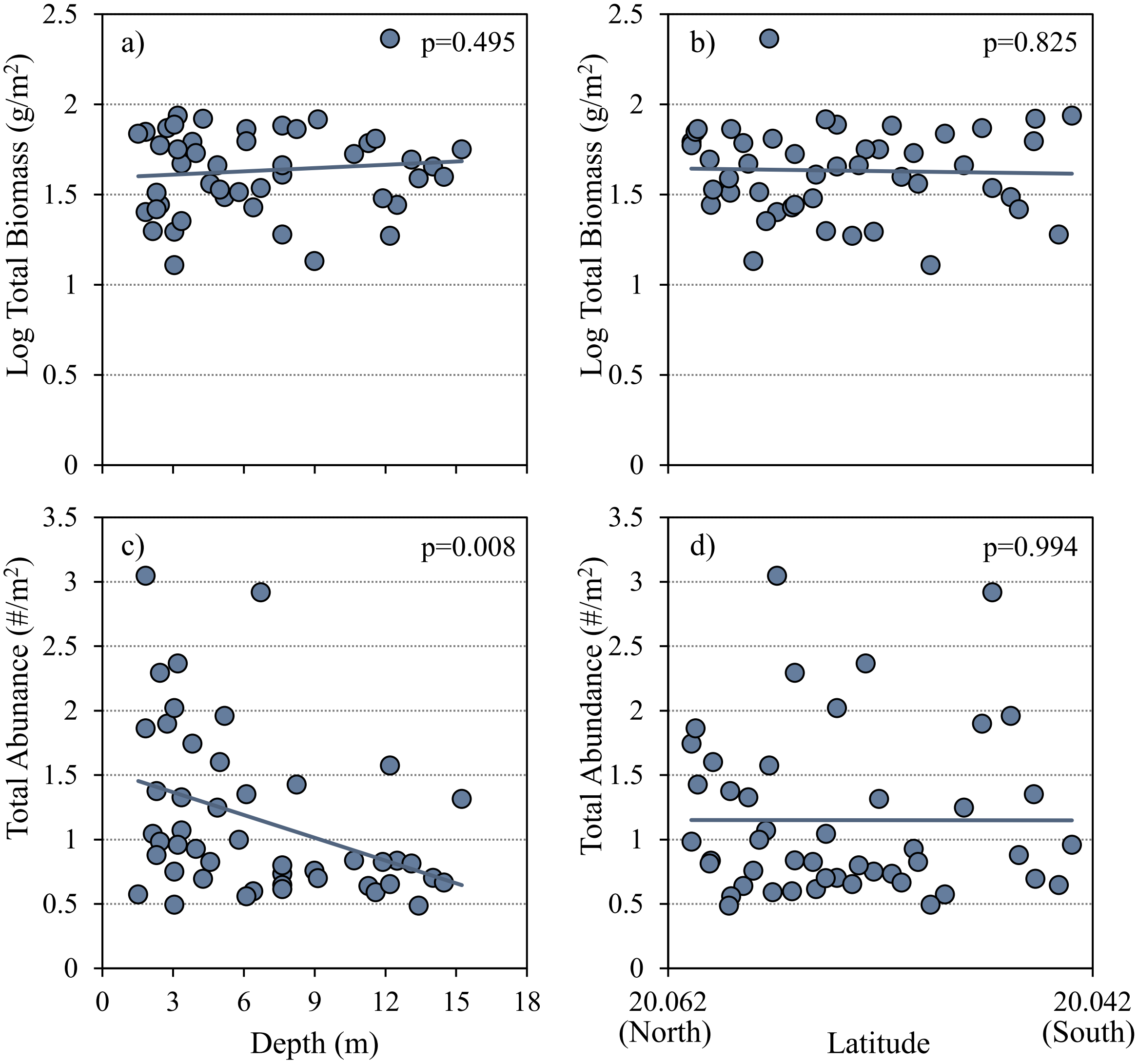

Figure 9. Total fish biomass (g/m^2) by depth (a) and latitude (b) and abundance (#/m^2) by depth (c) and latitude (d) at Honokoa in 2022. A trendline is provided to aid in visualizing the change in cover with latitude or depth. P-values provided for the Pearson correlation.

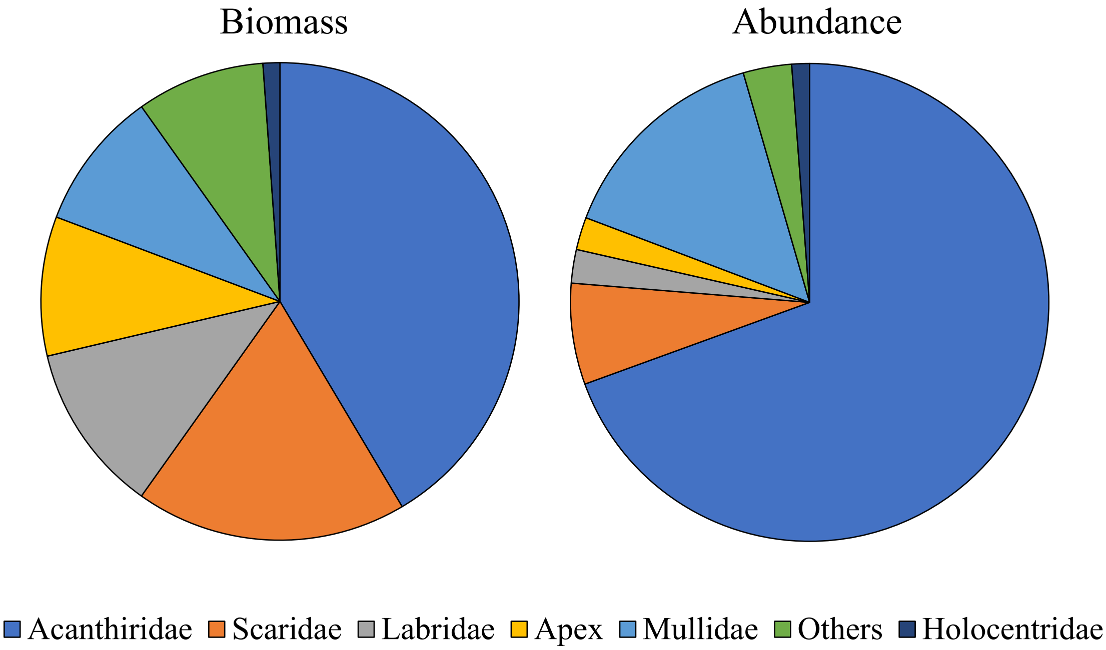

Figure 10. Composition of resource fish biomass and abundance at Honokoa in 2022.

promote a phase-shift on Hawaiian reefs to a benthic community dominated by CCA (Smith *et al.* 2001). While nutrients were not measured as part of this survey, the presence of onsite disposal systems (*i.e.*, cesspools) increases the likelihood of nutrient inputs entering the coastal waters from leaky treatment systems. Nutrient pulses may also occur when periodic flash floods from the various gulches transport turbid, sediment-laden water into the nearshore waters. Nutrients are often adsorbed to sediment particles. This suggests nutrients may, at least periodically, be elevated. However, herbivore biomass at Honokoa in 2022 was 22.6 ± 3.0 g/m^2, which was slightly below average for West Hawai‘i reefs (27.9 ± 3.3 g/m^2). Whether this level of nutrients and herbivory is sufficient to favor CCA growth is unclear but cannot be discounted.

Three invasive fish species were intentionally introduced to Hawai‘i between 1955 and 1961 and have successfully established permanent populations throughout the main Hawaiian Islands. All three were present at Honokoa.

Invasive fish were observed at 35% (8 of 51) sites. When present at a site, invasive fish species tended to comprise a large percentage of the biomass or to occur in large schools. For example, *Cephalopholis argus* was observed at only eight sites, but accounted for over 12% of the total fish biomass on average at those sites. Similarly, *Lutjanus kasmira* was found at only six sites, but were seen in schools from nine to 68 individuals.

Lutjanus kasmira was the most abundant invasive fish species (1.5 ± 0.8 individuals/125 m^2) within the Honokoa survey area and also had the highest average biomass (1.0 ± 0.5 g/m^2).

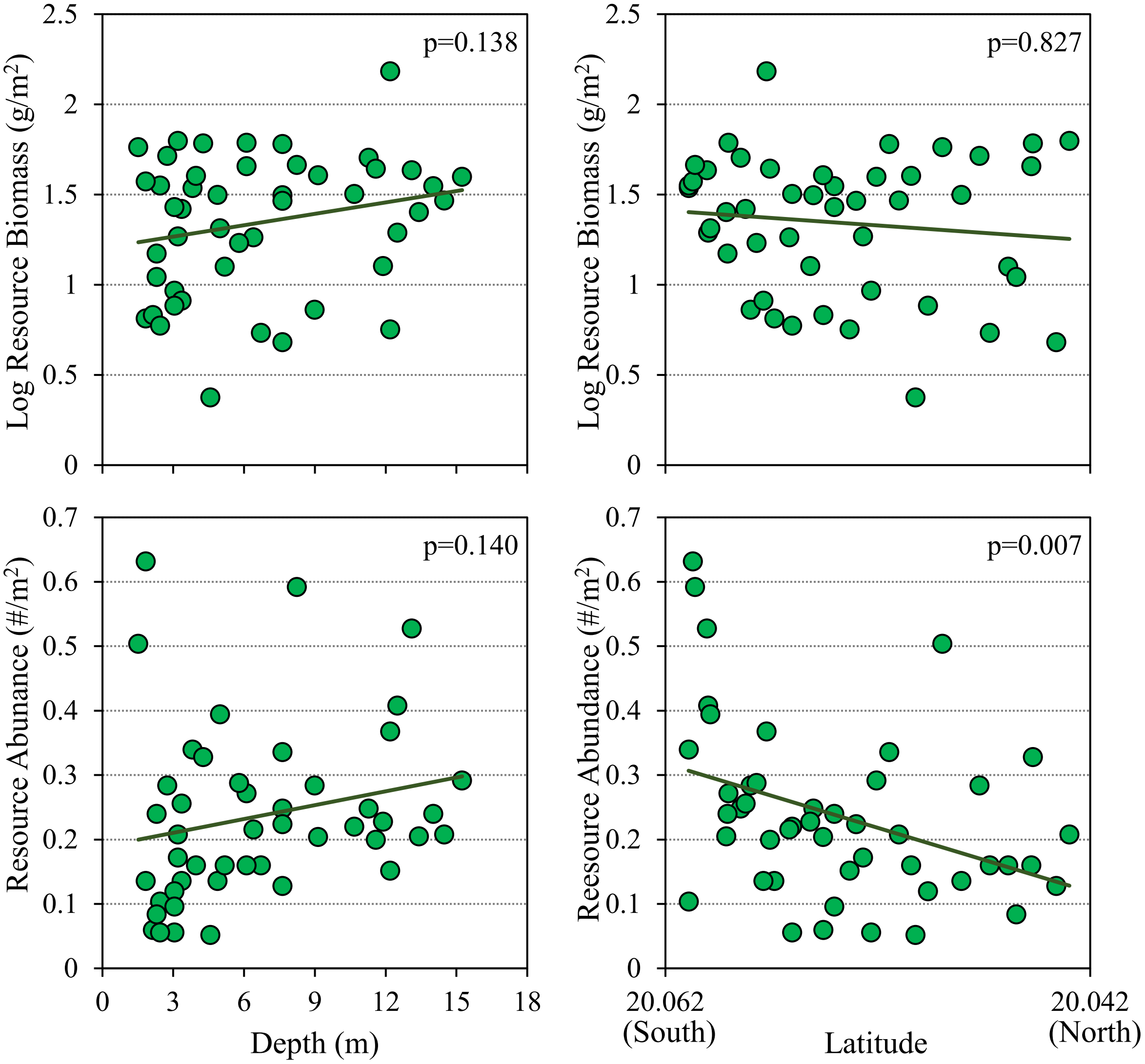

Figure 11. Resource fish biomass (g/m^2; top row) and abundance (#/m^2; bottom row) by depth (left column) and latitude (right column) at Honokoa in 2022. A trendline is provided to aid in visualizing the change in cover with latitude or depth. P-values provided for the Pearson correlation.

While *Cephalopholis argus* had the second highest average biomass (Table 5), it had lower biomass than that frequently observed on many other West Hawai‘i reefs (Giddens *et al.* 2017, TNC unpub data). Finally, *L. fulvus*, which tends to be the least commonly observed invasive fish species on Hawaiian reefs, was relatively abundant within the Honokoa survey area but had about the half the biomass of the other two invasives species (Table 5).

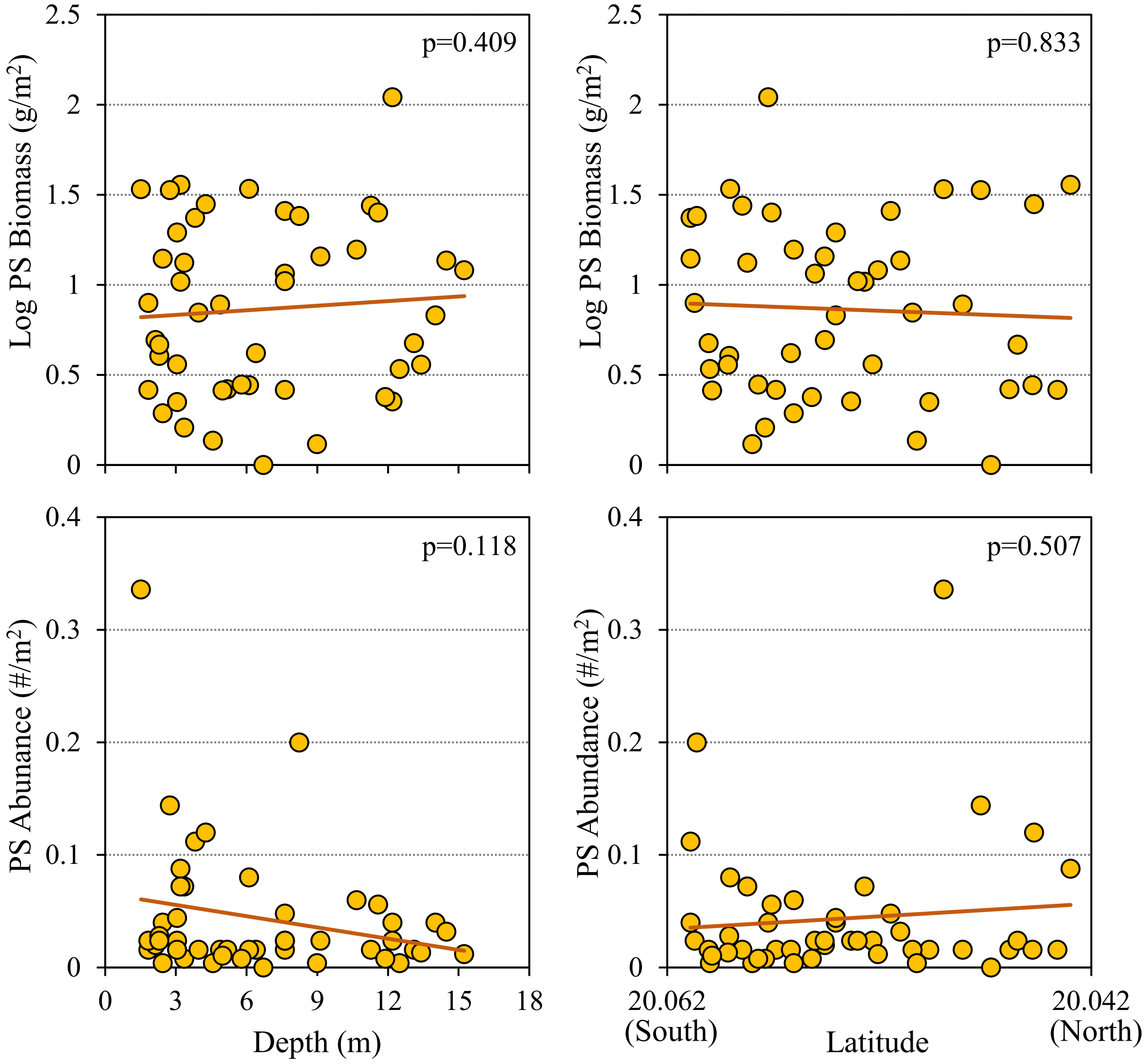

Figure 12. Prime Spawner (PS) biomass (g/m^2; top row) and abundance (#/m^2; bottom row) by depth (left column) and latitude (right column) at Honokoa in 2022. A trendline is provided to aid in visualizing the change in cover with latitude or depth. P-values provided for the Pearson correlation.

Table 5. The number of sites (% of the total sites) where observed and average biomass (g/m^2) and abundance (individuals/125 m^2) of invasive fish at Honokoa in 2022.

	Sites (%)	**Biomass**	**Abundance**
Lutjanus kasmira	8 (15.7)	1.0 ± 0.5	1.5 ± 0.8
Cephalopholis argus	10 (19.6)	1.0 ± 0.4	0.2 ± 0.1
Lutjanus fulvus	6 (11.8)	0.5 ± 0.2	0.4 ± 0.2
Total	**18 (35.3)**	**2.5 ± 0.8**	**2.1 ± 0.9**

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Appendix A: Site Metadata

Site metadata for TNC surveys conducted within the Honoka reef tract in 2022. Benthic (B) and fish (F) data were collected at all sites except 2022-HON-043. “Obs” is the number of fish transects surveyed at each site (see Survey Methods).

Site Code	Date	Latitude	Longitude	Obs	Rugosity	Depth (m)
2022-HON-001	2022-06-01	20.05405	-155.84572	1	-	14.02
2022-HON-002	2022-05-30	20.04808	-155.83920	1	1.48	4.88
2022-HON-003	2022-05-31	20.06091	-155.84969	2	1.55	3.81
2022-HON-006	2022-05-31	20.05604	-155.84532	2	2.47	10.67
2022-HON-007	2022-06-01	20.05799	-155.84642	2	1.95	8.99
2022-HON-010	2022-06-03	20.05232	-155.84282	1	1.26	3.05
2022-HON-012	2022-05-30	20.05688	-155.84474	1	1.21	1.83
2022-HON-013	2022-06-01	20.05457	-155.84355	2	1.35	2.13
2022-HON-015	2022-06-01	20.05847	-155.84726	1	1.80	11.28
2022-HON-016	2022-05-30	20.04587	-155.83832	1	1.33	5.18
2022-HON-017	2022-05-31	20.05147	-155.84264	1	1.16	7.62
2022-HON-018	2022-05-31	20.05823	-155.84579	1	1.18	3.35
2022-HON-019	2022-06-03	20.05709	-155.84574	1	1.32	11.58
2022-HON-023	2022-06-01	20.05739	-155.84525	1	1.50	3.35
2022-HON-025	2022-06-03	20.06090	-155.84882	1	1.39	2.44
2022-HON-026	2022-06-02	20.06071	-155.84808	1	1.51	1.83
2022-HON-028	2022-06-01	20.05617	-155.84467	1	1.54	6.4
2022-HON-029	2022-05-30	20.05725	-155.84634	1	1.70	12.19
2022-HON-034	2022-06-01	20.06000	-155.84923	2	1.93	12.5
2022-HON-035	2022-05-31	20.04298	-155.83563	2	1.55	3.2
2022-HON-036	2022-05-31	20.04361	-155.83699	1	1.59	7.62
2022-HON-037	2022-06-01	20.05604	-155.84405	2	1.58	2.44
2022-HON-038	2022-05-31	20.04674	-155.83905	1	1.18	6.71
2022-HON-039	2022-06-02	20.05333	-155.84505	1	2.04	12.19
2022-HON-041	2022-05-30	20.05504	-155.84417	1	1.50	7.62
2022-HON-042	2022-06-03	20.04470	-155.83694	1	1.14	4.27
2022-HON-043	2022-06-03	20.04897	-155.83851	1	1.19	1.52
2022-HON-044	2022-06-02	20.05904	-155.84779	1	1.48	6.1
2022-HON-045	2022-05-31	20.05908	-155.84679	2	1.45	2.29
2022-HON-047	2022-05-31	20.05101	-155.84231	2	1.54	14.48
2022-HON-048	2022-06-03	20.04722	-155.83863	2	1.28	2.74
2022-HON-049	2022-06-01	20.05207	-155.84379	2	1.98	15.24

Site Code	Date	Latitude	Longitude	Obs	Rugosity	Depth (m)
2022-HON-050	2022-06-03	20.05271	-155.84351	2	1.53	3.2
2022-HON-051	2022-05-31	20.06006	-155.85010	1	1.52	13.11
2022-HON-052	2022-05-31	20.04964	-155.83905	2	1.45	3.05
2022-HON-054	2022-06-01	20.05044	-155.84054	1	-	3.96
2022-HON-056	2022-05-30	20.05406	-155.84459	2	1.34	3.05
2022-HON-058	2022-06-02	20.05406	-155.83973	2	1.39	4.57
2022-HON-060	2022-05-31	20.05302	-155.84437	1	1.08	7.62
2022-HON-063	2022-05-30	20.05458	-155.84482	2	1.48	9.14
2022-HON-069	2022-06-01	20.04548	-155.83751	2	1.61	2.29
2022-HON-070	2022-06-03	20.05519	-155.84501	2	1.78	11.89
2022-HON-072	2022-06-03	20.06062	-155.85005	2	1.53	8.23
2022-HON-073	2022-06-01	20.04478	-155.83792	1	1.32	6.1
2022-HON-076	2022-06-03	20.05772	-155.84587	2	1.73	5.79
2022-HON-RR1A	2022-06-03	20.05915	-155.84875	1	1.96	15.24
2022-HON-RR1B	2022-06-02	20.05914	-155.84866	1	1.90	12.8
2022-HON-RR1C	2022-06-02	20.05900	-155.84833	1	1.58	12.19
2022-HON-RR2A	2022-06-02	20.05971	-155.84820	1	1.38	4.57
2022-HON-RR2B	2022-06-02	20.05989	-155.84842	1	1.75	4.57
2022-HON-RR2C	2022-06-02	20.06008	-155.84870	1	1.71	5.79