Ukumehame Reef Assessment
2022-2023

by

Dwayne Minton[1], Ryan Carr[2], Kim Falinski[2], Harry Lynch[2], Nalei Sampson[2], Tiara Stark[2], Julia Rose[2], Emily Fielding[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

In 2020, The Nature Conservancy (TNC) published *The Atlas of the Reefs of West Maui* (Minton *et al.* 2020). This volume analyzed data collected between 1999 and 2019 by numerous public and private organizations to describe the abundance, biomass, and diversity of marine life on the coral reefs of the West Maui Region[1] (WMR). Within the *Atlas*, the WMR reefs were partitioned in smaller geographic areas, called *reef tracts*, for which in-depth analyses of the available data were conducted to yield detailed spatial and temporal information on the benthic and fish assemblages.

While considerable data were available for most reef tracts, information for some, including the Ukumehame reef tract, was limited in the number of sites sampled and/or the number of years for which it was collected. Data for the Ukumehame reef tract included a handful of sites with limited taxonomic resolution and poor spatial distribution across the reef tract. This resulted in numerous analytical and visualization challenges and resulted in little information for the Ukumehame reef tract appearing in the final published volume.

In recent years, a partnership involving several organizations, agencies, and community groups has been collaborating on a number of initiatives to restore the Olowalu-Ukumehame area. The lack of data on the condition of the coral reef resources along the Ukumehame reef tract has been a critical gap in these efforts. To fill this data gap, TNC conducted benthic and fish surveys across the Ukumehame reef tract in 2022 and 2023. This report presents the results of those surveys, including placing the findings within the broader context of the Olowalu area and the WMR.

Geographic Setting

Marine ecosystems are not isolated from other adjacent, and often distant ecosystems; instead, they are subject to emigration and immigration of juveniles and adult individuals, sources of external environmental stress, and fluxes of important nutrients from distant marine and terrestrial sources. Equally important, most coral reefs provide essential ecological *functions* (biological, chemical, and physical) to other marine and terrestrial ecosystems, and culturally- and economically-important *services* to people. Therefore, effective conservation of coral reefs must consider the role of specific reefs in the broader spatial network of marine and terrestrial ecosystems if effective place-based management is to occur.

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[1] Within the *Atlas*, the West Maui Region extended from the Pali Tunnel on Honoapiʻilani Highway (Rte 30) to Līpoa Point and included 38 km (23.6 mi) of coral reefs, algal flats, sandy beaches, and basalt cliffs (Minton *et al.* 2020).

The *Atlas* recognized three reef tracts in the Olowalu area[2]: Olowalu Point, Olowalu, and Ukumehame (Figure 1). For this report, the Ukumehame reef tract is a contiguous stretch of hardbottom that lies between the outlet of Ukumehame Stream and the Pali Tunnel on Honoapiʻilani Highway (Rte. 30). It is separated from the Olowalu reef tract by a sandy channel cut through the reef structure by Ukumehame Stream. These boundaries for the Ukumehame reef tract differ slightly from those described in the *Atlas*. In the *Atlas*, the Olowalu reef tract included a small portion of the hardbottom on the east side of the sandy channel. The decision was made to adjust the Ukumehame reef tract boundary for this report to include all the contiguous hardbottom on the east side of the sandy channel to better reflect the geomorphology of the reef.

Within the Olowalu area, coastal development is light, with a few residential homes and a small community on the north side of Honoapiʻilani Highway. Historic sugar cane operations (Pioneer Mill) have transitioned into limited-but-diversified agriculture and fallow fields. While the majority of the land upslope is under conservation management, sediment and nutrient inputs into the coastal waters are an issue. Data collected from a network of water quality monitoring stations across the WMR[3] have identified higher than average turbidity across much of the Olowalu area, especially the Ukumehame reef tract, but nutrient values below the average for the WMR. This suggests water quality within the Olowalu area is generally good, but may be compromised, especially during or following storm events.

Survey Methods

TNC collected fish and benthic data at a total of 72 randomly-selected sites within the Ukumehame reef tract in October 2022 (62 sites) and February 2023 (10 sites) (Figure 1). All sites were between 1 and 17 m depth on predominately hardbottom. Locational information (latitude/longitude) and other metadata for all survey sites have been compiled in Appendix A.

In 2022, survey teams navigated via a small, motorized boat to each predetermined site using a Garmin GPS unit. Once on site, divers on scuba were deployed and descended directly to the bottom. In 2023, survey teams entered from shore and used GPS units to snorkel to the survey sites. At each site, fish surveyors established transect start-points. When two fish surveyors were present (34 sites, see Appendix A), start points were spaced approximately 10 m apart. From each start-point, divers deployed a 25-m transect lines 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

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[2] The Olowalu area (called a Focus Window in the *Atlas*) extends from the intersection of Honoapiʻilani Highway (Rte 30) and the Recycling & Refuse Center Road to the highway's Pali Tunnel and encompassed Olowalu Point and a small embayment known for its well-developed spur-and-groove coral reef.

[3] Hui O Ka Wai Ola and the State Department of Health collect water quality data at 20 sites in the WMR, including seven locations in the Olowalu FW: Olowalu Shore Front, Olowalu Point, Camp Olowalu, Mile Marker 14, Ukumehame Park, Pāpalaua Park, and Pāpalaua Pali (Hui O Ka Wai Ola 2022). To learn more about Hui O Ka Wai Ola and download raw data, visit huiokawaiola.com.

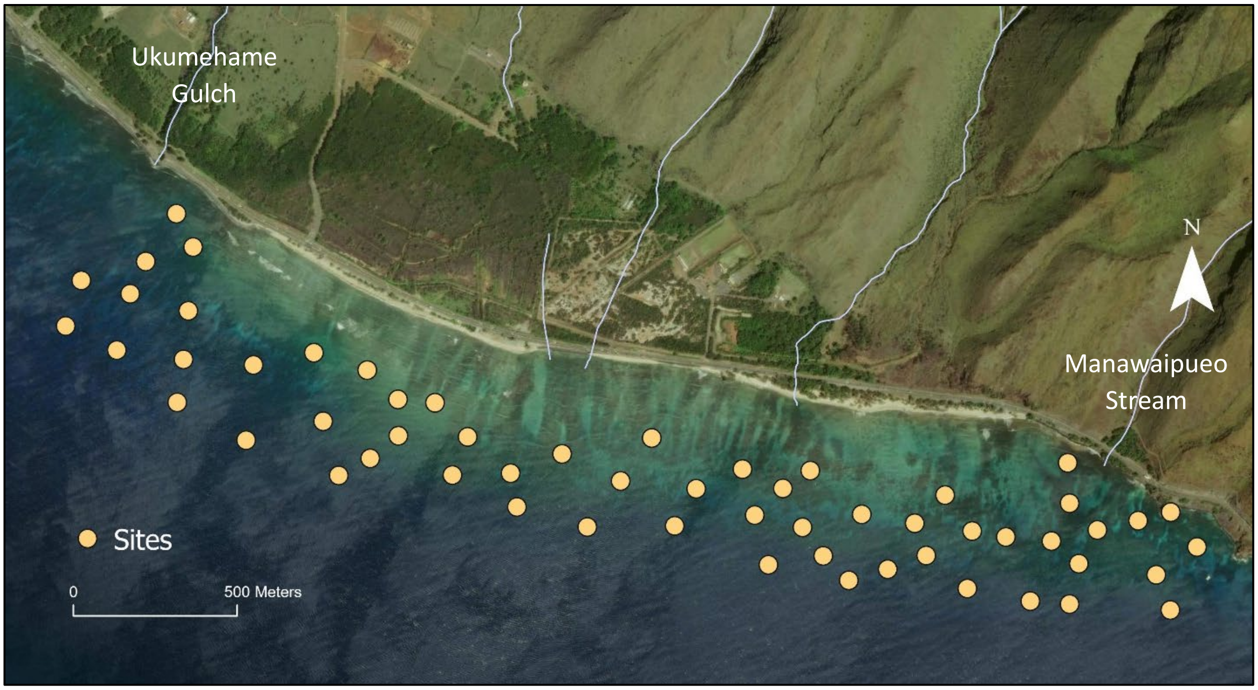

Figure 1. The Olowalu area is comprised of the Ukumehame, Olowalu, and Olowalu Point reef tracts. Dots indicate the sites within the Ukumehame reef tract surveyed by TNC in 2022 and 2023.

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collection was conducted along one or both transect lines by trained divers who had been calibrated to reduce surveyor variability. Benthic data were collected at all 72 sites, however, site conditions allowed for fish data to be collected at only 58 sites. 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.

At some sites, high turbidity interfered with the photo-analysis. For any site at which >5% of the photo-points could not be identified due to turbid water, the benthic data were excluded from the analysis. This included 7 survey sites, resulting in 65 surveys sites with usable benthic data from the Ukumehame reef tract. All survey sites that had fish data had corresponding benthic data, but some sites with benthic data did not have corresponding fish data.

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[4] including a selected non-resource group for comparison, prime spawners, and invasive fish. The biomass of manta rays (Myliobatidae) and *Decapterus macarellus* (mackerel scad or ʻōpelu) was not included in these biomass estimates because these transient fish are seldom observed on transects. When present, they heavily skew the transect estimates due to their large size or their presence in very large schools.

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

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

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.

Prime spawners are individual resource fishes larger than 70% of the maximum size reported for the species in Hawaiʻi. Fishes at the high end of their size range tend to be a disproportionately important component of total stock breeding potential due to their high fecundity and higher larval survival compared to smaller breeding individuals (Williams *et al.* 2008). In addition, fishers preferentially target large resource fish, making prime spawner biomass a good indicator of fishing impacts.

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, central TNC server that is backed up daily to an offsite location to protect against data loss. All means are presented as the average ± the standard error of the mean (SEM) unless otherwise stated.

Maps within this report were generated using a spatial technique called interpolation. This technique uses available survey data to generate a complete spatial model of the data by estimating the values between the surveys data using a mathematical algorithm that considers the values of nearby data weighed by their distance away. Areas with a higher density of surveys will produce more “accurate” interpolations than areas with lower survey density. Interpolation maps were generated primarily to display general spatial patterns and should not be used to predict exact values at any given location. For example, an interpolation map can, with a high degree of reliability, indicate that one area of a reef tract has more coral than another, but it should not be used to estimate the “exact” coral cover at a specific location. To estimate coral cover, amount of fish, etc., current survey data from the specific location should always be used over the interpolation maps when those data are available.

Survey site data were imported into ArcMap and used to generate interpolation models across the Ukumehame reef tract and the broader Olowalu area to help visualize spatial patterns within the data. This technique uses available survey data to generate a complete spatial model of the data

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

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

by estimating values between the surveys data using a mathematical algorithm that considers the values of nearby data, so areas with a higher density of surveys will produce more “accurate” interpolations than areas with lower survey density. Interpolation maps were generated primarily to display general spatial patterns and should not be used to predict exact values at any given location. For example, an interpolation map can, with a high degree of reliability, indicate that one reef area has more coral than another reef area, but it should not be used to estimate the "exact" coral cover at a specific location.

Coral cover was modeled using an Inverse Distance Weighted (IDW) interpolation and optimized to accurately represent the habitat across the survey area. Interpolation was carried out using 5 neighbors, with a semi-axis size of 200m. The power parameter for interpolation was set to 3 after fine-tuning through an iterative process guided by model fit assessments and Root Mean Square values obtained from cross-validation. Fish abundance and distribution interpolation maps were generated through the application of Empirical Bayesian Kriging in ArcGIS Pro. To enhance normality, the fish data underwent a log empirical transformation. Given the density of points across the study area, the interpolation process employed a standard circular search neighborhood with a radius of 350m and a maximum of 15 neighbors and a minimum of 2 neighbors, utilizing an exponential semivariogram type. Optimization of map accuracy involved the Geostatistical Wizard and cross-validation techniques. An overlap factor of 5 was selected, and the subset size ranged between 20 to 50 to minimize mean error while aligning the root mean square and average standard error. The selection of suitable models was based on a comparison of prediction and measured distributions, ensuring that the interpolation method accurately represented the underlying data distribution.

Additional Data

Benthic results for Ukumehame were compared with recent data from the Olowalu reef tract collected by the Maui Office of the Hawaiʻi Division of Aquatic Resources (DAR) in 2020-2023 (199 sites). All years were pooled together to ensure adequate spatial coverage of the Olowalu reef tract prior to any statistical analysis or interpolation. Data were not analyzed for temporal trends.

Due to differences in taxonomic resolution between the datasets, direct comparisons were made primarily at higher taxonomic levels (*e.g.*, coral, turf, macroalgae, etc.). However, coral data at the species-level were generally comparable, especially for common species. Fish data were not compared because collection methods varied sufficiently between the DAR and TNC data that biomass estimates were likely not comparable.

Results and discussion

Benthic Assemblage

The reef at Ukumehame showed considerable spatial variability both in composition and coverage of the benthic community. Similar to most Hawaiian reefs, algal turf was the dominant benthic type at Ukumehame, averaging 47.5 ± 2.2% (Table 2). Coral cover averaged 25.2 ± 2.3% but showed considerable variability among the survey sites, ranging from 0 to 58% cover. Crustose coralline algae (CCA), other macroalgae, and cyanobacteria comprised <5% of the

Table 2. Average (±SEM) percent cover of benthic groups and taxa for the shallow (<9.1 m; n=36), and deep (≥9.1 m; n=17) benthic assemblages at Ukumehame. Data are from 2020-2023.

	Ukumehame	**Shallow**	**Deep**
Turf	47.7 ± 2.4	52.9 ± 1.9	36.7 ± 3.1
Coral	26.8 ± 2.6	21.4 ± 3.5	38.4 ± 3.2
Montipora capitata	7.5 ± 1.2	3.0 ± 0.8	17.1 ± 2.1
Porites lobata	6.8 ± 0.8	6.8 ± 1.1	7.0 ± 1.0
Porites compressa	6.3 ± 1.1	5.3 ± 1.5	8.3 ± 1.7
Montipora patula	5.1 ± 0.8	5.5 ± 1.1	4.1 ± 0.7
Pavona varians	0.4 ± 0.1	0.1 ± 0.1	1.0 ± 0.3
Pocillopora meandrina	0.2 ± 0.1	0.3 ± 0.1	<0.1
Porites rus	0.2 ± 0.2	0.2 ± 0.2	0
Pavona duerdeni	0.1 ± 0.1	0.1 ± 0.1	<0.1
Pocillopora eyedouxi	<0.1	0	0.1 ± 0.1
Psammocora nierstraszi	<0.1	<0.1	<0.1
Montipora flabellata	<0.1	<0.1	0
Porites monticulosa	<0.1	0	<0.1
Leptastrea bewickensis	<0.1	<0.1	0
Leptastrea purpurea	<0.1	<0.1	0
Porites evermanni/lutea	<0.1	<0.1	0
Psammocora stellata	<0.1	<0.1	0
Crustose Coralline Algae	4.7 ± 0.6	3.8 ± 1.3	6.6 ± 0.7
Macroalgae	1.2 ± 0.4	1.8 ± 0.1	0.1 ± 0.6
Cyanobacteria	0.2 ± 0.1	0.1 ± 0.2	0.5 ± 0.1
Other	<0.1	<0.1	0
Abiotic	19.3 ± 2.9	20.0 ± 4.0	17.8 ± 3.8
Sand	17.0 ± 2.6	17.4 ± 3.4	16.1 ± 3.8
Rubble	2.3 ± 0.8	2.6 ± 1.2	1.5 ± 0.5
Recently dead coral	<0.1	<0.1	0.1 ± 0.1

cover on average. The remaining benthic area (21.6 ± 2.7%) was composed primarily of sand, but also included rubble and recently dead coral.

Like many reefs in Hawaiʻi, the benthic assemblage varied with depth, primarily in coral cover and assemblage structure. Shallow water (<9.1 m/30 ft) sites had lower coral cover (21.5 ± 3.0%) than deep (≥9.1 m/ 30 ft) sites (31.8 ± 3.2%), with the differences being offset primarily by cover of algae (Figure 2). The shallow assemblage had higher coral species richness than the deep. In the shallow coral assemblage, *Porites lobata*, *Montipora patula*, and *P. compressa* (Figure 3)

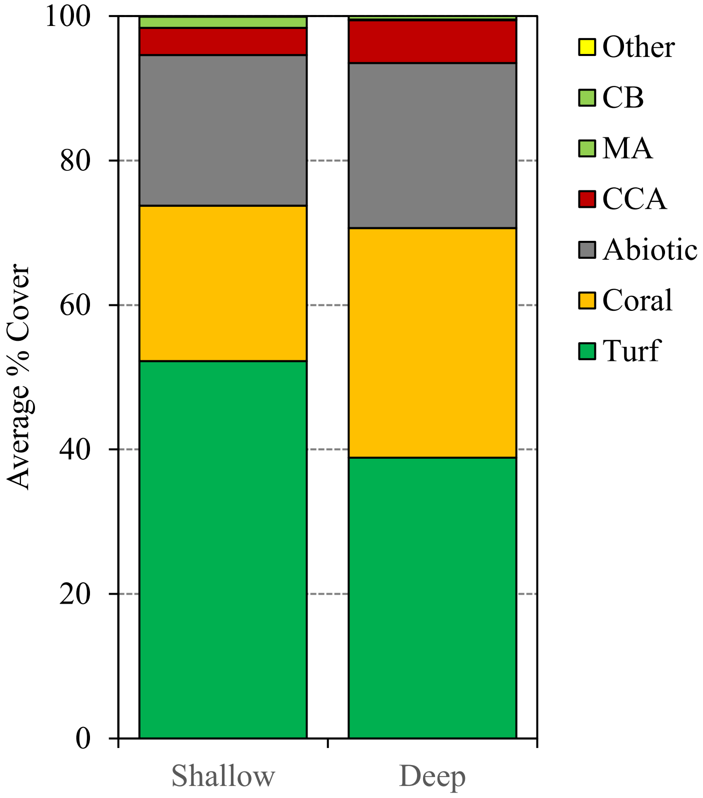

Figure 2. Average percent cover by benthic group in for the shallow (<9.1 m) and deep (≥9.1 m) benthic assemblages at Ukumehame. CB=cyanobacteria, MA=macroalgae, CCA=crustose coralline algae.

were the dominant coral species, comprising 82% of the observed coral cover at shallow sites (Figure 4). Although relatively rare, other species commonly observed in surf-exposed and/or turbid waters were also present, including *Leptastrea bewickensis*, *L. purpurea*, *P. rus*, *Pavona duerdeni*, and *P. varians*. Unlike the shallow coral assemblage, the deep coral assemblage was dominated by *Montipora capitata* (Figures 3 and 4), particularly its branching form. On most Hawaiian reefs, *M. capitata* grows with an encrusting colony morphology, but can assume a highly complex branching form when in sheltered waters (*e.g.*, Kāneʻohe Bay on Oʻahu). In general, branching corals are generally found in low water motion environments, such as deeper areas of the reef slope or protected embayments. Branching *M. capitata* and *P. compressa* comprised 66% of the coral cover observed at deep sites at Ukumehame.

Coral cover in both shallow and deep assemblages tended to increase from west-to-east along the Ukumehame reef tract (Figure 5, Appendix B). Along this spatial gradient, the shallow coral assemblage changed little in the relative abundance of their species; instead, the cover of all species showed similar relative increases—all dominant species showed an increase in cover from west-to-east. Unlike the shallow coral assemblage, the deep coral assemblage underwent a pronounced shift in structure. The cover of *Porites lobata* decreased from west-to-east (Figure 6), whereas the other dominant species (*M. capitata*, *M. patula*, and *P. compressa*) all increased in cover. The rate of increase for *M. capitata* was greater in the deep assemblage compared to the shallow assemblage (as indicated by the difference in the steepness of the shallow and deep trendlines in Figure 6), suggesting the increase in cover along the west-to-east gradient was driven primarily by a shift from *P. lobata* to *M. capitata* at depth in Ukumehame. This shift in coral assemblage structure is likely driven by variation in the environmental conditions, and likely associated with inputs of sediment and other potential pollutants from Ukumehame Gulch at the western end of the reef tract. *Porites lobata* is tolerant of sediment (Erftemeijer *et al.* 2012) and burial (Duckworth *et al.* 2017) and is often found on reefs with high turbidity or that

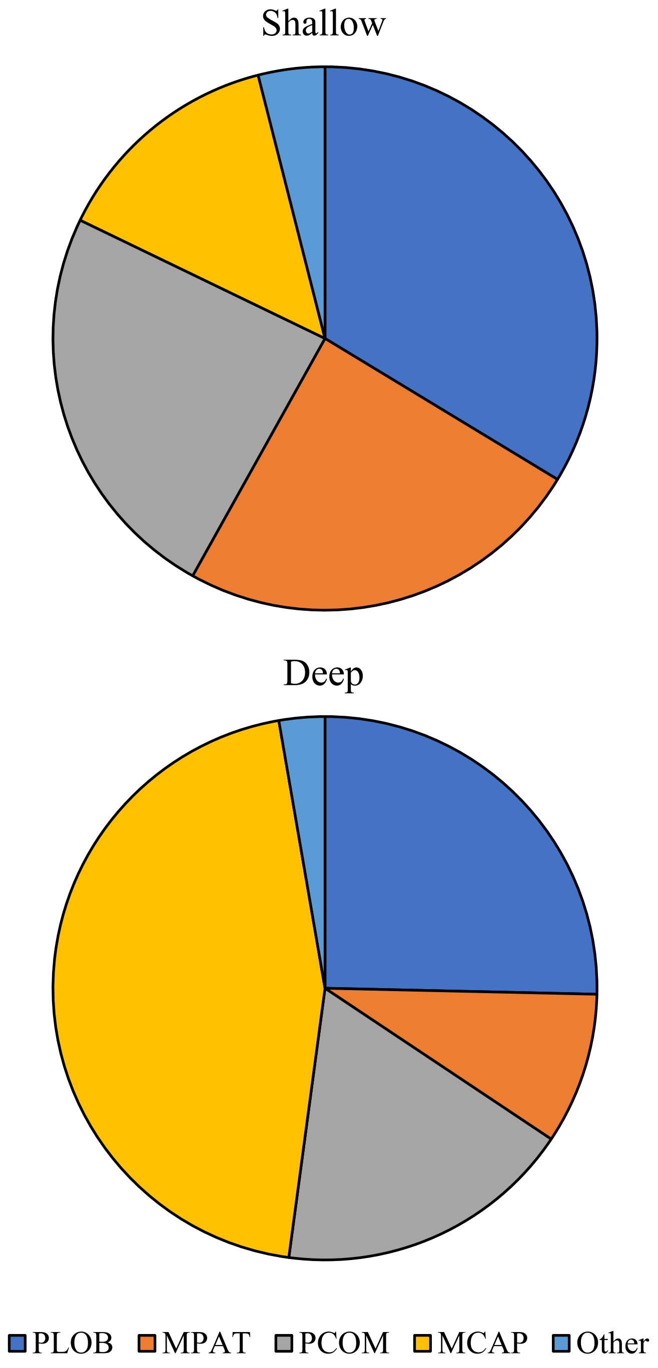

Figure 3. Relative composition of coral in the shallow (<9.1 m) and deep (≥9.1 m) benthic assemblages within the Ukumehame reef tract. PLOB=*Porites lobata*, MPAT=*Montipora patula*, PCOM=*P. compressa*, MCAP=*M. capitata*, Other=all other coral species.

experience periodic sedimentation events. Interestingly, while *P. lobata* cover generally decreased from west to east, it increased at the most easterly sites surveyed (Figure 5), near the outflow of Manawaipueo Stream, a known source of sediment. Turbidity plumes are frequently noted in that area of the Ukumehame reef.

The shallow assemblage showed higher variability in coral cover on the eastern half of the Ukumehame reef tract (Figure 5). Shallow sites in the western half tended to have lower coral cover than deeper sites, but in the western half, shallow sites and deep frequently had similar coral cover. This change in variability at shallow sites is likely due to changes in shallow water environmental conditions; the western half of the reef tract may be experiencing a chronic stressor, perhaps from Ukumehame Gulch (e.g., consistent fresh water or sediment) or more frequent or stronger acute events (e.g., sedimentation events) than the eastern half. Additional study would be needed to determine the cause.

Coral Bleaching

Coral bleaching was observed at 50 of the 63 (73%) sites at Ukumehame that had coral, and on average, 9.4 ± 1.5% of all coral tissue showed signs of paling or bleaching. Four species showed some degree of bleaching at more

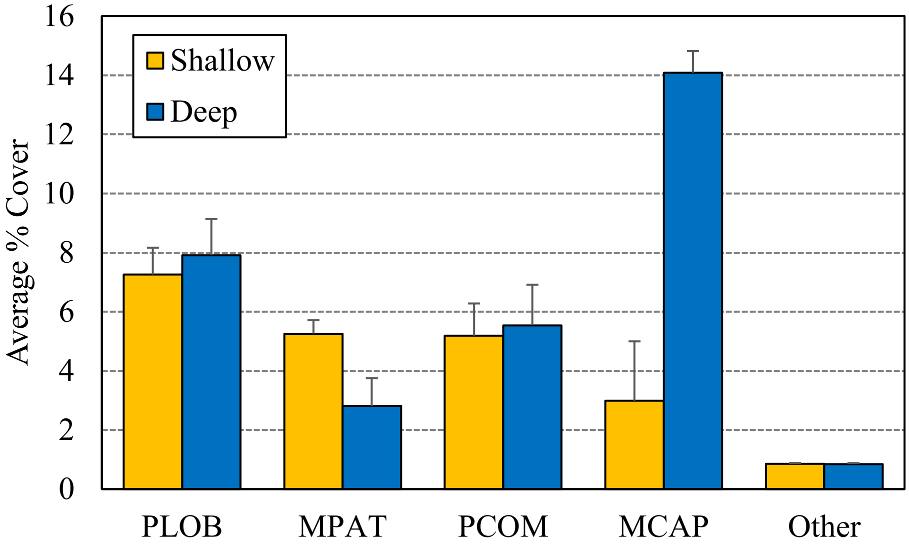

Figure 4. Average percent cover of *Porites lobata* (PLOB), *Montipora patula* (MPAT), *P. compressa* (PCOM), *M. capitata* (MCAP), and all other coral species in shallow (<9.1 m) and deep (≥9.1 m) benthic assemblages at Ukumehame.

than one site: *M. capitata* (37.4 ± 4.2% of coral tissue bleached), *Pocillopora meandrina* (24.5 ± 7.5), *M. patula* (12.8 ± 3.5%), and *Porites compressa* (4.3 ± 1.4). Bleached *Pavona varians* was observed at one site. Notably, no bleached or paled *P. lobata* were observed.

Coral tissue bleaching rates were considerably higher at deep (20.3 ± 3.0%) compared to shallow (3.1 ± 0.5%) sites due primarily to the prevalence of bleaching susceptible species such as *M. capitata* at depth. However, all species showed similar or higher tissue bleaching rates at deep compared to shallow sites (Figure 7), indicating that differences in species composition do not fully explain the difference in bleaching between the two depth assemblages.

Comparisons with the Olowalu Reef Tract

The benthic communities of both the Ukumehame and Olowalu reef tracts were dominated by turf and coral, with Olowalu having greater cover for both (Figure 8). The lower turf and coral cover at Ukumehame were offset by higher average cover of unconsolidated bottom (i.e., sand and rubble) at the Ukumehame sites.

Average coral cover within the Ukumehame reef tract (26.8 ± 2.6%) was about a third less than that of the Olowalu reef tract (33.6 ± 1.1%) (Figure 9). Twenty-three coral species were identified across the two reef tracts, with Olowalu having 21 species compared to 16 species for Ukumehame, although some of the higher species richness in the Olowalu reef tract may be associated with the greater survey effort at Olowalu (211 vs. 65 survey sites). Both reef tracts

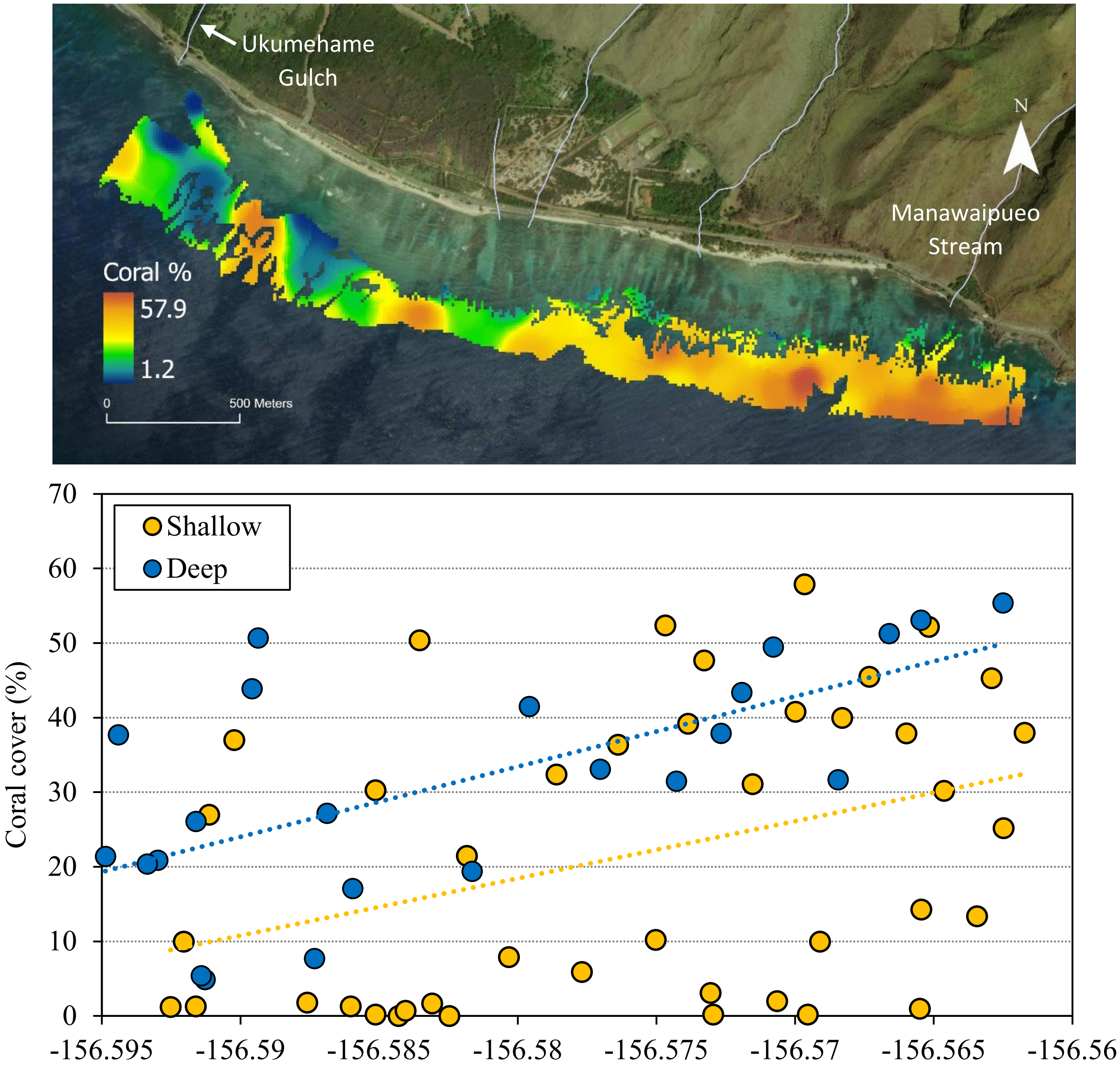

Figure 5. Coral cover across the Ukumehame reef tract. The map (top) is interpolated from 2022-2023 survey data across hardbottom. Yellow color is the average coral cover for the reef tract (26.8%) and red would be considered high coral cover for Ukumehame. Areas without color do not contain hardbottom or were too shallow/deep to be within the prescribed surevey area. In the graph (bottom), the lines are linear trend lines for coral cover along the east-west axis for the shallow (gold) and deep (blue) benthic assemblages.

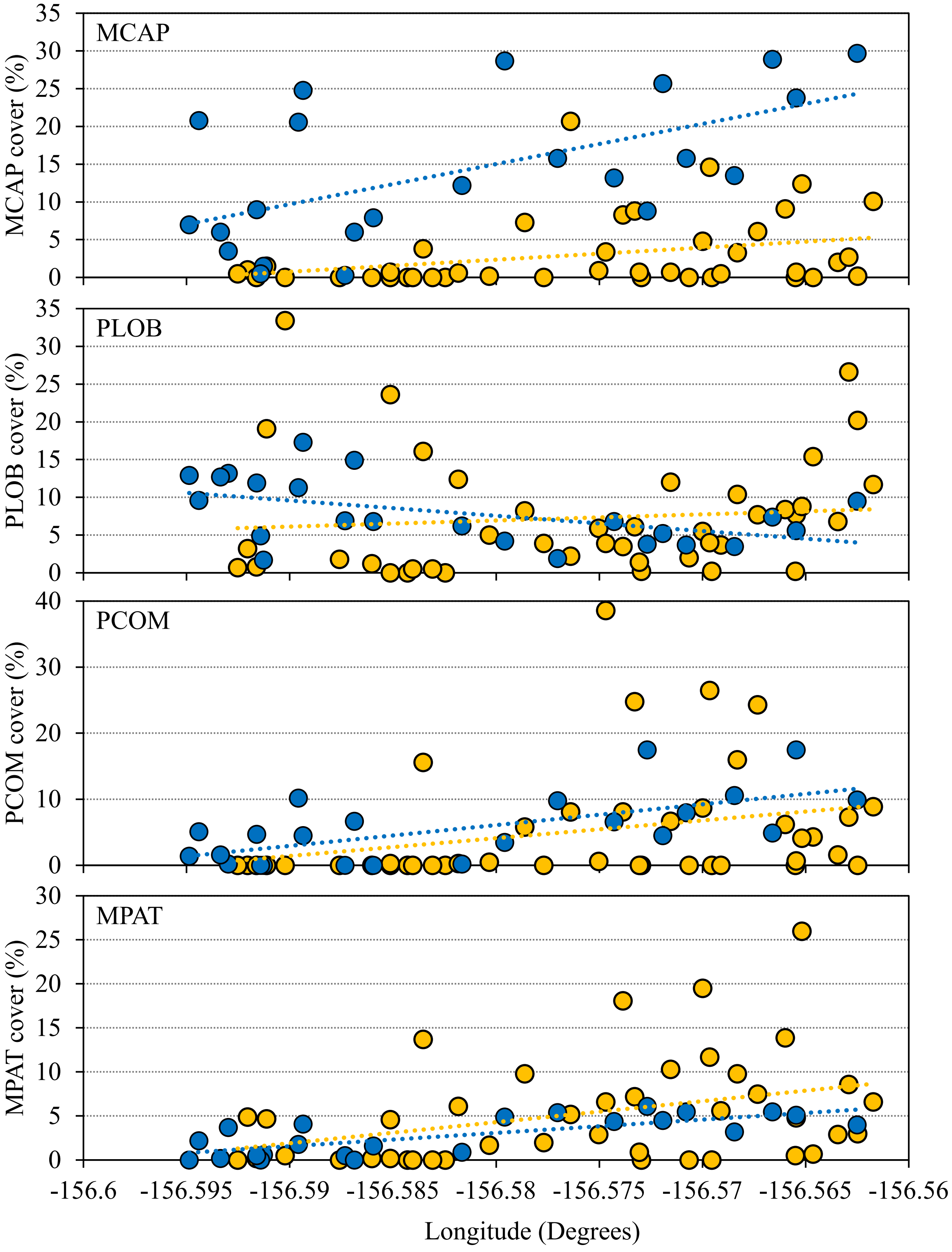

Figure 6. Cover of *Porites lobata* (PLOB), *Montipora patula* (MPAT), *P. compressa* (PCOM) and *M. capitata* (MCAP) at shallow (gold) and deep (blue) survey sites at Ukumehame in 2022-2023. The lines are linear trend lines for coral cover along the east-west axis for the shallow and deep benthic assemblages.

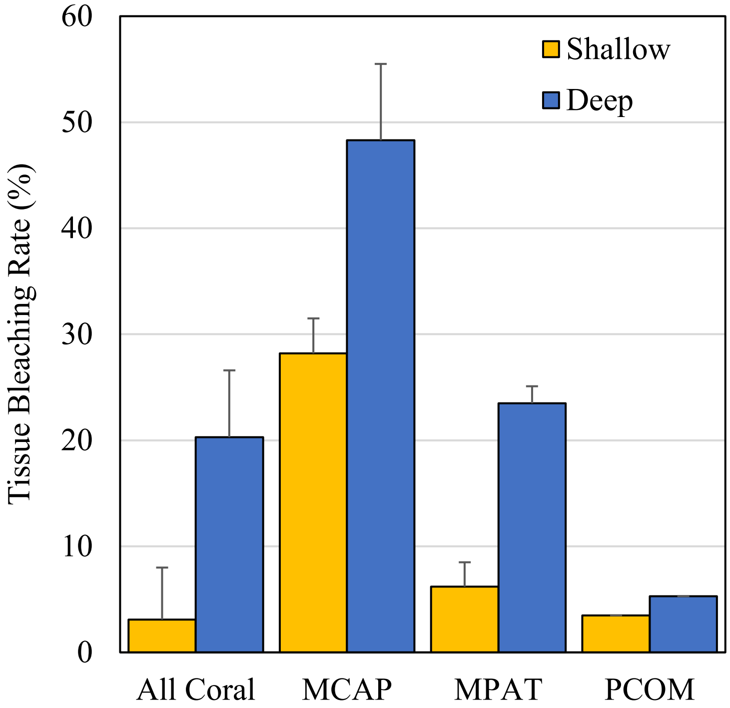

Figure 7. Average tissue bleaching rate for all coral, *Montipora capitata* (MCAP), *M. patula* (MPAT), and *Porites compressa* (PCOM) in shallow (<9.1 m) and deep (≥9.1 m) coral assemblages at Kamehameha in 2022-2023. *Pocillopora meandrina* (not shown), was present at only two deep sites, but had a 100% tissue bleaching rate at deep sites.

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were dominated by the same four coral species: *M. capitata* (including both its encrusting and branching forms), *P. lobata*, *P. compressa*, and *M. patula*. Although *P. lobata* comprised a greater and *M. patula* a lower percentage of the coral assemblage compared to Olowalu (Table 3).

Many reefs on Maui and Hawaiʻi Island are dominated by *Porites* species. In contrast, *M. capitata* and *M. patula* were common in the coral assemblages on both the Ukumehame and Olowalu reef tracts, and together accounted for approximately half of all observed coral (Table 3). For *M. capitata*, the branching form was prevalent, especially in adjacent Olowalu reef tract (Minton *et al.* 2020). This area of the coast is sheltered from most swells by Olowalu Point and Lānaʻi to the west, southeast Maui to the east, and Kahoʻolawe to the south (Minton *et al.* 2020). *Porites lobata* was only the third most common coral species within the Olowalu reef tract (Table 8.3) but became a more dominant component of the reef assemblage at Ukumehame, likely due to increased exposure as the reef becomes more distant from Olowalu Point.

Table 3. Average (±SEM) percent cover of benthic groups and taxa for the Olowalu (n=211), and Ukumehame (n=53) reef tracts. Data are from 2020-2023.

	Olowalu	**Ukumehame**
Turf	57.6 ± 1.0	47.7 ± 2.4
Coral	33.6 ± 1.1	26.8 ± 2.6
Montipora capitata	9.4 ± 0.9	7.5 ± 1.2
Porites lobata	7.7 ± 0.5	6.8 ± 0.8
Porites compressa	6.9 ± 0.5	6.3 ± 1.1
Montipora patula	8.1 ± 0.5	5.1 ± 0.8
Pavona varians	0.9 ± 0.1	0.4 ± 0.1
Pocillopora meandrina	0.2 ± 0.1	0.2 ± 0.1
Porites rus	0	0.2 ± 0.2
Pavona duerdeni	0.2 ± 0.1	0.1 ± 0.1
Pocillopora eyedouxi	<0.1	<0.1
Psammocora nierstraszi	<0.1	<0.1
Montipora flabellata	<0.1	<0.1
Porites monticulosa	0.1 ± 0.1	<0.1
Leptastrea bewickensis	<0.1	<0.1
Leptastrea purpurea	<0.1	<0.1
Porites evermanni/lutea	<0.1	<0.1
Psammocora stellata	0	<0.1
Porites solida	0.1 ± 0.1	0
Pavona maldivensis	<0.1	0
Porites duerdeni	<0.1	0
Gardineroseris planulata	<0.1	0
Montipora studeri	<0.1	0
Cyphastrea ocellina	<0.1	0
Leptastrea transverse	<0.1	0
Crustose Coralline Algae	3.0 ± 0.3	4.7 ± 0.6
Macroalgae	1.6 ± 0.3	1.2 ± 0.4
Cyanobacteria	<0.1	0.2 ± 0.1
Other	<0.1	<0.1
Abiotic	4.2 ± 0.7	19.3 ± 2.9
Sand	4.0 ± 0.6	17.0 ± 2.6
Rubble	0.1 ± 0.1	2.3 ± 0.8
Recently dead coral	<0.1	<0.1

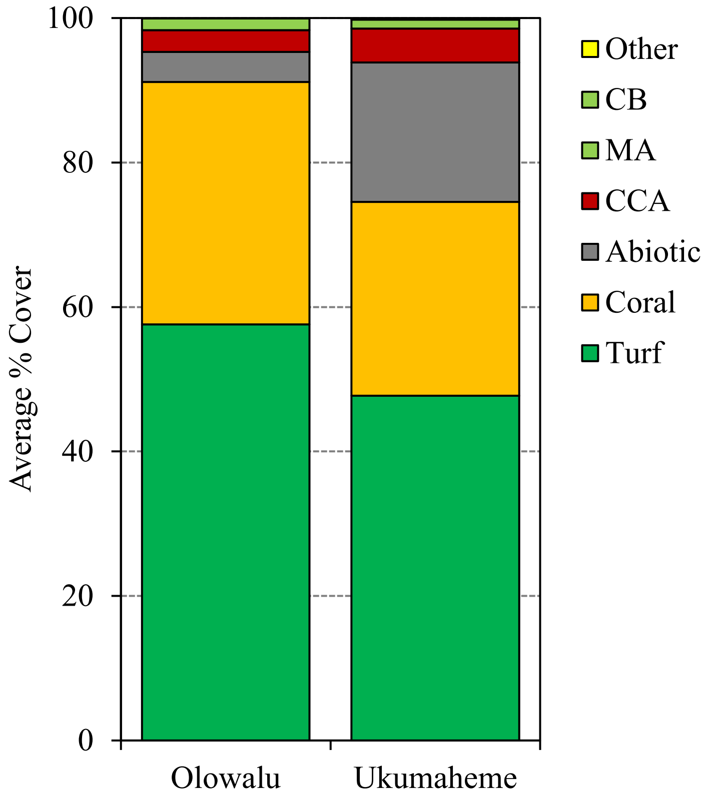

Figure 8. Average percent cover by benthic group in for the Ukumehame and Olowalu benthic assemblages. CB=cyanobacteria, MA=macroalgae, CCA=crustose coralline algae.

Fish Assemblage

One hundred and two fish species representing 25 families were observed at Ukumehame in 2022 (Table 4). Average total fish biomass was 39.1 ± 8.0 g/m^2, which was close to the average for West Maui reefs (42.2 ± 3.9 g/m^2) but low when compared to reefs on East Maui or within protected areas (Figure 10). Acanthuridae (surgeonfish) contributed the most to fish biomass at Ukumehame, accounting for over a third of the total fish biomass within the reef tract. Acanthurid biomass was 3.3-times higher than the next family (Balistidae). Acanthurids were also numerically dominant and along with the Pomacentridae (damselfish), accounted for more than two thirds of the abundance at Ukumehame (Table 4).

Fish biomass was not uniformly distributed across the Ukumehame reef (Figure 11, Appendix B). Total fish biomass was highest on west edge of the reef tract, where several sites had more than 90 g/m^2 of fish, and one site had an incredible 447 g/m^2. Reasons for this fish hotspot are unclear, but it is likely that this area of Ukumehame benefits from being adjacent to the Olowalu reef tract, which has relatively high fish biomass for a West Maui reef (Minton *et al.* 2020). Without this high-biomass area, fish biomass at Ukumehame would be among the lowest on Maui at around 12 g/m^2.

For this report, resource fish[5] 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 21.8 ± 7.6 g/m^2, which represented almost 56% of the total fish biomass. This percentage is lower than that observed at many Maui sites and suggests Ukumehame's fish

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[5] Those fish most prized by fishers. See Table 1 for a list of species that comprise the resource fish for this report.

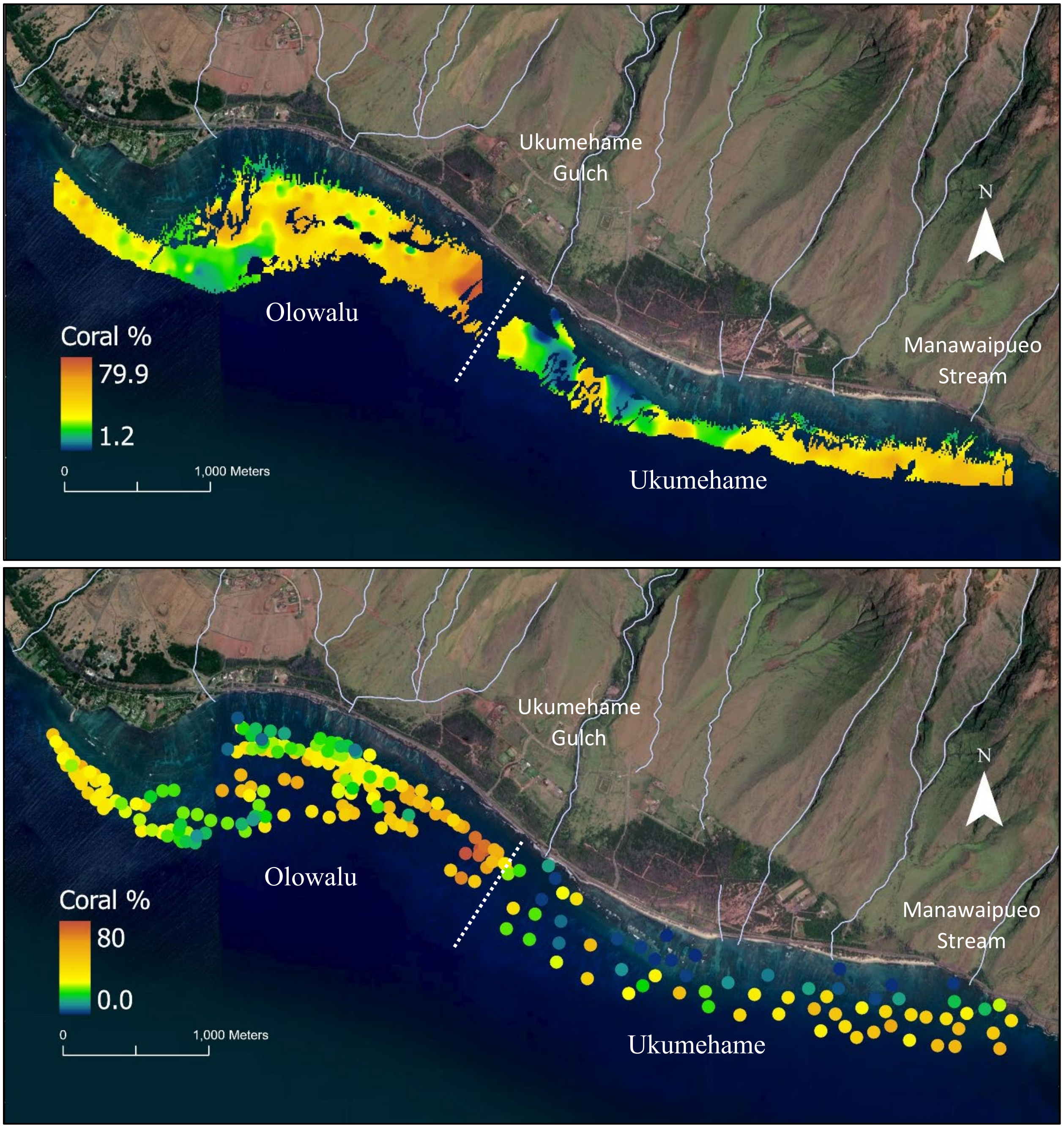

Figure 9. Coral cover across the Olowalu and Ukumehame reef tracts. The top map is interpolated from 2022-2023 survey data across hardbottom (see methods for more detail on the data). The lower map is individual site data for coral cover at all sites used to creation the interpolation. Yellow color in both maps is the average coral cover within the Ukumehame reef tract (26.8%) and red would be considered high coral cover.

Table 4. Fish biomass (g/m^2) and abundance (individuals/125 m^2) by fish family within the Ukumehame (n=58) reef tract. Data are from 2022-2023. *Individuals were present, but biomass was not estimated for this family.

	Biomass	**Abundance**
Acanthuridae	14.8 ± 3.6	37.2 ± 4.5
Balistidae	4.5 ± 0.7	3.0 ± 0.4
Scaridae	4.0 ± 0.7	12.8 ± 0.8
Lethrinidae	3.7 ± 3.2	1.2 ± 0.9
Labridae	3.4 ± 0.8	3.3 ± 0.7
Chaetodontidae	2.6 ± 0.4	2.6 ± 0.4
Serranidae	2.1 ± 0.7	0.3 ± 0.1
Lutjanidae	1.4 ± 0.8	0.1 ± 0.1
Pomacentridae	0.7 ± 0.2	23.0 ± 3.5
Mullidae	0.6 ± 0.1	1.8 ± 0.2
Fistulariidae	0.4 ± 0.2	0.1 ± 0.1
Holocentridae	0.3 ± 0.2	0.1 ± 0.1
Monacanthidae	0.2 ± 0.1	0.1 ± 0.1
Cirrhitidae	0.2 ± 0.1	1.1 ± 0.2
Zanclidae	0.1 ± 0.1	0.1 ± 0.1
Tetraodontidae	0.1 ± 0.1	1.3 ± 0.2
Carangidae	<0.1	0.1 ± 0.1
Pomacanthidae	<0.1	0.2 ± 0.1
Aulostomidae	<0.1	<0.1
Synodontidae	<0.1	<0.1
Blenniidae	<0.1	0.1 ± 0.1
Belonidae	<0.1	<0.1
Ostraciidae	<0.1	<0.1
Unidentified	*	0.3 ± 0.3
Muraenidae	*	<0.1
Myliobatidae	*	<0.1
Total Fish Biomass	**39.2 ± 8.0**	**88.7 ± 7.6**

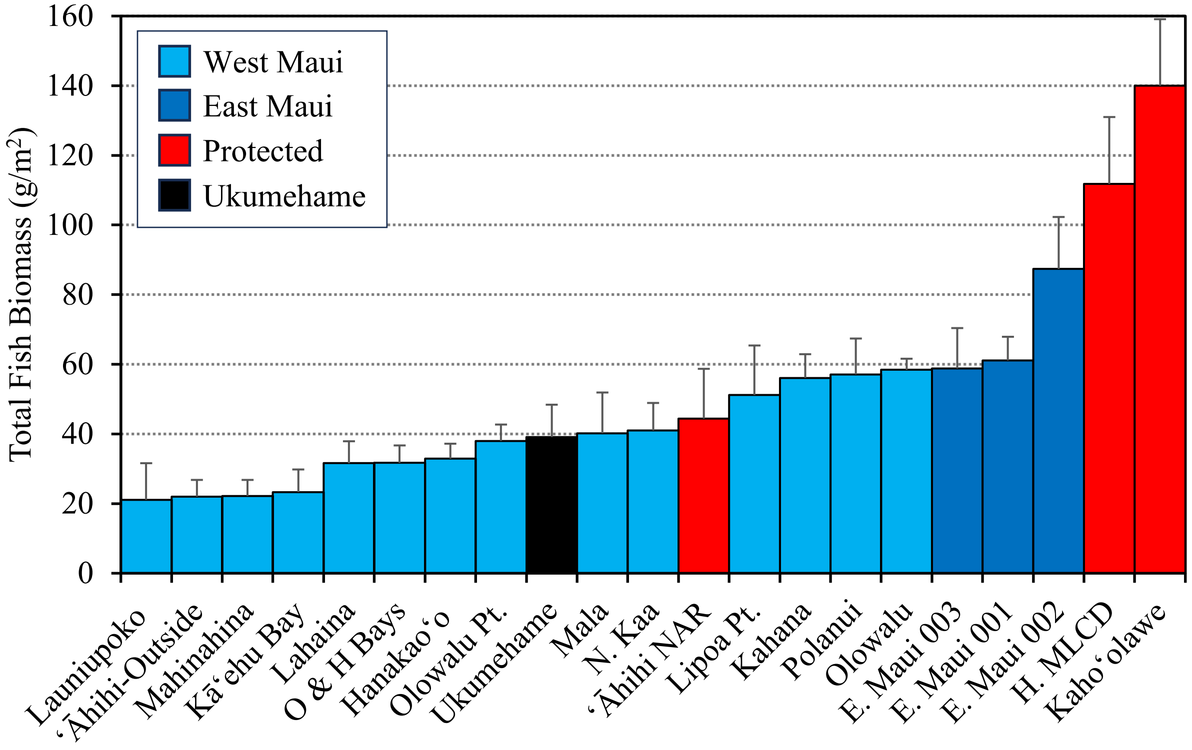

Figure 10. Total fish biomass at Ukumehame in 2022 (gold bar) and 20 Maui Nui sites. West Maui data were compiled by Minton *et al.* (2020), ʻĀhihi NAR and ʻĀhihi-Outside by Minton *et al.* (2016a), Kahoʻolawe by Minton *et al.* (2016b), and Kāʻehu Bay, E. Maui 001, E. Maui 002, and East Maui 003 by TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays; H. MLCD=Honolua MLCD.

assemblage may be experiencing relatively high fisheries impacts for Maui reefs. The resource fish biomass at Ukumehame was only slightly lower than the average for West Maui (26.3 ± 3.5 g/m^2), but considerably lower than most protected areas on Maui (Figure 12).

Not surprisingly, resource fish biomass had a similar spatial distribution to total fish biomass. Resource fish biomass was highest on west edge of Ukumehame reef (Figure 13, Appendix B). Again, reasons for this fish hotspot are unclear, but it may be due to its proximity to the Olowalu reef tract, which has relatively high fish biomass for a West Maui reef (Minton *et al.* 2020).

Surgeonfish accounted for the largest percentage of the resource fish biomass (~46%; Figure 14). Other important groups included parrotfish (16%), and other resource fish (17%), which at Ukumehame consisted exclusively of *Monotaxis grandoculis* (Bigeye emperor or *mū*). *Ctenochaetus strigosus* (goldring bristletooth or *kole*) were the most common resource fish species by far within the Ukumehame reef tract and had three times more biomass than *Naso hexacanthus* (sleek unicornfish or *opelu kala*), the second most common resource species. The

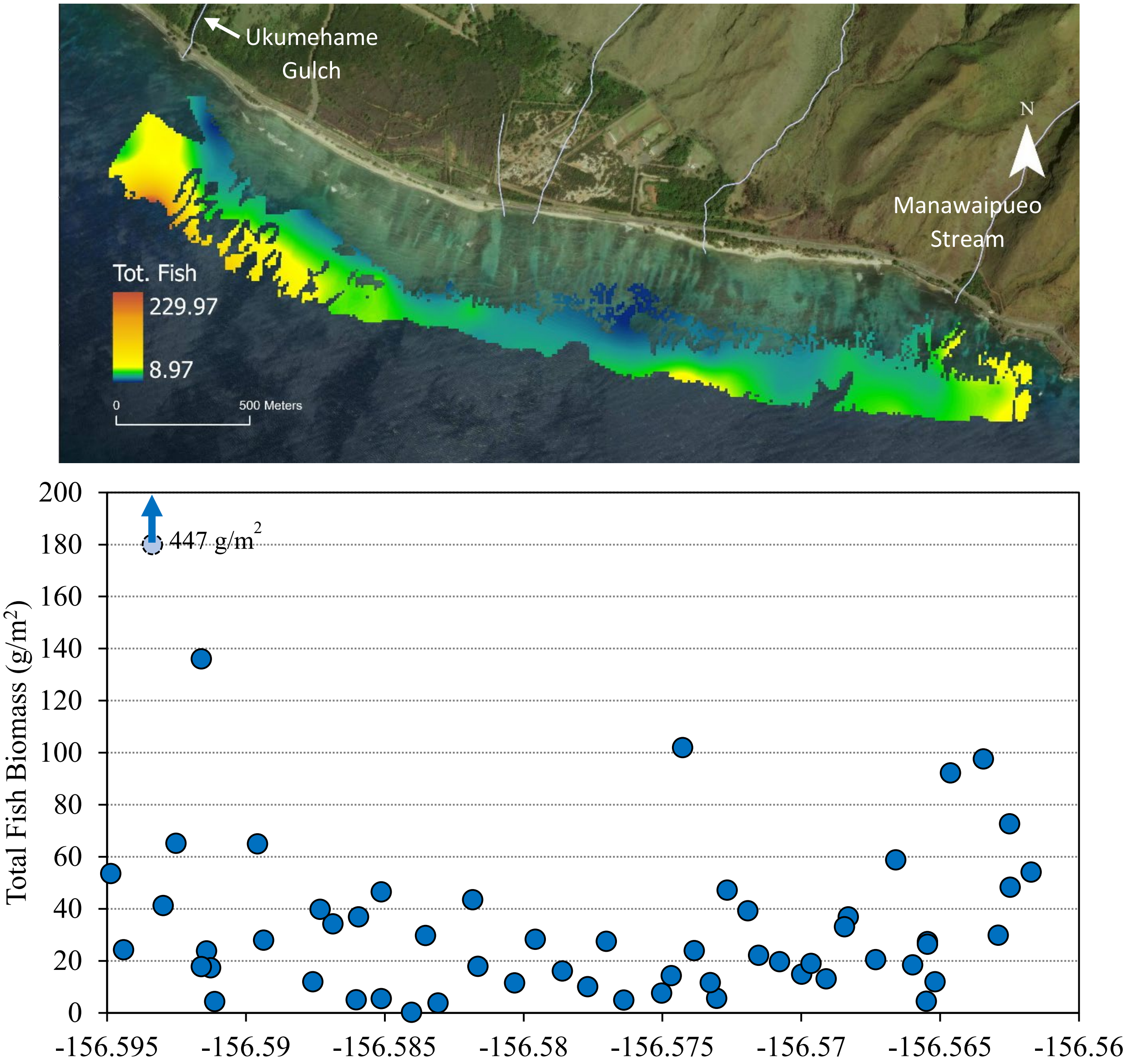

Figure 11. Total Fish biomass (g/m^2) across the Ukumehame reef tract. The map (top) is interpolated from 2022-2023 survey data across hardbottom. Yellow color is the average total fish biomass (39.2 g/m^2) for the reef tract and red would be considered high fish biomass for Ukumehame. Areas without color do not contain hardbottom or were too shallow/deep to be within the prescribed surevey area.

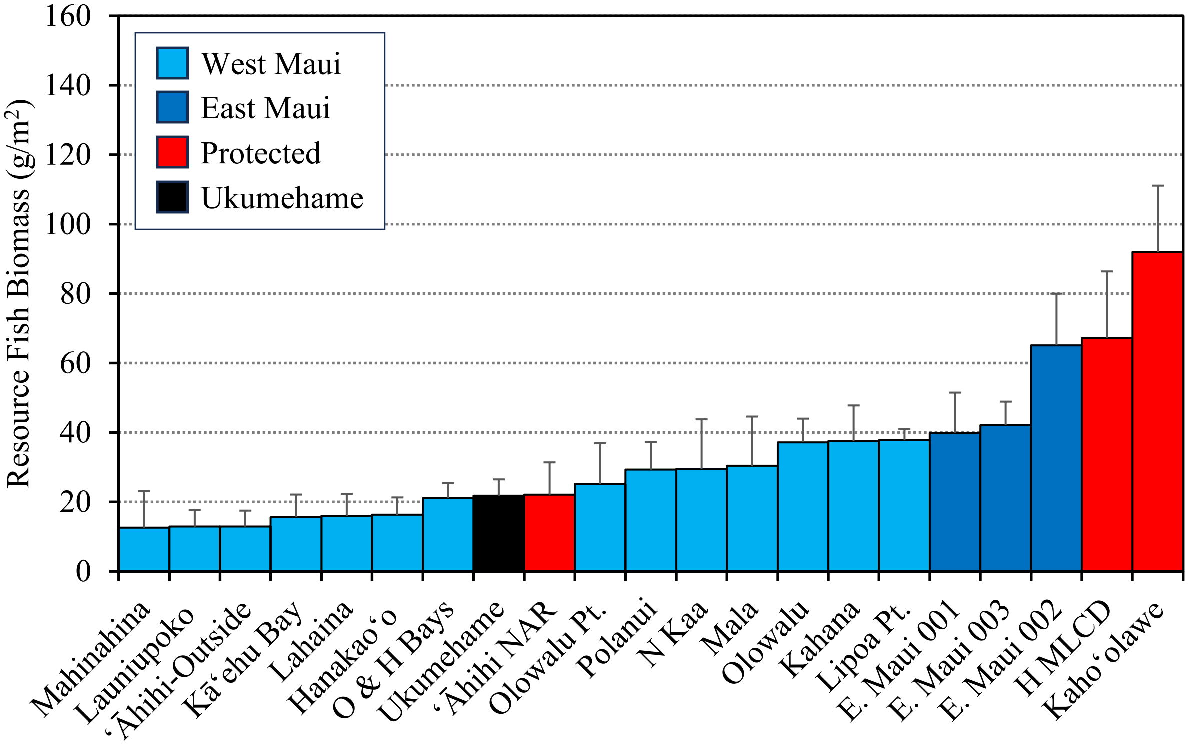

Figure 12. Resource fish biomass at Ukumehame in 2022 (black bar) and 20 Maui Nui sites. West Maui data were compiled by Minton *et al.* (2020), ʻĀhihi NAR and ʻĀhihi-Outside by Minton *et al.* (2016a), Kahoʻolawe by Minton *et al.* (2016b), and Kāʻehu Bay, E. Maui 001, E. Maui 002, and East Maui 003 by TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays; H. MLCD=Honolua MLCD.

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goatfish *Parupeneus multifasciatus* (manybar goatfish or *moano*) and the parrotfish *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 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 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).

At Ukumehame, the prime spawner biomass was 5.4 ± 1.0 g/m^2, which was slightly lower than the average for West Maui reefs (6.3 ± 1.7g/m^2), and considerably lower than many reefs on East Maui or within protected areas (Figure 15). Prime spawner abundance was 2.3 ± 0.5 individuals/125 m^2 (per survey site).

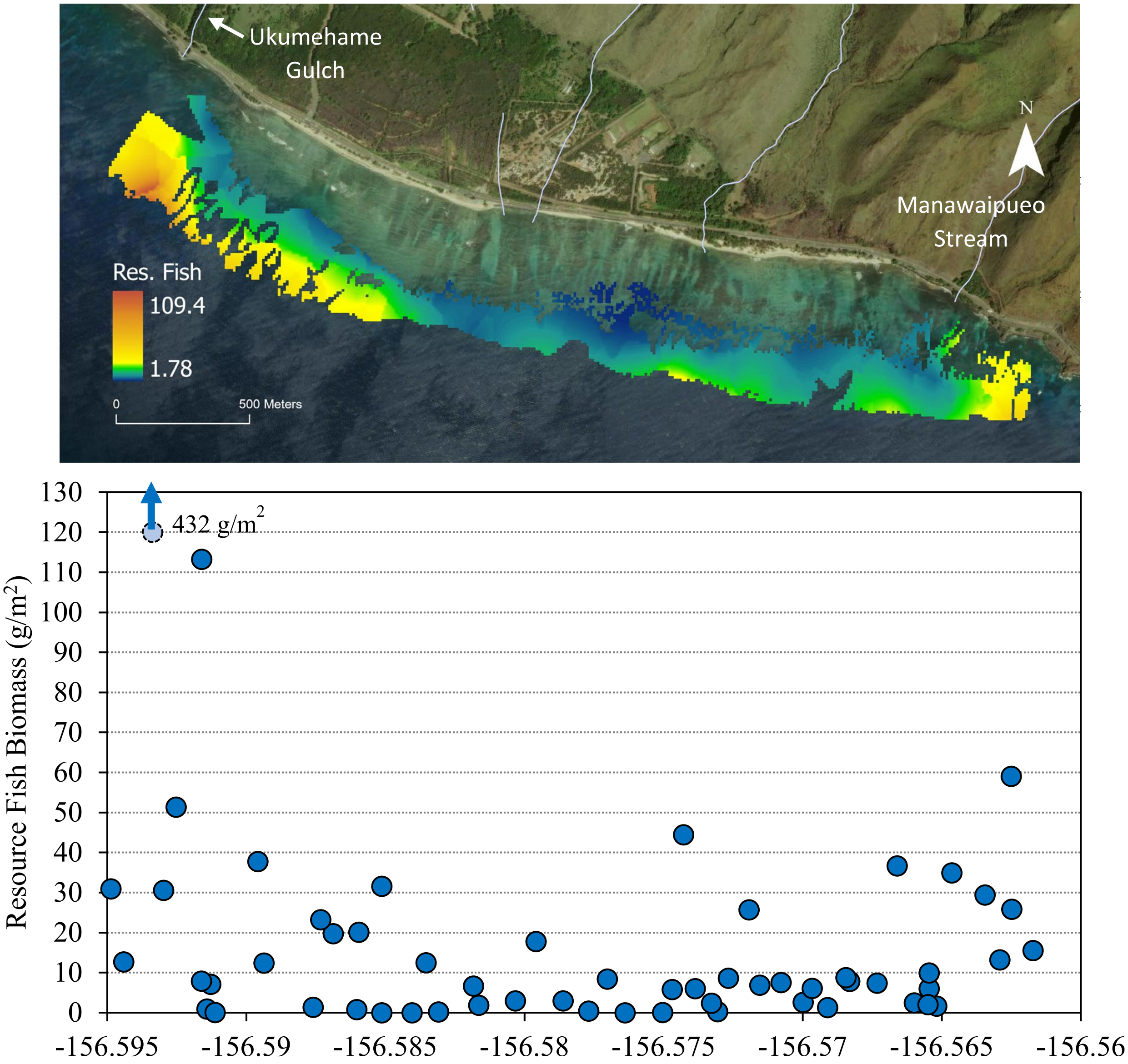

Figure 13. Resource fish biomass (g/m^2) across the Ukumehame reef tract. The map (top) is interpolated from 2022-2023 survey data across hardbottom. Yellow color is the average resource fish biomass (21.8 g/m^2) for the reef tract and red would be considered high resource fish biomass for Ukumehame. Areas without color do not contain hardbottom or were too shallow/deep to be within the prescribed surevey area.

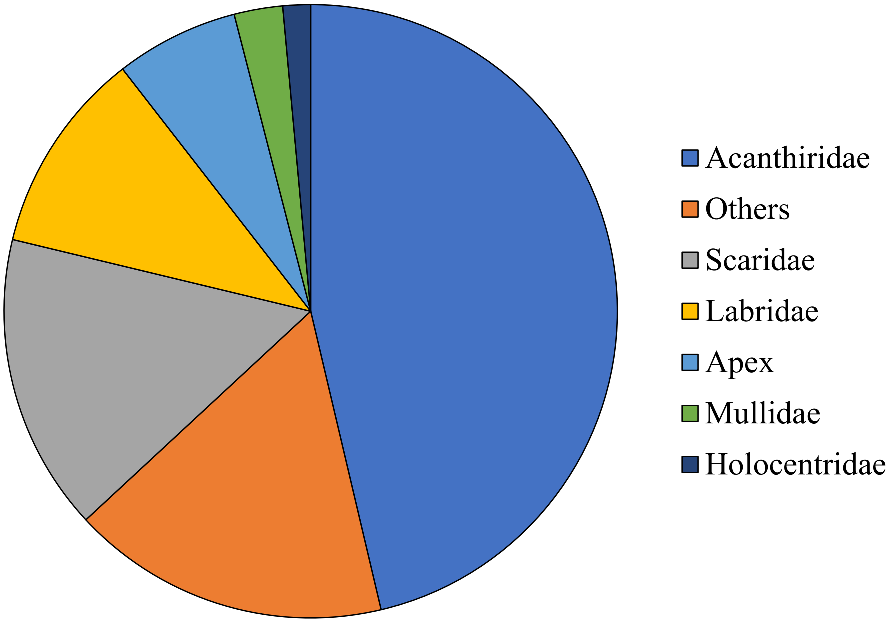

Figure 14. Resource fish composition (% of total resource fish biomass) at Ukumehame in 2022.

Prime spawners had a slightly different spatial distribution than total fish and resource fish biomass. While all three showed “hotspots” along the western edge of the Ukumehame reef tract, this area of high prime spawner biomass was extended much farther east than either the total or resource fish (Figure 16, Appendix B). In addition, prime spawner biomass peaked again at the eastern end of the reef tract.

Seventeen prime spawner species were observed, including representatives from all resource fish groups except apex predators. Four species accounted for over 71 % of the total prime spawner biomass, including *Acanthurus olivaceus* (41%), *Scarus psittacus* (14%), *Chlorurus spilurus* (12%) and *Bodianus albotaeniatus* (10%). *Acanthurus olivaceus* was also by far the most abundant prime spawner at Ukumehame, averaging nearly one prime spawner individual per survey site and 40% of all prime spawners observed at Ukumehame. Other relatively abundant species included *S. psittacus* (23% of all prime spawners) and the goatfish *Parupeneus multifasciatus* (11%).

While three invasive fish species are commonly observed on Hawaiian reefs, only *Cephalopholis argus* (peacock grouper or *roi*) and *Lutjanus fulvus* (blacktail snapper or *toʻao*) were observed at Ukumehame. Surprisingly, no *L. kasmira* (bluestriped snapper or *taʻape*) were encountered—this species is common on many Hawaiian reefs and can be very abundant when present.

Cephalopholis argus is a species of considerable concern among fishers on Maui and has been the target of community-led control efforts for over a decade. The Olowalu area has been a focus of these efforts on Maui, with hundreds of *C. argus* individuals removed between 2008 and 2011

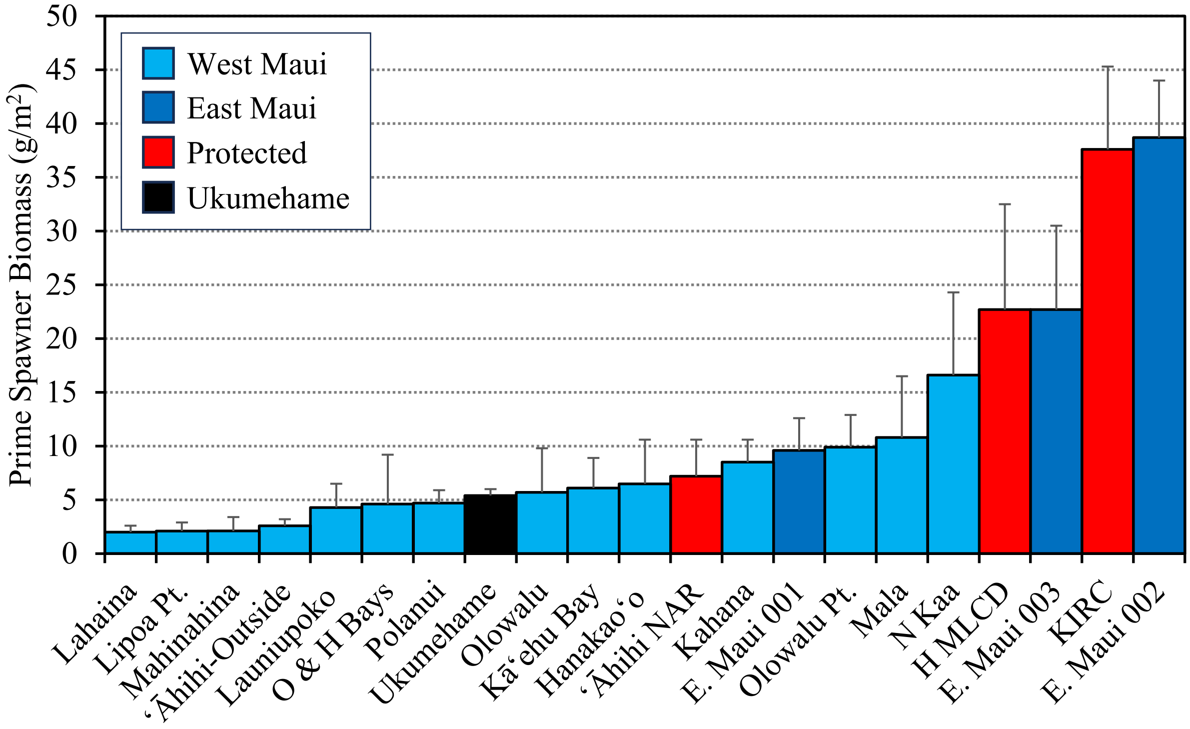

Figure 15. Prime spawner fish biomass at Ukumehame in 2022 (black bar) and 20 Maui Nui sites. West Maui data were compiled by Minton *et al.* (2020), ʻĀhihi NAR and ʻĀhihi-Outside by Minton *et al.* (2016a), Kahoʻolawe by Minton *et al.* (2016b), and Kāʻehu Bay, E. Maui 001, E. Maui 002, and East Maui 003 by TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays.

(Donovan *et al.* 2013). Twenty-six *C. argus* were observed at 14 of the 58 survey sites (24%), with one to four *C. argus* individuals observed at each site when present. Surveyors noted only a single *L. fulvus* at Ukumehame, indicating this species, while present, is not abundant and is unlikely to present a significant concern.

Minton *et al.* (2020) noted several factors were likely affecting the fish assemblage within the Olowalu area. These included fish harvest and variation in habitat quality along the reef. Their analysis included few data from Ukumehame, which limited their ability to drawn inference with respect to this reef tract.

The 2022-2023 fish data from Ukumehame support the finding that local fishing impacts are likely occurring within the Ukumehame reef tract. Examining the ratio of resource fish to non-resource fish (R:NR) can shed light on fishing pressure because areas with high fishing pressure tend to have a lower R:NR ratio than areas with relatively low fishing pressure (Minton *et al.* 2020). The R:NR ratio at Ukumehame was higher than what might be expected for an area that is heavily fished (Figure 17), but this R:NR ration benefited from a few high-biomass sites on west

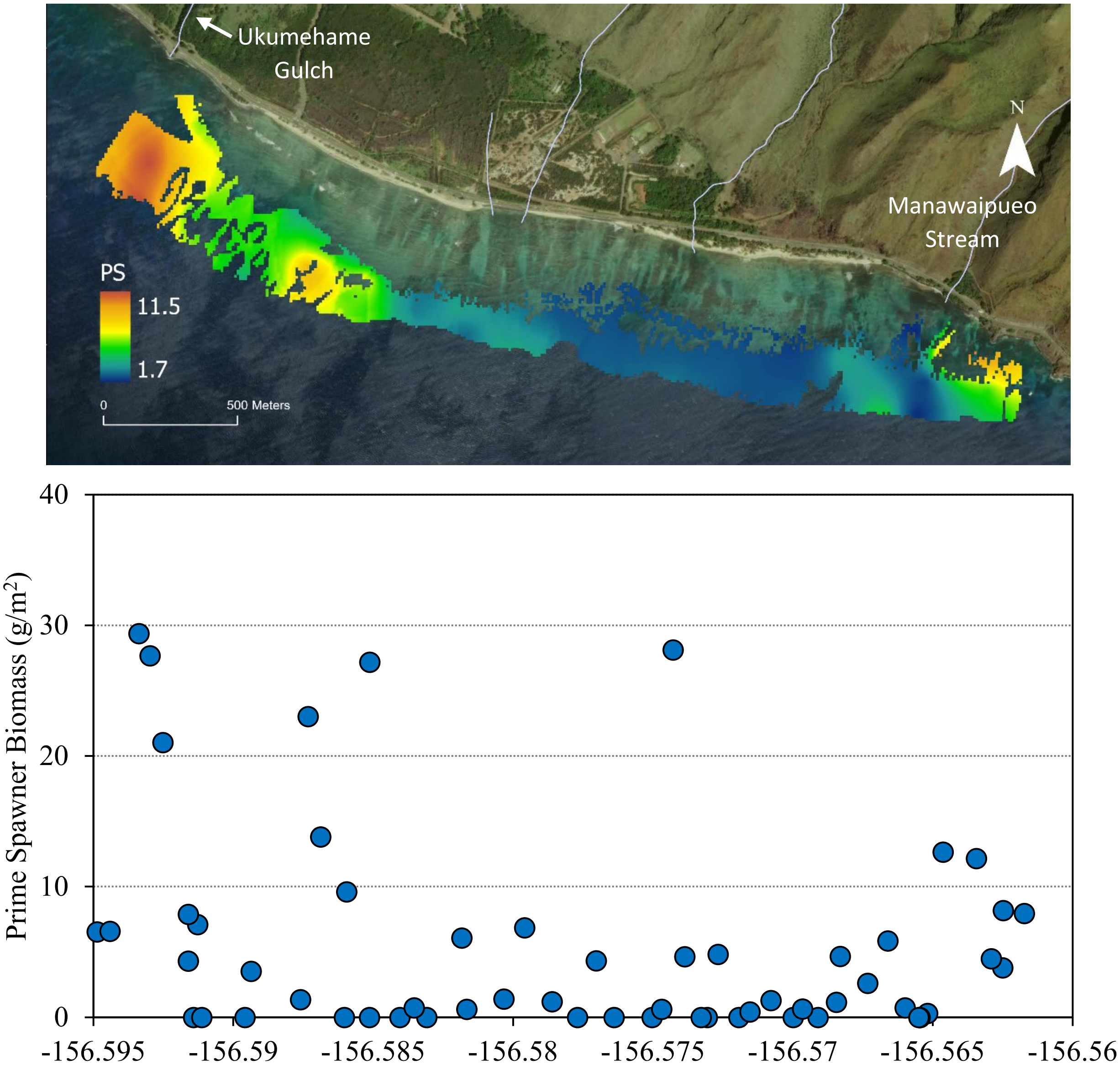

Figure 16. Prime spawner biomass (g/m^2) across the Ukumehame reef tract. The map (top) is interpolated from 2022-2023 survey data across hardbottom. Yellow color is the average prime spawner biomass (5.4 g/m^2) or the reef tract and red would be considered high prime spawner biomass for Ukumehame. Areas without color do not contain hardbottom or were too shallow/deep to be within the prescribed surevey area.

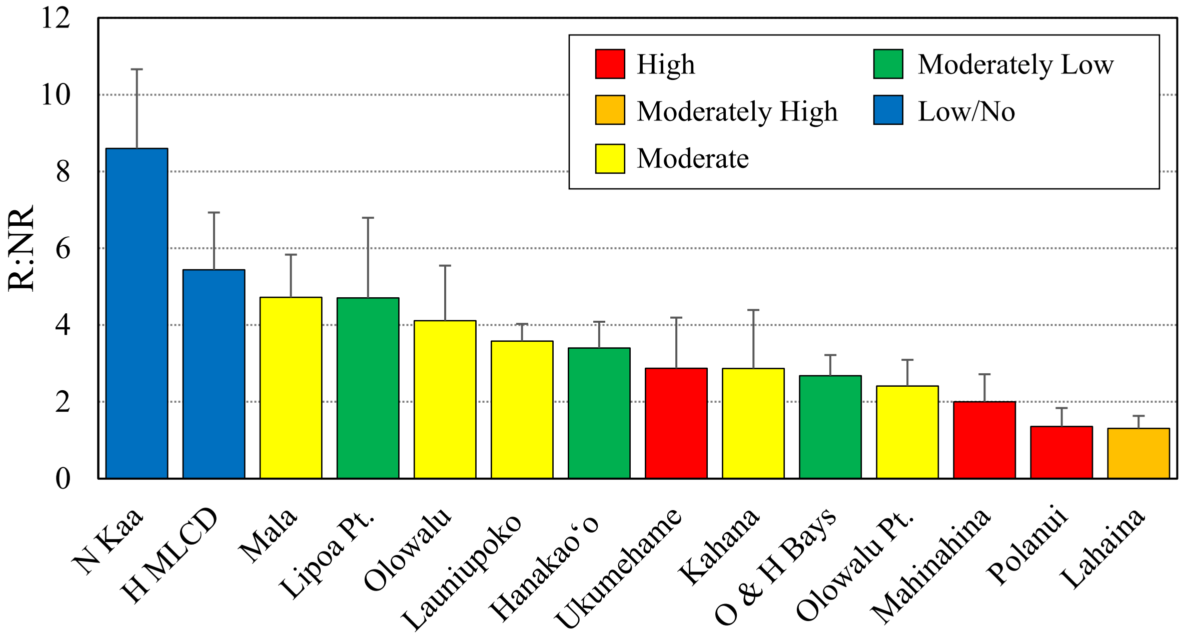

Figure 17. Ratio of mean resource fish biomass to non-resource fish biomass (R:NR) for 14 reef areas in West Maui. N Kaa=North Kaanapali; H MLCD=Honolua MLCD; O & H Bays= Oneloa and Honokaua Bays. Figure modified from Minton *et al.* (2020).

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edge of the Ukumehame reef, nearest the Olowalu reef tract. Without these sites, Ukumehame had the worst R:NR ratio compared to all areas currently assessed in West Maui (see Minton *et al.* 2020).

The reef at Ukumehame is accessed easily from a main highway, has ample parking at Ukumehame Beach Park, and is almost always safe to fish due to its sheltered location. Total fish biomass in Hawaiʻi is correlated with human population density, shoreline access, and the level of fishing regulation (Friedlander *et al.* 2013, Friedlander *et al.* 2017). Easily accessible areas near population centers, such as Ukumehame, tend to have lower total fish biomass than more isolated areas and/or areas with greater fishery management. Interestingly, both resource fish and prime spawner biomass increase at the edges of the Ukumehame reef tract, which are the most distant locations from the parking lot.

A broader context is needed to fully understand fishing pressure on Maui and the other main Hawaiian Islands. Many coral reef fish species, especially large, predatory species (*e.g.*, sharks, jacks, etc.) range widely, which exposes them to fishing pressure even if their range may overlap a sparsely fished or closed area. These wide-ranging species are subject to “regional” fishing pressure, which can result in lower fish biomass even in protected or remote areas. Notably, apex predators, which tend to roam widely or have large home ranges, were relatively rare on West Maui reefs, including Ukumehame. Apex predators contributed little to Ukumehame’s resource fish biomass, only about ~6.5% of the resource fish biomass (Figure 14), and no apex predator prime spawners were observed at any of the 58 sites surveyed for fish.

While fishing effects are certainly occurring at Ukumehame, other factors such as variation in habitat quality are also likely contributing to Ukumehame's low fish biomass. Habitat condition is an important factor affecting the capacity of a reef area to support fish biomass and abundance. While coral cover itself is usually not a strong predictor of fish biomass, coral are the primary source of three-dimensional structure on reefs that create fish habitat, and also tend to be indicators of good environmental conditions due to their sensitivity to water quality conditions. The reef area to the east of the parking lot in Ukumehame Beach Park had relatively low coral cover[6] (Figure 5), and low rugosity (a measure of three-dimensional structure) than the western and eastern edges of the reef tract, suggesting this reef area provide lower quality fish habitat. This does not necessarily imply that this reef area has been adversely affected by any specific anthropogenic source. Reefs vary in their value as fish habitat for many natural and anthropogenic reasons, and factors that might be responsible for the lower coral cover and rugosity cannot be conclusively identified with the data available for this analysis.

Acknowledgements

We are indebted to the many individuals and agencies whose contributions made it possible to conduct these surveys and place the results in the context of broader spatial and temporal trends in the area. The Maui Office of the Hawai‘i Division of Aquatic Resources provided invaluable assistance with these surveys, specifically Russell Sparks in the design of the surveys and Tatiana Martinez in providing DAR data from adjacent areas that allowed us to expand the spatial scale of this analysis and examine temporal trends. Exact Game Fishing, Inc., Lee James, and Captain Craig provided excellent and safe boat support for our team of divers. West Side Air provided SCUBA tanks and flexible schedules for the dive team.

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[6] Cover is this area was not the lowest in the reef tract. Lowest cover areas were shallow reef areas on the western edge of the reef tract, nearest the output of Ukumehame Stream.

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Appendix A: Site Metadata

Site metadata for TNC surveys conducted within the Ukumehame reef tract in 2022 and 2023. At most sites, both benthic (B) and fish surveys were conducted (F); exceptions are noted. Sites in italics were not included in any analysis due to poor water visibility adversely affecting the photo-analysis (see methods for more discussion)

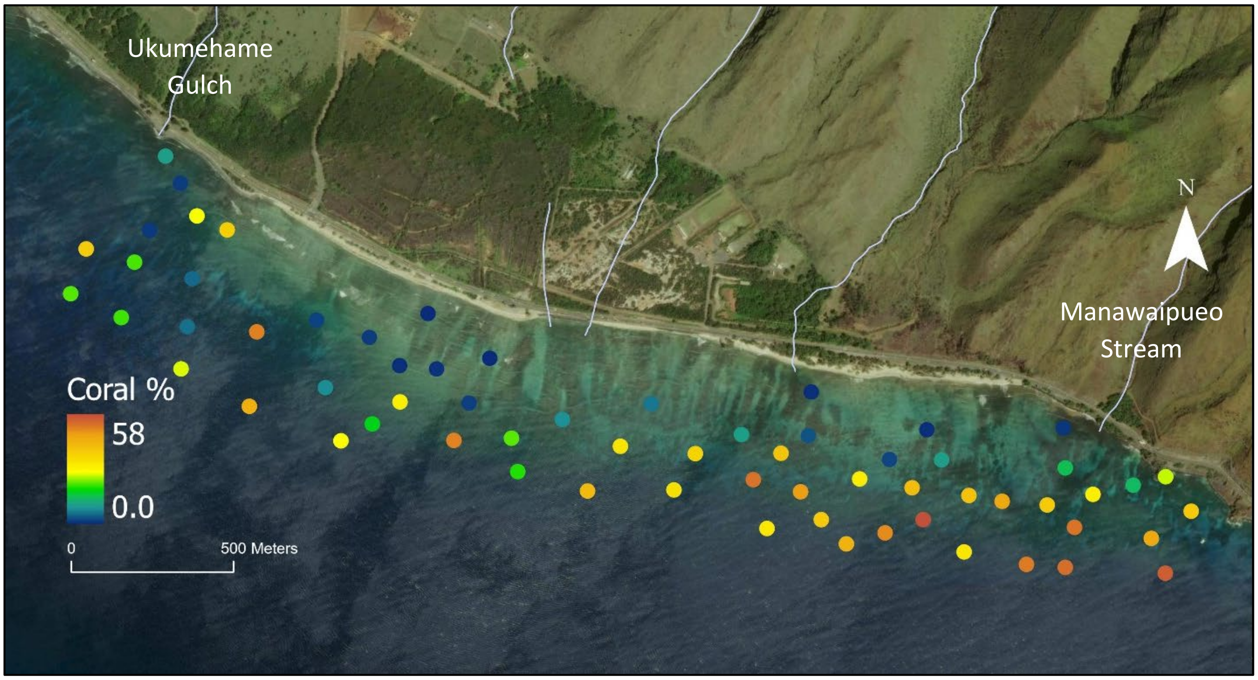
Site Code	Date	Latitude	Longitude	Rugosity	Depth (m)	Type
2022-UKU-001	10/27/2022	20.79035	-156.56546	11.75	2.1	B,F
2022-UKU-002	10/27/2022	20.79115	-156.58688	12.5	13.1	B,F
2022-UKU-004	10/27/2022	20.78823	-156.57193	20.34	14	B,F
2022-UKU-005	10/27/2022	20.7922	-156.58309	11	1.5	B,F
2022-UKU-007	10/24/2022	20.79453	-156.5876	11.8	3	B,F
2022-UKU-008	10/24/2022	20.7898	-156.56999	15.45	3.4	B,F
2022-UKU-009	10/25/2022	20.78867	-156.57429	13.4	15.5	B,F
2022-UKU-010	10/27/2022	20.79216	-156.5777	12	2.4	B,F
2022-UKU-011	10/25/2022	20.79461	-156.59337	14.9	15.8	B,F
2022-UKU-013	10/24/2022	20.79076	-156.57639	16.21	4.6	B,F
2022-UKU-014	10/27/2022	20.7942	-156.58937	15	10.1	B,F
2022-UKU-015	10/28/2022	20.78913	-156.56173	13.3	3.7	B,F
2022-UKU-016	10/28/2022	20.78961	-156.56464	14.51	3.7	B,F
2022-UKU-017	10/25/2022	20.79098	-156.57861	12.9	4.9	B,F
2022-UKU-018	*10/22/2022*	*20.79268*	*-156.57999*	-	-	*B*
2022-UKU-019	10/28/2022	20.79121	-156.58184	14.67	2.7	B,F
2022-UKU-020	10/28/2022	20.78891	-156.57268	15	11	B,F
2022-UKU-022	10/27/2022	20.78958	-156.56831	19	3.7	B,F
2022-UKU-023	10/26/2022	20.78975	-156.57703	13.04	11.3	B,F
2022-UKU-024	10/26/2022	20.78931	-156.56599	17.85	3.7	B,F
2022-UKU-029	10/28/2022	20.79528	-156.59488	14.9	15.8	B,F
2022-UKU-031	10/26/2022	20.79317	-156.59161	16.8	15.2	B,F
2022-UKU-032	*10/22/2022*	*20.79173*	*-156.57371*	-	*1.8*	*B*
2022-UKU-035	10/27/2022	20.79058	-156.56911	15.45	2.1	B,F
2022-UKU-036	10/28/2022	20.78868	-156.56519	13.51	4.6	B,F
2022-UKU-039	10/24/2022	20.78972	-156.57959	13.1	15.2	B,F
2022-UKU-040	10/26/2022	20.79324	-156.58514	12.5	1.5	B,F
2022-UKU-043	10/25/2022	20.7913	-156.57504	13	2.4	B,F
2022-UKU-044	10/25/2022	20.79224	-156.58513	13	4.6	B,F
2022-UKU-047	10/24/2022	20.79126	-156.57306	13.5	1.8	B,F

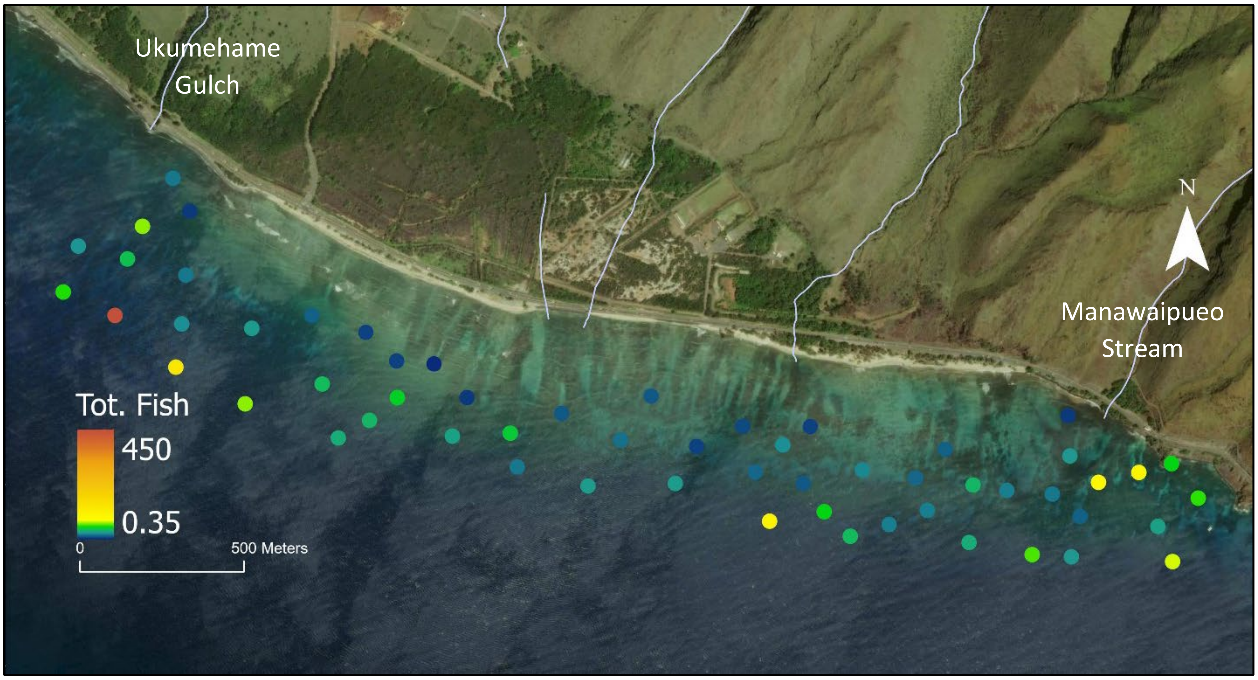
Site Code	**Date**	**Latitude**	**Longitude**	**Rugosity**	**Depth (m)**	**Type**
2022-UKU-048	10/24/2022	20.78986	-156.56345	16	3	B,F
2022-UKU-050	10/28/2022	20.79077	-156.57386	11.5	2.1	B,F
2022-UKU-051	10/26/2022	20.78757	-156.56546	16	13.4	B,F
2022-UKU-052	10/27/2022	20.79173	-156.58033	13.22	3.4	B,F
2022-UKU-056	10/28/2022	20.79315	-156.58405	12.5	2.1	B,F
2022-UKU-058	10/26/2022	20.79005	-156.57154	14	3.7	B,F
2022-UKU-059	10/24/2022	20.79653	-156.59441	15	12.2	B,F
2022-UKU-060	10/24/2022	20.7897	-156.57329	13	5.5	B,F
2022-UKU-061	*10/22/2022*	*20.791*	*-156.57138*	-	*2.1*	*B*
2022-UKU-062	10/28/2022	20.79435	-156.59142	10.95	12.2	B,F
2022-UKU-063	10/24/2022	20.79115	-156.58354	15.27	4.3	B,F
2022-UKU-064	10/26/2022	20.78854	-156.57079	15.85	11.3	B,F
2022-UKU-065	10/27/2022	20.79004	-156.57469	15.8	5.2	B,F
2022-UKU-067	10/25/2022	20.79705	-156.59253	11.08	9.1	B,F
2022-UKU-068	10/26/2022	20.78942	-156.56733	13	3.7	B,F
2022-UKU-069	10/26/2022	20.7901	-156.56249	16.01	1.5	B,F
2022-UKU-070	10/26/2022	20.79745	-156.59113	13	2.7	B,F
2022-UKU-071	10/24/2022	20.7957	-156.59128	11.33	9.8	B,F
2022-UKU-072	10/24/2022	20.78739	-156.56251	15.1	12.2	B,F
2022-UKU-073	10/25/2022	20.79836	-156.59162	10.3	2.1	B,F
2022-UKU-074	10/26/2022	20.79027	-156.58166	14.3	12.5	B,F
2022-UKU-076	10/24/2022	20.788	-156.56845	16.5	13.7	B,F
2022-UKU-077	10/25/2022	20.79212	-156.58959	17.03	16.8	B,F
2022-UKU-080	10/28/2022	20.78891	-156.56966	14.05	7.6	B,F
2022-UKU-082	10/25/2022	20.79264	-156.58733	11.9	9.8	B,F
2022-UKU-083	10/27/2022	20.79404	-156.58603	10.3	1.5	B,F
2022-UKU-086	10/25/2022	20.78837	-156.56292	14.07	5.2	B,F
2022-UKU-090	10/27/2022	20.78765	-156.56661	14.4	14.3	B,F
2022-UKU-091	10/28/2022	20.79616	-156.59298	12.7	10.7	B,F
2022-UKU-094	10/28/2022	20.79162	-156.58596	12.96	9.4	B,F
2022-UKU-096	10/22/2022	20.79249	-156.57296	-	1.5	B
2022-UKU-098	10/25/2022	20.79146	-156.5655	11.75	1.5	B,F
2023-UKU-021	*2/21/2023*	*20.79055*	*-156.56747*	*13.35*	*2.1*	*B*
2023-UKU-033	*2/21/2023*	*20.79228*	*-156.57609*	*10.5*	*1.5*	*B*
2023-UKU-038	2/21/2023	20.79706	-156.59023	13	1.2	B
2023-UKU-045	2/21/2023	20.79471	-156.5843	10	1.2	B
2023-UKU-049	2/21/2023	20.79345	-156.58247	13	1.2	B

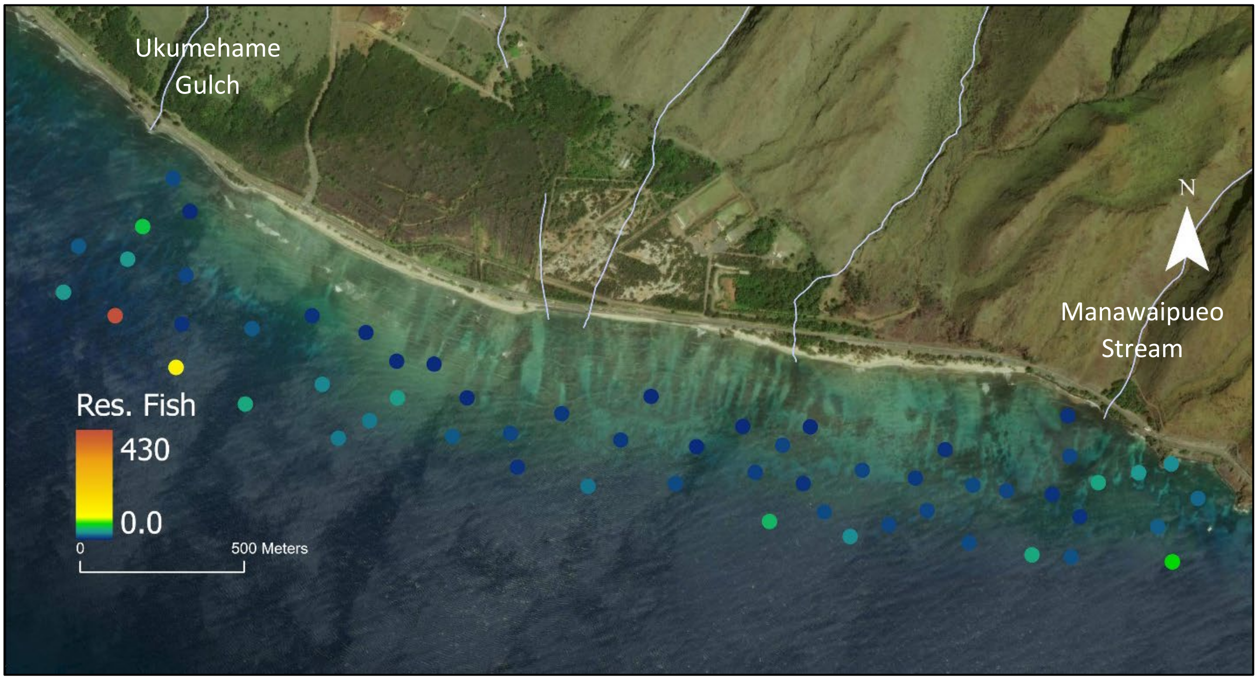
Site Code	Date	Latitude	Longitude	Rugosity	Depth (m)	Type
2023-UKU-054	2/21/2023	20.79913	-156.59205	14	1.5	B
2023-UKU-057	2/21/2023	20.79142	-156.56955	11.2	1.5	B
2023-UKU-075	*2/21/2023*	*20.79109*	*-156.56458*	*11.3*	*1.5*	*B*
2023-UKU-081	*2/21/2023*	*20.79382*	*-156.58055*	*10*	*1.5*	*B*
2023-UKU-100	2/21/2023	20.79059	-156.57065	10.35	3.7	B

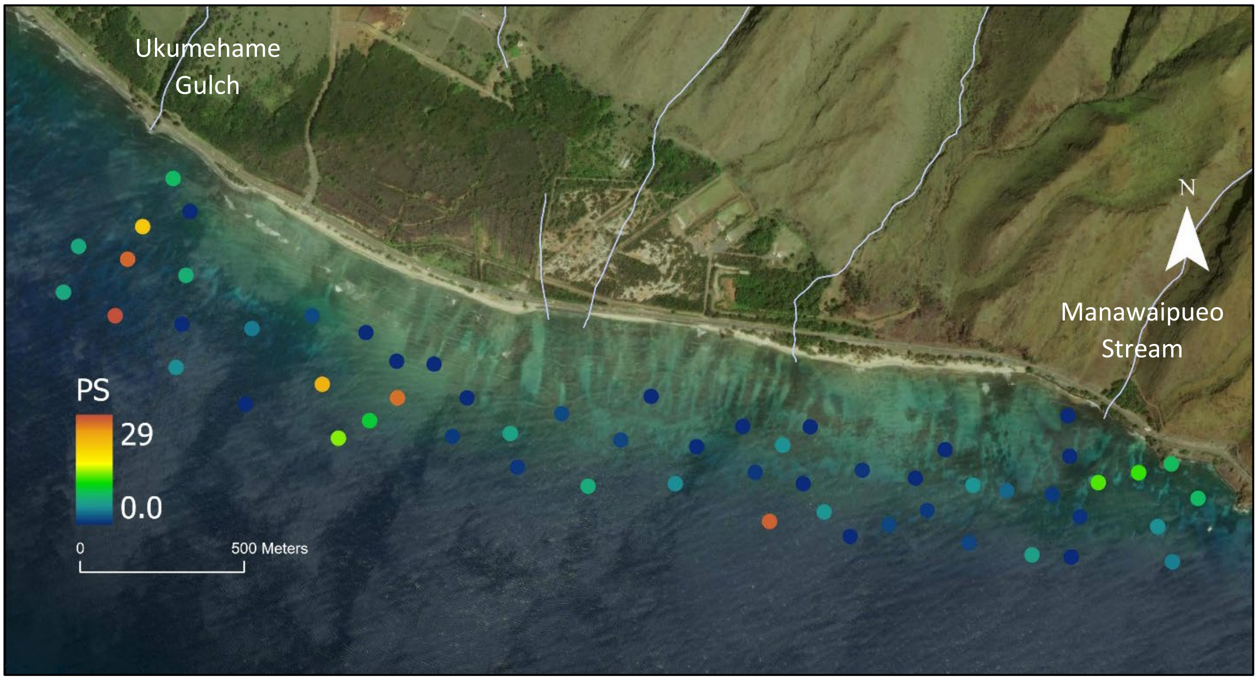
Appendix B: Coral and Fish Data Maps

Individual site data for coral cover (percent cover), total fish biomass (g/m^2), resource fish biomass (g/m^2), and prime spawner biomass (g/m^2) at all sites surveyed at Ukumehame in 2022 and 2023. Coloring ramping is the same as in Figures 5, 11, 13, and 16. Yellow color is the average value for the reef tract, and red would be considered high cover/biomass for Ukumehame.






Ukumehame
Gulch
Manawaipueo
Stream
N
Res. Fish
430
0.0
0
500 Meters


Ukumehame
Gulch
Manawaipueo
Stream
N
PS
29
0.0
0
500 Meters