Coral Reef and Water Quality Surveys of south shore Molokai

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NOAA CORAL REEF CONSERVATION PROGRAM

Coral Reef and Water Quality Surveys of south shore Molokai

by

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List of English Common, Hawaiian, and Scientific Names of Species Included in this Report

Common Name	Hawaiian Name	Scientific Name
Ocellated coral	-	*Cyphastrea ocellina*
Mushroom coral	ʻĀkoʻakoʻa kohe	*Fungia scutaria*
Crust coral	Koʻa	*Leptastrea purpurea*
Transverse coral	-	*Leptastrea transversa*
Swelling coral	-	*Leptoseris incrustans*
Rice coral	ʻĀkoʻakoʻa	*Montipora capitata*
Branching rice coral	-	*Montipora incrassata*
Sandpaper coral	Koʻa	*Montipora patula*
Porkchop coral	-	*Pavona duerdeni*
Maldive coral		*Pavona maldivensis*
Corrugated coral	ʻĀkoʻakoʻa	*Pavona varians*
Cauliflower coral	Koʻa	*Pocillopora meandrina*
Lace coral	-	*Pocillopora damicornis*
Finger coral	Pōhaku puna	*Porites compressa*
Lobe coral	Pōhaku puna	*Porites lobata*
Lichen coral	-	*Porites lichen*
Mound coral	-	*Porites lutea*
Plate and pillar coral	-	*Porites rus*
Plate and knob coral	-	*Porites monticulosa*
Stellar coral	-	*Psammocora stellata*

Common Name	Hawaiian Name	Scientific Name
-	Limu koho	*Amansia glomerata*
-	Limu kohu	*Asparagopsis* spp.
-	-	*Halimeda* spp.
-	-	*Padina* spp.

Common Name	Hawaiian Name	Scientific Name
Achilles tang	Pākuʻikuʻi	*Acanthurus achilles*
Ringtail surgeonfish	Pualu	*Acanthurus blochii*
Eyestripe surgeonfish	Palani	*Acanthurus dussumieri*
Whitebar surgeonfish	Maikoiko	*Acanthurus leucopareius*
Goldrim surgeonfish	-	*Acanthurus nigricans*
Brown surgeonfish	Māʻiʻi	*Acanthurus nigrofuscus*
Bluelined surgeonfish	Maiko	*Acanthurus nigroris*
Orangeband surgeonfish	Naʻenaʻe	*Acanthurus olivaceus*
Convict tang	Manini	*Acanthurus triostegus*
Yellowfin surgeonfish	Pualu	*Acanthurus xanthopterus*
Smalltoothed jobfish	Wahanui	*Aphareus furca*
Green jobfish	Uku	*Aprion virescens*

Common Name	Hawaiian Name	Scientific Name
Hawaiian hogfish	‘A‘awa	*Bodianus albotaeniatus*
Bluefin trevally	‘Ōmilu	*Caranx melampygus*
Peacock grouper	Roi	*Cephalopholis argus*
Multiband butterflyfish	-	*Chaetodon multicinctus*
Ornate butterflyfish	-	*Chaetodon ornatissimus*
Fourspot butterflyfish	-	*Chaetodon quadrimaculatus*
Teardrop butterflyfish	-	*Chaetodon unimaculatus*
Milkfish	Awa	*Chanos chanos*
Cigar wrasse	Kupou	*Cheilio inermis*
Bullethead parrotfish	Uhu	*Chlorurus spilurus*
Spectacled parrotfish	Uhu ‘ahu‘ula	*Chlorurus perspicillatus*
Stocky hawkfish	Po‘opa‘a	*Cirrhitus pinnulatus*
Yellowstriped coris	Hilu	*Coris flavovittata*
Yellowtail coris	Hinālea ‘aki-lolo	*Coris gaimard*
Mackerel scad	‘Ōpelu	*Decapterus macarellus*
Rainbow runner	Kamanu	*Elagatis bipinnulata*
Bluestriped snapper	Ta‘ape	*Lutjanus kasmira*
Blacktail snapper	Toau	*Lutjanus fulvus*
Bigeye emperor	Mū	*Monotaxis grandoculis*
Paletail unicornfish	Kala lōlō	*Naso brevirostris*
Orangespine unicornfish	Umaumalei	*Naso literatus*
Ringtail wrasse	Po‘ou	*Oxycheilinus unifasciatus*
Saber squirrelfish	‘Ala‘ihi	*Sargocentron spiniferum*
Tahitian squirrelfish	‘Ala‘ihi	*Sargocentron tiere*
Palenose parrotfish	Uhu	*Scarus psittacus*
Ember parrotfish	Uhu ‘ele‘ele	*Scarus rubroviolaceus*
Doublespotted queenfish	Lai	*Scomberoides lysan*
Great barracuda	Kākū	*Sphyraena barracuda*
Old woman wrasse	Hinālea lauhine	*Thalassoma ballieui*
Saddle wrasse	Hinālea lau-wili	*Thalassoma duperrey*
Surge wrasse	Hou	*Thalassoma purpureum*

Note on names: Common and Hawaiian names were obtained primarily from three sources: Randall (2007) for fish and Hoover (1998) and Bernice P. Bishop Museum for invertebrates.

Summary of Findings

South shore Molokai has the longest continuous fringing coral reef in the Hawaiian Islands, a critical component of which is the Kawela reef tract, extending from just east of Kaunakakai Harbor channel approximately 17 km (10.6 mi) to Kamalō. For over a century, the reef has been subject to threats that have degraded its condition and likely impaired its capacity to function as habitat for coral, reef fish and other reef-associated species. Deforestation, urban development, excessive grazing and browsing by feral ungulates, and agriculture have resulted in considerable erosion and subsequent sediment runoff during heavy rainfall events, delivering terrestrial sediment- and nutrient-enriched water to the Kawela reef tract. The sediment plumes generated can last hours to days, decrease water quality (*i.e.*, increase turbidity), and are responsible for depositing most of the sediment onto Kawela's reef flat. This sediment can degrade coral reef communities by directly smothering and killing coral, as well impairing coral settlement, growth, health, and ability to compete with invasive algae species.

To reduce upland erosion rates and decrease sediment delivery to the Kawela reef, The Nature Conservancy (TNC), in partnership with the State Division of Forestry and Wildlife, installed ungulate-proof fences and conducted intensive animal control over portions of the Kawela watershed starting in 2007 to reduce feral ungulate activity. This has led to substantial revegetation of the area and significant reductions in erosion, with US Geological Survey (USGS) monitoring showing reductions in sediment export from the Kawela ahupuaʻa from an average of 7,100 tons to 1,850 tons annually between 2006-2011 and 2016-2018, respectively.

Well over a decade has passed since upland restoration efforts were initiated, but coral and fish communities on the Kawela reef tract have not been examined in detail since USGS and University of Hawaiʻi (UH) researchers assessed baseline conditions in the early 2000's. This creates a unique opportunity to examine the response of a Hawaiʻi coral reef ecosystem to many years of sediment reduction, as well as to establish a new baseline of water quality and reef condition against which to measure the effects of ongoing and expanding upland restoration efforts. To capitalize on this opportunity, TNC repeated as closely as possible the USGS and UH baseline studies, collecting sediment, water quality, and biological (benthic and fish) data in 2023 at Kawela to evaluate the reef tract's response to upland restoration, inform management actions moving forward, and provide an updated baseline against which to measure future change.

Normalized Difference Vegetation Index analysis of watershed satellite imagery documented bare ground cover in the watershed dropped from 763 acres in 2010 to 160 acres of bare ground in to 2023, decreasing by more than 80% across Kawela watershed from 2010-2023.

Between April 11 and 30, 2023, TNC collected water quality, sediment and benthic data at 54 sites along nine shore-normal transects initially established on shallow reef flats throughout the Kawela reef tract by USGS in 2000. In addition, TNC collected fish and benthic data from 56

sites between 1 and 18 m depth along the adjacent forereef to look at sediment impacts on the forereef and assess the condition of coral and fish resources.

While upland restoration efforts have been underway for nearly two decades, long residence times for sediment on the reef flat and continued inputs, even if lower today than in the early 2000s, have slowed potential recovery. The Kawela watershed has much less sediment exported today than in the past, but worsening conditions in neighboring watersheds and the new threat of coastal erosion with sea level rise have slowed potential recovery. Inclement weather conditions during portions of the surveys and the lingering effects of a major storm event in February 2023 (two months before surveys were conducted) made interpretation of sediment and water quality data difficult. For instance, sediment traps measured an overall mean sedimentation rate of 118 ± 24.8 mg/cm^2/d during windy conditions but 53 ± 36.3 mg/cm^2/d during calmer conditions. Regardless, sedimentation rates measured were upwards of 10 times higher at some nearshore locations than is generally considered suitable for coral health. All but 7 suspended sediment concentration (SSC) samples taken across all transects exceeded 10 mg/L, the threshold typically identified at which coral reef development would be limited. Sediment grab samples had a mean of 32.3 ± 2.30% s.e. terrigenous material and 21.6 ± 0.83% organic material, with an average total of over 50% fine sediments. Overall, sediment characteristics indicated siltier, more terrigenous sediments were located nearshore (especially less than 400 m from shore) and moving west towards Kaunakakai pier, and similar values found by studies in the 2000's.

Despite the lack of clear signals of improvements in water quality and sediment metrics, there were promising indications of the beginnings of recovery in the benthic cover data. The amount of sand/silt observed on the benthos tended to decrease with distance from shore, and significantly decreased from 81.5 ± 3.3% in 2005 to 73.8 ± 3.8% in 2023. Coral cover has not significantly increased since 2005, but the number of sampling sites at which coral was observed has increased from 15 (27%) sampling sites in 2005 to 20 (36%) in 2023. In addition, no measurable coral cover was found at sampling sites <400 m from shore in 2005, yet surveyors in 2023 found 12.1% coral cover at one 250 m sampling site, and there are indications that corals may be settling closer to shore than in 2005. While these changes are relatively small, they indicate a positive recovery trajectory for the reef flat benthic assemblage.

On the forereef, coral cover was high at 40.4 ± 2.8% and dominated by *Montipora capitata* and *M. patula* (~75% of observed coral cover). Unlike many reefs in Hawaiʻi, the coral assemblage did not vary with depth, but had a clear alongshore spatial pattern, with coral cover substantially higher on the east end of the reef tract. One hundred nineteen fish species representing 27 families were observed, with an average total fish biomass of 61.5 ± 8.8 g/m^2, which was towards the higher end of total fish biomass for Maui Nui sites but less than that found within many protected areas in Maui Nui. As on most Hawaiian reefs, Acanthuridae (surgeonfish) contributed the most to fish biomass at Kawela, accounting for over a third of the total fish biomass, with Scaridae (parrotfish) having the second highest biomass.

1. Introduction

South shore Molokai has the longest continuous fringing coral reef in the Hawaiian Islands and is often divided into three reef tracts (Field *et al.* 2019): Kolo, Pālāʻau, and Kawela. For over a century, these reef tracts have experienced heavy runoff of sediment that has degraded their condition and likely impaired their capacity to function as habitat for coral, reef fish and other reef-associated species. From 2000 to 2005, the U.S. Geological Survey (USGS) and their partners at the University of Hawaiʻi (UH) conducted extensive studies of the south shore Molokai reefs that have provided an in-depth understanding of their health at that time and the processes that shaped them.

The Kawela reef tract is an important component of the south shore fringing reef, extending from just east of Kaunakakai Harbor channel approximately 17 km (10.6 mi) to Kamalō. The reef tract is encompassed within three ahupuaʻa, Kaimiloa, Kawela and Kamalō. This large, morphologically-complex reef tract that has been heavily affected by high levels of sediment runoff (Field *et al.* 2019). Deforestation, urban development, excessive grazing and browsing by feral ungulates, and agriculture have resulted in considerable erosion and subsequent sediment runoff during heavy rainfall events (Field *et al.* 2008a; Field *et al.* 2008b; Stock *et al.* 2011), delivering terrestrial sediment- and nutrient-enriched water to the Kawela reef tract. The resulting sediment plumes can last hours to days, decrease water quality (*i.e.*, increase turbidity), and are responsible for depositing most of the sediment onto Kawela's reef flat. Adverse effects from this runoff are compounded by frequent remobilization and transport of the deposited sediment along the reef (Ogston *et al.* 2004; Storlazzi *et al.* 2004; Presto *et al.* 2006), allowing impacts from a single storm event to be evident for months. Terrestrial mud deposited on the Kawela reef flat has been measured from 5-50 cm deep (Field *et al.* 2008a), with sediment residence times estimated at several years up to as long as 30 years, indicating that sediment likely takes years to be flushed out of the system after initial deposition on the reef flat (Presto *et al.* 2006). While sediment effects are most pronounced on the Kawela reef flat, sediment is eventually transported over the reef crest, where it can be deposited on the forereef (Storlazzi *et al.* 2004; Bothner *et al.* 2006).

High turbidity and sedimentation rates can degrade coral reef communities in several ways. High sediment loads can directly kill coral by smothering them. They can also decrease coral growth and survival on the reef through decreased light availability to corals' symbiotic zooxanthellae and increased energy expenditures by corals to remove sediment to avoid burial. Turbidity and sedimentation can lower larval settlement rates, lower coral calcification rates, reduce productivity, cause localized bleaching, and increase susceptibility to diseases (Erftemeijer *et al.* 2012). Nutrients associated with the runoff contribute to algal growth, giving them a competitive advantage over coral and potentially promoting the dominance of invasive macroalgae, which abundant on the reef flats Molokai's south shore (Smith *et al.* 2008; Tejchma *et al*. 2017).

To reduce upland erosion rates and decrease sediment delivery to the Kawela reef, The Nature Conservancy (TNC), in partnership with the State Division of Forestry and Wildlife (DOFAW), installed ungulate-proof fences and conducted intensive animal control over portions of the Kawela watershed starting in 2007 to reduce feral ungulate activity, leading to substantial revegetation of the area and significant reductions in erosion. While this report doesn't get into the details of the watershed restoration actions taken at Kawela, monitoring efforts show sediment export from the Kawela ahupuaʻa dropped dramatically from an average of 7,100 tons to 1,850 tons annually between 2006-2011 and 2016-2018, respectively (USGS 2019). Following revegetation, storm-generated runoff contained only 26% of the suspended sediment concentration observed in runoff prior to the revegetation. With support from the National Fish and Wildlife Foundation (NFWF), DOFAW and TNC have continued to fence areas in the watershed and expect sediment loads to decrease by an additional 1,500 tons per year (TNC and EMoWP 2019).

Well over a decade has passed since upland restoration efforts were initiated, but coral and fish communities on the Kawela reef tract have not been examined in detail since researchers assessed the baseline conditions of the reef community in 2005 and coral recruitment in 2007. This creates a unique opportunity to examine the response of a Hawaiʻi coral reef ecosystem to many years of sediment reduction, as well as to establish a new baseline of water quality and reef condition against which to measure the effects of ongoing and expanding upland restoration efforts. To capitalize on this opportunity, TNC repeated as closely as possible the USGS and UH studies from the early 2000's, collecting sediment, water quality, and biological (benthic and fish) data in 2023 at Kawela to evaluate the reef tract's response to upland restoration, inform management actions moving forward, and provide an updated baseline against which to measure future change.

2. Methods

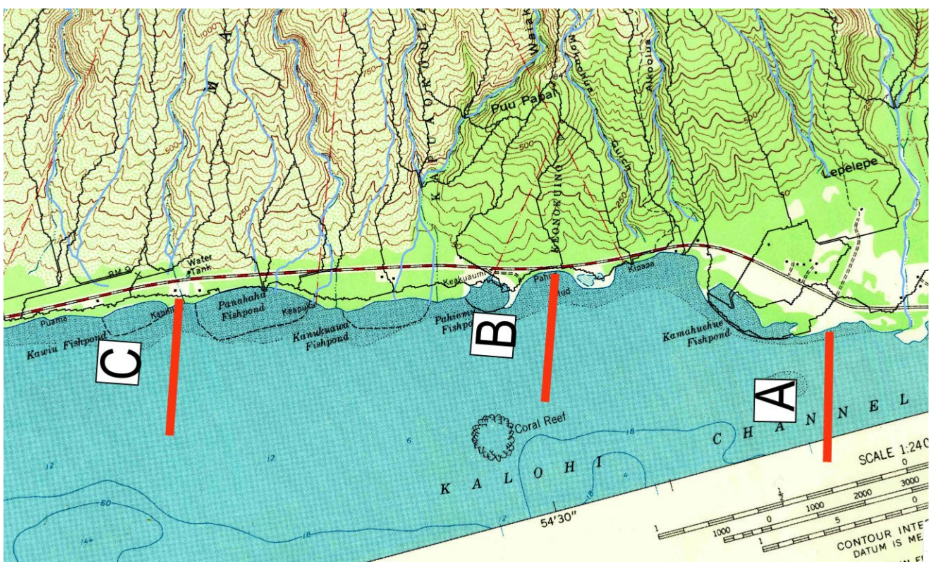
2.1. Overall

TNC collected sediment, water quality, and biological (fish and benthic organisms) data in both the reef flat (nearshore) and forereef (offshore) areas of the Kawela reef tract. Data collection methods varied in nearshore and offshore areas due to differing objectives. On the reef flat, TNC resurveyed nine USGS/UH transects (Table 2.1) originally established in the early 2000s to assess changes in the condition of the reef flat environment and benthic community following considerable upland restoration of native forest. In contrast, forereef surveys were conducted primarily to characterize the benthic and fish components of the coral reef community and augment information to improve resource management by local groups and the Hawaiʻi Division of Aquatic Resources (DAR).

2.2. Study Site: South Shore Molokai's Kawela Reef Tract

The fringing reef along the south shore of Molokai is considered to be one of the most well-developed reef tracts in the Hawaiian archipelago (Storlazzi *et al.* 2003), with the Kawela reef tract one of the cornerstone components of this system. This reef tract, however, has been subjected to a variety of natural (Branham *et al.* 1971) and anthropogenic (Roberts 2001; J. Reich *oral comm*. 2001) stresses during the course of human habitation.

Upland and coastal characteristics: The upland area consists of numerous ridges and stream valleys, and coastal areas fronted by sandy beaches and fishponds. The 1968 USGS maps in Figure 2.1 show the place names, key historical reefs, fishponds and wahi pana. The USGS/UH survey transects described below are added for reference. The south shore was historically ringed with fishponds at every discharge point along the 17 km coastline, though many of those fishponds have since fallen into disrepair and been degraded by invasive species and sediment deposition. The fishponds thrived at the locations with freshwater inputs. In addition, the flatter areas along the coast were historically wetlands where taro or later rice was grown.



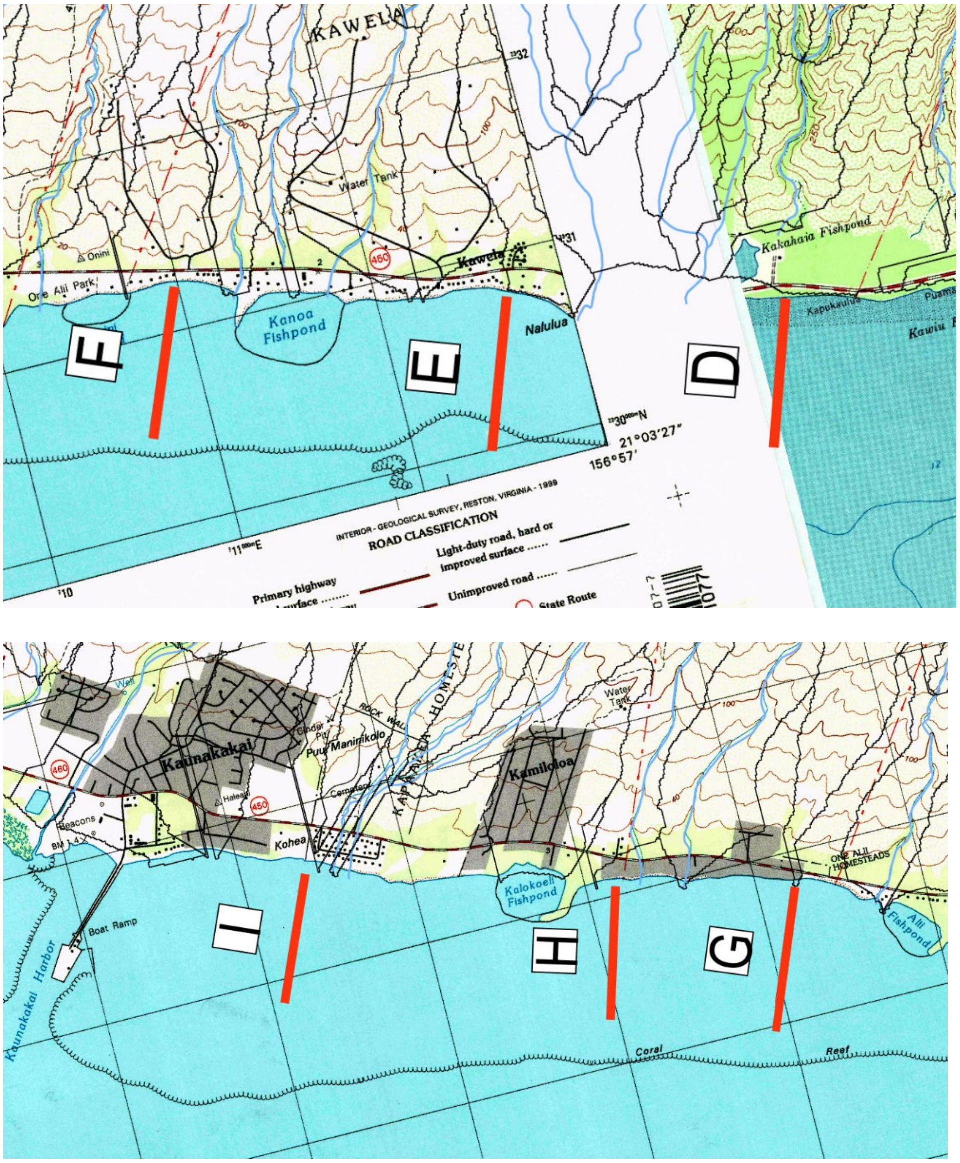


Figure 2.1. USGS 1968 Topo map with place names and subwatershed boundaries, as well as the USGS/UH survey transects. The three panels show consecutive sections of the Kawela reef tract from the eastern boundary (top panel) through the western boundary (bottom panel). The transects move from farthest east (A) to farthest west (I).

Coastal oceanography. The Kawela reef tract flats experience mixed semi-diurnal tides with a mean range of 0.6 m and a maximum spring range of 0.9 m (Ogston *et al.* 2004; Storlazzi *et al.* 2004). High tides have cooler water temperatures, lower salinity, and higher suspended sediment concentrations than low tides (Storlazzi *et al.* 2004). Because of the east–west orientation of the reef system off Molokai's southern shore, waves influencing sediment resuspension are from four primary sources: northeast trade winds, southern swell, Kona storm swell, and north Pacific swell (Bothner, 2006; Moberly and Chamberlain 1964; Storlazzi *et al.* 2004). Large swells from the North Pacific refract around the east and west ends of the island. Northeast trade-wind-driven waves and currents frequently resuspend the reef flat sediment, and that resuspension is greatest at high tide when the water depth is higher. The net flux of sediment resuspended on the reef flat is to the southwest and offshore along south-central Molokai (Ogston *et al*. 2004).

Site Selection: Survey sites were chosen for both nearshore reef flat and offshore monitoring (Figure 2.2). The reef flat sites were organized along nine shore-normal transects (A through I) that were established by the USGS in the year 2000. At each of the transects, benthic and sediment parameters were measured at 50 m, 100 m, 250 m, 400 m, 550 m and 700 m from the shoreline (see Fig 2.3 for representative photos of transect habitats). For offshore monitoring, four existing Coral Reef Assessment and Monitoring Program (CRAMP) sites on the Kawela forereef were surveyed, with an additional 52 sites randomly located within the survey area.

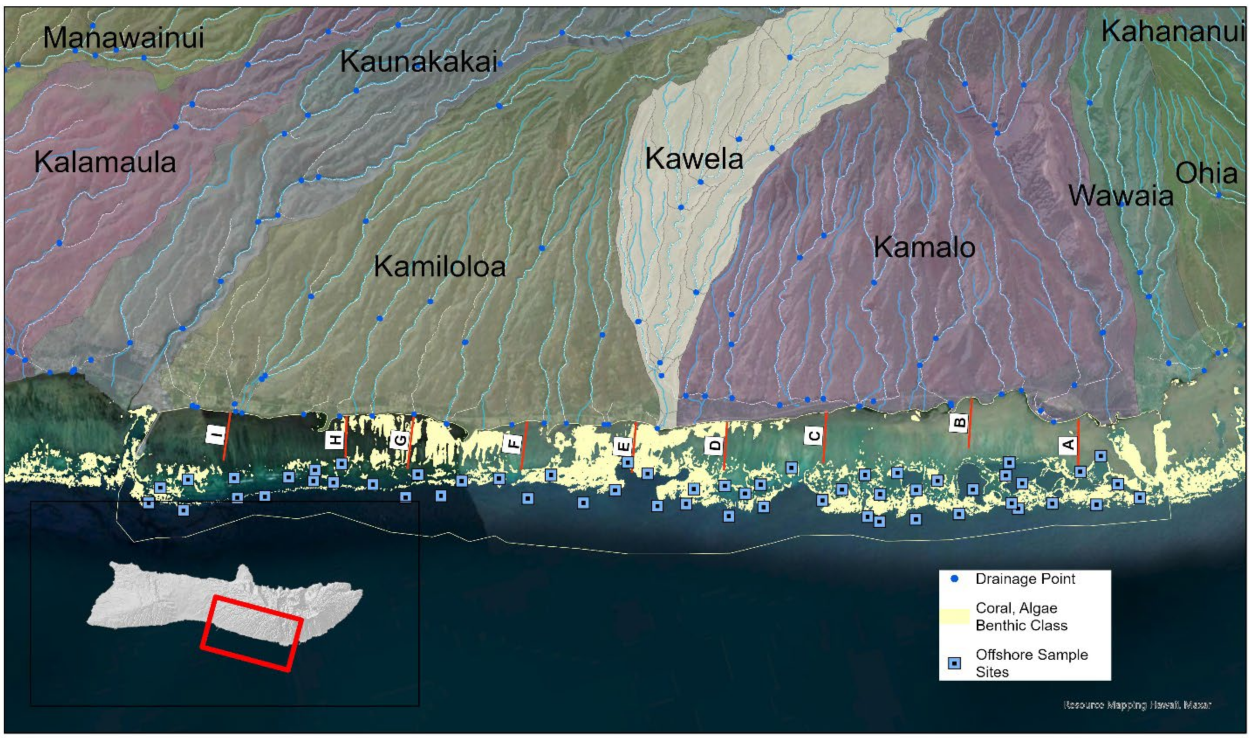


Figure 2.2. Sites surveyed by TNC in the Kawela Reef Tract, Molokai between April 11, 2023, and April 30, 2023. Base imagery is from December 2021.

Table 2.1. The location, name, and characteristics of the nine transects described in this report, originally established by USGS in 2000.

Transect	Name	Description
A	Kamāhuʻehuʻe Fishpond	Kamāhuʻehuʻe Fishpond east of mile marker (MM) 9; big current and exposure to wind, close to Kamalō
B	Pāhoa inlet	Pāhoa east of MM 8; deep mud bay that comes close to highway
C	Pānāhāhā Fishpond	between Pānāhāhā and Kawiʻu Fishponds east of MM 6; between ponds, with nearshore soft mud
D	Kakahaiʻa	east of Kakahaiʻa Fishpond east of MM 5, at park's east end; straight coastline with hau, freshwater source
E	Kawela Stream West	west of Kawela stream mouth (Moku), east of MM 4; changing alluvial plain of the stream, channel offshore
F	One Aliʻi East	east of One Alii Park east of MM 3; mud flats close to shore; beach with evidence of terrestrial deposits; below Kawela plantation
G	Cook pine	west of Alii Fishpond east of MM 2; mud flats close to shore
H	Molokaʻi Shores	Kamiloloa east of MM 1; hard bottom with sand, rocks
I	Kapaʻakea	Kapaʻakea (east of Kaunakakai Wharf) < 1 mile east of Kaunakakai Wharf; deeper sediment, adjacent to community on shore

Transect A Transect C Transect E

Figure 2.3. Aerial imagery of select transects used in this study to show the variety of different reef flat environments surveyed.

2.3. Changes in Vegetation and Hydrology

It was predicted that removal of ungulates from parts of the Kawela watershed would lead to increased vegetative cover, reduced bare land, reduced sediment, and less flooding downstream. Stream gage data available from the USGS at Kawela stream station (USGS 16415600, elevation 40ft), including discharge, total suspended sediment, and turbidity were analyzed to assess changes in hydrology. Data were available from 9/24/2004 to 2/1/2023, with the exception of years 2012-2015, and summarize by date. For each date, water year was calculated to be the year from October to September (i.e., October 1, 2021 to September 30, 2022 would be water year 2022).

The vegetation cover change over time was conducted via Normalized Difference Vegetation Index (NDVI), a land cover analysis of multispectral satellite imagery for vegetation and bare ground sediment source. Detecting trends in bare ground at geographic scales and time scales relevant to land and marine managers can be done by measuring NDVI in high resolution (e.g., 2m multispectral) during the dry summer in Hawaiʻi. Eight-band WorldView-2 and WorldView-3 satellite imagery taken in 2010 and July 2023 were analyzed to reflect the beginning of and 13+ years into improved land management of this watershed. The NDVI rasters were created and then classified into the following plant cover classes: bare ground, grass only, grass / shrubs, and shrubs / small trees. From this, the area of bare ground was calculated for 2010 and 2023.

2.4. Sediment and Water Quality

2.4.1. Survey conditions

To assess how water quality may have changed after many years of watershed restoration efforts and documented reductions in sediment delivery to the nearshore reef, surveys were conducted along the coastline of the Kawela reef tract both parallel (alongshore) and perpendicular to shore along the USGS/UH transects surveyed in the early 2000s (Field *et al.* 2008; Jokiel *et al.* 2014). The nine USGS/UH transects (A to I) from Kamalō to Kaunakakai pier, respectively, were established for this study using previous GPS markers obtained from the original UH research team.

Nearshore field work was conducted from April 11 to April 15, 2023, from 1000 to 1700 and April 18 to April 20, 2023, from 0900 to 1700, with approximately 8 km of coastline surveyed each day. Wind conditions were 20-25 knot trade winds coming from the east/northeast direction for the first week and quieting to 5-10 knots the second week. The first week was a neap tide with lows in the middle of the day, while the second week was spring tide full moon with lows in the morning (Table 2.2). Waters and currents were very active during the April 11-14 period, especially.

Table 2.2: Tides during the nearshore water quality assessment

Date	Time of Day	Height		Date	Time of Day	Height
11-Apr	3:24	0.4		16-Apr	1:21	1.9
	6:30	0.5		Sun	8:08	-0.1
	12:34	-0.1			14:15	1.3
	20:52	2			19:43	0.2
12-Apr	5:48	0.4		17-Apr	2:05	1.8
	7:54	0.4			8:32	-0.2
	13:30	0			14:55	1.6
	22:13	1.9			20:42	0.2
13-Apr	6:50	0.2		18-Apr	2:44	1.7
	10:53	0.4			8:56	-0.3
	15:03	0.2			15:33	1.9
	23:27	1.9			21:36	0.1
14-Apr	7:19	0.1		19-Apr	3:20	1.5
	12:30	0.6			9:21	-0.3
	17:02	0.3			16:10	2.1
15-Apr	0:29	1.9			22:28	0.1
	7:44	0		20-Apr	3:54	1.3
	13:29	1			9:47	-0.3
	18:34	0.2			16:45	2.3
					23:17	0.2

2.4.2. Benthic sediment samples

To map the extent and quality of benthic sediment on the Kawela reef tract, sediment depth measurements and sediment grab samples were taken at each of the six distances from shore (50 m, 100 m, 250 m, 400 m, 550 m and 700 m) along the nine transects for a total of 54 samples.

Sediment composition and grain size

Sediment grab samples were collected to determine sediment grain size, origin (terrestrial or marine), and organic content. Approximately 500 g wet weight of sediment was collected into Whirl-Pak bags. The samples were allowed to settle, then overlying water was decanted from the samples. At the sediment laboratory located at the Hawaiʻi Institute of Marine Biology, the samples were oven-dried at 100 °C to constant weight, weighed three times (dry weight), burned in a muffle furnace at 500 °C, reweighed (ash-free dry weight), and finally reburned at 1000 °C and weighed a third time (non-carbonate dry weight). The weight data were used to calculate the organic fraction of each sample and the ratio of terrigenous (basaltic) sediment to marine (carbonate) sediment (Craft *et al.* 1991).

Grain size for each sample was determined by filtering a 10 g sample through 2.8 mm (gravel), 500 µm (coarse sand), 250 µm (medium sand) and 63 µm (fine sand) sieves onto pre-weighed Whatman filters. In addition to each sieve, material < 63 µm (silt/clay) that passed through was also collected and processed. The filters were dried to a constant weight and weighed three times and the percentages of gravel, coarse sand, medium sand, fine sand and silt/clay fractions were estimated. Data were further analyzed to calculate the percentages of course, medium and fine sand and silt/clay fractions without the gravel included.

Sediment depth

For these measurements, the closest area of soft sediment to each sample location was identified and a graduated fiberglass rod inserted into the sediment until hard bottom was reached or the entire length of the rod (1 m) was inserted. Ten measurements of depth (recorded to the nearest cm) were collected at each site and used to generate a site average for depth. These measurements were collected at each of the 54 study sites.

2.4.3. Sedimentation rates

We measured sediment accumulation over an approximate 48-hour period to assess resuspension in the absence of a storm event using paired sediment traps deployed along the nine reef flat transects at four distances from shore (50 m, 100 m, 250 m, 400 m). Sediment traps were deployed twice, from April 11 to 16, 2023 (all traps) and April 16 to 22, 2023 (only Transects B, D, F). During the first deployment, winds were strong - mostly above 20 knots and coming from the east - raising a question of how much of the resuspension measured was driven by the wind conditions. The second deployment was conducted when winds were calmer, providing a differing set of conditions for comparison for a subset of the transects.

Sediment traps were 5.2 cm (2.09 in) inner diameter and 15 cm in height. Traps were deployed in duplicated, attached to rebar stakes with the bottom approximately 20cm from the benthos. Prior to retrieval of the traps, water column parameters were measured at each trap deployment site, including total suspended sediments. After approximately 48 hours of soak time, the traps were capped underwater and retrieved. Samples were allowed to settle, decanted, and filtered through Whatman 4 qualitative circles upon return to the laboratory. Filters were air dried until constant weight could be achieved over multiple days. Samples were analyzed for dry weight. Sediment accumulation (mg/cm^2/day) was calculated as the average of the two traps deployed at each sampling site during a single deployment.

2.4.4. Nearshore water quality

At each site, a 1-L water sample was collected to calculate suspended sediment concentration. Within 6 hours, the entire bottle was filtered through pre-weighed GF/F filters. Filters were dried at 60degC back at the lab and weighed. Suspended sediment concentration was calculated as change in weight over volume of water filtered.

To survey broad-scale variation in physical water quality parameters throughout the coastal reef zone within the priority area, water quality sensors (YSI Pro DSS or EXO1, Xylem Inc.) were attached to kayaks to conduct transects through the area. Sensors took surface measurements of turbidity, dissolved oxygen, pH, salinity, and temperature every 30 seconds from a pair of kayaks paddled parallel to the coast through the entire ca. 17 km study area. Alongshore kayak transects were conducted at each of the 6 distances from shore surveyed on the USGS/UH transects - 50 m, 100 m, 250 m, 400 m, 550 m and 700 m. Six to ten kilometers were covered by each kayak per day.

2.4.5. Continuous water quality measurements

A water quality sonde (YSI EXO1, Xylem Inc) was deployed April 20, 2023 at 250 m offshore at Transect G between dusk and the following dawn with the intent of measuring changes in turbidity over tidal and diurnal cycles. The sonde was deployed on a rebar stake approximately 5cm from the benthos. Data collected by the sonde included turbidity, temperature, and water depth. Because the water was so murky on its deployment, it was not possible to fully secure the sonde and it was only able to capture one tidal cycle in the evening, when wind was light, instead of the intended full daily cycle.

2.5. Benthic Assemblage

2.5.1. Reef flat surveys

The objective of the reef flat surveys was to compare conditions in 2023 with those observed in 2005 by Rodgers *et al.* (2005). The sites surveyed and the methods employed by TNC were intended to reproduce as closely as possible those used during the earlier study. TNC made some changes to the methods to optimize its data collection (*e.g.*, fewer photos were taken) while maintaining the comparability of the two datasets. While the use of a larger plot is likely to decrease variability in the 2023 data, we believe the methods employed are sufficiently similar as to produce comparable data between the two datasets.

Briefly, biological surveys were conducted at six sampling sites along the nine shore-normal transects that had been established earlier on the reef flat between Kaunakakai and Kamalō by the USGS (Table 2.1). The six sampling sites were at fixed distances from the shore: 50 m, 100 m, 250 m, 400 m, 550 m, and 700 m . GPS coordinates of each sampling site for all transects were provided by K. Rodgers.

At each sampling site, a survey team established a 7 m radius circular plot. Within each plot, the position for either 26 photopoints or 20 *in-situ* quadrat-points was haphazardly selected by surveyors. For photopoints, surveyors walked 3-7 steps in a random direction without looking at the bottom before placing the camera into the water and taking a picture. For *in-situ* quadrat-points, surveyors stood in the center of the circular plot and tossed a PVC quadrat square over their shoulder without looking. Photo- and quadrat-points were stratified such that approximately one quarter of all points were in each quadrant of the circular plot. This distribution resulted in a dispersion of the sampling points across the circular plot that was similar to that used by Rodgers *et al.* (2005).

The choice to use photographs or an *in-situ* quadrat depended upon field conditions. While photographs were the preferred sampling method, poor visibility and/or shallow water at several sites did now allow for usable benthic photographs to be taken (see Appendix A for representative benthic images from each transect and distance). At these sites the Point Intercept method was used to collect benthic data with a 0.25 m^2 PVC quadrat double strung to produce a grid with 25 intersections. The dominant benthic organism beneath each intersection was identified to the lowest possible taxonomic level using either a bathyscope or by collecting a small "pinch" of the underlying organisms. If no organism was present beneath the intersection, the bottom type (*e.g.*, sand, silt, etc.) was noted. The raw point data from each quadrat was combined to calculate the percent cover of each benthic component for the circular plot.

When water clarity and depth were sufficient to allow for useful photographs to be taken, one picture was collected at each of the 26 photopoints using an Olympic Tough camera or equivalent. Twenty randomly-selected photographs were imported into CoralNet, an online repository and resource for benthic image analysis maintained by the University of California, San Diego (Beijbom *et al.* 2015), and analyzed to estimate the percent cover of coral, algae, and other benthic categories. 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 (generally to species), macroalgae (to lowest possible taxonomic resolution), crustose coralline algae, turf, other biotic, and abiotic (to sand/silt, 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 circular plot.

In surveys conducted in 2007, coral recruitment was assessed along Transects E and H using standardized coral recruitment arrays in which two unglazed terracotta tiles were deployed at each sampling site (Jokiel *et al.* 2014). Arrays were deployed offshore 100 m, 250 m, 400 m, 550 m, and 700 m. The 50 m sampling sites were excluded due to their shallow depth at low tide. After approximately 7 months, the arrays were collected, and all attached corals were identified to the lowest possible taxonomic level, usually genus.

In 2023, TNC did not have the resources to deploy settlement tiles and instead collected information on small corals (<1 cm to 5 cm in size) found on naturally occurring benthic substrate at all sampling sites along all transects. Four quadrat-points were haphazardly selected within each 7 m diameter circular plot using the same methods described above for *in-situ* quadrat-points. Surveyors carefully searched each 0.25 m^2 quadrat and identified to the lowest possible taxonomic level and sized to the nearest centimeter all corals whose longest length was <5 cm. To avoid over- or under-estimation bias, colonies were counted only if the geometric center was within the quadrat (Zuvloni *et al.* 2008).

Given the difference in the methods employed and the data collected, the 2023 data are not directly comparable to those collected in 2007 (Jokiel *et al.* 2014), However, the presence of small (<5 cm) corals indicates successful recruitment at the sampling site, so while comparisons of the specific amount of recruitment occurring in 2007 versus 2023 cannot be made, the presence or absence of recruitment at a sampling site can be compared between the two datasets.

Finally, as the survey team walked out from the shore to each sampling site along a transect, they recorded the GPS position of the first coral they encountered. To increase their efficiency at locating the coral colony nearest to shore, the survey team fanned out in a line (parallel to shore), spaced approximately 3-4 meters apart, and carefully searched the bottom as they walked between sampling sites. The distance from shore for the first observed coral was calculated using ArcGIS.

2.5.2. Forereef surveys

While the primary focus of this study was to recreate the earlier studies conducted by USGS and UH of the shallow reef flat areas, a secondary goal was to complement those surveys with an assessment of the condition of the offshore forereef and how sediment and other stressors may be affecting those resources. To accomplish this goal, TNC surveyed 52 randomly-selected sites and four existing Coral Reef Assessment and Monitoring Program (CRAMP) sites on the Kawela forereef from April 24-28, 2023 (Figure 2.2). All sites were between 1 and 18 m depth on predominately hardbottom. Metadata for all survey sites have been compiled in Appendix B.

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. At each site, the surveyors established two transect start-points spaced approximately 10 m apart. From each start point, divers deployed a 25-m transect line along a predetermined compass bearing, which 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.

Photographs of the bottom were taken every meter along one of the 25-m transect lines 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 selected for analysis using CoralNet and analyzed using the same methods described above for the reef flat photographs. Once completed, the raw point data from each photograph was combined to calculate the percent cover of each benthic component for the survey site.

2.6. Benthic Topography

The topographic complexity of the bottom at each forereef site was measured using an index of rugosity calculated along the first 10 m of the same 25-m transect line used to collect benthic cover data. The index was calculated 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. Rugosity was collected at all survey sites (Appendix B).

2.7. Reef Fish Assemblage

Fish assemblage data were collected only at the 54 fore reef sites. While slowly deploying the parallel 25-m transect lines described above in section 2.5.2, fish surveyors identified to species and sized to the nearest centimeter all fishes within and passing through a 5-m wide belt along the transect. 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 species-specific, size-to-weight conversion parameters from FishBase (Froese and Pauly 2010) or the Hawai‘i Cooperative Fishery Research Unit. 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.

2.8. Other Data

Several additional datasets were considered as part of this assessment (Table 2.3). In many cases, the raw data were obtained from researchers who collect it or from published reports. Due to differences in the data collection methods and/or the spatial extent of the sampling areas, direct comparisons were often challenging, but qualitative comparisons were made where informative.

Table 2.3. Additional historical and comparative datasets for the Kawela reef tract.

Dataset Name	Reference/Source	Description
Reef Flat Benthic Cover 2005	Rodgers *et al.* (2005)	Raw benthic cover at six sampling sites along nine reef flat transects (A-I). Data are directly comparable with the 2023 data.
Sediment Grain Size	CRAMP	Grain size of sediment at CRAMP sites in March 2000. Data are directly comparable with the 2023 data.
Suspended sediment concentration	Rodgers *et al.* (2005)	Suspended sediment at each of the 54 transect sampling sites for April 2005. Data are directly comparable with the 2023 data.
Sediment parameters	Jokiel *et al.* (2014)	Suspended sediment concentration, turbidity, grain size and composition at each of the 54 transect sampling sites for April 2007. Data are directly comparable with the 2023 data.
Reef Flat Coral Recruits 2008	Jokiel *et al.* (2014)	Number and density of coral recruits on terracotta tiles in April 2007. These data are not directly comparable with the 2023, but qualitative comparisons were informative.

Forereef Fish 2005	Friedlander and Rodgers (2007)	Summary fish biomass and abundance at several forereef survey sites. Sites are spatially clustered making direct comparisons challenging, but qualitative comparisons with the 2023 data were possible.
CRAMP 2000-2022	Maui DAR	Benthic cover data obtained from two Coral Reef Assessment and Monitoring Program sites at Kamiloloa and Kamalō. Different data collection methods make direct comparisons challenging, but qualitative comparisons with the 2023 data were possible
SIO Large-area Timeseries 2017-2023	McCarthy *et al.* (2024)	Benthic cover data obtained from five large-area imagery survey plots within the forereef area of the Kawela reef tract. Data have limited replication across the reef tract, making direct comparisons challenging, but qualitative comparisons with the 2023 data were possible.
FAHU Benthic 2021-2023	Maui DAR	Raw benthic cover at several sites in the forereef area of the Kawela reef tract. Sites are spatially clustered making direct comparisons challenging, but qualitative comparisons with the 2023 data were possible.
FAHU Fish 2021-2023	Maui DAR	Raw fish biomass and abundance estimate at several sites in the forereef area of the Kawela reef tract. Sites are spatially clustered making direct comparisons challenging, but qualitative comparisons with the 2023 data were possible.

2.9. Data Management and Analysis

2.9.1. Data handling

All fish and site data were entered into a custom Access database and checked for errors. All benthic data were downloaded from CoralNet, compiled in Excel spreadsheets, and checked for errors prior to analysis. All databases and spreadsheets supported safeguards to ensure high data quality and reside on a secure, TNC cloud storage platform that is regularly backed up to protect against data loss.

Fish data were pooled into several groups for analysis: total (all) fish, fish family, resource fish[1] including a selected non-resource group for comparison, prime spawners, and invasive fish. The

[1] In other TNC reports, "resource fish" may be called "target fish." The species comprising these groups are identical (see Table 2.4).

biomass for some fish species was excluded from these calculations, notably eels and manta rays (Myliobatidae). Biomass of eels could not be calculated (see Section 2.7) and manta rays tend to be transient fish seldom observed on transects, but when present, heavily skew the transect's biomass estimates due to their large size. However, all species were included in abundance calculations.

Resource fish refer to fishes desirable for food, commercial activity, and/or cultural practices in Hawaiʻi (Williams *et al.* 2008), whereas the selected non-resource fish are species not routinely targeted by fishers in Hawaiʻi to a significant degree (Table 2.4). 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 are widely considered to be a disproportionately important component of total stock breeding potential due to their high fecundity and the tendency for their offspring to have higher survival rates compared to smaller breeding individuals (Birkeland and Dayton 2005, Williams *et al.* 2008). In addition, fishers often preferentially target large resource fish, making prime spawner biomass a good indicator of fishing pressure.

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

Table 2.4. 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 Group	Species	
Acanthuridae (Surgeonfishes)	*Acanthurus achilles* *Acanthurus blochii* *Acanthurus dussumieri* *Acanthurus leucopareius* *Acanthurus nigroris*	*Acanthurus olivaceus* *Acanthurus triostegus* *Acanthurus xanthopterus* *Ctenochaetus* spp. *Naso* spp.
Apex	*Aphareus furca* *Aprion virescens* All Carangidae (jacks)	All Priacanthidae (big-eyes) All Sphyraenidae (barracuda)
Labridae (Wrasses)	*Bodianus albotaeniatus* *Cheilio inermis* *Coris flavovittata* *Coris gaimard*	*Iniistius* spp. *Oxycheilinus unifasciatus* *Thalassoma ballieui* *Thalassoma purpureum*
Mullidae (Goatfishes)	All	
Others	*Chanos chanos* *Cirrhitus pinnulatus*	*Monotaxis grandoculis*
Holocentridae (Redfish)	*Myripristis* spp. *Sargocentron spiniferum*	*Sargocentron tiere*
Scaridae (Parrotfishes)	All	
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

2.9.2. Statistical programs and libraries

All statistical analyses and some graphics were conducted in R ver. 3.4.2 or R ver. 4.2.1 (2022-06-23). For some figures, final data were exported to Microsoft Excel for graphing and figure generation.

3. Results and Discussion

3.1. Changes in Vegetation and Hydrology

3.1.1. Rainfall and stream discharge

The USGS stream monitoring gage has operated at Kawela stream from Sept 23, 2004 to the present day, with a break in the data from 2012-2015. For this analysis, data from Sept 23, 2004 to Feb 9, 2023 were used, for a total of 5128 observations. Flow was summarized by water year (Figure 3.1) and also presented with continuous discharge data (Figure 3.2) in order to understand the frequency and magnitude of stream events over time. Water year 2018 had the most frequent events yielding the great mean discharge (Figure 3.1) yet did not have the highest peak flows (Figure 3.2). The highest instantaneous peaks were in water years 2007 and 2022, at 1920 cfs and 1950 cfs, respectively (Figure 3.2). However, the two storm events were different – the average daily discharge (Figure 3.3) was much higher in 2022 (415 cfs versus 205 cfs), indicating the storm was longer and more powerful in 2022. This has implications for downstream flooding and sediment delivery, with the longer 2022 storm likely mobilizing more sediment and contributing to more downstream flooding.

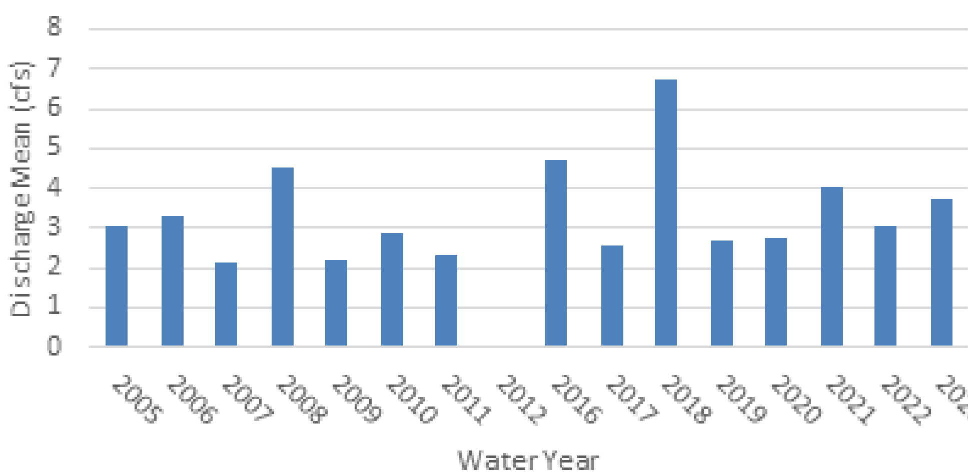


Figure 3.1. Geometric mean yearly discharge at USGS Kawela stream gage. Note that the gauge broke during the Jan 31, 2023 storm that greatly impacted south shore Molokai.

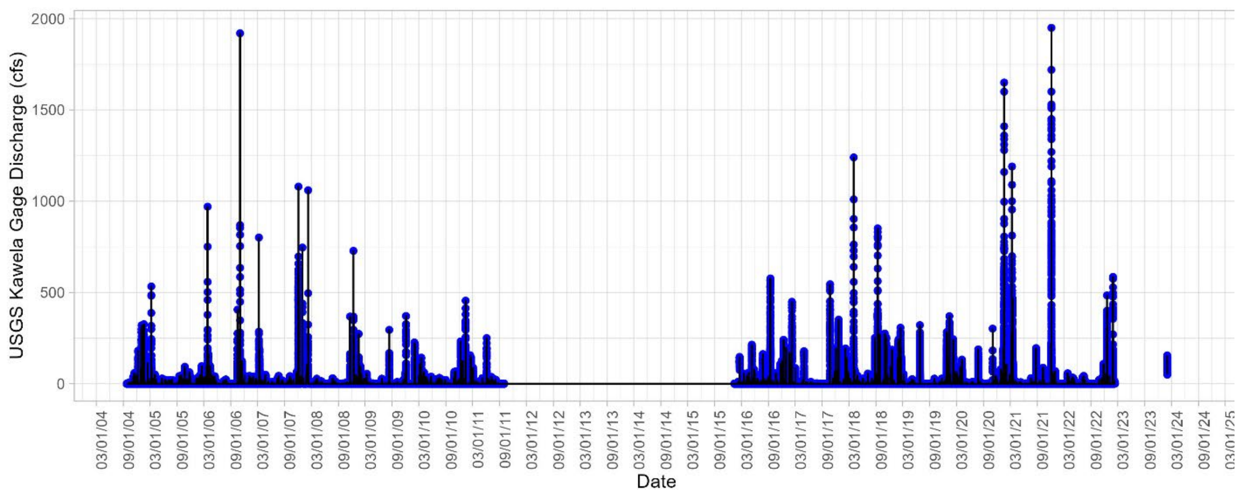


Figure 3.2. Discharge at USGS Kawela stream gage. Previous nearshore sediment studies were conducted in April 2004. Note: the gage broke during the Jan 31, 2023 storm event, two months prior to our sampling in April 2023.

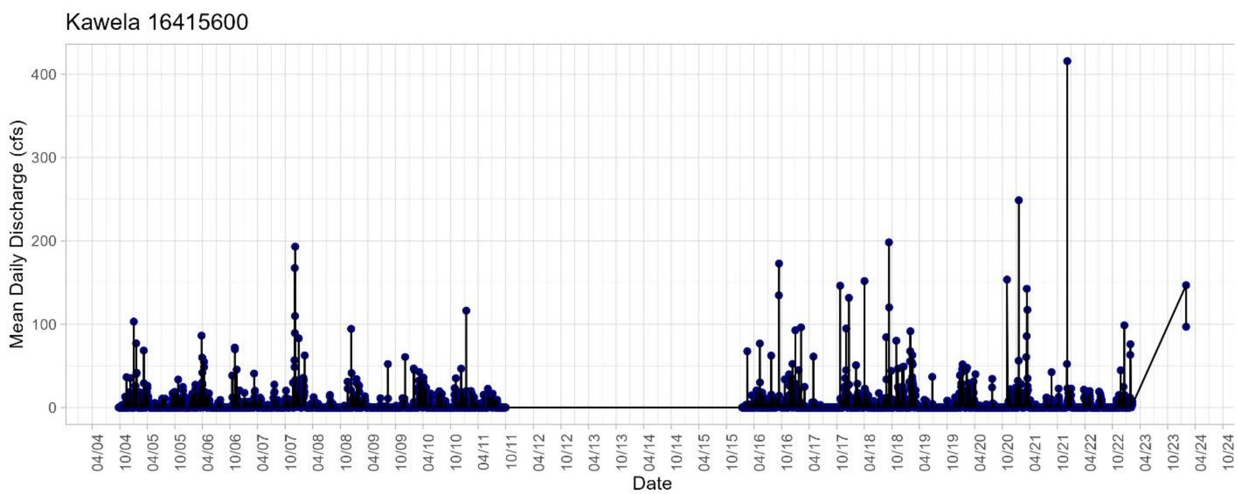


Figure 3.3. Average daily flow at USGS Kawela stream gage.

Analysis of suspended sediment data from the USGS Kawela stream gage demonstrated that sediment export from the Kawela ahupuaʻa dropped dramatically from an average of 7,100 tons annually (2006-2011) to 1,850 tons annually (2016-2018), based on stream mouth sediment recorded by USGS. Following revegetation, storm-generated runoff contained only 26% of the suspended sediment concentration observed in runoff prior to the revegetation.

3.1.2. Changes in bare ground over time

Following intensive ongoing land management, the 763 acres detected in 2010 (Figure 3.4) was only 160 acres of bare ground in to 2023, decreasing by more than 80% across Kawela watershed from 2010-2023 (Figure 3.4). Plant cover returned to more than 1400 acres, which is greater than 40% of the entire watershed. The revegetation of bare ground corresponds with the reduction of stream sediment detected by USGS described above.

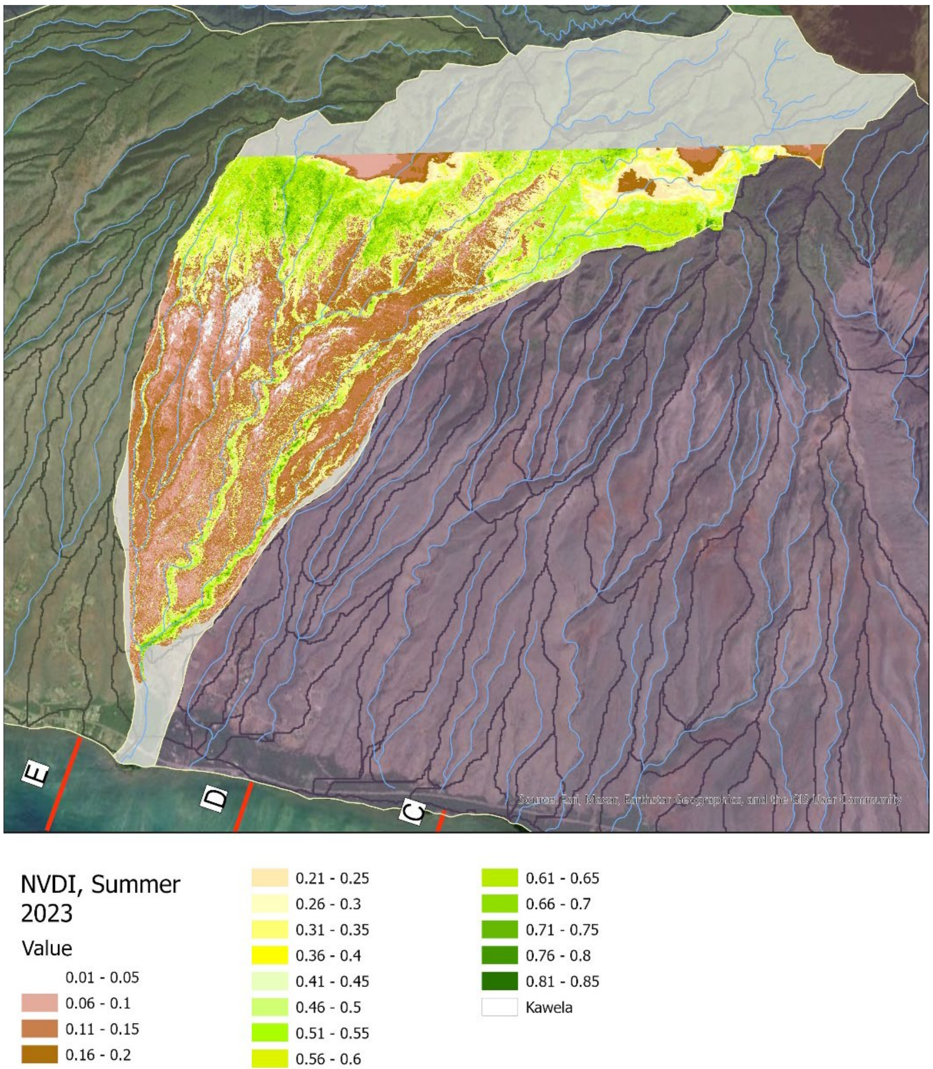


Figure 3.4. The NVDI analysis calculated for a portion of Kawela watershed in summer of 2023. The white and light pink colors, with low NVDI numbers (0.0-0.2), indicate areas of bare ground.

3.2 Sediment and Water Quality

The survey of the shallow reef waters for water column turbidity, benthic sediment characteristics and sedimentation rates indicated that the Kawela reef tract has some of the most turbid and sediment-affected waters in the Hawaiian islands, as detailed below.

3.2.1. Benthic sediment samples

A summary of benthic sediment composition, grain size, sedimentation rate and sediment depth data collected as part of this study is summarized for each USGS/UH transect and distance from shore in Figure 3.5.

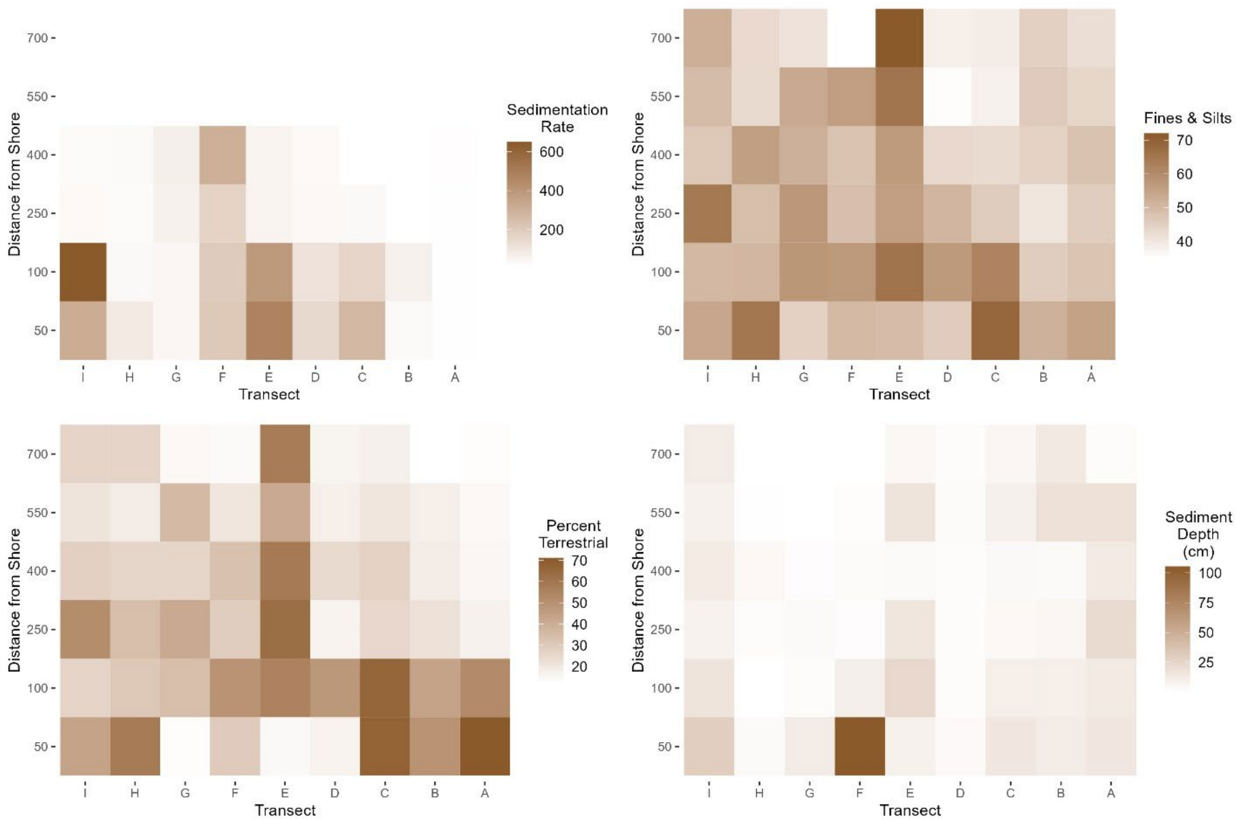


Figure 3.5. Sediment data collected in this study including, clockwise from upper left: a) the sedimentation rate in mg/cm^2/d, b) the percent of sediment within grab samples that were comprised of fines and silts, c) the mean sediment depth in cm, and d) the percent of sediment within grab samples that were comprised of terrestrially (i.e., terrigenous)-derived sediments. The horizontal axis indicates the USGS/UH transect along which data were collected (see Figure 2.2), while the vertical axis represents the distance from shore along the transects.

Sediment composition and grain size

Sediment samples collected in April 2023 had a high percentage of terrigenous material (Figure 3.5), with the samples having a mean of 32.3% (± 2.30% s.e.) terrigenous material, 21.6% (± 0.83%) organic material and only 46.0% (± 2.71%) calcareous (i.e., marine) material (see table in Appendix C). For grain size, fines and silt comprised on average 21.7% (± 0.78%) and 28.6% (± 0.70%), respectively, for an average total of over 50% fine sediments. The mud in nearshore Kawela was soft to the touch and resuspended with any breeze. As would be expected, coarse grain size correlated to calcareous percentages, while fines and silt size correlated with terrigenous percentages (Figure 3.6). Organic carbon fractions correlated with silt only (r^2 = 0.31; Figure 3.6).

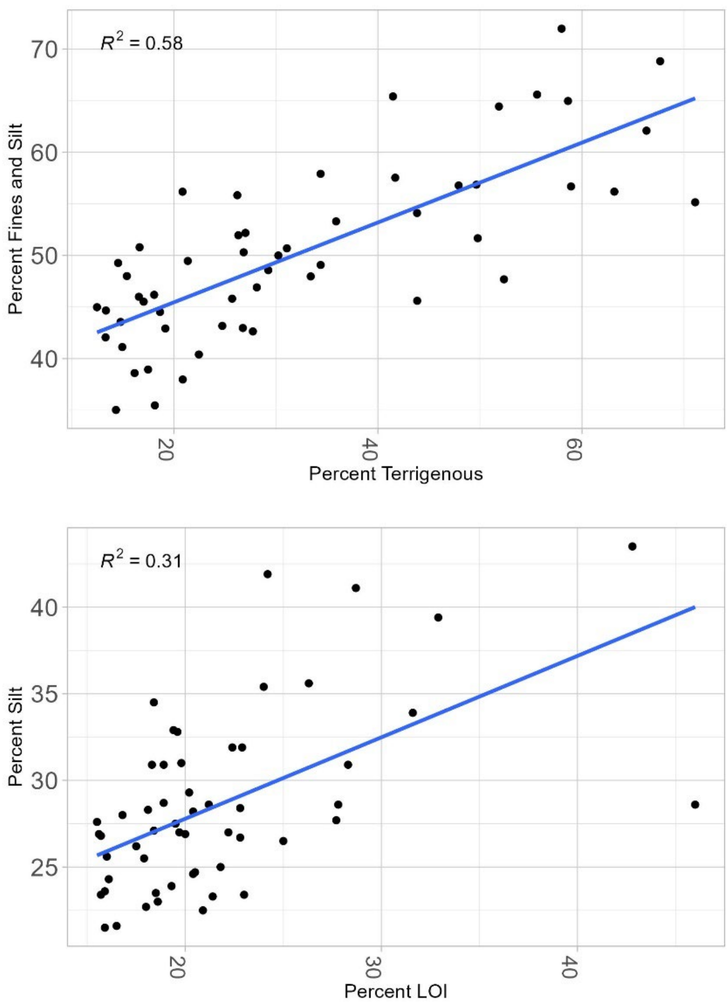


Figure 3.6. Sediment composition versus sediment grain size. Top: Precent fines and silts versus percent terrigenous. Bottom: Percent Silts versus percent organic carbon (i.e., Loss on Ignition, or "LOI").

The percentages of terrigenous sediment and organic matter decreased with distance from shore while the percentage of carbonate material (i.e., marine-derived sediment) increased with distance from shore (Figure 3.7) – a pattern that is to be expected in Hawaiʻi's nearshore environments. Benthic photograph analysis described in section 3.3 below confirm this finding.

However, the data also suggest that there is a slight increase of terrigenous material, organic carbon and fine sediments at 100 m from the shoreline as compared to 50 m from shore. This may be related to currents alongshore that may be moving fines away from 50 m at a faster rate than 100 m. The organic content of the samples in 2023, with a maximum of 46% by mass, is very high, regardless of location. Sites with the highest percentage organic matter were in the E and F transects, offshore between 250 m and 400 m (Figure 3.5).

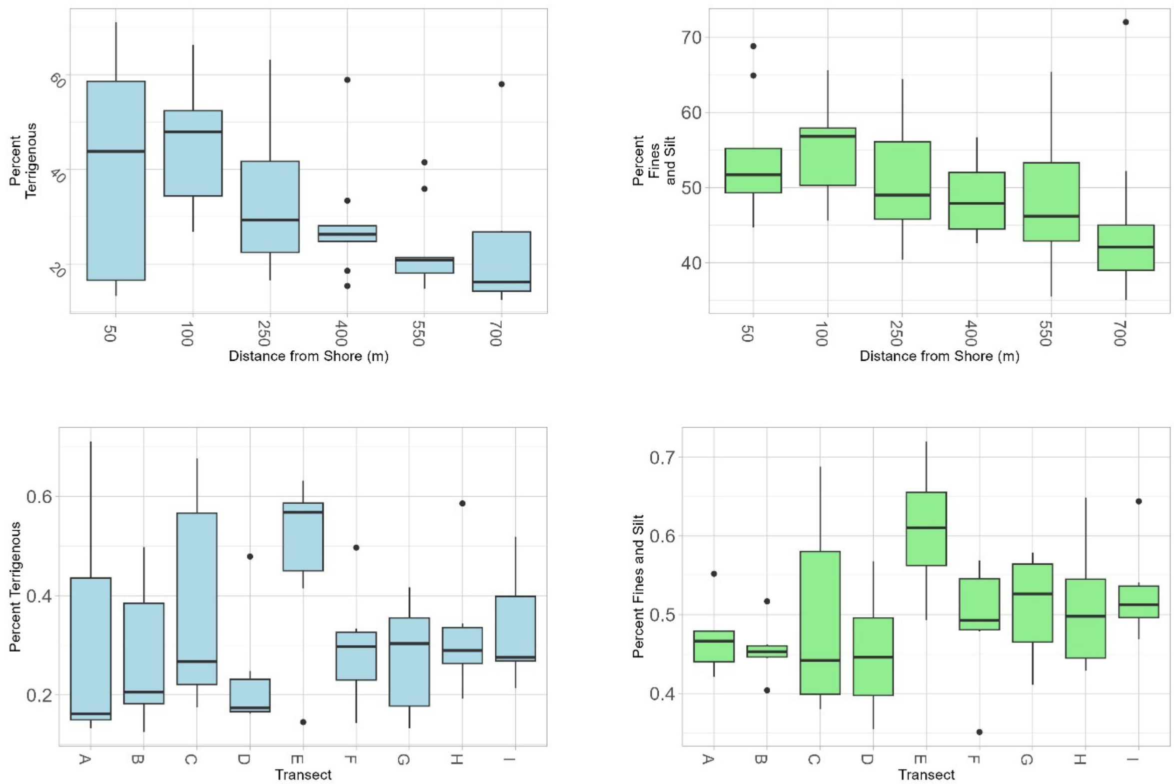


Figure 3.7. Sediment composition (left panels) and sediment grain size (right panels) compared to distance from shore (top panels) and by transect (bottom panels).

Compared to other locations: The current study's percent terrigenous is much higher than previous similar sediment sampling efforts in Lāna'i in the last three years, where averages for Keōmoku, Lāna'i were 8.9% for terrigenous material and 4.3% for organic material. However, the current Kawela percent terrigenous results more closely match sampling in 2022 for Olowalu, Maui where averages were 44.6% terrigenous material and 5.1% organic material (Falinski, *unpublished data*). The samples collected here represented the nearshore reef flat exclusively and that may reflect the difference with Lāna'i, where samples were also collected from deeper forereef environments.

Change over time: There have been multiple studies of sediment composition and grain size measurements over the years on the Kawela reef tract. Ogston *et al.* (2004) note that the inner reef flat acted as a reservoir of fine sediment available for resuspension and that the terrestrial fraction was between 58-65%. Cochran-Marquez (2005) also found that the inner reef was dominated by terrestrial mud. Compared to samples measured in 2007, the percent organic carbon is higher in the current study than previously measured. In 2007, organic carbon was 8.1% along transects E and H (Jokiel *et al.* 2014), compared with 23.6% in this study. Calhoun and Field (2008), similar to this study, found that the percentage of calcium carbonate fraction of the sediment increases with distance offshore with a maximum contribution between 400 and 650 m offshore.

Sediment depth

Sediment depth was measured at each of the six distances from shore along each of the nine USGS/UH reef flat transects, for a total of 54 survey sites. Average depth at sites ranged from 0.8 cm to 105.2 cm (Figure 3.5). Sediment depth and sediment composition parameters were not well correlated, and sediment depth was only weakly positively correlated with both percent organic matter and percent terrigenous. Depth did not have a strong relation to grain size metrics except for medium sand. This indicates that depth might be a quick proxy measurement for whether a sample is terrigenous or calcareous in some settings once a baseline has been established, but likely is not the right tool to measure for places with silt concentrations. In addition, there was little relationship between sediment depth and water column turbidity (Appendix Table C.1).

Overall, sediment characteristics indicated siltier, more terrigenous sediments were located nearshore (especially less than 400 m from shore) and moving west towards Kaunakakai pier. The nearshore area of transect F was found to have the deepest sediment at 105 cm (Figure 3.5), while the overall average was 10.1 cm (± 14.8 cm s.d.) for all sites. Similar to the other metrics of sedimentation, but less pronounced, sediment depth decreased to 400 m offshore, followed by a slight increase at 550 m (Figure 3.8). The 550 m and 700 m distances were more likely to be sands of carbonate material (Figure 3.5).

In contrast, Storlazzi *et al.* (2010) found sediment depth in the reef flats between 5 to 90 cm at some of the most sediment-dominated locations near the shoreline. Residents describe sediment depth in the 1970s to be above the knee consistently, while the values measured here correspond to mid-calf or ankle heights, suggesting that sediment depths may have decreased from earlier sampling efforts.

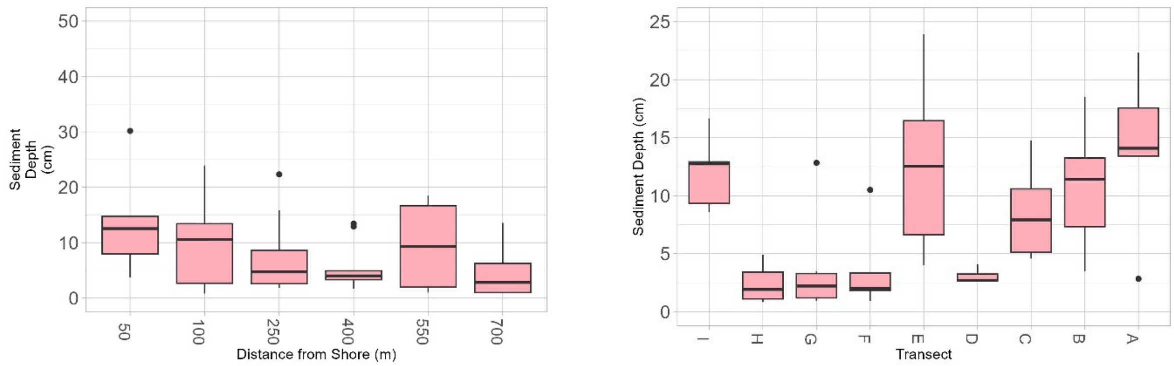


Figure 3.8. Box and whisker plots of mean sediment depth by distance from shore (left panel) and transect (right panel).

3.2.2 Sedimentation rates

Sediment traps were deployed at four distances from shore along each of the nine USGS/UH reef flat transects, for a total of 36 survey sites. Traps were deployed and recovered first during the windy week from April 11-16, 2023, and then again at a subset of transects (B, D, F) the following week (April 18-22) when wind conditions were calmer. In the first week, traps had an overall mean of 118 mg/cm^2/d (± 24.8 mg/cm^2/d, range from 11.5 to 649 mg/cm^2/d), while the second week traps had a mean of 53 mg/cm^2/d (± 36.3 mg/cm^2/d, range from 7.9 to 122.5 mg/cm^2/d), suggesting that wind conditions strongly influence resuspension rates.

The typical pattern of sedimentation rates being highest closest to shore was found here (Figure 3.9), For instance, rates at 250 m and 400 m were lower, with averages of 49.0 mg/cm^2/d and 60.9 mg/cm^2/d respectively, compared to the 100 m high of 186.2 mg/cm^2/d. Sediment is less likely to resuspend as the depth increases, one likely explanation for why sites farther from shore have lower sedimentation rates (Figure 3.9).

The transects alongshore where the mean sedimentation rates were the highest were transects I (Kapaʻakea) and E (Kawela). These transects represent two locations where there is transport from the nearshore mud flat to the forereef through channels. However, as will be seen below, the reef surrounding transect E is in a healthier state than the reef at transect I.

Compared to other locations. These rates are comparable to data from four similar simple sediment trap experiments on Oʻahu, Kauaʻi, Guam and Molokai in the existing literature, of which the highest was 200 mg/cm^2/day (Storlazzi *et al*., 2011). The values recorded here for the 250-m sites are comparable to those from a similar study conducted by Field *et al*. (2013) in Hanalei Bay, which found net sediment accumulations of 6.7-17.2 mg/cm^2/day.

Change Over time: In 2000, Ogston and Storlazzi estimated rates over the span of one year averaged approximately 2 mg/cm^2/d, with a max of 10 mg/cm2/d – much lower than the values found in this study. Ogston *et al.*'s methods were different however, limiting the comparability of these data to the present study. Bothner *et al*. (2006) set out traps at Kamiloloa (transect H) between 2000 and 2002 on both the reef flat at approximately 250 m from shore, and on the forereef. They found post-storm rates of over 590 mg/cm^2/d on the forereef and about 100 mg/cm^2/d on the reef flat. For non-storm samples, rates at site H-250 were between 10 and 100 mg/cm^2/d, compared to our findings of 27.0 mg/cm2/d at approximately the same location (Bothner *et al.* 2006, Storlazzi *et al*. 2011). Because of the difference in methods, it is difficult to make a direct comparison, but a high-level comparison suggests that sedimentation rates today are similar to historical rates.

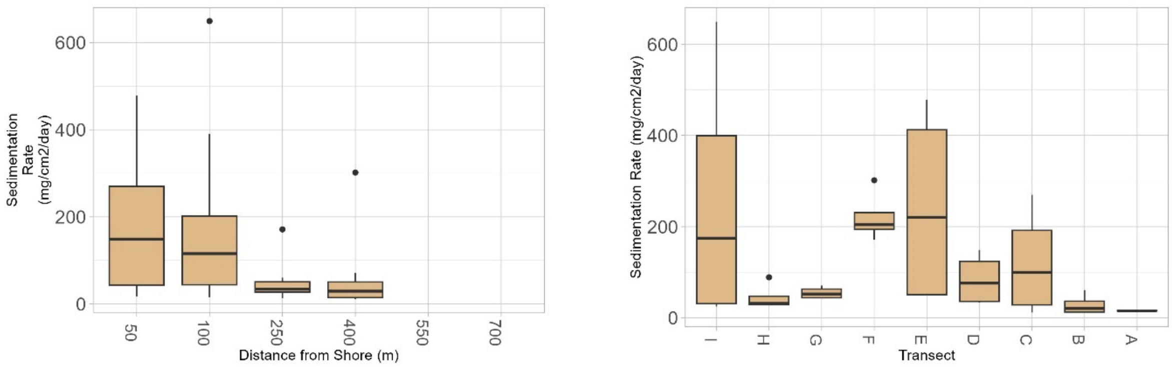


Figure 3.9. Box and whisker plot of mean sedimentation rates at different distances from shore (left panel) and at each of the nine USGS/UH reef flat transects (right panel).

3.2.3. Nearshore water quality

Suspended sediment concentration

Suspended sediment concentrations (SSC) were measured at all 54 reef flat sampling sites (Figure 3.10). Unfortunately, weather conditions changed over the course of sampling, making it difficult to clearly interpret the results, with temporal changes in SSC confounding spatial patterns. It was hypothesized that there would bet clear onshore-offshore gradients, similar to those reported from 2007 in Jokiel *et al.* (2014) and found in the sediment composition and grain size data (see Section 3.2.1). However, the three transects surveyed during the windiest days (A, B and C) had by-far the highest SSC averages of 146 mg/L, 94 mg/L and 149 mg/L, respectively (Figure 3.10), suggesting that these values were wind-driven and not representative of typical conditions along those transects. All but 7 samples taken across all transects exceeded 10 mg/L, the threshold typically identified at which coral reef development would be limited (Jokiel *et al.* 2014).

Ogston and Storlazzi (2004) took continuous SSC measurements for one year in 2000 using an instrument at site H-250. They found concentrations up to 100 mg/L and noted how variable SSC was over the tidal cycle, the daily cycle, and in relation to winds and currents. In a paired study, Presto *et al.* (2006) mapped the SSC concentrations around transects G, H and I and found considerable differences between low tide and high tide (see Figure 3.11). The values between the 2000 studies and the 2023 data are within the same range, mostly – with the 2023 values having a higher maximum likely due to high tide and high wind conditions after a big storm event.

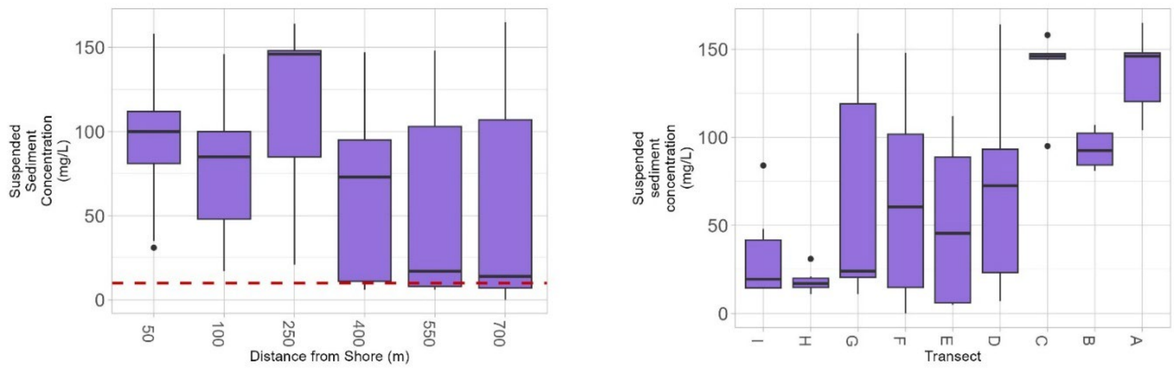


Figure 3.10. Box and whisker plot of suspended sediment concentrations at different distances from shore (left panel) and at each of the nine USGS/UH reef flat transects (right panel. The red dotted line in the left figure is the 10 mg/L concentration that has been identified as where detrimental effects to corals begin.

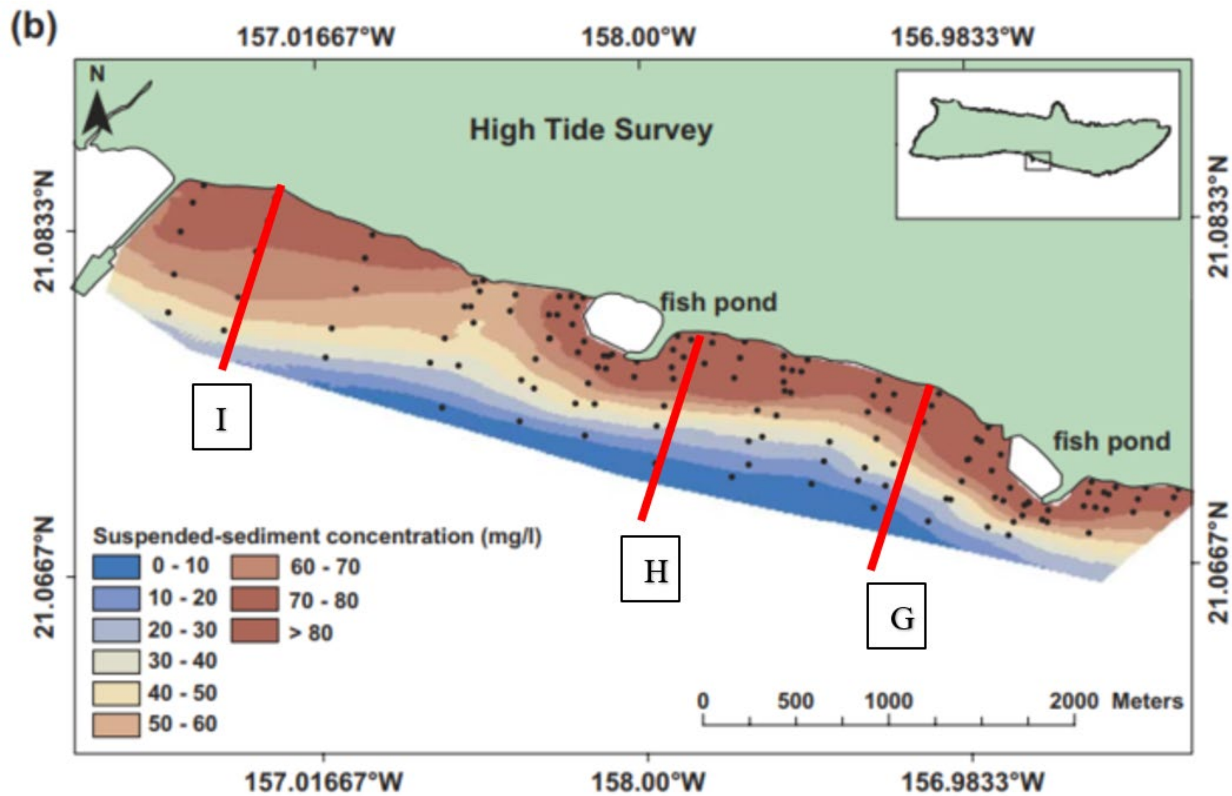


Figure 3.11. Sediment map from Presto et al 2006 showing similar patterns in the year 2000 as those found in our 2023 study. Values and patterns of SSC were similar between 2000 and 2023 studies.

Turbidity

The *in situ* water quality measurements (turbidity, salinity, dissolved oxygen) taken while kayaking suffered some of the same challenges as the SSC samples, with the exception that efforts were made to conduct an entire alongshore transect at a given distance from shore in one day, rather than spread data collection over multiple days. On April 11, 2023, for instance, a pair of kayakers paddled from Kamalō to Kapaakea between 0900 and 1600 in heavy winds on a falling neap tide. The effects of afternoon resuspension cannot be ruled out for this particular day's kayak, but general patterns can be observed. The most turbid waters (greater than 50 FNUs) along the Kawela reef tract were near transect I (Figure 3.12). At 50 m from the shoreline, over 70% of every 5-min samples were above 10 FNU (Figure 3.12), while the average was 40.0 FNU (± 67 FNU). The exceptions were in front of the eastern fishponds and wetlands—Kamahu‘ehu‘e pond, Kanoa fishpond and Kipapa fishpond. The effects of fishponds on nearshore water quality were especially visible at Kanoa fishpond.

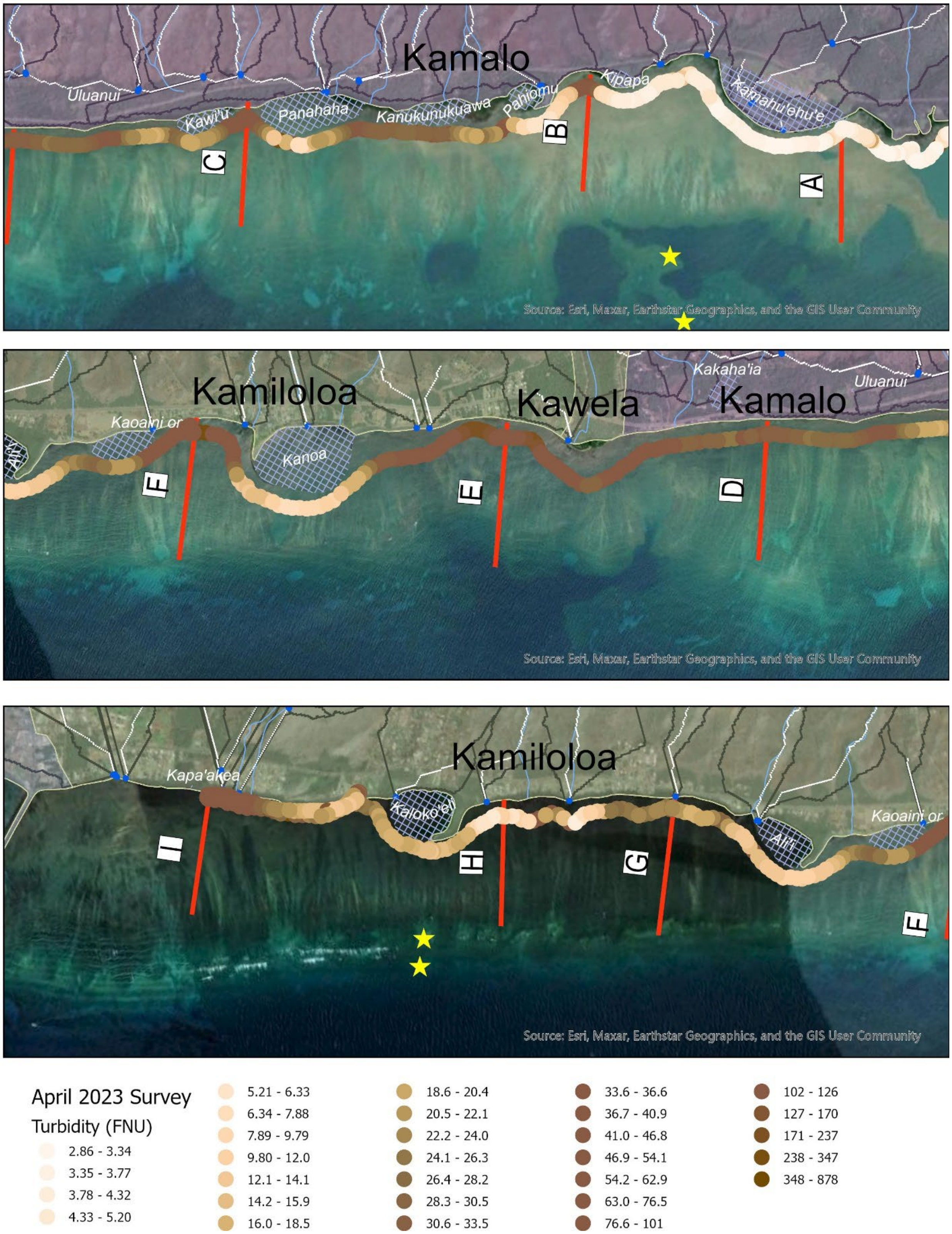


Figure 3.12: *In situ* turbidity readings from April 11, 2023 at 50 m from shore.

Salinity

Salinity was less variable with weather conditions than turbidity, yet still changed with the tide. The results from the alongshore transect surveys are clearest for days like the nearshore (50 m) on April 11 that was conducted entirely on a falling tide. Figure 3.13 below shows the salinity for each section of the coastline. It is notable that the area to the west (down current) of Kawela stream mouth outlet had large amounts of fresher water, indicating submarine groundwater discharge flow.

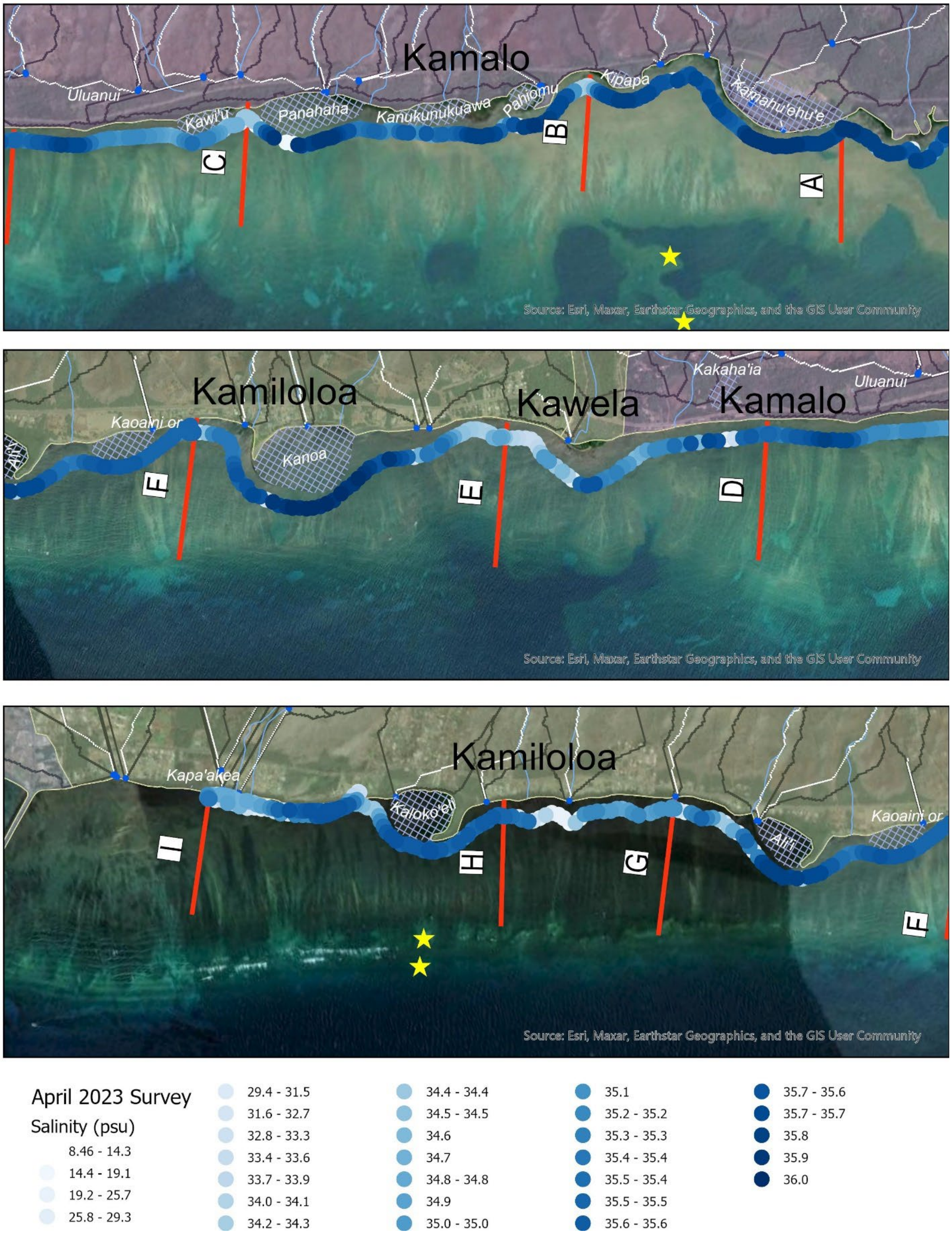


Figure 3.13: *In situ* salinity readings from April 11, 2023 at 50 m from shore.

Tidal and wind-driven cycles

During the study, turbidity was observed to increase by 0900 and with increasing tides, validating the results of Piniak and Storlazzi (2008). The deployment of a continuous sensor at 250 m offshore at Transect G on April 20, 2023 provided a more comprehensive look how turbidity changed over a daily tidal cycle. Water depth was 3-4ft at this site. Turbidity dropped from the afternoon high of approximately 12 FNU to a baseline of less than 2 FNU by morning. Unfortunately, data were only acquired from 1800 to 0700 due an installation failure, but the changes in turbidity overnight are clear - as the wind dies down, the water clears. A slight increase in turbidity with the rising tide can be seen in the middle of the night (0300), which is different than Piniak and Storlazzi found for their sensor at 500 m offshore, where there was no nighttime increase with higher tides. This deployment was conducted near the new moon with a larger-than-average tide.

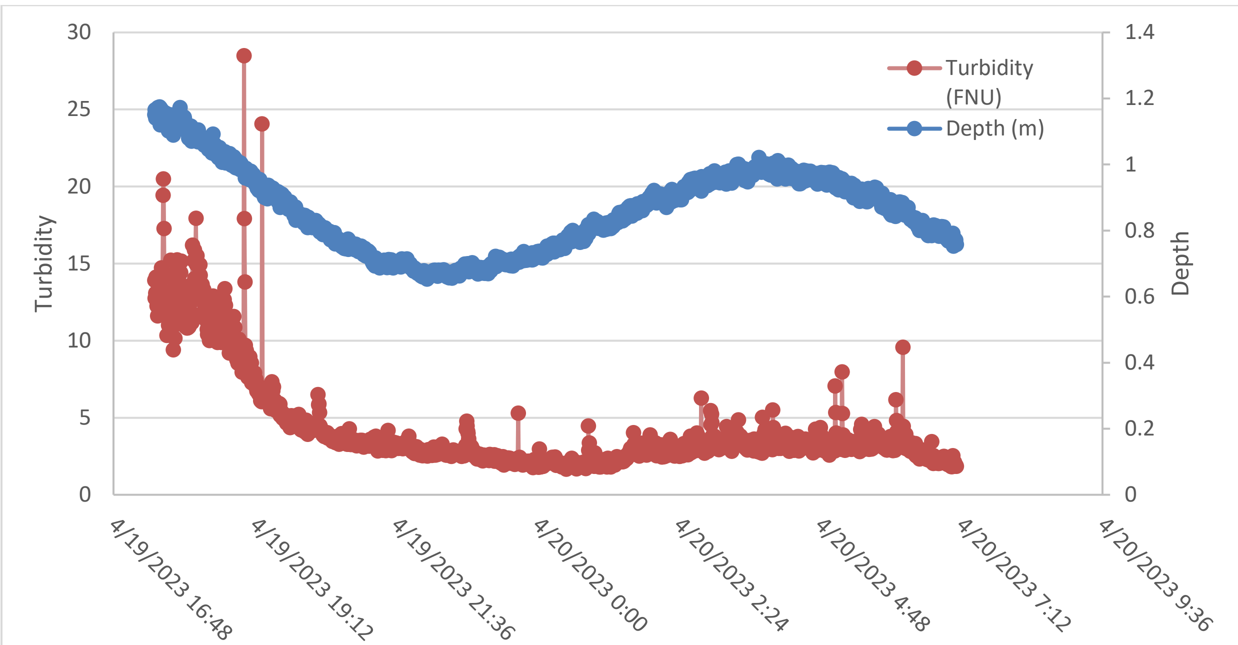


Figure 3.14. Turbidity and water depth over time during a shallow water deployment at transect G on April 20, 2023.

3.3 Reef Flat Benthic Assemblage

In 2023, the benthic assemblage on the Kawela reef flat continued to reflect a community under considerable sediment stress. Abiotic substratum, primarily unconsolidated sand and silt (sand/silt), was the dominant bottom type on all transects, especially at sampling sites close to shore (<400 m distance from shore). The amount of sand/silt tended to decrease with distance from shore (Figure 3.15). Sand/silt accounted for 92.8 ± 2.0% of the bottom at sampling sites

≤250 m from shore compared to 48.5 ± 5.6% at sites farther away. Sediment was dark in color, consistent with a sizable terrestrial component. (Figure 3.5; Appendix A). Marine-derived sediment in Hawai‘i is predominantly light/white calcium carbonate derived from organisms such as coral, calcareous algae, molluscs, and foraminifera. At sites farther from shore, unconsolidated bottom was replaced primarily by turf, but coral and macroalgae were also more abundant at sites farther from shore (Figure 3.15). Turf and coral grow almost exclusively on hardbottom, indicating less sediment has accumulated on the bottom at more distant sampling sites compared to sites closer to shore.

The benthic assemblage on all transects showed the same general pattern with distance from shore, although differences were observed among the transects (Figure 3.16). Sediment effects were most noticeable at the reef flat transects nearest the eastern (transects A and B) and western (Transects H and I) boundaries of the reef tract. Between these areas (Transects C-F), the cover of sand/silt was lower on average and corals were both more abundant and often observed closer to shore than on transects near the reef tract boundaries (Figure 3.16). Transects H and I had almost no coral at any distance from shore, whereas coral cover on Transects C-E was as high as 20% at sites 700 m from the shore.

Since 2005, the benthic assemblage has shown modest improvements in condition (Figure 3.17). The cover of sand/silt significantly decreased from 81.5 ± 3.3% in 2005 to 73.8 ± 3.8% in 2023 (paired t-test, t_{51}=-2.54, p=0.014). Unfortunately, coral cover has not significantly increased since 2005 (paired t-test, t_{51}=-0.22, p=0.825). On a more positive note, the number of sampling sites at which coral was observed has increased from 15 (27%) sampling sites in 2005 to 20 (36%) in 2023. In addition, no measurable coral cover was found at sampling sites <400 m from shore in 2005, yet surveyors in 2023 found 12.1% coral cover at the 250 m sampling site on Transect C (Figure 3.16). While these changes are relatively small, they indicate a positive recovery trajectory for the reef flat benthic assemblage. This is promising considering sediment residence time on the reef flat has been estimated to be >30 years (Presto *et al.* 2006), and significant recovery of the benthic community is likely to occur only after the majority of sediment has moved from the reef flat.

When present on the reef flat, corals were surprisingly diverse. Eight species were observed across the nine reef flat transects, with *Montipora capitata* and *Porites lobata* being most common. Species richness was stable at sites >400 m from shore and included six or seven coral species. At the single 250 m site that had measurable coral cover, surveyors found only four species, and no measurable coral cover was observed closer to shore on any transect. At the 550 m and 700 m sites, montiporids (*M. capitata* and *M. patula*) tended to dominate the coral assemblage, comprising almost 70% and 50% of the coral cover respectively. However, at the 400 m sites, *P. lobata* and *P. compressa* tended to dominate, accounting for almost 85% of the coral cover at these sites. These two poritid species are generally more sediment tolerant than most montiporids (Erftemeijer *et al.* 2012) and are often found in areas with elevated turbidity and sedimentation.

Changes in species richness since 2005 are difficult to assess due to the differences in the methods and likely effort. However, qualitative patterns are apparent. Montiporids were a dominant component of the coral assemblage in both 2005 (Rodgers *et al.* 2005) and 2023. Likewise, poritids were well-represented in both years. However, in 2005 *Pocillopora meandrina* and *P. damicornis* were more frequently observed than in 2023. Reasons for this apparent decline in their representation within the coral assemblage are not clear, but *P. damicornis* is often considered a "weedy" species capable of settling and surviving in very degraded areas for at least short periods of time. In 2005, *P damicornis* was the most frequently observed coral species at the 400 m sites (Rodgers *et al.* 2005). The decline in abundance of this species on the Kawela reef flat may be indicative of improvements in water and benthic quality over the past two decades.

Successful recruitment of coral larvae to the reef flat will be critical to the recovery of the Kawela reef tract. In a 2007 study along two of the Kawela reef flat transects (E and H), Jokiel *et al.* (2014) found coral recruitment rates to be among the lowest observed on any reef in Hawaiʻi. Only five recruits (equating to 5.1 recruits/m^2/yr) were found on settlement plates deployed over the spawning season in 2007, and none were found closer than 550 m from the shore (Jokiel *et al.* 2014). Recruitment rates elsewhere in Hawaiʻi ranged from 24 to 7,924 recruits/m^2/year. Jokiel *et al.* attributed the lack of coral recruits at Kawela to sediment.

Recruitment plates were not deployed in 2023, but the density of small (<5 cm) corals was estimated along all reef flat transects. Individuals of this size represent successful recruitment of settled coral larvae to the reef flat assemblage and their subsequent survival for one or more years. While the 2023 small-coral data are not directly comparable to the recruitment data collected by Jokiel *et al.* (2014), the two datasets can shed light on potential change in conditions affecting recruitment on the Kawela reef tract.

In 2023, small corals were not observed closer than 550 m from shore for transects E and H, the reef flat transects included in the 2007 recruitment study (Table 3.1). However, small corals were observed as close as 400 m from shore on two other transects: A-400 m and C-400 m.

In 2005, Jokiel *et al.* (2014) found measurable coral cover at C-400 (10.78%), indicating that coral recruitment had occurred at this location at some point prior to 2007. In 2023, coral cover at C-400 was 9.4%, which suggests little change in its coral assemblage has likely occurred. At A-400, no measurable coral was observed in 2005 (Rodgers *et al*. 2005), yet several small corals were found at A-400 in 2023, indicating that recruitment at this location had occurred, likely within the last 1 to 2 years, based on the sizes of the colonies observed. Sampling site A-400 also had fairly robust coral cover (28.8%), composed of *Porites compressa* (18.7%), *P. lobata* (9.1%) and *Pocillopora damicornis* (1%), all of which are reasonably tolerant to sediment (Erftemeijer *et al.* 2012). Review of photos for this location shows what appears to be fairly large colonies dispersed within a field of sediment and rubble. Unfortunately, while this finding supports a conclusion that conditions have improved at this location, we cannot entirely rule out that surveys at A-400 in 2005 and 2023 were conducted at slightly different locations on the reef, especially given the large increase in coral cover measured between the survey years. While the differences between the 2007 recruitment study and the 2023 data are relatively minor, they suggest recruitment habitat has improved at sampling sites closer to shore. This would be consistent with decreases in sediment stress on at least the seaward margins of the Kawela reef flat and would point toward a positive recovery trajectory for the reef flat benthic assemblage.

Table 3.1. Density (#/m2) of small coral colonies on suitable habitat at the six distances from shore (m) along the benthic transects at Kawela. Numbers represent the density of all colonies <5 cm in size and the number within the parenthesis () is the density of colonies <1 cm in size. Transects are arranged from most western (Transect I) to most eastern (Transect A) on the Kawela reef tract.

	I	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**A**
50	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0
400	0	0	0	0	0	0	1 (0)	0	16 (1)
550	0	20 (6)	0	0	2 (0)	7 (1)	23 (3)	0	0
700	0	20 (5)	4 (0)	0	19 (2)	11 (0)	17 (2)	11 (0)	0
Total	**0**	**6.7 (1.8)**	**0.7 (0)**	**0**	**3.5 (0.3)**	**3 (0.2)**	**6.8 (0.8)**	**1.8 (0)**	**2.7 (0.2)**

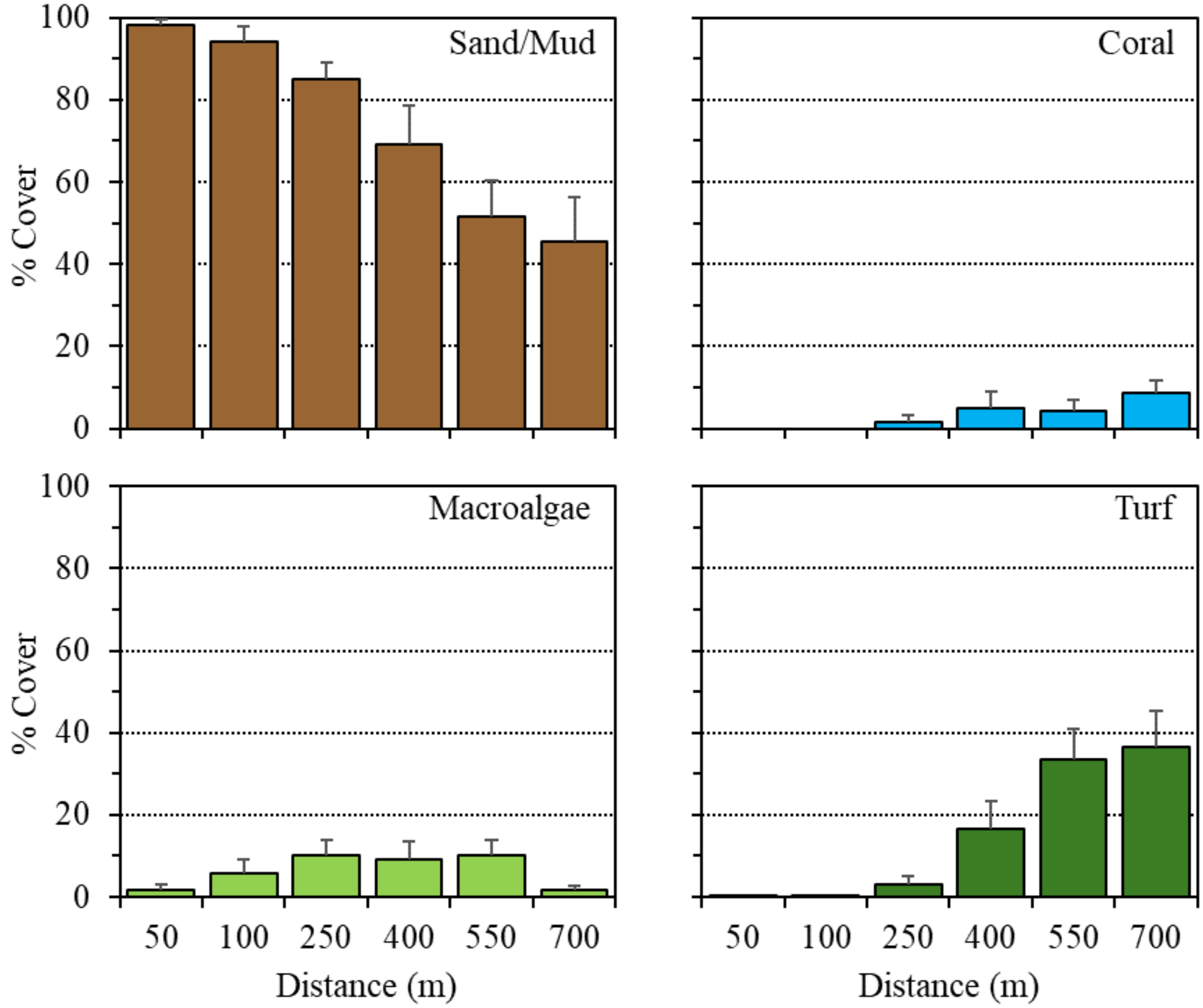


Figure 3.15. Average percent cover (±SEM) of sand/silt, coral, macroalgae, and turf by distance from shore. Bars represent the average of nine reef flat transects (Transects A-I).

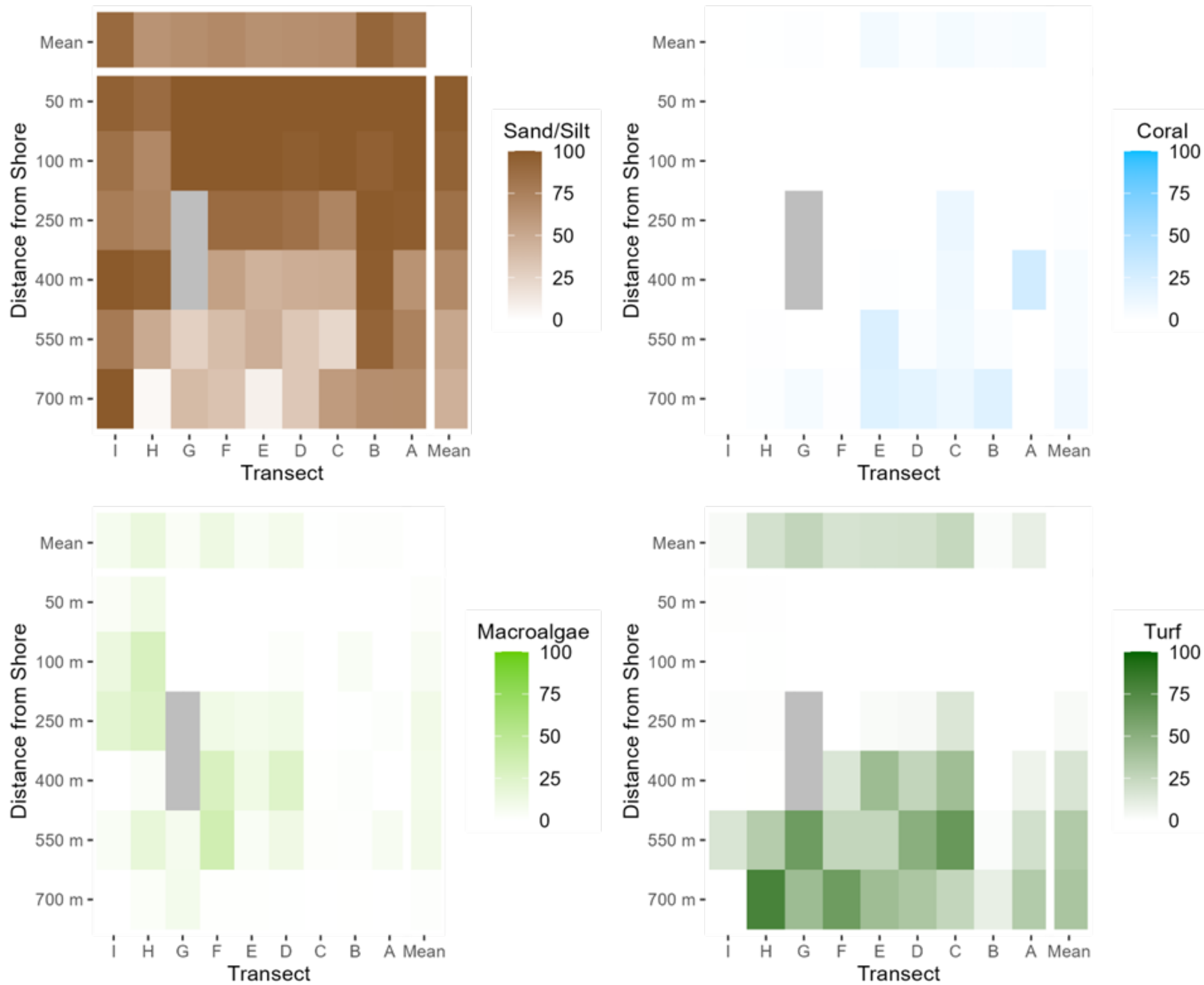


Figure 3.16. Percent cover of sand/silt, coral, macroalgae, and turf along nine reef flat transects (Transects A-I) in the Kawela reef tract. Column and row averages represent the average cover by transect (top horizontal bar) and by distance from shore (right vertical bar). Transects are arranged from west to east and with sampling sites farthest from the shore at the bottom of the figures. Gray cells represent no data were available for the sampling site.

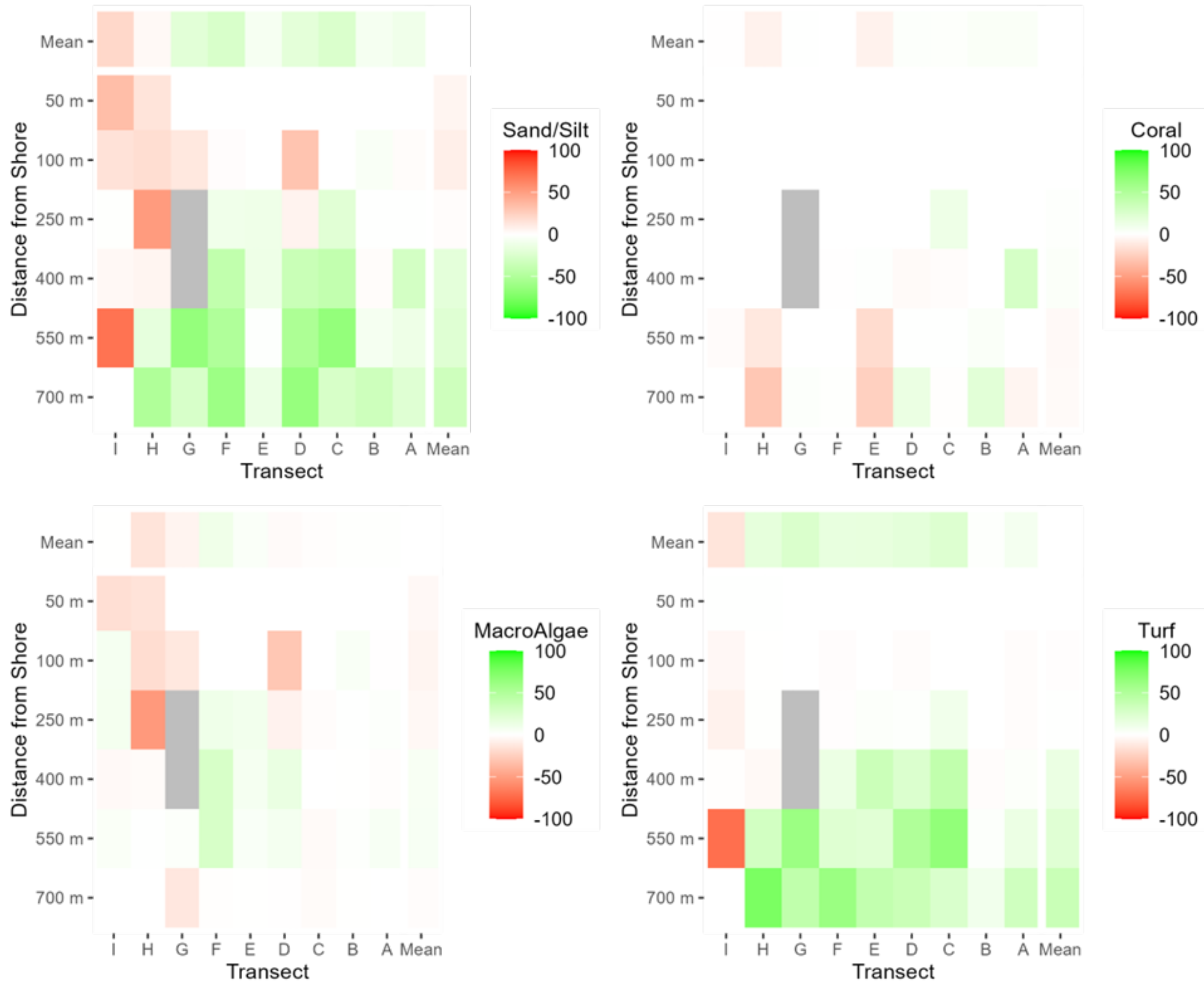


Figure 3.17. Change in absolute cover (Cover2023 - Cover2005) of sand/silt, coral, macroalgae, and turf along nine reef flat transects (Transects A-I) in the Kawela reef tract from 2005-2022. Column and row averages represent the average change in cover by transect (top horizontal bar) and by distance from shore (right vertical bar). Visually, green cells represent an "improvement" and red cells represent a "worsening" of condition. Transects are arranged from west to east and with sampling sites farthest from the shore at the bottom of the figures. Gray cells represent no data were available for the sampling site.

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3.4 Summary: Reef Flat Changes over Time

For over a century, the Kawela reef flat has been affected by sediment runoff from the land. While upland restoration efforts have been underway for nearly two decades, long residence times for sediment on the reef flat and continued inputs, even if lower today than in the early 2000s, have slowed potential recovery. While Kawela watershed has much less sediment exported today than in the past, worsening conditions in neighboring watersheds and the new threat of coastal erosion with sea level rise have slowed potential recovery.

Two months prior to sampling in April 2023, one of the larger floods of the last decade affected the area. Although the rainfall amounts were similar to previous years, the response of the streams was higher than had been seen in a decade. Residents described mud up to their calves on the beach and mud filling in under houses and in fishponds, requiring extensive removal efforts. Over a year post-flood (May 2024), residents describe how the muddy nearshore conditions lasted for months before finally clearing up.

Is it too much sediment for coral growth?

Conditions measured in April 2023 clearly indicate that there remains a sediment problem in the nearshore reef flat of the Kawela reef tract. The sedimentation rates measured are upwards of 10 times higher at some nearshore locations than is generally considered suitable for coral health. A highly significant inverse relationship exists between coral growth and survival and sedimentation rates. Tolerance limits of corals to sedimentation range from less than few $mg/cm^2/day$ to >100 $mg/cm^2/day$ (for a review, see Erftmeiger *et al.* 2012 and Tuttle and Donahue 2022). For example, *M. capitata* experiences reduced growth at <5 $mg/cm^2/day$, but *P. lobata* can survive sedimentation rates >200 $mg/cm^2/day$ and can even recover from complete, short-term burial. Tolerance may also depend on how acclimated the corals are to turbid conditions, and whether there is enough light for zooxanthellae to survive. Some mature corals may be less prone to sediment stress, while juveniles are constrained by larvae lacking clear substrate on which to settle. The effects of sedimentation are usually most severe for nearshore locations on the reef flat.

In the windy conditions that we measured, we were recording SSC values of nearly 150 mg/L and turbidity over 500 FNU at the transects least likely to have other sedimentation issues by Kamalō. SSC is a good indicator of resuspension as compared with sediment depth or composition, and as such is very much affected by wind and time of day. Even so, if corals are experiencing such high turbidity, it would be unlikely for larvae to be able to successfully settle or juveniles to survive. According to Rogers (1990), 10 mg/L is the critical suspended sediment concentration (SSC) for coral reef success, above which there is a negative impact to coral growth and recruitment. Tuttle and Donahue (2022) continued to investigate the threshold question and developed a model for impact to adult corals that considered both time and concentration of the sediment threat. They found that sediment levels above 80 $mg/cm^2/day$ or 80 mg/L for more than 20 days had a negative impact.

Corals show a surprising tolerance to high doses of sediment over short time periods, but under chronic conditions, such as those present at Kawela, many coral species will experience increased mortality rates, and sediment-sensitive species will be lost from the coral assemblage.

3.5 Forereef: Benthic Assemblage

The forereef at Kawela showed considerable spatial variability both in composition and abundance of the benthic community. Reefs at Kawela were notably different from many reefs in Hawaiʻi, which tend to be dominated by turf algae. Some reefs in Maui Nui can have average turf cover >70% (Minton *et al.* 2020), which was more than twice the average observed at Kawela (Table 3.2). Coral cover at Kawela (40.4 ± 2.8%) was high (Figure 3.18), especially compared to reefs along more populated coastlines such as West Maui (Minton *et al.* 2020).

Many reefs on Maui and Hawaiʻi Island are dominated by *Porites* species. In contrast, *M. capitata* and *M. patula* were the dominant coral species at Kawela, comprising three-quarters of the observed coral cover at forereef survey sites (Table 3.2). Montiporids can be locally abundant (*e.g.*, Olowalu on Maui, Keōmuku reef on Lānaʻi), although they tend to be less common than both *P. lobata* and *P. compressa* on Maui Nui reefs and on reefs across the state more generally. While present, *P. lobata* and *P. compressa* were a less-abundant component of the coral assemblage on Kawela reefs.

Although terrestrial sediment may be the primary driver affecting the Kawela reef flat benthic community, sediment effects on the forereef are likely to be considerably less. Sediment deposition on the forereef is a complicated process, likely driven more by periodic high wave events and resuspension of marine sediment than simply the result of plumes of terrestrial sediment. The south shore reefs of Molokai are protected from the large north Pacific swell by the island itself and from storm waves and south Pacific swell by Lānaʻi and Kahoʻolawe (Field *et al.* 2008). The eastern margin of the Kawela reef tract, near Kamalō Point, experiences the lowest wave stress along the south shore of Molokai, under almost all wave and wind conditions (Storlazzi *et al.* 2008). The relatively calm wave conditions are likely the primary driver for the observed species dominance structure and spatial patterns (see below) of Kawela's forereef coral assemblage, with sediment playing a secondary role. The dominance of montiporid over poritid corals on the Kawela forereef is likely associated with low wave energy (Storlazzi *et al.* 2002); where robust species like *P. lobata* are more prevalent on reefs with high wave stress.

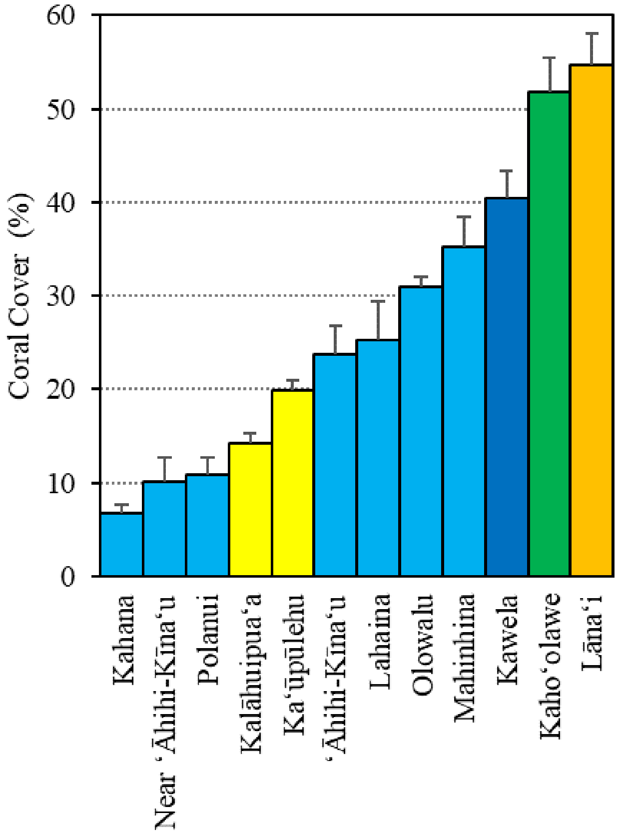

Figure 3.18. Comparison of coral cover within the Kawela reef tract (dark blue) and eleven other locations in Maui (blue bars), Lānaʻi (orange bar), Hawaiʻi Island (yellow bars), and the sheltered side of Kahoʻolawe (green bar). Data from Minton et al. (2016a, 2016b, 2020, 2021a,b) and Falinski et al. (2021).

Table 3.2. Average (±SEM) percent cover of benthic groups and taxa for the forereef benthic assemblage at Kawela.

	Kawela
Turf	35.4 ± 2.4
Coral	40.4 ± 2.8
Montipora capitata	20.2 ± 1.9
Montipora patula	10.5 ± 1.3
Porites compressa	5.2 ± 1.3
Porites lobata	3.6 ± 0.7
Pocillopora meandrina	0.6 ± 0.1
Pavona varians	0.2 ± 0.1
Leptastrea purpurea	<0.1
Montipora flabellata	<0.1
Pocillopora damicornis	<0.1
Porites rus	<0.1
Pavona duerdeni	<0.1
Psammocora nierstraszi	<0.1
Coral spp.	<0.1
Crustose Coralline Algae	12.0 ± 1.3
Macroalgae	1.6 ± 0.4
Cyanobacteria	0.1 ± 0.1
Other	0.1 ± 0.1
Abiotic	10.5 ± 1.8
Sand	8.7 ± 1.6
Rubble	1.8 ± 0.4
Recently dead coral	0.1 ± 0.1

Also unlike many reefs in Hawaiʻi, the coral assemblage did not vary with depth. On many Hawaiian reefs, *P. lobata*, a wave-tolerant mounding coral, is the dominant shallow water species, giving way to branching *P. compressa* in deeper areas. Wave stress is strongly depth dependent, and at Kawela, the lack of difference between shallow and deep reef areas is likely due to the sheltered conditions prevalent along the reef tract.

While no pattern in the forereef benthic community was found with depth, a clear alongshore spatial pattern was observed. Survey sites towards the west end of the Kawela reef tract tended to have lower coral cover and higher cover of turf and abiotic substratum (primarily sand) than sites to the east (Figures 3.19-3.21). Survey sites near the western boundary of the reef tract often had <5% coral cover, whereas coral cover towards Kamalō Point was routinely >30% and reached as high as 67% (Figure 3.19). This difference in coral cover was driven primarily by changes in the cover of the two montiporid species, especially at shallow (<9 m) sites (Figure 3.22). Cover of montiporids increased notably to the east of the Ali‘i Fishpond and One Ali‘i County Park, whereas the cover of *P. compression* changed little and *P. lobata* decreased considerably from west to east at deep water sites. As noted earlier, these spatial patterns in the abundance and species composition of the coral assemblage are consistent with what would be expected under the wave stresses modeled for the Kawela reef tract (Storlazzi *et al.* 2008).

Comparisons of the 2023 benthic data with other data sets are challenging because the methods and survey designs differ among the various studies. For example, data obtained by Scripps Oceanographic Institute (SIO) was collected at five locations on the Kawela reef tract using photomosaics of large area quadrats (100 m^2). Each quadrat was surveyed every other year from 2017 to 2023, providing a powerful design to examine temporal changes in the benthic community, but limited spatial resolution for the entire reef tract. In addition, the procedure for selecting the survey sites is not known, which makes it difficult to assess if sites are a representative sample of the reef tract. Similar concerns exist for other data (Table 2.3), but qualitative comparisons may still be insightful.

Average coral cover in the SIO large area quadrats (65.2 ± 3.1%) was considerably greater than that estimated from the 2023 data (40.4 ± 2.8). Both datasets found *M. capitata* and *M. patula* were the dominant coral species, but the relative abundances of these monitporids suggests the lower average coral cover in 2023 was the result of surveying a wider range of depths on the forereef. The SIO quadrats had an average depth of 11.3 ± 2.7 m, and if only sites within this depth range were considered from 2023, average coral cover was 50.1 ± 5.9%. Likewise, average coral cover derived from data collected by DAR in 2021 and 2022 were also similar to those derived from TNC's 2023 surveys, but only when sites within 0.5 kilometers of the DAR survey areas were used. These comparisons highlight the spatial heterogeneity of the coral community across the Kawela reef tract.

Finally, TNC revisited two sites (Kamalō and Kamiloloa) that are part of the Coral Reef Assessment and Monitoring Program (CRAMP). These sites have been surveyed at least ten times since 2000 using the same methods. Unfortunately, while general patterns were maintained, it was difficult to draw concrete conclusions, likely due to the much coarser spatial scale of the methods employed in 2023 compared to the CRAMP methods. For example, the Kamalō monitoring site had considerably greater coral cover than the Kamiloloa site and at each site, the deep (10 m) transect had greater coral than the shallow (3 m) transect.

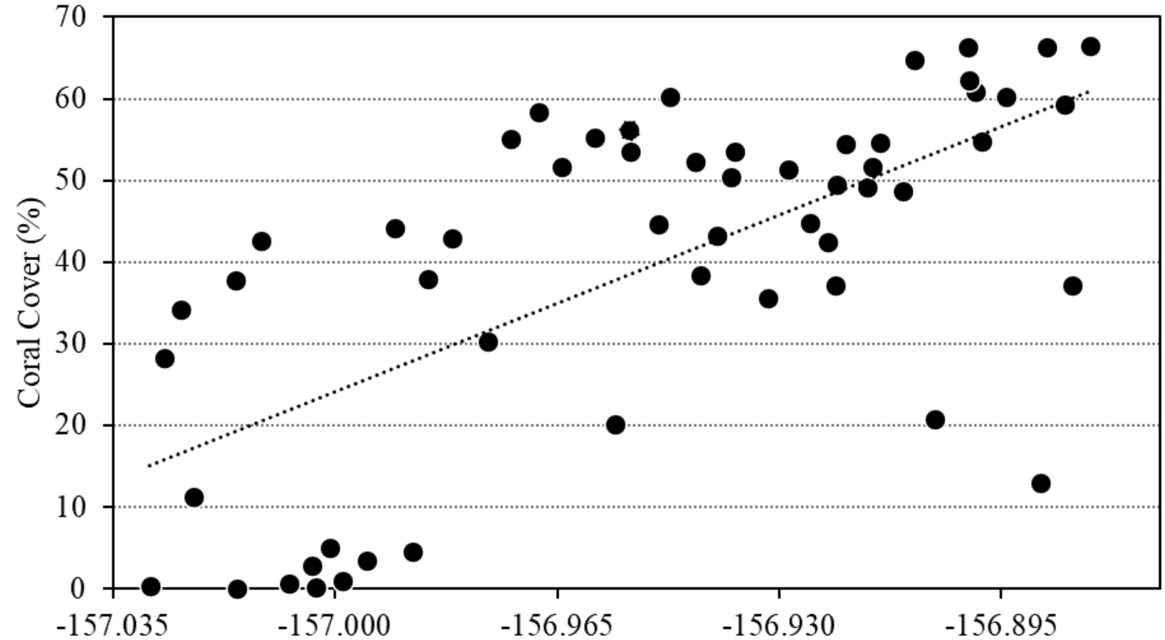

Figure 3.19. Coral cover across the Kawela reef tract forereef. Dotted line is the linear trend line for coral cover along the east-west axis of the Kawela reef tract. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

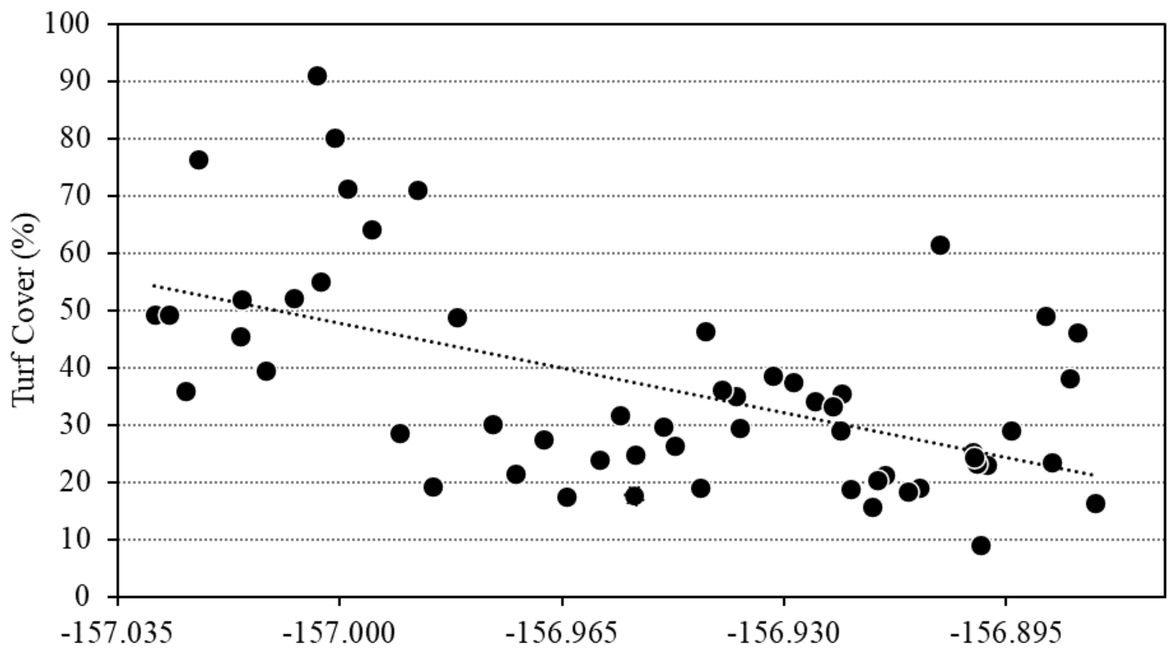

Figure 3.20. Turf cover across the Kawela reef tract forereef. Dotted line is the linear trend line for turf cover along the east-west axis of the Kawela reef tract. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

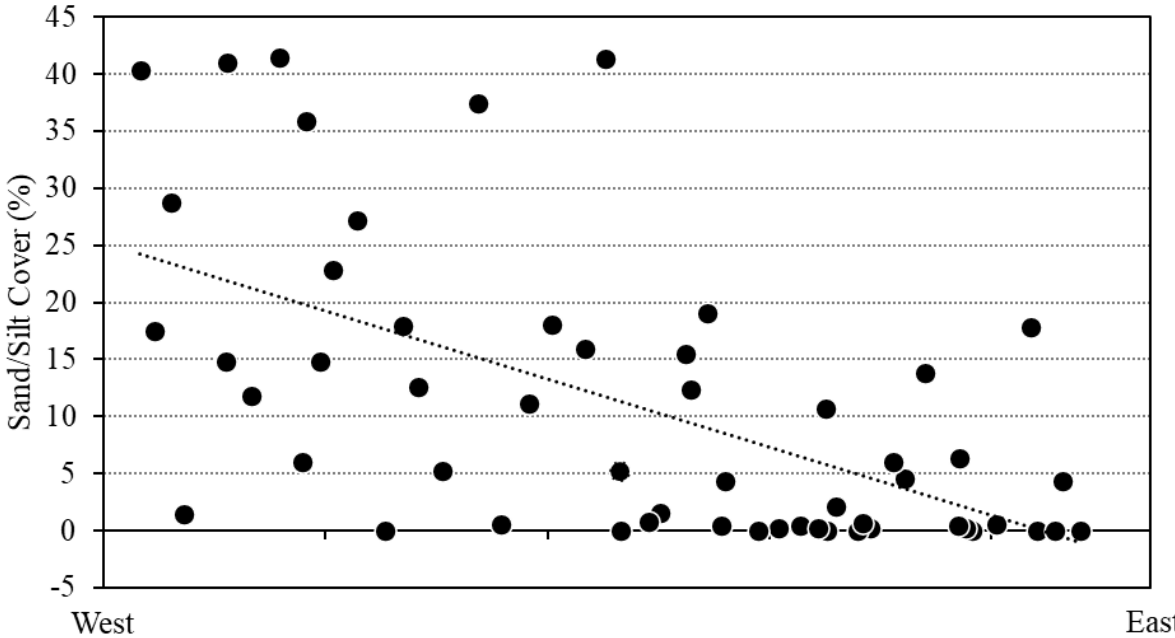

Figure 3.21. Sand/silt cover across the Kawela reef tract forereef. Dotted line is the linear trend line for sand/silt cover along the east-west axis of the Kawela reef tract. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

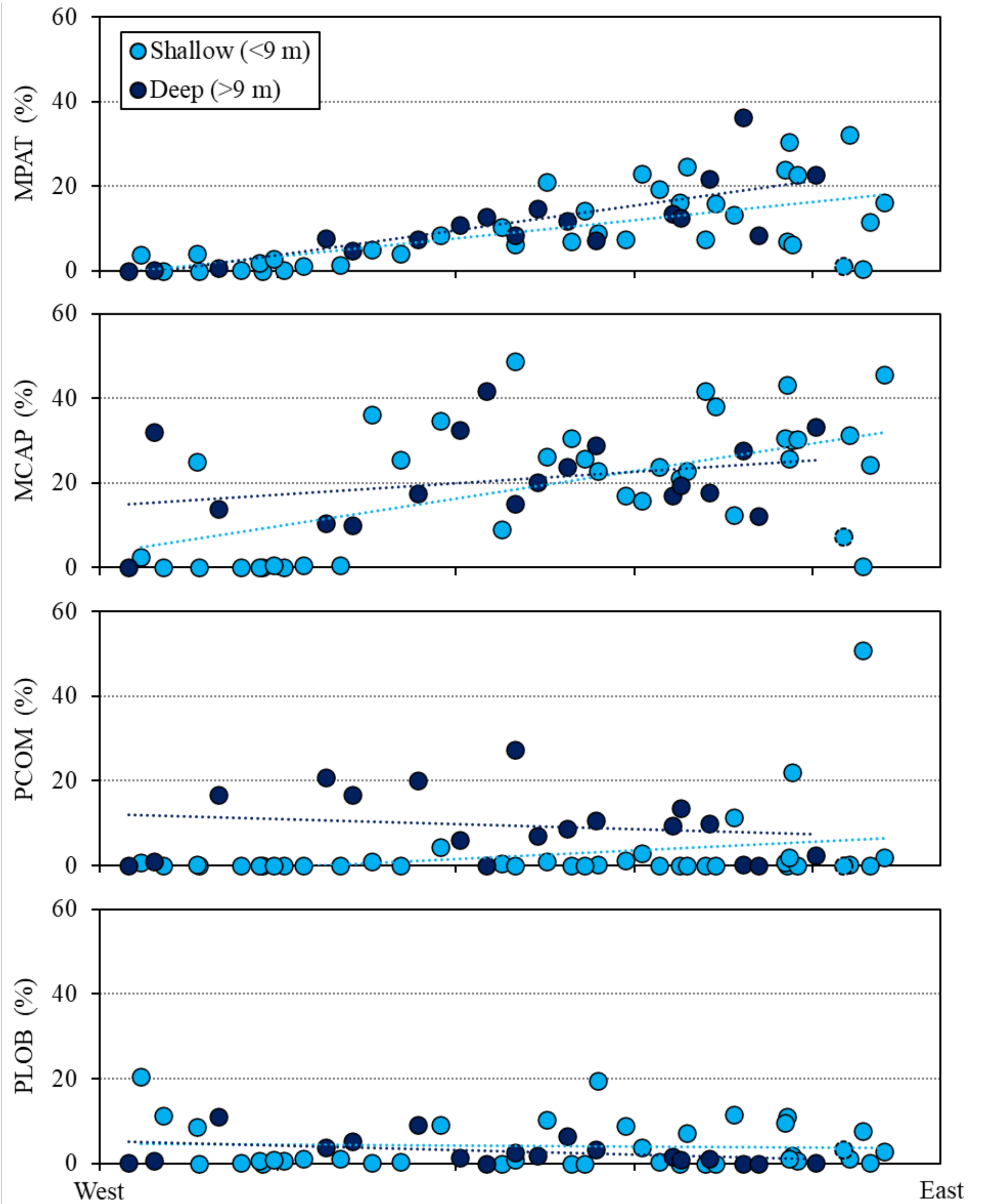

Figure 3.22. Cover of *Montipora patula* (MPAT), *M. capitata* (MCAP), *Porites compressa* (PCOM), and *P. lobata* (PLOB) at shallow and deep forereef survey sites at Kawela in 2023. The lines are linear trend lines. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

Wave stress may be the primary factor influencing the species composition and spatial patterns of the forereef coral assemblage, but coral condition appears to be substantially affected by sediment. Coral bleaching, which occurs when a coral loses its zooxanthellae, is a generalized stress response that is most often associated with elevated water temperature. However, forereef temperatures at the time of the field surveys (April 24-28, 2023) were unlikely to be sufficiently high to trigger a bleaching response. Other stressors can induce a bleaching response in coral, including sedimentation. Coral colonies often undergo bleaching when sediment is deposited atop them and/or when light intensity is reduced due to sediment suspended in the water column (Erftemeijer *et al.* 2012).

Coral bleaching was observed at 47 of the 51 (92%) sites that had measurable coral cover, and on average, 5.4 ± 0.8% of all coral tissue showed signs of paling or bleaching. Four species showed signs of bleaching at more than one site: *M. capitata* (27.6 ± 2.9% of coral tissue bleached), *Pocillopora meandrina* (25.2 ± 4.5%), *M. patula* (8.2 ± 2.4%), and *Porites compressa* (0.4 ± 0.3%). *P. lobata* was observed bleaching at only one site within the Kawela reef tract forereef.

Coral tissue bleaching rates were generally consistent across most of the Kawela reef tract, showing no clear pattern with depth or long-shore position. However, tissue bleaching rates were considerably higher at four survey sites, all on the western margin of the reef tract between Kaunakakai Wharf and Kaloko‘eli Fishpond (Figure 3.23). At one site (2023-KAW-008), the coral tissue bleaching rate was 68.7%. This area of the Kawela reef tract has long been identified as significantly degraded and is where much of the reef flat sediment and other turbid water flushes offshore (Ogston *et al.* 2007).

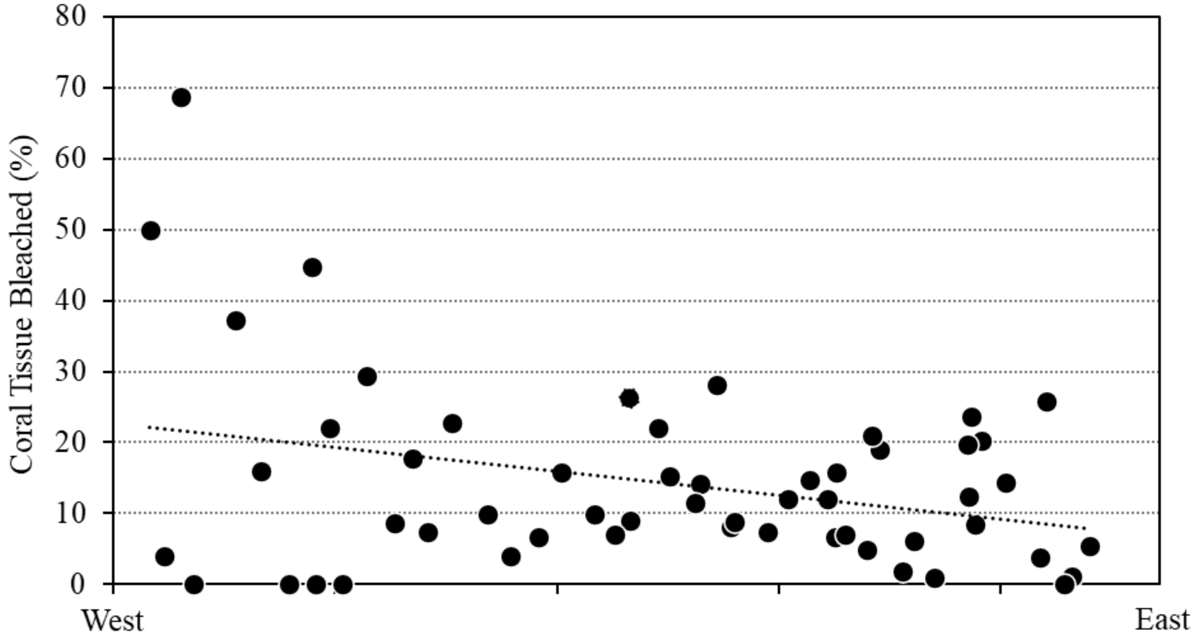

Figure 3.23. Percent of coral tissue bleached across the Kawela reef tract forereef. Dotted line is the linear trend line for coral tissue bleaching along the east-west axis of the Kawela reef tract. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

3.6 Forereef: Fish Assemblage

One hundred and nineteen fish species representing 27 families were observed on the forereef of the Kawela reef tract in 2023 (Table 3.3). Average total fish biomass was 61.5 ± 8.8 g/m^2, which was towards the higher end of total fish biomass for sites that have been assessed in Maui Nui and comparable to reefs on East Maui but less than that found within many protected areas in Maui Nui (Figure 3.24). As on most Hawaiian reefs, Acanthuridae (surgeonfish) contributed the most to fish biomass at Kawela, accounting for over a third of the total fish biomass within the reef tract. Scaridae (parrotfish) had the second highest biomass. Acanthurids and scarids were also numerically dominant, and along with the Labridae (wrasses) and Pomacentridae (damselfish), accounted for over 88% of all individuals observed on Kawela's forereef (Table 3.3).

Total fish biomass showed a weak increasing trend moving west-to-east on the Kawela reef tract (Figure 3.25-). As is typically seen on Hawaiian reefs, a few survey sites had high total fish biomass, and these seemed to cluster in two areas of the reef tract. Several high biomass sites were found on the western margin of the reef tract, and their high total fish biomass was likely associated with their close proximity to the Kaunakakai Harbor channel. Large-scale topographic structures like harbor channels are often associated with large apex predators, and these sites had high abundance and biomass of *Caranx melampygus* (bluefin trevally or *ʻōmilu*), *Carangoides* *orthogrammus* (island jack or *ulua*), and *Aprion virescens* (green jobfish or *uku*), which comprised as much as 80% of the fish biomass at these survey sites. In addition, a cluster of high biomass sites was present near the middle of the reef tract. These sites were not associated with large topographic features such as the Kaunakakai Harbor channel and did not have high abundance or biomass of apex predators. Instead, high biomass was attributable to multiple reef-associated species such as scarids and acanthurids, and these sites likely represent the natural variability of reef fish populations on Hawaiian reefs.

Two other fish datasets are available for the Kawela reef tract but due to differences in the methods and sampling design, quantitative comparisons are challenging. Surveying over a slightly wider area of the south shore of Molokai, Friedlander and Rodgers (2008) observed 99 species, with *Chlorurus spilurus* (bullethead parrotfish or *uhu*) being the most common, comprising about 10% of the total fish biomass. Similar to the recent surveys, Acanthuridae and Scaridae comprised the largest percentage of the total fish biomass and Acanthuridae and Labridae were numerically dominant. Also similar to 2023, high fish biomass was observed near the middle of the Kawela reef tract, suggesting this area has a history of being a favorable location for fish. More recently, Maui DAR surveyed two locations on the Kawela reef tract (near Kamiloloa and Kamalō) in 2021 and 2022. Unfortunately, survey sites were clustered in different areas of the reef in the two survey years making it challenging to conduct a timeseries analysis given the spatial heterogeneity of the fish community. Similar to TNC's 2023 survey, DAR found small parrotfishes *Chlorurus spilurus* and *Scarus psittacus* (palenose parrotfish or *uhu*) comprised a large percentage of the total fish biomass at both locations.

Table 3.3. Fish biomass (g/m^2) and abundance (individuals/125 m^2) by fish family within the Kawela (n=56) reef tract forereef. Data are from 2023. *Individuals were present, but biomass was not estimated for this family.

	Biomass	**Abundance**
Acanthuridae (Surgeonfish)	23.7 ± 4.9	39.8 ± 4.0
Scaridae (Parrotfish)	12.2 ± 2.8	29.8 ± 5.8
Lutjanidae (Snappers)	4.7 ± 1.8	1.0 ± 0.5
Serranidae (Groupers)	4.3 ± 1.4	0.8 ± 0.2
Labridae (Wrasses)	4.1 ± 0.6	14.7 ± 1.0
Carangidae (Jacks)	2.8 ± 1.5	0.4 ± 0.3
Mullidae (Goatfish)	2.6 ± 1.7	2.3 ± 0.5
Chaetodontidae (Butterflyfish)	1.9 ± 0.3	3.2 ± 0.6
Balistidae (Triggerfish)	1.6 ± 0.3	1.1 ± 0.2
Pomacentridae (Damselfish)	1.1 ± 0.3	12.2 ± 3.2
Fistulariidae (Cornetfish	0.9 ± 0.9	0.2 ± 0.2
Holocentridae (Squirrelfish)	0.8 ± 0.5	0.3 ± 0.1
Lethrinidae (Emperors)	0.3 ± 0.3	0.1 ± 0.1

Cirrhitidae (Hawkfish)	0.1 ± 0.1	0.7 ± 0.1
Pomacanthidae (Angelfish)	0.1 ± 0.1	0.4 ± 0.1
Monacanthidae (Filefish)	0.1 ± 0.1	0.2 ± 0.1
Tetraodontidae (Pufferfish)	0.1 ± 0.1	1.5 ± 0.2
Zanclidae (Moorish idols)	<0.1	<0.1
Aulostomidae (Trumpetfish)	<0.1	<0.1
Scorpaenidae (Scorpionfishes)	<0.1	<0.1
Blenniidae (Blennies)	<0.1	0.2 ± 0.1
Ostraciidae (Boxfish)	<0.1	<0.1
Gobiidae (Gobies)	<0.1	<0.1
Muraenidae (Eels)	*	0.1 ± 0.1
Myliobatidae (Eagle rays)	*	<0.1
Unidentified	*	0.3 ± 0.2
Total	61.5 ± 8.8	109.4 ± 8.9

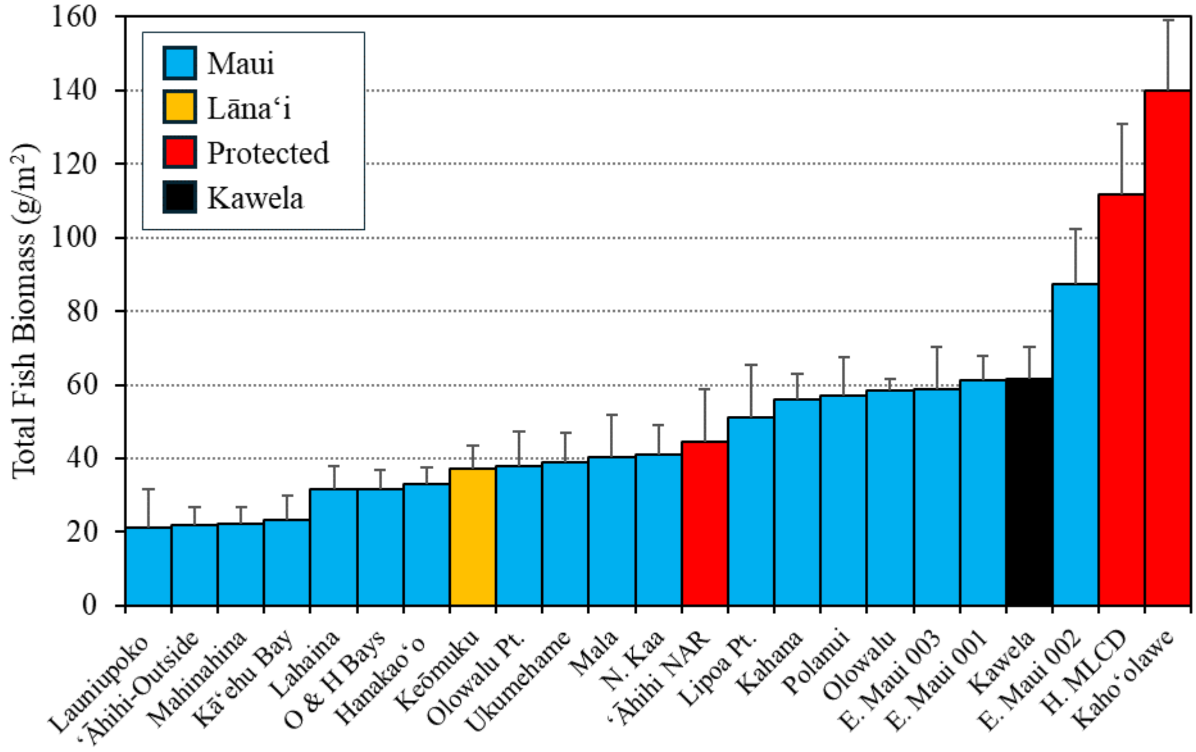

Figure 3.24. Total fish biomass (g/m^2) at Kawela in 2023 (black bar) and 22 Maui Nui sites. Data were compiled from Minton *et al.* (2016a, 2016b, 2020, 2022, 2024) and TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays; H. MLCD=Honolua MLCD.

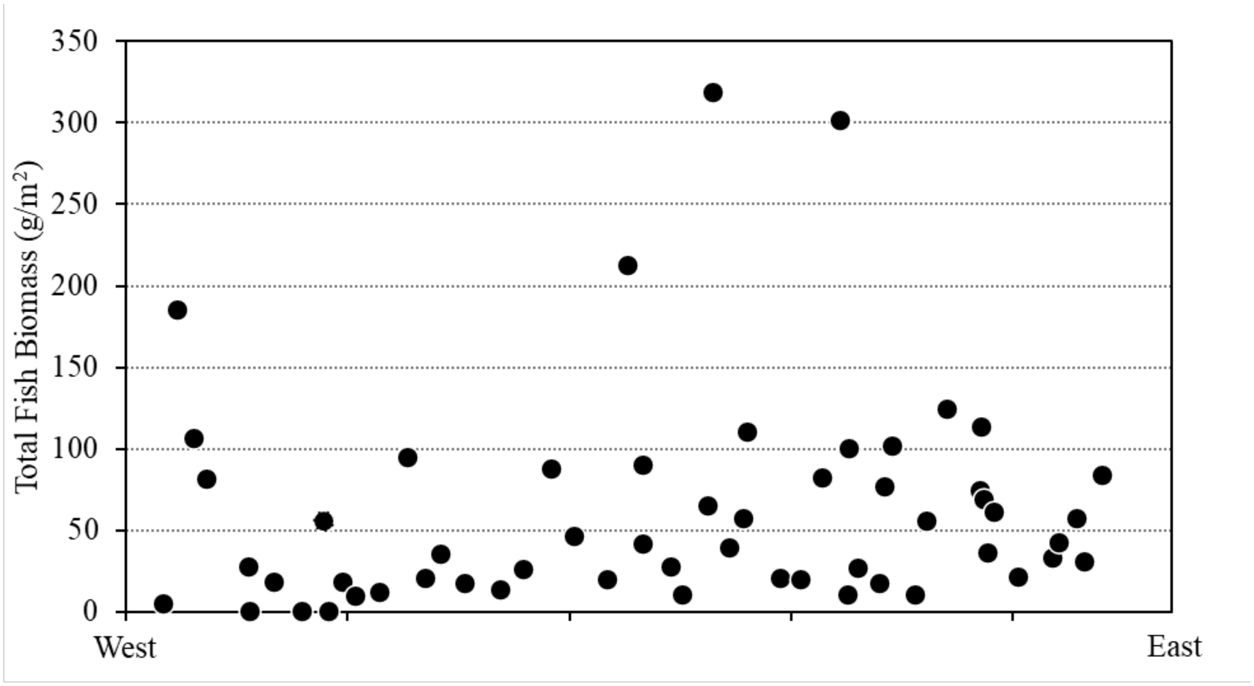

Figure 3.25. Total fish biomass (g/m2) across the Kawela reef tract forereef. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

3.6.1. Resource fish

For this report, resource fish (Table 2.4) include fish desirable for food, commercial activity, or cultural practices that reside in the habitats and depth ranges surveyed by TNC divers. At Kawela, total resource fish biomass was 43.0 ± 7.2 g/m^2, which was nearly double the average for sites on West Maui (26.3 ± 3.5 g/m^2). Resource fish biomass at Kawela was comparable to reefs on East Maui, yet still below many of Maui Nui's protected areas (Figure 3.26). Resource fish represented 70% of the total fish biomass at Kawela. This percentage is higher than that observed at many Maui Nui sites, suggesting Kawela's fish assemblage may be experiencing relatively light fishing impacts compared to other Maui Nui reefs. Not surprisingly, resource fish biomass showed a similar spatial distribution as total fish biomass at Kawela (Figure 3.27).

Acanthurids accounted for the largest percentage of the resource fish biomass (~45%; Figure 3.28). Other important groups included scarids (28%), and apex predators (11%). Apex predators at Kawela consisted of five species, including *Caranx melampygus*, which was the most frequently observed apex predator species at Kawela (40 individuals). Common resource fish species included the small parrotfishes *Chlorurus spilurus* and *Scarus psittacus*, and the surgeonfishes *Acanthurus blochii* (ringtail surgeonfish or *pualu*), *Naso hexacanthus* (sleek unicornfish or *opelu kala*), and *A. triostegus* (convict tang or *manini*).

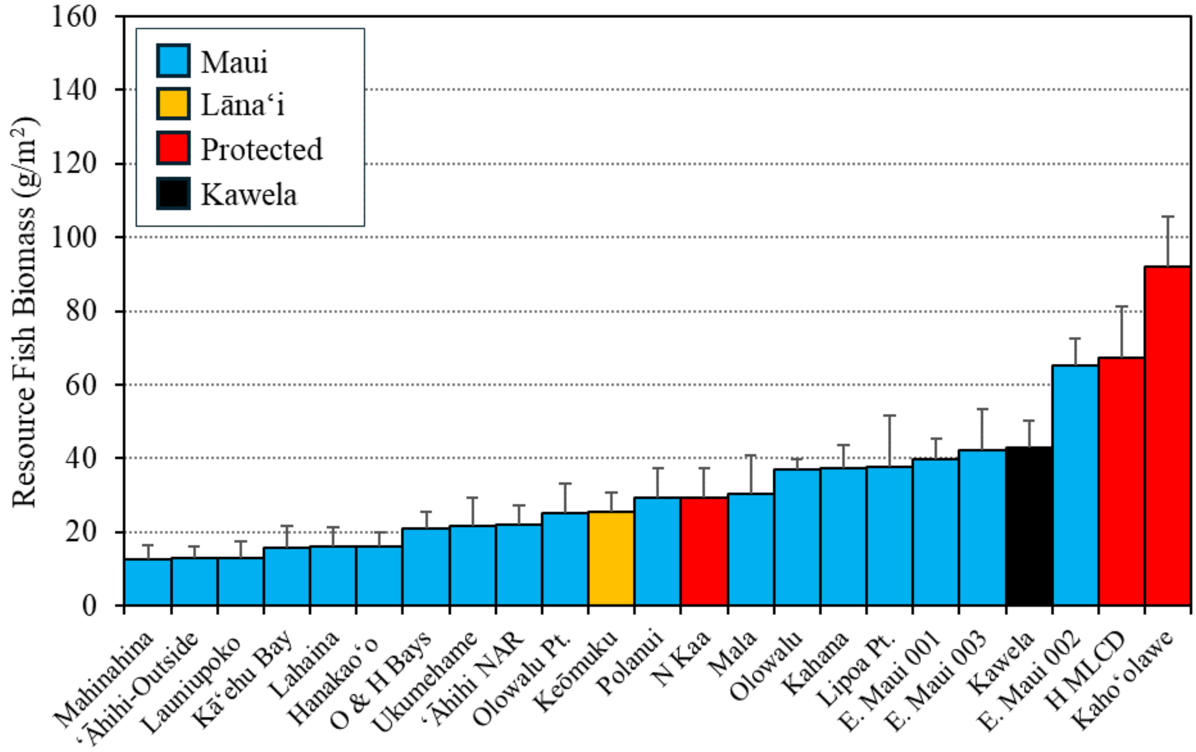

Figure 3.26. Resource fish biomass at Kawela in 2023 (black bar) and 22 Maui Nui sites. Data were compiled from Minton *et al.* (2016a, 2016b, 2020, 2022, 2024) and TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays; H. MLCD=Honolua MLCD.

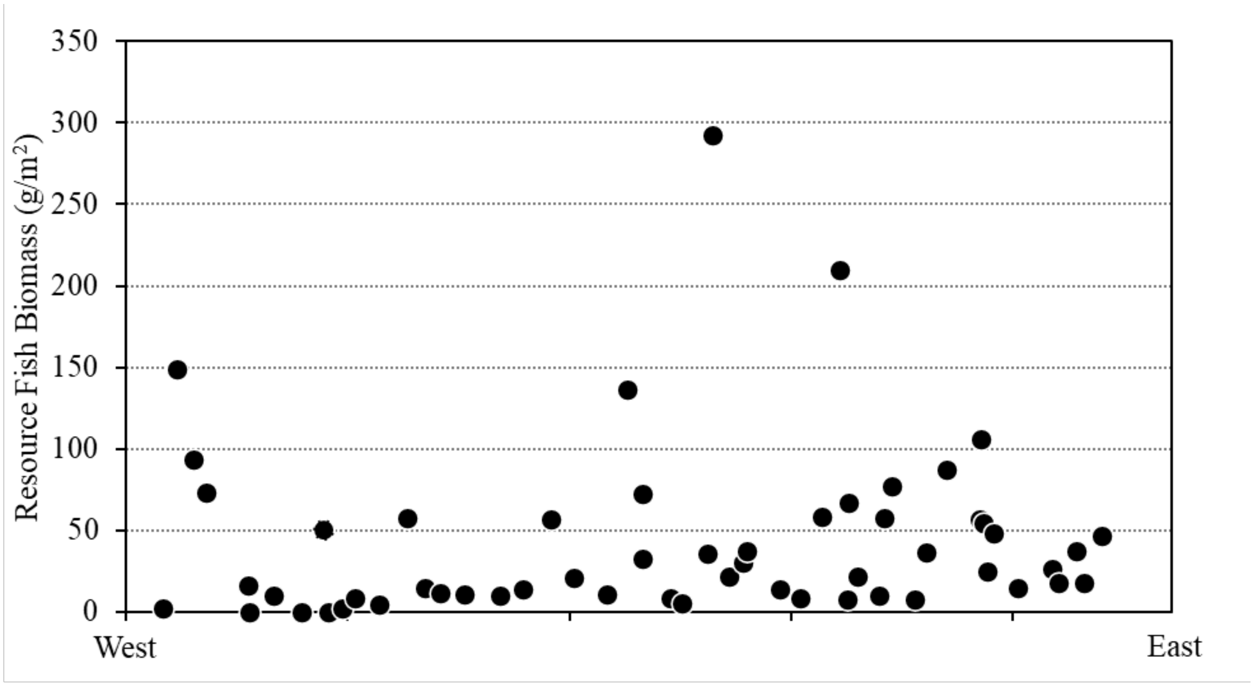

Figure 3.27. Resource fish biomass (g/m2) across the Kawela reef tract forereef. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

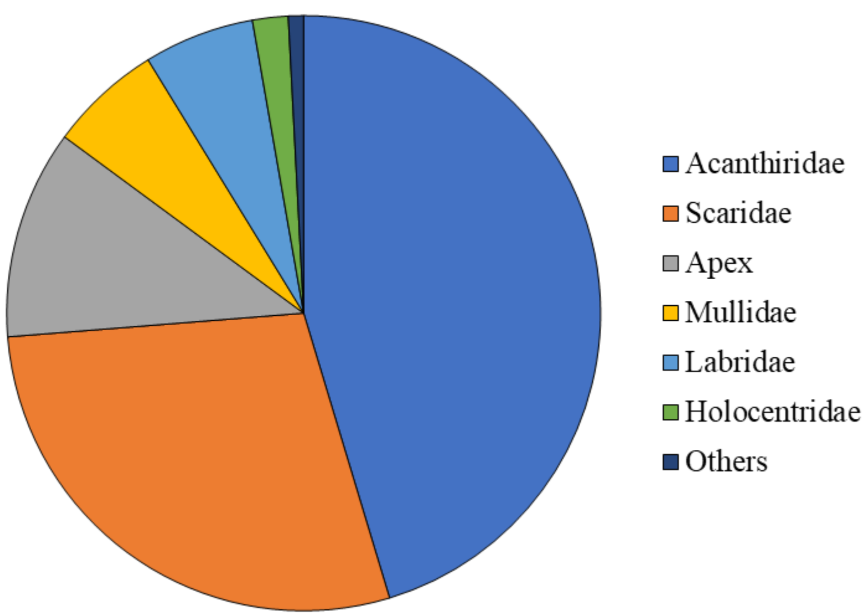

Figure 3.28. Resource fish composition (% of total resource fish biomass) on the Kawela reef tract forereef in 2023.

3.6.2. Prime spawners

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 spawner biomass is a good indicator of fishing impacts, *e.g.*, prime spawner biomass often decreases markedly as fishing pressure increases.

At Kawela, the prime spawner biomass was 12.6 ± 4.0 g/m^2, which was twice the average for West Maui reefs (6.3 ± 1.7g/m^2), but lower than most East Maui reefs or reefs within protected areas (Figure 3.29). Prime spawner abundance was 5.2 ± 1.5 individuals/125 m^2 (per survey site). With the exception of a handful of survey sites near the middle of the reef tract, prime spawners showed little spatial variability across the Kawela reef (Figure 3.30).

Prime spawners were diverse. Twenty-two prime spawner species were observed at Kawela, including representatives from all resource fish groups. Unlike what is found on many Hawaiian reefs, prime spawner biomass was not dominated by one or a few species. Seven species accounted for >5% of the total prime spawner biomass, including *Acanthurus blochii* (21% of the prime spawner biomass), *Mulloidichthys vanicolensis* (yellowfin goatfish, *weke ʻula*, 13.4%), *Chlorurus spilurus* (11.6%), *A. olivaceus* (orangeband surgeonfish or *naʻenaʻe*, 11.3%), *A. triostegus* (10.8%), and *Scarus rubroviolaceus* (ember parrotfish or *uhu pālukaluka* and *uhu ʻele ʻele*, 8.4%). *Acanthurus triostegus* was by far the most abundant prime spawner at Kawela, averaging nearly 1.5 individuals per survey site and 28% of all prime spawners observed at Kawela.

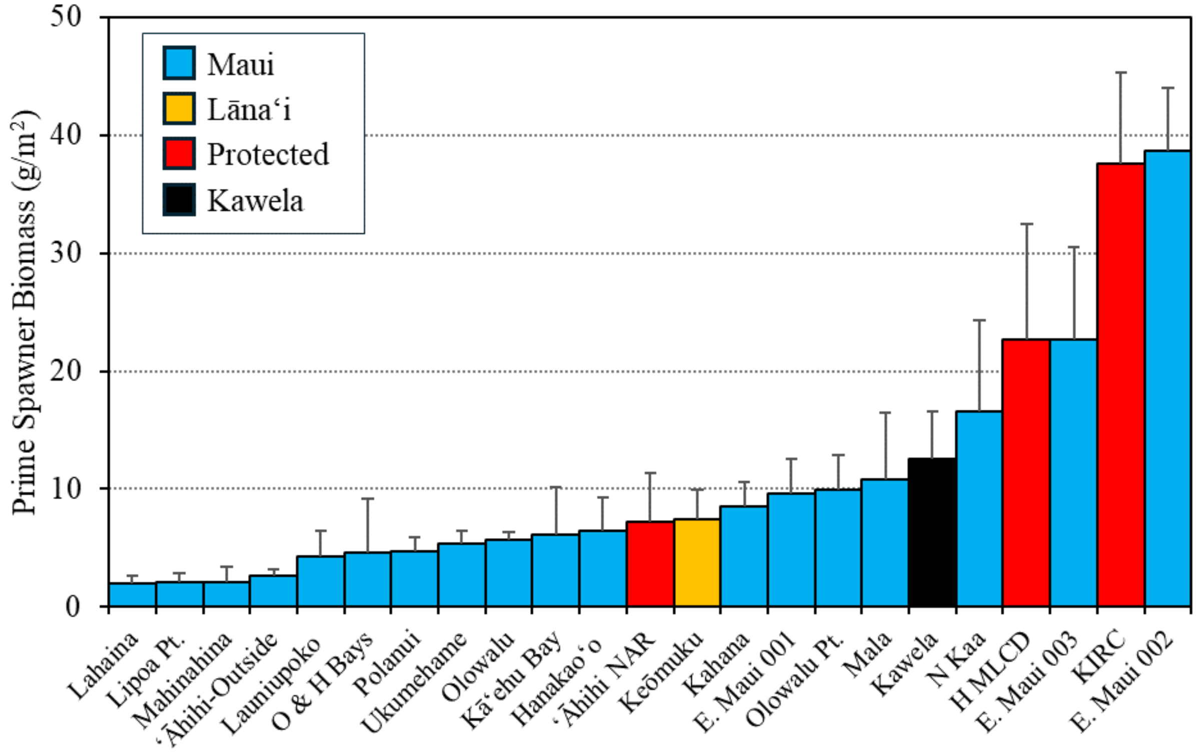

Figure 3.29. Prime spawner biomass at Kawela in 2023 (black bar) and 22 Maui Nui sites. Data were compiled from Minton *et al.* (2016a, 2016b, 2020, 2022, 2024) and TNC. Bars represent SEM. N. Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays; H. MLCD=Honolua MLCD.

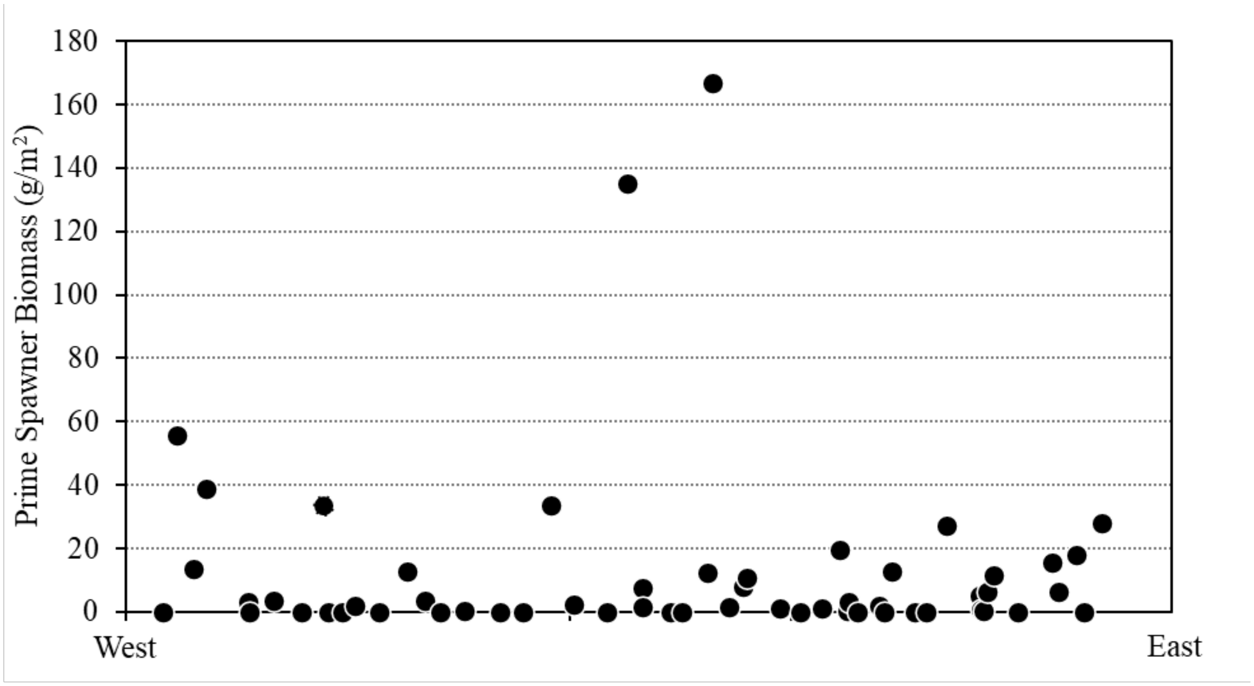

Figure 3.30. Prime spawner fish biomass (g/m2) across the Kawela reef tract forereef. Data are arranged from the reef tract's west (left) to east (right) boundary. At the request of the community, detailed positional information for the survey sites has been intentionally obscured in the figure.

3.6.3. Invasive species

Three invasive fish species commonly found on Hawaiian reefs were observed on the Kawela reef tract. *Cephalopholis argus* (peacock grouper or roi) was the most commonly observed invasive fish species by both number of individuals and percent of sites at which it was observed (Table 3.4). *Cephalopholis argus* is a species of considerable concern among fishers in Maui Nui and has been the target of community-led control efforts on multiple islands for over a decade, with hundreds of *C. argus* individuals removed (*e.g.*, see Donovan *et al.* 2013). Ninety-four *C. argus* were observed at 30 of 56 survey sites (54%), with one to nine *C. argus* individuals observed at each site when present. *Lutjanus fulvus* (blacktail snapper or to‘au) was found at only seven survey sites, but as a schooling species, it was relatively abundant when present. Schools of 24 and 35 individuals were observed. *Lutjanus kasmira* (bluestriped snapper or ta‘ape) was the rarest of the three invasive species observed at Kawela. This species is common on many Hawaiian reefs and can be very abundant when present. However, other than one school of 25 individuals, *L. kasmira* was almost entirely absent from the Kawela reef tract.

Table 3.4. Biomass (g/m2), abundance (individuals/125 m^2) and prevalence (number of sites) of three invasive fish species within the Kawela (n=56) reef tract. Data are from 2023.

	Biomass	Abundance	# Site (%)
Cephalopholis argus	4.2 ± 1.4	0.8 ± 0.1	30 (54)
Lutjanus fulvus	2.1 ± 1.3	0.7 ± 0.4	7 (13)
Lutjanus kasmira	0.5 ± 0.5	0.3 ± 0.2	3 (5)
Total Invasive Fish	**6.9 ± 1.9**	**1.8 ± 0.45**	**34 (61)**

4. Outreach

With the close-knit Molokai community, it was essential for the success of this project to talk to individuals and members of the community about the issues that they are concerned about with their marine resources, and the connections between these resources and the past, present, and future terrestrial restoration efforts. In the early stages of the project, TNC staff spoke to several members of the community to solicit their input on the key questions and concerns to address with this study, and their observations of the changes that have been seen over time, both before and during the extensive terrestrial restoration efforts in the watershed. These discussions included site visits to shoreline areas where the specific inputs and impacts could be seen and discussed.

The project was also shared at the Molokai Earth Day celebrations attended by thousands of island residents, a substantial portion of the island's population. At the Earth Day 2023 celebration, a two-pager informational handout was developed (Appendix D) and shared with residents that visited TNC's booth at the event. The handout described the work that was planned and solicited input from community members on questions they had about the work and the health of the reef. At Earth Day 2024, a revised informational handout was developed (Appendix D) and shared, highlighting the project, key observations from the survey team, and some of the preliminary findings from the analysis of the data collected.

Figure 4.1. Earth Day 2024

In addition to the individual meetings and outreach through the Earth Day events, TNC included an update on the watershed restoration work underway in Kawela and the recent marine monitoring surveys conducted in a Nature's Newsflash mailing that TNC distributes to island residents semi-annually (Appendix D). An update on the project and the results of the surveys has been prepared for the upcoming Nature's Newsflash issue which will be released later in 2024.

The results of the surveys were shared at the 2024 Hawaii Conservation Conference, ‘Auamo Kuleana, and will be shared directly with members of the Molokai community at the upcoming annual meeting of the East Molokai Watershed Partnership to be held at the Kawela Clubhouse on September 27, 2024. These outreach activities and the conversations they catalyze have and will continue to build understanding and support within the community for the ongoing watershed restoration efforts, and help ensure that those efforts and the monitoring data collected to evaluate them address concerns and questions from the community.

5. Acknowledgements

The design and objectives for this work were developed with valuable input and insight from NFWF staff, Russell Sparks of the Division of Aquatic Resources on Maui, and TNC’s Molokai staff. TNC’s Molokai staff also provided essential logistical support for the surveys and the outreach events to share the project. The Coral Reef Ecology Lab and Ku‘ulei Rogers of the Hawai‘i Institute of Marine Biology provided laboratory space and instruction for the processing of sediment samples, along with guidance and data from the previous work. DAR Maui staff and Orion McCarthy very helpfully provided data from DAR and the Smith/Sandin Lab at Scripps Institution of Oceanography, respectively, and we are indebted to both for their contributions to these analyses. The survey work could not have been done without TNC Surveyors Hank Lynch, Tiara Stark and Nalei Sampson, as well as Kupu intern Christiane Keyhani. Kupu intern David Perreira spent countless hours in the lab working through samples. This work would not have been possible without the financial support for this project provided by the NOAA Coral Reef Conservation Program through a grant from the National Fish and Wildlife Foundation (NFWF), with matching support provided by the Harold K.L. Castle Foundation and private donations to The Nature Conservancy.

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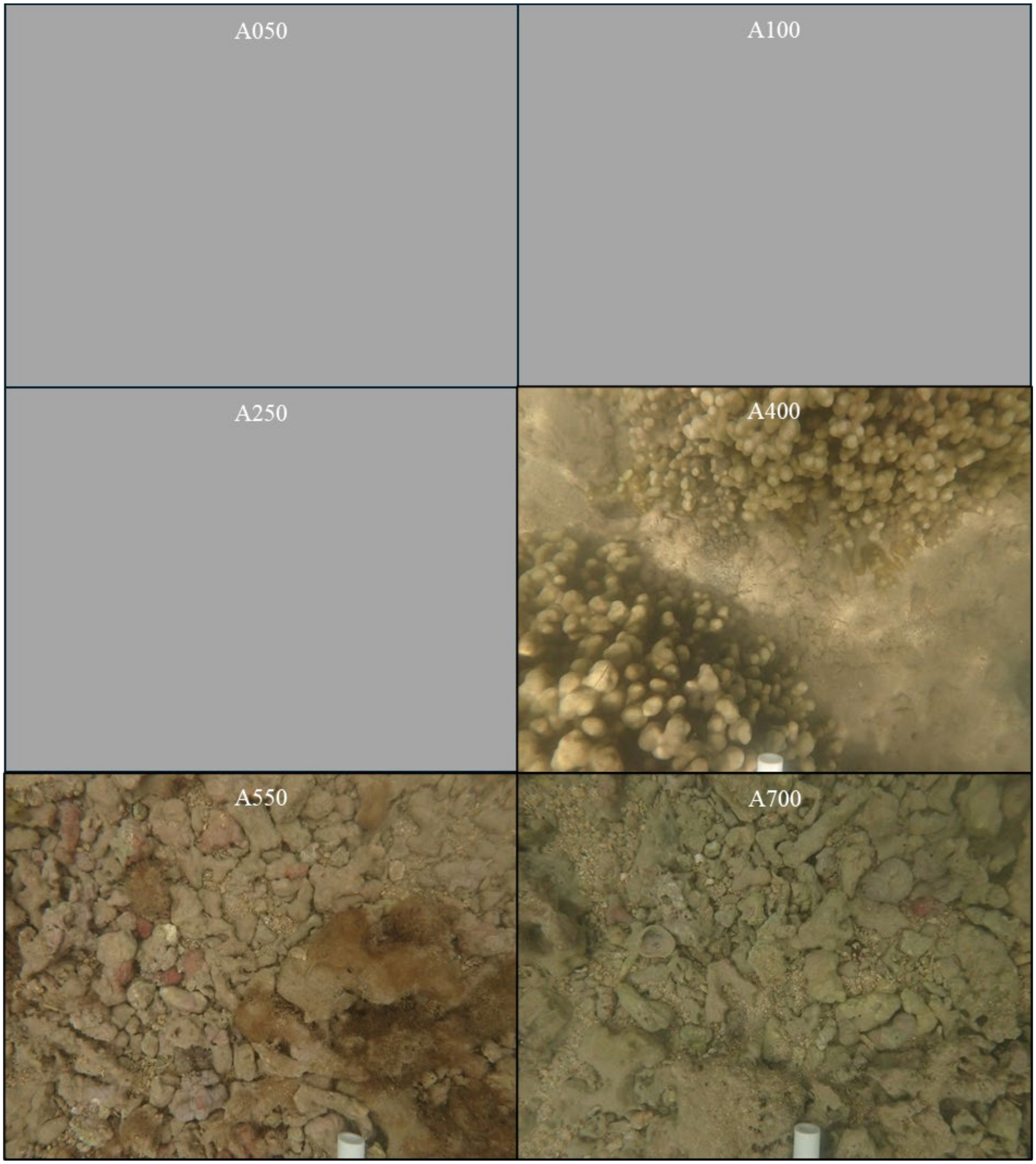
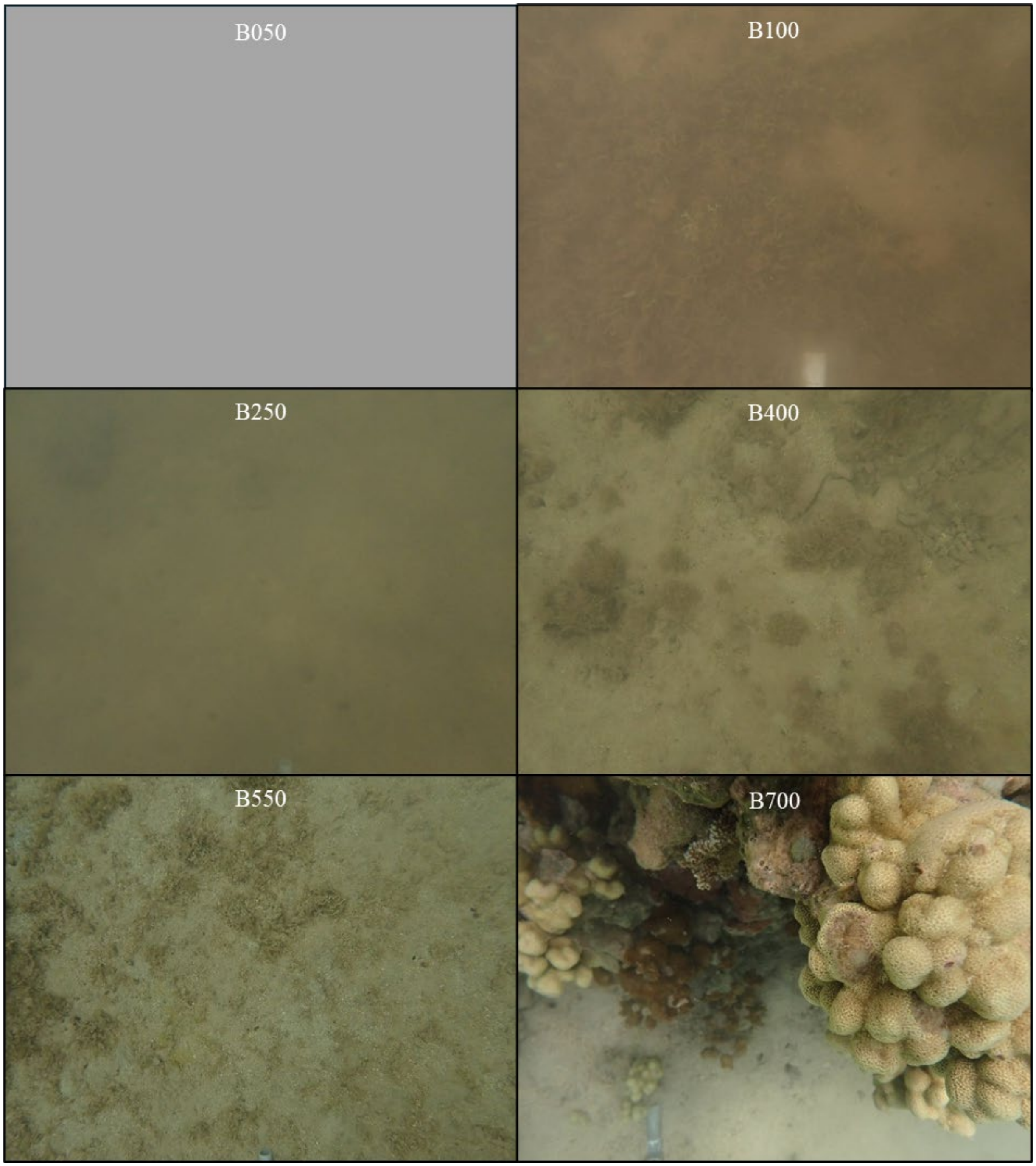
7. Appendix A. Transect Images

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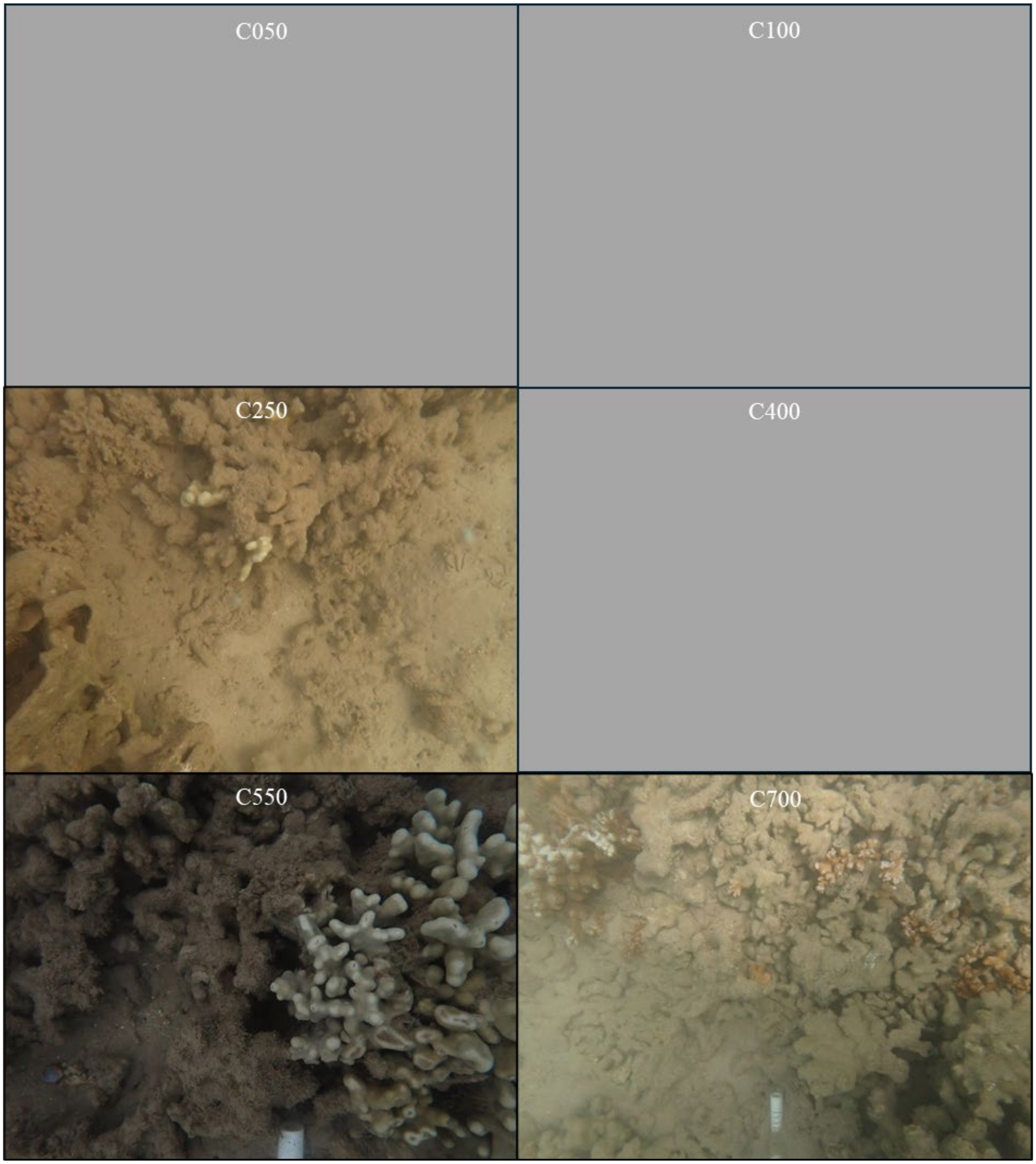
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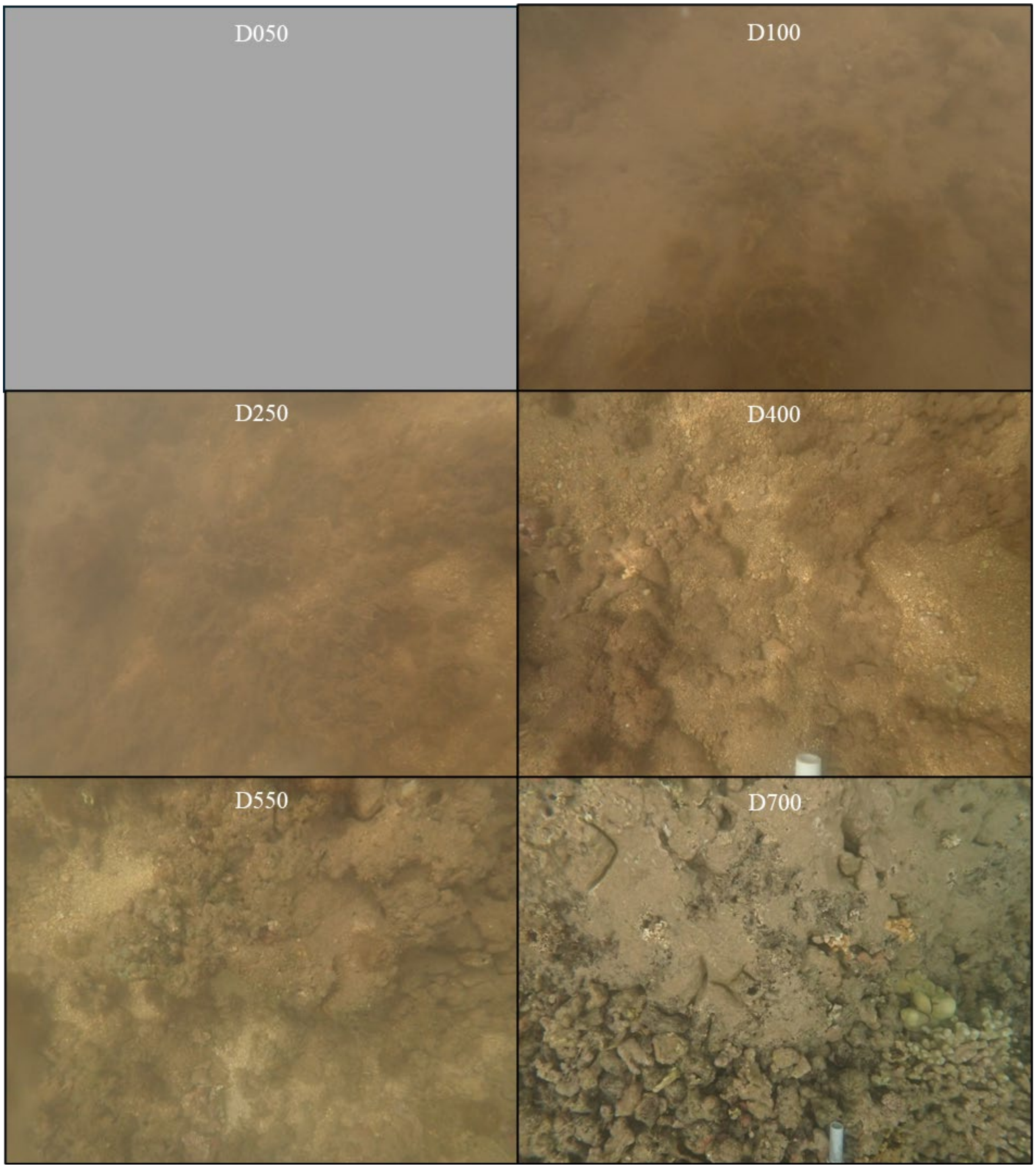
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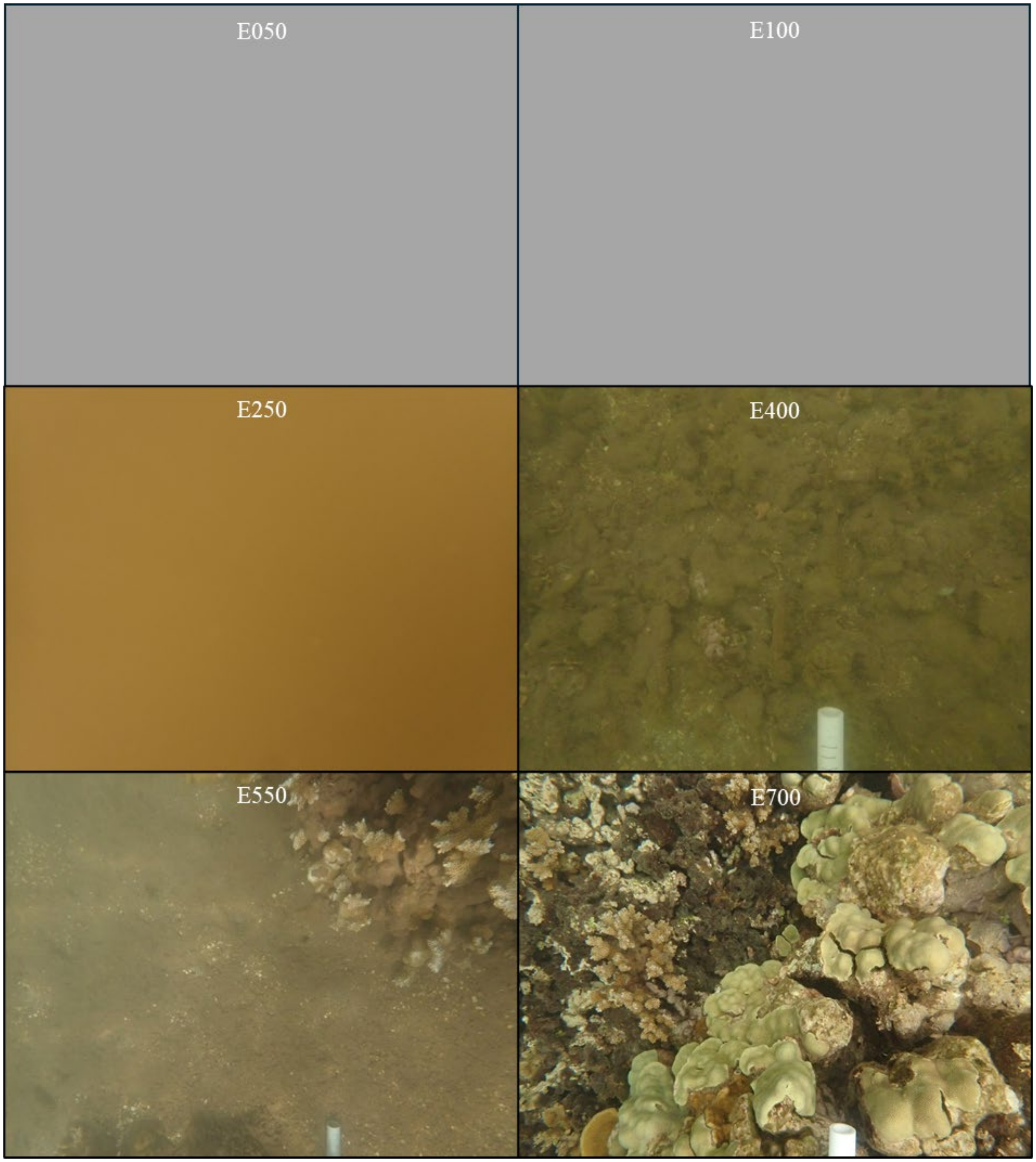
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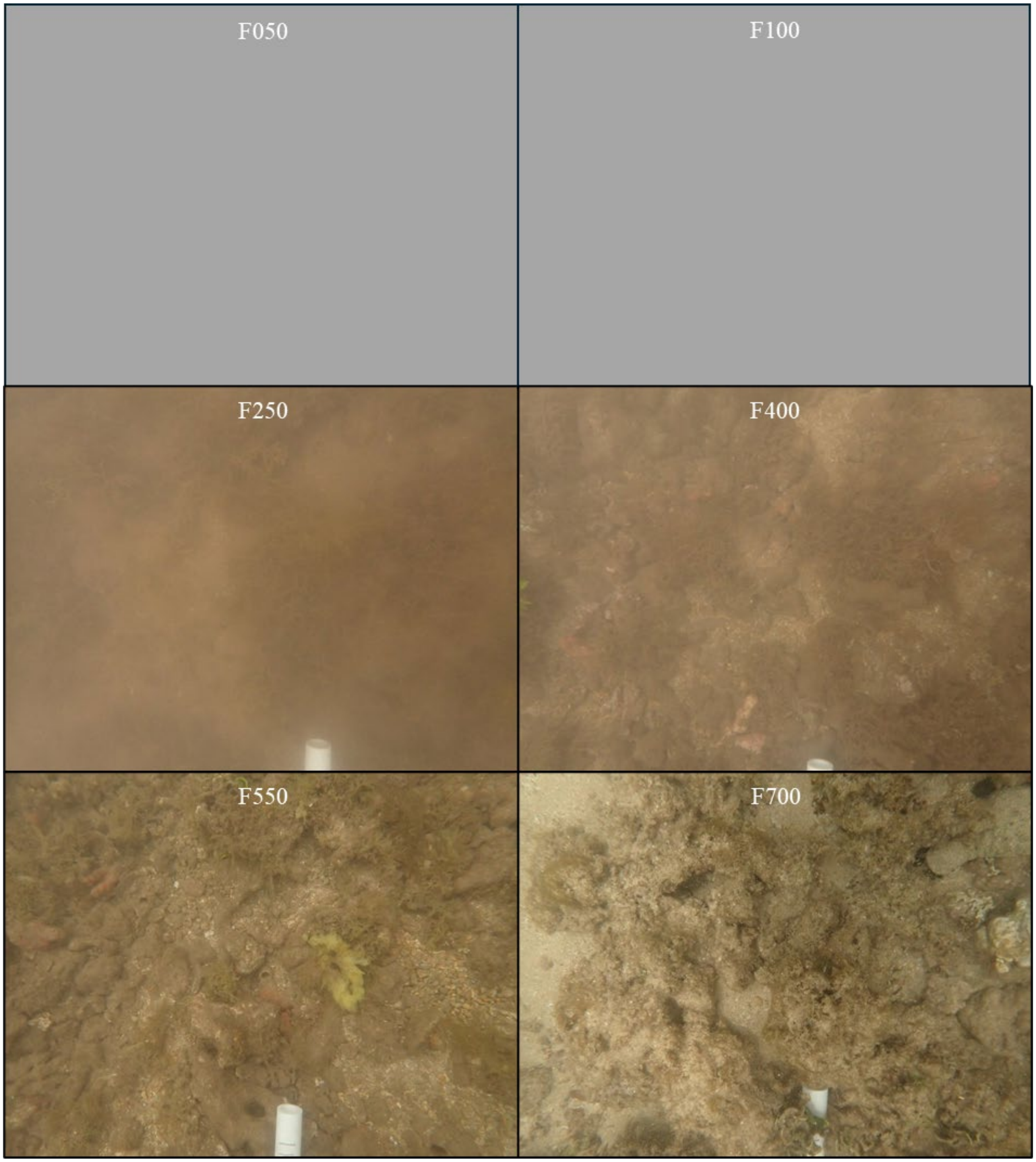
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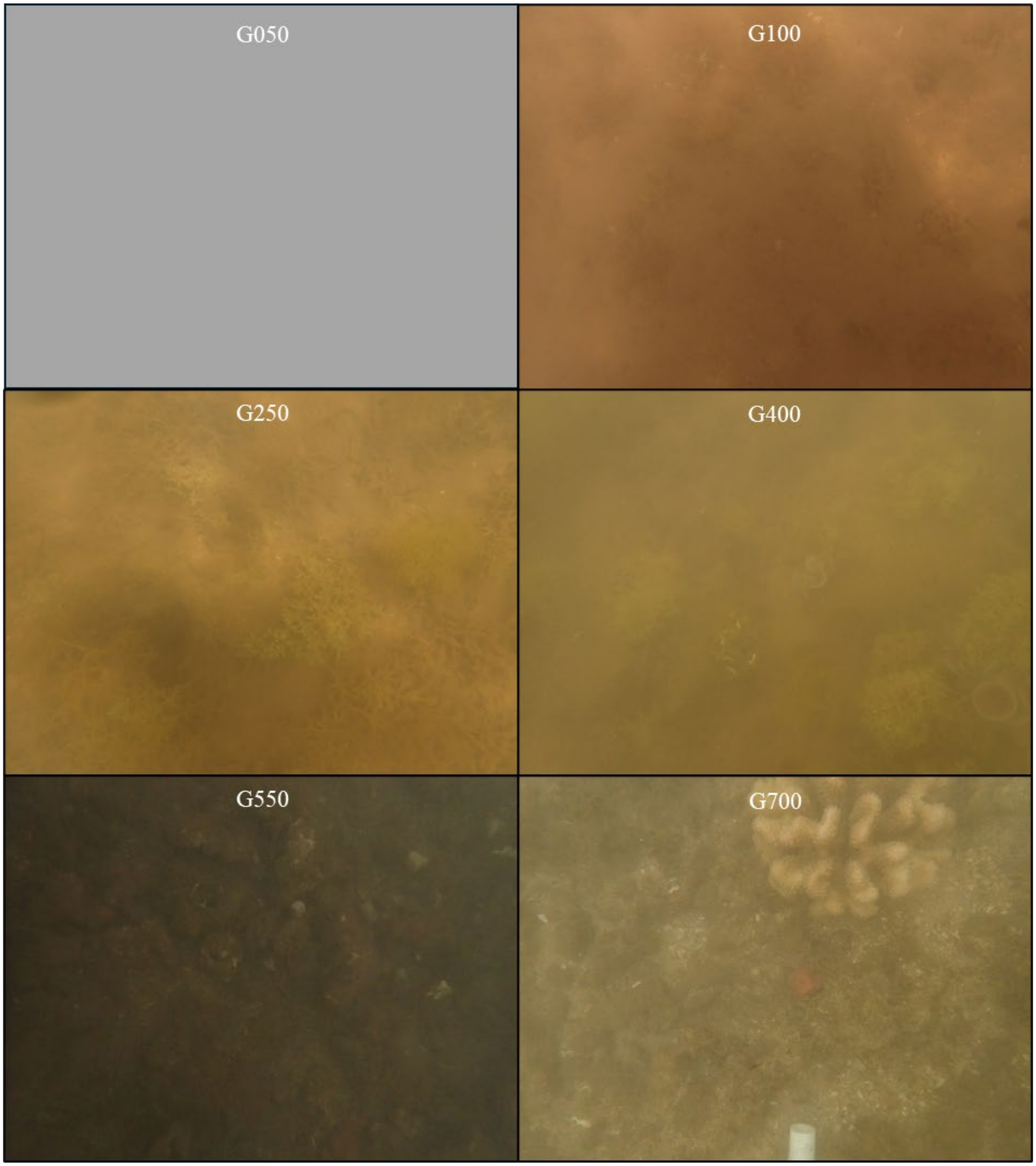
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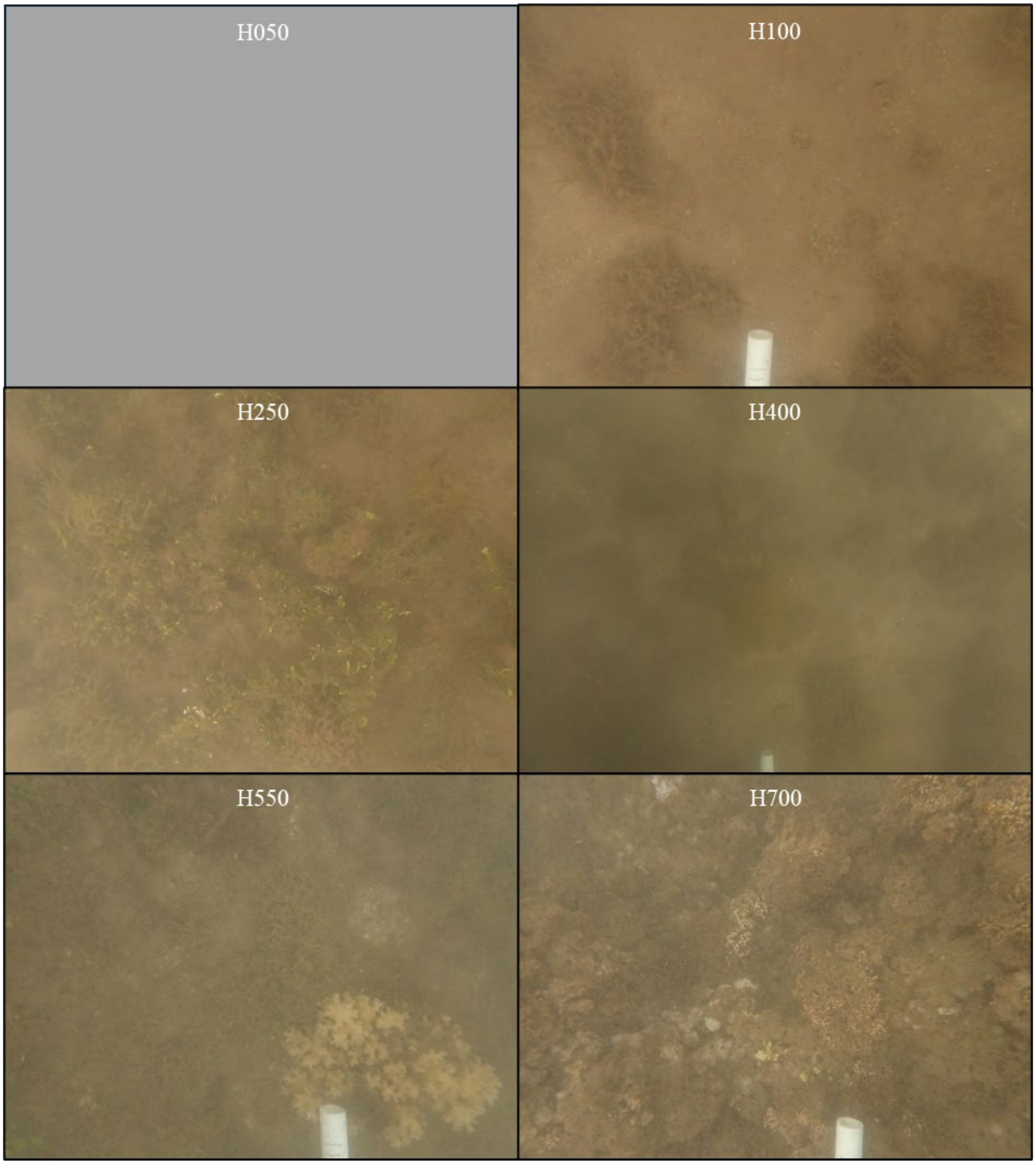
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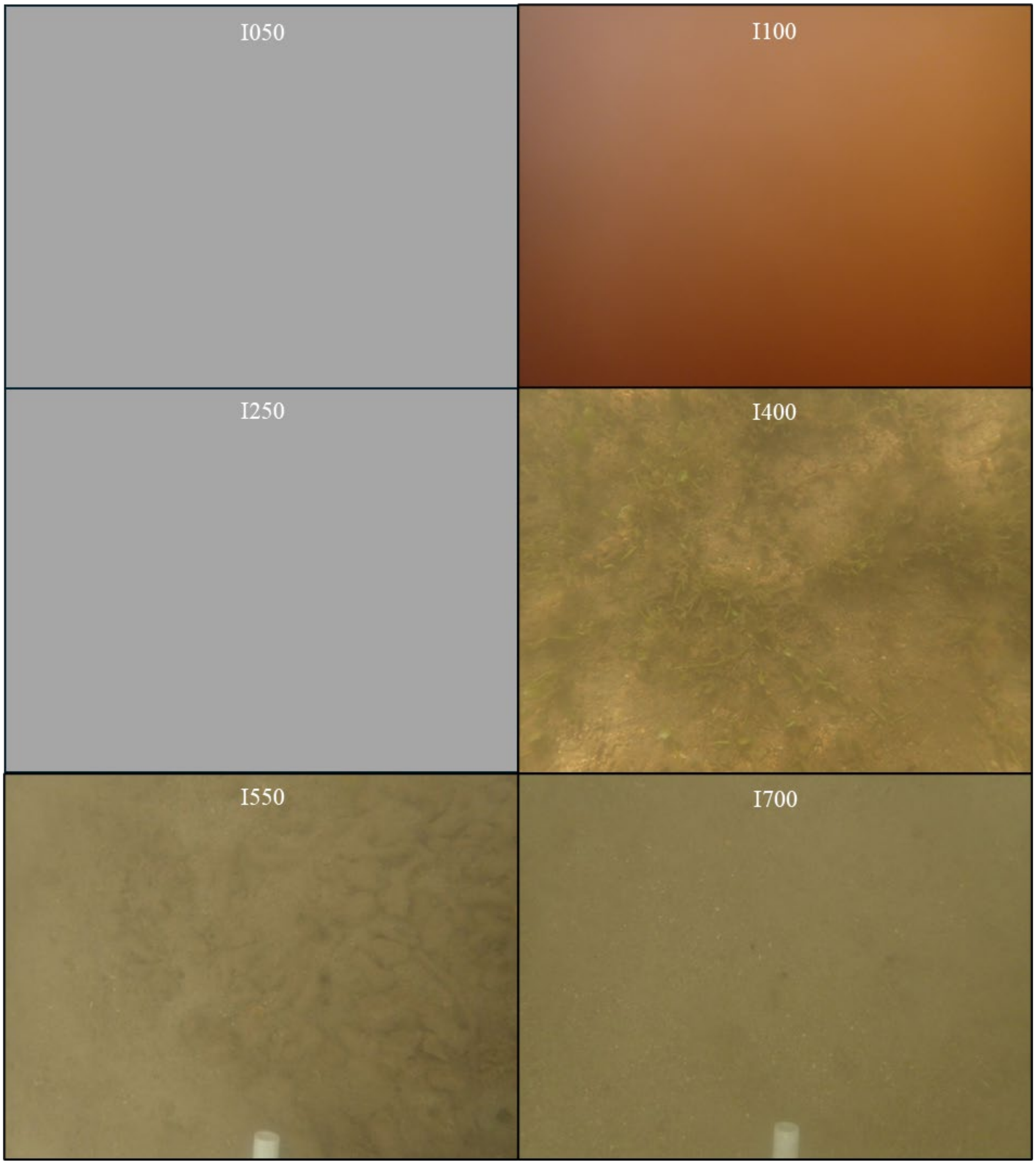
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8. Appendix B. Site Metadata

Latitude, longitude, depth and rugosity for all offshore sites surveyed at Kawela in 2022. Latitude and Longitude values are shared in low resolution to respect community sensitivities with presenting spatially explicit information about fisheries resources.

Site	Lat.	Long.	Depth	Rug.
2023-KAW-002	21.1	-157.0	14.5	1.852
2023-KAW-005	21.1	-157.0	15.7	1.554
2023-KAW-006	21.1	-157.0	1.4	0
2023-KAW-008	21.1	-157.0	17.5	1.207
2023-KAW-011	21.1	-157.0	5	1.5
2023-KAW-014	21.1	-157.0	1.4	1.38
2023-KAW-015	21.0	-157.0	2.7	1.505
2023-KAW-016	21.1	-157.0	2.4	1.196
2023-KAW-017	21.1	-157.0	4.1	1.55
2023-KAW-018	21.0	-157.0	1.8	1.595
2023-KAW-020	21.1	-157.0	5.2	1.121
2023-KAW-023	21.0	-157.0	4.7	1.502
2023-KAW-024	21.1	-157.0	12.8	1.675
2023-KAW-025	21.1	-157.0	0.9	1.013
2023-KAW-027	21.1	-157.0	4	2.15
2023-KAW-028	21.0	-157.0	18.1	1.978
2023-KAW-029	21.1	-157.0	15.5	1.723
2023-KAW-036	21.1	-157.0	6.1	1.23
2023-KAW-037	21.0	-157.0	7.3	1.57
2023-KAW-040	21.0	-157.0	15.4	1.54
2023-KAW-042	21.0	-157.0	10.8	1.575
2023-KAW-043	21.0	-157.0	5.9	1.31
2023-KAW-044	21.1	-157.0	2.3	1.312
2023-KAW-046	21.1	-157.0	12.8	1.71
2023-KAW-048	21.0	-157.0	3.2	1.771
2023-KAW-050	21.1	-157.0	1.8	1.185
2023-KAW-052	21.1	-157.0	1.5	1.4
2023-KAW-054	21.1	-157.0	12.2	1.784
2023-KAW-056	21.1	-157.0	7.6	1.22
2023-KAW-057	21.0	-157.0	7.5	1.495
2023-KAW-058	21.0	-157.0	2.1	1.525
2023-KAW-060	21.0	-157.0	3.2	1.47

Site	Lat.	Long.	Depth	Rug.
2023-KAW-061	21.0	-157.0	8.4	1.57
2023-KAW-063	21.0	-157.0	1.4	1.62
2023-KAW-064	21.1	-157.0	6.6	1.785
2023-KAW-065	21.0	-157.0	1.5	1.32
2023-KAW-066	21.0	-157.0	1.8	1.91
2023-KAW-069	21.0	-157.0	3.7	1.556
2023-KAW-070	21.0	-157.0	16.3	1.709
2023-KAW-071	21.0	-157.0	9.3	1.05
2023-KAW-072	21.1	-157.0	11.1	1.337
2023-KAW-075	21.0	-157.0	14	1.61
2023-KAW-077	21.1	-157.0	13.1	1.01
2023-KAW-080	21.1	-157.0	2.4	1.56
2023-KAW-082	21.1	-157.0	2.4	1.258
2023-KAW-084	21.0	-157.0	1.5	1
2023-KAW-085	21.1	-157.0	14	2.08
2023-KAW-088	21.1	-157.0	3.4	1.598
2023-KAW-089	21.1	-157.0	6.7	1.346
2023-KAW-091	21.1	-157.0	2.9	1.454
2023-KAW-093	21.0	-157.0	11.7	1.719
2023-KAW-100	21.0	-157.0	14	1.625
2023-KAW-Kamalo10m	21.0	-157.0	6.1	1.706
2023-KAW-Kamalo3m	21.0	-157.0	1.2	1.44
2023-KAW-Kamiloloa10m	21.1	-157.0	3.7	1.045
2023-KAW-Kamiloloa3m	21.1	-157.0	1.1	1.16

9. Appendix C: Sediment Summary Statistics

Table C-1

	md2 (N = 54)
Percent Terrigenous	
min	12
max	71
mean (se)	32.31 ± 2.30
Percent Calcareous	
min	2
max	72
mean (se)	46.07 ± 2.71
Percent Organic Carbon	
min	16
max	46
mean (se)	21.59 ± 0.83
Percent Fines	
min	12
max	40
mean (se)	21.65 ± 0.78
Percent Silts	
min	22
max	44
mean (se)	28.59 ± 0.70
Sedimentation Rate	
min	11.57
max	649.4
mean (se)	36; 118.39 ± 24.83
Sedimentation Rate Calm	
min	7.88
max	122.48
mean (se)	12; 53.31 ± 36.34

Table C-2: Sediment summary statistics by transect.

	A (N = 6)	B (N = 6)	C (N = 6)	D (N = 6)	E (N = 6)	F (N = 6)	G (N = 6)	H (N = 6)	I (N = 6)
Percent Terrigenous									
min	13	12	17	16	14	14	13	19	21
max	71	50	68	48	63	50	42	59	52
mean (se)	30.50 ± 10.12	27.50 ± 6.35	37.67 ± 9.41	23.50 ± 5.08	48.67 ± 7.53	29.50 ± 4.98	27.67 ± 4.81	32.67 ± 5.66	33.17 ± 4.91
Percent Calcareous									
min	13	28	4	28	2	20	39	9	24
max	70	72	61	63	66	70	71	61	63
mean (se)	52.33 ± 10.02	53.33 ± 7.70	39.33 ± 10.77	53.50 ± 5.49	27.67 ± 9.07	44.50 ± 8.35	53.67 ± 5.78	44.00 ± 7.49	46.33 ± 5.70
Percent Organic Carbon									
min	16	16	18	18	18	16	16	18	16
max	18	25	29	32	43	46	23	33	24
mean (se)	17.00 ± 0.37	19.00 ± 1.55	22.83 ± 1.66	22.83 ± 2.01	23.83 ± 3.89	25.83 ± 4.55	19.00 ± 1.10	23.50 ± 2.36	20.50 ± 1.18
Percent Fines									
min	14	19	15	12	16	14	14	14	22
max	32	22	28	21	40	26	26	26	28
mean (se)	21.33 ± 2.68	20.33 ± 0.56	20.50 ± 2.19	16.17 ± 1.25	28.50 ± 3.76	20.50 ± 1.63	21.33 ± 2.01	21.33 ± 2.19	24.83 ± 0.91
Percent Silts									
min	23	22	23	23	27	22	27	25	22
max	28	32	41	35	44	34	33	39	42

	A (N = 6)	B (N = 6)	C (N = 6)	D (N = 6)	E (N = 6)	F (N = 6)	G (N = 6)	H (N = 6)	I (N = 6)
mean (se)	25.67 ± 0.76	25.17 ± 1.47	29.00 ± 3.11	28.83 ± 1.97	32.17 ± 2.55	28.83 ± 1.62	29.67 ± 0.95	29.83 ± 2.01	28.17 ± 2.94
Sedimentation Rate									
min	14.43	12.16	11.57	33.24	50.27	171.16	43.01	27.2	24.8
max	16.92	60.79	269.84	148.84	478.19	301.69	70.77	88.81	649.4
mean (se)	4; 15.50 ± 0.53	4; 28.41 ± 11.41	4; 120.22 ± 60.36	4; 83.57 ± 28.88	4; 242.41 ± 112.23	4; 220.36 ± 28.24	4; 54.52 ± 6.71	4; 44.68 ± 14.77	4; 255.81 ± 147.65
Sedimentation Rate Calm									
min	Inf	7.88	Inf	24.43	Inf	51.44	Inf	Inf	Inf
max	-Inf	26.66	-Inf	122.48	-Inf	94.33	-Inf	-Inf	-Inf
mean (se)	0; NaN ± NA	4; 17.32 ± 7.93	0; NaN ± NA	4; 70.13 ± 40.66	0; NaN ± NA	4; 72.47 ± 23.08	0; NaN ± NA	0; NaN ± NA	0; NaN ± NA

Table C-3: Sediment summary statistics by distance from shore

Distance (m)	50 (N = 9)	100 (N = 9)	250 (N = 9)	400 (N = 9)	550 (N = 9)	700 (N = 9)
Percent Terrigenous						
min	13	27	17	15	15	12
max	71	66	63	59	42	58
mean (se)	40.67 ± 7.68	45.33 ± 4.23	33.56 ± 5.32	28.78 ± 4.16	23.44 ± 3.05	22.11 ± 4.86
Percent Calcareous						
min	4	2	17	20	39	19
max	71	52	65	69	67	72
mean (se)	36.78 ± 8.48	29.67 ± 5.87	45.56 ± 5.44	49.56 ± 5.65	57.11 ± 3.38	57.78 ± 5.79
Percent Organic Carbon						
min	16	18	16	16	16	16
max	33	43	32	46	23	28
mean (se)	22.67 ± 2.00	25.00 ± 2.50	20.89 ± 1.61	21.56 ± 3.12	19.44 ± 0.78	20.00 ± 1.39
Percent Fines						
min	16	19	17	16	12	14
max	32	28	27	28	38	40
mean (se)	22.67 ± 1.88	24.00 ± 0.94	21.56 ± 1.14	21.44 ± 1.25	20.89 ± 2.61	19.33 ± 2.96
Percent Silts						
min	24	22	22	23	23	22
max	41	44	42	31	34	32
mean (se)	31.33 ± 1.86	30.78 ± 2.36	29.33 ± 1.97	27.11 ± 0.96	26.78 ± 1.13	26.22 ± 1.09
Sedimentation Rate						
min	16.92	15.56	12.64	11.57		
max	478.19	649.4	171.16	301.69		

Distance (m)	50 (N = 9)	100 (N = 9)	250 (N = 9)	400 (N = 9)	550 (N = 9)	700 (N = 9)
mean (se)	177.44 ± 51.90	186.24 ± 69.75	48.95 ± 16.09	60.91 ± 30.78		
Sedimentation Rate Calm						
min	19.82	26.66	14.9	7.88		
max	122.48	90.46	51.44	59.4		
mean (se)	3; 78.88 ± 53.05	3; 63.78 ± 33.16	3; 30.26 ± 18.95	3; 40.31 ± 28.23		

10. **Appendix D: Outreach Materials**

Two-page outreach document prepared to share the project at the Molokai Earth Day 2023 celebration and solicit community input and observations.

MAUKA: A HOTSPOT FOR EROSION

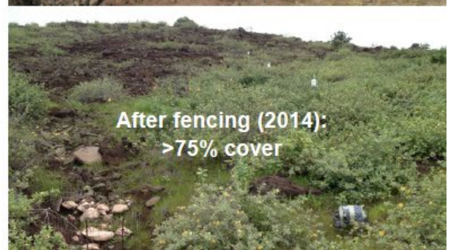
Kawela is one of the largest watersheds in the East Molokaʻi mountain range. The reef system fronting this watershed is part of the longest, continuous fringing reef in the United States, extending approximately 30 miles along the island's southern coastline. The reef has been characterized as one of the best examples of coral ecosystems in the state of Hawaiʻi and is a significant food source for residents of Kawela and the larger community.

This reef system has been inundated by sediment from erosion since the introduction of cattle in the 19th century and is driven today largely by the destructive grazing of feral goats, deer, and other hooved animals, converting native ecosystems to bare ground. The forks of Kawela stream and the associated gulch comprise one of the largest outflows along the island's southern coastline which for many decades has delivered tons of sediment to the nearshore reef.

To reduce erosion and sediment flowing onto the reef, the East Molokaʻi Watershed Partnership went to work installing animal-proof fences over portions of the Kawela watershed from 2006-2021. During that time, the US Geological Survey conducted a study in the middle elevations of Kawela on a fenced/unfenced area to see if the impacts from goats could be reduced with fencing. Their study confirmed that vegetation cover increased from 1% to 75% in just seven years!

Sediment export within the Kawela watershed dropped dramatically, from an average of 7,100 tons to 1,850 tons annually, thanks to these efforts effectively reducing feral goat activity and leading to substantial revegetation of the area.

To expand on the successes seen at Kawela, the Division of Forestry and Wildlife and The Nature Conservancy, with support from the National Fish and Wildlife Foundation, began a project to fence the Kawela watershed in 2022. The sediment load is expected to decrease by an additional 1,500 tons per year.



Photos: (Header) Jowell Guerreiro/TNC, (Before/After) Russell Kallstrom/TNC, (Coastal sediment) Kim Falinski/TNC, (Fish/Coral) Mike Field/USGS

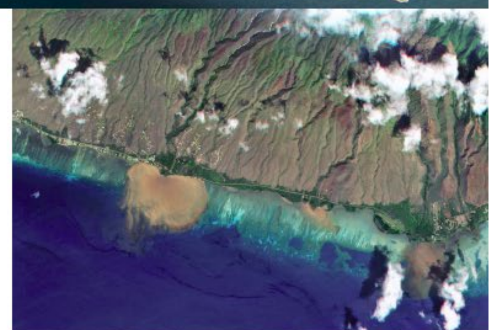
MAKAI: A CHANCE TO MEASURE CHANGE

Conducting makai surveys is an opportunity to see how the reef has changed as a result of mauka management.
In the early 2000s, to understand the sediment impacts on the reef, the Hawai‘i Institute of Marine Biology and US Geological Survey conducted studies that documented water clarity harmful to corals, declines in coral settlement due to sedimentation, and reductions in coral cover offshore and downstream. In April and May 2023, TNC is replicating these two in-water studies to understand how sediment reduction on land has impacted Moloka‘i’s nearshore waters between Kaunakakai and Kamalō.

Sediment surveys *(April 10-21)*: These kayak-based surveys are conducted in the shallow reef to identify where sediment is impacting the reef and where the reef is healthy. Findings from this study can show changes in the nearshore following 15 years of upland fencing and management.

Reef and Fish surveys *(end of April/early May)*: These boat-based SCUBA surveys take place offshore on the deeper reef to assess the health and abundance of coral and fish at 60 sites. Survey methods mirror those used by the Division of Aquatic Resources and others, which allows TNC to compare findings with past surveys and to other locations in Hawai‘i. However, to avoid publicizing detailed information on fisheries, none of the fish data will be paired with spatial data, meaning the data will not be associated with site-specific locations.

What do you think we should be looking at?
Mahalo for taking the time to learn about these efforts along the southern coast of Moloka‘i. We’d love to hear what you’re observing in this area and are interested in hearing more about!



HOW TO GET INVOLVED & LEARN MORE

Contact Jowell Guerreiro, TNC Moloka‘i Program Coordinator:
jowell.guerreiro@tnc.org

Photos: (Map) Ryan Carr/TNC, (Coastline aerial) Planet Labs 2015, (Kayak survey) Kim Falinski/TNC, (Divers) David Slater

Three-page outreach document prepared to share the project and the preliminary results at the Molokai Earth Day 2024.

Kawela, Mauka to Makai

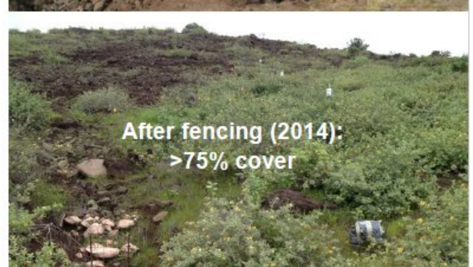
MAUKA: A HOTSPOT FOR EROSION

Kawela is one of the largest ahupua'a and watersheds in East Moloka'i. The area's coral reef ecosystem is part of the longest, continuous fringing reef in the United States, extending approximately 30 miles along the island's southern coastline. The reef has been characterized as one of the best examples of coral ecosystems in the state of Hawai'i and is also an important fishing area for residents of Kawela and the larger Moloka'i community.

This reef system has been inundated by sediment from erosion since the introduction of cattle in the 19th century. Today, this erosion is driven largely by the destructive grazing of feral goats, deer, and other hooved animals, which convert native ecosystems to introduced vegetation and bare ground. Kawela stream and its tributaries comprise one of the largest drainages along the island's southern coastline which for many decades has delivered tons of sediment to the nearshore reef.

To reduce erosion and sediment flowing onto the reef, the East Moloka'i Watershed Partnership went to work installing fences to keep out hooved animals over portions of the Kawela watershed from 2006-2021. During that time, the US Geological Survey conducted a study in the middle elevations of Kawela on fenced and unfenced areas to see if the impacts from feral goats could be reduced with fencing. Their study confirmed that vegetation cover increased in the fenced area from 1% to 75% in just seven years!

Sediment export within the Kawela watershed dropped dramatically, from an average of 7,100 tons to 1,850 tons annually. The recovery was a result of the efforts to effectively reduce feral goat activity allowing substantial revegetation of the area by native plants. **To expand on the successes seen at Kawela**, the Division of Forestry and Wildlife and The Nature Conservancy, with support from the National Fish and Wildlife Foundation, began a project to fence the relatively inaccessible mid- and lower-elevations of Kawela gulch in 2022. This work is expected to decrease sediment loads by an additional 1,500 tons per year.



MAKAI: A CHANCE TO MEASURE CHANGE

Conducting makai surveys is an opportunity to see how the reef has changed as a result of mauka management.
In the early 2000s, to understand the sediment impacts on the reef, the Hawai'i Institute of Marine Biology (HIMB) and US Geological Survey (USGS) conducted studies that documented water clarity harmful to corals, declines in coral settlement due to sedimentation, and reductions in coral cover offshore and down current. In April 2023, TNC replicated these two in-water studies on reef flat and reef slope habitat between Kaunakakai and Kamalō to understand how sediment reduction on land has impacted these 10 miles of Moloka'i's nearshore waters.

Reef Flat Sediment Surveys *(April 10-21, 2023)*: These kayak-based surveys were conducted on the shallow reef to identify where sediment is impacting the reef and where the reef is healthy. Findings from this study can show changes following 15 years of upland fencing and management.

Reef Slope and Fish Surveys *(April 22-28, 2023)*: These boat-based SCUBA surveys took place offshore on the reef slope. Surveyors collected data to assess the health and abundance of coral and fish at 60 sites. Survey methods mirror those used by the Division of Aquatic Resources and others previously, which allow TNC to compare findings with past surveys and to other locations in Hawai'i. To avoid publicizing detailed information on fish locations, none of the fish data are paired with spatial data, meaning the data cannot be associated with specific locations.

HOW TO GET INVOLVED & LEARN MORE

Contact Jowell Guerreiro, TNC Moloka'i Program Coordinator: jowell.guerreiro@tnc.org

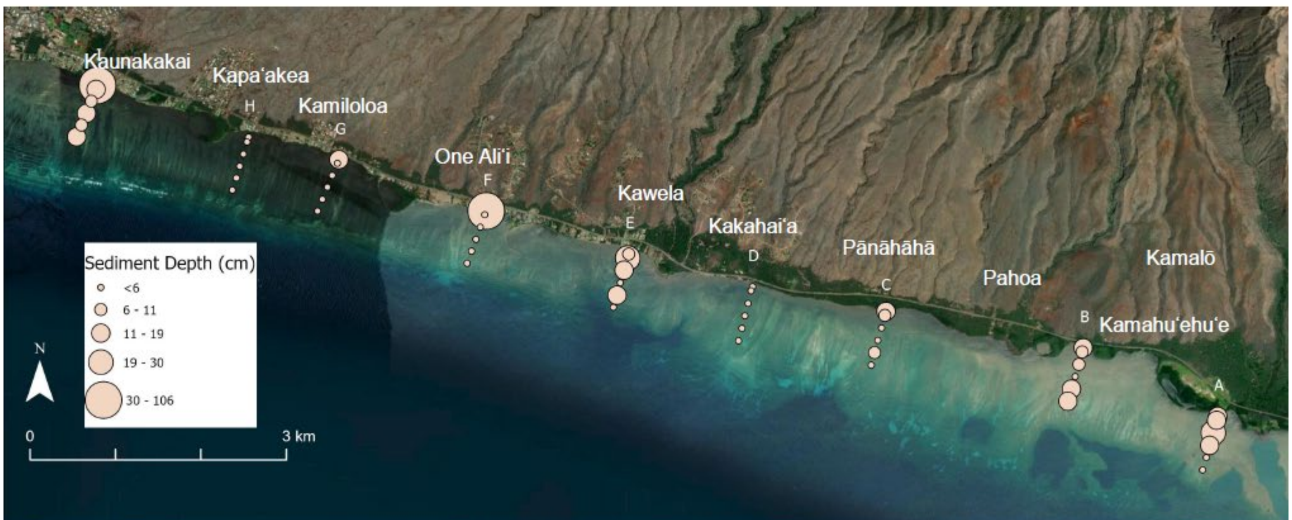
Photos - Page 1: (Header) Jowell Guerreiro/TNC, (Before/After) Russell Kallstrom/TNC, (Coastal sediment) Kim Falinski/TNC, (Fish/Coral) Mike Field/USGS; Page 2: (Map) Ryan Carr/TNC, (Coastline aerial) Planet Labs 2015, (Kayak survey) Kim Falinski/TNC, (Divers) David Slater; Page 3: (Maps) Ryan Carr/TNC

WHAT OUR FINDINGS SAY IN APRIL 2024

Our data provide a snapshot into what current sediment and coral conditions look like between Kaunakakai and Kamalō. The coastal system of this area is highly variable, changing every day with wind, and yearly with storm events. A single storm event can pile up sediment on beaches and in the nearshore from ankle to hip deep in some places. This can last for months but can eventually clear up.

Sediment Depth & Coral Cover

There are portions of the reef flat that have comparatively good coral populations. On the far west side of the project area closest to Kaunakakai, there is major sediment impact and very little live coral. On the far east side near Kamalō, there is less sediment impact and more areas of live coral. The central portion near Kakahaiʻa is less impacted by sediment and has more live coral, including more live coral close to shore.



THIS ANALYSIS IS PRELIMINARY

We are working to compare our 2023 data to the HIMB and USGS data from the early 2000s. We anticipate having this analysis complete and to share it with the Molokaʻi community in the summer of 2024.

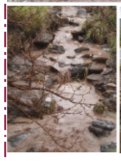
Suggested Citation: The Nature Conservancy. 2024. Summary of Findings, 2023 Sediment, Coral Reef, and Fish Surveys, Kawela, Molokaʻi. 3 pp.

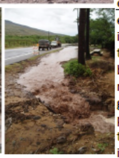
TNC Publication shared with Molokai residents with a summary of the project and solicitation for questions and input.

Kawela Recovery

By Russell Kallstrom, TNC Molokai Program Manager

While upper reaches of Kawela are intact forest, middle to lower areas have experienced soil erosion at a rate up to 100x natural. According to USGS, a research organization studying the issue since the 1990's, this erosion was due to goats, which were eating their way up the mountain, leaving behind only rock and dirt. When it rains, that washes down into the stream, and is deposited on the coral reef, coating the reef in up to half a foot or more of sediment (mud) in places, choking fish and *limu*, a key food source for Molokai people. Reef damage occurs long after rain stops however, because trade winds kick up the sediment every day until it can move off the reef, which one USGS scientist estimated can take up to 10 years. To address this problem, the East Molokai Watershed Partnership (EMoWP) with the support of landowners and cultural practitioners, constructed a 5'-6' goat fence across upper Kawela in 2006-2007 and began intensive animal control in steep gulches there in 2009. Vegetation rebounded– USGS's study plot went from 1% cover to over 75% cover as the erosion rate dropped 10-fold in the study plot (see photo right). Comparing Kawela Stream gage data since fencing and animal control began, the amount of sediment on average in the Kawela stream has dropped by almost 100 fully loaded semi-tractor trailers worth of dirt in the stream per year (~4000 short tons annually). As less dirt was entering the stream, discharge (liquid volume of water/time) went up as well, indicating that on average, the stream was now flowing cleaner, too. Nevertheless, with almost 30 fully loaded tractor trailers of sediment still potentially being dumped out on the reef every year, it's apparent more could be done to reduce Kawela's erosion and protect the reef, namely by fencing the main gulch system, an action which the EMoWP began pursuing in 2021. When protected from the browsing by hooved animals, vegetation along the sides of the gulch is expected to increase and act like a filter, catching sediment before it fills the stream and is ejected on the reef. Fencing only the gulch will not only reduce sedimentation on the reef, it avoids the costly alternative of fencing the entire ahupua'a while maintaining hunting opportunities for residents on vast unfenced areas that can be safely ground hunted. Over time, the need for aerial shooting in steep gulches that are fenced would be reduced as well, allowing management resources to be directed to other high priorities. This year, the Conservancy's marine team repeated USGS's 2005 reef study and in another 6 months, will be analyzing that information to see how the reef has changed since management began. Please email us (Jowell Guerreiro, Jowell.guerreiro@tnc.org) if you're interested in hearing more about those latest results.





Mahalo Nui Loa for your kōkua!

Volunteers & Partners

July 2022 – June 2023

He waiwai nui ka lōkahi — "Unity is a precious possession." -'Ōlelo No'eau # 977

Partners: 'Āina Momona, 'Āina Pulapula, 'Aha Kiole, Alu Like, Americorps Hawaii, Bayer, Division of Aquatic Resources (DAR), Department of Hawaiian Homelands, Department of Land & Natural Resources— Division of Forestry & Wildlife, Division of Conservation & Resources Enforcement (DoCARE), Native Ecosystems Protection & Management (NEPM), Department of Transporation Highways, Department of Water Supply, Dunbar Ranch, Dunnam Ranch, Friendly Isle Auto, Friendly Market Center, Haku Designs, Hawaii Association of Watershed Partnerships, Hawaii Commission on Water Resource Management, Hawaii Emergency Management Office, Hawaii Farmers Union United, Hawaii Rural Water, Ho'ahu Energy Cooperative, Hui o Kuapa, Hui Malama o Mo'omomi, Ka Honua Momona, Ka Pa Hula o Hina I Ka Po La'ila'i, Kalaupapa National Historic Park, Kamehameha Schools, Kapualei Ranch, Kawela Plantation Homeowners Association, Kilohana Elementary School, Kualapu'u Public Charter School, Kumu Farms, KUPU Hawaii Youth Conservation Corps, Mana'e Mauka Working Group, Maui County Council, Maui County Fire Department, Maui County Fire & Public Safety Commission, Maui County Office of Economic Development, Maui County Parks & Recreation, Maui Forest Bird Recovery Project, Maui Nui Seabird Recovery Project, Maui County Recycling, Misakis Inc., Mokulele Airlines, Molokai Arts Center, Molokai Community Health Center, Molokai Fire Department, Molokai High School, Molokai Human Society, Molokai Hunting Club, Molokai Island Services, Molokai Maui Invasive Species Committee (MoMISC), Molokai Land Trust (MLT), Molokai-Lanai Soil and Land Conservation District, Molokai Plant Extinction Prevention Program (MoPEPP), Molokai Portapotties, Molokai Police Department, Molokai Properties Ltd., National Oceanic & Atmospheric Agency (NOAA), National Fish & Wildlife Foundation, Nene o Molokai, O Hina I Ka Malama, Office of Hawaiian Affairs, Pacific Birds Habitat Joint Venture, Papahana Kuaola Lelekamanu, Pono Pacific Land Management, Public Works, Pu'u o Hoku Ranch, Rawlins Texaco, Snail Extinction Prevention Program (SEPP), Sustainable Coastlines Hawaii, Sustainable Molokai, TNC Maui Marine Program, University of Hawaii—CTAHR/RCUH, U.S. Army Corps of Engineers, U.S. Department of Agriculture—Natural Resources Conservation Service (NRCS), U.S. Fish & Wildlife, U.S. Geological Survey (USGS), Wiliwli Hawaiian Plants, Windward Aviation, YMCA. **Individuals:** Adrian "Mataio" Sibayan, AK Shingle, Akita & Marietta Alapai, Ali Lucas, Alicia Edgar, Andrew Aoki, Andrew Gomes, April Kealoha, Audrey Newman, Barbara & Charles Bostwick, Barbara Kalipi, Brittany Speier, Cammy & Ron Kimball, Cheryl Corbiell, Chris Forster, Christopher Lightfoot, Clint Arnold, Cyrus Siu, Dan Bennett, Dan McGuire, David Lima, Dennis Keanini, Denise, Ed & Matthew Epperson, Dianthe Kaili, Earl Dunnam, Eddie & Wina Tanaka, Eesha & Wayde Phifer, Ehiku Arnold, Ekolu, Susan & Willie Ah Yee, Eliza Chang, Emilio Macalalad, Erica Espaniola, Evelyn Haase, Gyson Aalona, Hiikapu Lima, Hoku Bailey, Iokewe Moses, Jake Merkel, Jennifer Webster, Jesica Parker, Joe & Diana Kitagawa, John Habon, Joseph Chong, Kaeo & Malia Waitts, Kahiki, Kaupoohiwi & Kekama Helm, Kailiah Chong, Kamalii Demello, Kaniala "Moke" Makekau, Kathy Tachibana, Kauionalani Kalima, Kawai Spencer, Kawehi Soares, Kealoha, Kevin & Mahinahina Comcowich, Kekoa Hanapi, Kira-Kai Yamazaki-Gray, Kolby Dudoit-Alapai, Laila Juario, Lloyd & Linda Yonemura, Lono & Waila'ahia Lima-Maioho, Lynette Williams, Maile McLaughlin, Malia & Wiliama Akutagawa, Margaret "Lapeka" Makekau, Mapuana Dudoit, Megan Meyer, Miki'ala Pescaia, Nadine Powell, Opu'ulani Albino, Patrick & Denise Kawano, Penny Martin, Rachel "Lahela" Kalima, Randyn Cabreros, Rikki Cooke, Robert Bento, Sonja Angst, Shirley Lightfoot, Stephanie Dunbar-Co, Steven Pua'a, Sybil Lopez, Tehani Kaalekahi, Thomas-Kekai Kalima-Preciado, Tim Paul, Timothy Robinson, Torrey Goodman, Valerie Corcoran, Walter Ritte.

EMoWP Update: Mākolelau now in final stages of transfer to State Forest Reserve lands through TNC, State and USFWS partnership. See: www.nature.org/en-us/newsroom/makolelau-acquisition/

Guided Preserve hikes to Kamakou and Mo'omomi are back!
Hikes occur from March through October.
Email HIKE_MOLOKAI@TNC.ORG to reserve a spot today!

The Nature Conservancy
Hawai'i and Palmyra

Funding for Nature's Newsflash is provided in part by the State of Hawai'i Natural Area Partnership Program.

Mahalo for supporting Conservation work island-wide! Have a Blessed Summer (:

Nature's Newsflash

Aloha! Nature's Newsflash is a semi-annual publication that features stories and insights of conservation activities that help preserve and protect Moloka'i's native natural resources. If you would like to contribute information to our publication, please send to:
The Nature Conservancy, P. O. Box 220, Kualapu'u 96757

Let's all make a difference by "Thinking globally, Acting locally"

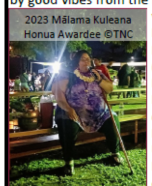
July 2023 Issue

Molokai Earth Day Back in Action

By TNC Molokai Staff

Teoraroa keiki showing off theirTahitian skills. ©TNC

The Molokai Earth Day celebration on April 21st was a splendid success! Coordinated by the Nature Conservancy and co-sponsored by the County of Maui and the East Molokai Watershed Partnership, and this year's theme was "Pili 'umauma i ke ala ola honua"- Unity forges a path for Earth's survival. The event brought the Molokai community back together to honor Earth and 'āina after a three-year pandemic-pause, and to enjoy, learn and hear updates from over 30 exhibitors made up of conservation, education & health professionals. Emceed by Brian "Da Hawn" Naeole, the event commenced with the spiritual blessings of kupuna wahine, 'Ōpu'ulani Albino. With a bangin' beat of the drums, local entertainment began with the lovely Tahitian of Teoraroa, followed by good vibes from the Kalaupapa Backyard Band, and closing with the heartwarming voice of Keaka Kaiama. Playing catch up, three recipients were honored with the Mālama Kuleana Honua (caring for the Earth responsibly) Award: Colette Machado (2021), Kauka Noa Emmett Aluli (2022), and Malia Akutagawa (2023, see photo left), pivotal leaders of unity in action for Molokai. Congratulations to the grand prize raffle winners— Lauren Foster ($100 gas), Maddie Foster (Bike), Eli Albino (Dry Box), and Darlene Umemoto (round trip airfare). Special shoutout to Maui County Parks and Recreation and Mitchell Pauole staff, 2023 Earth Day Committee: Penny Martin, Dan Bennett, Robert Bento, Mapuana Dudoit, Emilio Macalalad, Ali Lucas, Sonja Angst, Jesica Parker, Tehani Kaalekahi, and Kathy Tachibana, and Molokai businesses & donors— Bayer Molokai, Bennett Pottery, Cyrus Siu, Dennis Keanini, Dr. Daniel McGuire, Friendly Market Center, Friendly Isle Auto Parts, Lloyd Yonemura, Misaki's Inc., Mokulele Airlines, Molokai Bicycle, Molokai Federal Credit Union, Molokai Police Department, Molokai Portapotties, Molokai Properties LLC., Patrick & Denise Kawano, and Rawlins Texaco— that continue to kokua to make this event successful. Mahalo to all the hardworking volunteers, exhibitors, raffle prize donors and partners who have made this 29th annual Molokai Earth Day celebration possible!

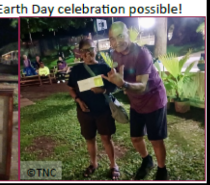


2023 Mālama Kuleana Honua Awardee ©TNC

©Debbie Delatour

Eventgoers inside MPC Exhibition Hall ©TNC

©TNC



©TNC

E Ola I Ka Wai

By Jowell Guerreiro, TNC Molokai Program Coordinator

Water is life—a vital element for all living things. On islands 2,500 miles from the nearest continent, Hawaiians knew that *wai* (freshwater) is *waiwai* (valuable). This is observed in many proverbs such as, *Ola i ka wai a ka 'ōpua "There is life in the water from the clouds" and Hahai nō ka ua i ka ululā'au* "Rain follows the forest" ('Ōlelo No'eau #2482 & #405); a description of the relationship between weather and our watersheds (areas of land that collect *wai*). Furthermore, the health of our forests is the health of our freshwater. Water collection is a function of every forest, but a Native Hawaiian forest outshines all of them. Acting like a giant living sponge, thick *'Ōhi'a* canopies intercept rainfall causing water to trickle down into a dense understory of *Hāpu'u* ferns, *Maile* vines, mosses, etc., traveling into fertile soil and seeping deep into our aquifers for human use. Even without rain, plants in

(E Ola continued on page 3)

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