MARINE ENVIRONMENTAL MONITORING PROGRAM

FOR THE NATURAL ENERGY LABORATORY OF HAWAII AUTHORITY

SURVEY REPORT April 2013

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EXECUTIVE SUMMARY

The Natural Energy Lab of Hawaii Authority is a state agency that operates a Hawaii Ocean Science and Technology Park at Kailua-Kona on the Island of Hawaii focused on research, education, and commercial activities that support sustainable industry development in Hawaii. Near shore marine resources in this area (Keahole Point) have long been recognized as very abundant and diverse, especially the near shore fish community. After the building of NELHA, which included infrastructure on the reef, a comprehensive monitoring program was commenced to ensure the long term health and protection of marine systems in the area. This monitoring program includes water quality, anchialine shrimp ponds, benthic communities and near shore fish communities.

Since 1989 a series of more than 30 surveys has been conducted and extensive reports have been prepared. Results, summaries and references for these reports can be found throughout this report which presents the results of the 2013 survey.

The anchialine ponds in the vicinity of the NELHA facility form northern and southern complexes consisting of five ponds in the North group and nine in the South group. A faunal census of each pond in the vicinity of the NELHA facility was undertaken on the 4th and 5th of April 2013. Temperature and salinity measurements were taken and visual observations of organisms within each pond were supplemented by photographs and high-definition video.

The results of the 2013 anchialine pond survey were consistent with previous surveys. Based on the faunal census performed, the anchialine ponds in the vicinity of the NELHA facility in which exotic fish were not present, supported communities of abundant and diverse native organisms. Further, ponds with fish had clear water and were not overgrown by opportunistic algae. This may indicate that the ōpae ʻula were still active in the ponds at night to avoid predation by the introduced fish.

There are six survey sites located along the NELHA coastline, containing three 50 m transects at one of three depths, 15 ft., 30 ft., and 50 ft. representing three different habitat zones. Benthic biota studies have shown a gradual increase in coral cover over time with *Porites meandrina* and *Porites lobata* always among the dominant species. Data from the present study show a similar pattern.

Over all, coral cover across the six study sites in 2013 was 52%, a statistically significant increase compared to last year. The two most dominant corals were *Porities lobata* (29.67%) and *Pocillopora meandrina* (12.42%) which were present on all transects. Other corals present were *Leptastrea bewichensis, Montipora capitata, Montipora flabellata, Montipora patula, Pavona varians,* *Pocillopora eydouxi, Pocillopora lingulata, Pocillopora meandrina, Porites compressa, Porites lutea and Fungia scutaria.* These corals accounted for approximately 10% of the coral cover.

The fish community was monitored at the same 6 sites as the benthic community but on 25 meter transects. Historical results show a highly variable fish community from year to year. Data from the 2013 study were significantly higher than 2012 although lower than 2010 findings. Some of that may be attributable to natural variation and some of it is likely due to survey techniques which will continue to be modified and improved in future surveys.

The results of the anchialine pond biota, benthic biota and near shore fish biota studies all support the conclusion that the habitats and communities adjacent to the NELHA facility are not impacted by human-mediated inputs.

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ANCHIALINE POND SURVEY

INTRODUCTION

The anchialine habitat is characterized by land-locked brackish bodies of water influenced by input from terrestrial groundwater and tidal influx from the marine environment. Interest in this habitat, described by Holthuis' (1973), stemmed from observations of a group of shrimp species that shared red coloration and an apparent restriction to this habitat that is distributed globally throughout the tropics. Anchialine systems are reported from over 30 islands within in the Pacific Ocean, the Western Indian Ocean, on Ascension Island in the Atlantic Ocean, as well as inland sites in North America, Mesoamerica, and at Ras Muhammad in the Red Sea (Chace & Manning, 1972; Holthuis, 1973; Maciolek, 1983; Iliffe, 1991; Hobbs, 1994; Brock & Bailey-Brock, 1998). Anchialine systems are commonly found along the shoreline of West Hawaiʻi, but also occur on Oʻahu, Maui, Molokaʻi, and Kahoʻolawe (Brock *et al*., 1987; Bailey-Brock & Brock, 1993).

The environmental conditions of anchialine systems often result in groups of native and/or endemic species (Peck, 1994). As elsewhere, the organisms found in the anchialine system throughout Hawaiʻi are uniquely suited to this habitat including plants, mollusks, arthropods, and other taxa. Table 1 summarizes the species previous reported from the ponds located near Keāhole Point, Hawaiʻi. However, these sites are primarily distinguished by the presence of two decapod shrimp species *Halocaridina rubra* (ʻōpae ʻula) and *Metabetaeus lohena*. Due to the critical role in the ecology of this unique habitat in Hawaiʻi, the fate of the habitat is intimately tied to that of *Halocaridina rubra*.

Ōpae ʻula utilize the ponds to feed, but most of the reproduction and dispersal within the anchialine system occurs in the subterranean (hypogeal) portion of the habitat. *Halocaridina rubra*, through its grazing mode of feeding, maintains a standing crop of plants, bacteria, diatoms, and protozoans that prevents overgrowth by opportunistic algae (Bailey-Brock & Brock, 1993). This 'gardening' contributes to the overall health of the anchialine communities in Hawaiʻi allowing other species to exploit the sunlit (epigeal) portion of the habitat. This shrimp, therefore, plays the role of keystone species. However, the effect on and response of ʻōpae ʻula to the introduction of exotic fish species into the anchialine habitat has been to either reduce their abundance through increased predation or to precipitate a shift in their foraging behavior (Capps *et al*., 2009) forcing them to be active at night. This has led to ponds in which exotic fish have become established being devoid of shrimp species during the day.

Additionally, the coastal areas of Hawaiʻi in which anchialine systems are found have been the focus of development, which has led to efforts to conserve and manage these resources from possible anthropogenic impacts. Recent investigations using techniques to examine the DNA of this species has provided a better understanding of their population dynamics and contributed to effective planning and management of anchialine resources in Hawai‘i. A study to elucidate the structure of *Halocaridina rubra* populations from the island of Hawai‘i has shown there to be two distinct lineages on the east and west coasts, and that within small geographic areas along each coast the populations are structured with low levels of gene flow (Santos, 2006). This suggests that monitoring of the anchialine ecosystem in Hawai‘i should be center at local scales, i.e. at the level of ponds and pond complexes, as is the case at the NELHA facility at Keāhole Point. While the pools offer windows into the cryptic habitat of *Halocaridina rubra*, generally, the two groups of ponds in the vicinity of the NELHA facility have been surveyed for more than 35 years (see Brock, 1995, 2002, 2008; Oceanic Institute, 1997, 2007; Ziemann & Conquest, 2008; and included citations). Through the continuing monitoring program at these sites, a change in the community of organisms has been noted by surveys after 1989 with the endemic shrimp species becoming absent in a number of the ponds (Brock, 2008; and Ziemann & Conquest, 2008). This may be explained by the establishment of exotic, poecilid fish species in ponds south of the NELHA facility. The findings of the April 2013 anchialine ponds survey as part of NELHA's Comprehensive Environmental Monitoring Program (CEMP) are reported herein.

METHODS

The anchialine ponds in the vicinity of the NELHA facility form northern and southern complexes (Figure 1) consisting of five ponds in the North group and nine in the South group. The northern pond complex, ponds N -1 to N - 5, was roughly 100 m inland of the cobble beach at Hoona Bay (Figure 2), and the southern complex, ponds S – 1 to S – 9, were 200 – 225 m from the shore at Wawaloli Beach Park adjacent to Makako Bay Drive (Figure 3). Table 2 details the location and size of each pond at the NELHA site. A Garmin hand-held GPS unit was used to record latitude and longitude coordinates for each pond. Pond size was calculated from measurements reported by Brock (2008); furthermore, pond dimensions and basin characteristics are included in Appendix 1.1 (Brock, 2008 Table 1).

As anchialine habitats are characterized by tidal influences, the water level and appearance of ponds varied with tide level. For instance, pond N – 1 is substantially shallower with less surface area at low versus high tide (Figures 4A and 4B, respectively). The effect of tide level was also apparent in the group of pools N – 2 through N – 5. At high tide the pools essentially form a single body of water (Figure 5, 6A, and 7A) as the channels between them filled up. This was enhanced by the rock wall construction surrounding these ponds. However, the pools were discrete and separated at lower tidal levels (Figures 6B – D, and 7B). The change is illustrated by the largest of these ponds (N – 5) in Figures 7A and 7B (arrows included to mark point of reference). Observations of organisms within the ponds, then, were taken at tide levels below the daily maximum that provided sufficient water in order to sample each pond separately. While the water levels in the ponds in the southern complex (Figures 8 – 9) were likewise affected by the tide level, the continuity of each pond remained unchanged in all but pond S – 6. This pond was found moist but with no standing water during this survey. Sampling of the ponds was conducted at tidal levels ranging from +0.6 to +2.0 feet.

Table 1. List of species previously reported from anchialine ponds and surrounding areas adjacent to the NELHA facility (Compiled from Brock, 2008, and Ziemann & Conquest, 2008).

	Taxon	Common Name
Anchialine ponds	*Cladophora* sp.	Algae
	Enteromorpha sp.	Algae
	Rhizoclonium sp.	Algae
	Trichocorixa reticulata	Algae
	Lygnbya sp.	Cyanophyte mat
	Schizothrix clacicola	Cyanophyte mat
	Ruppia maratima	Aquatic flowering plant
	Halocaridina rubra	Ōpae ʻula, shrimp
	Metabataeus lohena	Shrimp
	Macrobrachium grandimanus	Ōpae ʻoʻhaʻa, shrimp
	Metopograspus messor	Black rock crab
	Graspsus tenuicrustatus	Shore crab
	Assemenia sp.	Snail
	Melania sp.	Gastropod snail
	Theodoxus cariosa	Hihiwai, limpet
	Oligochaeta sp.	
Terrestrial	*Bacopa* sp.	Pickleweed
	Cladium sp.	Sedge
	Ipomoea pes-caprae	Pōhuehue
	Morinda citrifolia	Noni
	Pennisetum setaceum	Fountain grass
	Pluchea odorata	Pluchea
	Prosopis pallida	Kiawe
	Scaevola taccada	Naupaka
	Schinus terebinthifolius	Christmas berry
	Sesuvium portulacastrum	ʻĀkulikuli
Anchialine ponds, exotic	*Poecilia* sp.	Topminnows, mosquito fish
	Palaemon debilis	Glass shrimp, ʻōpae
	Macrobrachium lar	Prawn

Figure 1. The study area included northern and southern anchialine pond complexes in the vicinity of the NELHA facilities (Inset highlights the study site on the west coast of Hawaiʻi, Map generated using Google Earth 6.2).

Figure 2. Locations of northern complex of anchialine ponds (N – 1 through N – 5) inland of the cobble beach at Hoona Bay (Map generated using Google Earth 6.2).

Figure 3. Locations of southern group of anchialine ponds adjacent to Wawaloli Beach Park (Map generated using Google Earth 6.2).

Table 2. Site locations and sizes anchialine ponds in the vicinity of the NELHA facility (*calculated from measurements reported in Brock (2008)).

Pond No.	Latitude (Degrees)	Longitude (Degrees)	Size (m^2) *****
N-1	19.7313	-156.0568	93.0
N-2	19.7314	-156.0566	1.0
N-3	19.7315	-156.0566	22.5
N-4	19.7316	-156.0566	4.0
N-5	19.7315	-156.0567	22.5
S-1	19.7168	-156.0490	1.68
S-2	19.7167	-156.0489	1.0
S-3	19.7168	-156.0487	1.0
S-4	19.7168	-156.0487	0.01
S-5	19.7168	-156.0487	5.0
S-6	19.7169	-156.0482	0.01
S-7	19.7166	-156.0481	1.4
S-8	19.7165	-156.0481	1.0
S-9	19.7168	-156.0481	0.01

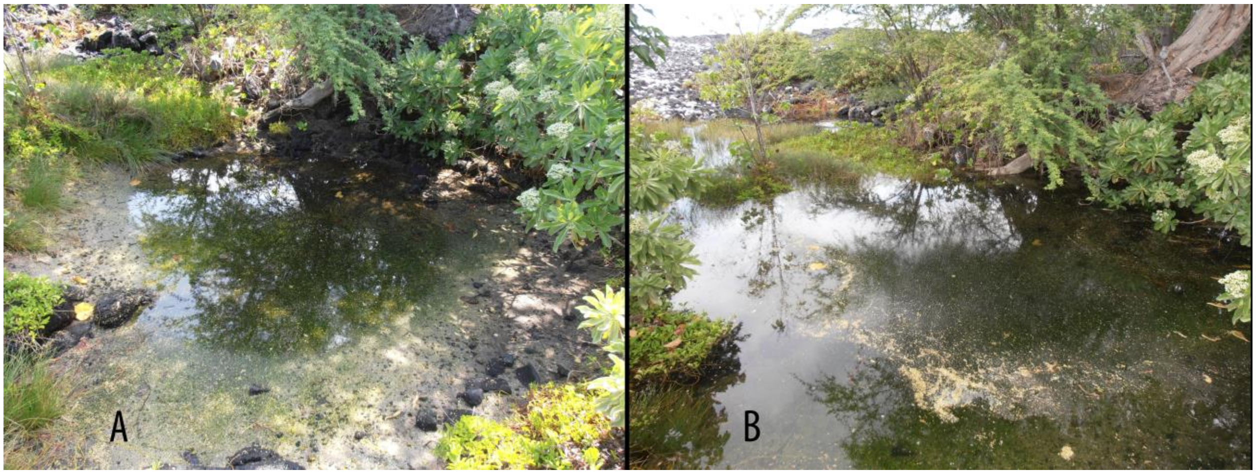

Figure 4. Pond N – 1 water levels at low (A, +0.7 ft.) and high (B, +2 ft.) tides.

Figure 5. High tide (+2 ft.) at ponds N – 2 through N – 5 with inter-connecting channels filled.

Figure 6. Ponds N – 2 through N – 5 as one continuous pond at high tide (A, +2 ft.), and separate ponds at lower tide levels (B – D, +0.7 ft.).

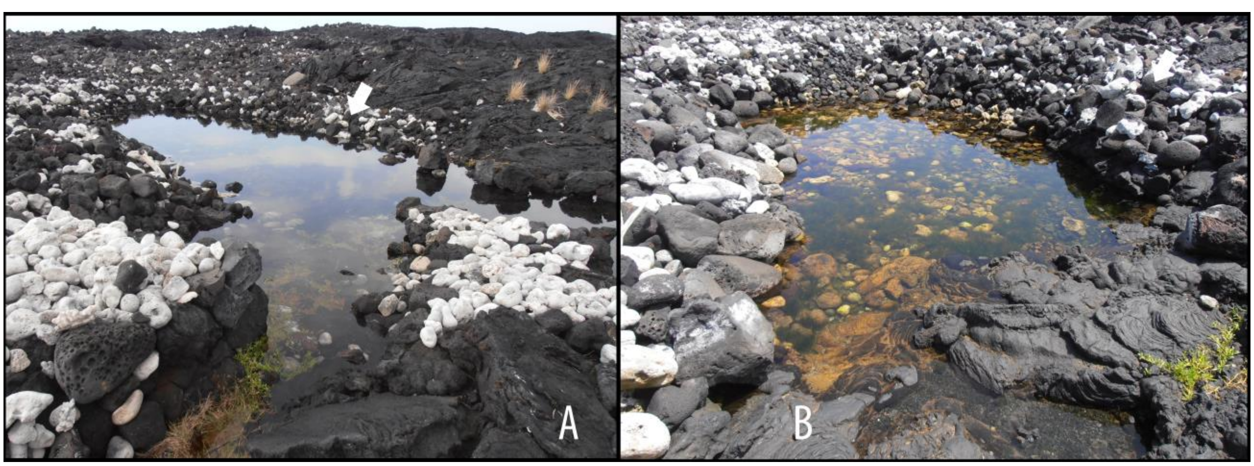

Figure 7. The change in water level at pond N – 5 between high (A, +2 ft.) and lower tide levels (B, +0.7 ft.) with arrows marking point of reference.

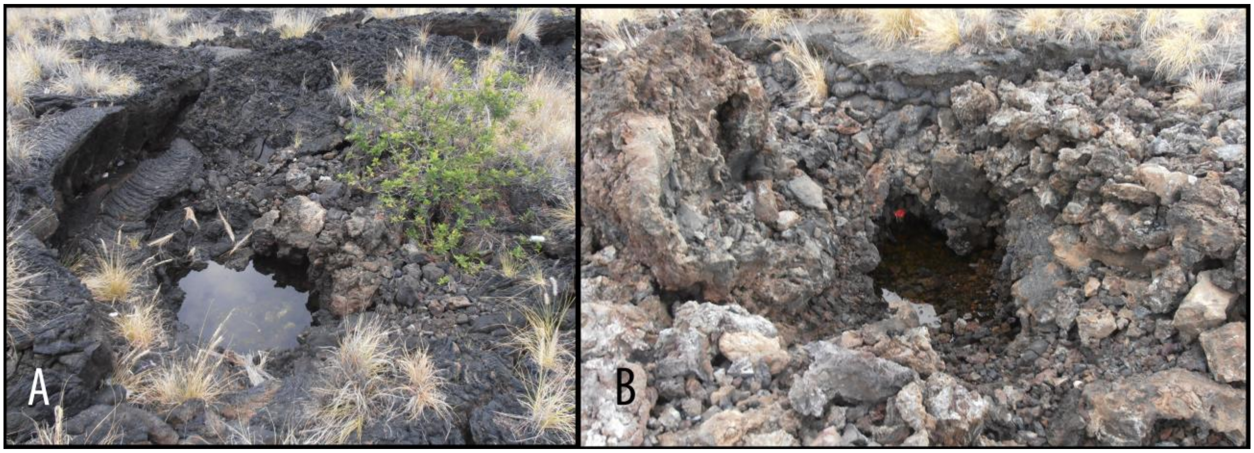

Figure 8. Southern ponds S – 1 (A, +1.8 ft.) and S – 2 (B, +1.4 ft.).

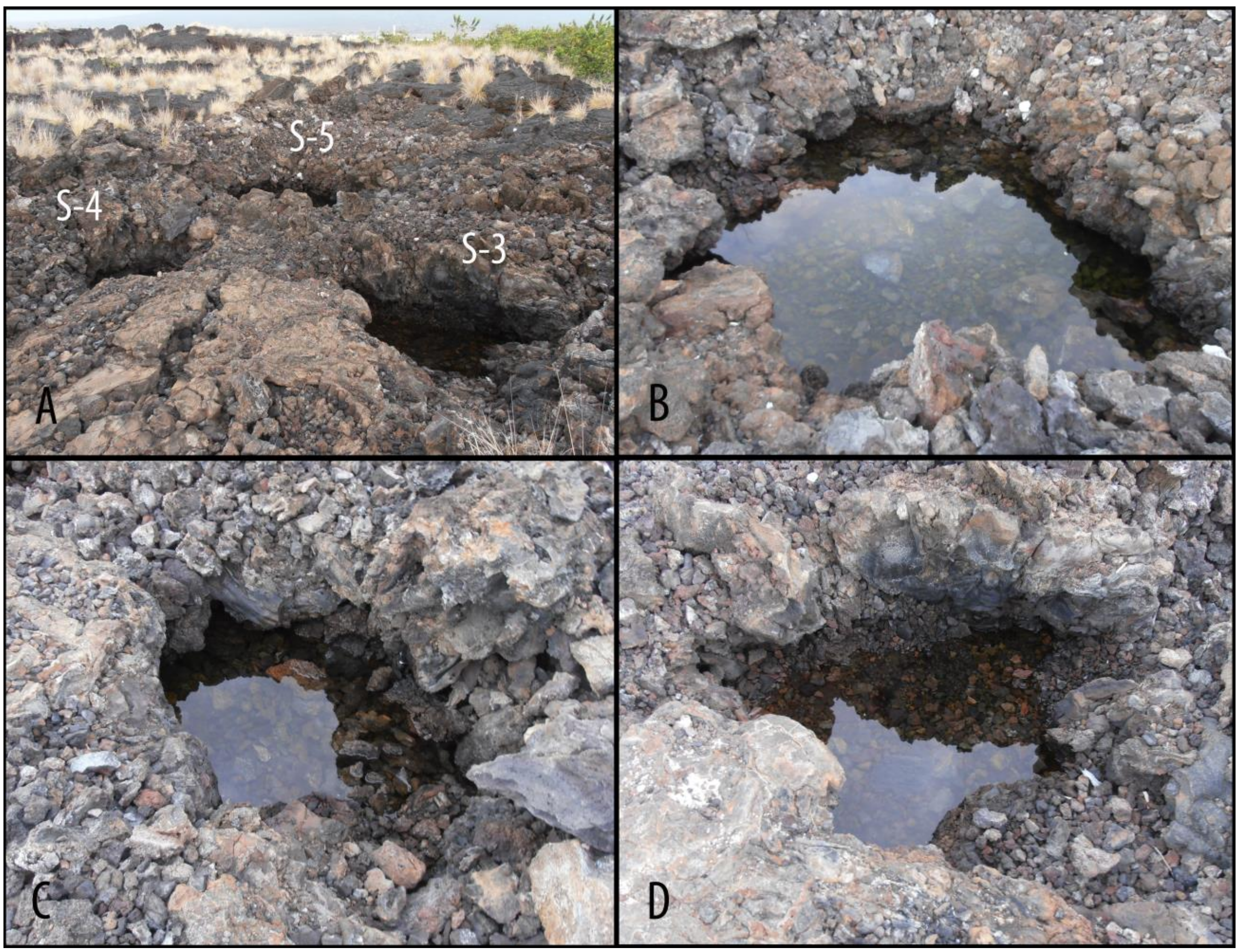

Figure 9. Cluster of ponds (A): S -5 (B), S – 4 (C), and S – 3 (D) (Tide level: +1.4 ft.).

A faunal census of each pond in the vicinity of the NELHA facility was undertaken April 4-5, 2013. Temperature and salinity measurements were taken concurrently employing a hand-held thermometer and hydrometer. Visual observations of organisms within each pond were supplemented by photographs and high-definition video taken with a GoPro Hero2 digital camera and waterproof housing. Randomly selected photo-quadrats ranging in size from 0.02 to 0.07 m^2 (Figure 10) were isolated from video footage obtained by placing the camera and housing in the pond mounted PVC frame. These photoquadrats were used to identify organisms and measure their densities. However, two ponds with low water levels were surveyed visually by noting presence or absence of flora and fauna. All densities were calculated for an area of 0.1 m^2 to facilitate comparisons among ponds within this survey and with previous anchialine pond surveys at these sites (see Appendices 1.2 and 1.3). In addition, two-minute segments of video from each pond were examined to qualitatively assess the community of organisms found. Only the presence or absence of non-native organisms was recorded for this survey.

RESULTS

The measurements of physical characteristics and results of the faunal census are summarized in Table 3. While ponds within each group share a similar composition of organisms, the differences between the two groups stem from the physical features of the local areas in which they are found, as well as the introductions of exotic species and active management of the ponds. The historical introductions of poecilid fish have affected the species composition anchialine ponds reducing the abundance of the keystone species of the habitat, ōpae ʻula. Moreover, the modification through building of rock walls has changed the ponds over time, especially in the northern group of ponds. This activity has, at higher tidal levels, led to ponds N – 2 through N – 5 to fill and constitute a single water body allowing motile organisms to expand and contract their distribution throughout these ponds. The results of the 2013 anchialine pond survey, still, were consistent with previous surveys reviewed by Brock (2008) and reported in Ziemann & Conquest (2008).

Northern anchialine ponds were dominated by *Halocaridina rubra* at higher densities than in the southern sites. Ponds N – 1, 2 and 5 had the highest densities and N – 3 and 4 had very low densities. The majority of individuals were feeding at the time of the survey and very few individuals were observed in the *Ruppia maratima*..

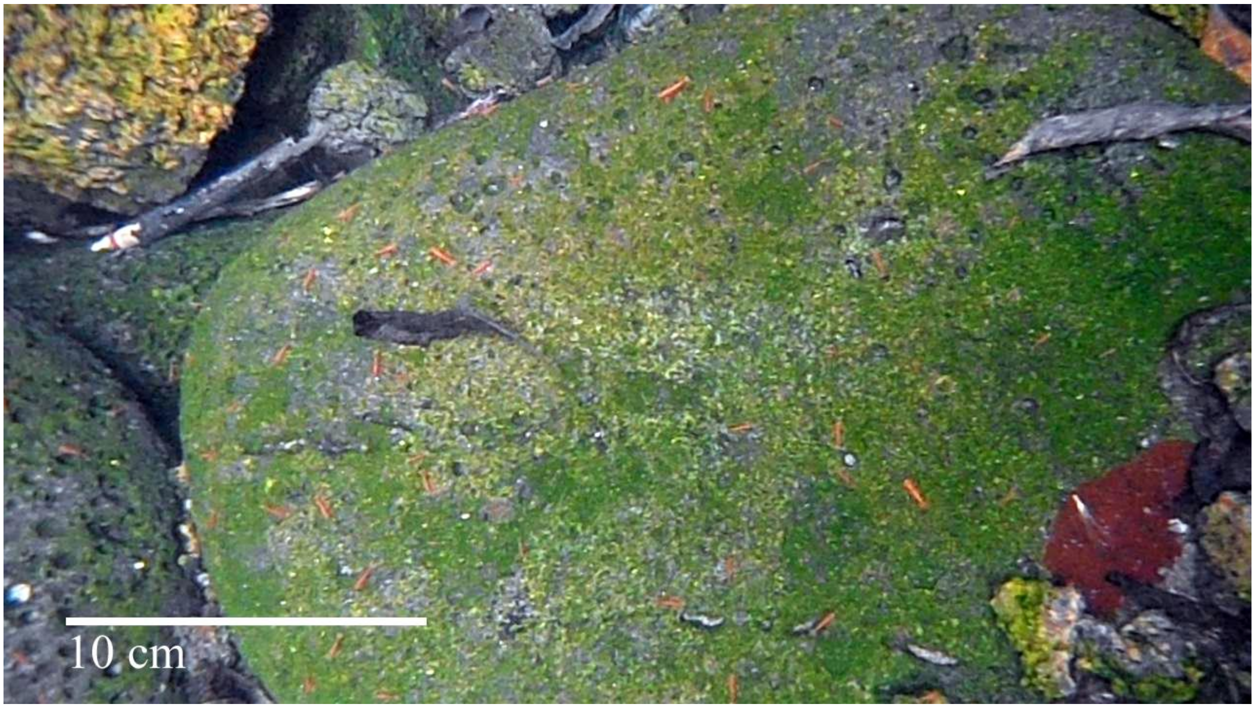

Figure 10. An example of a photo-quadrate showing individual *Halocaridina rubra*. The quadrate was extracted from the high-definition video taken from pond S – 8.

Table 3. Faunal census data collected from northern and southern groups of anchialine ponds sampled April 4-5 2013 at a tide above a +1 foot level. Poecilid fish were recorded as present or absent, other organism densities are reported as mean individuals per 0.1 square meters (± one standard deviation). The presence of *Ruppia maratima* and other organisms in ponds and quadrats was noted.

	Halocaridina rubra	*Ruppia maratima*	Poecilids	Temperature	Salinity	Comments/other species
Pond No.	**Mean ± St. Dev. (Ind./0.1 m²)**	**Pond**		**(C)**	**(PPT)**	
N - 1	106.68 ± 91.0	Present	Absent	25	16	
N - 2	220.1 ± 120.2	Absent	Absent	25	16	
N - 3	8.0 ± 12.3	Present	Absent	24	15	*Macrobrachium grandimanus*
N - 4	12.0 ± 13.1	Present	Absent	27.2	17	Many *Melania sp.*
N - 5	132 ± 67.4	Absent	Absent	24.8	15	Few *Melania sp*. present
S - 1	Present	Absent	Absent	27	12	Pond too small for quadrat
S - 2	0	Absent	Present	22.8	14	*Metabataeus lohena* present
S - 3	9.0 ± 3.0	Absent	Absent	21.6	15	*Metabataeus lohena* present
S - 4	6.0 ± 3.0	Absent	Absent	21.6	17	
S - 5	0	Absent	Present	22	18	
S - 6	-	-	-	-	-	Moist with no standing water
S - 7	Present	Absent	Absent	21.5	13	Pond too small for quadrat
S - 8	0	Absent	Present	22.6	17	*Macrobrachium grandimanus*
S – 9	Present	Absent	Absent	21.8	14	Pond too small for quadrat

The clearest difference between the communities of organisms found in the two groups of ponds this year was the absence of exotic poecilid fish in the northern ponds and their presence in three of nine ponds in the southern group. *Halocaridina rubra* and other native species were not observed in ponds S – 2, S – 5, S – 6, and S - 8, those with exotic fish. Southern ponds S – 1, S – 3, S – 4, and S – 7 and S - 9 were dominated by *Halocaridina rubra*; yet, and some also included individuals of *Metabetaeus lohena* (S – 2,3), *Macrobrachium grandimanus* (S – 8). Pond S – 6 was found to be dry during the survey.

Additional qualitative results utilizing sections of video and field notes augmented data collected from photo-quadrates to account for the mobile, cryptic, or less abundant taxa in the ponds. Differentiating between live and dead *Melania* sp. individuals was difficult, as noted by Brock (2008), but those observed in pond N – 1 were actively foraging making it possible to determine that there density was roughly half that of *Halocaridina rubra* in the videos of this pond. These snails were found to be less abundant (ca. less than 5 individuals per pond) in northern ponds N – 3 and N – 5, but found in their highest abundance in N - 4. *Melania* sp. were not observed in the southern ponds; *Metabetaeus lohena* were enumerated from the videos of ponds S – 2 and S – 3 and three *Macrobrachium grandimanus* shrimps were recorded in pond S – 8.

DISCUSSION

The anchialine ecosystem is unique in Hawai‘i, and the monitoring of two complexes of ponds adjacent to the NELHA facility is essential to continuing to build knowledge and improve management of this resource locally and throughout the island. This year’s survey echoed the results of previous studies of the site showing that the ponds within the two groups have similar communities of organisms, but that the two groups are distinguishable based on their physical features, effects of exotic fish introductions, and modification of the ponds.

The northern complex of ponds have been modified through wall construction producing a single large pond encompassing ponds N – 2 through N – 5 at high tidal levels which provides the potential for organisms to move among the ponds both in the epigeal and hypogeal portion of the habitat; however, the surface boundaries of pond N-1 are separate and distinct from the other ponds in the complex. A community of native species characterized by high abundances of ōpae ‘ula has been able to re-colonize and become established in the northern ponds following the removal of exotic fish in 2007 (Brock, 2008). These shrimp contribute to the water quality of the ponds by maintaining a standing crop of plants, bacteria and diatoms preventing the overgrowth of algae which allows other native organisms to exploit the anchialine habitat (Bailey-Brock & Brock, 1993). If the introduction of exotic fish can continue to be prevented, the current community of organisms and quality of ponds in this complex would be expected to remain in the currently robust state.

The complex of ponds south of the NELHA facility, on the other hand, continued to be affected by the presence of poecilid fish. No native shrimp species were found in the three southern ponds with exotic fish. Findings of Capps *et al*. (2009) suggest that the *Halocaridina rubra* may have been excluded from the pond through predation, or they have changed their behavior and were feeding at night in response to the introduction of the fish. As the ponds were surveyed during daylight hours, it was not possible to assess whether the ōpae ʻula were present but not active during the day at the NELHA sites. The ponds lacking exotic fish were found to have a greater crustacean diversity of native organisms than in the northern complex. While ōpae ʻula were the dominant members of the community, *Metabetaeus lohena* and *Macrobrachium grandimanus* were present albeit at lower abundances and densities. The prospect of future recovery in the southern ponds that are infested with alien fish through re-colonization from other ponds in the complex seems good in the event these fish could be removed. As evidence of that we report the presence of *H. rubra* in ponds S – 1 and S – 7 which were reported to have none in 2012. No fish were observed in these ponds as assume they were removed.

The 2013 anchialine pond survey augmented field observations with photo-quadrates extracted from high-definition video taken in ponds. This allowed for both quantitative and qualitative results to be gathered for the faunal census, provided the ability to record abundances and the behavior of various native organisms, and aided in noting the presence of motile and cryptic species. The use of a floating video camera appeared not to affect the behavior of the organisms in the being surveyed. Observations of *Halocaridina rubra* feeding behavior, for example, showed the shrimp were not disturbed and continued to feed in the same areas throughout the length of the videos. This meant that no changes that might be attributed to the presence of the camera in the pond were apparent. This technique also facilitated the survey of taxa more motile than *H*. *rubra* such as *Metabetaeus lohena, Macrobrachium grandimanus*.

Based on the faunal census performed on the 4th and 5th of April 2013 the anchialine ponds in the vicinity of the NELHA facility in which exotic fish were not present supported communities of abundant and diverse native organisms. Water quality was high, although salinity during this year's study increased, most likely due to the use of a simple hydrometer which was necessitated due to problems with our refractometer. Furthermore, ponds with fish had clear water and were not overgrown by opportunistic algae. This may indicate that the ōpae ʻula were still active in the ponds at night to avoid predation by the introduced fish. The results also support the conclusion that the anchialine ponds adjacent to the NELHA facility are not impacted by human-mediated inputs.

MARINE BENTHIC BIOTA SURVEY

INTRODUCTION

The Natural Energy Lab of Hawaii Authority is a state agency that operates an ocean science and Technology Park at Kailua-Kona on the Island of Hawaii focused on research, education, and commercial activities that support sustainable industry development in Hawaii. One of the unique technological aspects of the park is the pumping of deep cold sea water to the surface through large pipes that have been installed along the reef in specific locations. The nutrient rich water is used in a variety of aquaculture activities on land. Concerns over water discharge from aquaculture facilities and the potentially negative impacts to the adjacent reef communities have prompted regular monitoring. Benthic communities are often sensitive indicators of environmental change (Gray and Pearson 1982).

Since 1991, more than 30 surveys have been conducted on the benthic communities adjacent to NELHA. Extensive reports have been prepared detailing the results of each survey. Results and summaries of reports can be found in the following references: 1991-1995 are summarized in Marine Research Consultants, 1995. Surveys for 1995 and 1997 are reported in Oceanic Institute, 1997. Surveys conducted between 1997-2002 are in Marine Research Consultants, 2002. Surveys from July 2005 to January 2007 are found in Oceanic Institute 2007. For October 2007 and July 2008 surveys, summary is in Marine Research Consultants 2008. For October 2008, May 2009 and May 2010 surveys are reported in Ziemann 2008, 2009 and 2010. The results of the 2012 survey were reported in Bybee and Barrett 2012 and the results of the April 2013 survey are reported herein.

METHODS

There are six survey sites located along the NELHA coastline with three 50 m transects at each site, at one of three depths (15 ft., 30 ft., and 50 ft.) (Figure 11). On all transect lines, 10 quadrats, each 1.0 m x 0.6 m, were defined at random locations along the transect. All invertebrate species in the quadrats were enumerated by divers using SCUBA and assessed in terms of percent cover of the bottom. Substrate was also evaluated in terms of percent area coverage.

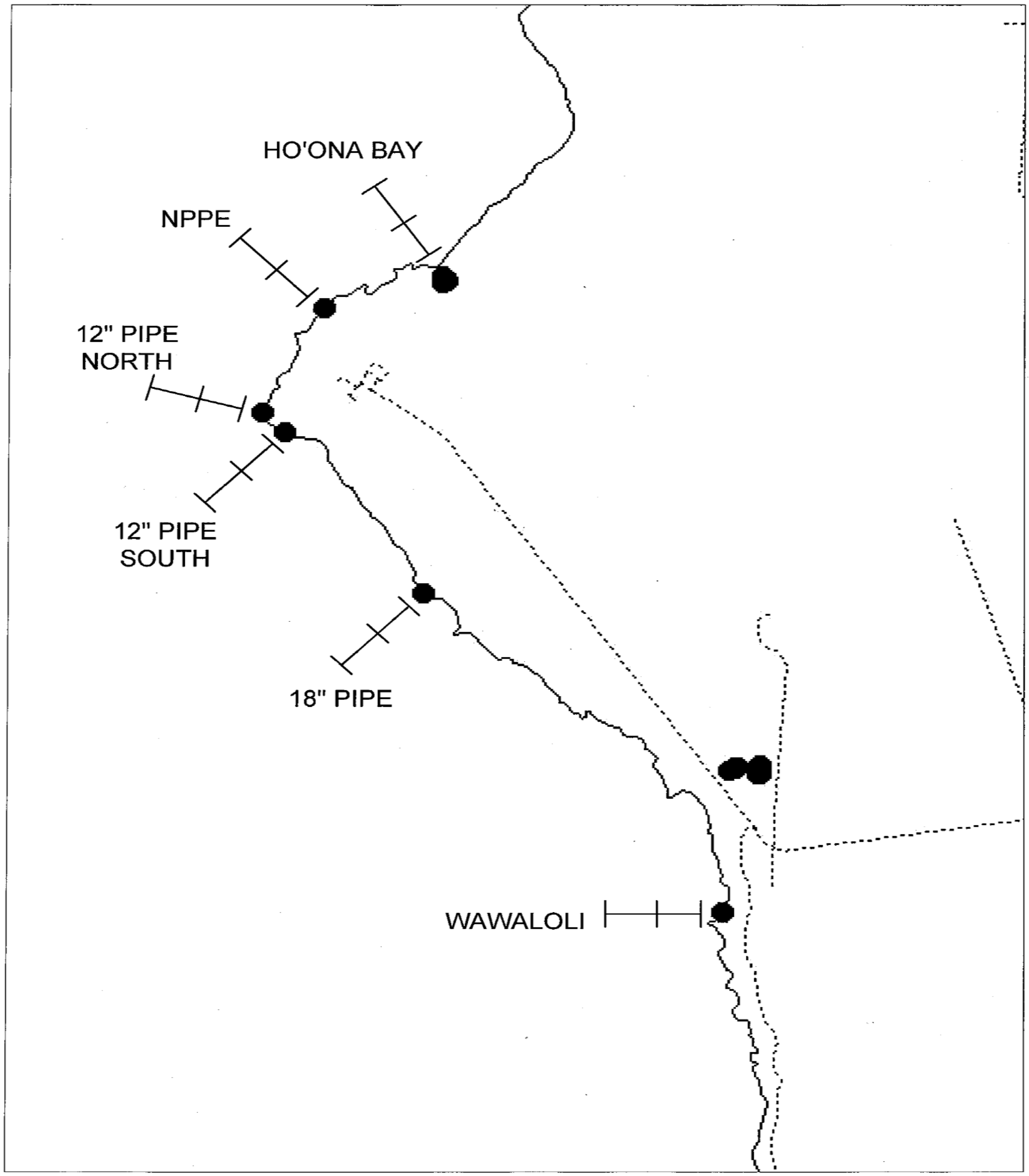

Figure 11. Six stations with three transects per station along the NELHA coastline.

In addition, each permanent quadrat was photographed using an underwater camera with a super wide angle lens mounted on a quadruped frame. Each photograph was separately labeled to designate the location of each frame within each transect. Photographs were taken using high resolution digital photography. In the laboratory, accurate estimates of the benthic cover of biota and substrata were performed using the software Coral Point Count with Excel Extensions (Kohler 2006) overlaying a 10 x 20 grid to divide the photographs into 200 equal sized segments and biota and substrate type at each point were identified. Statistical analysis of the data was performed using ANOVA, Tukey and pairwise comparisons. Results of these tests were considered to show significant differences in measured variables (coral cover, total fish, diversity etc.) between stations, habitats or years when they produced p-values of 0.05 or less. Values greater than 0.05 were not considered statistically significant.

RESULTS

Benthic biota observed in this study included stony corals, coralline algae, turf algae, echinoderms (sea urchins), sponges, and gastropod molluscs. All were present in very small numbers except for the stony corals which comprised the vast majority of the benthic biota. Percent cover and diversity of corals and other benthic biota as well as non-coral substrate are presented in detail in Appendix 2 and summarized in Table 4**.** Over all, coral cover across the six study sites was 52%. The two most dominant corals were *Porites lobata* (29.67%) and *Pocillopora meandrina* (12.42%) which were present on all transects. Other corals present were *Leptastrea bewichensis, Montipora capitata, Montipora flabellata, Montipora patula, Pavona varians, Pocillopora eydouxi, Pocillopora lingulata, Pocillopora meandrina, Porites compressa, Porites lutea and Fungia scutaria.* These corals accounted for approximately 10% of the coral cover.

Porites compressa was abundant in the deepest transects (50 feet) only at the three northern sites (Ho’ona Bay, NPPE and 12” Pipe North). *Porites compressa* was also present in smaller numbers in the middle transects (30 feet) at all sites except for 18” Pipe and Ho’ona Bay. In the shallow transects (15 feet) *P. compressa* occurred at all sites except for NPPE and 12” Pipe North, always in very low numbers. Color photographs of all quadrats are presented in Appendix 4.

Table 4 shows a comparison of the percent coral cover between sites and habitats. The Ho’ona Bay site was the highest in total coral cover (71.1%) due mostly to its abundant *P. lobata* and *P. compressa*. The three northern sites (Ho’ona Bay, NPPE and 12” Pipe North) had more total coral than the southern stations. *Porites lobata* was also found in its highest densities at the two most northerly stations (Ho’ona and NPPE), but *P. meandrina* was most abundant around the pipe sites (12’ North, 12’ South and 18’). The lowest overall coral cover (38.1%) was observed at Wawaloli, the southernmost site and increased at each site moving northward. The highest *P. lobata* cover was observed at Ho’ona Bay (45.9%) followed by NPPE (33.7%) while the lowest concentration of *P. lobata* occurred at 18” Pipe (21.38%).

Coral cover was higher in the shallow and middle transects (57.5% and 52.6%) than the than the deep stations (46.34%). Among the deep stations coral was most abundant at 12” Pipe North and Ho’ona Bay sites (65.9% and 85.25%) followed by NPPE (51.76%). *Porites lobata* was the dominant coral at all six sites.

Though measurable, most of the above mentioned differences were not statistically significant. The only significant differences detected between sites in this study were diversity, % total coral and % *P. meandrina*. The difference in diversity was observed between habitats ($p = 0.05$, ANOVA) in which deep stations were slightly higher than shallow stations. There were also marginally significant differences in % total coral cover ($p = .05$). The % *P. meandrina* was significantly different when all stations were compared ($p = .015$) and this was due to differences in abundance between 12” Pipe North and Wawaloli Beach ($p = .007$).

Other Benthic Invertebrates

At all stations there were clusters of gastropod molluscs visible on some of the rocks. They were small, oval in shape and only noted while analyzing photos in the lab so no specimens were collected in the field for species identification. Sea urchins were also observed in low numbers at all stations as well as two sabellid tube worms (at Ho’ona Bay) and one cushion sea star (*Culcita sp.).*

Table 4. Summary of photoquadrats from benthic surveys conducted April 2013

station		Wawaloli Beach				18" Pipe				12" Pipe South	
transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
% total coral	50.25	39.75	24.35		49.8	46.9	24.65		58.4	50.3	26.13
% P. lobata	41.7	29.2	12.95		27.2	23.3	13.65		29.5	31.01	10.95
% P. compressa	0.15	0.15	6.7		0.05	0	0.1		0.05	0.11	1.8
% Poc. Meandrina	3.7	6.35	1.9		12.45	17.7	7.85		19.55	14.95	11.9
Species	8	4	6		7	6	7		8	6	7
Diversity	0.68	0.77	1.24		1.25	1.1	1.14		1.23	0.92	1.14
station		12" Pipe North				NPPE				Ho'ona Bay	
transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
% total coral	55	44.11	65.9		69.75	68.45	51.76		61.83	66.3	85.25
% P. lobata	25.2	18.61	31.85		48.6	45.95	6.56		43.83	49.45	44.55
% P. compressa	0	0.39	9.65		0	5.55	33.3		0.22	0	26.15
% Poc. Meandrina	25.45	21.89	17.45		19.7	9	4.6		11.53	12.55	5
Species	6	8	8		6	9	8		8	6	7
Diversity	1	1.06	1.34		0.72	1.06	1.36		0.93	0.79	0.99
Survey Means	Wawaloli	18" pipe	12" Pipe S	12" Pipe N	NPPE	Ho'ona Bay	P value	Shallow	Middle	Deep	p value
% Total coral	38.1	40.45	44.9	55	63.3	71.1	**0.05**	57.5	52.6	46.34	0.53
% P. lobata	27.95	21.38	23.8	25.22	33.7	45.9	0.27	36	32.92	20.08	0.1
% Poc. Meandrina	3.98	12.66	15.46	21.59	11.1	9.69	**0.015**	15.39	13.74	8.11	0.16
Species	6	6.6	7	7.3	7.6	7	0.71	7.1	6.5	7.1	0.57
Diversity	0.89	1.16	1.09	1.13	1.04	0.9	0.52	0.96	0.95	1.2	0.06

Comparative analysis

Extensive analyses have been done comparing data from previous surveys at these same sites from 1992-2012 (Ziemann 2010, Bybee and Barrett 2012). The goal of the current study is not to duplicate that information but instead to discuss some of the main points of those previous analyses in light of the current data from 2013.

In previous reports total coral abundance estimates showed “a clear pattern over time” (Ziemann 2010). This pattern was one of general increase from 1992 - July 2008 ranging from 16.9% to 54.7%. In the years following, reported estimates declined to 39.5% in 2009 then rose to 43.2% in 2010 and 44% in 2012. The present survey records a statistically significant increase in in total coral abundance of 52% ($p = < .001$, ANOVA) which follows the noted pattern of increase over time.

Mean coral abundance has differed significantly between some sites over the 18 year period (Ziemann 2010). It did not differ significantly between sites in 2010-2012 but when combining 2010-2013 data there were significant differences detected between some sites. These differences reflect the previously noted pattern of increasing coral cover from southern to northern sites and are as follows: 12” pipe North-Wawaloli ($p = .05$), NPPE- Wawaloli ($p = < .001$), Ho’ona Bay- Wawaloli ($p = .02$), NPPE-18” Pipe ($p = .01$) and NPPE-12” Pipe South ($p = .03$)

The mean *P. lobata* cover has been similar to total coral cover in its pattern of change over time (1992-2012) ranging from 10.0 to 30.7%. The current survey shows a significant increase in range of 21.38% (18” Pipe) to 45.9% (NPPE) and an average of 30%, ($p = .004$, Tukey multiple comparison of means) when compared to 2010 and 2012.

Mean *P. meandrina* cover over time has exhibited the same general pattern of increase seen in mean total coral cover and mean *Porites lobata* cover (Ziemann 2010). The results of the current study show a wide range of *P. meandrina* cover between sites, from 3.98% (Wawaloli) to 21.59% (12” Pipe North) with an average of 12.41% cover and when 2010-2013 data are compared the increase observed this year is statistically significant ($p < .001$, Tukey multiple comparison of means).

DISCUSSION

As noted by previous authors (Dollar 1975, Dollar and Tribble 1993, Ziemann 2010), there is a recognizable zonation on many parts of Hawaii’s coral reefs. Those zonation patterns (*Pocillopora meandrina* and *Porites lobata* co-dominant in the upper regions and *Porites compressa* dominant on the deeper reefs) are visible off the shore of NELHA and were observed in this study as they have been in the past (Ziemann 2010, MRC 2008).

The overall total coral cover and *Porites lobata* cover have been observed to increase from south to north and from shallow to deep (Ziemann 2010). In this study the south to north increase is apparent in total coral cover but not in *P. lobata*, which was higher at Wawaloli than 18” Pipe, 12” Pipe South and 12” Pipe North. There was, however, no detectable increase in total coral cover or *Porites lobata* cover from shallow to deep. In fact the 2013 measurements seemed to indicate the opposite.

Pocillopora meandrina decreased in abundance from shallow to deep (not significantly) and was abundant at all shallow and middle stations except for Wawaloli where it was rare throughout the entire station. Its role as a colonizer of disturbed habitat and rough water (Dollar 1982) areas makes the shallower stations in this study ideal for settlement.

The varied results found between different monitoring teams throughout the past 20 years may become less of an issue in the future if permanent transect starting points are reinstalled along the pipes at specific depths. This wouldn’t make much of a difference at Wawaloli, Ho’ona Bay or NPPE but the other 3 sites would be more standardized, minimizing a potentially confounding variable.

Taking into consideration the historical data from previous monitoring reports showing a general increase in coral cover over time and the concurring data presented herein for 2013, there is no indication that the benthic community is being negatively impacted by the presence or activities of NELHA.

MARINE FISH BIOTA SURVEY

INTRODUCTION

The near shore fish populations off Keahole point where NELHA is located have long been noted for their unusual abundance and diversity among the Hawaiian Islands (Brock 1954, Brock, 1985; Brock, 1995). As such, they should be the focus of efforts in conservation, management, research and monitoring. Concerns over the possible decline in water quality due to activities at NELHA have prompted regular surveys of fish populations to monitor any detectable changes that might indicate negative impacts linked to the NELHA facilities.

METHODS

The fish community was monitored at the same 6 sites (18 transects total) as the benthic community (Figure 1). Fish communities were assessed using a visual census to estimate the abundance and biomass of fish present (Brock 1954). Data collected include a listing of all species present, the numbers of individual species and the estimated length of each for estimates of standing crop using linear regression techniques. The census was conducted over the entire length of a 4 X 25 meter transect line. All fish within the transect area to the water's surface were recorded on video by SCUBA divers and later counted and identified while reviewed on a laptop computer.

In previous studies, permanent transects were marked with subsurface floats to pinpoint transect lines (Brock 2008). In 2012 these markers were not present, so surveys were conducted at 15, 30 and 50 feet respectively at each of the six stations. A lead diver slowly fed the transect line out as he moved from north to south at the chosen depth filming along the way. A second diver followed at a distance while photographing the benthos.

Visual length estimates were converted to weight using the formula $M = a * L^b$ where M = mass in grams, L = standard length in mm and a and b are fitting parameters. Fitting parameters were obtained from Fishbase (Froese and Pauley 2000). Diversity was calculated, as in previous reports (Ziemann 2010) using Shannon's Index.

$$\hat{H} = -\sum_{i=1}^{n} \frac{n_i}{n} \ln \frac{n_i}{n}$$

RESULTS

A summary of the major variables measured during this study (total number of individuals, number of species, diversity and biomass) is found in Table 5 and the complete data set is found in Appendix 3.

Total number of individual fish per transect was not significantly different between sites ($p = .06$, ANOVA) with a range of 30-208 individuals. Nor was it significantly different between habitats ($p = .89$, ANOVA). The highest number of individuals occurred at the 12" Pipe South shallow transect (208 individuals). The lowest count occurred at Wawaloli middle transect. Total number of fish was higher at the deep stations (though not significantly).

Number of Species

Table 5 shows the number of species per transect recorded during the present study. The mean number of species per transect ranged from 13.3 at the deep transects to 15.8 at the shallow sites. Overall there was no statistically significant difference observed between sites ($p = 0.71$, ANOVA). The highs occurred at 12" Pipe North, middle transect (23 species) and 12" Pipe South, middle transect (22 species). The lows occurred at Wawaloli middle transect (6 species) and NPPE deep transects (9 species). There was no significant difference in number of species between habitats ($p = 0.71$, ANOVA).

The most abundantly represented families in this survey were the chaetodontids (butterfly fish), pomacentrids (damsel fish) and acanthurids (surgeon fish). The most abundant species were *Chromis vanderbilti, Chromis hanui, Chromis ovalis, Zebrasoma flavescens, Ctenochaetus hawaiiensis*, *Ctenochaetus strigosus, Thalassoma duperrey* and *Acanthurus nigrofuscus.* They were present in almost all habitats and transects.

Species Diversity and Biomass

Species diversity ranged from 1.8 at Wawaloli to 2.38 at 12" Pipe South. None of the differences among station or habitat were statistically significant ($p = .46$ and .13 respectively, ANOVA).

Biomass was highest at 12" Pipe South and lowest at Wawaloli. No significant differences in mean biomass were detected between sites or habitats ($p = .06$ and 0.35 respectively, ANOVA).

Table 5. Summary of quantitative fish transects conducted April 2013.
A complete data set is presented in Appendix 3

station		Wawaloli Beach				18" Pipe				12" Pipe South	
transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
Total number	86	30	78		94	133	165		208	157	157
Number of species	14	6	13		16	14	13		20	22	18
Diversity	1.9	1.42	2.14		2.34	2.29	1.88		2.35	2.42	2.37
Biomass (g/m2)	44.42	10.2	43.78		98.24	84.86	71		259.9	136.45	99.43
station		12" Pipe North				NPPE				Ho'ona Bay	
transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
Total number	68	202	130		113	51	62		76	59	150
Number of species	14	23	15		18	10	9		13	14	12
Diversity	2.35	2.6	1.79		2.35	1.96	1.43		2.35	1.96	1.29
Biomass (g/m2)	36.14	128.32	36.18		103.97	66.28	40.37		94.17	106.5	62.51
Survey Means	Wawaloli	18" pipe	12" Pipe S	12" Pipe N	NPPE	Ho'ona Bay	P value	Shallow	Middle	Deep	p value
Total number	64.6	130.1	174	133.3	75.3	95	0.06	107.5	105.3	123.6	0.89
Number of species	11	14.3	20	17.3	12.3	13	0.08	15.8	14.8	13.3	0.71
Diversity	1.8	2.17	2.38	2.21	1.9	1.92	0.46	2.27	2.11	1.82	0.13
Biomass (g/m2)	32.8	84.7	165.26	66.88	70.26	87.72	0.06	106.1	88.77	58.87	0.35

Comparative Analysis

Extensive analyses have been done comparing data from previous surveys at these same sites from 1992-2012 (Ziemann 2010, Bybee and Barrett 2012). The goal of the current study is not to duplicate that information but instead to discuss some of the main points of those previous analyses in light of the current data from 2013.

Previous studies have determined that even though much year to year variation has been observed, there have been no significant overall changes to fish populations, during an 18-year study period, that can be attributed to anthropogenic affect (Ziemann 2010). Data from 2012 was an extreme example of the wide variation mentioned above. Total number of fish per transect, number of species, diversity and biomass were all significantly lower ($p < .001$, ANOVA) than 2010 measurements. Data from the current study show a significant increase in total fish ($p = < .001$, pairwise comparisons using paired t-tests), number of species ($p = < .001$, pairwise comparisons using paired t-tests) and diversity ($p = < .001$, pairwise comparisons using paired t-tests) when compared to 2012 data. When compared to 2010 data the current results are still significantly lower in all areas ($p = < .001$) except diversity ($p = .79$). The possible significance of this observation is discussed below.

DISCUSSION

Ziemann (2010) noted the presence of large schools of fish that roamed between zones and had a dramatic impact on the abundance calculations. During the present study none of these large schools crossed transect lines during data collection.

He also concluded that these fish communities are "highly variable in nature over very small time and space scales" and that "any conclusions of change in fish community abundance or distribution need to be examined carefully in the context of natural variability." As an illustration of that point, there were significant differences between 2010, 2012 and 2013 data as mentioned above. Although this difference may be partially the result of natural variability, it is much more likely to be the result human variability in implementation of the survey method used.

In the 2012 study a team of multiple divers worked each transect simultaneously. The transect line was laid out by the 3 divers going from north to south. Upon reaching the 25 meter mark two of the divers turned around and moved along the transect line from south to north taking photoquadrats of the benthic community. Slightly behind them another diver moved from north to south collecting fish data along the same transect line. It is highly likely that many fish were disturbed by this activity and stayed out of sight the majority of the time. Anecdotal observations support this idea. We observed a great abundance of fish on the reef while in transit between transects but noticeably fewer on each measured transect line. A change in methodology for 2013 was implemented as mentioned in the methods section above. That change resulted in significant increases in total fish, species and diversity measured this year though still lower than 2010 levels. One possible explanation for these observations in addition to natural variability is that although the use of video has been helpful for viewing and counting many fish species after the dives, there are others that are much harder to count and identify via video. Thus, some groups may have been unintentionally excluded from or underrepresented in these surveys. Recording fish data on site with slate and pencil also requires more time on the transect than swimming it's length while filming. Increased time on the transect line could also contribute to more fish recorded in previous years. Future surveys will in employ more traditional methods of a diver with slate and pencil only.

Another factor that may have affected the data was weather related. During the period of the surveys there was an unusual spring swell that affected the study site's coastline and water conditions. This made shore access for divers impossible so that all dives were conducted from a boat in rough conditions. These conditions may have affected fish behavior, especially at the shallow sites.

The general observation in previous years was that the fish community seemed least developed off Wawaloli Beach and most developed near the 12" and 18" Pipe sites. In 2013 this observation holds true in total fish, number of species and diversity.

In summary, when taking into account all data from this long term study of the fish biota off NELHA, despite much variability from year to year and site to site there is no convincing evidence that activities at NELHA are negatively affecting the reef fish community.

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APPENDICES

Appendix 1: Environmental and biological data reported from anchialine pond surveys conducted between May 1989 and October 2008

Appendix 1.1 Physical characteristics of northern and southern anchialine ponds summarized from surveys conducted from May 1989 to October 2008 (Brock, 2008; and Ziemann & Conquest, 2008).

Pond No.	Dimensions (m)	Basin Characteristics	2009 salinity (ppt)
N-1	15.5 x 6	Deep mud bottom; in pahoehoe/basalt cobble	10
N-2	1 x 1	Rubble basin; in pahoehoe	10
N-3	7.5 x 3	Cobble basin; in pahoehoe	9
N-4	2 x 2	Rubble & mud bottom; in pahoehoe	9
N-5	7.5 x 3	Two interconnected basins in cobble	10
S-1	1.4 x 1.2	Pahoehoe and rubble	5
S-2	1 x 1	Pahoehoe and rubble	7
S-3	1 x 1	Pahoehoe and rubble	8
S-4	0.075 x 0.075	Pahoehoe and rubble	8
S-5	2 x 2.5	Pahoehoe and rubble	8
S-6	0.2 x 0.05	Pahoehoe and rubble	8
S-7	1 x 1.4	Pahoehoe and rubble	9
S-8	1 x 1	Pahoehoe and rubble	8
S-9	0.2 x 0.05	In small a'a crack	8

Appendix 1.2. Census data reported for northern and southern anchialine ponds from surveys conducted from May 1989 to August 2008 (Brock, 2008) with exotic fish species (Poecilid/*Poecilia*) recorded as present (x) or absent (0).

Census Data (no./0.1m²)

Pond No.	Species	May 89	Oct 91	Mar 92	May 92	Oct 92	May 93	Dec 93	May 94	Jun 94	Oct 94	Mar 95	Jun 95	Dec 97	Jun 98
N-1	*Melania*	78	35	49	56	24	31	42	31	43	19	40	63	39	41
N-1	*Melania*	71	52	31	29	62	54	59	72	68	72	52	50	67	53
N-1	*Poecilia*	x	x	x	x	x	x	x	x	x	x	x	x	x	x
N-1	*M. grandimanus*									2	0	0	1	0	0
N-1	*Palaemon*												2		
N-1	*Metopograpsus*													4	7
N-1	*T. cariosa*														6
N-1	*H. rubra*														
N-2	*Melania*	36	42	72	85	41	22	27	31	28	19	31	28	33	44
N-2	*H. rubra*	22	15	3	0	72	0	0	0	4	0	42	0	0	0
N-2	*Poecilia*	0	0	0	x	0	x	x	x	x	x	0	x	x	x
N-3	*Melania*	62	12	67	29	24	19	31	42	51	72	40	53	49	57
N-3	*Melania*	21	9	23	41	15	26	17	24	33	41	23	19	31	22
N-3	*Melania*		0	0	0	6	0	8	5	6	9	9	14	18	34
N-3	*H. rubra*	1	0	0	0	15	0	0	2	0	0	0	0	0	0
N-3	*H. rubra*	15	28	0	0	38	0	0	0	0	0	0	0	0	0
N-3	*Palaemon*	0	0	0	1	1	2	1	2	1	1	2	3	0	0
N-3	*M. lar*									1	0	1	0	0	0
N-3	*Poecilia*	0	0	x	x	0	x	x	x	x	x	x	x	x	x
N-4	*Melania*	39	0	0	14	10	9	14	12	26	25	26	25	27	33
N-4	*Melania*	115	4	9	3	85	42	61	53	49	19	19	23	17	21
N-4	*H. rubra*	3	0	0	0	12	0	0	0	0	0	0	0	0	0
N-4	*H. rubra*	21	23	0	0	31	0	0	0	0	0	0	0	0	0
N-4	*M. grandimanus*											5	0	0	0
N-4	*Poecilia*	0	0	x	x	0	x	x	x	x	x	x	x	x	x
N-5	*Melania*	2	2	61	9	8	12	23	19	27	51	21	29	33	42
N-5	*Melania*	4	4	2	1	1	1	17	27	6	29	19	16	13	27
N-5	*H. rubra*	0	0	0	0	41	0	0	0	0	0	0	0	0	0
N-5	*M. grandimanus*											3	0	0	0
N-5	*Metopograpsus*													3	5
N-5	*Poecilia*	0	0	x	x	0	x	x	x	x	x	x	x	x	x

Census Data (no./0.1m²)

Pond No.	Species	Nov 98	May 99	Dec 99	Jun 00	Nov 00	May 01	Nov 01	May 02	Dec 02	Dec 07	Aug 08
N-1	*Melania*	38	27	36	42	34	39	37	29	21	0	4
N-1	*Melania*	52	49	68	37	55	27	23	47	17	0	0
N-1	*Poecilia*	x	x	x	x	x	x	x	x	x	0	0
N-1	*M. grandimanus*	0	0	0	0	0	0	0	0	0	0	0
N-1	*Palaemon*			0	0	0	0	0	0	0	0	0
N-1	*Metopograpsus*	9	6	8	9	5	4	6	5	7	0	0
N-1	*T. cariosa*	5	6	3	2	4	3	2	9	5	0	0
N-1	*H. rubra*			0	0	0	0	0	0	0	0	100
N-2	*Melania*	56	47	47	39	51	79	66	72	37	0	3
N-2	*H. rubra*	0	0	0	0	0	0	0	0	0	0	10
N-2	*Poecilia*	x	x	x	x	x	x	x	x	x	0	0
N-3	*Melania*	28	39	37	44	34	41	39	27	41	0	2
N-3	*Melania*	26	24	31	51	29	22	33	19	38	0	0
N-3	*Melania*	14	22	12	6	9	3	3	5	5	0	0
N-3	*H. rubra*	0	0	0	0	0	0	0	0	0	0	25
N-3	*H. rubra*	0	0	0	0	0	0	0	0	0	0	21
N-3	*Palaemon*	0	0	0	0	0	0	0	0	0	0	0
N-3	*M. lar*	0	0	0	0	0	0	0	0	0	0	0
N-3	*Poecilia*	x	x	x	x	x	x	x	x	x	0	0
N-4	*Melania*	29	27	36	29	27	Dry	29	31	27	Dry	2
N-4	*Melania*	26	19	29	17	21		17	20	18		1
N-4	*H. rubra*	0	0	0	0	0		0	0	0		23
N-4	*H. rubra*	0	0	0	0	0		0	0	0		17
N-4	*M. grandimanus*	0	0	0	0	0		0	0	0		0
N-4	*Poecilia*	x	x	x	x	x		x	x	x		0
N-5	*Melania*	23	24	16	12	21	19	17	23	17	0	4
N-5	Melania	19	12	19	26	17	14	12	16	21	0	5
N-5	*H. rubra*	0	0	0	0	0	0	8	0	0	0	80
N-5	*M. grandimanus*	0	0	0	0	0	1	0	0	0	0	0
N-5	*Metopograpsus*	5	4	5	5	5	7	5	6	3	0	0
N-5	*Poecilia*	x	x	x	x	x	x	x	x	x	0	0

Census Data (no./0.1m²)

Pond No.	Species	May 89	Oct 91	Mar 92	May 92	Oct 92	May 93	Dec 93	May 94	Jun 94	Oct 94
S-1	*H. rubra*	56	29	31	61	29	49	37	47	52	84
S-1	*M. grandimanus*	0	0	1	1	0	0	1	2	0	0
S-1	Amphipoda	0	0	0	6	19	12	15	21	18	26
S-1	Poecilids										
S-2	*H. rubra*	71	31	40	14	34	54	Dry	Dry	Dry	
S-2	Amphipoda	185	32	6	2	9	2				
S-2	Poecilids										
S-3	*H. rubra*	38	21	43	64	56	Dry	49	37	86	94
S-3	*M. lohena*									1	0
S-3	Amphipoda	54	14	9	12	9		12	14	3	16
S-3	*Poecilids*										
S-4	*H. rubra*	9	42	6	9	7	Dry	Dry	21	Dry	39
S-4	Amphipoda	0	0	0	2	12			6		12
S-4	*Abudefduf sordidus*										
S-5	*H. rubra*	43	121	131	92	107	113	0	0	0	0
S-5	Amphipoda	94	65	48	27	34	7	0	0	0	0
S-5	*M. grandimanus*						1	0	1	4	1
S-5	Poecilids										
S-6	*H. rubra*	3	3	1	1	7	5	4	7	4	23
S-6	Amphipoda	0	9	2	3	3	2	3	3	3	0
S-6	White Amphipoda	0	2	0	0	2	1	1	3	1	2
S-7	*H. rubra*	97	95	87	96	49	72	68	82	94	113
S-7	Amphipoda	11	17	12	10	13	9	10	18	23	39
S-7	*M. grandimanus*	0.5	0.5	0.5	0.75	1	0.5	1	2	1	1
S-7	Poecilids										
S-8	*H. rubra*				65	72	81	71	68	81	80
S-8	*M. grandimanus*				0.5	0.75	1	1	2	1	1
S-8	Poecilids										
S-9	*H. rubra*					3	Dry	Dry	Dry	Dry	14
S-9	Poecilids										

Census Data (no./0.1m²)

Pond No.	Species	Mar 95	Jun 95	Dec 97	Jun 98	Nov 98	May 99	Dec 99	Jun 00	Nov 00	May 01	Dec 02	Dec 07	Aug 08
S-1	*H. rubra*	61	57	73	49	81	63	65	35	35	55	58	0	0
S-1	*M. grandimanus*	0	0	0	0	0	0	0	0	0	0	0	0	0
S-1	Amphipoda	23	27	24	23	14	12	14	16	9	11	9	0	0
S-1	Poecilids												x	x
S-2	*H. rubra*	Dry		Dry		Dry		Dry	6	Dry	Dry	48	0	0
S-2	Amphipoda	9			12		14		0			1	0	0
S-2	Poecilids												x	x
S-3	*H. rubra*	Dry	78	Dry	14	Dry	29	8	17	Filled w/ sand		0	0	0
S-3	*M. lohena*		2		0		0	0	0			0	0	0
S-3	Amphipoda		21		17		10	12	9			3	0	0
S-3	Poecilids												x	x
S-4	*H. rubra*	Dry	16	Dry	0	Dry	0	15	31	Dry	Dry	38	8	0
S-4	Amphipoda		3		2		3	4	8			1	0	0
S-4	*Abudefduf sordidus*													1
S-5	*H. rubra*	0	0	0	0	0	0	0	0	0	35	49	3	0
S-5	Amphipoda	0	0	0	0	0	0	0	0	0	0	4	0	0
S-5	*M. grandimanus*	2	1	0	0	0	0	0	0	0	0	0	0	0
S-5	Poecilids													x
S-6	*H. rubra*	Dry	17	Dry	12	Dry	6	Dry	4	Dry	Dry	7	Dry	5
S-6	Amphipoda		0		2		3		0			0		0
S-6	White Amphipoda		0		0		0		0			0		0
S-7	*H. rubra*	77	121	86	79	87	59	43	41	56	47	0	0	0
S-7	Amphipoda	25	29	21	31	20	18	14	22	6	9	0	0	0
S-7	*M. grandimanus*	1	3	0	1	2	3	2	1	1	1	1	0	0
S-7	Poecilids											x	x	x
S-8	*H. rubra*	52	61	55	57	63	72	30	38	48	80	81	0	0
S-8	*M. grandimanus*	1	1	0	0	0	1	0	0	0	0	0	0	0
S-8	Poecilids												x	x
S-9	*H. rubra*	Dry	9	Dry	12	Dry	10	4	1	7	Dry	27	0	0
S-9	Poecilids												x	x

Appendix 1.3 The anchialine ponds census data for the survey conducted October 2008. In addition to quantitative counts, qualitative abundances were noted as follows: + few animals; scattered plants, ++ animals common; plants abundant in patches, +++ animals too numerous to count; plants covering substrate, and – none observed (Ziemann & Conquest, 2008).

Pond no.	*Ruppia maratima*	*Melania sp.*	*Assemenia sp.*	*Theodoxus cariosa*	*Graspsus tenuicrustatus*	*Halocaridina rubra*	*Metabateaus lohena*	*Poecilia sp.*	*other species, comment*
N-1				+		++	-	-	Ruppia absent
N-2						+	-	-	Ruppia absent
N-3	+	+				+++	-	-	Ruppia present
N-4						+++	-	-	Ruppia absent
N-5	+	+				++	-	-	Ruppia present
S-1						-	2	+	
S-2						100	-	-	
S-3						200	1	-	
S-4						5	-	-	
S-5						-	-	+	
S-6						20	1	-	
S-7						-	-	++	
S-8						75	15	-	
S-9						-	-	-	

Appendix 2

Marine Benthic Community Survey Results

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	Wawaloli Shallow			Wawaloli Middle			Wawaloli Bay Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	0	0	0	0	0	0	0	0	0
Montipora capitata	38	1.9	0.12	81	4.05	0.23	24	1.2	0.15
Montipora flabellata	3	0.15	0.02	0	0	0	0	0	0
Montipora patula	1	0.05	0.01	0	0	0	0	0	0
Pavona varians	5	0.25	0.03	0	0	0	1	0.05	0.01
Pocillopora eydouxi	0	0	0	0	0	0	0	0	0
Pocillopora meandrina	74	3.7	0.19	127	6.35	0.29	38	1.9	0.2
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	3	0.15	0.02	3	0.15	0.02	134	6.7	0.36
Porites lobata	834	41.7	0.15	584	29.2	0.23	259	12.95	0.34
Porites lutea	47	2.35	0.14	0	0	0	31	1.55	0.18
Total coral	1005	50.25	0.68	795	39.75	0.77	487	24.35	1.24
Coralline Algae	0	0	0	5	0.25	0	24	1.2	0
Dead coral									
Dead coral with algae	0	0	0	32	1.6	0.25	1	0.05	0.07
old dead coral	132	6.6	0	251	12.55	0.11	57	2.85	0.02
recently dead coral	0	0	0	0	0	0	0	0	0
Other live									
Sponge	0	0	0	2	0.1	0	15	0.75	0
Mollusc	2	0.1	0.31	0	0	0	0	0	0
Urchin	9	0.45	0.16	2	0.1	0.31	0	0	0
Turf algae	0	0	0	0	0	0	14	0.7	0
Substrate									
Boulder	714	35.7	0.15	0	0	0	83	4.15	0.17
Coral Rubble	15	0.75	0.07	578	28.9	0.29	1283	64.15	0.08
Limestone	1	0.05	0.01	2	0.1	0.01	0	0	0
Rock	119	5.95	0.28	296	14.4	0.37	4	0.2	0.02
Sand	0	0	0	28	1.4	0.11	30	1.5	0.08

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	18" Pipe Shallow			18" Pipe Middle			18" Pipe Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	14	0.7	0.06	5	0.25	0.03	0	0	0
Montipora capitata	102	5.1	0.23	76	3.8	0.2	16	0.8	0.11
Montipora flabellata	0	0	0	0	0	0	0	0	0
Montipora patula	45	2.25	0.14	26	1.3	0.1	9	0.45	0.07
Pavona varians	41	2.05	0.13	11	0.55	0.05	0	0	0
Pocillopora eydouxi	0	0	0	0	0	0	19	0.95	0.13
Pocillopora meandrina	249	12.45	0.35	354	17.7	0.37	157	7.85	0.36
Pocillopora ligulata	0	0	0	0	0	0	17	0.85	0.12
Porites compressa	1	0.05	0.01	0	0	0	2	0.1	0.02
Porites lobata	544	27.2	0.33	466	23.3	0.35	273	13.65	0.33
Portites lutea	0	0	0	0	0	0	0	0	0
Total coral	996	49.8	1.25	938	46.9	1.1	493	24.65	1.14
Coralline Algae	29	1.45	0	18	0.9	0	3	0.15	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	34	1.7	0.23
old dead coral	341	17.05	0	469	23.45	0	317	15.85	0.09
recently dead coral	0	0	0	0	0	0	0	0	0
Other live									
Sponge	0	0	0	1	0.05	0	0	0	0
Mollusc	24	1.2	0.23	9	0.45	0.28	4	0.2	0.35
Urchin	9	0.45	0.35	5	0.25	0.37	11	0.55	0.23
Turf algae	0	0	0	0	0	0	1	0.05	0.35
Substrate									
Boulder	499	24.95	0.15	393	19.65	0.25	213	10.65	0.31
Coral Rubble	79	3.95	0.27	159	7.95	0.36	913	45.65	0.18
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	23	1.15	0.12	8	0.4	0.06	10	0.5	0.04

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	12" Pipe South Shallow			12" Pipe South Middle			12" Pipe South Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	4	0.2	0.02	0	0	0	4	0.21	0.04
Montipora capitata	69	3.45	0.17	67	3.54	0.19	10	0.53	0.08
Montipora flabellata	0	0	0	0	0	0	0	0	0
Montipora patula	43	2.15	0.12	11	0.58	0.05	9	0.48	0.07
Pavona varians	14	0.7	0.05	2	0.11	0.01	5	0.26	0.05
Pocillopora eydouxi	56	2.8	0.15	0	0	0	0	0	0
Pocillopora meandrina	391	19.55	0.37	283	14.95	0.36	225	11.9	0.36
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	1	0.05	0.01	2	0.11	0.01	34	1.8	0.18
Porites lobata	590	29.5	0.34	587	31.01	0.3	207	10.95	0.36
Porites Lutea	0	0	0	0	0	0	0	0	0
Total Coral	1168	58.4	1.23	952	50.3	0.92	494	26.13	1.14
Coralline Algae	1	0.05	0	4	0.21	0	62	3.28	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	0	0	0
old dead coral	464	23.2	0	124	6.55	0	235	12.43	0
recently dead coral	0	0	0	0	0	0	0	0	0
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	13	0.65	0.28	1	0.05	0.28	0	0	0
Urchin	6	0.3	0.36	0	0	0	1	0.05	0
Turf algae	0	0	0	6	0.32	0	61	3.23	0
Substrate									
Boulder	194	9.7	0.33	49	2.59	0.17	8	0.42	0.04
Coral Rubble	115	5.75	0.37	736	38.88	0.08	1021	53.99	0.02
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	38	1.9	0.24	15	0.79	0.07	9	0.48	0.04

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	12" Pipe North Shallow			12" Pipe North Middle			12" Pipe North Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	0	0	0	0	0	0	0	0	0
Montipora capitata	17	0.85	0.06	9	0.5	0.05	20	1	0.06
Montipora flabellata	0	0	0	0	0	0	0	0	0
Montipora patula	49	2.45	0.14	21	1.17	0.1	21	1.05	0.07
Pavona varians	1	0.05	0.01	2	0.11	0.02	0	0	0
Pocillopora eydouxi	0	0	0	8	0.44	0.05	87	4.35	0.18
Pocillopora meandrina	509	25.45	0.36	394	21.89	0.35	349	17.45	0.35
Pocillopora ligulata	20	1	0.07	18	1	0.09	4	0.2	0.02
Porites compressa	0	0	0	7	0.39	0.04	193	9.65	0.28
Porites lobata	504	25.2	0.36	335	18.61	0.36	637	31.85	0.35
Porites lutea	0	0	0	0	0	0	7	0.35	0.03
Total coral	1100	55	1	794	44.11	1.06	1318	65.9	1.34
Coralline Algae	37	1.85	0	29	1.61	0	34	1.7	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	0	0	0
old dead coral	302	15.1	0	224	12.44	0	297	14.85	0
recently dead coral	0	0	0	0	0	0	0	0	0
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	1	0.05	0.23	0	0	0	0	0	0
Urchin	9	0.45	0.09	0	0	0	0	0	0
Turf algae	1	0.05	0	4	0.22	0	4	0.2	0.27
Substrate									
Boulder	219	10.95	0.37	285	15.83	0.37	44	2.2	0.26
Coral Rubble	320	16	0.32	461	25.61	0.3	287	14.35	0.15
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	11	0.55	0.08	1	0.06	0.01	14	0.7	0.13

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	NPPE Shallow			NPPE Middle			NPPE Bay Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	0	0	0	0	0	0	0	0	0
Montipora capitata	4	0.2	0.02	36	1.8	0.08	28	1.4	0.07
Montipora flabellata	0	0	0	0	0	0	4	0.2	0.01
Montipora patula	9	0.45	0.03	103	5.15	0.17	9	0.45	0.03
Pavona varians	16	0.8	0.05	6	0.3	0.02	0	0	0
Pocillopora eydouxi	0	0	0	3	0.15	0.01	0	0	0
Pocillopora meandrina	394	19.7	0.36	180	9	0.24	92	4.6	0.16
Pocillopora ligulata	0	0	0	11	0.55	0.03	9	0.45	0.03
Porites compressa	0	0	0	111	5.55	0.18	666	33.3	0.37
Porites lobata	972	48.6	0.26	919	45.95	0.33	131	6.56	0.53
p. lutea	34	1.7	0.09	288	14.4	0.3	96	4.8	0.16
Total coral	1395	69.75	0.72	1369	68.45	1.06	1035	51.76	1.36
Coralline Algae	2	0.1	0	20	1	0	3	0.15	0
Dead coral									
Dead coral with algae	1	0.05	0.02	0	0	0	2	0.1	0.03
old dead coral	276	13.8	0	326	16.32	0.01	394	19.73	0.01
recently dead coral	0	0	0	4	0.2	0.05	2	0.1	0.03
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	20	1	0.09	56	2.8	0.03	0	0	0
Urchin	2	0.1	0.22	2	0.1	0.12	3	0.15	0.35
Turf algae	0	0	0	0	0	0	1	0.05	0.21
Substrate									
Boulder	259	12.95	0.04	105	5.26	0.29	1	0.05	0.1
Coral Rubble	11	0.55	0.13	58	2.9	0.37	28	0.4	0.3
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	0	0	0	1	0.05	0.03	6	0.3	0.3

Appedix 2. Percent coverage for photo-quadrats taken along benthic transects, the locations of which are given in Figure 11. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m.

	Ho'ona Bay Shallow			Ho'ona Bay Middle			Ho'ona Bay Deep		
CATEGORIES	# Points	%	SW Index	# Points	%	SW Index	# Points	%	SW Index
Coral									
Lepastrea bewickensis	46	2.5	0.13	8	0.4	0.03	0	0	0
Montipora capitata	50	2.72	0.14	38	1.9	0.1	24	1.2	0.06
Montipora flabellata	0	0	0	0	0	0	0	0	0
Montipora patula	12	0.65	0.05	35	1.75	0.1	1	0.05	0
Pavona varians	3	0.16	0.02	0	0	0	0	0	0
Pocillopora eydouxi	4	0.22	0.02	0	0	0	0	0	0
Pocillopora meandrina	212	11.53	0.31	251	12.55	0.32	100	5	0.17
Pocillopora ligulata	0	0	0		0	0	16	0.8	0.04
Porites compressa	4	0.22	0.02	0	0	0	523	26.15	0.36
Porites lobata	806	43.83	0.24	989	49.45	0.22	891	44.55	0.34
Porites lutea	0	0	0	5	0.25	0.02	150	7.5	0.021
Total coral	1137	61.83	0.93	1326	66.3	0.79	1705	85.25	0.991
Coralline Algae	1	0.05	0	1	0.05	0	0	0	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	1	0.05	0.04
old dead coral	109	5.93	0	101	5.05	0	134	6.7	0.01
recently dead coral	0	0	0	0	0	0	13	0.65	0.19
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	31	1.69	0.03	13	0.65	0.17	5	0.25	0.36
Urchin	0	0	0	1	0.05	0.17	7	0.35	0.31
Turf algae	0	0	0	0	0	0	0	0	0
Substrate									
Boulder	502	27.3	0.1	408	20.4	0.23	70	3.5	0.35
Coral Rubble	53	2.88	0.22	128	6.4	0.34	72	3.6	0.35
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	5	0.27	0.04	20	1	0.12	6	0.3	0.13

Appendix 3

Marine Fish Community Survey Results

Appendix 3. Abundance of fish observed along 25 m transects in April, 2013. Species are listed in taxonomic order.

		Wawaloli			18" Pipe			12" Pipe South			12" Pipe North			NPPE			Ho'ona Bay			Total
Family	**species**	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	
Holocentridae	*Myripristis berndti*																			0
	Myripristis amaena																			0
	Sargocentron xantherythrum																			0
Syngnathidae	*Aulostomas chinensis*											1								
Serranidae	*Cephalopholis argus*	2												1						3
Cirrhitidae	*Paracirrhites arcatus*							1												1
	Paracirrhites fosteri																			0
	Cirrhitus pinnulatus						1		1											
Mullidae	*Parupeneus multifasciatus*	1		7			3			3		3	1			1	1			17
	Parupeneus cyclostomus			2																
	Parupeneus insularis	1		1										1				2		5
Chaetodontidae	*Chaetodon lunula*	1											2			2				5
	Chaetodon ephipppium																			0
	Chaetodon kleinii																			0
	Chaetodon multicintus				2		2		4	7		4	1	4		1		2	4	24
	Chaetodon ornatissimus										1	4								5
	Chaetodon quadrimaculatus				1	6		1	2	2	2	1	5	1		2		1		22
	Chaetodon unimaculatus								2											
	Chaetodon miliaris										1						1			
	Chaetodon auriga																1			
	Forcipiger longirostris	1			1							2		2				1		7
	hemitaurichthys polylelpis							40			4	4								48
Pomacanthidae	*Centropyge potteri*																	2		2
Pomacentridae	Abudefduf abdominalis					1		2			2	2					8			15
	Chromis vanderbilti	40			6	21	40	8	30	35		42		20						207
	Chromis hanui			7		3	60	5		2	2	5	1			36	10		100	229
	Chromis agilis	8	15	5					3	7								4		35
	Chromis ovalis					18				20		26	60							104
	Dascyllus albisella					1				2		2							1	
	Stegastes marginatus								1											
	Plectroglyphidodon johnstonianus																			0

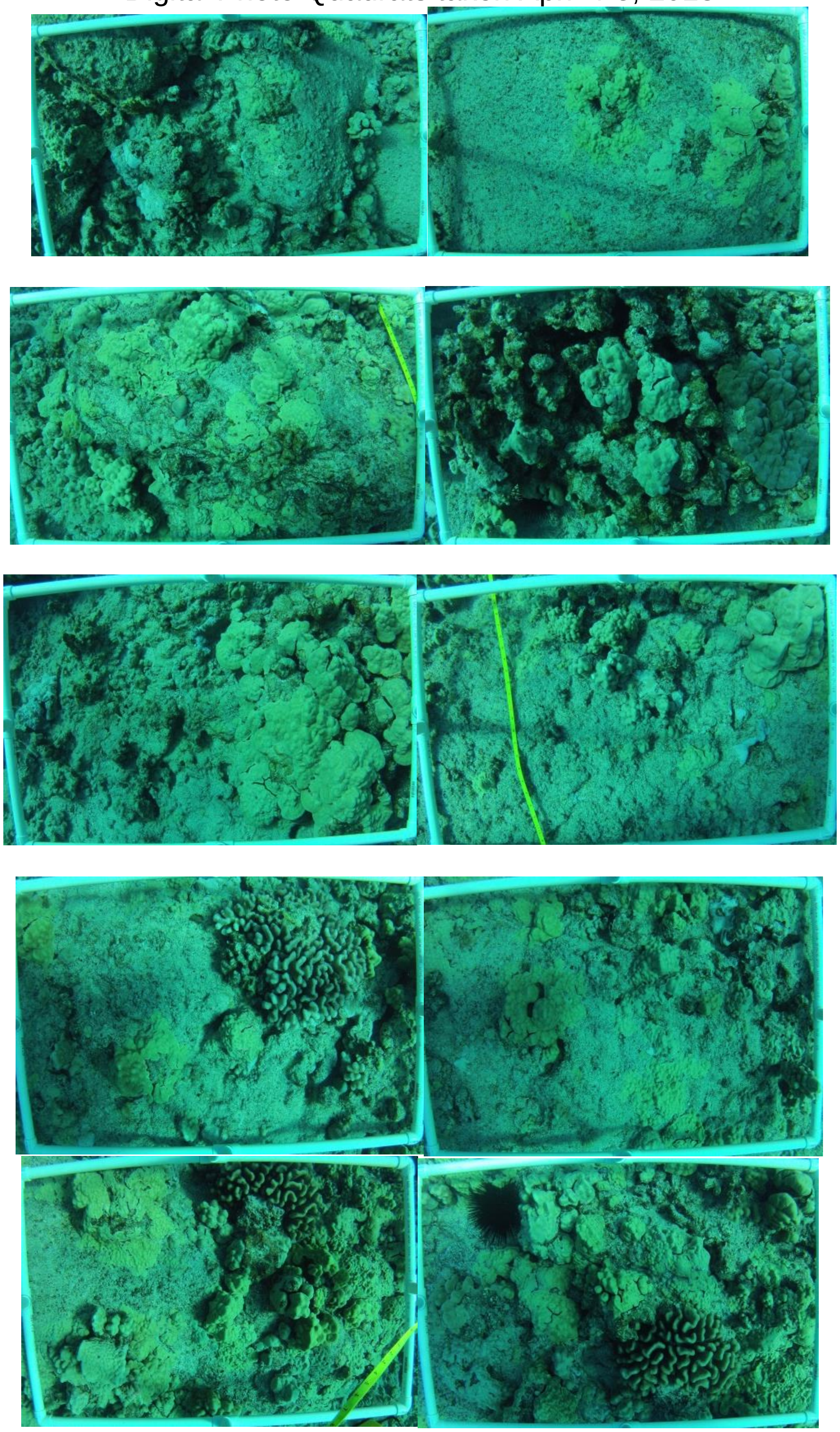
Labridae	*Coris gaimard*			1																1
	Coris flavovittata				2		2													4
	Gomphosus varius				6	1		2	10	1	2	4	2	3	4			4	1	39
	Halichoeres ornatissimus						1		1						2					4
	Labroides phthirophagus						1		1				2	2						6
	Thalassoma duperrey	3	6	25	11	12	5	24	26	10	16	21	8	15	11		12	13	3	211
Zanclidae	*Zanclus cornutus*							1		3	7		1							9
Acanthuridae	*Acanthuris achilles*				1						1									2
	Acanthurus nigrofuscus	5	2	5	6	12	15	10	5	2	5	10	8	4			3	3	1	94
	Acanthurus nigroris							3	2		7	2	3		1					18
	Acanthurus olivaceus						2		1						1					4
	Acanthurus triostegus							5						1						6
	Acanthurus blochii				8	2		30	13	7		3							2	58
	Ctenochaetus hawaiiensis	6	3	12	12	13	4	14	16	7	3	21	28	5	4	4	12	8	5	170
	Ctenochaetus strigosus	6	1	5	10	20	23	16	7	27		13		19	7	3	5	5	15	155
	Naso lituratus	2		2	3	4	2		1	2		5		7	6	3	9	12	3	59
	Naso unicornis																1		2	
	Zebrasoma flavescens	9	3	5	23	19	3	40	27	19	15	20	6	24	14	10	12		13	243
Balistidae	*Melichthys niger*	1			1			3						1				1		7
	Sufflamen bursa			1			1	1	1			1		1	1		1	1		9
	Melichthys vidua																			0
	Xanthichthys auromarginatus																			0
Ostraciidae	*Ostracion meleagris*																			0
Tetradontidae	*Canthigaster coronata*								1	1										1
	Plectroglyphidodon sindonis												2							2
Scaridae	*Chlorurus perspicillatus*							1	2					1						4
	Chlorurus spilurus				1			1				6		1						9
	Scarus dubius																			0
		86	30	78	94	133	165	208	157	157	68	202	130	113	51	62	76	59	150	1862

Appendix 4

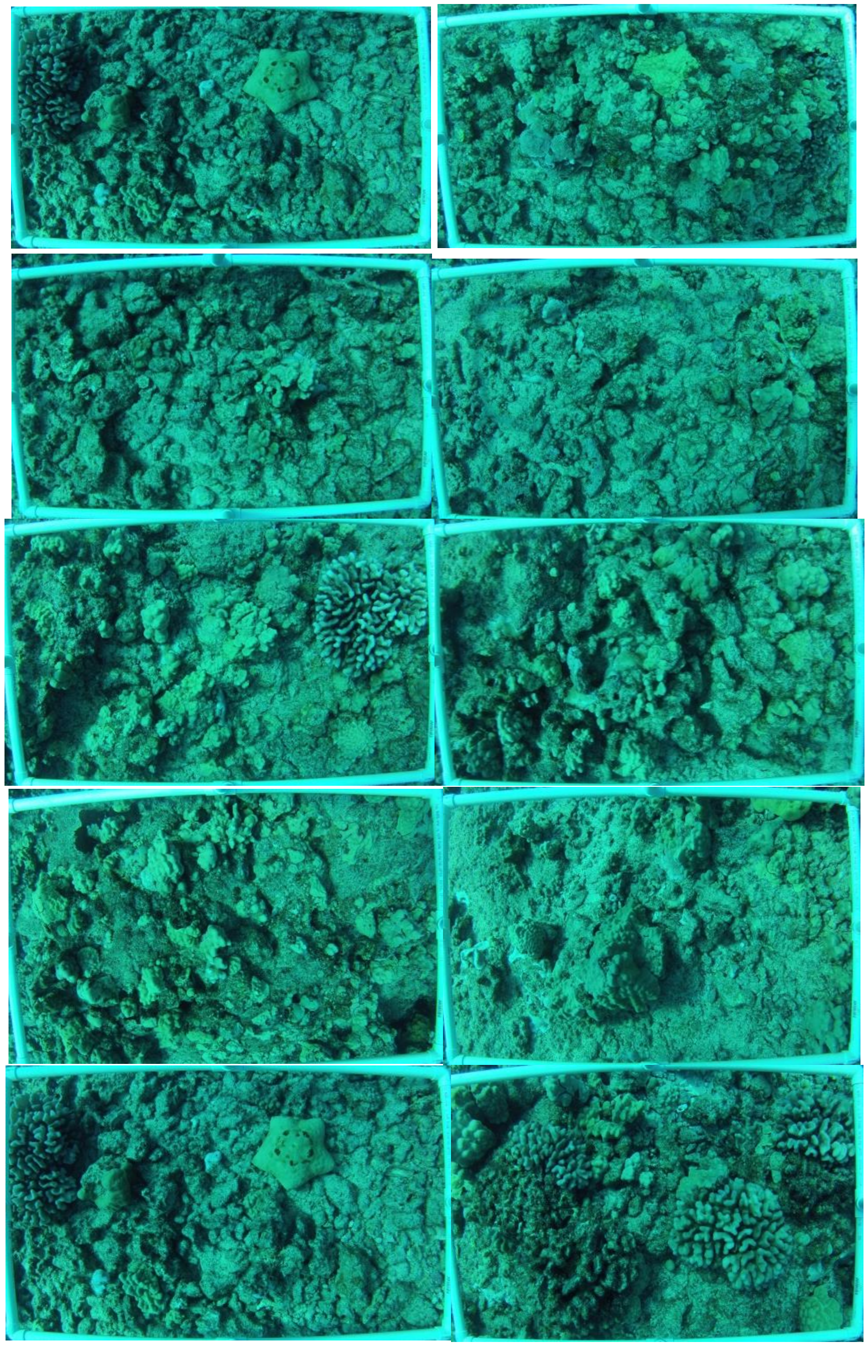
Digital Photo Quadrats taken April 4-5, 2013

Appendix 4

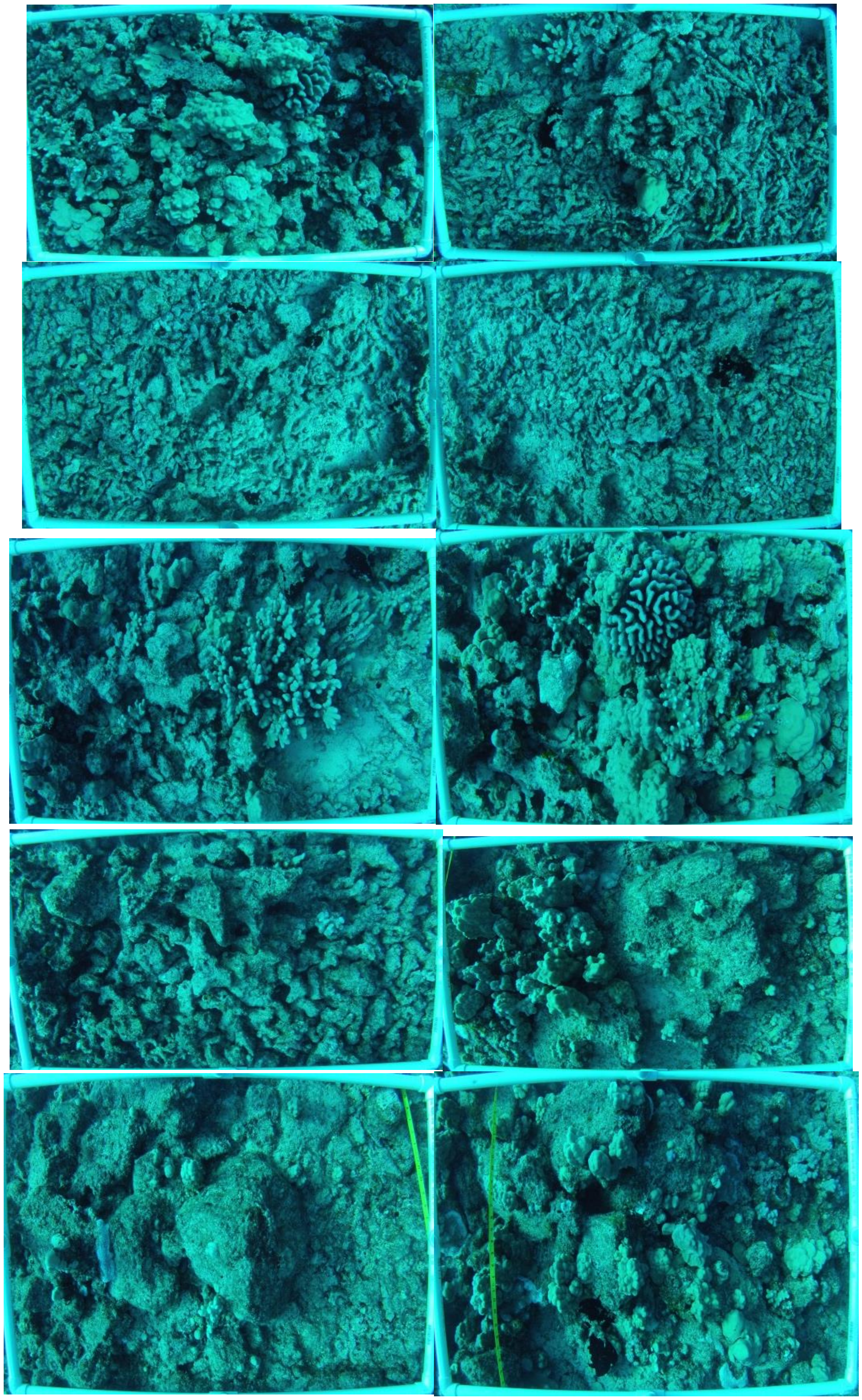
Digital Photo Quadrats taken April 4-5, 2013



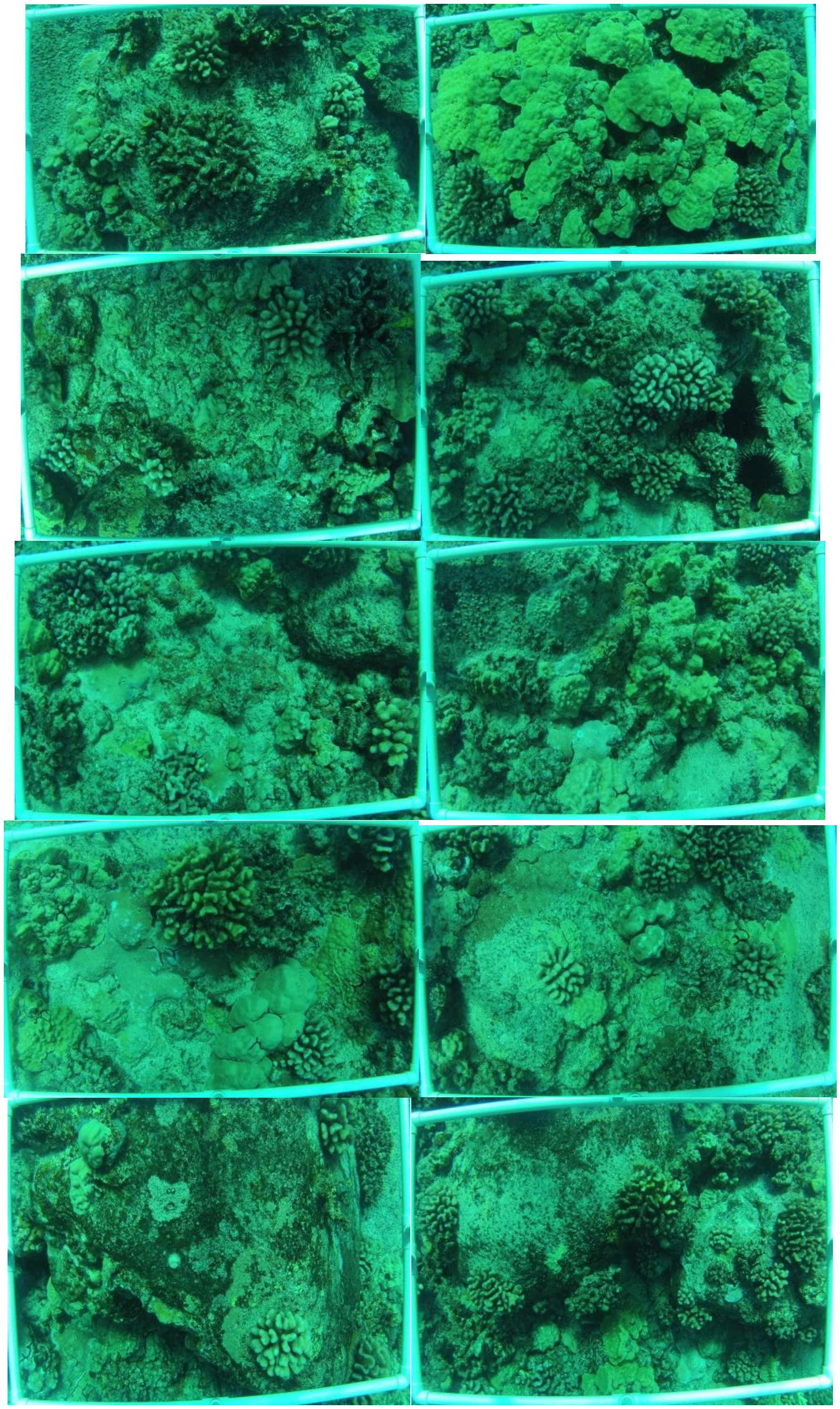
Photoquadrats taken along the 15 ft. transect at Wawaloli



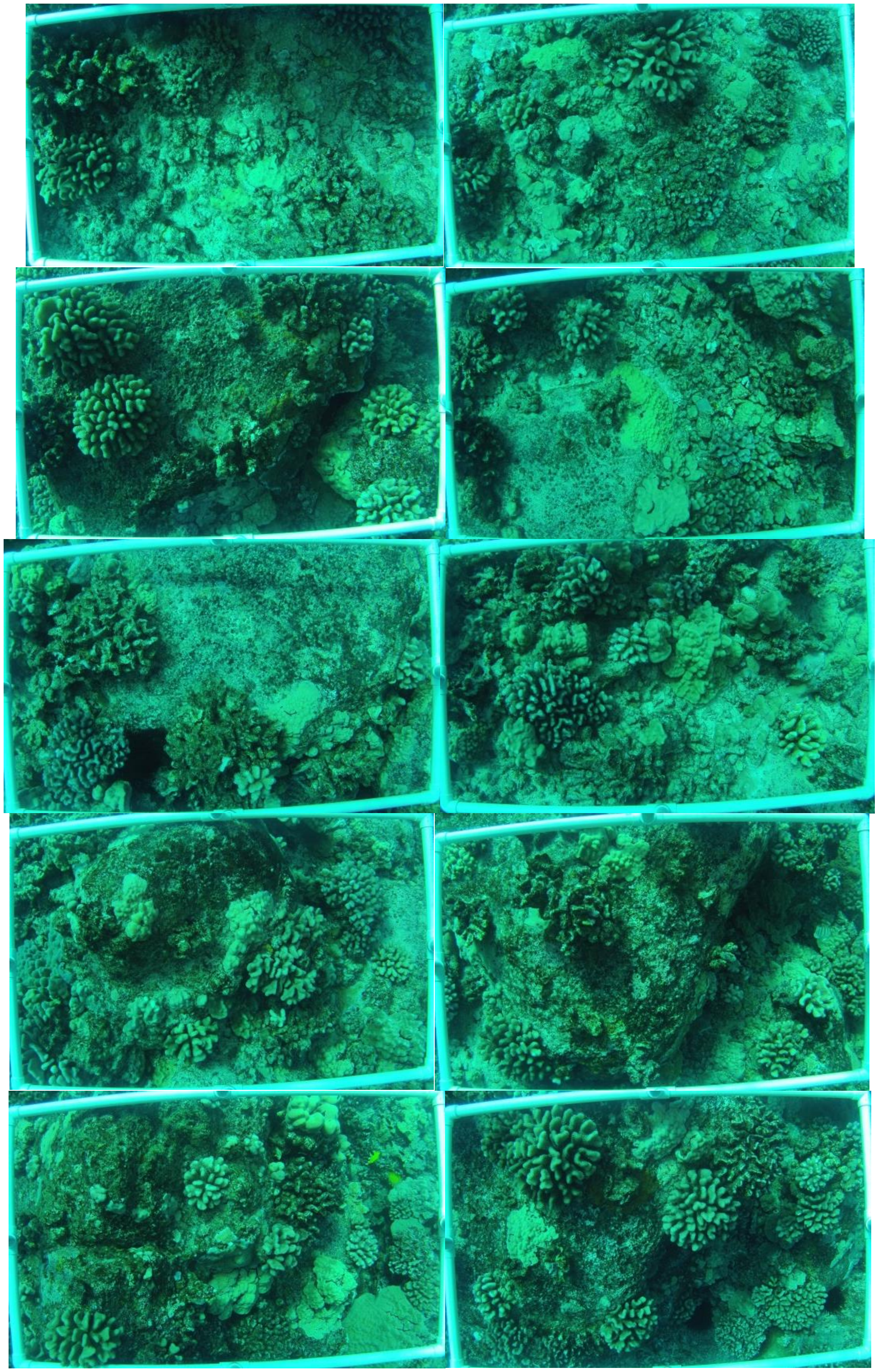
Photoquadrats taken along the 30 ft. transect at Wawaloli



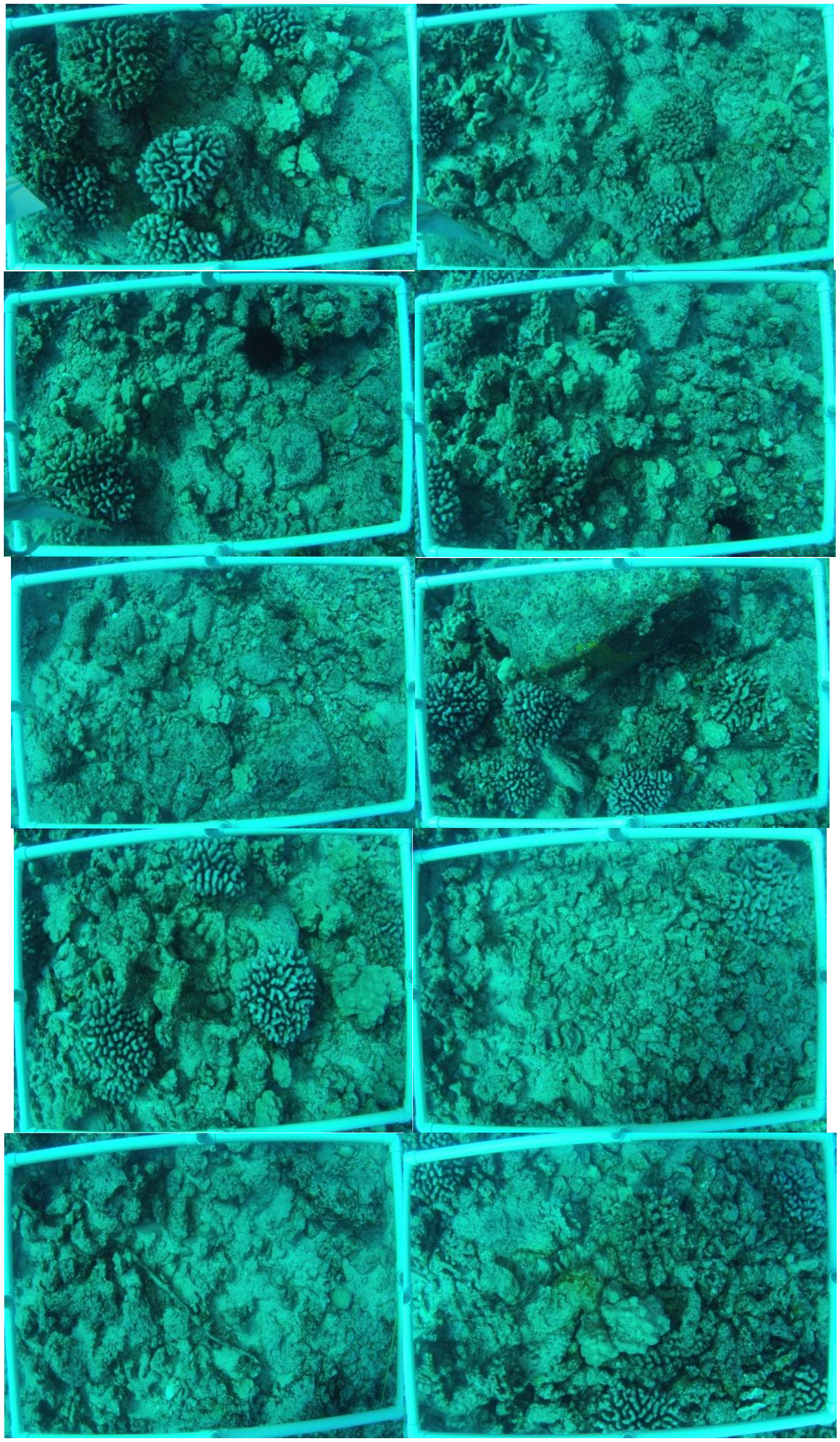
Photoquadrats taken along the 50 ft. transect at Wawaloli



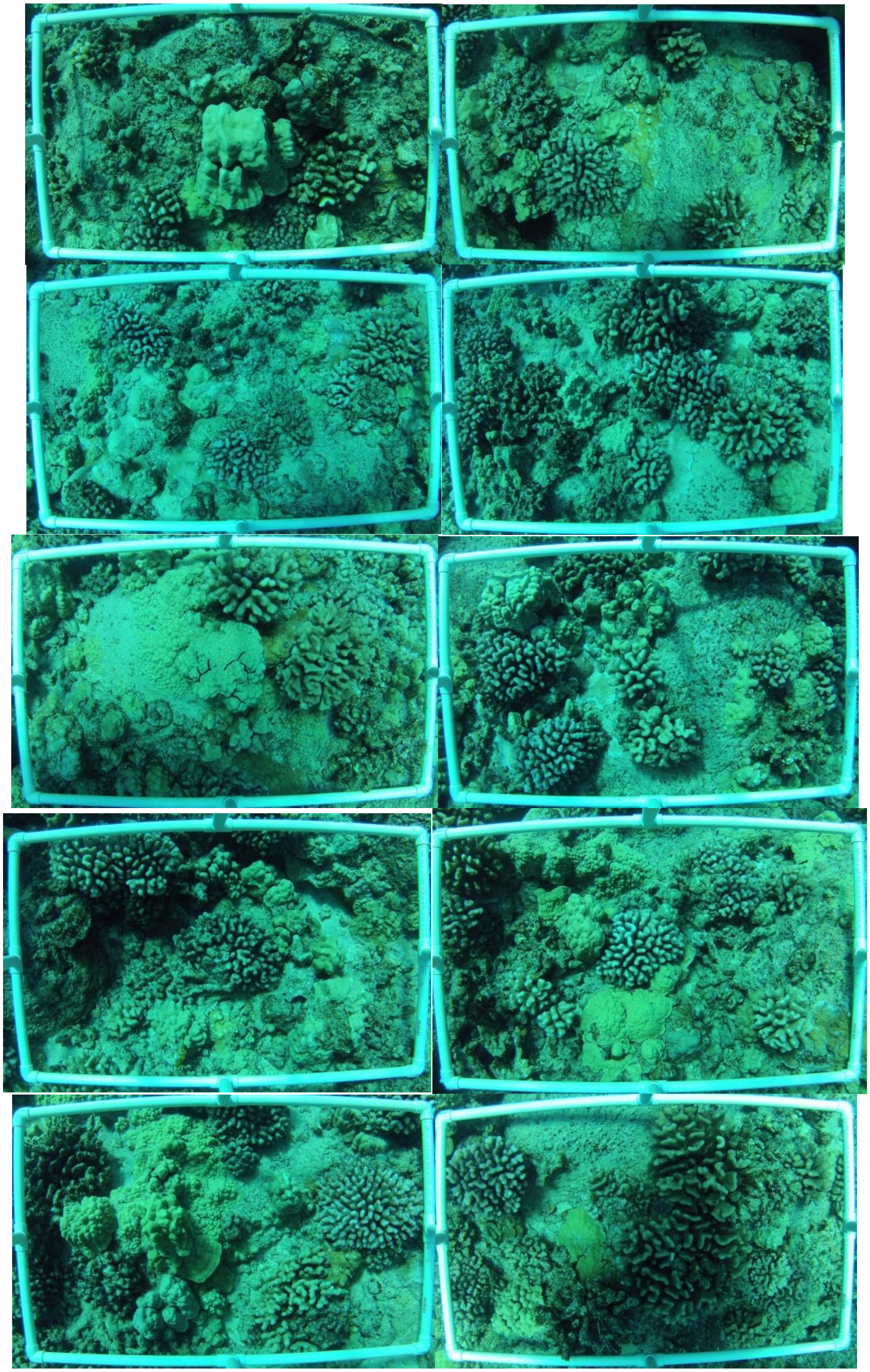
Photoquadrats taken along the 15 ft. transect at 18” Pipe



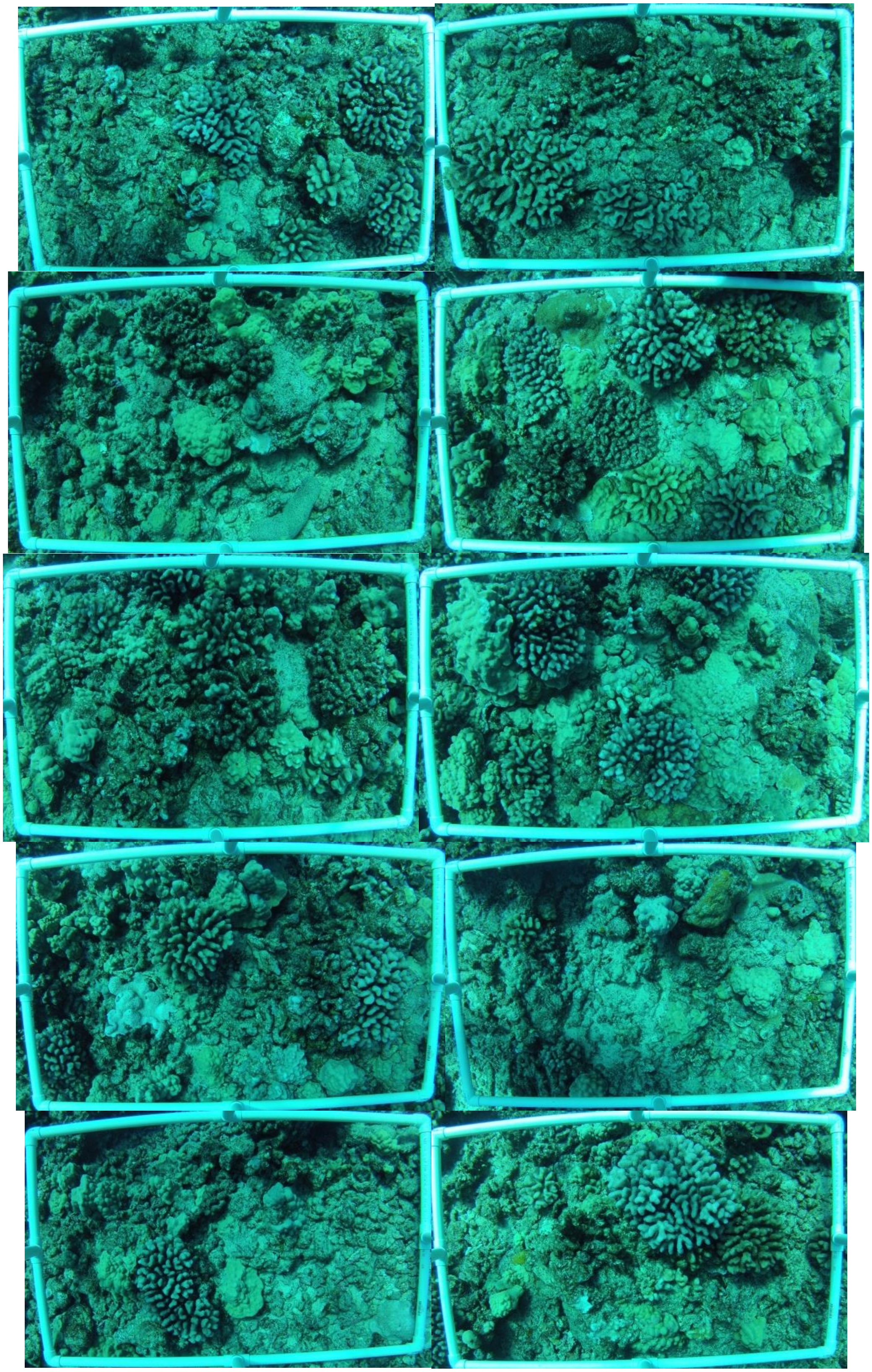
Photoquadrats taken along the 30 ft. transect at 18” Pipe



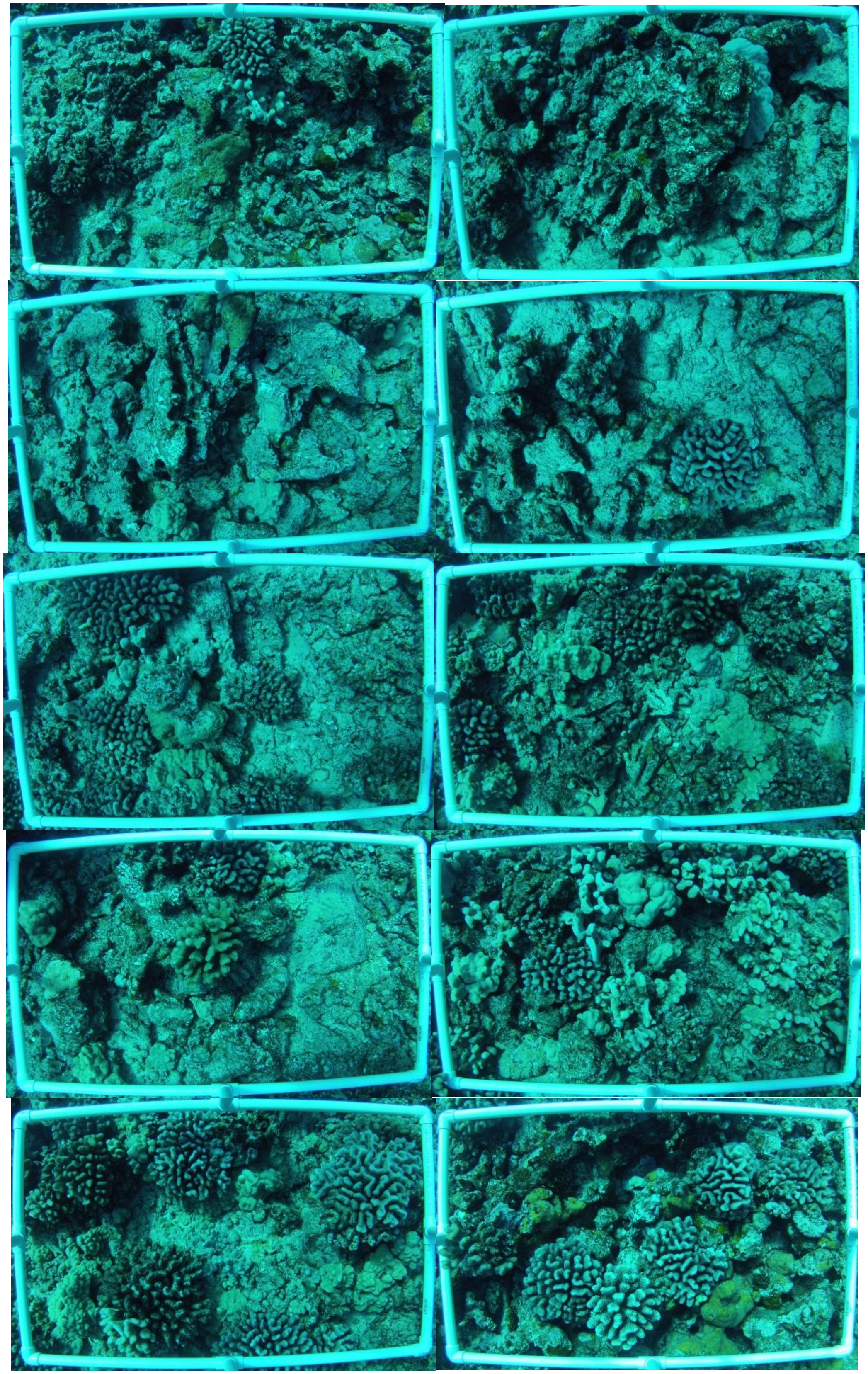
Photoquadrats taken along the 50 ft. transect at 18” Pipe



Photoquadrats taken along the 15 ft. transect at 12” Pipe South



Photoquadrats taken along the 30 ft. transect at 12” Pipe South



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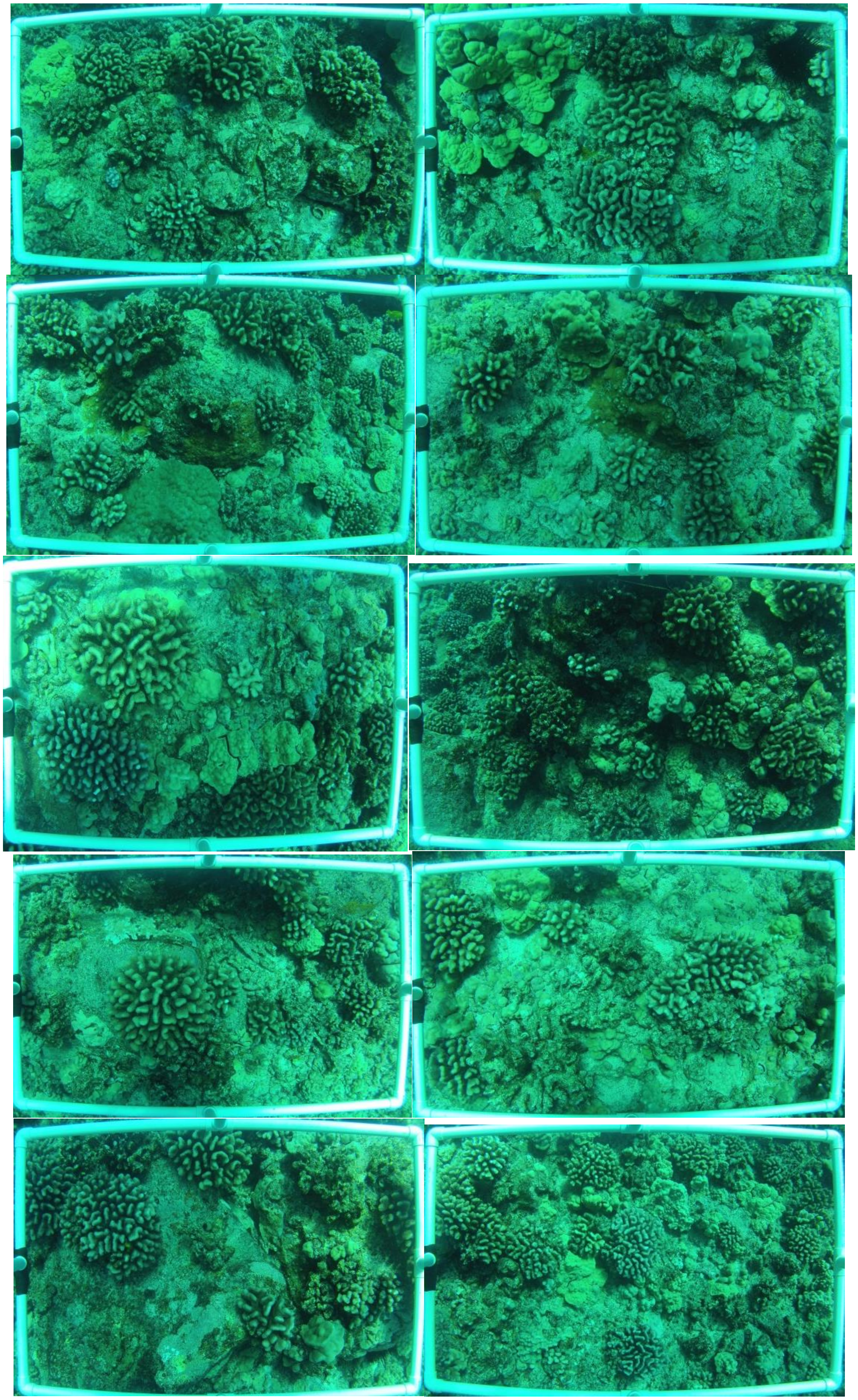
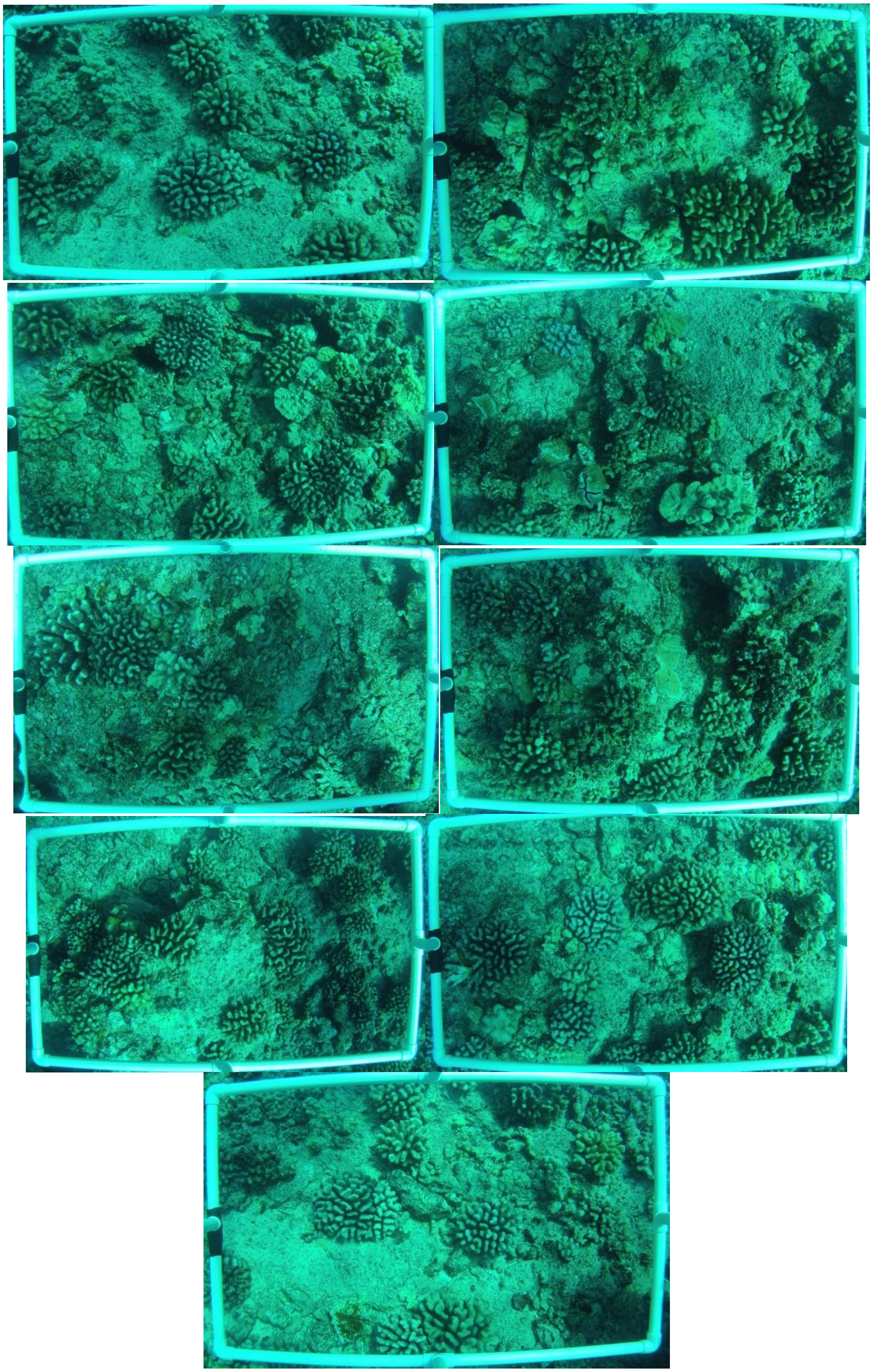
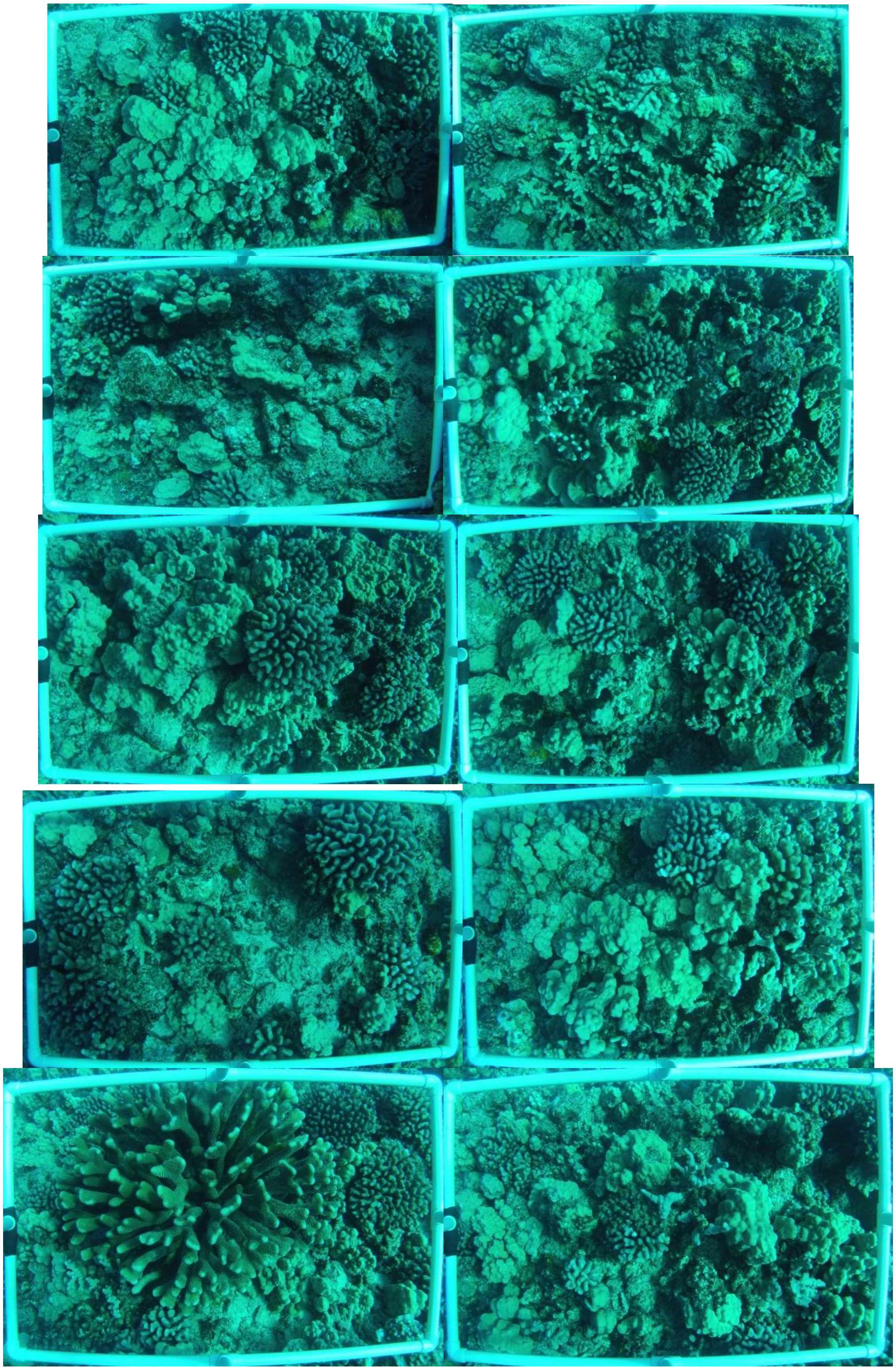


Photoquadrats taken along the 15 ft. transect at 12" Pipe North



Photoquadrats taken along the 30 ft. transect at 12” Pipe North



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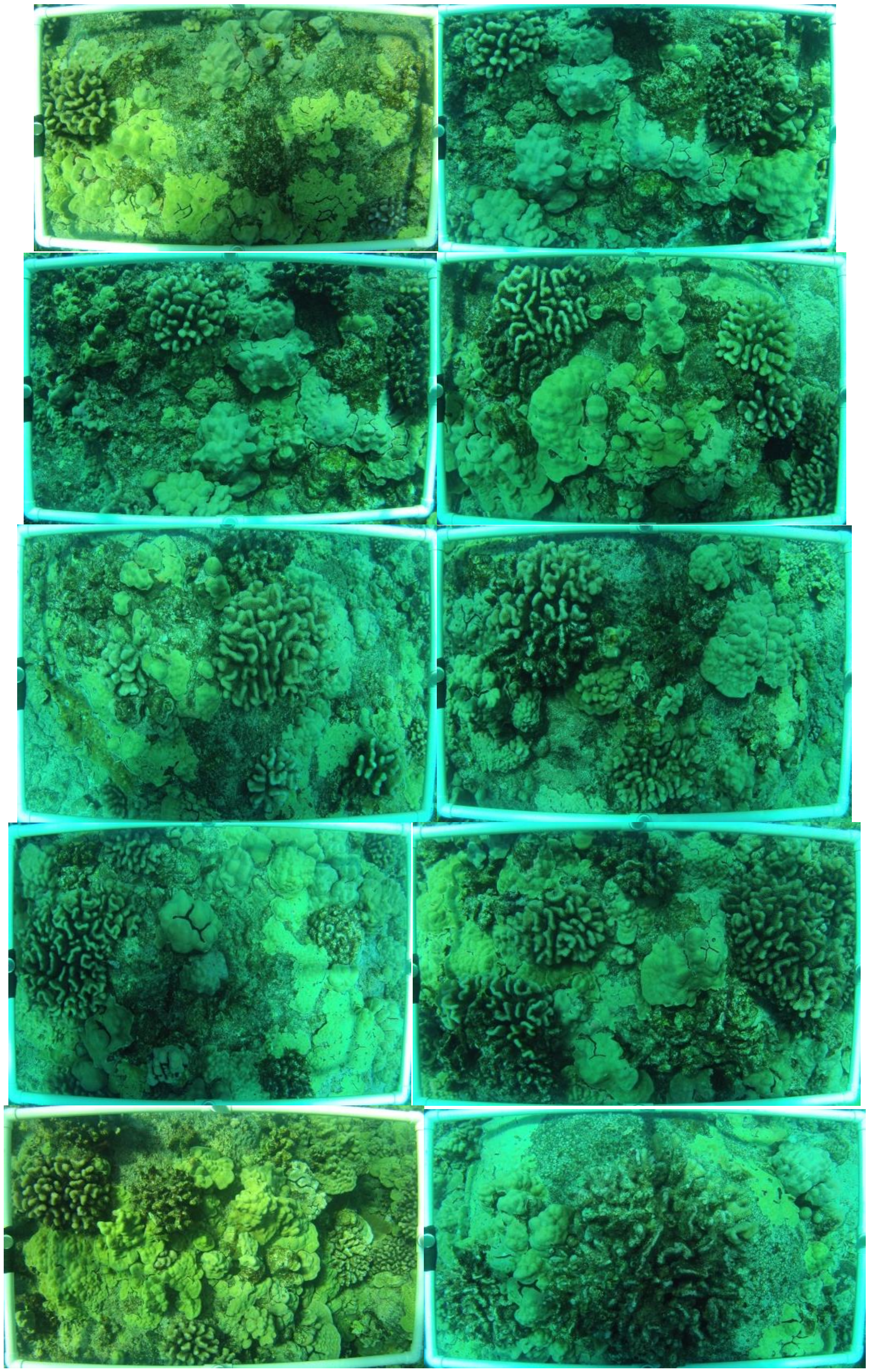
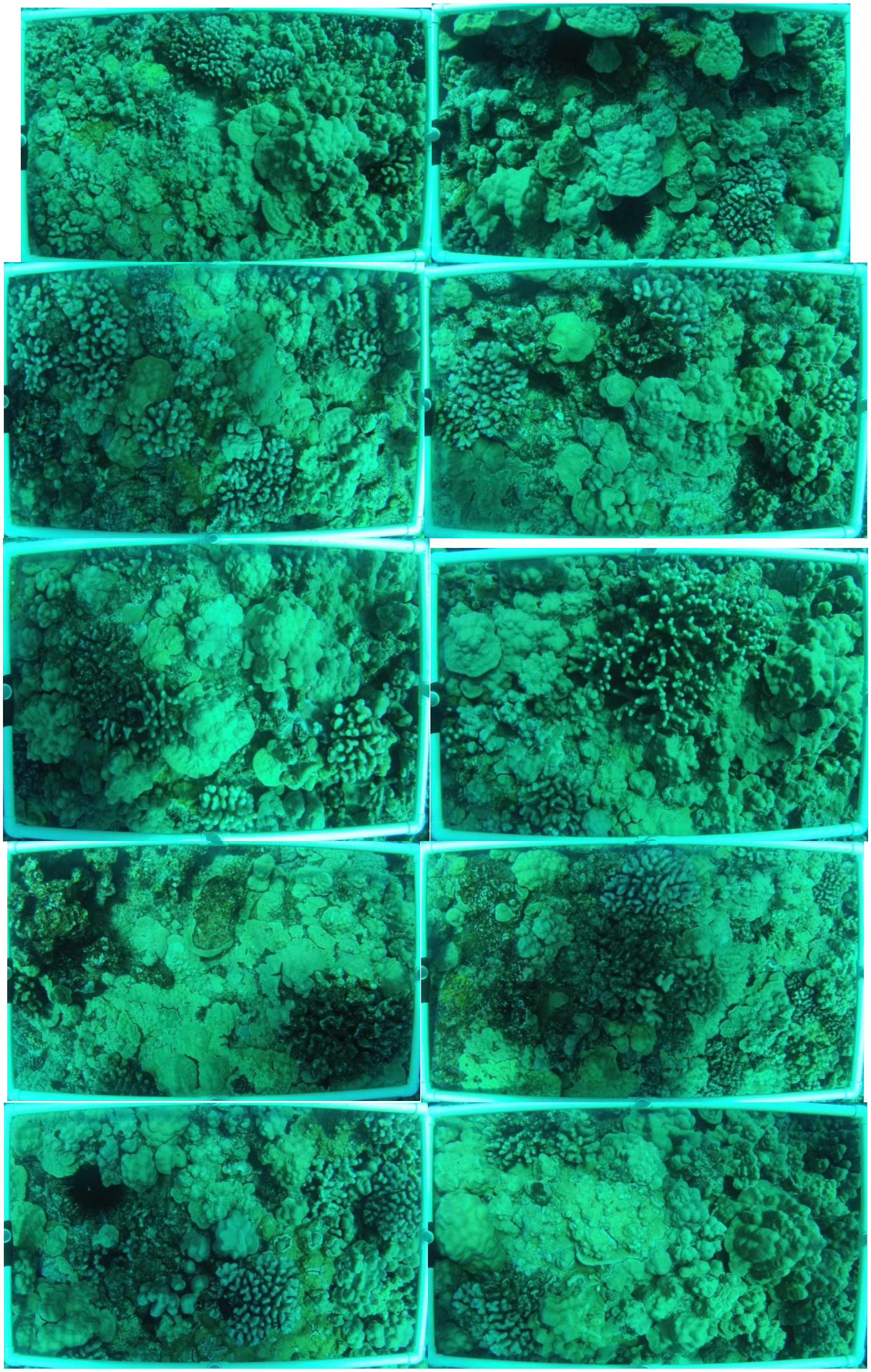
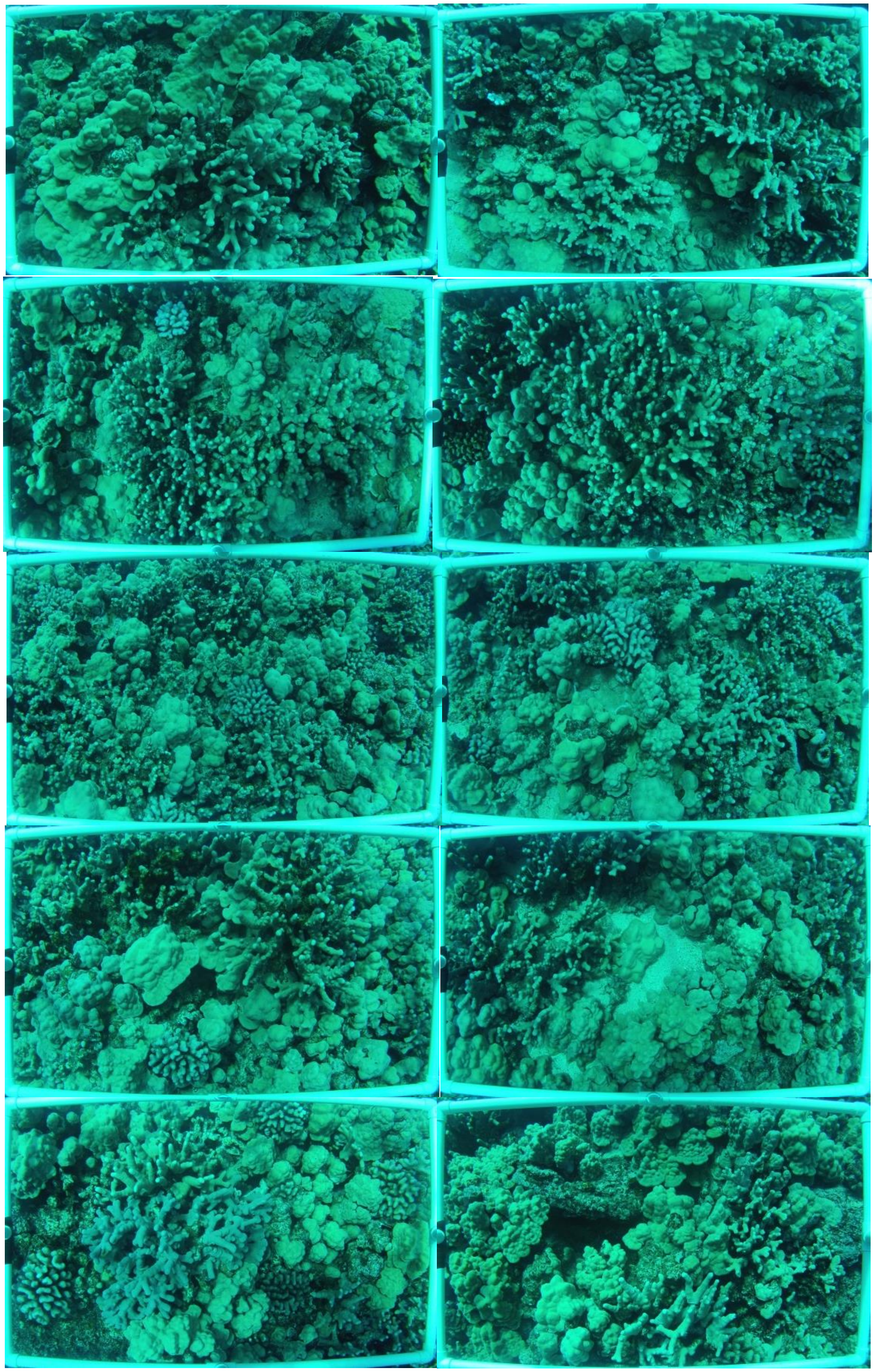


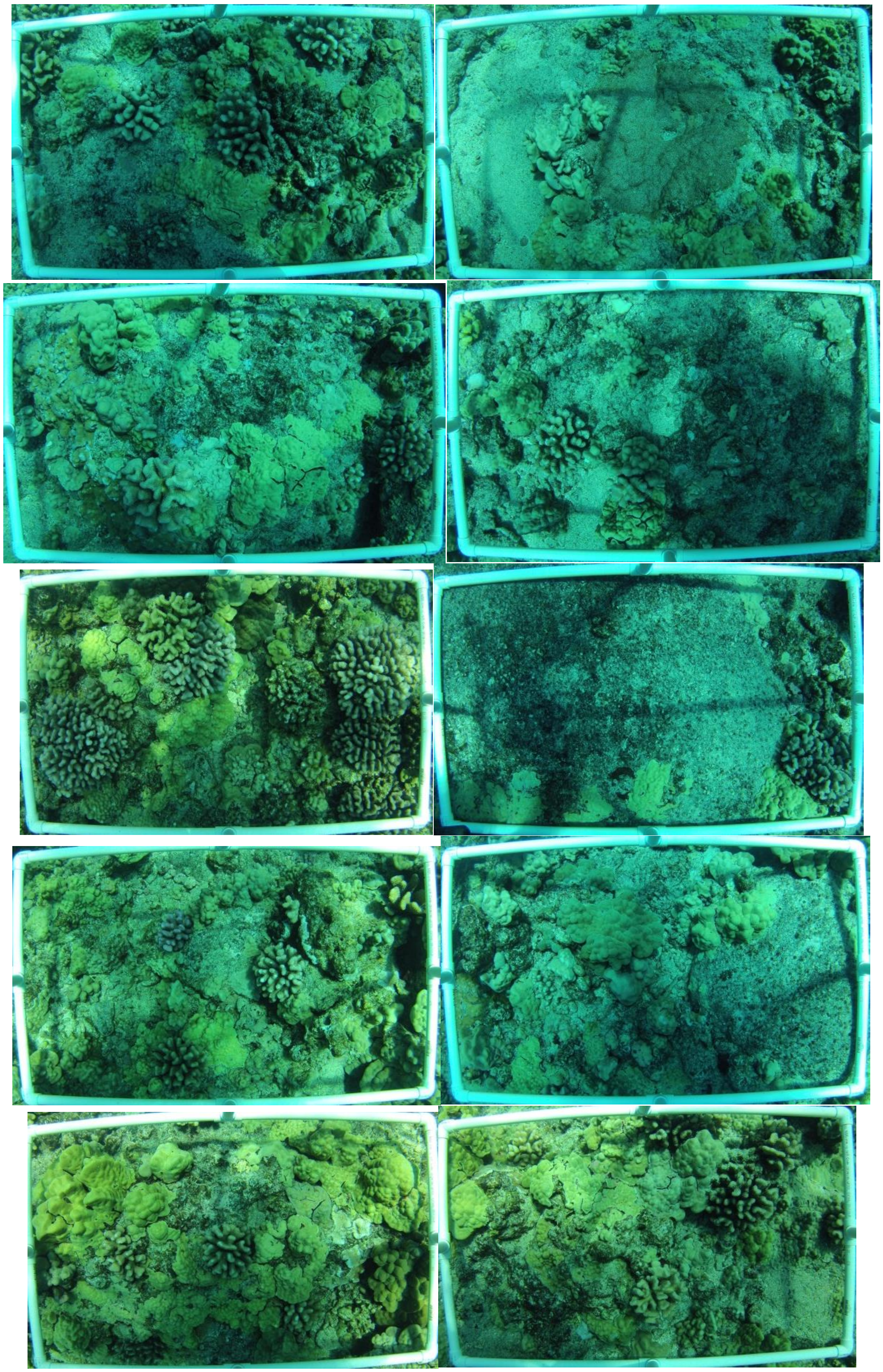
Photoquadrats taken along the 15 ft. transect at NPPE



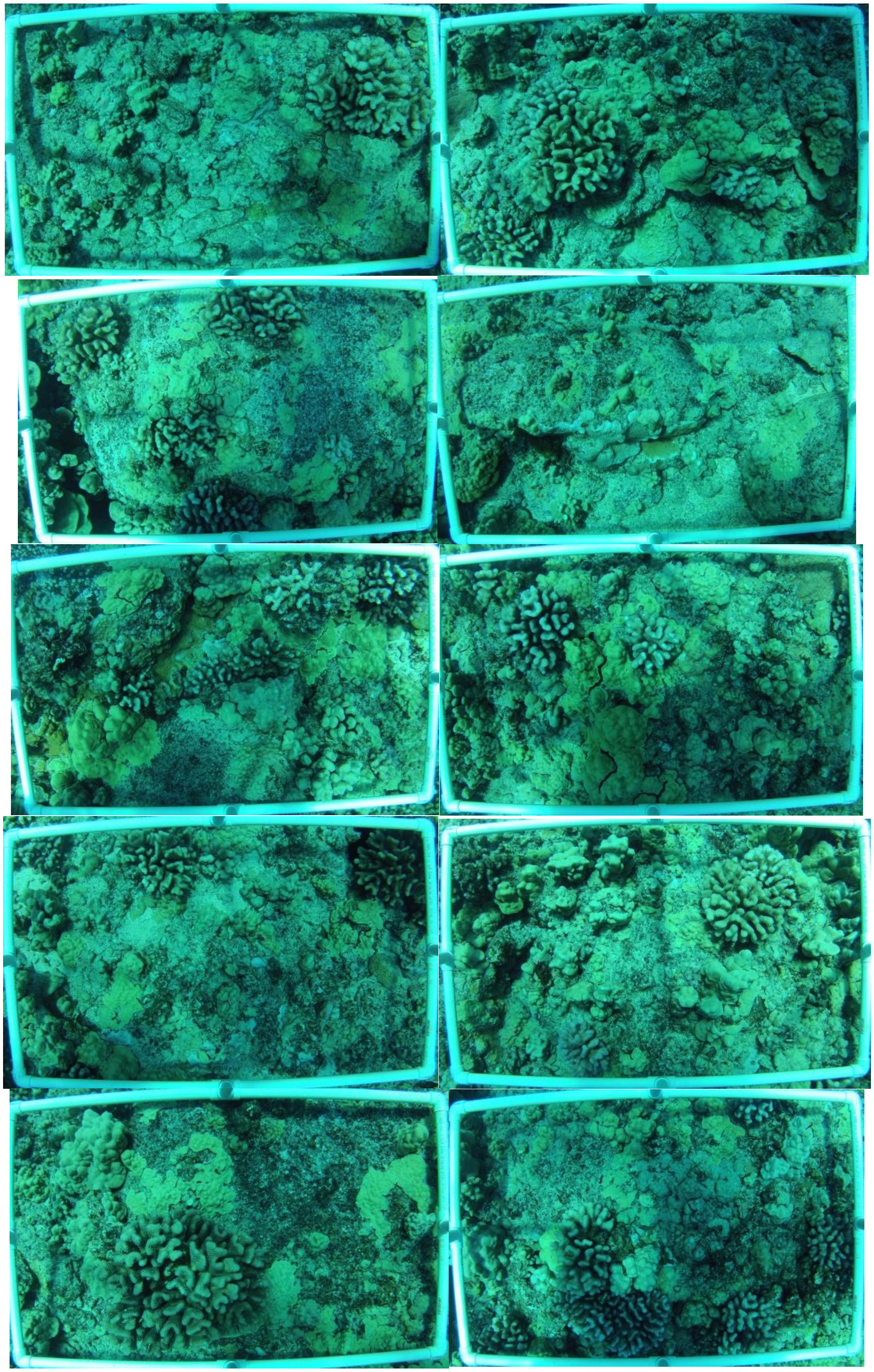
Photoquadrats taken along the 30 ft. transect at NPPE



Photoquadrats taken along the 50 ft. transect at NPPE



Photoquadrats taken along the 15 ft. transect at Ho’ona Bay



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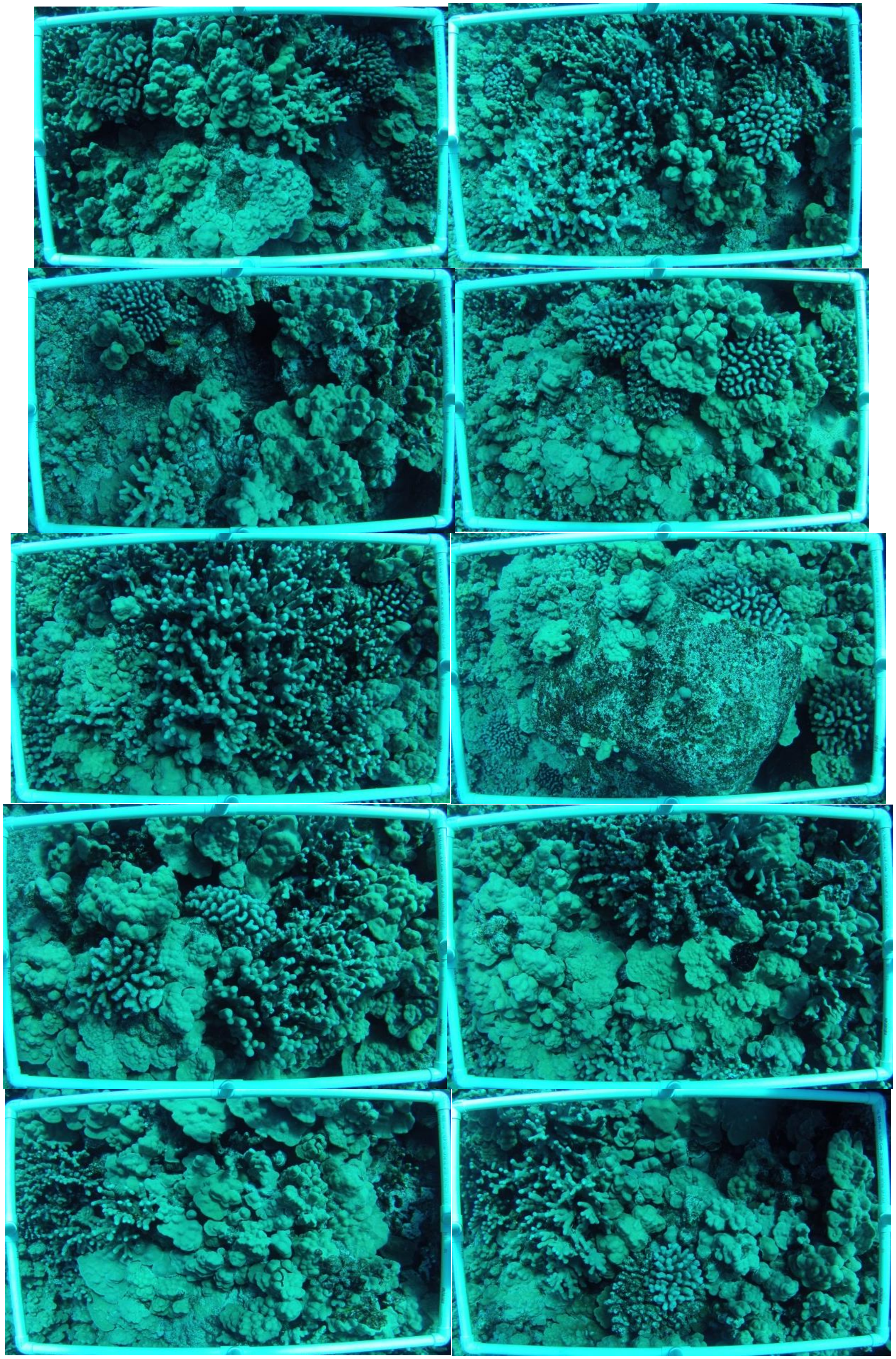

Photoquadrats taken along the 50 ft. transect at Ho’ona Bay