MARINE ENVIRONMENTAL MONITORING PROGRAM

NATURAL ENERGY LABORATORY OF HAWAII AUTHORITY

SURVEY REPORT - JULY 2014

Prepared for:

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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 2014 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 17th and 18th of July 2014. 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 2014 anchialine pond survey were consistent with previous surveys. Based on the faunal census performed, almost all 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 2014 was 53.8%. The two most dominant corals were *Porites lobata* (35.5%) and *Pocillopora meandrina* (10.6%) which were present on all transects. Other corals present were *Leptastrea purpurea, 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 7% 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 2014 study were, on average, higher than 2013 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.

TABLE OF CONTENTS

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 previously 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 ʻgardeningʼ 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 have provided a better understanding of their population dynamics and contributed to effective planning and management of anchialine resources in Hawaiʻi. A study to elucidate the structure of *Halocaridina rubra* populations from the island of Hawaiʻi 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 Hawaiʻi should be centered 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, poeciliid fish species in ponds south of the NELHA facility. The findings of the July 2014 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 – 2 which appeared to have been filled in with rocks. 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.	Worm
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 Hawai‘i, 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

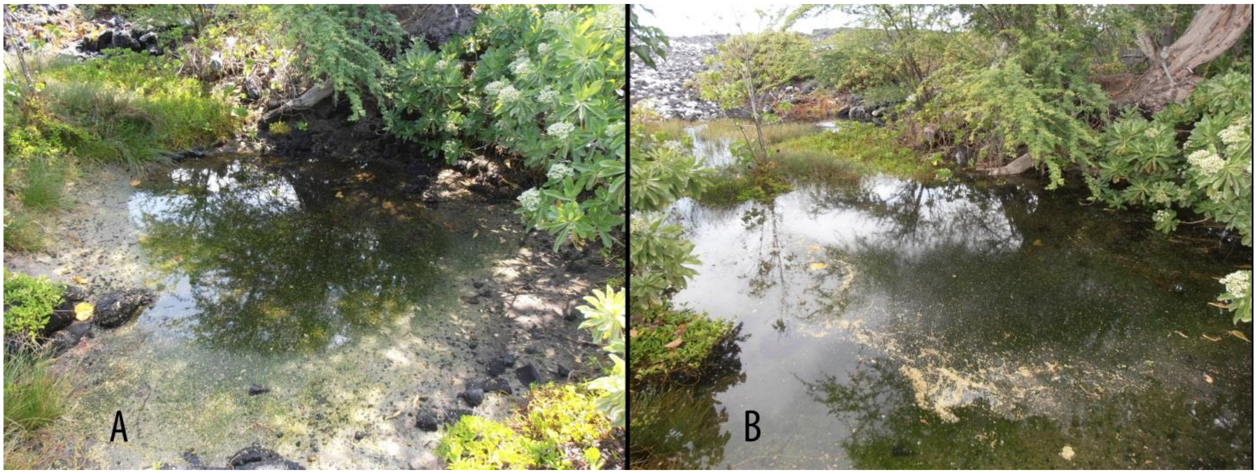

Figure 4. Pond N – 1 water levels at low (A, +0.7 ft.) and high (B, +2 ft.) tides.

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.).

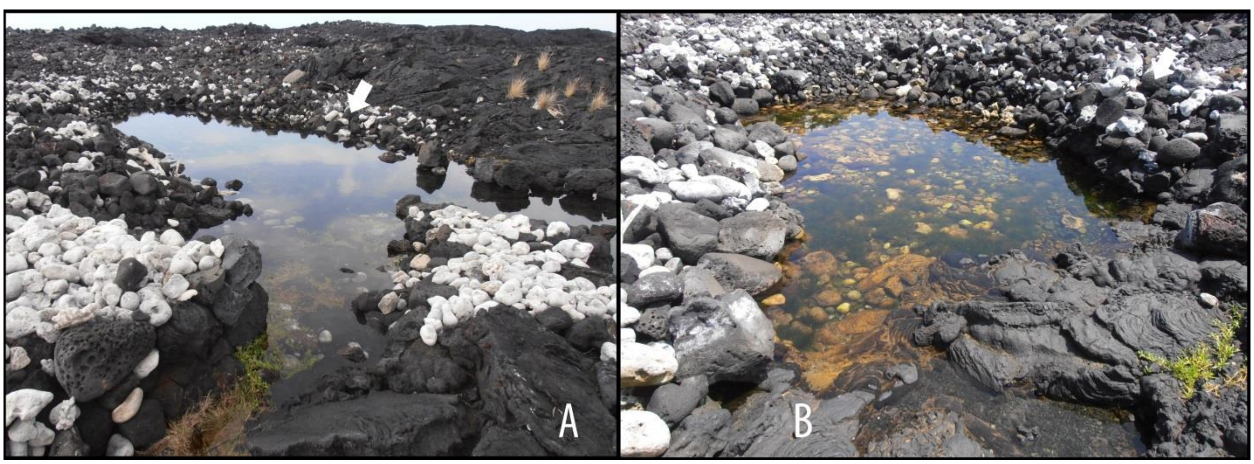

Figure 7. The change in water level at pond N – 5 between high (A, +2 ft.) and lower tide levels (B, +0.7 ft.) with arrows marking point of reference.

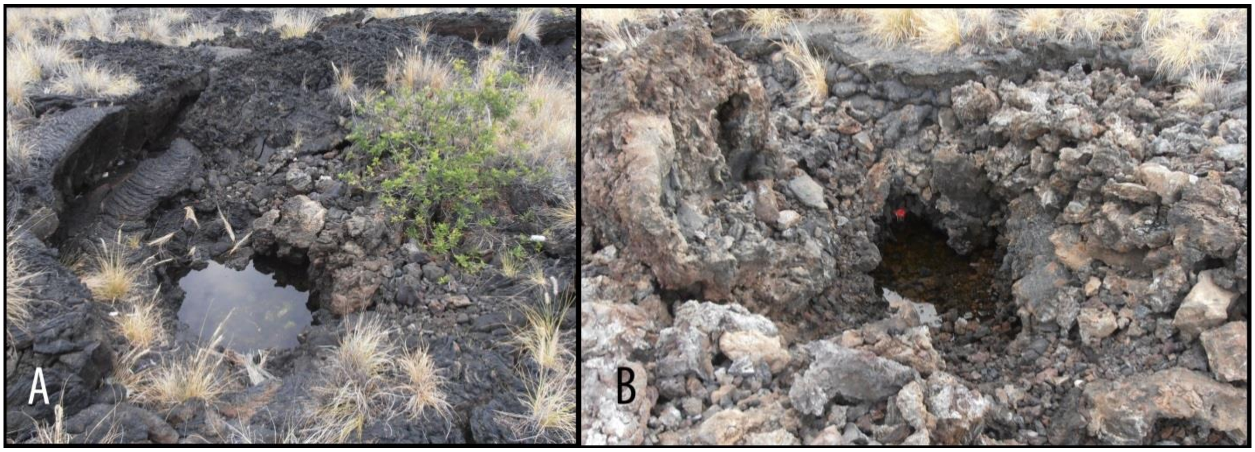

Figure 8. Southern ponds S – 1 (A, +1.8 ft.) and S – 2 (B, +1.4 ft.), photo taken in 2013 before being filled with rocks in 2014).

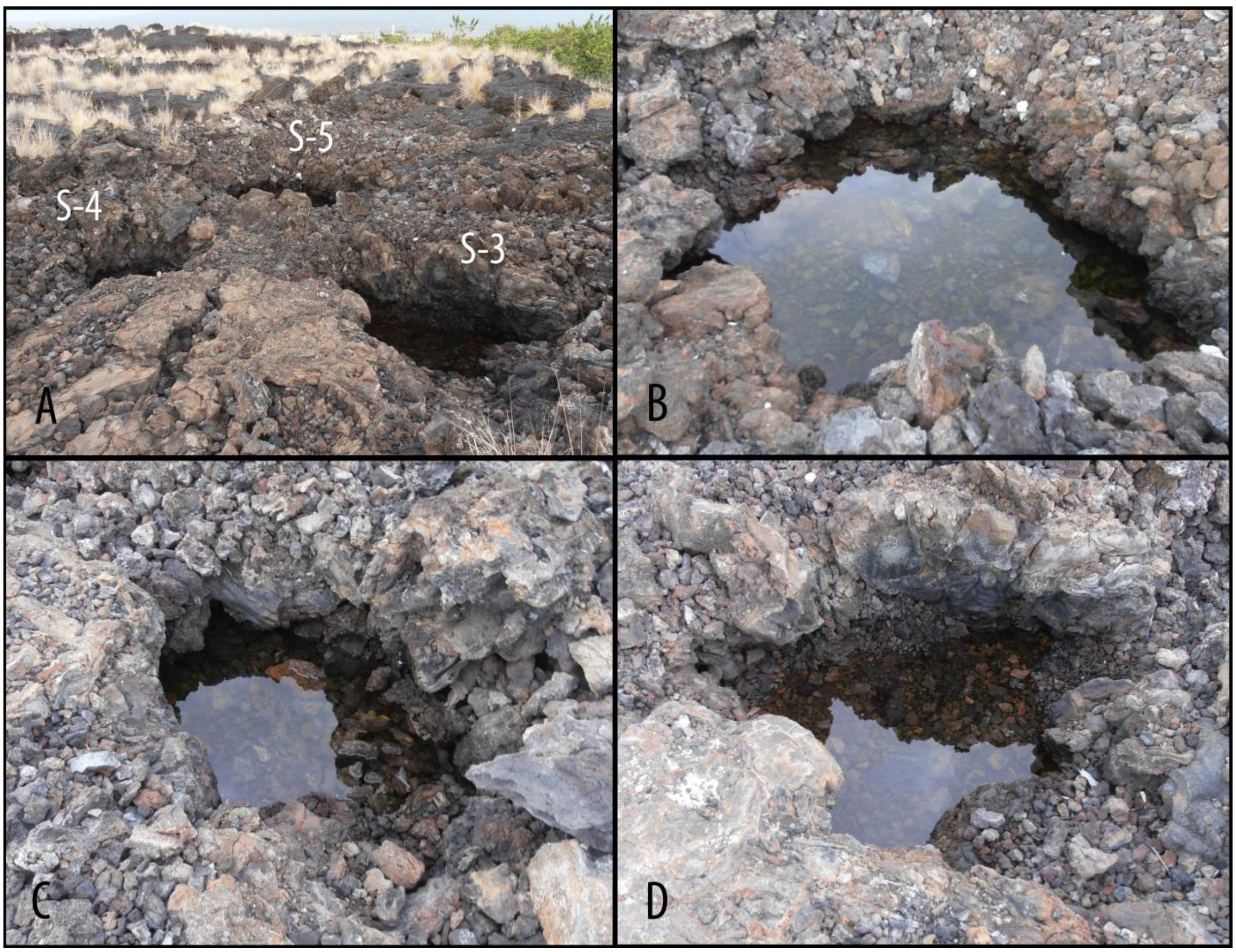

Figure 9. Cluster of ponds (A): S -5 (B), S – 4 (C), and S – 3 (D) (Tide level: +1.4 ft.).

A faunal census of each pond in the vicinity of the NELHA facility was undertaken in July 2014. 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, three 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 poeciliid 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.

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

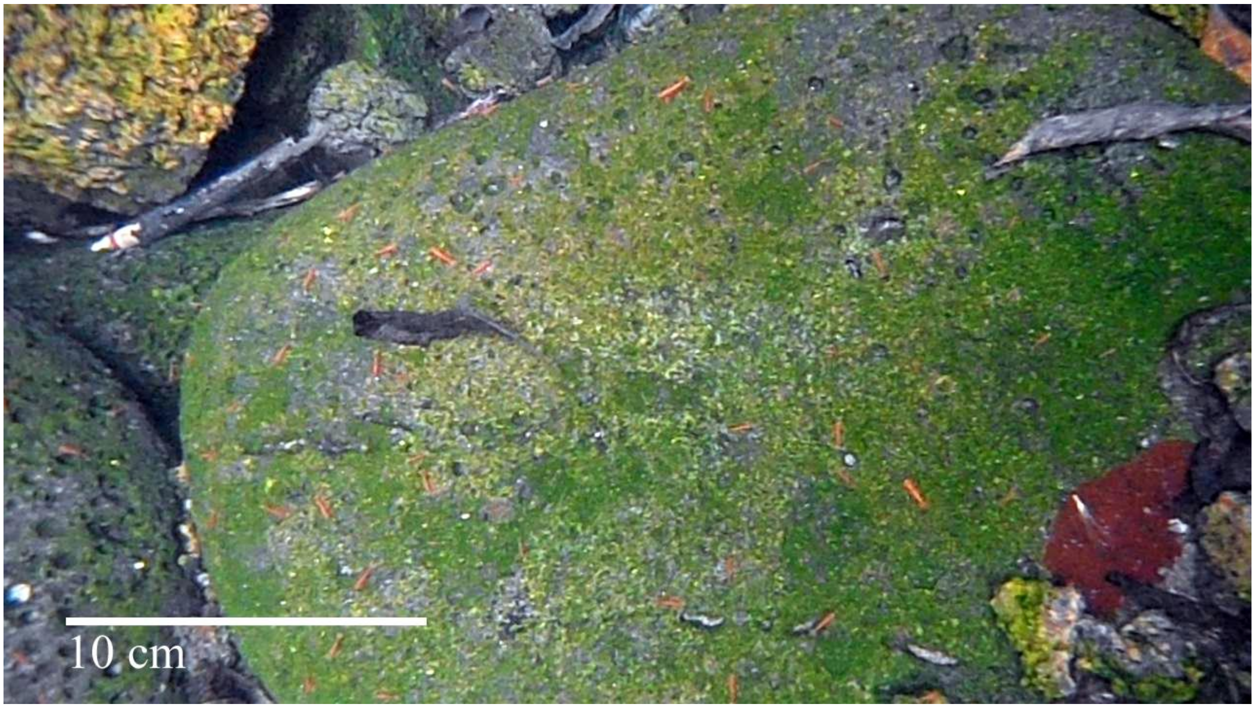

Figure 10. An example of a photo-quadrate showing individual *Halocaridina rubra*.

Table 3. Faunal census data collected from northern and southern groups of anchialine ponds sampled July 2014 at a tide above a +1 foot level. Poeciliid fish, *Ruppia maratima* were recorded as present or absent and other organisms in the pond were noted. *Halocaridina rubra* densities are reported as mean individuals per 0.1 square meters (± one standard deviation). Where water was too shallow for the photoquadrat (and densities very low), presence or absence was noted.

	Halocaridina rubra	*Ruppia maratima*	Poeciliids	Temperature	Salinity	Comments/other species
Pond No.	**Mean ± St. Dev. (Ind./0.1 m²)**	**Pond**		**(C)**	**(PPT)**	
N - 1	96 ± 31.7	Present	Absent	22	13	More *Ruppia* than last year
N - 2	240 ± 24	Absent	Absent	22	13	*Bacopa* sp.
N - 3	Absent	Present	Absent	23	11.5	*Melania sp*.
N - 4	Present	Absent	Absent	22	12	Shallow, many *Melania sp.*
N - 5	Absent	Present	Absent	22	12.5	Nothing living but *Ruppia*
S - 1	Absent	Absent	Present	22	10	*Macrobrachium grandimanus*
S - 2	-	-	-	-	-	Filled in with rocks
S - 3	20 ± 6.9	Absent	Absent	22	11	*Metabataeus lohena* present
S - 4	Present	Present	Absent	21	10	
S - 5	Absent	Absent	Present	21	10	
S - 6	Present	Present	Absent	21	9	Shallow, *M. grandimanus*
S - 7	Present	Absent	Absent	21	11	Shallow, *M. grandimanus*
S - 8	Absent	Absent	Present	20	10	*Macrobrachium grandimanus*
S – 9	Present	Absent	Absent	22	10	Shallow

The clearest difference between the communities of organisms found in the two groups of ponds this year was the absence of exotic poeciliid 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 N – 3, 5, or S – 2, 5, 6, and 8, which all had exotic fish. Southern ponds S – 3, 4, 6, 7 and 9 all had *Halocaridina rubra.* Some also included individuals of *Metabetaeus lohena* (S – 3), and *Macrobrachium grandimanus* (S – 6, 7, 8).

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 less abundant in pond N – 3, but found in their highest abundance in N - 4. *Melania sp*. was not observed in the southern ponds.

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).

The absence of *H. rubra* in ponds N – 3 and N -- 5 this year was unexpected. The absence of poeciliid fish in those ponds makes an explanation perhaps even more complicated. These are the two largest ponds in this group (N – 2, 3, 4, 5) which makes it more likely that there are actually some fish in the ponds which went undetected. Another consideration is the possible presence of predators other than fish. During the collection of field data several dragonflies were observed ovipositing in N – 3, though no larvae were seen in the videos. Dragonfly larvae are relatively large (over 5 centimeters long), generalist feeders and are known to have an important impact on prey populations (Benke 1978). Dragonflies are also one of the few insects whose larvae can tolerate brackish water and have been known to live in water with salinity ranging from 6.0 to 17.3 ppt. (Catling 2009). If dragonfly larvae have been established in some of the northern ponds, they could have a significant impact on populations of *H. rubra*. Further sampling would need to be done to determine if larvae are present in ponds N – 3 and N –5.

The complex of ponds south of the NELHA facility continued to be affected by the presence of poeciliid 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 native crustacean diversity 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.

The 2012-14 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. Observations of *Halocaridina rubra* feeding behavior showed the shrimp were not disturbed and continued to feed in the same areas throughout the length of the videos suggesting that no changes 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 16th and 17th of July 2014 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 (except for the two mentioned above). Water temperature and salinity measurements were all within expected ranges. 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 from aquaculture.

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 and 2013 surveys were reported in Bybee and Barrett 2012 Bybee et al. 2013 respectively. The results of the July 2014 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.

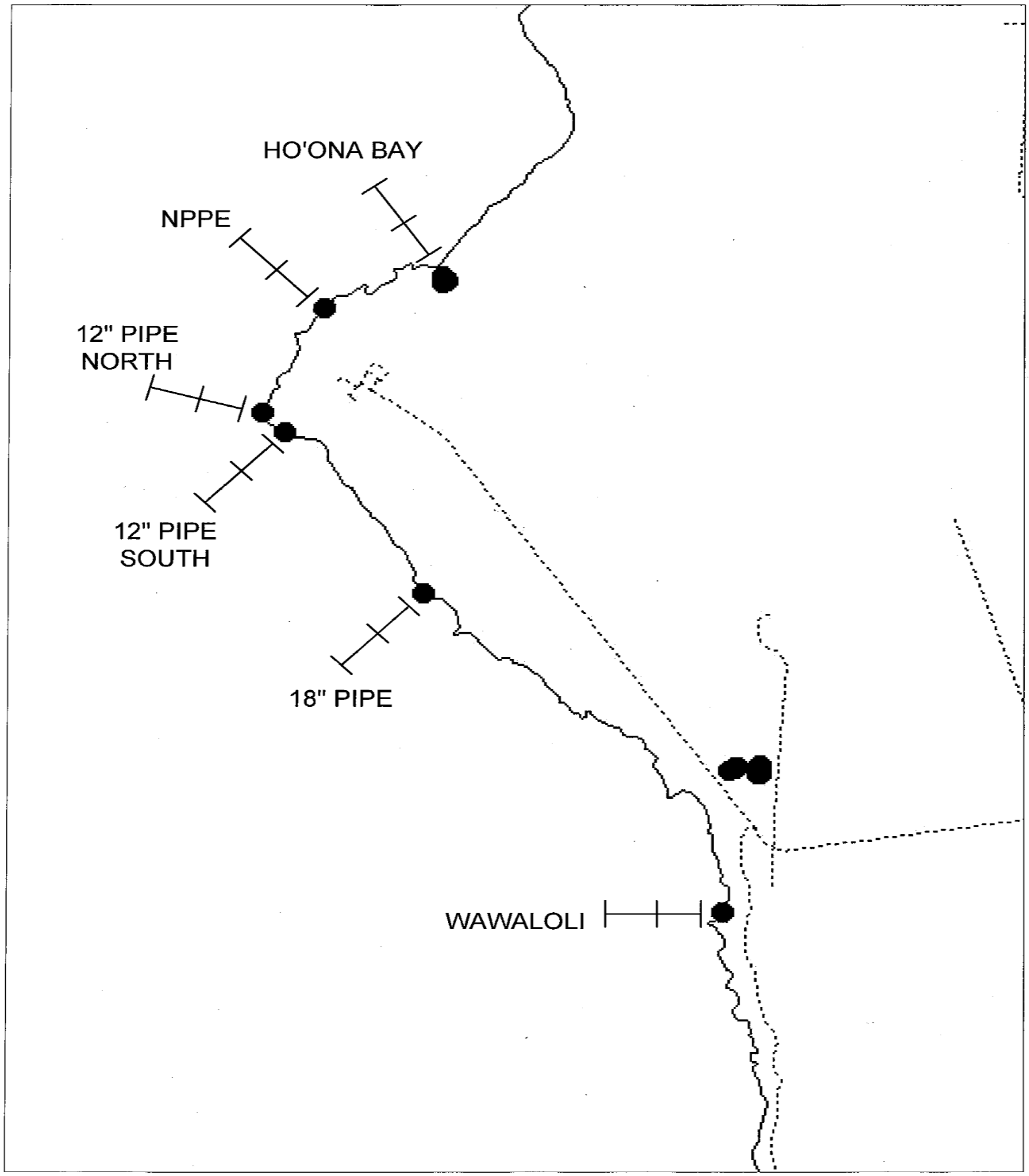

Figure 11. Six stations with three transects per station along the NELHA coastline.

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 (Appendix 4). 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 and sea cucumbers), 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 53.8%. The two most dominant corals were *Porites lobata* (35.5%) and *Pocillopora meandrina* (10.6%) which were present on all transects. Other corals present were *Leptastrea purpurea, Montipora capitata, Montipora flabellata, Montipora patula, Pavona varians, Pocillopora eydouxi, Pocillopora lingulata, Porites compressa, Porites lutea and Fungia scutaria.* These corals accounted for approximately 7% 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. In the shallow transects (15 feet) *P. compressa* was absent al all sites. Color photographs of each quadrats are presented in Appendix 4.

Table 4 shows a comparison of the percent coral cover between sites and habitats. The NPPE site was the highest in total coral cover (71.7%) 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). *Pocillopora meandrina* was most abundant around 12" Pipe North which was also the site with the lowest overall coral cover (36.8%). The highest *P. lobata* cover was observed at NPPE (51.58%) followed by Ho'ona Bay (41.15%) while the lowest concentration of *P. lobata* occurred at 12" Pipe South (18.7%).

Coral cover was higher at the middle and deep sites (61.65% and 55.17%) than the shallow stations (44.53%). Among the deep stations coral was most abundant at NPPE and Ho'ona Bay sites (85.38% and 90%) followed by 12" Pipe North (57.31%). *Porites lobata* was the dominant coral at all six sites.

Though measurable, the above mentioned differences were not statistically significant. The only significant difference detected between sites in this study was % *P. meandrina* at shallow and deep sites ($p = .007$).

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 sea cucumbers (at Wawaloli).

Table 4. Summary of photoquadrats from benthic surveys conducted July 2014

Station		Wawaloli Beach				18" Pipe				12" Pipe South	
Transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
% Total coral	43.35	70.7	28		50.75	54.36	35.45		33.4	42.35	34.85
% P. lobata	26.5	53.25	23.85		32.4	35.82	27.05		12.25	22.7	21.15
% P. compressa	0	7	1.2		0	0.85	1.2		0	0.3	0.5
% Poc. meandrina	10.75	4.7	1.7		11.9	14.03	5		17.2	16.5	9.3
Species	6	6	4		5	8	6		5	7	6
Diversity	1.05	0.88	0.58		0.97	0.95	0.81		1.06	0.99	1.07
Station		12" Pipe North				NPPE				Ho'ona Bay	
Transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
% Total coral	43.4	61.51	57.31		59	70.83	85.38		37.3	70.15	90
% P. lobata	25	47.05	34.63		37.95	55.39	61.39		19.85	49.65	53.95
% P. compressa	0	0.4	3.85		0	1.67	15.07		0	1.75	30.95
% Poc. meandrina	12.15	10.11	11.61		16.15	9.94	6.86		15.65	14.45	3.85
Species	6	5	7		7	6	8		7	7	6
Diversity	1.1	0.76	1.2		0.94	0.77	0.87		0.92	0.87	0.88
Survey Means	Wawaloli	18" pipe	12" Pipe S	12" Pipe N	NPPE	Ho'ona Bay	P value	Shallow	Middle	Deep	p value
% Total coral	47.35	46.85	36.87	54.07	71.74	65.82	0.16	44.53	61.65	55.17	0.27
% P. lobata	34.35	31.76	18.7	35.56	51.58	41.15	0.11	25.66	43.98	41.37	0.08
% Poc. meandrina	5.72	10.31	14.33	11.29	10.98	11.32	0.41	13.97	11.62	6.39	**0.007**
Species	5.33	6.33	6	6	7	6.67	0.52	6	6.5	6.17	0.7
Diversity	0.84	0.91	1.04	1.02	0.86	0.89	0.45	1	0.87	0.9	0.24

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 2014.

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, 44% in 2012 and increasing significantly To 52% ($p = < .001$, ANOVA) in 2013. The present study follows the noted pattern of increase over time with a total coral abundance of 53.8%)

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 ($p = .03$). Combined data with 2014 results show an identical pattern at the same sites except for 12” Pipe North.

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 2013 survey showed 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. Data for 2014 show a range of 18.7% (12” Pipe South) to 51.58% (NPPE) with an average of 29%, not significantly different than 2013.

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 2013 study showed 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 were compared the increase observed in 2013 was statistically significant ($p < .001$, Tukey multiple comparison of means). The current study shows no significant change in *P. meandrina* abundance compared to previous years but there was a significant decrease detected in *P. meandrina* abundance with depth ($p = .007$).

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, Bybee et al. 2013). In this study the northern sites do have more coral but 12" Pipe South had less coral than the two sites south of it. An identical pattern was observed with *P. lobata* cover, highest at the three northern sites but lower at 12" South than 18" Pipe and Wawaloli. Both total coral cover and *Porites lobata* cover were lowest at the shallow sites, highest at the middle sites and somewhere in-between at the deepest sites.

Pocillopora meandrina decreased significantly in abundance from shallow to deep and was abundant at all shallow and middle stations. 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 (and at non-pipe sites) at specific depths. This would make methods 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 2014, 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). During surveys conducted from 2012 to 2014 these markers were not present, so counts were made 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 = .12, ANOVA) with an average range of 73-164 individuals. Nor was it significantly different between habitats (p = .08, ANOVA). The highest number of individuals occurred at the 12" Pipe South deep transect (237 individuals). The lowest count occurred at NPPE and Ho'ona Bay deep sites (68 individuals). 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 middle transects to 16.3 at the shallow sites. Overall there was no statistically significant difference observed between sites (p = 0.69, ANOVA). The highs occurred at 18" Pipe, deep transect and 12" Pipe North, shallow transect (20 species each). The low occurred at Wawaloli shallow transect (10 species). There was no significant difference in number of species between habitats (p = 0.58, ANOVA).

The most abundantly represented families in this survey (as well as 2013) were the chaetodontids (butterfly fish), pomacentrids (damsel fish) and acanthurids (surgeon fish). The most abundant species represented (similar to previous years) were *Chromis vanderbilti, Chromis hanui, Chromis agilis, 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 1.95 at Wawaloli to 2.24 at NPPE. None of the differences among stations or habitat were statistically significant (p = .83 and .58 respectively, ANOVA).

Biomass was highest at 18" Pipe (112.56 g/m2) and lowest at Ho'ona Bay (48.74 g/m2). No significant differences in mean biomass were detected between sites or habitats (p = .33 and 0.48 respectively, ANOVA).

Table 5. Summary of quantitative fish transects conducted July 2014.
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	104	89	147		185	112	197		144	103	237
Number of species	10	12	17		15	15	20		20	14	16
Diversity	1.74	1.67	2.44		2.04	2.13	2.47		2.39	2.2	1.47
Biomass (g/m2)	51.37	60.65	157.79		79.61	82.47	175.61		88.92	54.43	65.79
Station		12" Pipe North				NPPE				Ho'ona Bay	
Transect	Shallow	Mid	Deep		Shallow	Mid	Deep		Shallow	Mid	Deep
Total number	146	110	157		123	100	68		114	39	68
Number of species	17	13	17		18	14	12		18	12	13
Diversity	2.2	1.86	2.27		2.31	2.3	2.12		2.24	2.15	2.01
Biomass (g/m2)	92.97	72.76	152.95		81.91	58.32	30.85		74.53	27.69	43.99
Survey Means	Wawaloli	18" pipe	12" Pipe S	12" Pipe N	NPPE	Ho'ona Bay	p value	Shallow	Middle	Deep	p value
Total number	113.33	164.66	161.33	137.66	97	73.66	0.12	136	92.16	145.66	0.08
Number of species	13	16.66	16.66	15.66	14.66	14.33	0.69	16.33	13.33	15.83	0.58
Diversity	1.95	2.21	2.02	2.11	2.24	2.13	0.83	2.15	2.05	2.13	0.58
Biomass (g/m2)	89.93	112.56	69.71	106.23	57.03	48.74	0.33	78.22	59.39	104.5	0.48

Comparative Analysis

As stated in the benthic comparative analysis, extensive work has been done comparing data from previous surveys at these same sites from 1992-2013 (Ziemann 2010, Bybee and Barrett 2012, Bybee et al. 2013). 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 2014.

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 2013 showed 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. Data from the 2014 survey were, on average, higher than 2013 though the difference was not statistically significant. When compared to 2010 data the current results are still significantly lower in all areas ($p = < .001$) except diversity ($p = .35$, pairwise comparisons using paired t-tests). 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 and 2012-2014 data as mentioned above. This difference may be the result of the wide range in natural variability seen throughout the years at this site as well as the result of human variability in implementation of the survey method used.

In the 2012 study, a team of 3-4 divers worked each transect simultaneously. A 50 m transect line was laid out by the divers going from north to south. Upon reaching the 50 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, though still lower than 2010 levels. Data for 2014 were higher in most measured variables than 2013 although not statistically significant.

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 its length while filming. Increased time on the transect line could also contribute to higher numbers of fish recorded in previous years.

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 held true in total fish, number of species and diversity. In 2014 the fish community at Wawaloli was still lowest in number of species and diversity and 18" Pipe was highest in all variables except for diversity and 12" Pipe South was among the highest in all areas except for biomass (Table 5).

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./0.1m^2)

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 purpurea	24	1.2	0.1	2	0.1	0.01	0	0	0
Montipora capitata	85	4.25	0.23	79	3.95	0.16	25	1.255	0.14
Montipora flabellata	6	0.3	0.03	0	0	0	0	0	0
Montipora patula	7	0.35	0.04	34	1.7	0.09	0	0	0
Pavona varians	0	0	0	0	0	0	0	0	0
Pocillopora eydouxi	0	0	0	0	0	0	0	0	0
Pocillopora meandrina	215	10.75	0.35	94	4.7	0.18	34	1.7	0.17
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	0	0	0	140	7	0.23	24	1.2	0.13
Porites lobata	530	26.5	0.3	1065	53.25	0.21	477	23.85	0.14
Porites lutea	0	0	0	0	0	0	0	0	0
Total coral	867	43.35	1.05	1414	70.7	0.88	560	28	0.58
Coralline Algae	4	0.2	0	0	0	0	2	0.1	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	0	0	0
old dead coral	131	6.55	0	164	8.2	0	12	0.6	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	0	0	0	0	0	0	0	0	0
Urchin	2	0.1	0	10	0.5	0	4	0.2	0.32
Turf algae	21	1.05	0	0	0	0	15	0.75	0
Substrate									
Boulder	783	39.15	0.17	1	0.05	0.01	0	0	0
Coral Rubble	79	3.95	0.2	399	19.95	0.03	1383	69.15	0.02
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	110	5.5	0.25	12	0.6	0.1	22	1.1	0.07

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 purpurea	4	0.2	0.02	7	0.35	0.03	1	0.05	0.01
Montipora capitata	28	1.4	0.1	41	2.05	0.12	29	1.45	0.13
Montipora flabellata	0	0	0	8	0.4	0.04	0	0	0
Montipora patula	97	4.85	0.22	14	0.7	0.06	14	0.7	0.08
Pavona varians	0	0	0	3	0.15	0.02	0	0	0
Pocillopora eydouxi	0	0	0	0	0	0	0	0	0
Pocillopora meandrina	238	11.9	0.34	280	14.03	0.35	100	5	0.28
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	0	0	0	17	0.85	0.07	24	1.2	0.11
Porites lobata	648	32.4	0.29	715	35.82	0.27	541	27.05	0.21
Portites lutea	0	0	0	0	0	0	0	0	0
Total coral	1015	50.75	0.97	1085	54.36	0.95	709	35.45	0.81
Coralline Algae	38	1.9	0	24	1.2	0	3	0.15	0
Dead coral									
Dead coral with algae	0	0	0	3	0.15	0.08	0	0	0
old dead coral	450	22.5	0	130	6.51	0.06	156	7.8	0
recently dead coral	0	0	0	5	0.25	0.12	0	0	0
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	42	2.1	0	10	0.5	0.29	0	0	0
Urchin	0	0	0	5	0.25	0.36	14	0.7	0
Turf algae	4	0.2	0	11	0.55	0.08	41	2.05	0.05
Substrate									
Boulder	190	9.5	0.36	35	1.75	0.15	0	0	0
Coral Rubble	210	10.5	0.36	609	30.51	0.14	1064	53.2	0.01
Limestone	36	1.8	0.2	0	0	0	5	0.25	0.02
Rock	0	0	0	0	0	0	0	0	0
Sand	15	0.75	0.11	77	3.86	0.24	6	0.3	0.03

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 purpurea	0	0	0	1	0.05	0.01	0	0	0
Montipora capitata	44	2.2	0.18	34	1.7	0.13	32	1.6	0.14
Montipora flabellata	0	0	0	0	0	0	0	0	0
Montipora patula	32	1.6	0.15	10	0.5	0.05	7	0.35	0.05
Pavona varians	3	0.15	0.02	0	0	0	0	0	0
Pocillopora eydouxi	0	0	0	12	0.6	0.06	39	1.95	0.16
Pocillopora meandrina	344	17.2	0.34	330	16.5	0.37	186	9.3	0.35
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	0	0	0	6	0.3	0.04	10	0.5	0.06
Porites lobata	245	12.25	0.37	454	22.7	0.33	423	21.15	0.3
Porites Lutea	0	0	0	0	0	0	0	0	0
Total Coral	668	33.4	1.06	847	42.35	0.99	697	34.85	1.07
Coralline Algae	27	1.35	0	23	1.15	0	29	1.45	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	0	0	0
old dead coral	309	15.45	0.01	374	18.7	0.01	150	7.5	0
recently dead coral	2	0.1	0.03	4	0.2	0.05	0	0	0
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	18	0.9	0	34	1.7	0.14	18	0.9	0
Urchin	0	0	0	1	0.05	0.09	0	0	0
Turf algae	0	0	0	18	0.9	0	24	1.2	0.04
Substrate									
Boulder	927	46.35	0.05	180	9	0.35	73	3.65	0.18
Coral Rubble	34	1.7	0.12	491	24.55	0.24	1005	50.25	0.07
Limestone	0	0	0	4	0.2	0.03	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	15	0.75	0.06	15	0.75	0.08	3	0.15	0.02

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 purpurea	2	0.1	0.01	0	0	0	0	0	0
Montipora capitata	13	0.65	0.06	41	2.05	0.11	59	2.95	0.15
Montipora flabellata	43	2.15	0.15	0	0	0	0	0	0
Montipora patula	67	3.35	0.2	38	1.9	0.11	68	3.4	0.17
Pavona varians	0	0	0	0	0	0	3	0.15	0.02
Pocillopora eydouxi	0	0	0	0	0	0	14	0.7	0.05
Pocillopora meandrina	243	12.15	0.36	202	10.11	0.3	232	11.61	0.32
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	0	0	0	8	0.4	0.03	77	3.85	0.18
Porites lobata	500	25	0.32	940	47.05	0.21	692	34.63	0.3
Porites lutea	0	0	0	0	0	0	0	0	0
Total coral	868	43.4	1.1	1229	61.51	0.76	1145	57.31	1.2
Coralline Algae	111	5.55	0	29	1.45	0	1	0.05	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	129	6.46	0.37
old dead coral	207	10.35	0	464	23.22	0	207	10.36	0.3
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	43	2.15	0.02	59	2.95	0.05	7	0.35	0.25
Urchin	1	0.05	0.09	3	0.15	0.15	3	0.15	0.36
Turf algae	0	0	0	0	0	0	0	0	0
Substrate									
Boulder	762	38.1	0.01	147	7.36	0.25	0	0	0
Coral Rubble	8	0.4	0.05	60	3	0.36	434	21.72	0.13
Limestone	0	0	0	2	0.1	0.04	42	2.1	0.21
Rock	0	0	0	2	0.1	0.04	0	0	0
Sand	0	0	0	0	0	0	30	1.5	0.17

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 purpurea	0	0	0		0	0	0		0	0	0
Montipora capitata	5	0.25	0.02		19	1.06	0.06		14	0.7	0.04
Montipora flabellata	14	0.7	0.05		0	0	0		0	0	0
Montipora patula	59	2.95	0.15		39	2.17	0.11		16	0.8	0.04
Pavona varians	8	0.4	0.03		0	0	0		3	0.15	0.01
Pocillopora eydouxi	12	0.6	0.05		0	0	0		2	0.1	0.01
Pocillopora meandrina	323	16.15	0.35		179	9.94	0.28		137	6.86	0.2
Pocillopora ligulata	0	0	0		0	0	0		0	0	0
Porites compressa	0	0	0		30	1.67	0.09		301	15.07	0.31
Porites lobata	759	37.95	0.28		997	55.39	0.19		1226	61.39	0.24
p. lutea	0	0	0		11	0.61	0.04		6	0.3	0.02
Total coral	1180	59	0.94		1275	70.83	0.77		1705	85.38	0.87
Coralline Algae	55	2.75	0		12	0.67	0		2	0.1	0
Dead coral											
Dead coral with algae	13	0.65	0.13		4	0.22	0.06		2	0.1	0.04
old dead coral	288	14.4	0.07		295	16.39	0.01		268	13.42	0.01
recently dead coral	11	0.55	0.12		0	0	0		0	0	0
Other live											
Sponge	0	0	0		0	0	0		0	0	0
Mollusc	0	0	0		85	4.72	0		0	0	0
Urchin	3	0.15	0		0	0	0		5	0.25	0
Turf algae	0	0	0		0	0	0		0	0	0
Substrate											
Boulder	440	22	0.02		81	4.5	0.29		6	0.3	0.37
Coral Rubble	3	0.15	0.03		40	2.22	0.36		9	0.45	0.31
Limestone	0	0	0		0	0	0		0	0	0
Rock	0	0	0		0	0	0		0	0	0
Sand	7	0.35	0.06		6	0.33	0.14		0	0	0

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 purpurea	4	0.2	0.03	0	0	0	0	0	0
Montipora capitata	7	0.35	0.04	70	3.5	0.15	19	0.95	0.05
Montipora flabellata	14	0.7	0.07	0	0	0	0	0	0
Montipora patula	6	0.3	0.04	5	0.25	0.02	0	0	0
Pavona varians	5	0.25	0.03	0	0	0	4	0.2	0.01
Pocillopora eydouxi	0	0	0	0	0	0	2	0.1	0.01
Pocillopora meandrina	313	15.65	0.36	289	14.45	0.33	77	3.85	0.13
Pocillopora ligulata	0	0	0	0	0	0	0	0	0
Porites compressa	0	0	0	35	1.75	0.09	619	30.95	0.37
Porites lobata	397	19.85	0.34	993	49.65	0.24	1079	53.95	0.31
Porites lutea	0	0	0	4	0.2	0.02	0	0	0
Total coral	746	37.3	0.92	1403	70.15	0.87	1800	90	0.88
Coralline Algae	27	1.35	0	42	2.1	0	0	0	0
Dead coral									
Dead coral with algae	0	0	0	0	0	0	0	0	0
old dead coral	133	6.65	0.01	334	16.7	0.07	169	8.45	0.07
recently dead coral	2	0.1	0.06	28	1.4	0.2	14	0.7	0.2
Other live									
Sponge	0	0	0	0	0	0	0	0	0
Mollusc	135	6.75	0.12	39	1.95	0	0	0	0
Urchin	0	0	0	0	0	0	0	0	0
Turf algae	0	0	0	0	0	0	0	0	0
Substrate									
Boulder	905	45.25	0.03	96	4.8	0.25	2	0.1	0.25
Coral Rubble	30	1.5	0.11	16	0.8	0.25	13	0.65	0.21
Limestone	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0
Sand	2	0.1	0.01	25	1.25	0.31	2	0.1	0.25

Appendix 3

Marine Fish Community Survey Results

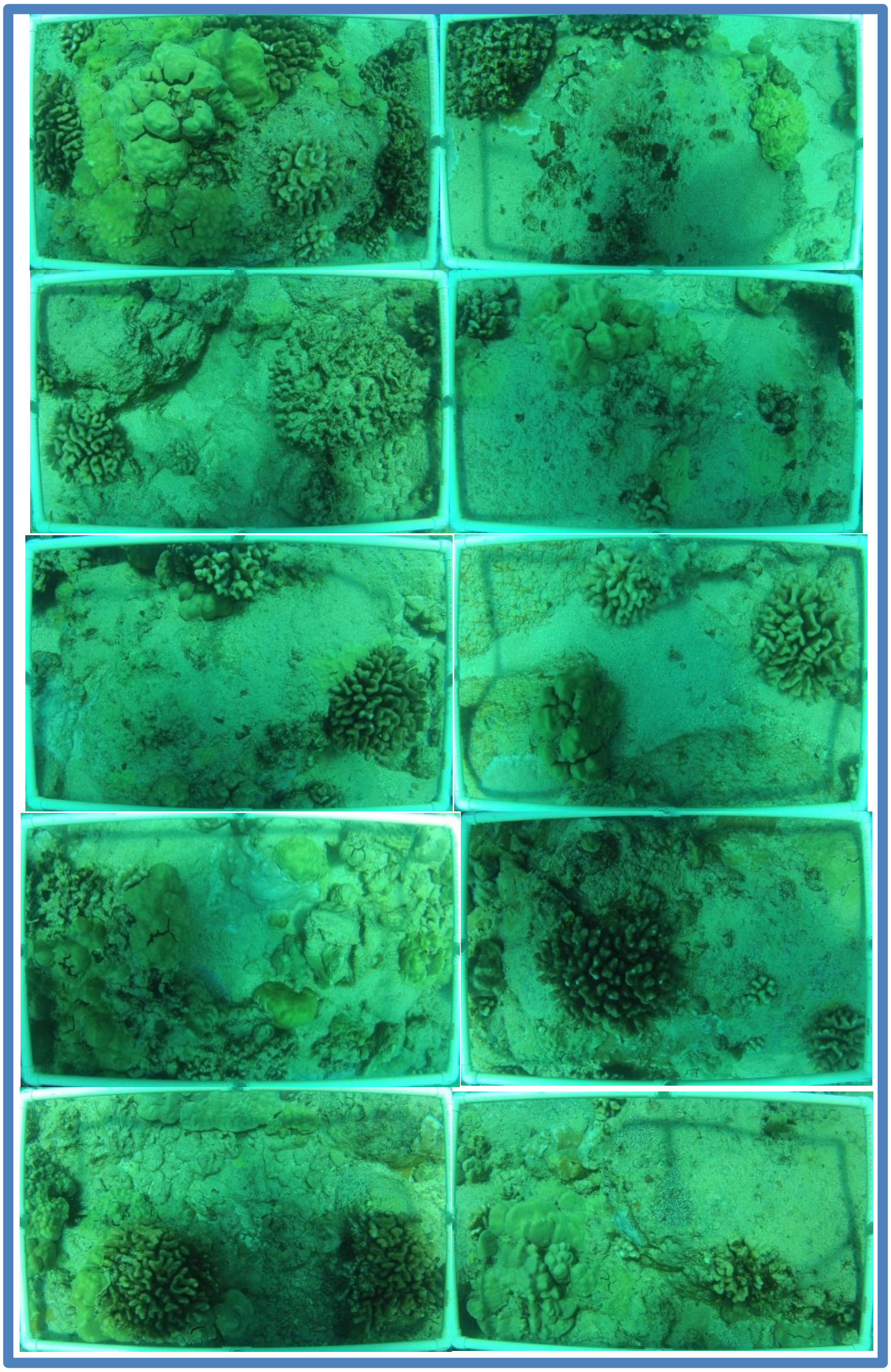
Appendix 3. Abundance of fish observed along 25 m transects in July, 2014. Species are listed in taxonomic order.

		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*												1							1
	Myripristis amaena																			0
	Sargocentron xantherythrum																			0
Syngnathidae	*Aulostomas chinensis*																			0
Serranidae	*Cephalopholis argus*						1													1
Cirrhitidae	*Paracirrhites arcatus*																			0
	Paracirrhites fosteri	2		1		2					1						1			7
	Cirrhitus pinnulatus																			0
Mullidae	*Parupeneus multifasciatus*		3	11				1	1	1			1	6						23
	Parupeneus cyclostomus			7																7
	Parupeneus insularis															1				1
	Mulloidichthys flavolineatus														9					9
Chaetodontidae	*Chaetodon lunula*																2			2
	Chaetodon ephipppium																			0
	Chaetodon kleinii																			0
	Chaetodon multicintus	3	2	1	2	9	9	6	7	4		3	6			2		2	3	55
	Chaetodon ornatissimus						2												1	3
	Chaetodon quadrimaculatus			2	4	2	1				7				1	1	1	1		20
	Chaetodon unimaculatus							1		2	1							2		4
	Chaetodon miliaris																			0
	Chaetodon auriga									1										0
	Forcipiger longirostris				3	2	2			4	1	1	3	2	2	2	3			21
	hemitaurichthys polylelpis			4			17		4	3		4	35	1						65
Pomacanthidae	*Centropyge potteri*																			0
Pomacentridae	*Abudefduf abdominalis*										17			2	12					31
	Chromis vanderbilti							18	25		3			12	10	18	3			89
	Chromis hanui			27	52	3	12	3		150							1		20	118
	Chromis agilis	22	48	18			6	1								12	2		1	110
	Chromis ovalis																			0
	Dascyllus albisella																			0
	Stegastes marginatus																			0
	Plectroglyphidodon johnstonianus																			0

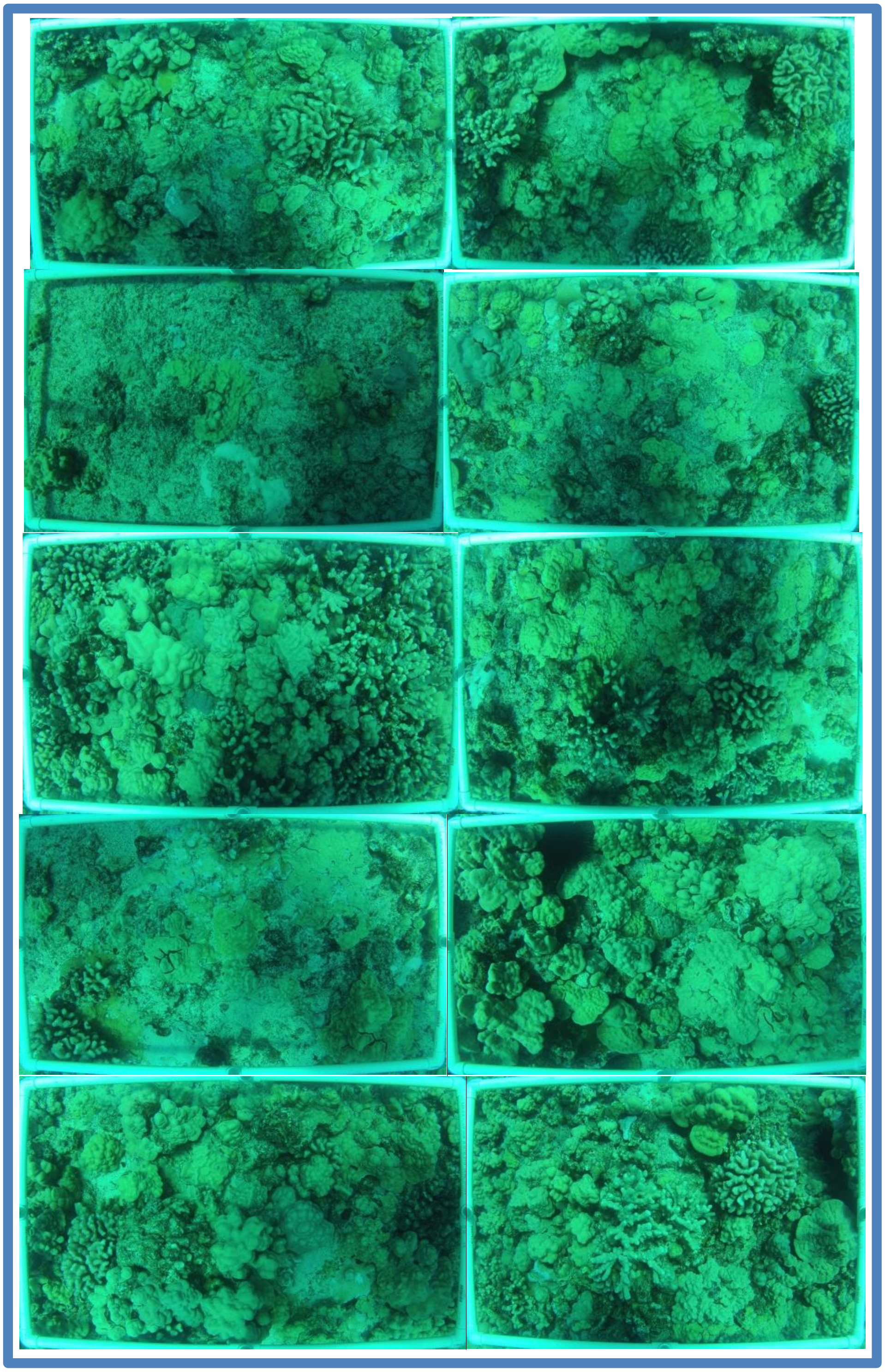
			Wawaloli			18" Pipe			12" Pipe South			12" Pipe North			NPPE			Ho'ona Bay		Total
Family	**Species**	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep	
Labridae	*Coris gaimard*		1	5				1						2						9
	Coris flavovittata							2						1			1			4
	Gomphosus varius	4		3	3	2	2	11	3	2	1		5	2	2		2	2	2	44
	Halichoeres ornatissimus							1												1
	Labroides phthirophagus							1		3				1				2		4
	Novaculichthys taeniourus																2			2
	Thalassoma duperrey	28	7	9	33	12	17	23	10	15	8	9	10	17	5		17	3		208
Zanclidae	*Zanclus cornutus*				1		1	1	3						2		5			13
Acanthuridae	*Acanthuris achilles*						1					4								5
	Acanthurus guttatus										1									1
	Acanthurus leucopareius		1		2						4		1	4						12
	Acanthurus nigrofuscus	34	8	28	35	17	18	17	8	7	15	10	20	20	18	7	20	7	10	292
	Acanthurus nigroris													1			5	1	3	10
	Acanthurus olivaceus	1												1		2				4
	Acanthurus triostegus																2	1		3
	Acanthurus blochii		1		2	5	14	1	1		4	1	3	4	1			1		38
	Ctenochaetus hawaiiensis	3		4		1	32	4			16	6	20	14	10	3	16	7	2	138
	Ctenochaetus strigosus	4	1	5	16	26	29	23	15	20	25	19	12	3	11	7			7	203
	Naso lituratus		4	13			2	4		1	1	1	4				1		1	31
	Naso unicornis										1								1	2
	Zebrasoma flavescens	2	7	7	28	27	28	23	20	19	40	48	31	30	16	10	30	10	16	373
Balistidae	*Melichthys niger*				3	2	1		1											7
	Sufflamen bursa	1	6	2	1	1	2						2		1	3				19
	Melichthys vidua																			0
	Xanthichthys auromarginatus																			0
Ostraciidae	*Ostracion meleagris*																			0
Tetradontidae	*Canthigaster coronata*																			0
	Plectroglyphidodon sindonis																			0
Scaridae	*Chlorurus perspicillatus*								2			3	2							7
	Chlorurus spilurus									4		1	1						1	3
	Scarus dubius					1		2	3	1										6
Kyphosidae	*Kyphosus hawaiiensis*				6															6
		104	89	147	185	112	197	144	103	237	146	110	157	123	100	68	114	39	68	2243

Appendix 4

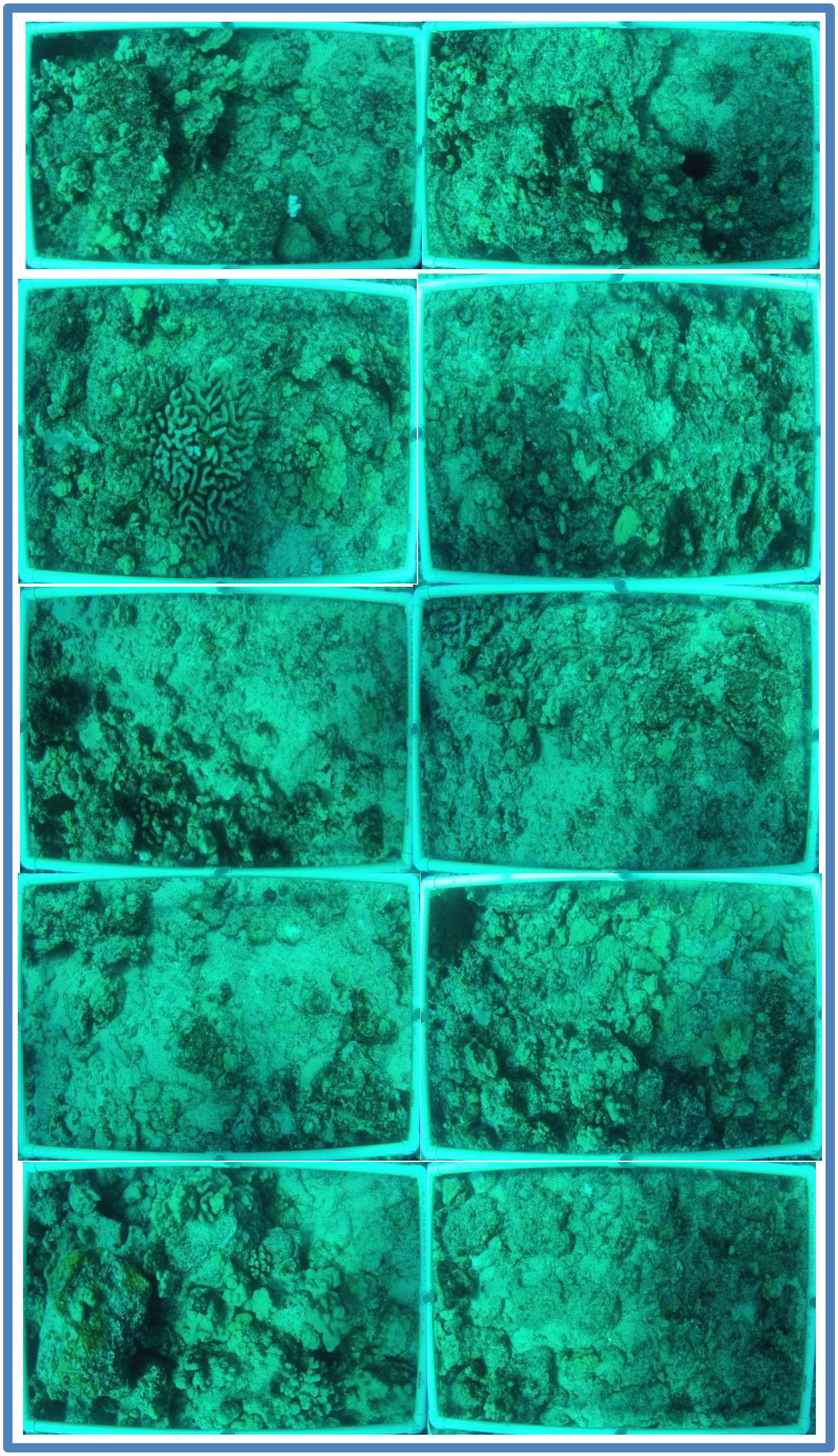
Digital Photoquadrats taken July 16-17, 2014



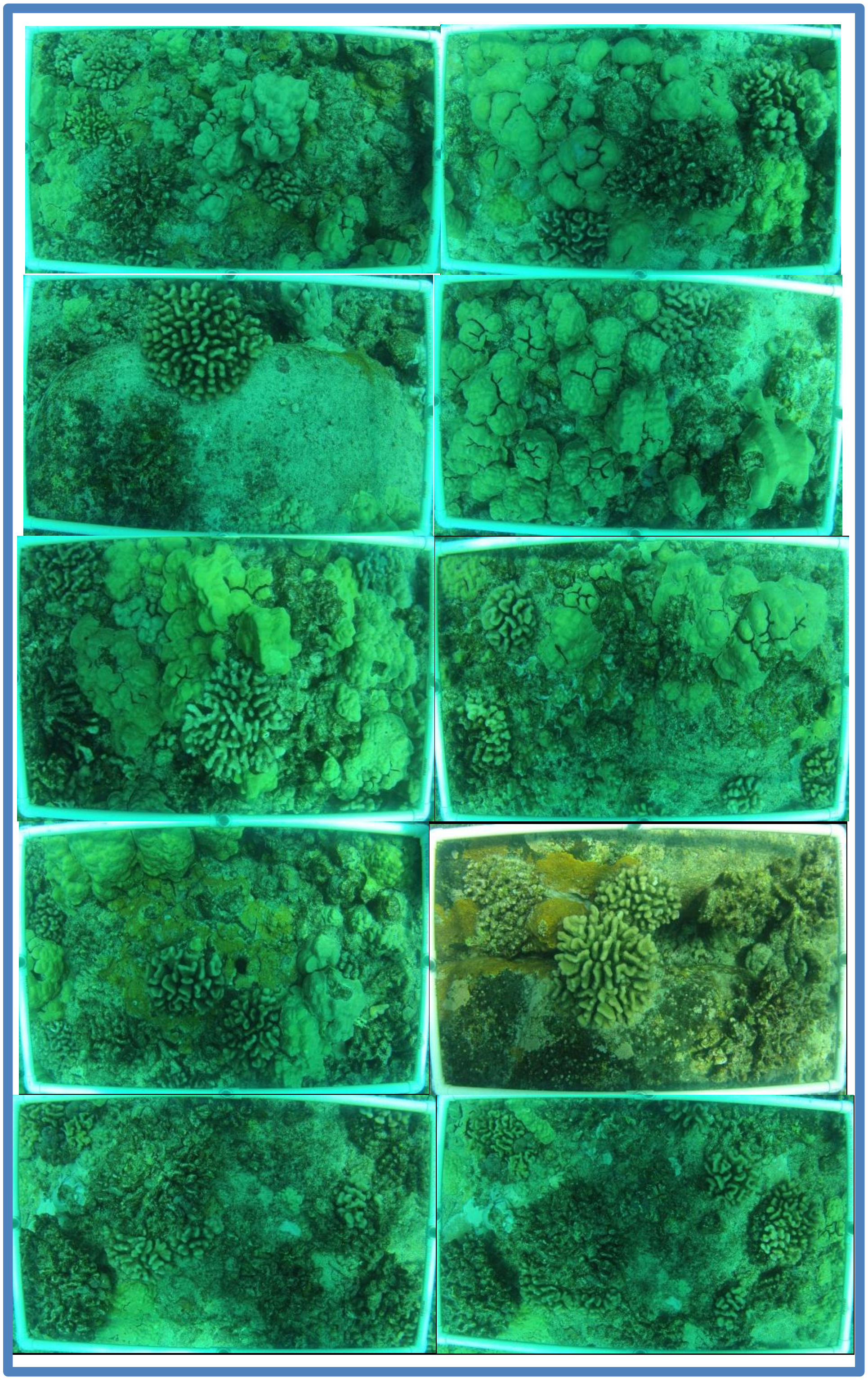
Photoquadrats taken along the 15 ft. transect at Wawaloli



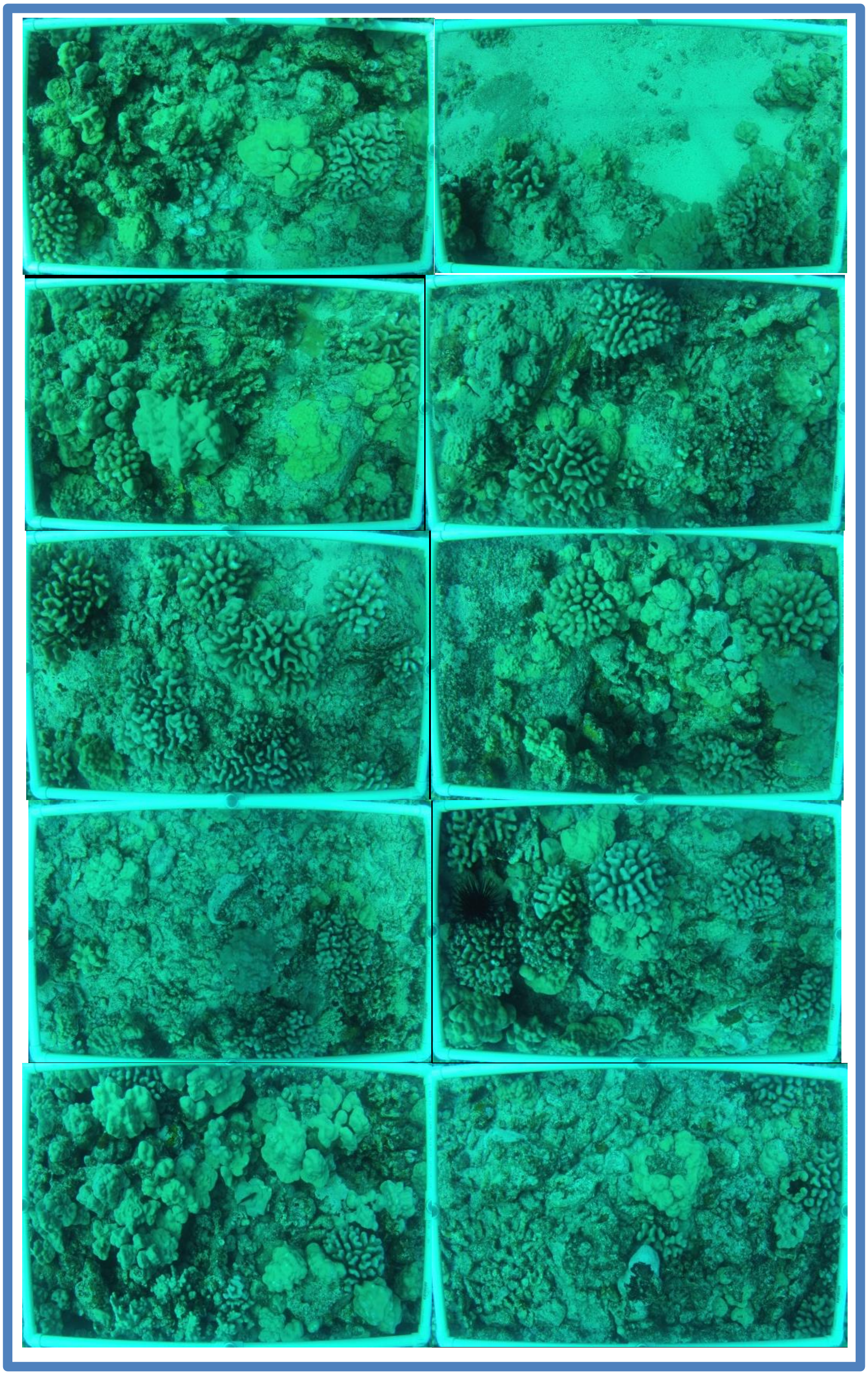
Photoquadrats taken along the 30 ft. transect at Wawaloli



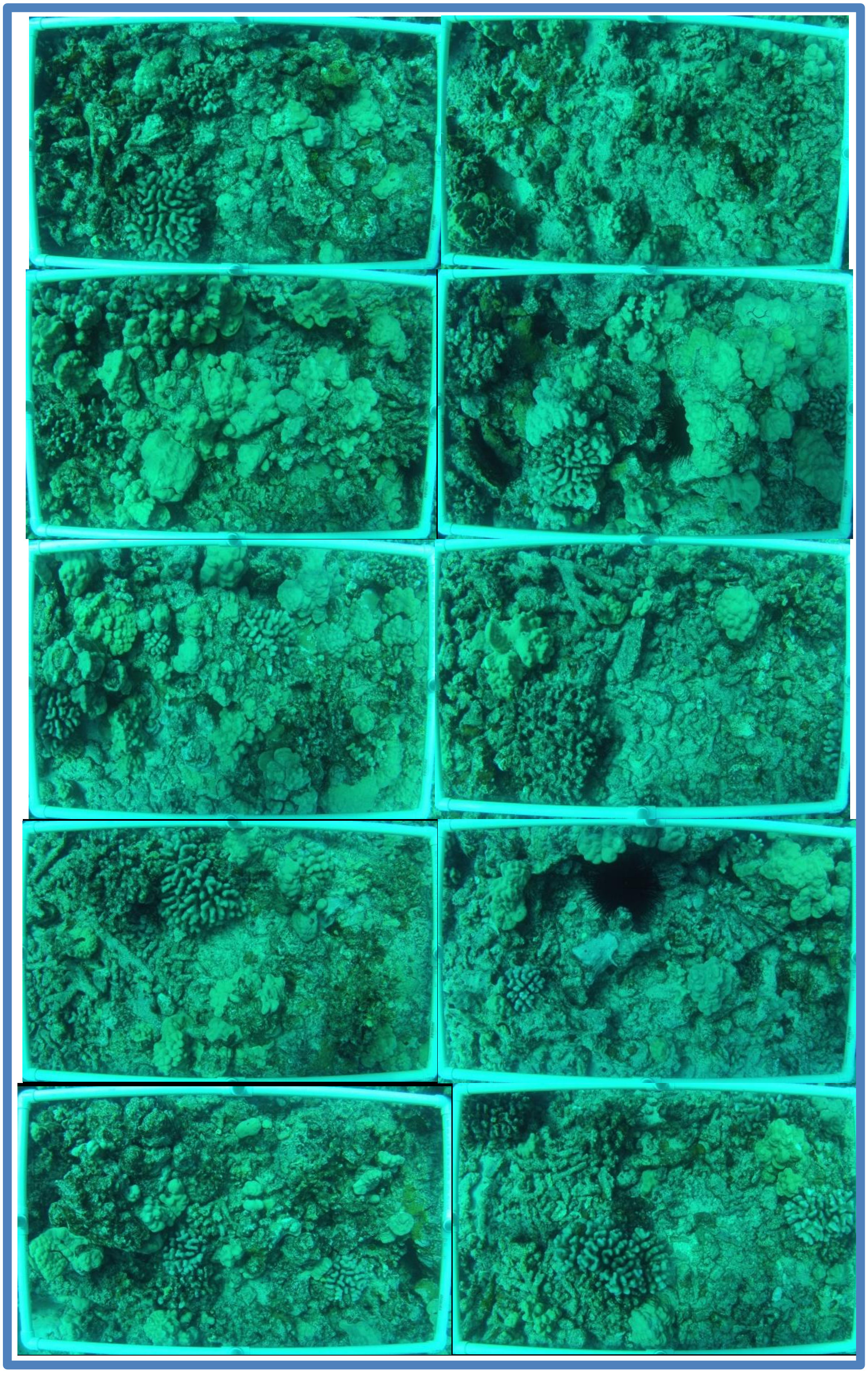
Photoquadrats taken along the 50 ft. transect at Wawaloli



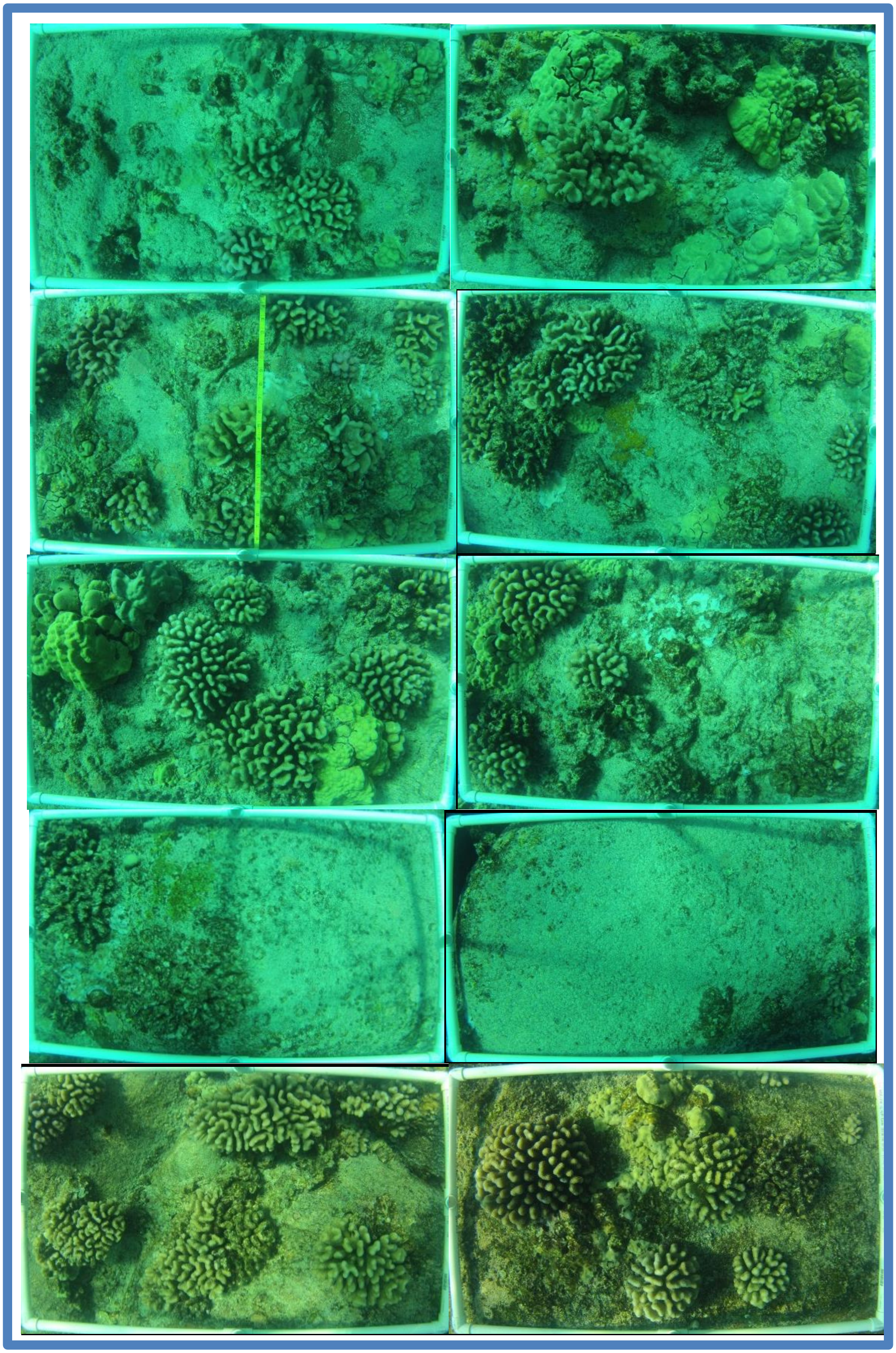
Photoquadrats taken along the 15 ft. transect at 18” Pipe



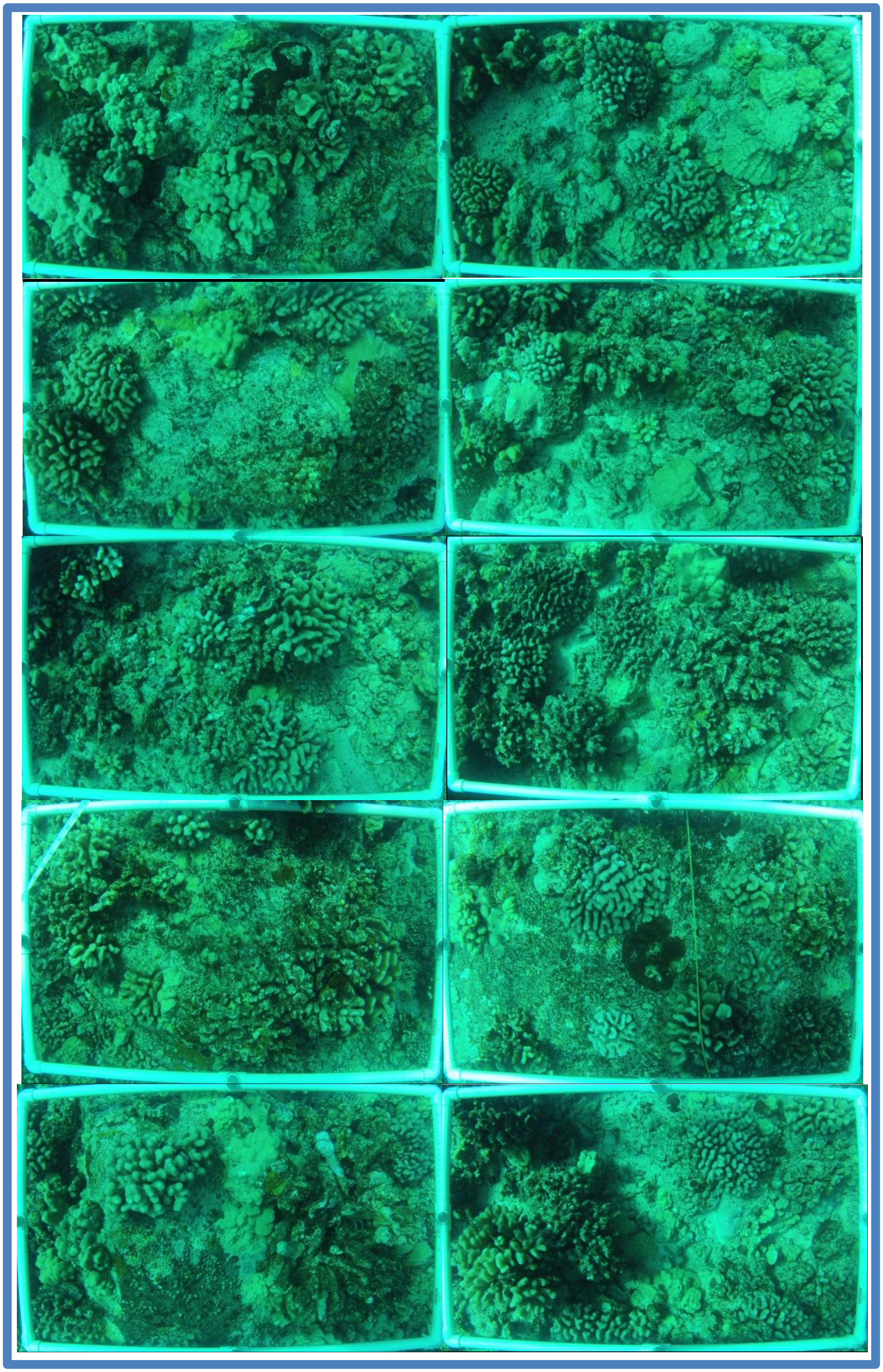
Photoquadrats taken along the 30 ft. transect at 18” Pipe



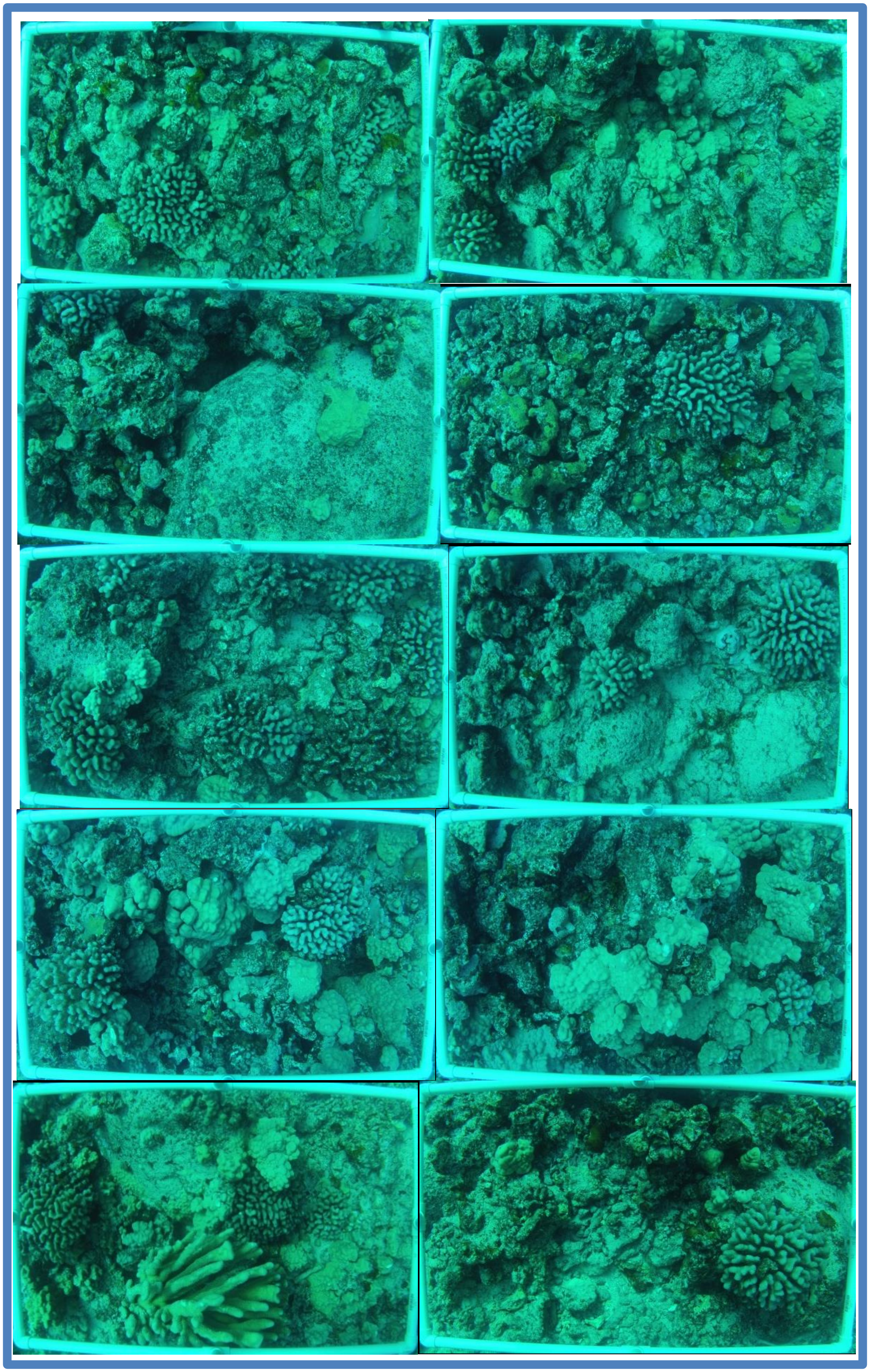
Photoquadrats taken along the 50 ft. transect at 18" Pipe



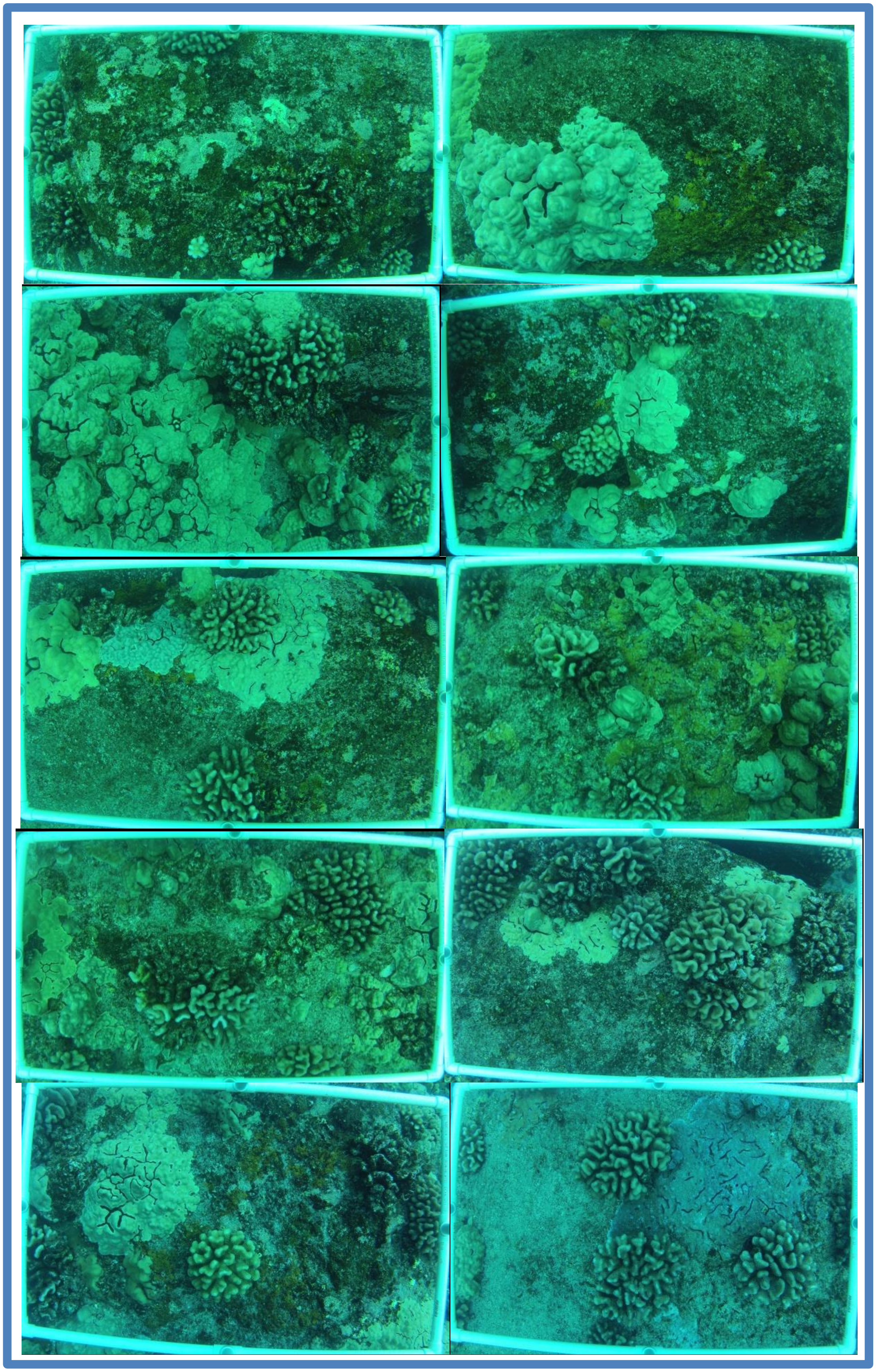
Photoquadrats taken along the 15 ft. transect at 12" Pipe South



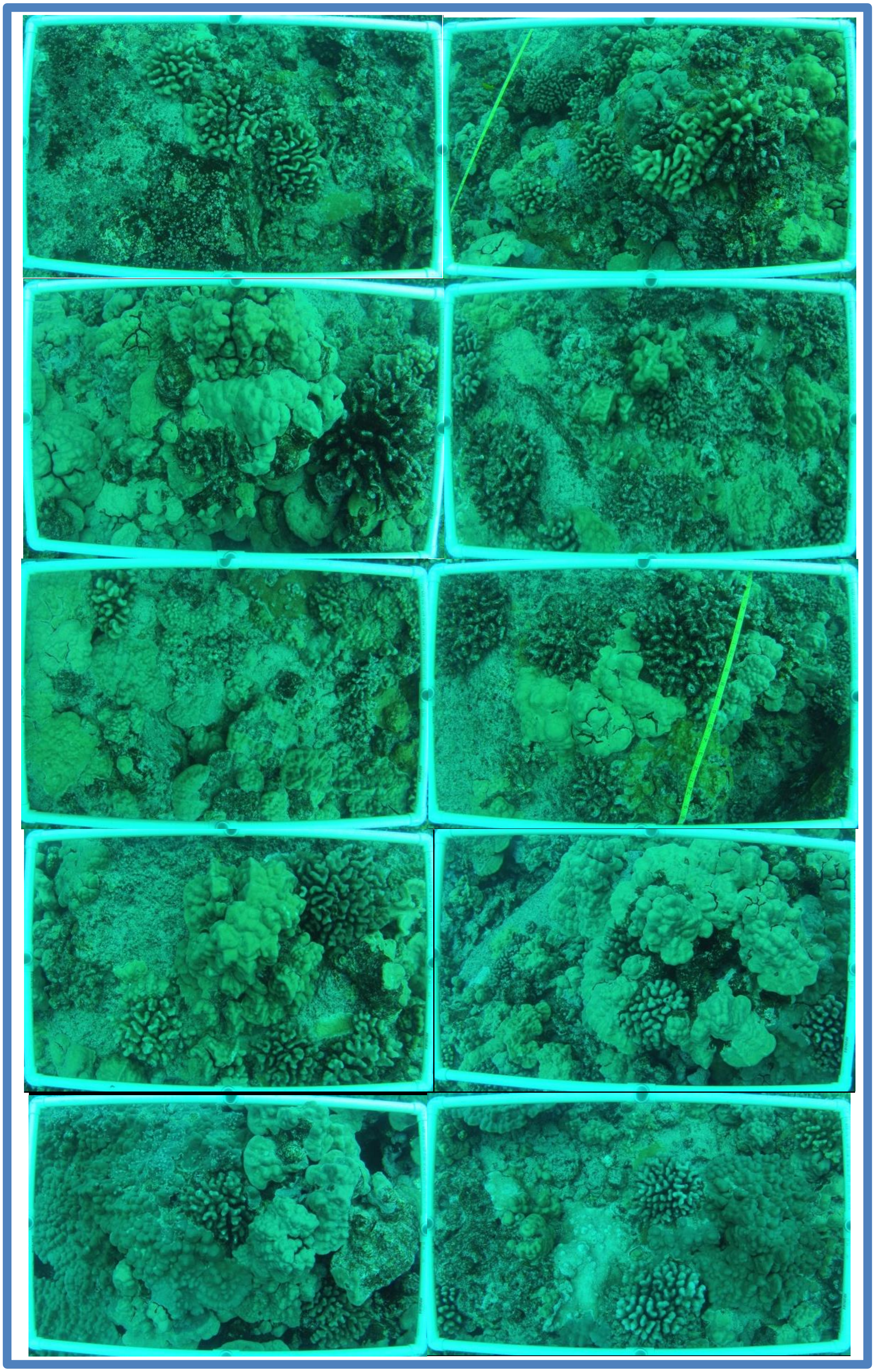
Photoquadrats taken along the 30 ft. transect at 12” Pipe South



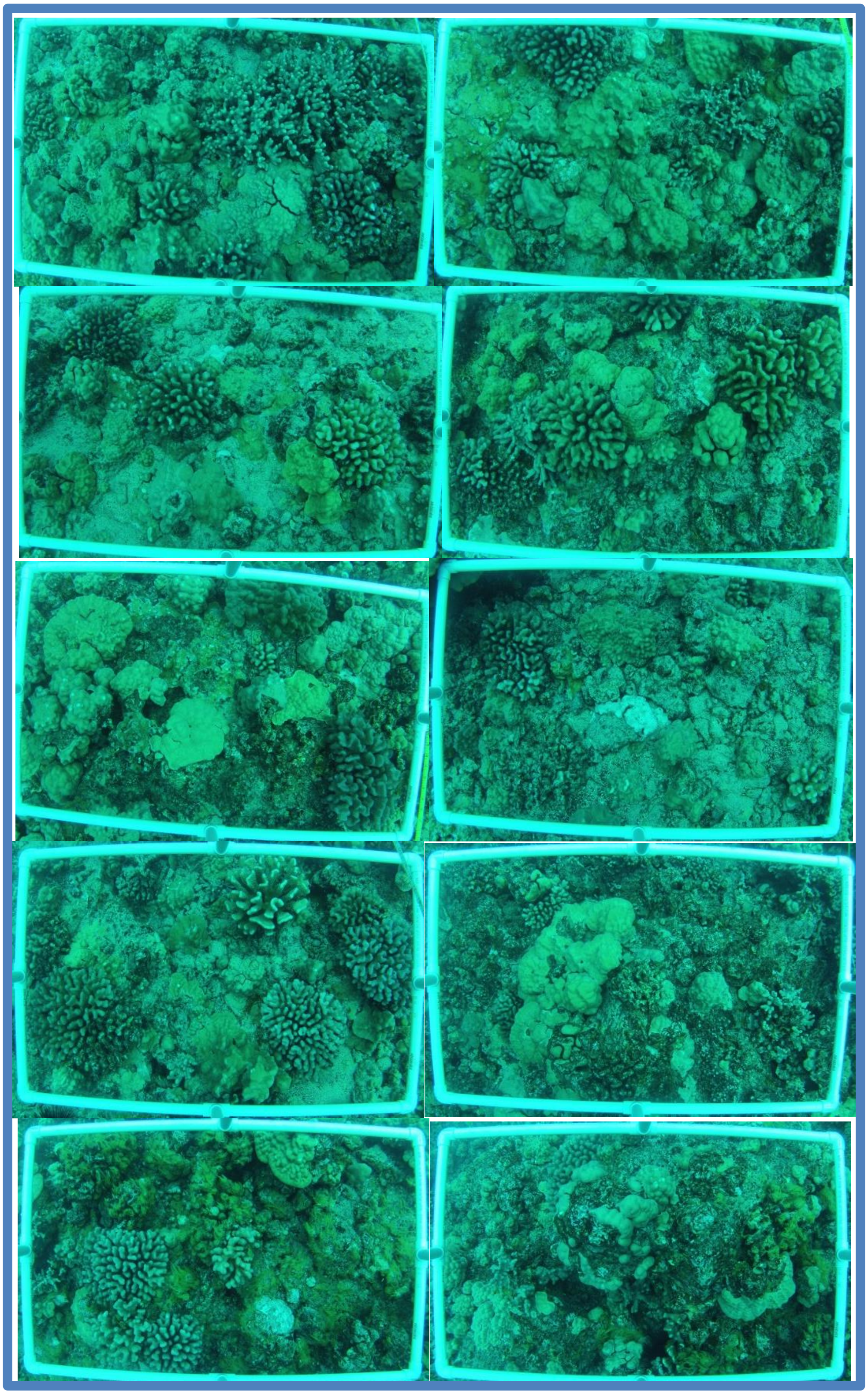
Photoquadrats taken along the 50 ft. transect at 12” Pipe South



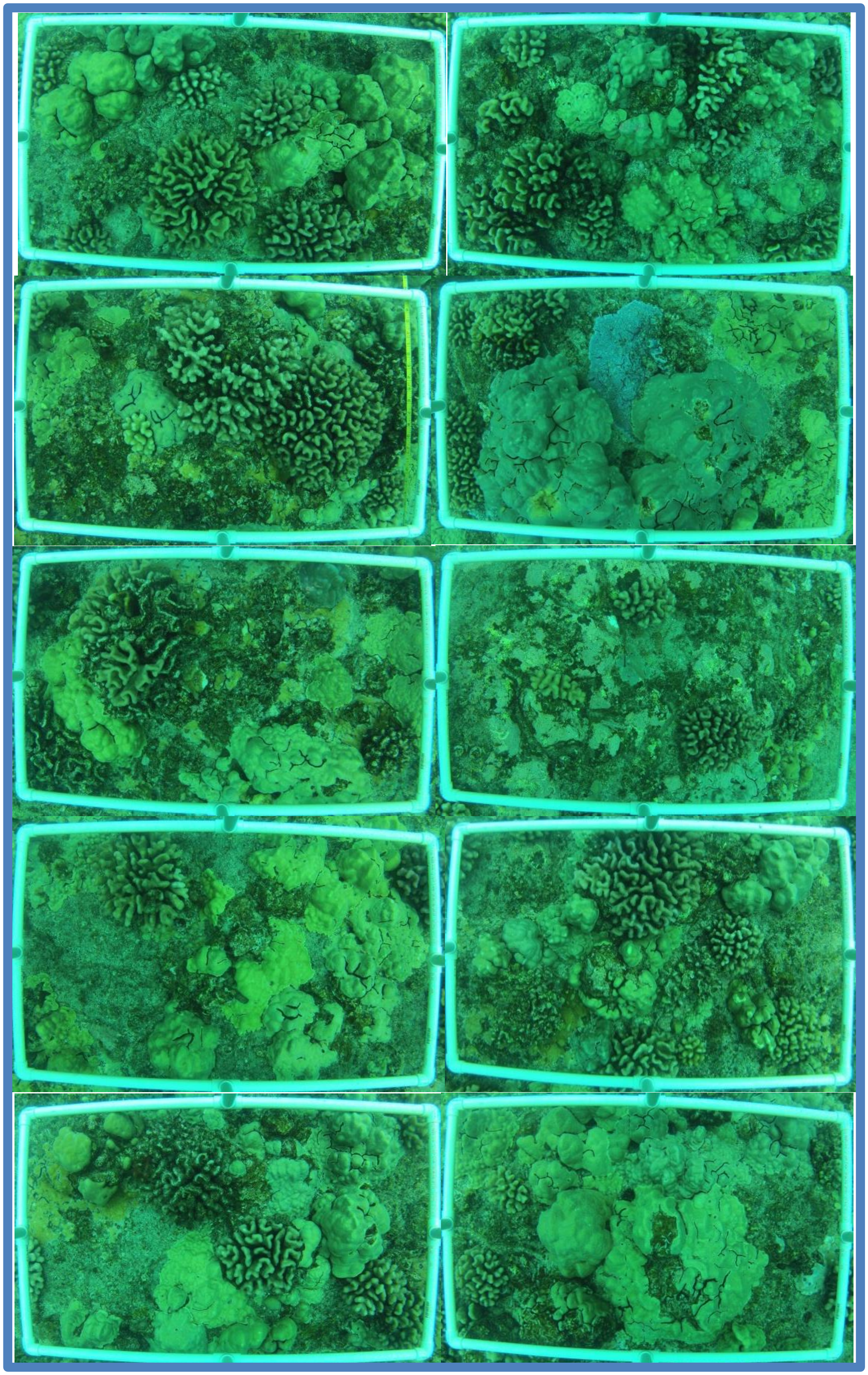
Photoquadrats taken along the 15 ft. transect at 12” Pipe North



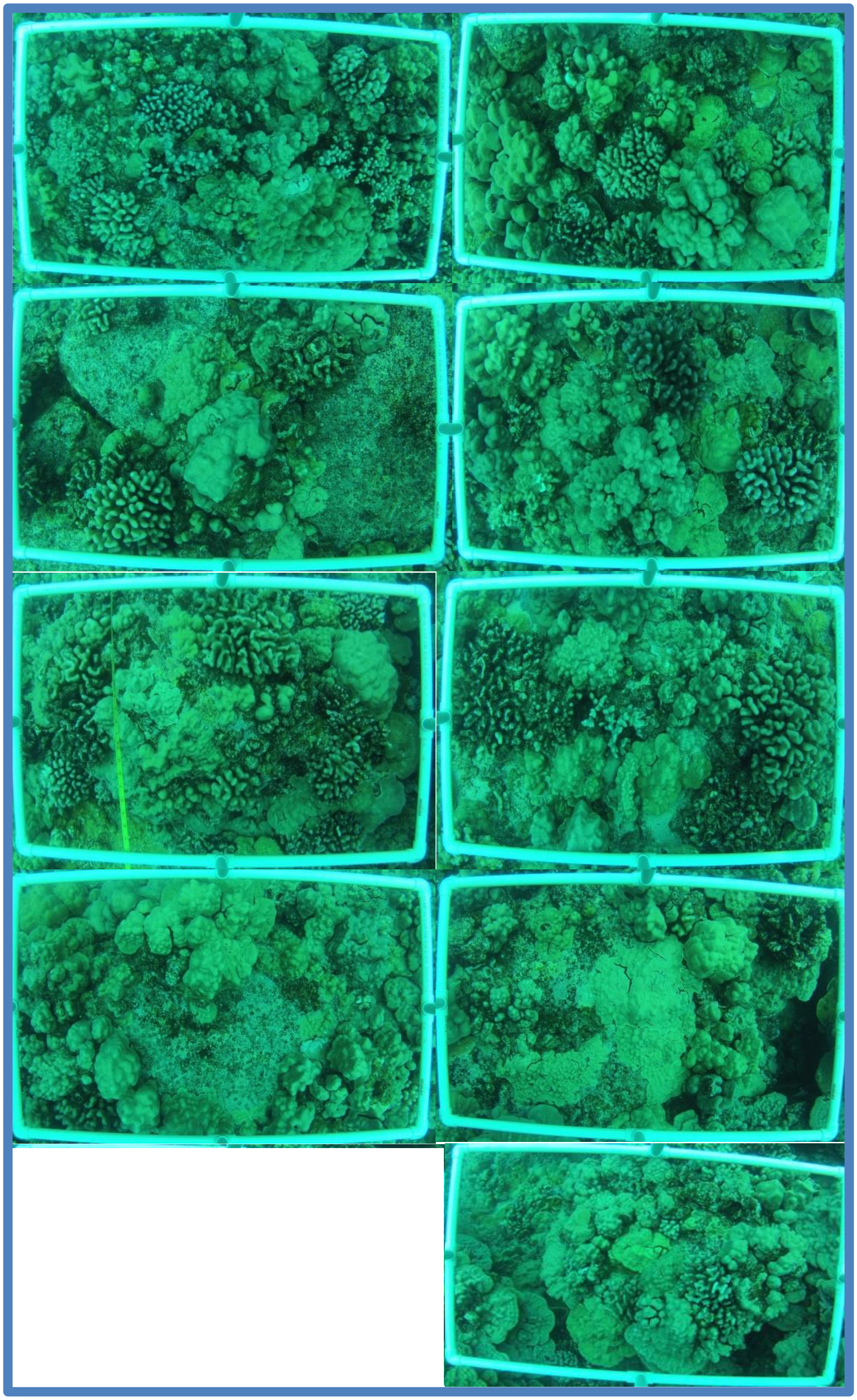
Photoquadrats taken along the 30 ft. transect at 12” Pipe North



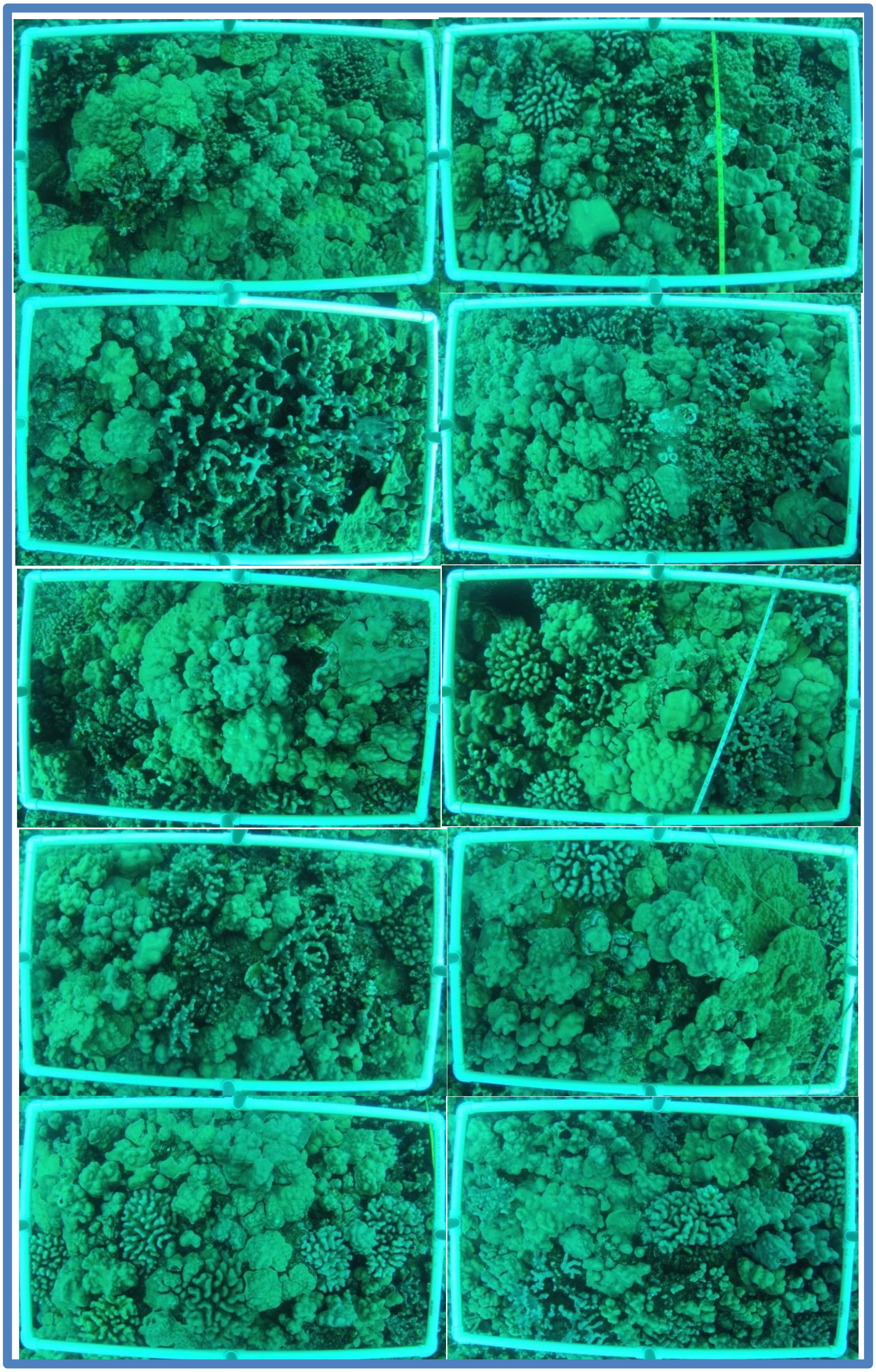
Photoquadrats taken along the 50 ft. transect at 12” Pipe North



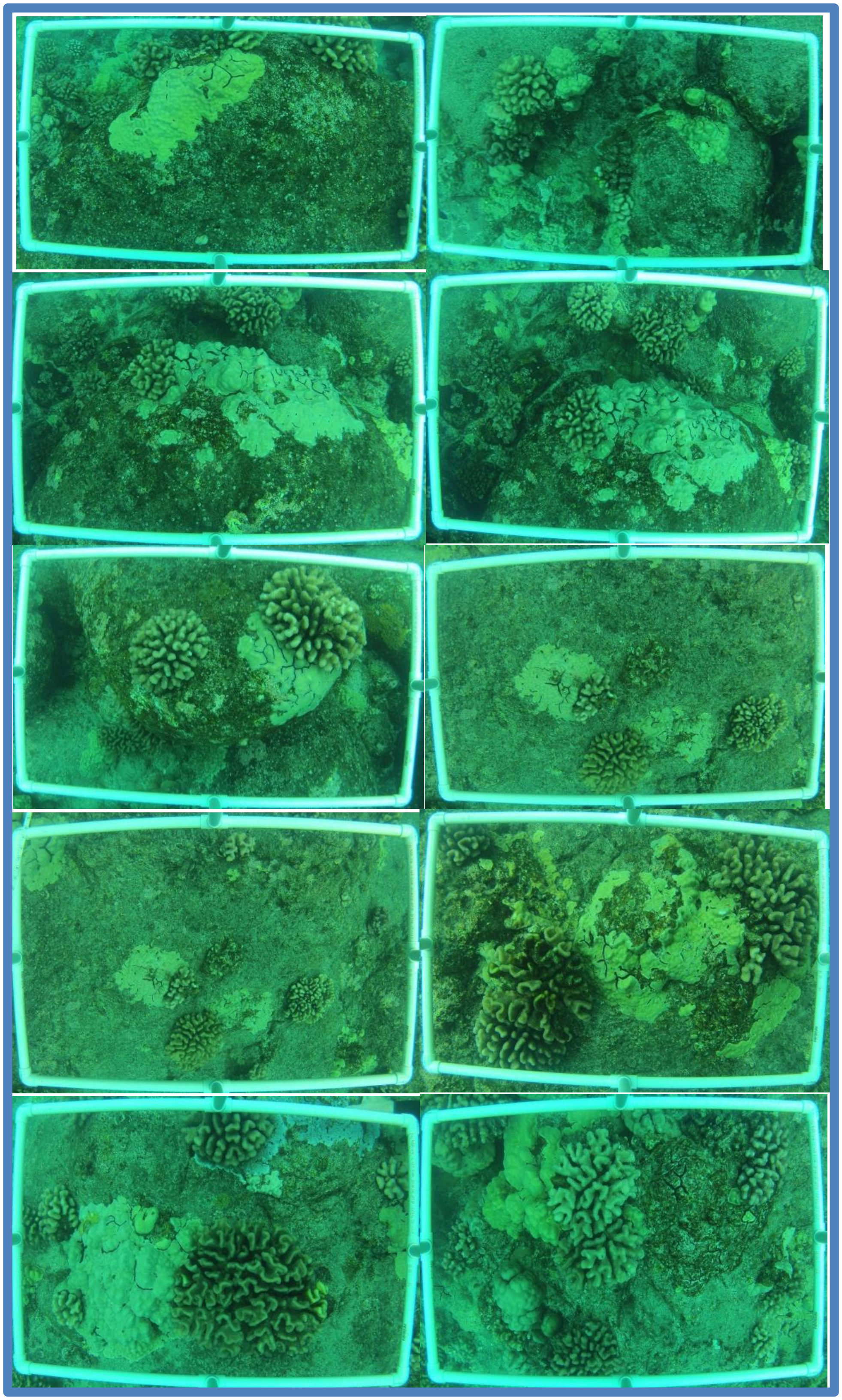
Photoquadrats taken along the 15 ft. transect at NPPE



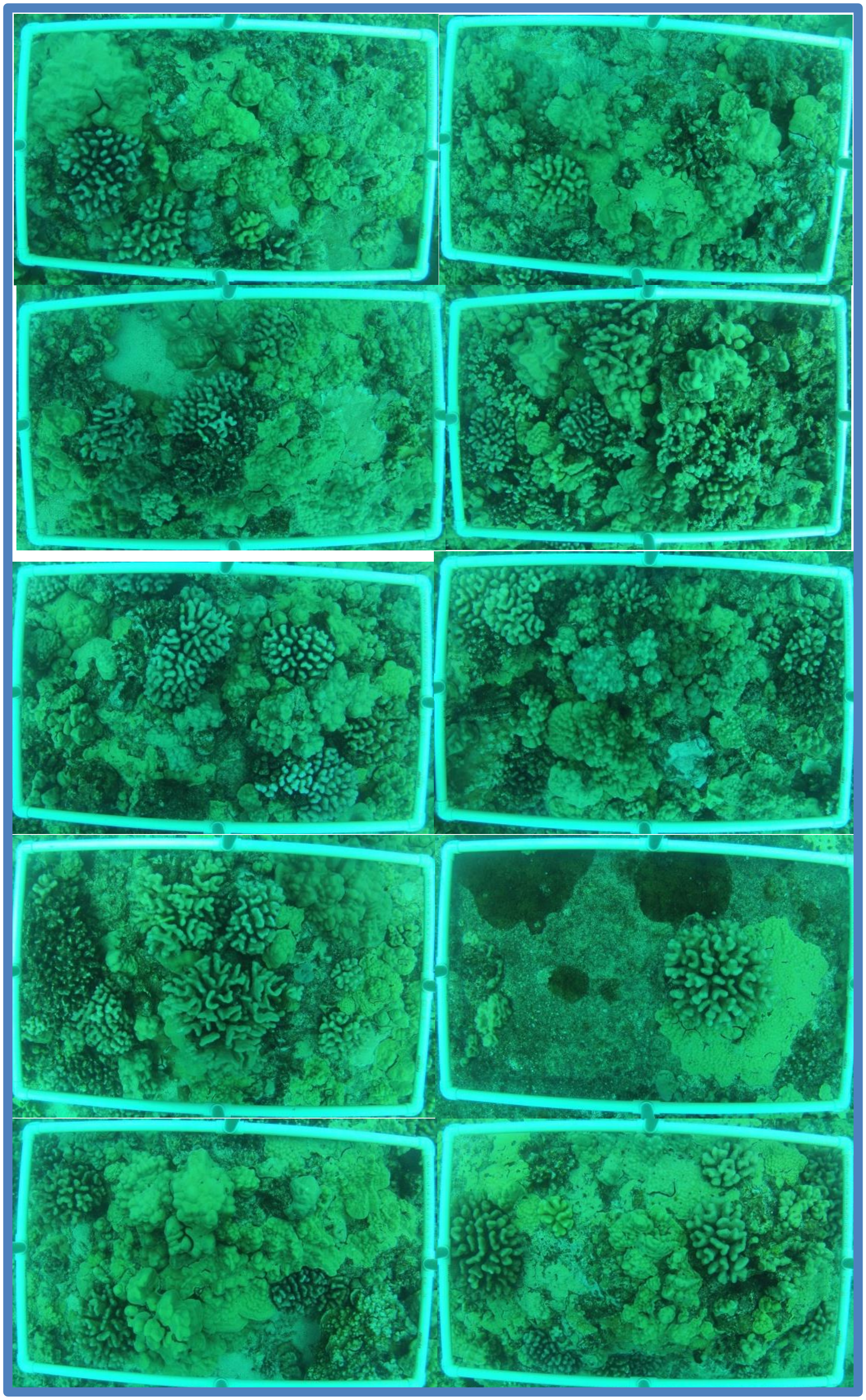
Photoquadrats taken along the 30 ft. transect at NPPE. One photo was inadvertently omitted.



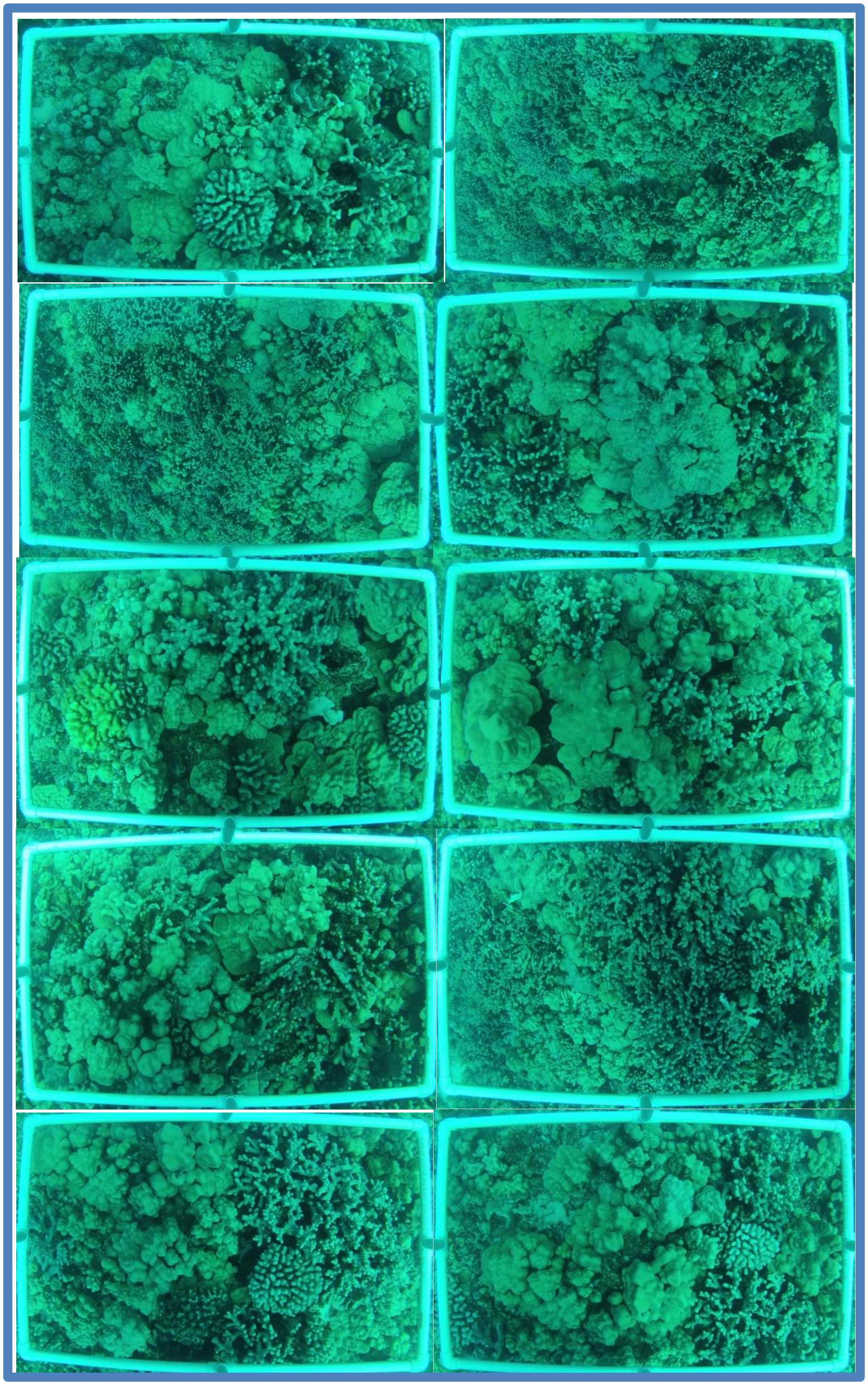
Photoquadrats taken along the 50 ft. transect at NPPE



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



Photoquadrats taken along the 30 ft. transect at Ho'ona Bay



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