PLANB
CONSULTANCY, INC.

PO Box 578
Papaikou, HI 96781
808-854-4057
www.planbconsult.net

Benthic and Biota Monitoring Program

Natural Energy Laboratory of Hawaii Authority

Survey Report – 2016

Prepared for:

Natural Energy Laboratory of Hawaii Authority (NELHA)
P. O. Box 1749 Kailua-Kona, HI 96745

Prepared by:

John HR Burns, Ph.D.

Lindsay Kramer, M.S.

PlanB Consultancy, Inc.
Environmental Division
PO Box 578
Papaikou, HI 96781

October 2016

EXECUTIVE SUMMARY

The Natural Energy Lab of Hawaii Authority (NELHA) is a Hawaii state agency that operates an Ocean Science and Technology Park at Kailua-Kona on the West side of Hawaii Island. The purpose of the NELHA facility is to promote research, education, and commercial activities that focus on development of sustainable industries. The nearshore marine environment surrounding NELHA, known as Keahole Point, is known for supporting abundant and diverse benthic and fish communities. The development of NELHA included the installment of pipeline infrastructure on the reef in order to pump deep seawater to the operational facilities. Since installing the underwater pipe components, a comprehensive monitoring program was developed to ensure the NELHA infrastructure and activities do not detrimentally affect the health and productivity of the nearby marine environments. This monitoring program performs annual characterizations of the anchialine habitats, benthic substrate, and nearshore fish assemblages.

Since the monitoring program began in 1989, more than 45 annual surveys of these environments have been conducted and extensive reports have been prepared. The results, findings, summaries, and references for these reports are both publicly available and discussed throughout this report, which presents the results of the 2016 survey.

There are several anchialine pond systems in the vicinity of the NELHA facility. The ponds exist in spatially distinct Northern and Southern systems. The North system supports five unique ponds, and the South system supports ten unique ponds. This report details the faunal census conducted in each pond in April and October, 2016. Physical parameters were measured (e.g., temperature, salinity, conductivity, pH) in conjunction with surveys of flora and fauna in each pond. The surveys were supplemented with digital images to provide a visual record of the pond systems.

The results of the 2016 anchialine pond survey were generally consistent with previous annual surveys. Based on the faunal census performed, almost all anchialine ponds in the vicinity of the NELHA facility that are devoid of introduced fish species supported communities of abundant native organisms, including ‘ōpae ‘ula (*Halocaridina rubra*). Similar to previous surveys, anchialine ponds with introduced fish present still maintained minimal turbidity levels (visually assessed) and were not overgrown by invasive or opportunistic algae. This suggests that current water quality conditions are consistent with previous conditions, and that *H. rubra* may be still actively grazing in these ponds at night, thus maintaining a cropped algal assemblage.

The marine surveys are conducted at six stations along the coastline adjacent to the NELHA facilities. At each station, transects are conducted at three depth gradients (~15-fsw, ~30fsw, and ~50fsw) for total of 18 transects. Benthic habitat is characterized by surveying all abiotic and biotic feature of the substrate along 50-m transects. The benthic surveys reported a gradual increase in coral cover for the first 20 years of the study (Ziemann 2010), and corals in the genus *Porites* have been the dominant species among all stations and depths. Data from the last six years have found the coral cover to stabilize in the range of ~40-50%. The overall coral cover for 2016 was 44.6%, which is within this range and shows the benthic communities to have exhibited relatively consistent values of coral cover for the last seven years.

Of the overall percent coral cover among the six stations (44.6%), the most dominant corals were *Porites lobata* (15.6%), *Porites evermanni* (8.32%), *Porites compressa* (9.10%), and *Pocillopora meandrina* (18.2%) These corals were present among all the stations. Other corals present were *Leptastrea purpurea, Leptastrea bewickensis, Montipora capitata, Montipora flabellata, Montipora patula, Pavona varians, Pocillopora eydouxi, Porites rus and Fungia scutaria.* These corals accounted for approximately 5% of the relative benthic cover.

Monitoring of the nearshore fish assemblages was conducted at the same six stations and depths as the benthic community. Surveys were performed at the same spatial locations of the benthic surveys, and used a 4 x 25-meter belt transect to record the abundance and size of all fish present in the survey area. Fish data exhibit inherent variability due to high mobility and spatial habitat ranges of the nearshore species. The results from this monitoring program have been variable throughout the 27-year period of this monitoring program. The findings from 2016 show an increase in fish abundance, diversity, and biomass compared to the last five years. Ultimately, data from the duration of the monitoring program shows the nearshore habitats surrounding NELHA support highly diverse and productive fish assemblages.

These results and findings from the surveys of the anchialine ponds, nearshore benthic substrate, and nearshore fish assemblages indicate these environments are not exhibiting any signs of detrimental impacts associated with the NELHA facility.

TABLE OF CONTENTS

ANCHIALINE POND SURVEY 5

INTRODUCTION 5

METHODS 7

RESULTS 9

DISCUSSION 11

MARINE BENTHIC BIOTA SURVEY 23

INTRODUCTION 23

METHODS 24

RESULTS 26

COMPARATIVE ANALYSIS OF TEMPORAL TRENDS IN BENTHIC DATA 29

DISCUSSION 31

MARINE FISH BIOTA SURVEY 33

INTRODUCTION 33

METHODS 34

RESULTS 35

COMPARATIVE ANALYSIS OF TEMPORAL TRENDS IN FISH DATA 37

DISCUSSION 38

REFERENCES 40

APPENDICES 44

Appendix 1: Environmental and biological data reported from anchialine pond surveys between May 1989 and October 2008. 44

Appendix 2: Nearshore marine habitat characterization data 51

Appendix 3: Nearshore fish assemblage data 62

Appendix 4. Digital images of quadrats used for benthic habitat characterization 68

ANCHIALINE POND SURVEY

INTRODUCTION

Anchialine ponds are a unique ecosystem characterized as nearshore land-locked, brackish bodies of water, influenced by terrestrial groundwater inputs and marine tidal influx. These unique aquatic conditions host a similarly unique array of species. Hawai’i Island is known for its relatively high concentration of these ponds, with numerous examples at Keāhole Point. Interest in these ecosystems, previously described by Holthuis (1973), stemmed from observations of an assemblage of small, red shrimp that appeared to be restricted to this particular habitat. 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 and Manning 1972, Holthuis 1973, Maciolek 1983, Iliffe 1991, Hobbs 1994, Brock and Bailey-Brock 1998). Anchialine ponds are commonly found along the shoreline of West Hawai‘i, and also occur on O‘ahu, Maui, Moloka‘i, and Kaho‘olawe (Brock *et al*. 1987, Bailey-Brock and Brock 1993).

The unusual environmental conditions of anchialine ponds have resulted in the presence of specialized native and endemic species (Peck 1994). As elsewhere, organisms found within the anchialine ponds in Hawai‘i are uniquely suited to the changing salinity conditions. Specialized species include crustaceans, mollusks, plants, and other taxa. Table 1 summarizes the species previously reported from the ponds located near Keāhole Point, Hawai‘i (Brock 2008, Ziemann and Conquest 2008). Two specialized decapod shrimp species *Halocaridina rubra* (‘ōpae ‘ula) and *Metabataeus lohena* are common residents in many of the Keāhole Point ponds. Anthropogenic alterations associated with coastal development and other shoreline activities can result in negative impacts to anchialine pond ecosystems. Examples include invasive species introductions, physical/structural alterations, and groundwater reduction/ contamination, all of which can result in pond decline.

Halocaridina rubra preferentially inhabit anchialine ponds throughout the day to feed on microalgae, macroalgae, and detritus (Yamamoto *et al.* 2015). Anchialine ponds are typically connected to one another via lava tubes, rock fissures, and micro-cracks in the surrounding basalt substrate. Reproduction and larval dispersal of *H. rubra* generally occurs within the subterranean (hypogeal) sections of anchialine systems (Yamamoto *et al.* 2015). *H. rubra* also works to maintain a standing crop of plants, bacteria, diatoms, and protozoans through active grazing, and will prevent overgrowth by opportunistic algae under a typical nutrient regime (Bailey-Brock and Brock 1993). This ‘gardening’ role contributes to the overall health of the anchialine pond ecosystem, allowing other species to reside within the sunlit (epigeal) portion of the ponds. Because of this critical ecosystem function, *H. rubra* (‘ōpae ‘ula) are thought to be a keystone species (Bailey-Brock and Brock 1993).

Introduced fish species (e.g. mosquitofish, guppies) can cause declines in *H. rubra* abundance due to increased predation, and can force shifts in foraging behavior, driving higher activity at night (Capps *et al*. 2009). Typically, anchialine ponds with established populations of introduced fish are not able to support *H. rubra* assemblages during the day.

Recent investigations using techniques to examine the DNA of *H. rubra* have provided a better understanding of population dynamics, and have contributed to effective planning and management of anchialine ponds in Hawai‘i (Santos 2006). A study to understand the population structure of *H. rubra* on Hawai‘i Island showed that two distinct lineages exist on the east and west coasts. Also, within small geographic areas along each coast, populations were structured with low levels of gene flow, suggesting that local assemblages are genetically unique (Santos 2006). Monitoring of anchialine ecosystems in Hawai‘i should therefore be conducted on a local scale, (i.e. at the level of ponds and pond complexes), similar to the methods described in this study for monitoring at Keāhole Point. The two groups of ponds in the vicinity of the NELHA facility have been surveyed for more than 30 years (Brock 1995, Brock 2002, Brock 2008, Oceanic Institute 1997, Oceanic Institute 2007, Ziemann and Conquest 2008, Bybee *et al.* 2012, Bybee *et al.* 2013, Bybee *et al.* 2014). Through the continued monitoring program at these sites, a change in pond communities has been noted during surveys conducted after 1989, with shrimp becoming absent in certain ponds as a result of Poeciliid fish introductions (Brock 2008, Ziemann and Conquest 2008). The findings of the April 2016 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, consist of five ponds in the Northern group and ten in the Southern group (Figures 1 – 3). The northern pond complex, ponds N - 1 to N - 5, was roughly 100 m inland of the cobble beach at Hoʻona Bay (Figure 2), and the southern complex, ponds S – 1 to S– 10, were approximately 200 m to 225 m from the shore at Wawaloli Beach Park, adjacent to Makako Bay Drive (Figure 3). Table 2 describes the location and size of each pond at the NELHA site. A Garmin hand-held GPS unit was used to locate and re-record latitude and longitude coordinates for each pond during the April 2016 survey. Pond size was calculated from measurements reported by Brock 2008 (Table 2), except for pond S-10, which was first surveyed in 2015 (Whale Environmental Services 2015). Pond dimensions and basin characteristics for historically surveyed ponds are included in Appendix 1.1 (Brock 2008).

As anchialine habitats are characterized by tidal influences, the water level and appearance of the NELHA ponds varies with tide level. The effect of tide level is apparent for a Northern pond cluster, including ponds N-2, N-3, N-4 and N-5. At low tide, these ponds were separated by basalt substrate, and at high tide these pools form a single body of water. While the water level in the Southern group ponds were also tidally affected, ponds were never interconnected. Faunal observations for the April 2016 survey were collected at tide levels below the daily maximum to provide sufficient water for organismal observation and photo-quadrat sampling if possible. Sampling of the ponds was conducted at tidal levels ranging from +0.6 to +2.0 feet. For pond “complexes,” ponds were surveyed only when physically separated (below the daily maximum tide).

A faunal census of each pond in the vicinity of the NELHA facility was undertaken in April 2016, and October 2016 (Pond S-10 only). Temperature and salinity measurements were taken concurrently employing a hand-held YSI Pro-Series Quatro water quality meter and data logger. Visual observations of organisms within each pond were supplemented by photographs and high-definition video taken with a Nikon Coolpix AW120 1080p digital (waterproof) camera. Images and videos were reviewed in the two weeks following the visual surveys. Randomly selected photo-quadrats ranged in size from 0.02 m^2 to 0.07 m^2 (based on feasibility according to pond size and depth). Individual photo-quadrats were isolated from video footage. The number of replicate photo-quadrats analyzed depended on pond area, and ranged from 3 to 6 replicates. An example 2016 photo-quadrat is shown in Figure 5. Photo-quadrats were used to identify organisms and calculate *H. rubra* density. Four ponds with low water levels (S-3, S-4, S-6, S-9) were surveyed visually by noting presence or absence of flora and fauna. All densities were calculated to an area of 0.1 m^2 to allow for comparisons with previous survey results (Appendices 1.2 and 1.3).

In addition, two-minute video segments were recorded at each pond, and later examined to qualitatively assess the biological community. Video surveys were designed to include less common, cryptic, or highly mobile species. Only the presence or absence of non-native organisms was recorded for this survey.

RESULTS

Water quality measurements and faunal census results from the April and October 2016 survey are summarized in Table 3. Pond characteristics were partially explained by location, with higher species diversity and surrounding vegetation density documented for the Northern ponds compared to the Southern ponds (Figures 4 - 9). Southern ponds tended to be surrounded by un-vegetated basalt, and were more likely to host introduced fish (Figures 8 and 9). Certain Southern ponds also experienced higher visitation rates due to their proximity to Wawaloli Beach Park.

The Southern ponds were cooler and less saline during the April 2016 survey compared to the Northern ponds, suggesting that relatively higher groundwater influence occurs within these ponds. For the Southern ponds, temperature ranged from 21.6 - 22.3 C°, and salinity ranged from 10.6 to 11.2 ppt. For the Northern ponds, temperature and salinity were slightly higher, ranging from 23.2 -25.7 C° and from 12.7 – 14.9 ppt., respectively (Table 3). This pattern matched previous surveys, including 2009 and 2014 measurements (Bybee *et al.* 2014, Appendix 1.1).

Similar to previous surveys, the majority of the Northern anchialine ponds hosted higher densities of shrimp species, *Halocaridina rubra* and *Metabataeus lohena*, compared to Southern ponds. All Northern ponds had *H. rubra* present, with the exception of N-5. This included N-3, in which *H. rubra* was not observed during the 2014 survey (Bybee *et al*. 2014). Several Northern ponds also hosted assemblages of the aquatic grass, *Ruppia maritima*, and similar to previous surveys, *H. rubra* was typically not found within these grass beds (Figure 6). *M. lohena* was observed in Ponds N-1, N-2, S-9, and S-10 (Table 3). *Macrobrachium grandimanus* was only observed in Pond S-7 (Table 3). Historically and in more recent surveys (excluding this one), *M. grandimanus* had also been observed in ponds S-1, S-5, and S-8 (Bybee *et al.* 2014, Appendix 1.2)

Table 3 lists additional species observed within and around each pond during video surveys and *in-situ* visual observations. Generally, higher species diversity was observed for the Northern area ponds. Thiarid snails (*Melanoides tuberculata* and *Tarebia granifera*) were observed in all five Northern ponds (Figure 7), with a just few individuals observed in Southern pond, S-7. Similar to previous censuses, high densities of Thiarid snails were observed in the Northern pond, N-4 (Table 3, Figure 7) (Bybee *et al.* 2014, Appendix 1.2).

Introduced Poeciliid fish, including *Gambusia affinis* and *Poecilia sp.* were observed in four of the Southern area ponds, including S-1, S-5, S-7, and S-8 (Figure 8, Table 3). Where introduced fish were present, shrimp populations, including *Halocaridina rubra* and/or *Metabataeus lohena*, were dramatically reduced or absent. As of the census date in April 2016, introduced fish were not observed in any of the Northern area ponds (Table 3).

Signs of visitor impacts were observed at four of the surveyed ponds, including Pond N-5 in the Northern area, and Ponds S-3, S-4, and S-5 in the Southern area. These ponds are in close proximity to the Wawaloli Beach Park (S-3, S-4, and S-5) and/or are easily visible from nearby access points (N-5). Modification from visitors included the construction of adjacent rock walls, the addition of rocks to pond basins (leading to increased shading and pond depth reduction), toilet paper additions to ponds (and associated products), and the removal of Poeciliid fish for fishing bait and other uses. For two of the Southern ponds (S-2 and S-4), surrounding rock structures appeared to be shifted, which partially or completely covered the ponds. For pond N-5, signs of visitation included apparent substrate disturbance (algal cover facing down), trampled *R. maritima*, and increased turbidity. On April 22, 2016, dogs were observed swimming within pond N-5, which precluded a full survey on that day.

DISCUSSION

The West Hawai'i coastline hosts numerous anchialine ponds, which are unique, tidally influenced brackish ecosystems that host a specialized array of species. Two complexes of ponds adjacent to the NELHA facility have been monitored for multiple decades (Appendix 1.2), providing essential knowledge on status and change in these ecosystems. These datasets can help improve management of the ponds locally and throughout Hawai'i Island by tracking ecosystem changes overtime. The anchialine ponds at NELHA were resurveyed in April 2016, and compared to previous censuses, spanning back to May 1989. The census results from April and October 2016 were similar to recent surveys (Bybee *et al.* 2013, Bybee *et al.* 2014, Whale Environmental Services 2015), and also highlight long term changes in the pond when compared to historical data. The major drivers of pond ecology were: 1) pond location, either Northern or Southern areas (Figures 1-3), 2) groundwater influence, 3) the presence or absence of introduced fish (Figure 8), and 4) the level of human visitation to the ponds.

All Northern ponds had *Halocaridina rubra* ('ōpae 'ula) present, with the exception of N-5 (Figure 5). In 2014, *H. rubra* were not observed in pond N-3, however this year, *H. rubra* were detected at a low density (1.5 $\pm$ 2.7 (count/ 0.1 m^2)) (Table 3). At high tide, ponds N-2, N-3, N-4 and N-5 were inter-connected, allowing for organismal exchange, which likely allowed for the rapid replenishment of *H. rubra* within pond N-3 since 2014. Similar to 2014, *H. rubra* were not detected in pond N-5, and regular habitat (and algal food source) disturbance may play a role in this absence. As documented in previous years, Poeciliid fish were absent in all Northern ponds (Bybee *et al.* 2014, Appendix 1.2).

The historical introduction of Poeciliid fish within anchialine ponds at NELHA has significantly affected pond ecology, and continues to alter pond ecology in four Southern area ponds including, S-1, S-5, S-7, and S-9 (Figure 8). Within these ponds, *H. rubra* and *M. lohena* were not observed in the April 2016, despite the presence of these shrimp in nearby uninvaded ponds. Capps *et al*. (2009) suggests that the *H. rubra* are driven out of fish-invaded ponds due to increased predation. In some cases, *H. rubra* may alter their behavior and only enter invaded ponds at night to feed. Alternatively, *H. rubra* may reside only within protected areas (inaccessible by fish) within an invaded pond. During this survey, ponds were surveyed during daylight hours, and a nocturnal assessment of *H. rubra* was not conducted. While *H. rubra* was the dominant community member in uninvaded ponds, *Metabataeus lohena* and *Macrobrachium grandimanus* were also occasionally observed (Table 3).

Despite the presence of introduced fish in certain ponds, water clarity was high and invasive algae was absent within the invaded ponds, according to visual, qualitative surveys (Table 3). This suggests that water quality has remained consistent, and/or that *H. rubra* has maintained a grazer role within the pond. Because of the subterranean (hypogeal) connections between the Southern area ponds, recolonization by *H. rubra* and other crustacean species would likely be rapid in the event that Poeciliids were removed from invaded ponds.

Video observations of the ponds allowed for documentation of less common, more motile species, and also provided a record of surrounding vegetation. Other species present at each pond are listed in Table 3, and generally, Northern area ponds tended to host a more diverse assemblage of pond inhabitants and surrounding vegetation (Figures 4-7, Table 3). Less common anchialine pond species, *Metabataeus lohena,* and *Macrobrachium grandimanus* were usually detected within video surveys, and were observed in April and October 2016 at ponds N-1, N-2, S-7, S-9, and S-10. Similar to *H. rubra*, *M. lohena* was never observed in ponds with Poeciliids present. A single *M. grandimanus* was observed in pond S-7, and was approximately 10 cm in length. Despite the presence of Poeciliids in Southern Pond S-7, *M. grandimanus* was able to co-exist, perhaps by reaching a size that would be preclude consumption.

Signs of visitor impacts were observed at four of the surveyed ponds, and impacted ponds were generally in close proximity to access points. Modifications included rock wall construction around the ponds, the addition of rocks to pond basins (leading to increased shading and pond depth reduction), toilet paper additions to ponds (and associated products), and the removal of Poeciliid fish for fishing bait and other uses. These structural changes and associated lighting changes likely influenced overall pond ecology, and may alter algal assemblages. For pond N-5, signs of visitation included apparent substrate disturbance (algal cover facing down), trampled *R. maritima*, and increased turbidity. Visitation and substrate disturbance, may influence species presence within Pond N-5, including *H. rubra*, which could easily recolonize at high tide. Also, Thiarid snails were previously observed in pond N-5 (Appendix 1.1), and regular anthropogenic disturbance may also play a role in Thiarid absence.

Water quality is a key indicator in assessing anchialine pond ecosystem health, and measurements collected in April and October 2016 were consistent with previous years (Bybee *et al.* 2014, Whale Environmental Services 2015, Appendix 1.1), suggesting that groundwater influence within the ponds has remained consistent. Although nitrogen and phosphorus level were not specifically measured within in the ponds during this survey, benthic communities had not changed substantially, even when compared to historical surveys, suggesting that water quality has remained consistent within the ponds to date. The Southern ponds were cooler and less saline during the April 2016 survey compared to the Northern ponds, suggesting that relatively higher groundwater influence occurs within these ponds. This finding complemented previous surveys (Appendix 1.1), suggesting that groundwater sources influencing the ponds have remained consistent.

These results, including water quality measurements and faunal surveys support the conclusion that the surveyed anchialine ponds, adjacent to the NELHA facility, are not currently impacted by human-mediated inputs from inputs from local aquaculture facilities.

FIGURES

Figure 1. The study area included northern and southern anchialine pond complexes in the vicinity of the NELHA facilities. (Map generated using Google Earth 7.1.7).

Figure 2. Locations of the northern complex of anchialine ponds (N – 1 through N –5) inland of the cobble beach at Ho'ona Bay. (Map generated using Google Earth 7.1.7).

Figure 3. Locations of the southern group of anchialine ponds adjacent to Wawaloli Beach Park. (Map generated using Google Earth 7.1.7).

Figure 4. Northern group Pond, N – 1 at a tide level of + 1.88' (white slate is facing North). Ponds in the Northern group were typically characterized by diverse surrounding vegetation and high densities of *H. rubra*. Compared to previous census years, surrounding vegetation had encroached into the pond substantially, as of April 2016.

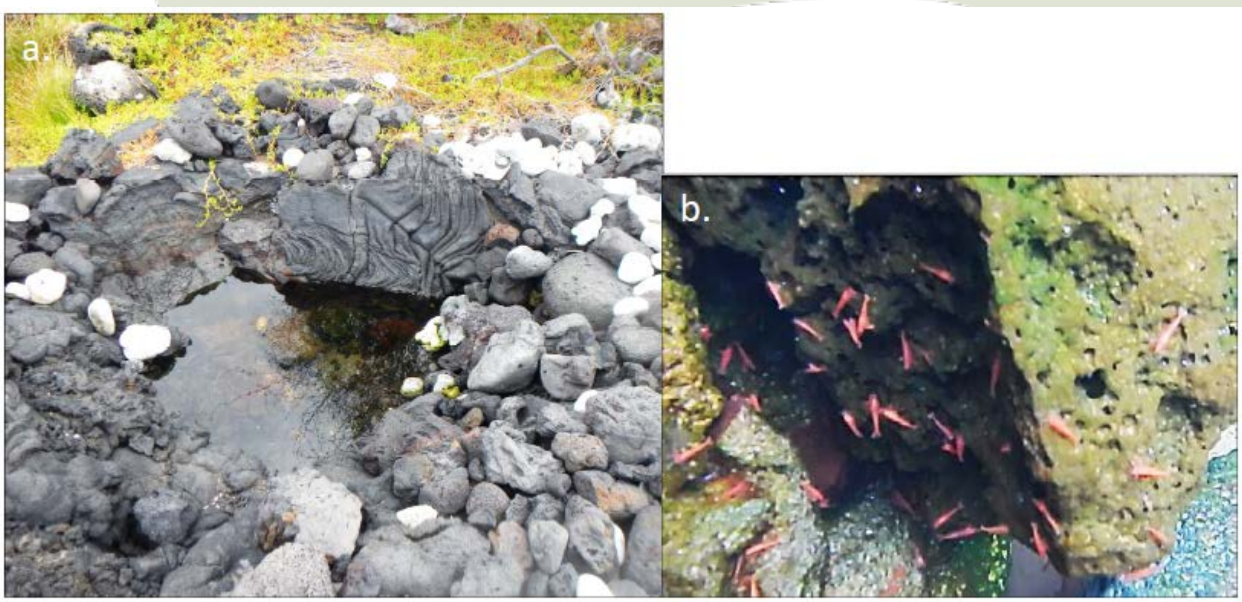


Figure 5. (a) A Northern group pond, N-2, at a tide level of + 1.07' (white slate is facing North), and (b) a typical photo-quadrat within N-2, with a high density of *Halocaridina rubra* (ʻōpae ʻula). Introduced fish (Poeciliids) are absent within the Northern ponds, allowing for *H. rubra* presence in the majority of ponds in that area.

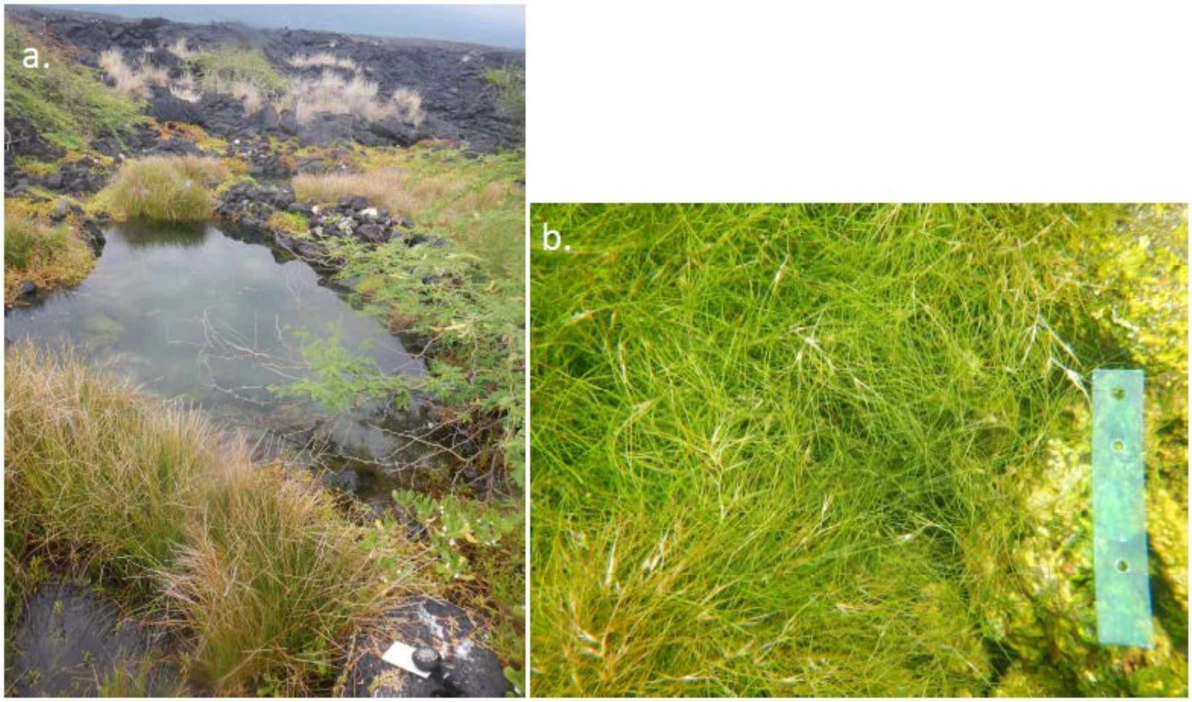


Figure 6. (a) A Northern group pond, N-3, at a tide level of + 1.22‘ (white slate is facing North), and (b) an area of cover of the aquatic grass, *Ruppia maritima*, within the pond.

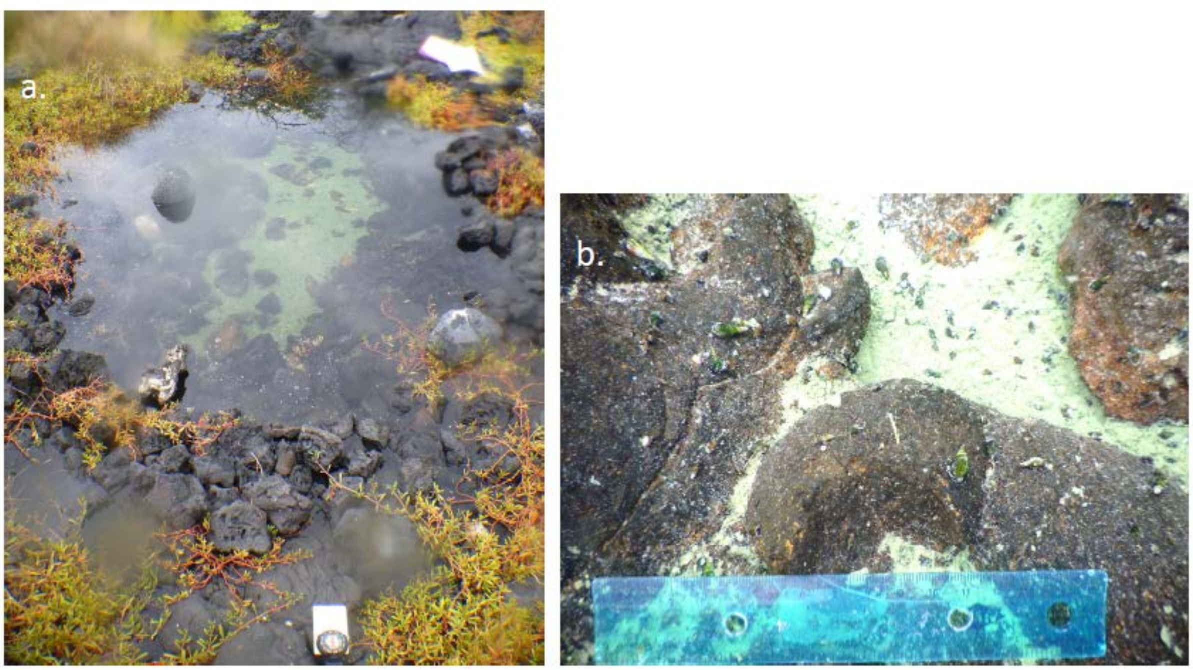


Figure 7. (a) A Northern group pond, N-4, at a tide level of + 1.41‘ (white slate is facing North), and (b) a typical photo-quadrat within N-4 with a high density of Thiarid snails (*Melanoides tuberculata and Tarebia granifera)* and remnant shells.

Figure 8. (a) Southern group pond, S-5, at a tide level of + 1.41‘ (white slate is facing North), and (b) introduced Poeciliids within Southern group pond S-5. Numerous ponds in the Southern group had populations of introduced fish, which was generally associated with dramatically reduced or absent *H. rubra* populations.

Figure 9. Southern group ponds, (a) S-6 (tide level: 1.07’) and (b) S-9 (tide level: 0.91’), both of which have a very small basin, and are located within ground-water fed, crack-like basalt features. Introduced Poeciliids were not observed in these ponds, and both hosted *H. rubra* populations.

TABLES

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

	TAXON	COMMON (HAWAIIAN) NAME	CLASSIFICATION
Anchialine pond: Native	*Halocaridina rubra*	Ōpae ʻula/ Ōpae hiki	Shrimp (Decapoda)
	Metabataeus lohena		Shrimp (Decapoda)
	Macrobrachium grandimanus	Ōpae ʻoehaʻa	Shrimp (Decapoda)
	Lyngbya sp.	Cyanophyte mat	Cyanobacteria (Cyanophyta)
	Schizothrix clacicola	Cyanophyte crust	Cyanobacteria (Cyanophyta)
	Ruppia maritima	Widgeon grass	Monocot plant
	Assiminea sp.	Snail	Aquatic Snail (Gastropoda)
	Theodoxus cariosa	Hihiwai	Limpet (Gastopoda)
	Trichocorixa reticulata	Water boatman	Aquatic insect
	Oligochaeta sp.	Worm	Aquatic worm
	Palaemon debilis	ʻŌpae huna, Glass shrimp	Shrimp (Decapoda)
	Metopograspus messor	Kūkūau	Crab (Decapoda)
	Graspsus tenuicrustatus	A 'ama	Crab (Decapoda)
	Cladophora sp.	Limu hulu'ilio	Green algae (Chlorophyta)
	Enteromorpha sp.	Limu 'ele 'ele	Green algae (Chlorophyta)
	Rhizoclonium sp.	Limu	Green algae (Chlorophyta)
	Lyngbya sp.	Cyanophyte mat	Cyanobacteria (Cyanophyta)
	Schizothrix clacicola	Cyanophyte crust	Cyanobacteria (Cyanophyta)
Anchialine pond: Introduced	*Melanoides tuberculata*	Red-rimmed Melania snail, Thiarid	Thiarid Snail (Gastropoda)
	Tarebia granifera	Quilted Melania snail, Thiarid	Thiarid Snail (Gastropoda)
	Poecilia sp.	Guppy (Topminnow)	Fish (Poeciliidae)
	Gambusia affinis	Mosquitofish (Topminnow)	Fish (Poeciliidae)
	Macrobrachium lar	Tahitian Prawn	Prawn (Decapoda)
Terrestrial plants	*Sesuvium portulacastrum*	ʻĀkulikuli, Pickleweed	Aizoaceae
	Bacopa sp.	Pickleweed (Invasive)	Plantaginaceae
	Morinda citrifolia	Noni	Rubiaceae
	Ipomoea pes-caprae	Pōhuehue, Beach morning glory	Convolvulaceae
	Scaevola taccada	Naupaka	Goodeniaceae
	Prosopis pallida	Kiawe, mesquite tree	Mimoseae
	Tournefortia argentea	Beach heliotrope	Boraginaceae
	Thespesia populnea	Milo	Malvaceae
	Pluchea odorata	Pluchea	Asteraceae
	Cladium sp.	Sedge	Cyperaceae
	Pennisetum setaceum	Fountrain grass (Invasive)	Poaceae
	Schinus terebinthifolius	Christmas berry (Invasive)	Anacardiaceae

Table 2. Site locations and sizes anchialine ponds in the vicinity of the NELHA facility (calculated from measurements reported in Brock 2008*, and Whale Environmental Group 2015**).

Area	Pond number	Latitude (Decimal degrees)	Longitude (Decimal degrees)	Size (m^2)*
Northern Ponds	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
Southern Ponds	S-1	19.7168	-156.0490	1.7
	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
	S-10	19.7138	-156.0482	0.9**

Table 3. Faunal census data collected from northern and southern groups of anchialine ponds sampled in April 2016 at a tide level above a +1.0 ft. Poeciliid fish and *Ruppia maritima* were recorded as present or absent, and other organisms in the observed in each pond were noted in the comments. *Halocaridina rubra* densities are reported as mean individuals per 0.1 square meters (± one standard deviation). If the water level was too shallow for the photo-quadrat placement, presence or absence was noted with a density estimate based on visual surveys.

Area	Pond number	Survey Date	Survey Time	Water Quality		Substrate	Faunal Surveys			Comments/ Other Species
				Temp (C°)	Salinty (ppt)		***H. rubra*** **(Count/0.1m^2) (Mean ± SD)**	**Poeciliids**	***Ruppia maritima***	
Northern Ponds	N-1	4/23/2016	16:45	23.2	14.9	Water-worn (rounded) basalt cobble, some silt and sand	137 ± 48	absent	present	Also observed: *M. lohena,* Thiarid snails*, Scaevola taccada, Prosopis pallida, Tournefortia argentea, Thespesia populnea*
	N-2	4/22/2016	13:30	25.7	12.9	Basalt rubble, with light silt, pahoehoe surroundings	235 ± 65	absent	absent	Also observed: *M. lohena,* Thiarid snails*, Pantala flavescens, Sesuviu portulacastrum, Prosopis pallida*
	N-3	4/22/2016	13:50	25.0	12.7	*Ruppia* dominant, underlying cobble, pahoehoe surroundings	1.5 ± 2.7	absent	present	Also observed: Thiarid snails (low density), *Pantala flavescens, Lyngbya sp., Sesuvium portulacastrum, Scaevola taccada, Prosopis pallida, Cladium sp.*
	N-4	4/22/2026	14:15	24.1	13.0	Silt bottom with cobble, pahoehoe surroundings	present (not detected in photoquadrats)	absent	absent	Also observed: Thiarid snails (high density)*, Sesuvium portulacastrur Cladium sp.*
	N-5	4/23/2016	16:10	24.6	14.0	Water-worn (rounded) basalt cobble and coral rock	absent (0 ± 0)	absent	present	Also observed: Orange cyanobacterial mat (~ 5% cover), *Sesuvium portulacastrum, Anax junius*, Thiarid snails shells (not live). Signs of usage.
Southern Ponds	S-1	4/23/2016	15:10	22.3	11.1	Basalt rubble/ pebbles, pahoehoe surroundings	absent (0 ± 0)	present	absent	Also observed: *Pennisetum setaceum, Schinus terebinthifolius*, orang cyanobacterial mat (low cover).
	S-2	4/23/2016	15:25	-	-	-	-	-	-	Pond filled in with rocks
	S-3	4/23/2016	14:35	22.2	11.2	Basalt rubble/ pebbles, pahoehoe surroundings	present (*In-situ*= 130 ± 36)	absent	absent	Too shallow for photoquadrats. *In-situ* visual survey estimate = 130 36 (count/0.1m^2). No surrounding vegetation. Toilet paper observe adjacent to pond.
	S-4	4/23/2016	14:45	22.1	11.2	Basalt rubble, pahoehoe surroundings	present (*In-situ*= 52 ± 32)	absent	absent	Too shallow for photoquadrats. *In-situ* visual surveys used. No surrounding vegetation. New rocks added to pond (?)
	S-5	4/23/2016	14:15	22.3	11.2	Basalt rubble, pahoehoe surroundings	absent (0 ± 0)	present (abundan t)	absent	Also observed: orange cyanobacterial mat (low cover). Both *Poecili* sp. and *Gambusia affinis* observed. Boys observed fishing for Poeciliids in pond.
	S-6	4/23/2016	14:00	21.6	11.0	Very narrow basalt crack, a'a surroundings.	present (*In-situ*= 130 ± 42)	absent	absent	Too shallow for photoquadrats. *In-situ* visual surveys used. Also observed: Cane spider molt. No surrounding vegetation.
	S-7	4/23/2016	12:50	22.1	11.1	Basalt rubble (some rounded), pahoehoe surroundings	absent (0 ± 0)	present (abundan t)	absent	Also observed: *Macrobrachium grandimanus*, Thiarid snails, *Ipomoe pes-caprae*, *Pennisetum setaceum*, orange cyanobacterial mat (low cover). Both *Poecilia sp*. (occasional) and *Gambusia affinis* (abundar observed.
	S-8	4/23/2016	13:15	21.6	11.0	Basalt rubble with a few white coral pieces, pahoehoe surroundings	absent (0 ± 0)	present (abundan t)	absent	Also observed: *Pennisetum setaceum*, orange cyanobacterial mat (l cover). Only *Gambusia affinis* observed (abundant). Rock wall surrounding pond.
	S-9	4/23/2016	13:40	21.9	10.6	Basalt crack, a'a surroundings.	present (*In-situ*= 97 ± 21)	absent	absent	Too shallow for photoquadrats. *In-situ* visual survey used. Also observed: *M. lohena.* No surrounding vegetation.
	S-10	10/13/2016	17:28	25.1	12.4	Pahoehoe with light organic material, small basalt pebbles	96 ± 41	absent	absent	Also observed: *M. lohena, Schinus terebinthifolius, Pennisetum setaceum,* mongoose feces, large opihi shell in pond

MARINE BENTHIC BIOTA SURVEY

INTRODUCTION

The Natural Energy Lab of Hawaii Authority (NELHA) is a State of Hawaii agency that is administratively attached to the Department of Business, Economic Development, and Tourism (DBEDT). NELHA's mission is to develop and diversify the Hawaii economy by providing resources and facilities for energy and ocean-relation research, education, and commercial activities in an environmentally sound and culturally sensitive manner. NELHA operates an ocean science and technology facility at Kailua-Kona on the West side of Hawaii Island. The facility operations are focused on research, education, and commercial activities that support sustainable industry development in Hawaii.

One of the utilities provided by the NELHA is the pumping of cold seawater from deep ocean depths (~3,000-fsw) to the surface through large pipes that have been installed on the benthic substrate in several locations along the coastal border of the facility. The pipelines run perpendicular to the shoreline to depths that enable delivery of nutrient rich water, which is used in a variety of aquaculture and sustainable energy activities on land. Concerns over water discharge from the various aquaculture and innovative energy operations, and the potentially negative impacts of this discharge to the adjacent reef communities, have prompted annual monitoring. Benthic communities are often sensitive indicators of environmental change (Gray and Pearson 1982). Conducting annual surveys allows for detecting any changes in the benthic substrate and associated reef organisms that may be indicative of larger changes occurring to the overall ecosystem structure and function.

Annual monitoring was initiated in 1989, and since then more than 45 surveys have been conducted to assess the ecological characteristics of both the nearshore and marine benthic communities adjacent to NELHA. Extensive reports were prepared that detail the results and findings of each survey, which are all publicly archived by NELHA. Results and summaries of the reports can be found in the following references: Surveys conducted from 1991-1995 are summarized by Marine Research Consultants (Marine Research Consultants 1995). Surveys conducted from 1995 and 1997 are summarized by Oceanic Institute (Oceanic Institute 1997). Surveys conducted from 1997-2002 are summarized by Marine Research Consultants (Marine Research Consultants 2002). Surveys conducted 2007-2008 surveys are summarized by Marine Research Consultants (Marine Research Consultants 2008). Surveys conducted from October 2008-2010 are summarized by Ziemann (Ziemann 2008, Ziemann 2009, and Ziemann 2010). The 2012-2014 surveys are summarized by Bybee and colleagues (Bybee and Barrett 2012, Bybee et al. 2013, Bybee et al. 2014). The 2015 surveys are summarized by WHALE Environmental (WHALE Environmental 2015). The results and findings for the May 2016 surveys are reported here.

METHODS

Benthic surveys were conducted using SCUBA at six stations located along the NELHA coastline. Three 50-m transect surveys were completed for each station at deep (~50-fsw), moderate (~35-fsw), and shallow (~15-fsw) depths (Figure 10). This amounted to three surveys at each of the 6 stations, for a total of 18 transects. 10 quadrats, each 1.0 m x 0.6 m, were placed at pre-determined random locations along each of the surveyed transects. All abiotic and sessile biotic organisms within the quadrat boundaries were enumerated by divers and recorded as a measure of percent cover of the benthic substrate. Sessile organisms were taxonomically identified to the species level. Mobile invertebrates were also surveyed, and measured in terms of counts of individuals present within the quadrat boundary. All mobile invertebrates were taxonomically identified to the species level.

Photographs were taken of each quadrat using an underwater camera with a wide-angle lens adaptor. The images were utilized for subsequent point count analysis to analyze benthic cover, and provide an archival of images of the substrate. Each photograph was labeled, and taken in succession with a picture of the enumerated datasheet so the photos can be properly linked to each quadrat location (Appendix 4) and *in-situ* data recorded by the diver (Appendix 2). Estimates of the benthic composition, in terms of percent cover, were validated using the software CoralNet (Beijbom et al. 2015). Each photographed was cropped, and 100 points were randomly assigned within the quadrat area. The points were manually annotated to and assigned to the biotic or abiotic features they were digitized upon. Values for benthic cover were averaged among the quadrats, and one mean value was computed for each transect in order to avoid pseudo-replication. The data were statistically analyzed using the software package, R. If data met the assumptions necessary for parametric statistical tests (normality, independence, and equal variance), then one-way ANOVA and Tukey pairwise comparisons were used to compare values of benthic cover among the transects at different stations and depths. If the data violated the assumptions for parametric statistical tests, then non-parametric alternatives were used (Kruskal-Wallis). The alpha for statistical significance was 0.05, and this was used to determine if any significant differences exist among sites and depths in terms of benthic substrate characteristics (percent cover, species richness, and species diversity).

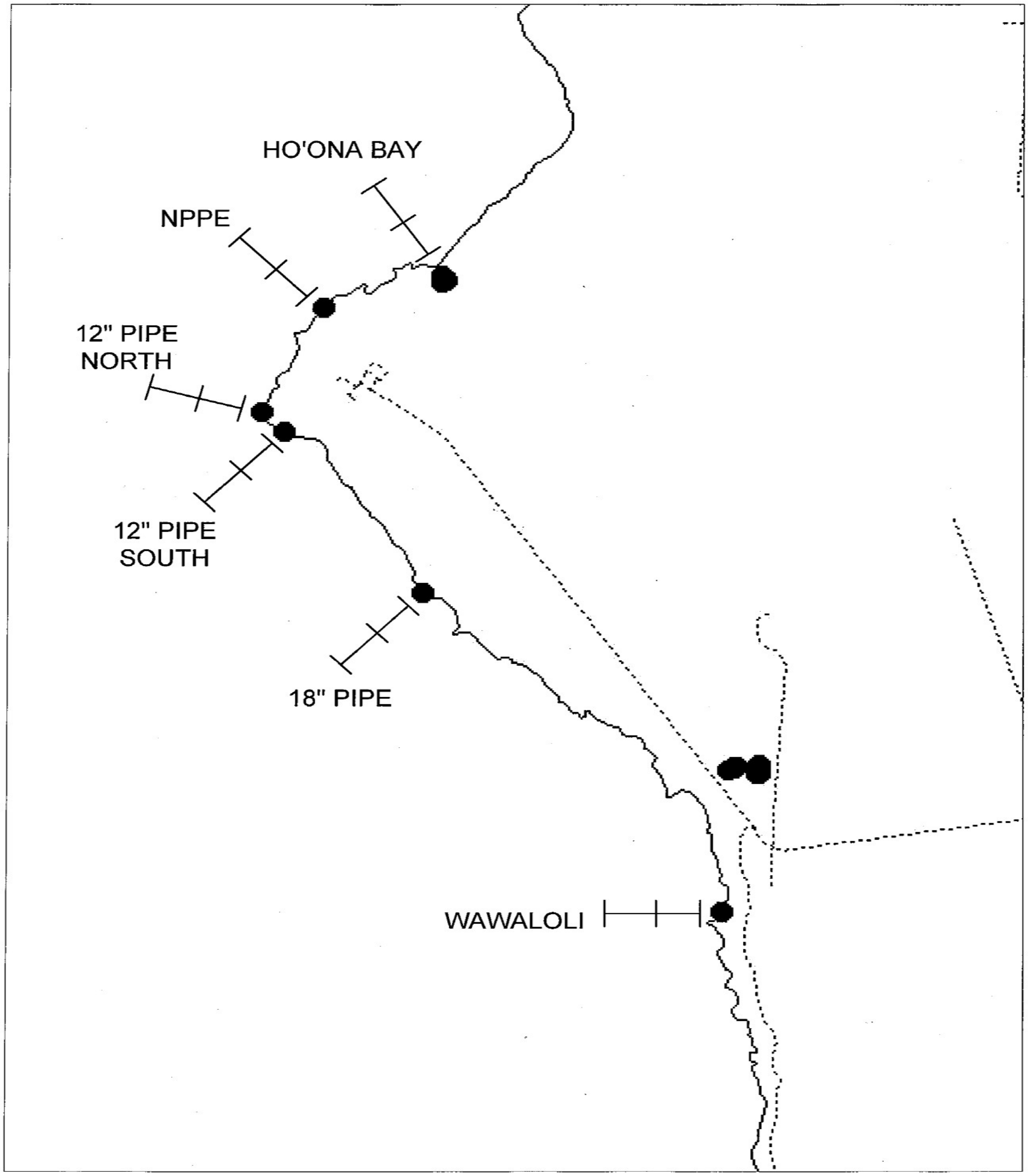


Figure 10. Six stations with three transects per station at deep (~50-fsw), moderate (~35-fsw), and shallow (~15-fsw) depths along the NELHA coastline. A total of 18 transects are completed for both the benthic monitoring and fish assemblage monitoring.

RESULTS

Benthic substrate characterization

The biotic benthic features observed in this study included scleractinian stony corals, crustose coralline algae, fleshy macroalgae algae, echinoderms (sea urchins and sea cucumbers), and gastropod molluscs. The scleractinian stony corals comprised the majority of the benthic substrate among all stations. Abiotic features recorded along the transect surveys included sand and coral rubble. Percent cover, species richness, and species diversity of corals and other benthic biota, as well as abiotic substrate, are presented in detail in Appendix 2 and summarized in Table 4**.**

Overall percent coral cover among the six stations was 44.6%. The most dominant corals, in terms of percent cover, were *Porites lobata* (15.6%), *Porites evermanni* (8.32%), *Porites compressa* (9.10%), and *Pocillopora meandrina* (18.2%) These corals were present among all the stations. Other corals present were *Leptastrea purpurea, Leptastrea bewickensis, Montipora capitata, Montipora flabellata, Montipora patula, Pavona varians, Pocillopora eydouxi, Porites rus* and *Fungia scutaria.* These corals accounted for approximately 5% of the relative benthic cover. Values of percent cover for the dominant coral species at each station and depth are provided in Table 4.

P. lobata was the most dominant coral in the shallow depths (~15-fsw) among all six stations. *P. lobata, P. evermanni,* and *P. meandrina* were the dominant corals in the moderate depths (~35-fsw) among the six stations. *P. meandrina* was most abundant at the 12” Pipe South station, and *P. evermanni* was most abundant at the Wawaloli station. *P. compressa* and *P. lobata* were the most dominant corals at the deep depths (~50-fsw) among the six stations. *P. compressa* had the highest levels of coral cover at 12” Pipe South and Hoona Bay, while *P. lobata* had the highest levels of coral cover at the other stations. The distribution, abundance, and percent cover of the corals among all stations in 2016 were similar to previous years. Photographs of each photographed quadrat are included in Appendix 4.

Table 4 provides a detailed comparison of the percent cover, species richness, and species diversity of corals among all stations and survey depths. The 12” Pipe South and NPPE sites exhibited the highest levels of coral cover (67.64% and 66.02% respectively). Coral cover at these two sites was dominated by *P. lobata, P. compressa,* and *P. meandrina.* Species richness and species diversity was highest at 12” Pipe North. The benthic substrate at this site was also predominantly occupied by *P. lobata* (12.2%), and also had high values of coral cover for *P. eydouxi* (10.0%), *M. patula* (7.2%), and *P. evermanni* (6.0%).

Values of coral cover were highest at the moderate and deep depths (44.98% and 39.16% respectively) compared to the shallow depths (36.08%). Among the deep stations, coral was most abundant at NPPE and Ho’ona Bay sites (57.25% and 66.90%)

followed by 12” Pipe South (32.69%). These patterns in coral cover among the surveyed depths are similar to previous years.

The differences among the data discussed above were measurable, however, no statistically significant differences were found when comparing all metrics pertaining to the benthic substrate among the six stations and different survey depths (Table 4).

Mobile Benthic Invertebrates

Several mobile invertebrates were observed among all stations. Gastropod molluscs (*Conus spp.*), several species of sea urchins (e.g. *Diadema spp., Echinometra spp., Tripnuestes spp., Acanthaster spp.*), and sea cucumbers (*Holothurian spp.*) were observed among the study sites. Counts of the all observed individual invertebrates that were within the survey quadrats were recorded and taxonomically identified to the species level. All data pertaining to the mobile invertebrates are provided in Appendix 2.

Table 4: Summary of benthic substrate data and comparative analyses from surveys conducted in May 2015

Station	Wawaloli				18" Pipe				12" Pipe South		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Overall coral cover	28.00	36.00	28.63		40.58	29.18	22.82		40.63	51.05	32.69
P. lobata	11.00	8.00	16.38		12.70	12.10	9.22		15.33	13.80	9.44
P. evermanni	0.00	15.00	0.00								
P. compressa			8.00				3.00			2.00	10.00
P. meandrina			1.50			2.00	4.00			25.00	
P. eydouxi					8.00						
M. capitata	5.00	3.00	1.75		3.00	8.20	1.60		7.80	3.75	9.00
M. patula	12.00	5.00	0.00		7.90	4.88	5.00		8.00	3.50	4.25
Species count	5.00	6.00	5.00		6.00	5.00	5.00		5.00	7.00	6.00
Species diversity (H)	1.15	0.96	1.14		1.10	1.19	1.20		1.18	0.95	1.10

Station	12" Pipe North				NPPE				Hoona Bay		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Overall coral cover	37.50	56.00	26.68		44.20	47.60	57.25		25.58	50.03	66.90
P. lobata	18.40	13.00	14.00		16.50	18.80	25.00		16.00	22.80	27.90
P. evermanni		6.00			10.00				2.00	7.50	6.00
P. compressa	2.00	6.00	2.00			8.30	16.67			8.40	30.50
P. meandrina	4.00					3.00					
P. eydouxi		10.00									
M. capitata	2.60	7.00	5.90		5.20	6.72	5.25		4.25	5.00	1.50
M. patula	7.50	9.00	4.80		9.50	9.80	5.33		2.33	3.33	
Species count	8.00	9.00	7.00		7.00	6.00	6.00		6.00	7.00	5.00
Species diversity (H)	1.36	1.38	1.25		1.05	1.46	1.27		0.96	1.35	1.07

Mean value comparisons	Wawa	18" Pipe	12" Pipe S	12" Pipe N	NPPE	H - Bay	p-value	Shallow	Moderate	Deep	p-value
Overall coral cover	53.06	47.18	67.64	55.60	66.02	60.07	0.46	36.08	44.98	39.16	0.45
P. lobata	12.50	11.41	12.89	12.20	20.10	22.23	0.47	14.98	14.75	16.99	0.46
P. evermanni				6.00		5.75	0.14	6.00	9.50	6.00	0.36
P. compressa	15.00				10.00		0.16	2.00	6.17	11.69	0.57
P. meandrina	8.00	3.00	6.00	3.60	13.00	22.00	0.08	4.00	10.00	2.75	0.80
P. eydouxi		8.00		10.00			0.08	8.00	10.00		0.31
M. capitata	2.90	4.60	6.50	5.60	5.90	3.60	0.57	4.64	5.61	4.16	0.41
M. patula	10.25	6.20	4.70	7.20	8.70	3.00	0.48	7.86	5.91	4.84	0.42
Species count	6.00	6.00	7.00	9.00	7.00	7.00	0.09	7.00	7.00	7.00	0.52
Species diversity (H)	1.15	1.27	1.18	1.39	1.38	1.29	0.46	1.05	1.27	1.17	0.45

COMPARATIVE ANALYSIS OF TEMPORAL TRENDS IN BENTHIC DATA

The goal of this report is to provide a detailed characterization of the marine benthic communities at the six stations used for long-term monitoring adjacent to the NELHA facilities. Previous reports have performed extensive analyses to compare data from these sites from 1992-2012 (Ziemann 2010, Bybee and Barrett 2012). This report will discuss the key findings from these previous reports, as well as reports from 2013-2015, and how they compare to the current data from 2016.

Reports from previous years (1992-2008) showed a pattern of increase in overall coral cover ranging from 16.9% to 54.7%. Surveys conducted in the following years (2009-2015) reported estimates of overall coral cover fluctuating from 39.5% to 52%. While several of the changes in overall coral cover among these years were noted as significant (ANOVA, $p<0.01$), the last six years have provided a consistent range (~40-50%) for which coral cover can be expected among the survey stations and depth gradients. The fluctuations in observed overall coral cover should be expected, as the surveys are not conducted at permanently marked locations and thus inherent variability in benthic cover will be evident among the survey years. The overall coral cover for 2016, 44.6%, is within this range and shows the benthic communities to exhibit consistent values of coral cover for the last 7 years.

Other studies conducted throughout the 18-year period of monitoring have found significant differences in overall coral cover among the six stations, and the depth gradient (Ziemann 2010, Bybee et al. 2014). The statistical differences observed among the sites showed that coral cover increased from the Southern to Northern sites, with Hoona Bay and NPPE exhibiting statistically higher values of coral cover than the 12" and 18" Pipe sites, and all sites exhibiting higher coral cover than Wawaloli. *P. meandrina* has also been shown to have significantly higher coral cover at shallow depths compared to deep depths, and *P. compressa* to have higher coral cover at deep depths compared to shallow depths. While the 2016 data did show the highest mean values of overall coral cover at the Hoona Bay and NPPE sites, there were no statistically significant differences among the six stations. There were also no significant differences among the depth gradients. Furthermore, the 2016 data also show no significant differences in species richness or species diversity among the six stations and three depth profiles. These findings indicate all survey locations support coral assemblages of similar diversity and community structure with relatively high coral cover.

Previous reports have also documented a pattern of increase in percent cover of *P. lobata* among the six survey stations. The average percent cover of *P. lobata* increased from 10.0% to 30.7% from the years 1992-2012. The 2013 survey report documented significant increases (ANOVA, $p<0.05$) in coral cover at the 18" Pipe station and NPPE station compared to the 2010 and 2012 data (Ziemann 2010). The average percent cover of *P. lobata* among all stations was 30%, 29%, and 25.8% for 2013, 2014, and 2015 respectively (Bybee et al. 2014, WHALE Environmental 2015). The average percent cover of *P. lobata* among all stations in 2016 was 15.5%. While this value is lower, there was

5.85% cover attributed to *P. evermanni,* which was possibly not identified in previous years due to morphological similarity. The overall percent cover of mounding *Porites* coral in 2016 is not statistically different to the previous three years, thus indicating this is the dominant coral among these stations, and this species is exhibiting minimal changes in community structure.

The average values of *P. compressa* cover have not fluctuated significantly over the last several years, and show a consistent trend of higher percent cover at deeper depths. The 2016 data also support this trend; with nearly all the *P. compressa* coral cover being observed at the deeper sites. This is expected, as this coral has a delicate morphology and typically grows at deeper depths along the reef slope throughout Hawaii.

The average values of *P. meandrina* have also shown a general increase from 1992 – 2014 (Ziemann 2010). The percent cover of *P. meandrina* exhibited a wide range in coral cover in 2013 (3.98% - 21.59%), and was found to have statistically higher values in shallow sites in 2014 (Bybee et al. 2014). The 2016 data exhibit a decrease in *P. meandrina* cover at some sites, and no colonies were observed at one station (Hoona). The range in percent cover of this species was larger than previous years (0-25%), and overall *P. meandrina* cover did not decrease significantly among all sites compared to previous years. Values of *P. meandrina* cover were highest at moderate depths, and this is likely due to the loss of *P. meandrina* corals along leeward coastlines at shallow depths throughout Hawaii due to regional elevations in seawater temperature seen in 2014 and 2015. This coral species is fast growing and relatively short-lived, thus the fluctuations seen throughout the survey years are expected considering its life history traits.

The counts of mobile invertebrate species from the 2016 surveys were similar to observations documented throughout the duration of the NELHA marine biota monitoring program.

DISCUSSION

Coral reef ecosystems throughout Hawaii exhibit distinct zonation patterns with depth that are driven by physical parameters such as disturbance and light availability (Dollar 1975, Dollar and Tribble 1993, Ziemann 2010). Corals with high growth rates or robust morphologies, such as *P. meandrina, P. lobata,* and encrusting corals, tend to be dominant in shallow reef zones where disturbance is high due to water motion. Larger mounding corals (e.g., *P. lobata, P. evermanni)* and delicate branching corals (*P. compressa*) are more dominant at deeper depths where disturbance due to wave action is minimal. The coral assemblages along the nearshore coastline surrounding the NELHA facility exhibit these typical zonation patterns (Marine Research Consultants 2008, Ziemann 2010, Bybee et al. 2014).

The overall coral cover, and percent cover of the dominant coral species (*P. lobata*), have exhibited a trend of increasing coral cover from south to north and from shallow to deep in previous years (Ziemann 2010, Bybee et al. 2013). Studies in 2014 and 2015 showed no significant increase in coral cover, and only found a few statistically significant differences in coral cover among the sites and depth gradients (Bybee et al. 2014, WHALE Environmental 2015). The data collected in 2016 shows similar characteristics of coral community structure, with no significant differences among either sites or depths. The general range of coral cover among the dominant species has also remained relatively stable from 2009-2016.

The mean values of *P. meandrina* cover have shown a significant decrease in abundance from shallow to deep, and have been observed at all shallow and moderate depths (Bybee et al. 2014, WHALE Environmental 2015). As mentioned above, this coral has high growth rates and serves as a colonizer of disturbed habitat in areas with high water motion (Dollar 1982). The 2016 data showed a decrease in *P. meandrina cover* in shallow sites, which is likely due to the statewide episodic increase in seawater temperatures in 2014-2015. Fortunately, the overall cover of this species did not decrease among all stations, thus future surveys will enable documentation of how effectively *P. meandrina* can re-colonize at the shallow survey stations that showed a decrease in percent cover compared to previous years.

The results and findings of the surveys conducted over the last 20 years have provided variable data regarding the characteristics of coral communities at the six stations. Considering that no permanent markers are used for the transects, there is an expected inherent variability due to the confounding factor of being unable to repeat surveys in the exact same spatial locations. Utilizing permanent markers would reduce this error, and enhance the capability to track changes in reef structure over time.

Despite variability in the mean values of coral cover among the survey stations and depths over time, the data has shown these corals exhibit patterns in zonation and community structure that are typical of Hawaiian reefs on leeward coastlines. The consistent values of species richness and diversity indicate the assemblages have not experienced any dramatics changes over the last two decades. The 2016 data show no significant variation in benthic composition among the stations and depths, and no significant changes compared to the last several years of monitoring. These findings indicate the nearshore marine benthic communities are not exhibiting any signs of detrimental impacts associated with the NELHA facility.

MARINE FISH BIOTA SURVEY

INTRODUCTION

The Natural Energy Lab of Hawaii Authority (NELHA) is a State of Hawaii agency that is administratively attached to the Department of Business, Economic Development, and Tourism (DBEDT). NELHA's mission is to develop and diversify the Hawaii economy by providing resources and facilities for energy and ocean-relation research, education, and commercial activities in an environmentally sound and culturally sensitive manner. NELHA operates an ocean science and technology facility at Kailua-Kona on the West side of Hawaii Island. The facility operations are focused on research, education, and commercial activities that support sustainable industry development in Hawaii.

One of the utilities provided by the NELHA is the pumping of cold seawater from deep ocean depths (~3,000-fsw) to the surface through large pipes that have been installed on the benthic substrate in several locations along the coastal border of the facility. The pipelines run perpendicular to the shoreline to depths that enable delivery of nutrient rich water, which is used in a variety of aquaculture and sustainable energy activities on land. Concerns over water discharge from the various aquaculture and innovative energy operations, and the potentially negative impacts of this discharge to the adjacent reef environments, have prompted annual monitoring of benthic and fish biota.

Keahole Point is known to support fish populations with high abundance and diversity compared to other sites throughout the Hawaiian Islands (Brock 1954, Brock, 1985; Brock, 1995). Productive fish assemblages are important resources to the state, thus conservation and management strategies are needed to avoid declines in the abundance and biomass of coastal fish populations. The NELHA facility is located along the shoreline of this point, thus annual monitoring has been conducted for the past 25 years to ensure that any impacts to water quality, associated with activities conducted on the NELHA facility, are not causing detrimental changes to the nearshore fish assemblages in this area.

The annual fish surveys utilize conventional techniques to detect any changes in the abundance, diversity, and biomass of all fish populations located at the same stations used for monitoring the benthic substrate. Utilizing this monitoring approach allows for detecting any detrimental reductions in the structure and overall productivity of these fish assemblages, which may be associated with anthropogenic activities on the adjacent land-tract.

METHODS

Surveys of the nearshore fish assemblages were conducted at the same six stations and depth gradients (18 total transect surveys) used for assessment of the benthic substrate (Figure 10). Surveys were conducted using SCUBA over the entire area of 4 x 25-m belt transects. Standard visual assessments were used to record the abundance and length of all fish present within the belt transects area (Brock 1954). The method used for this survey approach is the same belt-transect technique utilized by multiple agencies (e.g., NOAA, DAR, UH) for standardized monitoring and assessment of fish assemblages on Hawaiian coral reefs. Divers taxonomically identified all fish within the belt-transect area to the species level and also recorded the length of each fish (cm).

Previous studies had utilized permanent transects that were marked by subsurface floats to ensure repeatability in the same spatial location (Brock 2008). The markers have not been present since 2012, so surveys conducted during the last five years have been performed at the same locations and depths (~15-fsw, ~30-fsw, and ~50fsw) of the benthic characterization surveys. Divers work in a pair, with the fish surveyor deploying the transect-tape while visually assessing all fish present within the belt-transect area. The other diver waits behind the fish surveyor, in order to avoid disturbing the fish, and then performs the benthic characterization in the same spatial area. This approach allows for ensuring both habitat and fish assemblage data are collected from the same location, and thus can be collated if necessary.

The visual estimates of fish length (cm) are converted to biomass using the standard formula to compute values of biomass in g/m^2 ($M = a * L^b$). *a* and *b* are fitting parameters based on the specific fish species, *L* represents length in mm, and *M* represents mass in grams. Fitting parameters were obtained from the Fishbase online database (Froese and Pauley 2000). Diversity was calculated using the Shannon Index (H), as this index has been used in the previous monitoring reports (Ziemann 2010).

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

The data was statistically analyzed using the software package, R. If data met the assumptions necessary for parametric statistical tests (normality, independence, and equal variance), then one-way ANOVA and Tukey pairwise comparisons were used to compare mean values of fish assemblage parameters among the transects at different stations and depths. If the data violated the assumptions for parametric statistical tests, then non-parametric alternatives were used (Kruskal-Wallis). The alpha for statistical significance was 0.05, and this was used to determine if any significant differences exist among sites and depths in terms of fish assemblage structure (species count, number of species, species diversity, biomass).

RESULTS

The resulting mean values for each of the parameters measured for this study (total fish count, number of species, species diversity, biomass) are provided in Table 5, and the complete dataset is provided in Appendix 3.

Total Number of Individuals

The total number of individual fish was highest at 12" Pipe South and the lowest was at Wawaloli. This range in individuals was 106 to 296. Shallow and deep habitats had a similar number of individuals (226 and 220 respectively), with moderate sites having the lowest number (177 individuals). While there were differences in the mean values, there were no statistically significant differences in the total number of individual fish counted among all six stations (p=0.39) or among the three depth gradients (p=0.43). All values are reported in Table 5.

Number of Species

The mean number of species recorded was highest at the 18" Pipe, and lowest at Wawaloli. This range in mean number of species was 29 to 52. The shallow, moderate, and deep habitats all had 44 species of fish recorded for surveys among these depths. While there was differences in mean values of the number of species recorded, there was no statistically significant difference among the six stations (p=0.46) or among the three depth gradients (p=0.27). All values are reported in Table 5.

The fish families that exhibited the highest abundance among all surveys were the chaetodontids (butterfly fish), pomacentrids (damsel fish), cirrhitidae (hawkfish), Labridae (wrasses), and acanthurids (surgeon fish). The most abundant species represented among the surveys were *Z. falvescens, A. nigrofuscus, T. duperrey, C. strigosus, C. sordidus, N. literatus, C. multicinctus, C. agilis, C. vanderbilti, P. arcatus, H. ornatissimus, G. varius, C. jactotor, S. bursa, C. vanderbilti, P. multifasciatus, C. agilis, A. olivaceus, C. hawaiiensis, P. jonstonianus, S. fasciolatus, C. ornatissiums, C. quadrimaculatus, P. octotania, and Z. cornutus.* These fish were represented among all stations and depths surveyed for the study.

Species Diversity and Biomass

Species diversity ranged from 2.76 at 12" Pipe South to 3.28 at NPPE. The species diversity at the moderate and deep depths was 2.94, and 3.02 at the shallow depths. There were no significant differences in species diversity among the six stations surveyed (p=0.45). There were also no significant differences in species diversity among the three depth gradients (p=0.45)

Fish biomass was highest at 12" Pipe South (225.05 g/m2) and lowest at Wawaloli (85.26 g/m2). Biomass was lowest at moderate depths (99.79 g/m2), and highest at the shallow depths (186.45 g/m2). No significant differences in mean biomass were detected among the sites or depth gradients (p=0.45).

Table 5: Summary of fish survey data and comparative analyses from surveys conducted in May 2015

Station	Wawaloli				18" Pipe				12" Pipe South		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Fish count	120.00	63.00	135.00		218.00	305.00	247.00		376.00	186.00	328.00
Number of species	28.00	20.00	41.00		55.00	60.00	43.00		41.00	41.00	43.00
Diversity	2.77	2.59	3.16		3.17	2.67	2.53		2.92	2.70	2.66
Biomass	68.05	43.95	143.79		145.89	85.95	154.84		202.92	55.70	78.96

Station	12" Pipe North				NPPE				Hoona Bay		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Fish count	246.00	149.00	202.00		190.00	135.00	124.00		207.00	228.00	289.00
Number of species	42.00	39.00	52.00		47.00	52.00	41.00		55.00	52.00	48.00
Diversity	2.99	3.02	3.31		3.18	3.61	3.07		3.11	3.03	2.88
Biomass	269.10	129.85	140.39		141.64	100.86	68.63		88.76	126.73	259.97

Mean value comparisons	Wawa	18" Pipe	12" Pipe S	12" Pipe N	NPPE	H - Bay	p-value	Shallow	Moderate	Deep	p-value
Fish count	106.00	256.66	296.66	199.00	149.66	241.33	0.39	226.16	177.66	220.83	0.43
Number of species	29.60	52.66	41.66	44.33	46.66	51.66	0.46	44.66	44.00	44.67	0.27
Diversity	2.84	2.79	2.76	3.11	3.28	3.01	0.45	3.02	2.94	2.94	0.45
Biomass	85.26	128.89	225.05	179.78	103.71	158.48	0.45	186.45	99.79	154.26	0.45

COMPARATIVE ANALYSIS OF TEMPORAL TRENDS IN FISH DATA

The goal of this report is to provide a detailed characterization of the nearshore fish assemblages at the six stations and three depth gradients used for long-term monitoring of marine habitats adjacent to the NELHA facilities. Previous reports have performed extensive analyses to compare data from these sites from 1992-2015 (Ziemann 2010, Bybee and Barrett 2012, Bybee et al. 2013, 2014, Whale Environmental 2015). This report will discuss the key findings from these previous reports and how they compare to the current data from the 2016 surveys.

Previous studies have reported variation in fish assemblage structure over the past 25 years of the annual monitoring program, but no significant changes have been documented that are attributed to anthropogenic impacts or detrimental declines in fish productivity due to acute or prolonged disturbances (Ziemann 2010, Bybee et al. 2014).

Several years have exhibited substantial variation in mean values of fish counts and biomass. For example, 2012 had statistically significantly lower values of overall species count, species diversity, and biomass compared to data from 2010 (Bybee et al. 2014). A significant increase in these parameters was observed in 2013, and then values for all parameters were statistically similar in 2014 and 2015 (Bybee et al. 2014, WHALE Environmental 2015). All parameters showed a slight increase in 2015, and the 2016 data is not significantly different to the 2010 data. Results from the 2016 surveys show a marked increase in abundance, diversity, and biomass of the fish assemblages among all stations and depths.

DISCUSSION

Previous reports have suggested the variability in fish assemblage data is likely driven by large schools of reef-fish that sporadically enter into the belt-transect areas during the surveys (Ziemann 2010, Bybee et al. 2014). Reef fish communities are known to be highly variable in both spatial and temporal scales. Conducting the fish surveys on an annual basis provides a coarse resolution of temporal variability in fish assemblage structure, and likely contributes to the variability observed over the duration of this monitoring program. Furthermore, the different observers conducting the surveys will also introduce a level of variability in the data.

Small methodological changes were introduced in 2013 in order to minimize diver-based disturbance to the fish communities. Fish assemblage parameters exhibited a statistically significant increase that year, yet was still lower than values obtained in 2010 (Bybee et al. 2014). Attempting to reduce observer bias is important, but will not adequately allow for diminishing the confounding factors and determining the precise sources of variability in the data. The 2016 surveys were conducted using the standardized approaches that are utilized by multiple agencies for monitoring and assessing fish assemblages throughout Hawaii (e.g., NOAA, DAR, UH). Values were higher than previous years, and in the same range as those observed in 2010. These findings suggest that variability due to presence of the divers is minimal compared to the natural variability in fish assemblage structure. Fish are highly mobile, and their spatial habitat ranges in conjunction with a wide array of life-history traits create inherent variability in the parameters being assessed by this study. Therefore, the standardized approach utilized by this monitoring program should be expected to produce variable results, yet is entirely capable of detecting dramatic loss of fish abundance and productivity. Examining data across the 25 year time-span of the monitoring program is effective for noticing any substantial detrimental changes that may be associated with acute or long-term disturbances.

A general pattern that has been detected in previous years was that fish assemblages exhibited higher abundance, diversity, and biomass near the Pipe sites and lower values off Wawaloli Beach. This pattern is still evident, as values at Wawaloli were lowest in 2014, 2015, and in the 2016 data (Bybee et al. 2014, WHALE Environmental 2015, Table 5). The reason of this pattern is likely habitat differences. Both the northern sites and those adjacent to the pipes display steep topographic relief with highly complex basalt substrate. Complex habitat is a known driver of fish abundance and diversity. The Wawaloli Beach site is in an embayment, and the substrate not occupied by live coral is predominantly sand (Appendix 2 and 4). These differences in habitat composition may be driving the consistent differences in fish assemblages seen at Wawaloli, and they will likely remain evident in future surveys.

In summary, the reports conducted over the past 25 years show variability in fish assemblage data, but long-term trends indicate that the fish communities in the area are highly productive and diverse. There are no dramatic declines in abundance or changes in population structure that indicate any detrimental impacts are associated with proximity to the NELHA facility.

REFERENCES

Bailey-Brock, and J. H., Brock, R. E. 1993. Feeding, reproduction, and sense organs of the Hawaiian anchialine shrimp *Halocaridina rubra* (Atyidae). Pacific Science 47(4): 338-355.

Bailey-Brock, J. H., Brock, V. R., and Brock, R. E. 1999. Intrusion of anchialine species in the marine environment: the appearance of an endemic Hawaiian shrimp, *Halocaridina rubra*, on the south shore of O'ahu. Pacific Science 53: 367-369.

Benke, A. C. (1978). Interactions among coexisting predators--a field experiment with dragonfly larvae. The Journal of Animal Ecology, 335-350.

Brock, R. E. 1985. An assessment of the conditions and future of the anchialine pond resources of the Hawaiian Islands. Pp. C-1 – C-12. In: Us Army Corps of Engineers. Final Environmental Impact Statement, U. S. Department of the Army Permit Application. Waikoloa Beach Resort, Waikoloa, South Kohala District, Island of Hawaii. Honolulu.

Brock, R. E., Norris, J. E., Ziemann, D. A., and Lee, M. T. 1987. Characteristics of water quality in anchialine ponds of the Kona, Hawaii Coast. Pacific Science 41(1-4): 200-208.

Brock, R. E. 1995. Cooperative Environmental Monitoring Program for the Natural Energy Laboratory of Hawaii. Survey for Anchialine and Marine Fish Resources. 23 June 1995 Survey. Prepared for NELHA, Kailua-Kona, Hawaii. EAC Report No. 95-07. 56 pp.

Brock, R. E., Bailey-Brock, J. H. 1998. An unique anchialine pool in the Hawaiian Islands. International Review of Hydrobiology 83(1): 65-75.

Brock, R. E. 2002. Cooperative Environmental Monitoring Program for the Natural Energy Laboratory of Hawaii. Survey for Anchialine and Marine Fish Resources. May 2002 Survey. Prepared for NELHA, Kailua-Kona, Hawaii. EAC Report No. 2002-13A. 61 pp. plus Appendix.

Brock, R. E. 2008. Cooperative Environmental Monitoring Program for the Natural Energy Laboratory of Hawaii. Survey for Anchialine and Marine Fish Resources. Synopsis of 2007-2008 Surveys. Prepared for NELHA, Kailua-Kona, Hawaii. EAC Report No. 2008-16. 60 pp. plus Appendix.

Brock, V. E. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildlife Mgmt. 18:297-304.

Bybee, D.R., and Barrett, B. 2012. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report April 2012. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 55 pp. + Appendices 1 - 4

Bybee, D.R., Hyde, S.K., Smith, B.L., Munton, C. 2013. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report April 2013. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 52 pp. + Appendices 1 - 4

Capps, K. A., Turner, C. B., Booth, M. T., Lombardozzi, D. L., McArt, S. H., Chai, D., and Hairston, N. G., Jr. 2009. Behavioral responses of the endemic shrimp *Halocaridina rubra* (Malacostraca: Atyidae) to an introduced fish, *Gambusia affinis* (Actinopterygii: Poeciliidae) and implications for the trophic structure of Hawaiian anchialine ponds. Pacific Science 63(1): 27-37.

Catling, P. M. (2009). Dragonflies (Odonata) Emerging from Brackish Pools in Saltmarshes of Gaspé, Quebec. The Canadian Field-Naturalist, *123*(2), 176-177.

Chace, F. A., Jr., and Manning, R. B. 1972. Two new caridean shrimps, one representing a new family, from marine pools on Ascension Island (Crustacea: Decapoda: Natantia). Smithsonian Contributions to Zoology 131: 1-18.

Dollar, S. J. 1975. Zonation of reef corals off the Kona Coast of Hawaii. M.S. thesis, Dept. of Oceanography, University of Hawaii, Honolulu, 183 pp.

Dollar, S. J. 1982. Wave stress and coral community structure in Hawaii. Coral Reefs 1: 71-81.

Dollar, S. J. and G. W. Tribble. 1993. Recurrent storm disturbance and recovery: a long-term study of coral communities in Hawaii. Coral Reefs 12:223-233.

Froese, R. and D. Pauly, Editors. 2000. FishBase 2000: concepts, design and data sources. ICLARM, Los Baños, Laguna, Philippines. 344 p.

Google Inc. 2012. Google Earth. Version 6.2. Mountain View, CA.

Gray, J. H., and Pearson, J. H. 1982. Objective selection of sensitive species indicative of pollution-induced change in benthic communities. I. Comparitive methodology. Marine Ecology Progress Series 9: 111-119.

Hobbs, H. H. I. 1994. Biogeography of subterranean decapods in North and Central America and the Caribbean region (Caridea, Astacidae, Brachyura). Hydrobiologia 287(1): 95-104.

Holthuis, L. B. 1973. Caridean shrimps found in land-locked saltwater pools at four Indo-West Pacific localities (Sinai Peninsula, Funafuti Atoll, Maui and Hawaii Islands), with the description of one new genus and four new species. Zoologische Verhandelingen 128: 1-48.

Kohler, K. E. , and Gill, S. M. 2006. Coral Point Count with Excel extensions (CPCe): a visual basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences, 32 (9) (2006), pp. 1259-1269.

Iliffe, T. M. 1991. Anchialine fauna of the Galapagos Islands. Topics in Geobiology 8: 209-231.

Maciolek, J. A., and Brock, R. E. 1974. Aquatic survey of the Kona coast ponds, Hawai'i Island. Sea Grant Advisory Report, UNIHISEAGRANT-AR-74–04. U.S. Department of Commerce and Hawaii Cooperative Fishery Unit. Honolulu, HI,

Maciolek, J. A. 1983. Distribution and biology of Indo-Pacific insular hypogeal shrimp. Bulletin of Marine Science 33: 606-618.

Marine Research Consultants. 1995. Benthic Marine Biota Monitoring Program at Keahole Point, Hawaii. Report XI, May 1995. Prepared for the Natural

Energy Laboratory of Hawaii Authority, Kailua-Kona. 15 pp. + figs. and appendices.

Marine Research Consultants. 1998. Benthic Marine Biota Monitoring Program at Keahole Point, Hawaii. November 1997. Prepared for the Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 17 pp. + figs. and appendices.

Marine Research Consultants. 2002. Benthic Marine Biota Monitoring Program at Keahole Point, Hawaii. June 2002. Prepared for the Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 15 pp. + figs.and appendices.

Marine Research Consultants. 2008. Benthic Marine Biota Monitoring Program at Keahole Point, Hawaii. July 2008. Prepared for the Natural Enerty Laboratroy of Hawaii Authority, Kailua-Kona. 13 pp. + tables, figures and appendices.

Oceanic Institute. 1997. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Final Report - November 1995 - May 1997. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 35 pp. + Appendices A - E.

Oceanic Institute. 1997. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Final Report – November 1995-1997. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 35 pp. + Appendices A - E.

Oceanic Institute. 2005a. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Survey Report – July 2005. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 37 pp. + Appendices A - D.

Oceanic Institute. 2005b. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Survey Report – November 2005. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 37 pp. + Appendices A - D.

Oceanic Institute. 2006. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Survey Report - July 2006. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 38 pp. + Appendices A - D.

Oceanic Institute. 2007. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority, Final Report - January 2007. Prepared for Natural Energy Laboratory of Hawaii Authority, Kailua-Kona. 38 pp. + Appendices A - D.

Peck, S. B. 1994. Diversity and zoogeography of the non-oceanic Crustacea of the Galapagos Islands, Ecuador (excluding terrestrial Isopoda). Canadian Journal of Zoology 72(1): 54-69.

Santos, S. 2006. Patterns of genetic connectivity among anchialine habitats: a case study of the endemic Hawaiian shrimp *Halocaridina rubra* on the island of Hawaii. Molecular Ecology 15: 2699–2718.

Whale Environmental Services. 2015. NELHA Benthic and Biota Monitoring Study June 2015. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 35 pp. + Appendices 1 – 3

Ziemann, D. A., and Conquest, L. D. 2008. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report October 2008. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 49 pp. + Appendices A - E.

Ziemann, D. A., and Conquest, L. D. 2008. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report October 2008. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 49 pp. + Appendices A - E.

Ziemann, D. A., and Conquest, L. D. 2009. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report May 2009. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 38 pp. + Appendices A - E.

Ziemann, D. A., and Conquest, L. D. 2010. Marine Biota Monitoring Program for Natural Energy Laboratory of Hawaii Authority Keahole Point, District of North Kona Island of Hawaii. Survey Report March 2010. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 38 pp. + Appendices A - E.

APPENDICES

Appendix 1: Environmental and biological data reported from anchialine pond surveys 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, Ziemann and Conquest 2008), and water quality surveys in 2009. Pond S-10 was not surveyed during these surveys.

Area	Pond number	Dimensions (m)	Basin Characteristics	Salinity (2009) (ppt)
Northern Ponds	N-1	15.5 x 6	Deep mud substrate; in pahoehoe/basalt cobble	10
	N-2	1 x 1	Rubble basin substrate; in pahoehoe	10
	N-3	7.5 x 3	Cobble basin substrate; in pahoehoe	9
	N-4	2 x 2	Rubble and mud substrate; in pahoehoe	9
	N-5	7.5 x 3	Two inter-connected basins in cobble	10
Southern Ponds	S-1	1.4 x 1.2	Pahoehoe and rubble substrate	5
	S-2	1 x 1	Pahoehoe and rubble substrate	7
	S-3	1 x 1	Pahoehoe and rubble substrate	8
	S-4	0.075 x 0.075	Pahoehoe and rubble substrate	8
	S-5	2 x 2.5	Pahoehoe and rubble substrate	8
	S-6	0.2 x 0.05	Pahoehoe and rubble substrate	8
	S-7	1 x 1.4	Pahoehoe and rubble substrate	9
	S-8	1 x 1	Pahoehoe and rubble substrate	8
	S-9	0.2 x 0.05	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 introduced fish species (Poeciliids) recorded as present (x) or absent (0).

Survey Date	**Pond: N-1 (Count/0.1m²)**								**Pond: N-2 (Count/0.1m²)**			**Pond: N-3 (Count/0.1m²)**								
	Thiarid Snails (Melania sp.)		***H. rubra***	**Poecilia sp.**	***M. grandi-manus***	***P. debilis***	***M. messor***	***T. cariosa***	**Thiarid Snails (Melania sp.)**	***H. rubra***	***Poecilia sp.***	**Thiarid Snails (Melania sp.)**			***H. rubra***		**Poecilia sp.**	***M. lar***	***P. debilis***
	a	b	a						a	a		a	b	c	a	b			
May 1989	78	71		x					36	22	0	62	21		1	15	0		0
Oct 1991	35	52		x					42	15	0	12	9	0	0	28	0		0
Mar 1992	49	31		x					72	3	0	67	23	0	0	0	x		0
May 1992	56	29		x					85	0	x	29	41	0	0	0	x		1
Oct 1992	24	62		x					41	72	0	24	15	6	15	38			1
May 1993	31	54		x					22	0	x	19	26	0	0	0	0		2
Dec 1993	42	59		x					27	0	x	31	17	8	0	0	x		1
May 1994	31	72		x					31	0	x	42	24	5	2	0	x		2
Jun 1994	43	68		x	2				28	4	x	51	33	6	0	0	x	1	1
Oct 1994	19	72		x	0				19	0	x	72	41	9	0	0	x	0	1
Mar 1995	40	52		x	0				31	42	0	40	23	9	0	0	x	1	2
Jun 1995	63	50		x	1	2			28	0	x	53	19	14	0	0	x	0	3
Dec 1997	39	67		x	0		4		33	0	x	49	31	18	0	0	x	0	0
Jun 1998	41	53		x	0		7	6	44	0	x	57	22	34	0	0	x	0	0
Nov 1998	38	52		x	0		9	5	56	0	x	28	26	14	0	0	x	0	0
May 1999	27	49		x	0		6	6	47	0	x	39	24	22	0	0	x	0	0
Dec 1999	36	68		x	0	0	8	3	47	0	x	37	31	12	0	0	x	0	0
June 2000	42	37		x	0	0	9	2	39	0	x	44	51	6	0	0	x	0	0
Nov 2000	34	55		x	0	0	5	4	51	0	x	34	29	9	0	0	x	0	0
May 2001	39	27		x	0	0	4	3	79	0	x	41	22	3	0	0	x	0	0
Nov 2001	37	23		x	0	0	6	2	66	0	x	39	33	3	0	0	x	0	0
May 2002	29	47		x	0	0	5	9	72	0	x	27	19	5	0	0	x	0	0
Dec 2002	21	17		x	0	0	7	5	37	0	x	41	38	5	0	0	x	0	0
Dec 2007	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug 2008	4	0		0	0	0	0	0	3	10	0	2	0	0	25	21	0	0	0

Appendix 1.2. (continued)

Survey Date	Pond: N-4 (Count/$0.1m^2$)						Pond: N-5 (Count/$0.1m^2$)					
	Thiarid Snails (Melania sp.)		*H. rubra*		Poecilia sp.	*M. grandi-manus*	Thiarid Snails (Melania sp.)		*H. rubra*	Poecilia sp.	*M. grandi-manus*	*M. messor*
	a	b	a	b			a	b	a			
May 1989	39	115	3	21	0		2	4	0	0		
Oct 1991	0	4	0	23	0		2	4	0	0		
Mar 1992	0	9	0	0	x		31	2	0	x		
May 1992	14	3	0	0	x		9	1	0	x		
Oct 1992	10	85	12	31	0		8	1	41	0		
May 1993	9	42	0	0	x		12	1	0	x		
Dec 1993	14	61	0	0	x		23	17	0	x		
May 1994	12	53	0	0	x		19	27	0	x		
Jun 1994	26	49	0	0	x		27	6	0	x		
Oct 1994	25	19	0	0	x		51	29	0	x		
Mar 1995	26	19	0	0	x	5	21	19	0	x	3	
Jun 1995	25	23	0	0	x	0	29	16	0	x	0	
Dec 1997	27	17	0	0	x	0	33	13	0	x	0	3
Jun 1998	33	21	0	0	x	0	42	27	0	x	0	5
Nov 1998	29	26	0	0	x	0	23	19	0	x	0	5
May 1999	27	19	0	0	x	0	24	12	0	x	0	4
Dec 1999	36	29	0	0	x	0	16	19	0	x	0	5
June 2000	29	17	0	0	x	0	12	26	0	x	0	5
Nov 2000	27	21	0	0	x	0	21	17	0	x	0	5
May 2001	dry						19	14	0	x	1	7
Nov 2001	29	17	0	0	x	0	17	12	8	x	0	5
May 2002	31	20	0	0	x	0	23	16	0	x	0	6
Dec 2002	27	18	0	0	x	0	17	21	0	x	0	3
Dec 2007	dry						0	0	0	0	0	0
Aug 2008	2	1	23	17	0	0	4	5	80	0	0	0

Appendix 1.2. (continued)

Survey Date	Pond: S-1 (Count/0.1m2)				Pond: S-2 (Count/0.1m2)			Pond: S-3 (Count/0.1m2)				Pond: S-4 (Count/0.1m2)			
	H. rubra	Poecilia sp.	*M. grandi-manus*	*Amphi-poda*	*H. rubra*	Poecilia sp.	*Amphi-poda*	*H. rubra*	Poecilia sp.	*M. lohena*	*Amphi-poda*	*H. rubra*	Poecilia sp.	*Abudefduf sordidus*	*Amphi-poda*
May 1989	56		0	0	71		185	38			54	9			0
Oct 1991	29		0	0	31		32	21			14	42			0
Mar 1992	31		1	0	40		6	43			9	6			0
May 1992	61		1	6	14		2	64			12	9			2
Oct 1992	29		0	19	34		9	56			9	4			12
May 1993	49		0	12	54		2	dry				dry			
Dec 1993	37		1	15	dry			94			12	dry			
May 1994	47		2	21	dry			37			14	21			6
Jun 1994	52		0	18	dry			86	1		3	dry			
Oct 1994	84		0	26	dry			94	0		16	39			12
Mar 1995	61		0	23	dry		9	dry				dry			
Jun 1995	57		0	27				78		2	21	16			3
Dec 1997	73		0	24	dry			dry				dry			
Jun 1998	49		0	23			12	14		0	17	0			2
Nov 1998	81		0	14	dry			dry				dry			
May 1999	63		0	12			14	29		0	10	0			3
Dec 1999	65		0	14	dry			8		0	12	15			4
June 2000	35		0	16	6		0	17		0	9	31			8
Nov 2000	35		0	9	dry			filled w/				dry			
May 2001	55		0	11	dry			sand				dry			
Dec 2002	58		0	9	48		1	0		0	3	38			1
Dec 2007	0	x	0	0	0	x	0	0	x	0	0	8			0
Aug 2008	0	x	0	0	0	x	0	0	x	0	0	0		1	0

Appendix 1.2. (continued)

Survey Date	Pond: S-5 (Count/0.1m2)				Pond: S-6 (Count/0.1m2)				Pond: S-7 (Count/0.1m2)				Pond: S-8 (Count/0.1m2)			Pond: S-9 (Count/0.1m2)	
	H. rubra	Poecilia sp.	*M. grandi-manus*	*Amphi-poda*	*H. rubra*	Poecilia sp.	*Amphi-poda*	*Amphi-poda (white)*	*H. rubra*	Poecilia sp.	*M. grandi-manus*	*Amphi-poda*	*H. rubra*	Poecilia sp.	*M. grandi-manus*	*H. rubra*	Poecilia sp.
May 1989	43			94	3		0	0	97		0.5	11					
Oct 1991	121			65	3		9	2	95		0.5	17					
Mar 1992	131			48	1		2	0	87		0.5	12					
May 1992	92			27	1		3	0	96		0.75	10	65		0.5		
Oct 1992	107			34	7		3	2	49		1	13	72		0.75	3	
May 1993	113		1	7	5		2	1	72		0.5	9	81		1	dry	
Dec 1993	0		0	0	4		3	1	68		1	10	71		1	dry	
May 1994	0		1	0	7		3	3	82		2	18	68		2	dry	
Jun 1994	0		4	0	4		3	1	94		1	23	81		1	dry	
Oct 1994	0		1	0	23		0	2	113		1	39	80		1	14	
Mar 1995	0		2	0	dry				77		1	25	52		1	dry	
Jun 1995	0		1	0	17		0	0	121		3	29	61		1	9	
Dec 1997	0		0	0	dry				86		0	21	55		0	dry	
Jun 1998	0		0	0	12		2	0	79		1	31	57		0	12	
Nov 1998	0		0	0	dry				87		2	20	63		0	dry	
May 1999	0		0	0	6		3	0	59		3	18	72		1	10	
Dec 1999	0		0	0	dry				43		2	14	30		0	4	
June 2000	0		0	0	4		0	0	41		1	22	38		0	1	
Nov 2000	0		0	0	dry				56		1	6	48		0	7	
May 2001	35		0	0	dry				47		1	9	80		0	dry	
Dec 2002	49		0	4	7		0	0	0	x	1	0	81		0	27	
Dec 2007	3		0	0	dry				0	x	0	0	0	x	0	0	x
Aug 2008	0	x	0	0	5		0	0	0	x	0	0	0	x	0	0	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 and Conquest 2008).

Area	**Pond number**	***Ruppia maritima***	**Thiarid Snails**	***Assiminea sp.***	***Theodoxus cariosa***	***Graspsus tenuicrustatus***	***Halocaridina rubra***	***Metabataeus lohena***	**Poecilia sp.**	**Other Species, Comments**
Northern Ponds	N-1				+		++	-	-	Ruppia absent
	N-2						+	-	-	Ruppia absent
	N-3	+	+				+++	-	-	Ruppia absent
	N-4						+++	-	-	Ruppia absent
	N-5	+	+				++	-	-	Ruppia absent
Southern Ponds	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						-	-	-	

B

Appendix 2: Nearshore marine habitat characterization data

Table 2.1 Benthic habitat characterization data - Algae

Site	Depth	Location	Sub-Categories	Algae	Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
12S	50	1								20																		63		4
12S	50	2								15	3																	67		3
12S	50	5								5																		65		
12S	50	9								20	2																	73		
12S	50	10								30																		55		
12S	50	14								48																		50		
12S	50	16								50																		35		
12S	50	18								40																		54		
12S	50	29								45																		47		
12S	50	30								20																		38		
12S	35	12									3																	82		
12S	35	13								10	10																	64		
12S	35	14									6							1										61		
12S	35	22									2																	57		
12S	35	23								20	10																	55		
12S	35	24								15																		59		
12S	35	25								5																		77		
12S	35	27								10	2																	68		
12S	35	29									5																	80		
12S	35	36								12								1										42		
12S	15	0								10																		45		
12S	15	2								5	3																	71		
12S	15	10								30	5																	47		
12S	15	17								15	5																	48		
12S	15	20								6	5																	74		
12S	15	22									7																	75		
12S	15	30								5																		63		
12S	15	35								10																		59		
12S	15	40								5	5																	60		
12S	15	42								10																		67		

					Asptax	Caurac	Caulser	Caulsert	Codara	CCA	BG	Dasyir	Dichmar	Dictcav	Dictver	Dicty	Gibhaw	Halop	Lobvar	Marflab	Marfrag	Neoman	Padina	Porhor	Prewel	Sarg	Turbor	Turf	venven	
Site	Depth	Location	Sub-Categories	Algae	Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
12N	50	3								6	1											1						74		
12N	50	7								5	3																	62		
12N	50	8								7																		50		
12N	50	9								5																		75		
12N	50	10								6								2										61		
12N	50	19																										41		
12N	50	22								5																		85		
12N	50	23								20	4																	48		
12N	50	28																										42		
12N	50	34								10																		57		
12N	35	3								10	2																	43		
12N	35	4								5	5																	56		
12N	35	11								20																		53		
12N	35	14								15																		52		
12N	35	15								15																		69		
12N	35	21								6																		64		
12N	35	23								5	5																	39		
12N	35	24								10																		80		
12N	35	28								5								1										39		
12N	35	30								6	2																	49		
12N	15	5								15																		66		
12N	15	7																										54		
12N	15	9								6																		52		
12N	15	14									3																	76		
12N	15	17								10																		74		
12N	15	26								10																		75		
12N	15	33								5																		85		
12N	15	35																										70		
12N	15	36								5																		58		
12N	15	42								30																		47		

Site	Depth	Location	Sub-Categories	Algae	Asptax	Caurac	Caulser	Caulsert	Codara	CCA	BG	Dasyir	Dichmar	Dictcav	Dictver	Dicty	Gibhaw	Halop	Lobvar	Marflab	Marfrag	Neoman	Padina	Porhor	Prewel	Sarg	Turbor	Turf	venven	
					Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
NPPE	50	0			1																							49		
NPPE	50	1			2					10																		53		
NPPE	50	8			5					5	1																	30		
NPPE	50	12			10																							42		
NPPE	50	13			5					10																		55		
NPPE	50	19								15																		39		
NPPE	50	21																										69		
NPPE	50	22								8	5																	46		
NPPE	50	29								12	3																	35		
NPPE	50	30			3					10																		32		
NPPE	35	1								8	3																1	64		
NPPE	35	3																										53		2
NPPE	35	6								10																		57		
NPPE	35	8								5	2																	33		
NPPE	35	13								8																		53		
NPPE	35	18								25																		37		
NPPE	35	20			1					10																		64		
NPPE	35	21									5																	82		
NPPE	35	27								15												1					1	57		
NPPE	35	31								15																		40		
NPPE	15	3								10																		80		
NPPE	15	15								15																		75		
NPPE	15	17								8	5																	53		
NPPE	15	19								25																		38		
NPPE	15	21									6																	59		
NPPE	15	24								20	2																	68		
NPPE	15	28								15																		60		
NPPE	15	29								15																		67		
NPPE	15	35								10																		52		
NPPE	15	37																									1	52		

Site	Depth	Location	Sub-Categories	Algae	Asptax	Caurac	Caulser	Caulsert	Codara	CCA	BG	Dasyir	Dichmar	Dictcav	Dictver	Dicty	Gibhaw	Halop	Lobvar	Marflab	Marfrag	Neoman	Padina	Porhor	Prewel	Sarg	Turbor	Turf	venven	
					Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
H-bay	50	4								2																		19		
H-bay	50	5								5																		25		
H-bay	50	18																										57		
H-bay	50	19								5																		17		
H-bay	50	20								3																		47		
H-bay	50	23								5																		10		
H-bay	50	25								10							1											45		
H-bay	50	27								15																		28		
H-bay	50	33								10																		18		
H-bay	50	38								20												1						61		
H-bay	35	6								3																	1	51		
H-bay	35	7								15																		36		3
H-bay	35	16								6	10											1					2	56		
H-bay	35	22																									1	51		
H-bay	35	23																					1				2	55		
H-bay	35	26																				1					1	66		
H-bay	35	27								5	10																3	45		
H-bay	35	30								15	10																2	48		
H-bay	35	31								25	5							1										37		
H-bay	35	36								10																	2	52		
H-bay	15	1									4																	92		
H-bay	15	9			1					8																	6	67		
H-bay	15	14								5																		68		
H-bay	15	18								6																		78		
H-bay	15	19								5																		65		
H-bay	15	28								8	3																	83		
H-bay	15	30								18	5																	50		
H-bay	15	34								5	10																2	62		
H-bay	15	36								6	4																	61		
H-bay	15	46								5																		73		

Site	Depth	Location	Sub-Categories	Algae	Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
					Asptax	Caurac	Caulser	Caulsert	Codara	CCA	BG	Dasyir	Dichmar	Dictcav	Dictver	Dicty	Gibhaw	Halop	Lobvar	Marflab	Marfrag	Neoman	Padina	Porhor	Prewel	Sarg	Turbor	Turf	venven	
18	50	1								5	10							2										72		
18	50	6								15	5							3										71		
18	50	10								20	10																	61		
18	50	12								5	3																	54		
18	50	14								10	2																	78		
18	50	15								8	5							6										50		
18	50	25																12										55		
18	50	29								10	3											1						40		
18	50	31								15	5																	39		
18	50	32								7								2										23		
18	35	1								20	5																	44		
18	35	2								6								2										61		
18	35	7								6	3																	58		
18	35	18									4																	82		
18	35	20								7	7																	70		
18	35	21								10																		62		
18	35	29									10																	74		
18	35	30									3																	69		
18	35	35								10	5																	52		
18	35	36								10																		50		
18	15	1								15	10																	50		
18	15	6								5																		69		
18	15	9								40	10																	47		
18	15	23								2	10															3		63		
18	15	26								10	6																	50		
18	15	28									10																	67		
18	15	29								6	15																	69		
18	15	30								35	6																	38		
18	15	35								5	3																	49		
18	15	41								6	3																	65		

Site	Depth	Location	Sub-Categories	Algae	Asparagopsis taxiformis (Asptax)	Caulerpa racemosa (Caurac)	Caulerpa serrulata (Caulser)	Caulerpa sertularioides (Caulsert)	Codium arabicum (Codara)	Crustose Coralline (CCA)	Cyanophyta (BG)	Dasya iridescens (Dasyir)	Dichotomaria marginata (Dichmar)	Dictyospaeria cavernosa (Dictcav)	Dictyosphaeria versluysii (Dictver)	Dictyota species (Dicty)	Gibsmithia hawaiiensis (Gibhaw)	Halimeda opuntia (Halop)	Lobophora variegata (Lobvar)	Martensia flabelliformis (Marflab)	Martensia fragilis (Marfrag)	Neomeris annulata (Neoman)	Padina species (Padina)	Portieria hornemanii (Porhor)	Predaea weldii (Prewel)	Sargassum (Sarg)	Turbinaria ornata (Turbor)	Turf (Turf)	Ventricaria ventricosa (venven)	red algae
Wawa	50	3									2																	40		
Wawa	50	6																										20		
Wawa	50	7									5																	30		
Wawa	50	11									5																	52		
Wawa	50	13									3																	46		
Wawa	50	18								6																		33		
Wawa	50	19								10						1						1						46		
Wawa	50	24								15																		35		
Wawa	50	25								20	3																	45		
Wawa	50	27								10																		47		
Wawa	35	1								10	3																	71		
Wawa	35	3									1																	62		
Wawa	35	4									5																	63		
Wawa	35	7																										40		
Wawa	35	9																												
Wawa	35	10																												
Wawa	35	11								1																				
Wawa	35	12																										10		
Wawa	35	13																												
Wawa	35	24																										66		
Wawa	15	1								3																		81		
Wawa	15	3								5																		70		
Wawa	15	6								5	6																	53		
Wawa	15	7								15	2																	80		
Wawa	15	9								2	2																	92		
Wawa	15	20								5	5																	55		
Wawa	15	22								10																		62		
Wawa	15	30								10	10																	74		
Wawa	15	33								5																		65		
Wawa	15	39								5																		58		

Table 2.2 Benthic habitat characterization data – Sessile Invertebrates & Abiotic Substrate

Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrealla vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbew)	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdam)	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tuboc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tuboc			Basalt		Limest	Quad	Sand
12S	50	1												6												7									
12S	50	2														1										8									3
12S	50	5														10										15									5
12S	50	9																																	5
12S	50	10																								15									
12S	50	14																								2									
12S	50	16																								15									
12S	50	18																								6									
12S	50	29														3										5									
12S	50	30												12		3								10		12									5
12S	35	12												2		2										8									3
12S	35	13														1										15									
12S	35	14												7												10									15
12S	35	22												2		4										20									15
12S	35	23																								15									
12S	35	24									4					7										15									
12S	35	25									2			4										2		10									
12S	35	27																								20									
12S	35	29																								15									
12S	35	36																				25				10									10
12S	15	0														15										20									10
12S	15	2														1										10									10
12S	15	10											3													15									
12S	15	17												12													10								10
12S	15	20																								15									
12S	15	22																								15	3								
12S	15	30												3												25									4
12S	15	35												15												10									6
12S	15	40												4												20									6
12S	15	42												5												8									20

Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrealla vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbew)	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdam)	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tuboc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tuboc			Basalt		Limest	Quad	Sand
12N	50	7												12												18									
12N	50	8												5												13									25
12N	50	9												3		7										8									2
12N	50	10												4		3								2		20									2
12N	50	19			1									10		3										20									25
12N	50	22																								6									4
12N	50	23																								8									20
12N	50	28			1									7												20									30
12N	50	34					2							4		10								2		12									3
12N	35	3												10												10									25
12N	35	4			1									6		1									6										20
12N	35	11												5		7										15									
12N	35	14												3										10		15									5
12N	35	15														3			5							8									
12N	35	21												5												10									15
12N	35	23			1									25												15									10
12N	35	24												1		3										6									
12N	35	28												5		20					10					20									
12N	35	30												3		20								2		18									
12N	15	5												3		5										6									5
12N	15	7												1		20										20									5
12N	15	9					1							1												40									
12N	15	14														3										13									5
12N	15	17																					3			13									
12N	15	26																					5			7									3
12N	15	33																								10									
12N	15	35												3										2		25									
12N	15	36												5		2										30									
12N	15	42																	3							20									

B

Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrealla vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbev	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdar	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdan	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
NPPE	50	0														5								15		30									
NPPE	50	1																						5		30									
NPPE	50	8												4										20		35									
NPPE	50	12												15										15		15									3
NPPE	50	13																						5		25									
NPPE	50	19														6								25		15									
NPPE	50	21												1		5			5					5		15									
NPPE	50	22												1												40									
NPPE	50	29																						20		30									
NPPE	50	30																						40		15									
NPPE	35	1												4												20									
NPPE	35	3												10		10								10		15									
NPPE	35	6												5		13										15									
NPPE	35	8												8		6								5		40									1
NPPE	35	13												10		5			1					10		13									
NPPE	35	18														15							3	5		15									
NPPE	35	20												7										8		10									
NPPE	35	21												3												10									
NPPE	35	27																	1					5		20									
NPPE	35	31																						15		30									
NPPE	15	3																								10									
NPPE	15	15																								10									
NPPE	15	17											3	1		15									10	5									
NPPE	15	19												2												35									
NPPE	15	21												6		4										25									
NPPE	15	24																								10									
NPPE	15	28														5										20									
NPPE	15	29														8										10									
NPPE	15	35												5		10										20									3
NPPE	15	37												12		15										20									

Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrealla vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbev	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdar	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdan	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
H-bay	50	4												2										65		10									2
H-bay	50	5																						60		10									
H-bay	50	18												1												2									40
H-bay	50	19																						8		70									
H-bay	50	20																						15		35									
H-bay	50	23																						20		65									
H-bay	50	25												3										10	6	25									
H-bay	50	27												1										6		50									
H-bay	50	33												1					1					60		10									
H-bay	50	38												1												2									15
H-bay	35	6									1			4					2					10		28									
H-bay	35	7												7		3								10		25									1
H-bay	35	16												3		4										15									3
H-bay	35	22												5		3								7	10	20									3
H-bay	35	23														2								5		20									15
H-bay	35	26												4												25									3
H-bay	35	27												2										10	5	20									
H-bay	35	30																								25									
H-bay	35	31												10		2										20									
H-bay	35	36														6										30									
H-bay	15	1																								4									
H-bay	15	9												1												15									2
H-bay	15	14											1	4		2										15									5
H-bay	15	18											1													15									
H-bay	15	19												10												20									
H-bay	15	28																								6									
H-bay	15	30														2										25									
H-bay	15	34														3										15									3
H-bay	15	36												2												25									2
H-bay	15	46																							2	20									

B

					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdan	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tuboc			Basalt		Limest	Quad	Sand
Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrella vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbev	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdar	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
18	50	1												1												5						5			
18	50	6												2									4												
18	50	10												1												8									
18	50	12																								3						5			30
18	50	14																								10									
18	50	15												1												20									10
18	50	25														5								3		25									
18	50	29																								1						10			35
18	50	31																								1									40
18	50	32												3												10									55
18	35	1			1											4										16									10
18	35	2											2	10		2										13									4
18	35	7														10										23									
18	35	18												3												6									5
18	35	20												3												3									10
18	35	21												10		3										10									5
18	35	29														4										12									
18	35	30					4									6							2			13									3
18	35	35					3									5										10									15
18	35	36												15		5										15									5
18	15	1																								25									
18	15	6														10										8									8
18	15	9																								3									
18	15	23														4										13									5
18	15	26												5		17										7									5
18	15	28														3										15									5
18	15	29																								10									
18	15	30														15										6									
18	15	35												1		2										30	5								5
18	15	41														4			4		8					10									

					Sponge	Sponge			cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdan	Poceyd	Poclig	Pocmea	Porcom	Porev	Porlob		Tuboc			Basalt		Limest	Quad	Sand
Site	Depth	Location	Sub-Categories	Inverts	Sponge (Sponge)	Spirastrella vagabunda	Palythoa tuberculosa	Coral	Cyphastrea agassizi (cypag)	Cyphastrea ocellina (cypoc)	Fungia scutaria (Funscu)	Leptastrea purpurea (Leppur)	Leptoseris bewickensis (Lepbev	Montipora capitata (Moncap)	Montipora flabellata (Monfla)	Montipora patula (Monpat)	Montipora species (Monsp)	Pavona duerdeni (Pavdue)	Pavona varians (Pavvar)	Pocillopora damicornis (Pocdar	Pocillopora eydouxi (Poceyd)	Pocillopora ligulata (Poclig)	Pocillopra meandrina (Pocmea)	Porites compressa (Porcom)	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
Wawa	50	3																								3									55
Wawa	50	6																																	80
Wawa	50	7																																	65
Wawa	50	11											1	1									1			10									30
Wawa	50	13												1												15									35
Wawa	50	18												4												2									55
Wawa	50	19												1												1									40
Wawa	50	24																								50									
Wawa	50	25																					2			30									
Wawa	50	27																						8		20									15
Wawa	35	1												1												15									
Wawa	35	3			1		1							5											15	5									10
Wawa	35	4			1								5	1		5									15	5									
Wawa	35	7																														10			50
Wawa	35	9																														10			90
Wawa	35	10																														5			95
Wawa	35	11																														3			96
Wawa	35	12																													10	3			77
Wawa	35	13																														2			98
Wawa	35	24			2									5												7									20
Wawa	15	1												3												10									3
Wawa	15	3																								15									10
Wawa	15	6					1							7		13										15									
Wawa	15	7																								3									
Wawa	15	9																								4									
Wawa	15	20														20										15									
Wawa	15	22														3										25									
Wawa	15	30																								6									
Wawa	15	33																								10									20
Wawa	15	39																								7									30

Table 2.3 Benthic habitat characterization data – Mobile Invertebrates

Row Labels	Count of sponges	Count of Conus sp.	Count of hermits	Count of D. paucispinum	Count of Echinometra mathaei	Count of Echinothrix sp.	Count of Holothuria atra	Count of Holothuria pervicax	Count of Acanthaster planci
⊟ 18	1			2			2		
15									
35	1			1					
50				1			2		
⊟ 12N	3	1	1	1	4	1	1		
15			1		3				
35	2				1	1	1		
50	1	1		1					
⊟ 12S	1	2	1	1	3	1			1
15	1	1	1						
35		1			2				
50				1	1	1			1
⊟ H-bay		1			10				
15					5				
35		1			2				
50					3				
⊟ NPPE		1			9	3			
15					1				
35		1			5	1			
50					3	2			
⊟ Wawa		1			5	1		1	
15					3				
35						1			
50		1			2			1	

Appendix 3: Nearshore fish assemblage data

Table 3.1 Abundance and length of all fish observed among sites and depths

Haona Bay	5/7/16							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
A. nigrofuscus	3	8	*A. nigrofuscus*	8	8	*A. nigrofuscus*	10	10
A. nigrofuscus	2	10	*A. nigrofuscus*	14	9	*A. nigrofuscus*	2	8
A. nigrofuscus	1	12	*A. nigrofuscus*	8	10	*A. nigrofuscus*	19	12
C. potteri	2	7	*A. nigrofuscus*	8	12	*A. nigrofuscus*	5	14
C. potteri	2	8	*A. nigrofuscus*	4	14	*A. nigrofuscus*	1	9
C. potteri	1	9	*C. agilis*	36	4	*A. nigrofuscus*	4	13
C. potteri	2	10	*C. agilis*	32	5	*C. strigosus*	2	13
C. agilis	12	3	*C. agilis*	20	6	*C. strigosus*	5	14
C. agilis	10	4	*C. strigosus*	1	4	*C. strigosus*	5	12
C. agilis	33	5	*C. strigosus*	1	6	*C. jactator*	1	7
C. agilis	15	6	*C. strigosus*	1	13	*C. jactator*	1	6
C. agilis	10	7	*C. strigosus*	1	11	*C. vanderbiliti*	33	3
C. hawaiiensis	1	14	*C. strigosus*	2	7	*C. vanderbiliti*	28	4
C. hawaiiensis	1	16	*C. strigosus*	2	9	*C. vanderbiliti*	33	2
C. strigosus	2	10	*C. strigosus*	1	10	*T. duperrey*	2	6
C. strigosus	4	12	*C. jactator*	1	5	*T. duperrey*	1	7
C. strigosus	4	14	*C. jactator*	1	6	*T. duperrey*	1	9
D. albisella	5	13	*C. vanderbiliti*	23	4	*T. duperrey*	3	11
D. albisella	3	12	*C. vanderbiliti*	20	5	*T. duperrey*	1	14
C. argus	1	42	*N. literatus*	1	19	*T. duperrey*	1	18
C. argus	1	50	*N. literatus*	1	24	*Z. flavescens*	2	14
M. kuntee	25	14	*N. literatus*	1	13	*Z. flavescens*	3	16
M. kuntee	57	16	*N. literatus*	1	12	*Z. flavescens*	1	15
M. kuntee	50	18	*N. literatus*	1	27	*S. bursa*	1	18
N. literatus	1	15	*T. duperrey*	2	14	*C. sordidus*	2	22
C. ornatissimus	1	12	*T. duperrey*	1	16	*C. sordidus*	1	14
P. johnstonianus	1	6	*Z. flavescens*	3	14	*C. sordidus*	1	16
P. tetrataenia	1	5	*Z. flavescens*	1	11	*C. sordidus*	1	17
P. octotania	1	6	*Z. flavescens*	1	13	*C. sordidus*	1	20
T. duperrey	1	14	*S. bursa*	1	17	*C. multicinctus*	3	13
T. duperrey	1	15	*S. bursa*	1	18	*P. arcatus*	2	8
T. duperrey	1	5	*C. sordidus*	1	26	*P. arcatus*	2	9
Z. flavescens	1	10	*C. sordidus*	1	16	*P. arcatus*	1	6
Z. flavescens	4	8	*C. sordidus*	1	17	*G. varius*	1	7
Z. flavescens	4	9	*C. sordidus*	1	21	*G. varius*	1	14
Z. flavescens	3	6	*C. multicinctus*	2	8	*P. multifasciatus*	1	9
S. bursa	1	18	*P. arcatus*	1	8	*P. multifasciatus*	1	19
S. bursa	1	21	*P. arcatus*	1	9	*P. multifasciatus*	1	17
C. sordidus	1	21	*A. furca*	1	32	*M. vidua*	1	20
C. sordidus	1	23	*M. grandoculis*	1	44	*M. vidua*	1	24
C. sordidus	1	26	*A. thompsoni*	1	15	*Z. cornutus*	1	14
C. multicinctus	1	11	*P. forsteri*	1	19	*Z. cornutus*	2	16
P. arcatus	1	8	*G. varius*	1	9	*C. verater*	1	15
A. furca	1	29	*G. varius*	1	16	*C. ornatissimus*	1	18
M. grandoculis	1	42	*G. varius*	1	11	*A. leucopareius*	1	1
S. rubroviolaceus	1	54	*P. multifasciatus*	1	22	*A. leucopareius*	2	14
A. thompsoni	5	10	*P. forsteri*	1	19	*A. leucopareius*	2	16
A. thompsoni	6	12	*H. ornatissimus*	1	9	*A. leucopareius*	2	18
P. forsteri	1	17	*M. vidua*	1	24	*F. flavissimus*	1	13
			Z. cornutus	1	17	*M. niger*	2	18
			A. nigricans	1	8	*M. niger*	1	22
			A. abdominalis	1	14	*M. berndti*	1	19
			A. vaigiensis	7	13	*A. chinensis*	1	75
						S. fasciolatus	1	9
						S. psittacus	1	16
						Synodus spp.	1	14

NPPE	5/7/16							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
A. nigrofuscus	3	8	A. nigrofuscus	4	8	A. nigrofuscus	6	9
A. nigrofuscus	3	10	A. nigrofuscus	1	6	A. nigrofuscus	8	10
C. strigosus	2	13	A. nigrofuscus	8	10	A. nigrofuscus	8	12
C. strigosus	1	9	C. strigosus	1	14	C. strigosus	5	12
C. strigosus	5	12	C. strigosus	6	12	C. strigosus	7	14
P. johnstonianus	1	8	C. strigosus	6	10	C. strigosus	7	16
P. johnstonianus	1	9	C. strigosus	5	7	C. strigosus	11	13
H. polylepis	1	13	C. strigosus	5	13	C. strigosus	3	9
H. polylepis	1	12	C. strigosus	8	15	C. sordidus	2	22
G. varius	1	11	P. johnstonianus	1	9	C. sordidus	1	28
G. varius	1	7	G. varius	1	9	Z. flavescens	16	14
C. potteri	1	8	G. varius	1	12	Z. flavescens	4	15
C. sordidus	1	17	C. sordidus	1	19	Z. flavescens	13	12
P. octotania	1	12	C. sordidus	1	24	Z. flavescens	2	10
C. hanui	1	5	C. sordidus	2	22	Z. flavescens	10	16
C. hanui	1	6	T. duperrey	2	9	C. multicinctus	1	9
T. duperrey	1	11	T. duperrey	1	7	C. multicinctus	1	10
T. duperrey	2	13	T. duperrey	1	11	C. multicinctus	2	8
Z. flavescens	4	7	T. duperrey	1	14	C. multicinctus	2	11
Z. flavescens	4	6	T. duperrey	2	10	P. arcatus	1	10
Z. flavescens	4	9	Z. flavescens	1	13	P. arcatus	1	12
Z. flavescens	7	12	Z. flavescens	1	12	C. argus	1	20
Z. flavescens	1	14	Z. flavescens	2	16	S. bursa	1	17
Z. flavescens	3	10	C. multicinctus	1	8	T.duperrey	1	10
C. multicinctus	1	8	C. multicinctus	2	9	C. jactoator	1	6
C. multicinctus	2	10	C. multicinctus	2	7	M. berndti	1	15
P. arcatus	1	12	P. arcatus	1	10	M. berndti	1	18
F. flavissimus	1	11	P. arcatus	1	12	H. ornatissimus	1	11
C. agilis	3	7	C. agilis	10	5	H. ornatissimus	1	8
C. agilis	20	4	C. agilis	1	6	C. ornatissimus	1	14
C. agilis	20	5	S. bursa	1	15	C. vanderbilti	5	2
C. agilis	15	6	Z. cornutus	1	13	C. vanderbilti	38	3
Z. cornutus	1	15	C. quadrimaculatus	2	12	C. vanderbilti	10	4
C. jactator	1	6	C. quadrimaculatus	2	9	N. literatus	1	26
O. unifaciatus	1	22	C. hawaiiensis	1	17	N. literatus	1	22
C. hawaiiensis	1	15	H. ornatissimus	1	14	N. literatus	1	20
H. ornatissimus	1	9	P. multifasciatus	1	11	N. literatus	1	30
P. multifasciatus	1	17	P. multifasciatus	1	17	C. auriga	1	20
A. nigricans	1	13	C. ornatissimus	2	14	A. chinensis	1	40
C. argus	1	35	C. vanderbilti	4	2	P. aspricaudus	2	10
M. grandoculus	1	27	C. vanderbilti	11	3	S. fasciolatus	1	9
C. verater	1	13	N. literatus	2	24	S. fasciolatus	1	8
			N. literatus	1	30	S. fasciolatus	1	11
			N. literatus	1	14	Z. veliferum	1	28
			N. literatus	5	10	X. auromarginatus	1	19
			N. literatus	3	12	A. abdominalis	1	13
			N. literatus	1	30	C. unimaculatus	1	6
			N. literatus	5	26	Kyphosus spp.	1	30
			N. literatus	1	13	Kyphosus spp.	1	24
			A. thompsoni	6	19			
			A. olivaceus	1	29			
			P. insularis	1	26			
			P. aspricaudus	1	11			

12 Pipe North	5/7/16							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
A. nigrofuscus	1	8	*A. nigrofuscus*	1	9	*A. nigrofuscus*	1	12
A. nigrofuscus	1	10	*A. nigrofuscus*	2	12	*A. nigrofuscus*	2	10
A. nigrofuscus	2	12	*A. nigrofuscus*	6	13	*C. strigosus*	2	10
C. strigosus	1	13	*C. strigosus*	8	12	*C. strigosus*	13	14
C. strigosus	8	14	*C. strigosus*	8	14	*C. strigosus*	7	12
C. strigosus	2	9	*C. strigosus*	1	16	*G. varius*	1	14
C. strigosus	3	11	*C. strigosus*	11	12	*G. varius*	1	6
C. strigosus	10	12	*C. gaimard*	1	10	*C. gaimard*	3	14
C. strigosus	5	10	*C. sordidus*	1	27	*C. sordidus*	2	18
C. strigosus	5	16	*C. sordidus*	1	26	*C. sordidus*	1	22
P. johnstonianus	2	7	*C. hawaiiensis*	1	17	*T. duperrey*	1	9
P. johnstonianus	1	8	*T. duperrey*	2	9	*T. duperrey*	1	7
G. varius	1	14	*T. duperrey*	1	12	*Z. flavescens*	15	10
C. gaimard	1	13	*T. duperrey*	1	14	*Z. flavescens*	20	16
C. sordidus	1	26	*T. duperrey*	1	7	*Z. flavescens*	20	12
C. sordidus	2	16	*T. duperrey*	1	15	*Z. flavescens*	29	14
C. sordidus	1	24	*Z. flavescens*	4	16	*C. multicinctus*	1	11
C. sordidus	1	30	*Z. flavescens*	15	14	*C. multicinctus*	1	12
C. sordidus	2	13	*Z. flavescens*	8	13	*P. arcatus*	1	11
C. hawaiiensis	1	14	*Z. flavescens*	12	12	*C. vanderbilti*	26	2
T. duperrey	1	13	*P. arcatus*	1	7	*C. vanderbilti*	26	3
T. duperrey	1	14	*P. arcatus*	1	9	*N. literatus*	1	22
T. duperrey	1	12	*P. forsteri*	1	18	*C. jactator*	2	7
T. duperrey	1	9	*C. vanderbilti*	28	3	*C. jactator*	1	6
Z. flavescens	6	15	*C. vanderbilti*	10	2	*C. quadrimaculatus*	2	14
Z. flavescens	21	14	*C. vanderbilti*	2	4	*C. quadrimaculatus*	2	12
Z. flavescens	8	10	*A. xanthopterus*	1	44	*C. argus*	1	24
Z. flavescens	3	8	*S. bursa*	1	19	*C. argus*	1	26
Z. flavescens	16	12	*N. literatus*	1	25	*A. triostegus*	11	15
Z. flavescens	9	16	*C. ornatissimus*	1	16	*A. blochii*	4	36
C. multicinctus	1	12	*H. polylepis*	2	14	*A. blochii*	3	40
C. multicinctus	3	11	*C. argus*	1	25	*A. blochii*	3	30
C. multicinctus	1	9	*C. argus*	1	30	*A. blochii*	3	50
P. arcatus	1	10	*C. melampygus*	1	27	*A. leucopareius*	2	14
P. forsteri	1	15	*M. berndti*	6	19	*A. nigricans*	1	12
C. agilis	3	6	*P. aspricaudus*	1	12	*C. ornatissimus*	2	15
C. agilis	5	5	*A. nigroris*	1	16	*Z. cornutus*	1	15
C. agilis	6	3	*A. nigricans*	1	13	*S. fasciolatus*	2	10
F. flavissimus	1	16	*A. nigricans*	1	10	*S. fasciolatus*	1	12
H. thompsoni	1	15	*F. commersonii*	1	142	*S. rubroviolaceus*	1	22
H. ornatissimus	1	12				*S. rubroviolaceus*	1	47
P. multifasciatus	1	21				*S. psittacus*	1	24
C. vanderbilti	23	2				*Decapterus spp.*	26	24
C. vanderbilti	24	3						
S. balteata	1	9						
A. olivaceus	2	29						
A. xanthopterus	2	36						
A. xanthopterus	1	42						
S. bursa	1	19						
N. literatus	2	24						
M. vidua	1	22						
P. insularis	1	18						
P. pleurostigma	1	19						

12 Pipe South	5/7/16									
50'				35'				15'		
Species	**Individuals**	**Size (cm)**		**Species**	**Individuals**	**Size (cm)**		**Species**	**Individuals**	**Size (cm)**
A. nigrofuscus	7	8		*A. nigrofuscus*	1	9		*A. nigrofuscus*	5	10
A. nigrofuscus	5	10		*A. nigrofuscus*	6	10		*A. nigrofuscus*	5	12
A. nigrofuscus	5	12		*A. nigrofuscus*	9	12		*A. nigrofuscus*	3	13
C. agilis	52	5		*C. jactator*	1	6		*C. vanderbiliti*	40	2
C. agilis	17	4		*C. jactator*	2	7		*C. vanderbiliti*	47	3
C. agilis	65	6		*C. vanderbiliti*	38	2		*C. vanderbiliti*	35	4
C. strigosus	4	10		*C. vanderbiliti*	40	3		*N. literatus*	1	31
C. strigosus	1	5		*N. literatus*	1	21		*C. sordidus*	1	35
C. jactator	1	7		*T. duperrey*	1	11		*C. sordidus*	1	28
C. jactator	51	6		*T. duperrey*	2	16		*C. sordidus*	1	24
C. vanderbiliti	30	2		*T. duperrey*	3	9		*C. multicinctus*	2	8
C. vanderbiliti	30	3		*C. sordidus*	1	16		*P. arcatus*	1	11
N. literatus	1	26		*C. sordidus*	1	25		*C. quadrimaculatus*	1	14
T. duperrey	1	14		*C. sordidus*	1	32		*Z. flavescens*	3	10
T. duperrey	1	10		*C. sordidus*	1	22		*Z. flavescens*	8	12
T. duperrey	1	17		*C. multicinctus*	2	11		*Z. flavescens*	3	14
S. bursa	1	17		*P. arcatus*	2	8		*H. thomnpsoni*	8	18
S. bursa	1	13		*P. arcatus*	1	10		*Z. cornutus*	1	14
C. sordidus	1	24		*H. ornatissimus*	1	7		*F. flavissimus*	1	13
C. sordidus	1	22		*H. ornatissimus*	1	9		*A. furca*	1	45
C. sordidus	1	14		*H. polylepis*	4	12		*A. triostegus*	3	17
C. multicinctus	1	12		*H. polylepis*	6	13		*A. abdominalis*	12	16
P. arcatus	1	8		*P. octotania*	1	12		*A. abdominalis*	12	18
P. arcatus	1	11		*F. flavissimus*	1	14		*A. vaigiensis*	6	16
G. varius	1	7		*F. flavissimus*	1	12		*A. vaigiensis*	5	18
G. varius	1	13		*P. johnstonianus*	1	10		*A. triostegus*	3	17
G. varius	1	15		*Z. cornutus*	2	16		*C. strigosus*	10	13
H. ornatissimus	1	11		*Z. flavescens*	11	14		*A. olivaceus*	1	30
C. potteri	1	8		*Z. flavescens*	1	12		*A. blochii*	2	30
C. potteri	1	12		*Z. flavescens*	1	16		*A. blochii*	1	38
B. albotaeniatus	1	32		*A. furca*	1	36		*C. hawaiiensis*	1	22
F. commersonii	1	125		*C. dumerilii*	1	15		*C. hawaiiensis*	1	18
C. gaimard	1	27		*M. vidua*	1	22		*C. hawaiiensis*	1	20
A. olivaceus	1	28		*A. triostegus*	1	15		*C. hawaiiensis*	2	24
H. polylepis	5	13		*A. triostegus*	1	16		*A. dussumieri*	2	40
P. octotania	1	9		*P. aspricaudus*	1	7		*A. dussumieri*	1	36
C. kleinii	1	11		*A. abdominalis*	29	15		*A. dussumieri*	1	30
H. thomnpsoni	4	16		*C. lunula*	2	17		*Kyphosus spp.*	30	30
A. xanthopterus	3	18		*H. thomnpsoni*	1	20		*Kyphosus spp.*	30	42
O. unifasciatus	1	30		*H. thomnpsoni*	1	17		*Kyphosus spp.*	40	34
O. unifasciatus	1	38		*X. auromarginatus*	2	16		*Kyphosus spp.*	40	38
N. hexacanthus	5	22		*N. taeniourus*	1	11		*M. vanicolensis*	4	27
N. hexacanthus	10	26								
N. hexacanthus	7	30								

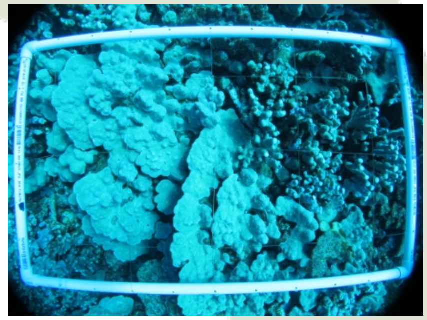
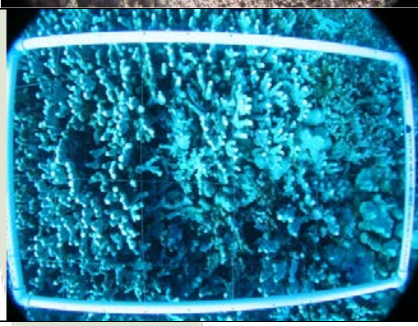
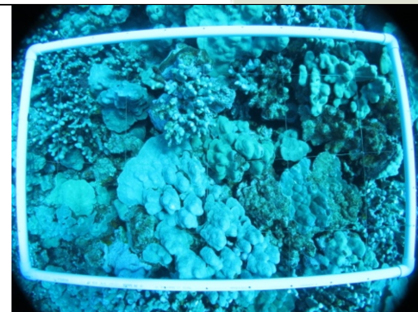
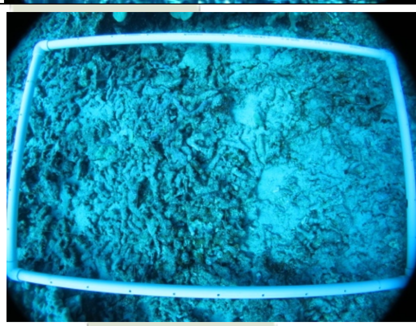
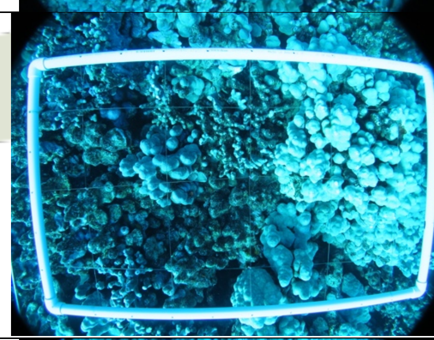
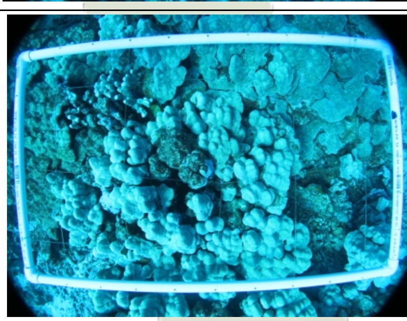
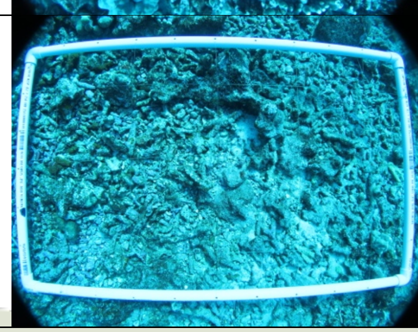
18	5/8/16							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
A. nigrofuscus	21	12	*A. nigrofuscus*	6	11	*A. nigrofuscus*	7	8
A. nigrofuscus	4	11	*A. nigrofuscus*	6	13	*A. nigrofuscus*	13	10
A. nigrofuscus	2	8	*A. nigrofuscus*	6	15	*A. nigrofuscus*	13	12
A. nigrofuscus	5	14	*A. nigrofuscus*	4	8	*A. nigrofuscus*	4	14
C. agilis	6	4	*A. nigrofuscus*	5	10	*C. agilis*	1	5
C. agilis	2	5	*A. nigrofuscus*	5	12	*C. agilis*	1	4
C. strigosus	2	16	*A. nigrofuscus*	8	14	*C. strigosus*	3	9
C. strigosus	2	14	*C. agilis*	2	5	*C. strigosus*	11	10
C. jactator	1	4	*C. strigosus*	2	12	*C. strigosus*	17	12
C. jactator	2	6	*C. strigosus*	1	10	*C. strigosus*	11	14
C. vanderbiliti	25	2	*C. strigosus*	1	8	*C. jactator*	1	5
C. vanderbiliti	77	3	*C. strigosus*	1	4	*C. vanderbiliti*	6	2
C. vanderbiliti	50	4	*C. jactator*	1	6	*C. vanderbiliti*	41	3
N. literatus	1	32	*C. vanderbiliti*	45	2	*C. vanderbiliti*	30	4
N. literatus	1	38	*C. vanderbiliti*	75	3	*N. literatus*	1	28
T. duperrey	2	13	*C. vanderbiliti*	75	4	*T. duperrey*	1	16
T. duperrey	1	9	*N. literatus*	1	28	*T. duperrey*	1	6
T. duperrey	1	16	*N. literatus*	1	23	*T. duperrey*	1	17
T. duperrey	2	14	*T. duperrey*	1	6	*C. multicinctus*	1	9
T. duperrey	1	8	*T. duperrey*	1	4	*C. multicinctus*	1	10
S. bursa	1	18	*T. duperrey*	1	12	*P. arcatus*	1	12
C. multicinctus	1	10	*T. duperrey*	1	17	*Z. flavescens*	1	14
C. multicinctus	1	7	*T. duperrey*	1	9	*Z. flavescens*	1	16
C. multicinctus	1	8	*T. duperrey*	1	13	*Z. flavescens*	3	12
A. olivaceus	1	31	*T. duperrey*	1	16	*Z. flavescens*	3	15
P. arcatus	1	10	*S. bursa*	1	23	*S. fasciolatus*	1	8
C. argus	1	40	*C. multicinctus*	2	8	*S. fasciolatus*	3	9
P. johnstonianus	1	7	*C. multicinctus*	1	5	*S. fasciolatus*	2	10
P. johnstonianus	2	8	*C. multicinctus*	1	7	*G. varius*	1	6
P. johnstonianus	1	6	*C. multicinctus*	1	9	*C. gaimard*	1	24
P. octotania	1	10	*P. arcatus*	1	8	*Z. cornutus*	1	12
P. octotania	1	8	*P. johnstonianus*	1	8	*Z. cornutus*	2	14
M. vidua	1	25	*P. johnstonianus*	1	6	*C. ornatissimus*	1	10
A. furca	1	37	*P. octotania*	1	9	*C. ornatissimus*	2	17
P. multifasciatus	1	16	*P. octotania*	1	11	*C. jactator*	1	5
P. multifasciatus	1	13	*P. multifasciatus*	1	17	*C. hanui*	1	4
Z. flavescens	1	5	*Z. flavescens*	8	14	*C. sordidus*	1	18
Z. flavescens	2	7	*Z. flavescens*	2	16	*C. sordidus*	1	20
Z. flavescens	1	6	*Z. flavescens*	7	12	*C. sordidus*	1	26
Z. flavescens	4	12	*Z. flavescens*	1	10	*F. flavissimus*	2	15
Z. flavescens	6	14	*S. fasciolatus*	1	10	*C. quadrimaculatus*	1	11
Z. flavescens	3	15	*G. varius*	1	12	*C. quadrimaculatus*	1	9
Z. flavescens	4	13	*G. varius*	1	9	*H. ornatissimus*	3	12
S. fasciolatus	1	12	*C. gaimard*	1	18	*H. ornatissimus*	1	15
			Z. cornutus	1	15	*H. ornatissimus*	1	16
			C. ornatissimus	1	9	*C. hawaiiensis*	2	20
			N. literatus	1	28	*A. thompsoni*	5	25
			N. literatus	1	23	*A. nigricans*	1	10
			A. olivaceus	1	28	*A. leucopareius*	1	16
			A. olivaceus	2	26	*O. meleagris*	1	10
			A. olivaceus	1	5	*A. furca*	1	30
			A. olivaceus	1	6	*A. furca*	1	34
			P. forsteri	1	19	*M. burndti*	1	17
			C. sordidus	1	30	*A. scriptus*	1	50
			F. flavissimus	2	14	*P. aspricaudus*	1	14
			C. lunula	1	16	*C. amboinensis*	1	9
			C. quadrimaculatus	1	12			
			H. ornatissimus	1	12			
			H. ornatissimus	1	10			
			H. ornatissimus	1	8			
			H. ornatissimus	1	7			

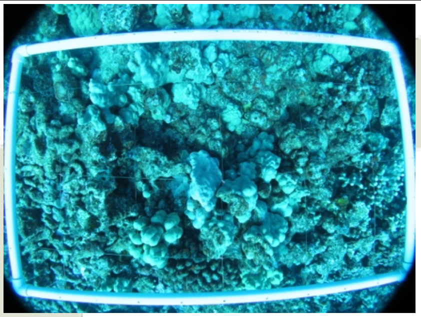
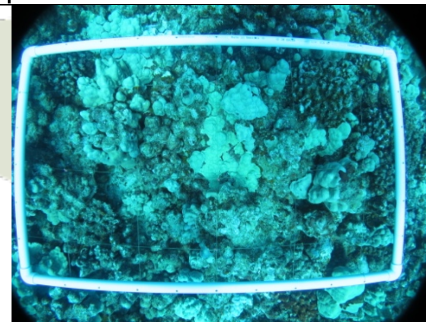
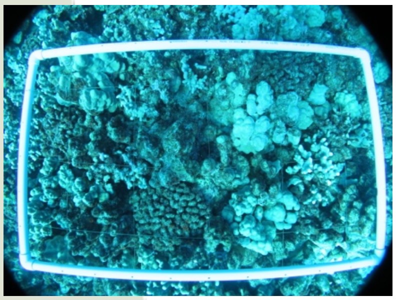
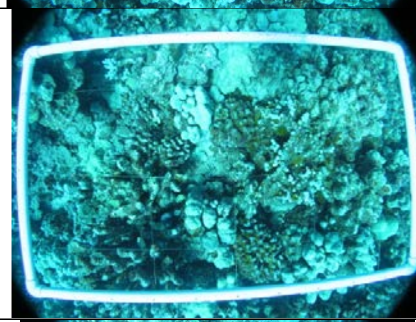
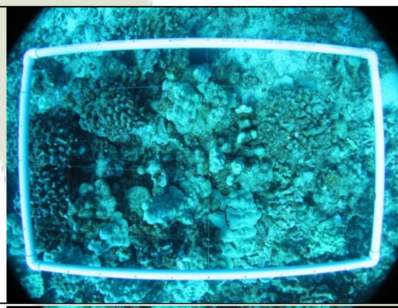
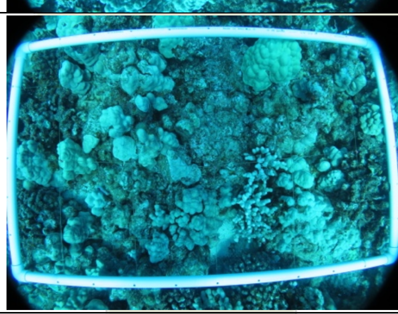
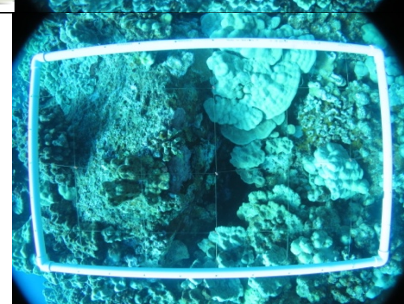
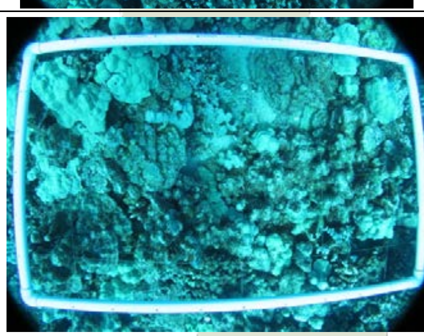
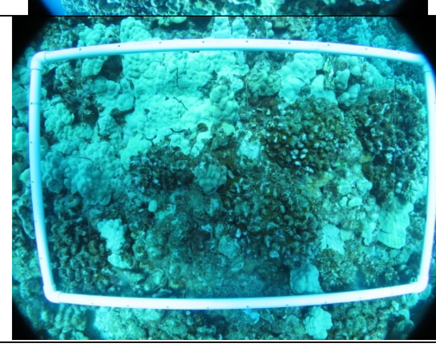
Wawa	5/8/16	
50'		
Species	**Individuals**	**Size (cm)**
A. nigrofuscus	14	8
A. nigrofuscus	6	7
C. agilis	4	4
C. agilis	24	5
C. strigosus	3	6
C. strigosus	8	13
C. strigosus	6	9
C. vanderbiliti	6	2
N. literatus	1	22
N. literatus	11	14
T. duperrey	1	17
T. duperrey	1	18
T. duperrey	1	7
T. duperrey	1	15
S. bursa	1	17
A. olivaceus	1	11
A. olivaceus	1	12
P. octotania	1	12
P. multifasciatus	1	20
P. multifasciatus	1	9
P. multifasciatus	1	24
Z. flavescens	2	10
Z. flavescens	4	8
Z. flavescens	4	12
C. potteri	1	5
C. potteri	1	7
Z. cornutus	1	12
Z. cornutus	1	15
C. sordidus	1	22
C. sordidus	1	27
C. hanui	4	5
C. hanui	2	5
P. forsteri	1	17
C. hawaiiensis	1	17
C. kleinii	4	10
A. thompsoni	6	27
A. thompsoni	2	16
C. miliaris	1	12
O. unifasciatus	1	22
O. unifasciatus	1	33
A. xanthopterus	1	32
A. xanthopterus	1	36

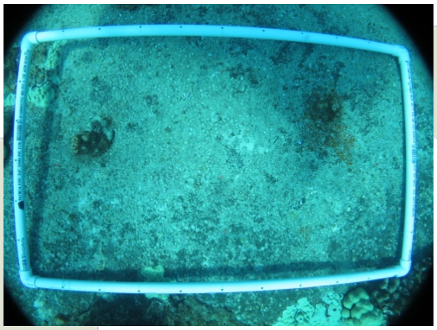
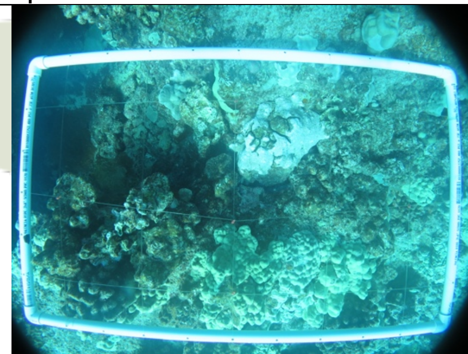
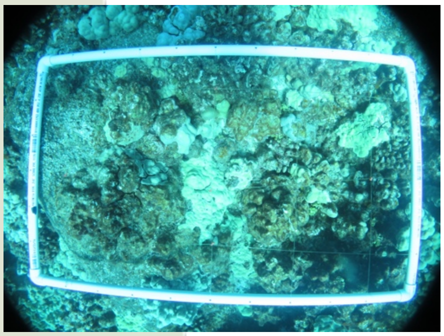
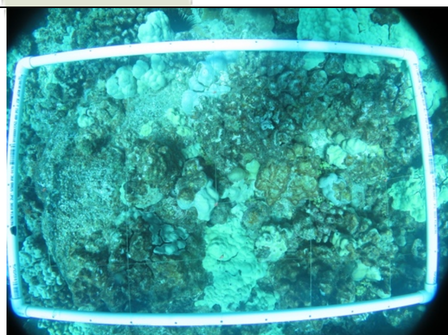
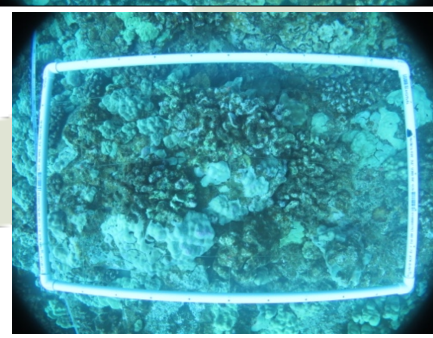
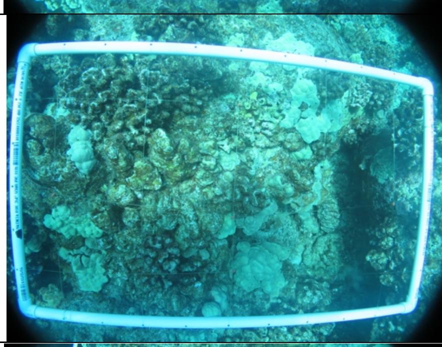
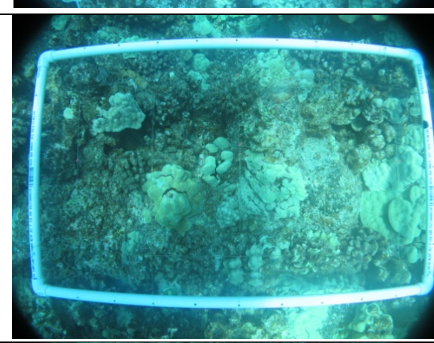
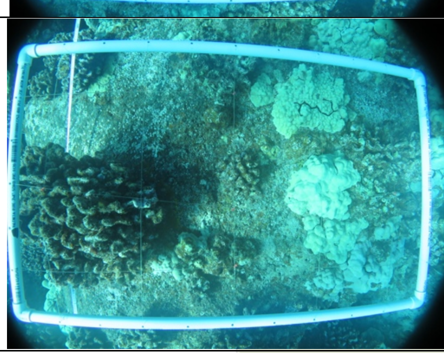
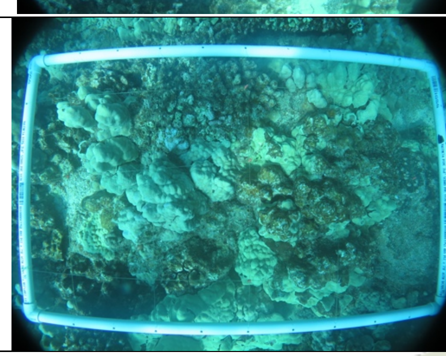
35'		
Species	**Individuals**	**Size (cm)**
A. nigrofuscus	5	9
A. nigrofuscus	7	10
A. nigrofuscus	3	12
C. vanderbiliti	6	2
C. vanderbiliti	15	3
C. vanderbiliti	7	4
T. duperrey	1	8
T. duperrey	1	11
T. duperrey	2	15
T. duperrey	2	14
T. duperrey	1	12
P. octotania	1	11
Z. flavescens	3	16
Z. flavescens	1	14
P. arcatus	1	8
P. arcatus	1	9
H. ornatissimus	1	12
H. ornatissimus	1	9
C. gaimard	1	23
N. taeniourus	1	3
Iniistius spp.	2	14

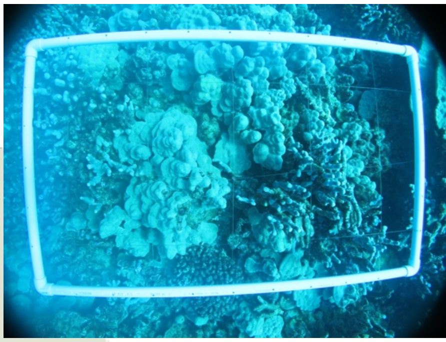
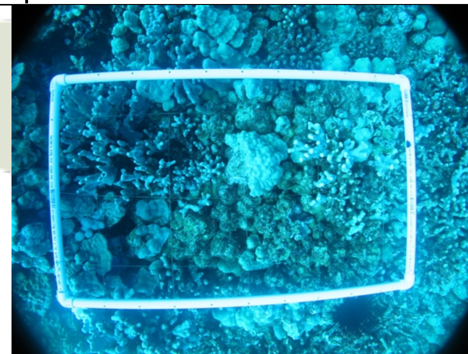
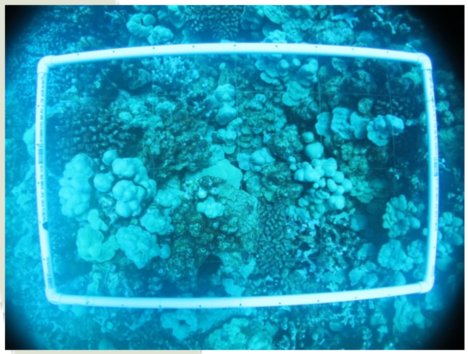
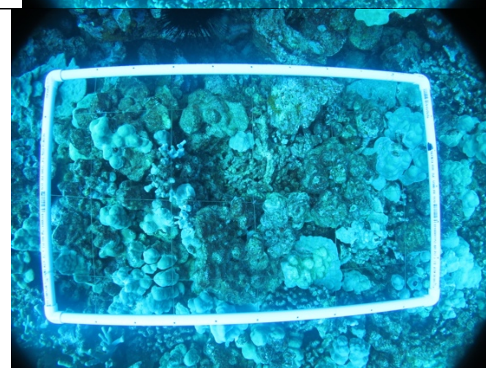
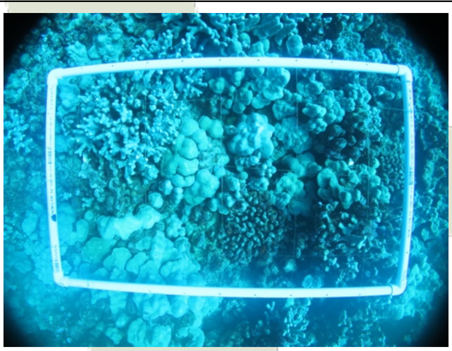
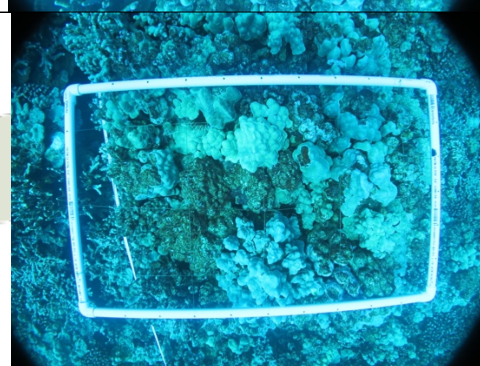
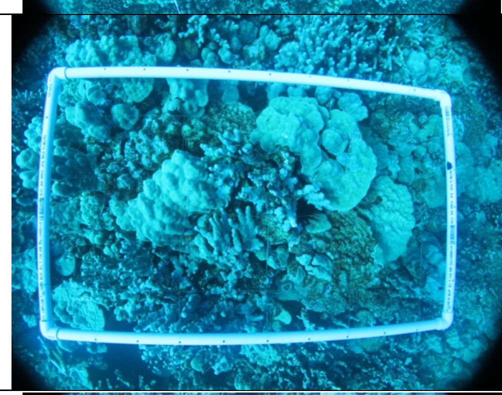
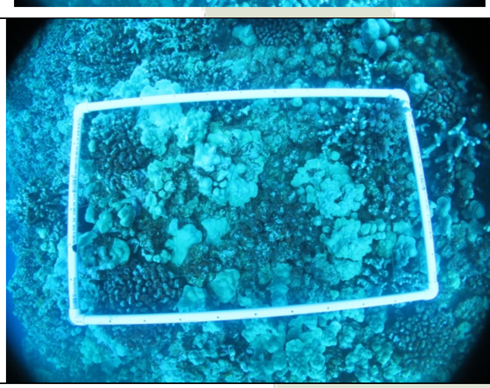
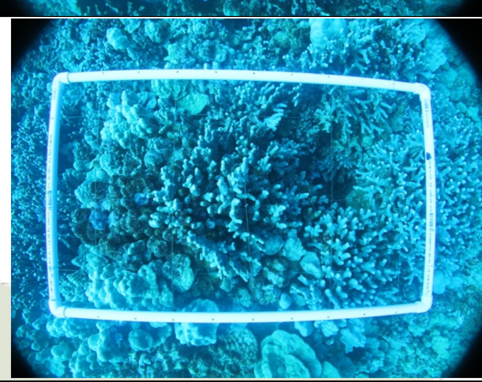
15'		
Species	**Individuals**	**Size (cm)**
A. nigrofuscus	15	10
A. nigrofuscus	24	11
A. nigrofuscus	13	12
A. nigrofuscus	5	8
A. nigrofuscus	5	7
N. literatus	1	24
T. duperrey	1	6
T. duperrey	2	9
T. duperrey	1	11
S. bursa	1	18
S. bursa	2	17
S. bursa	1	15
Z. flavescens	9	14
Z. flavescens	5	13
Z. flavescens	1	12
P. forsteri	1	15
A. olivaceus	2	24
A. leucopareius	1	17
C. vanderbilti	9	3
C. vanderbilti	9	4
H. ornatissimus	1	13
C. ornatissimus	2	14
C. gaimard	1	20
C. lunula	1	12
C. jactator	1	7
C. multicinctus	2	12
C. quadrimaculatus	2	12
C. quadrimaculatus	1	14
S. balteata	1	9

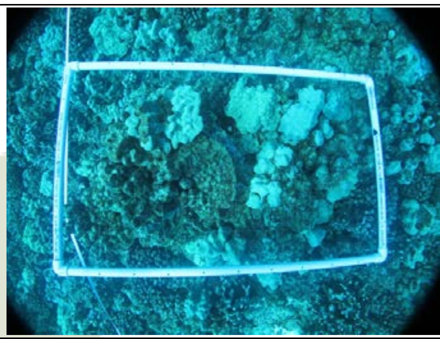
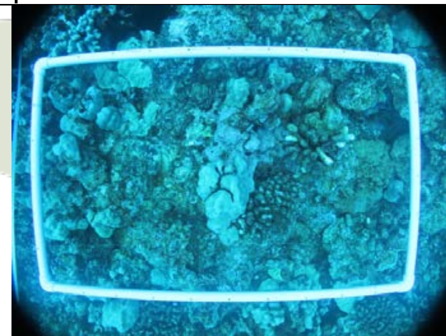
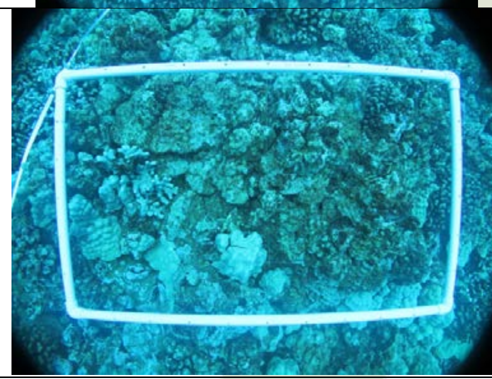
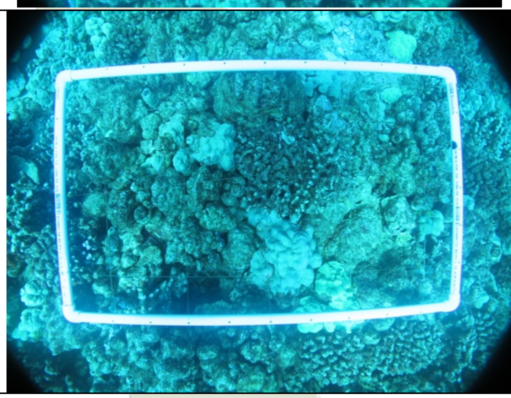
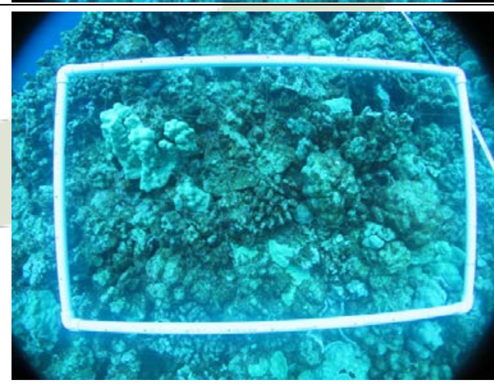
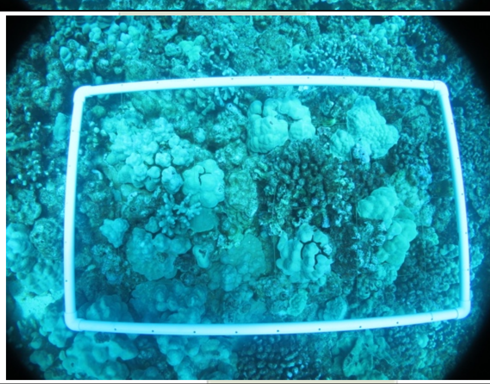
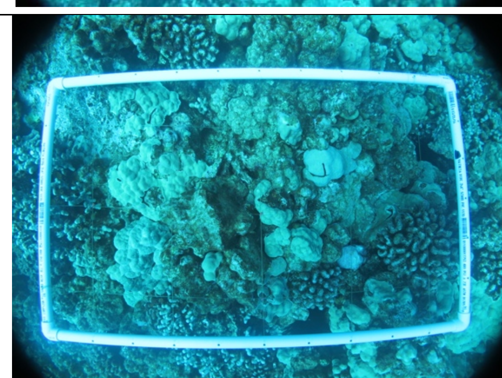
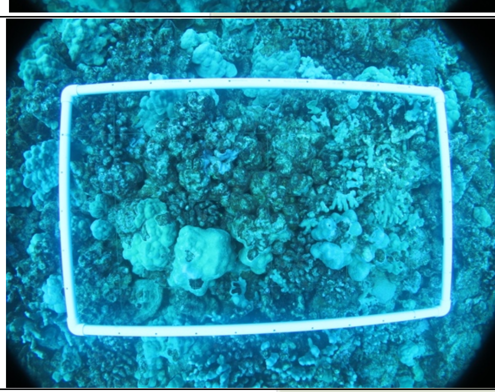
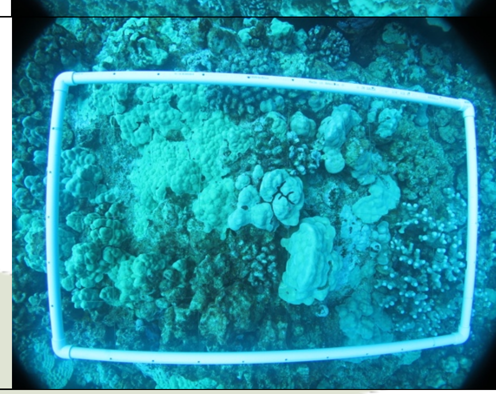
Appendix 4. Digital images of quadrats used for benthic habitat characterization

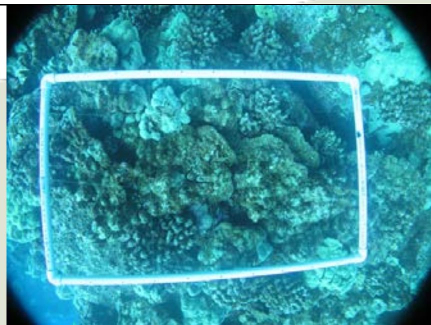
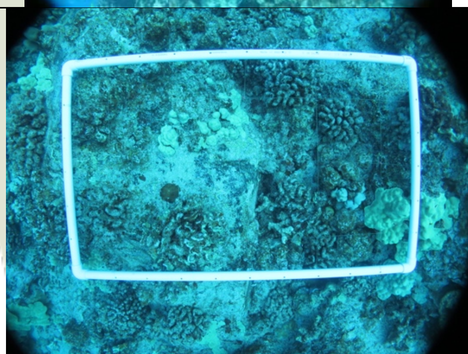
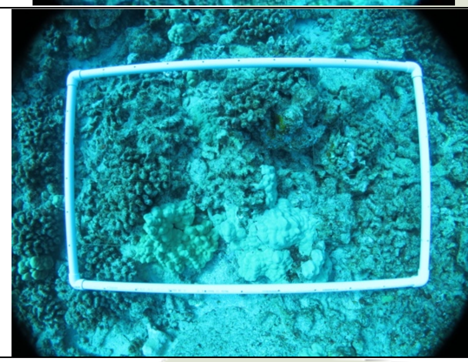
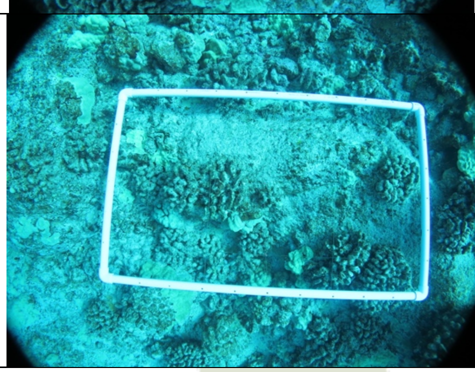
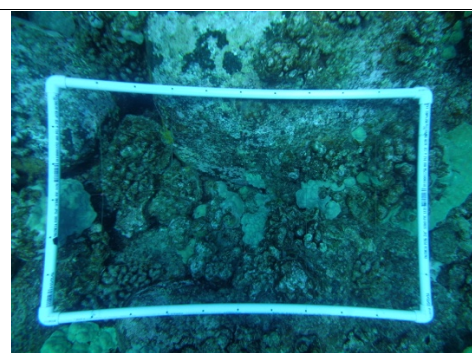
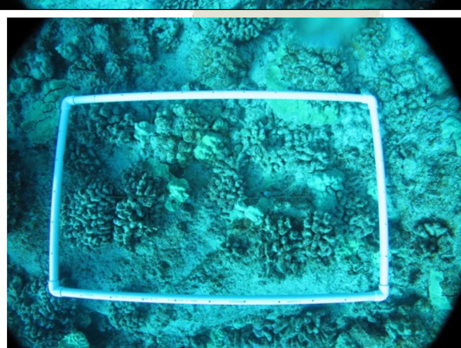
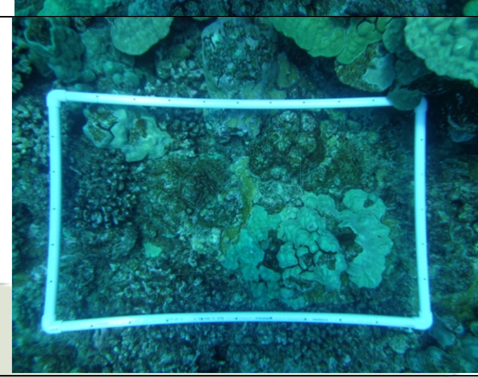
Site: Hoona Depth: 50fsw	
	
	
	
	
	

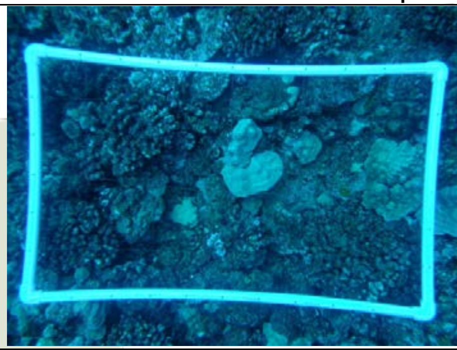
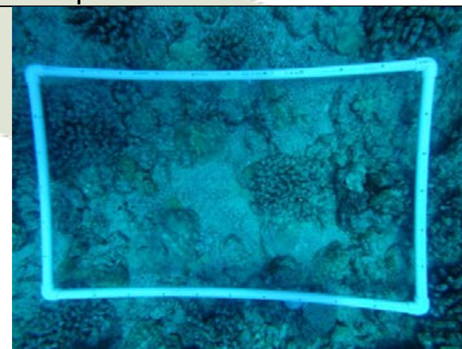
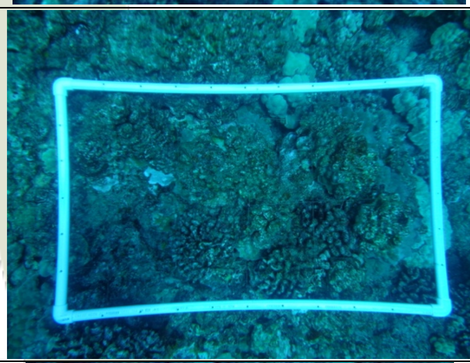
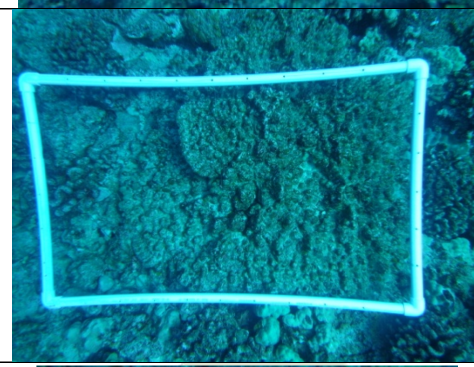
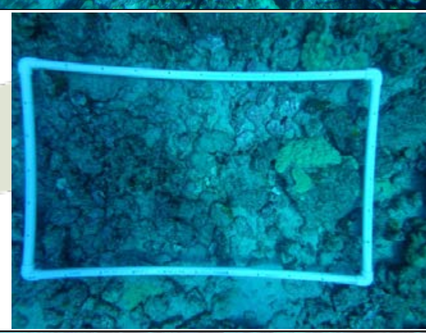
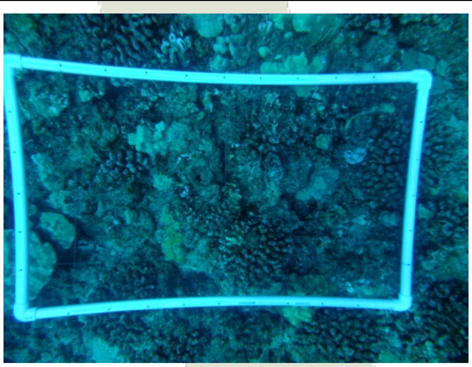
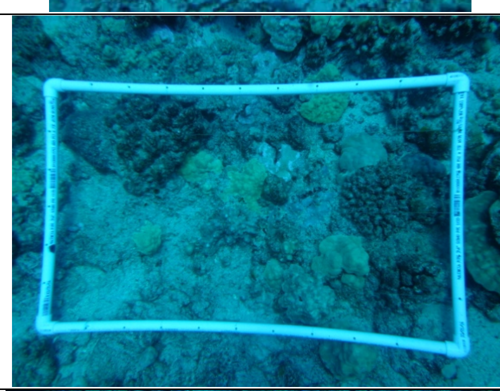
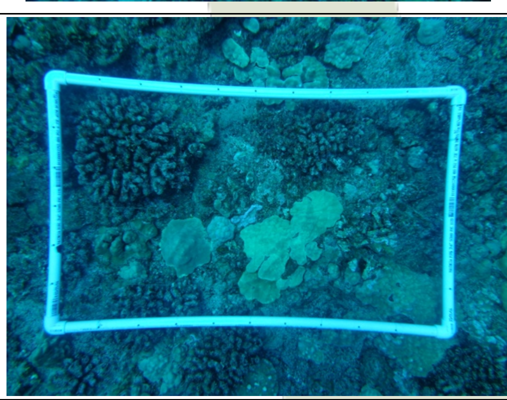
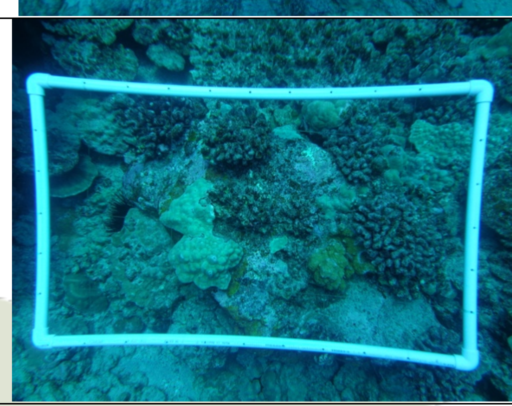
Site: Hoona Depth: 30fsw	
	
	
	
	
	

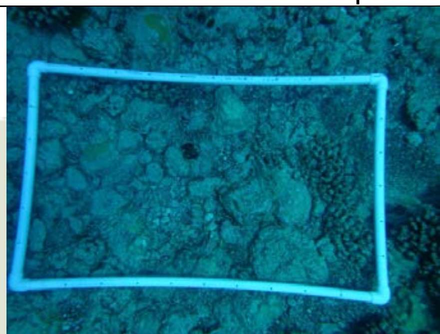
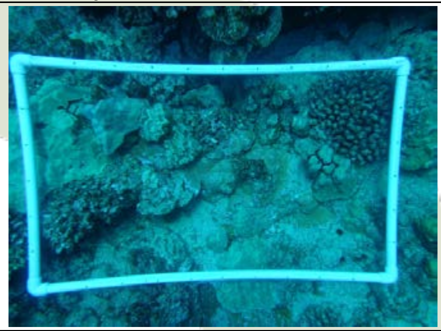
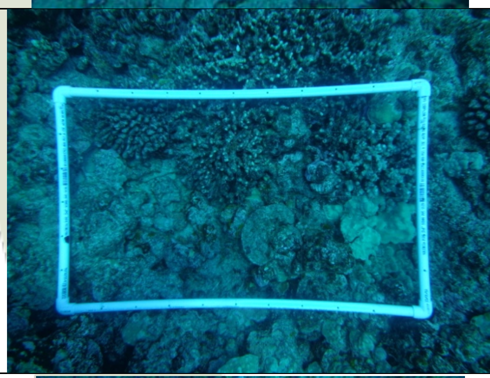
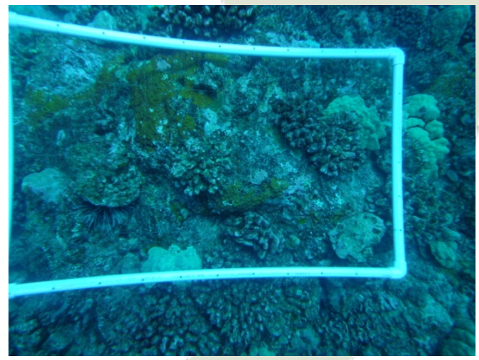
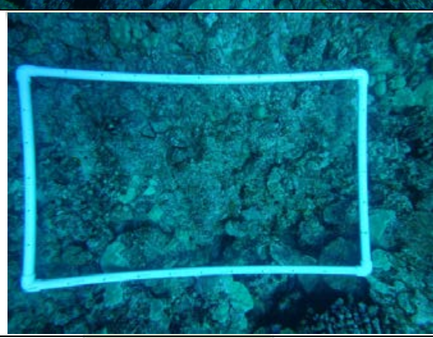
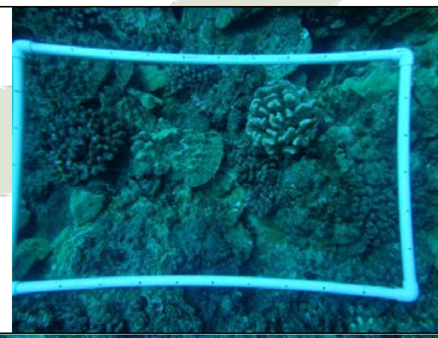
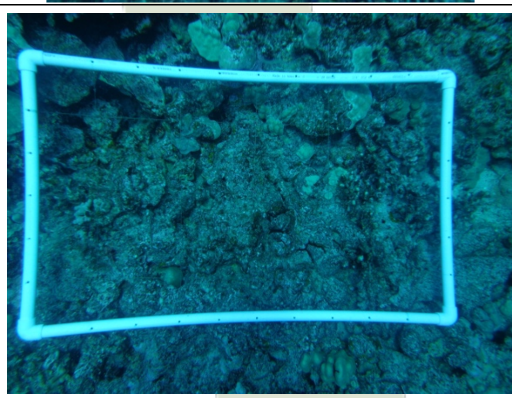
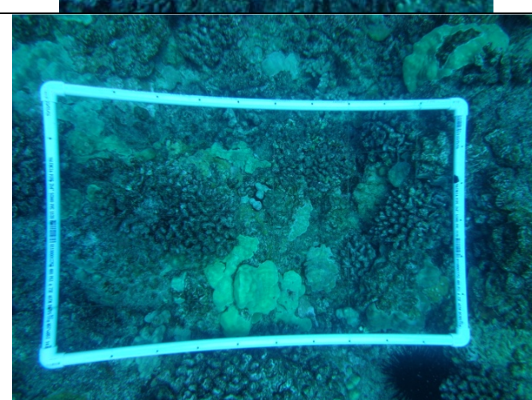
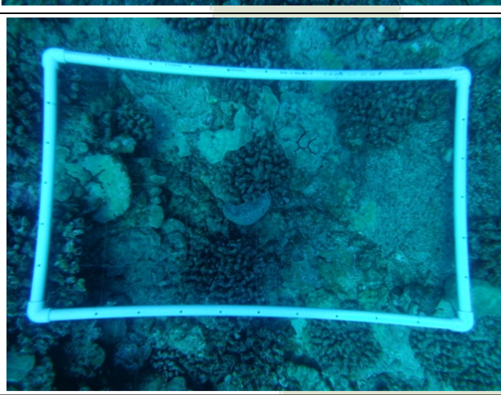
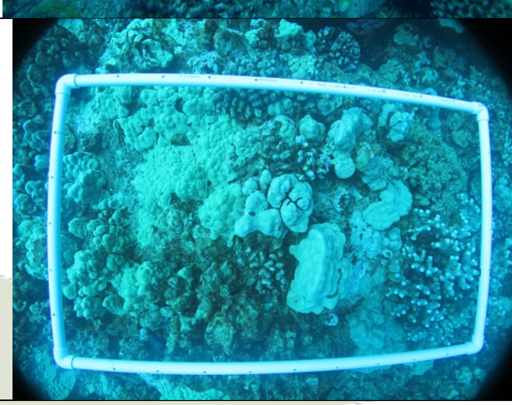
Site: Hoona Depth: 15fsw	
	
	
	
	
	

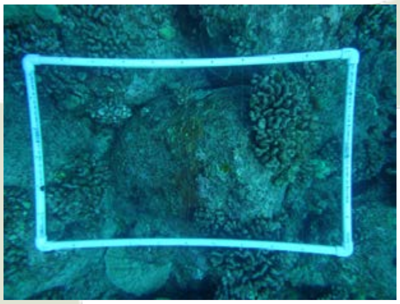
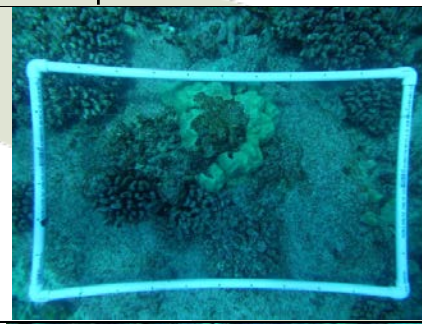
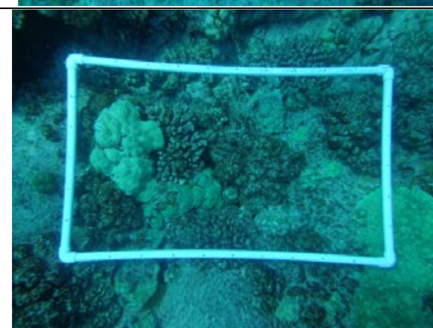
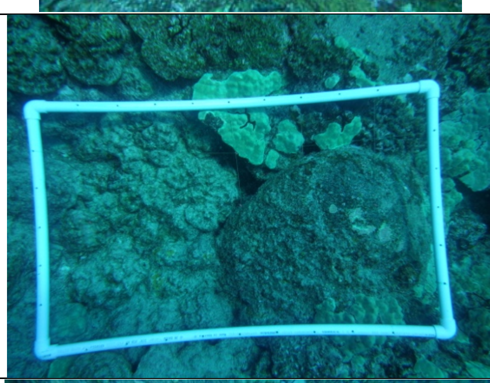
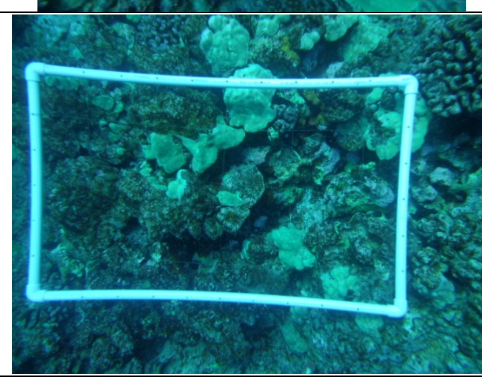
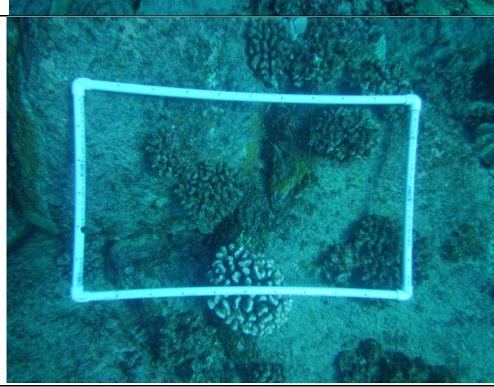
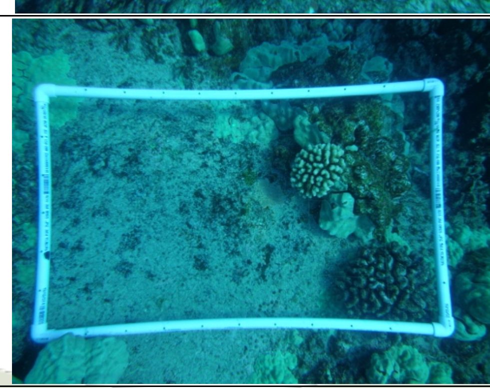
Site: NPPE	Depth: 50fsw
	
	
	
	
	

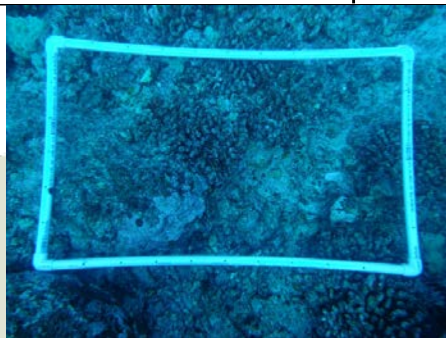
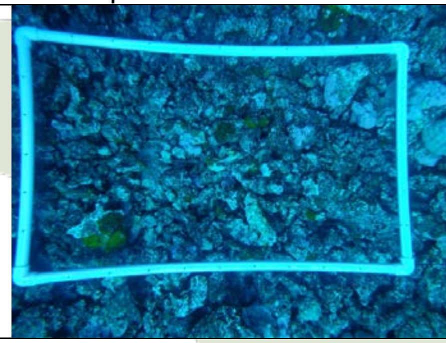
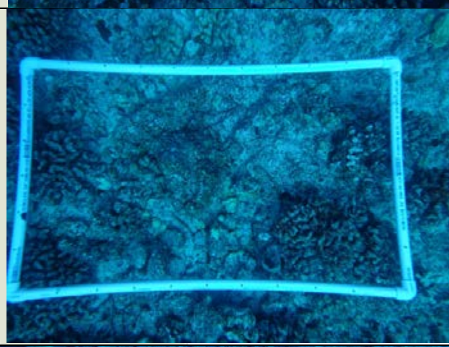
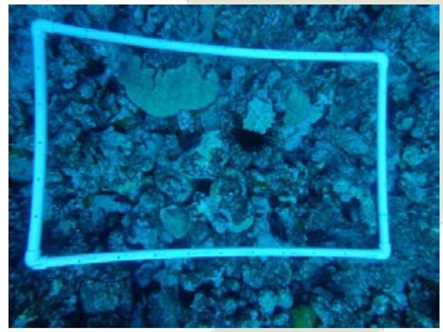
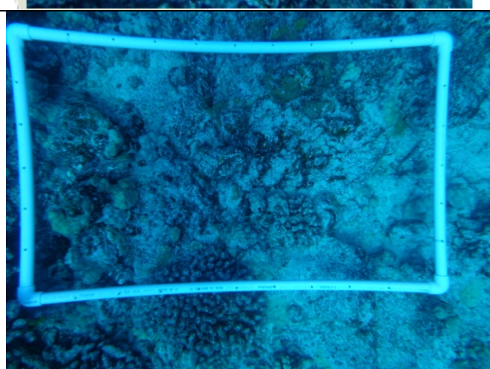
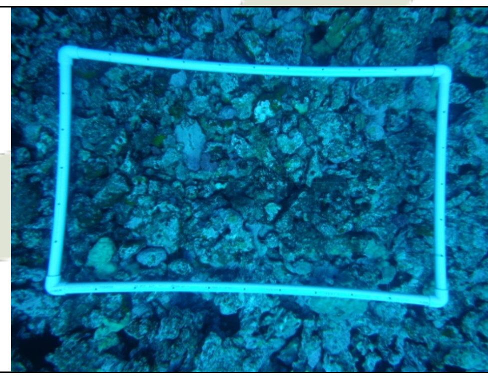
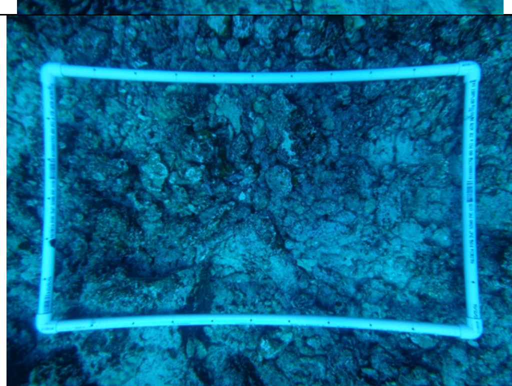
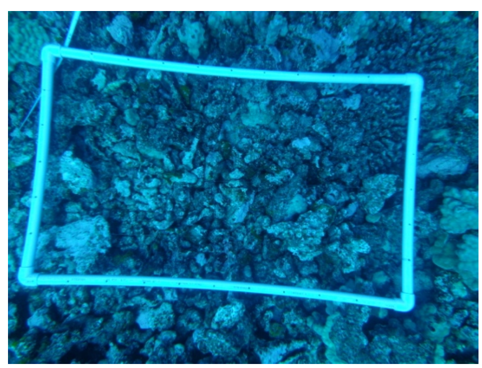
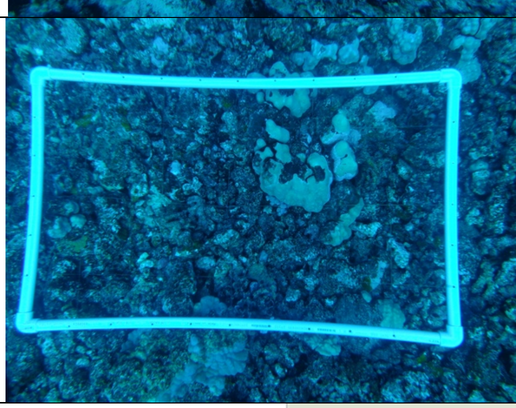
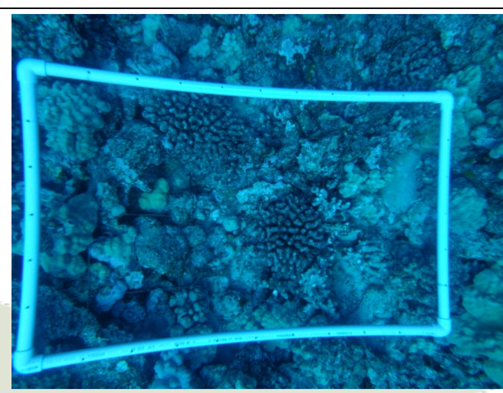
Site: NPPE Depth: 30fsw	
	
	
	
	
	

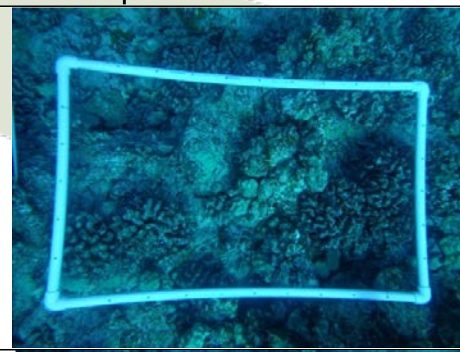
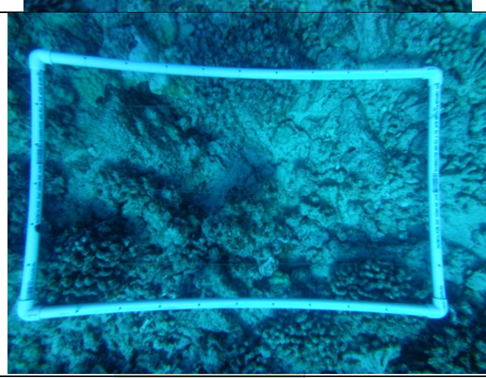
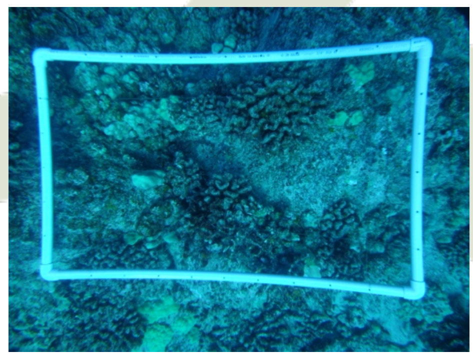
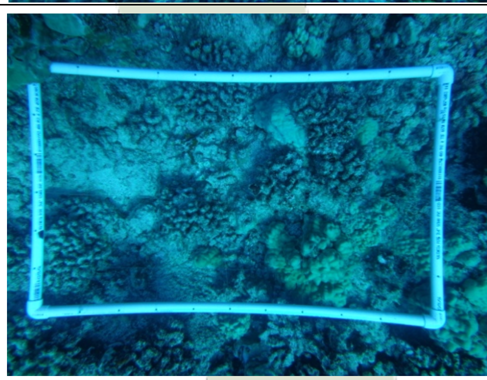
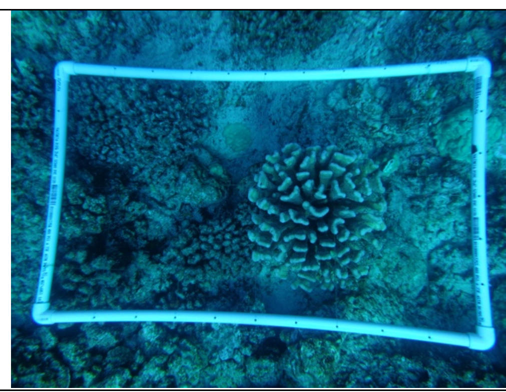
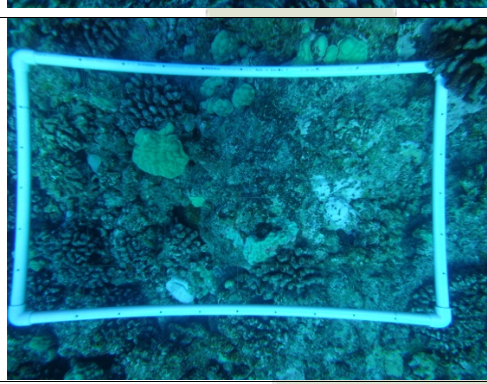
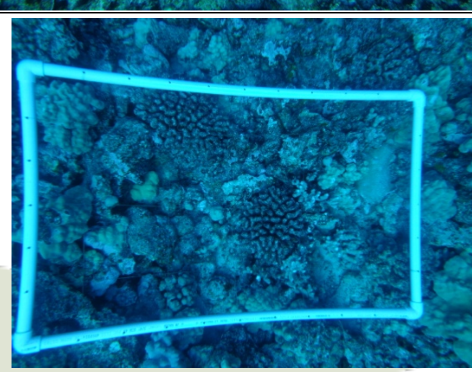
Site: NPPE Depth: 15fsw	
	
	
	
	
	

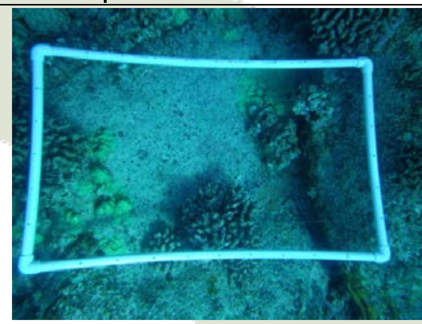
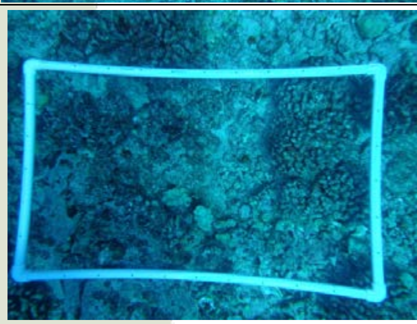
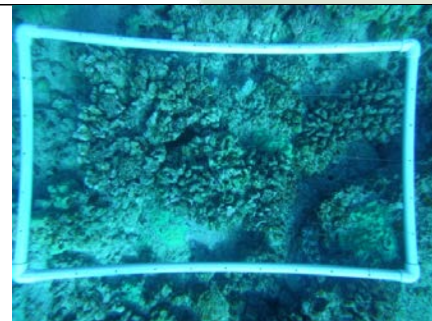
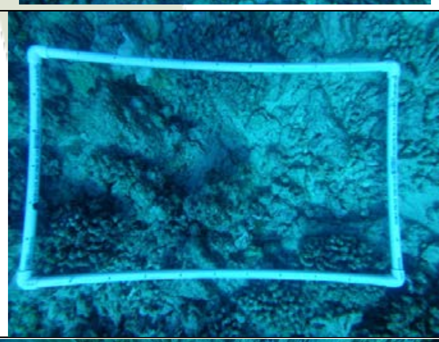
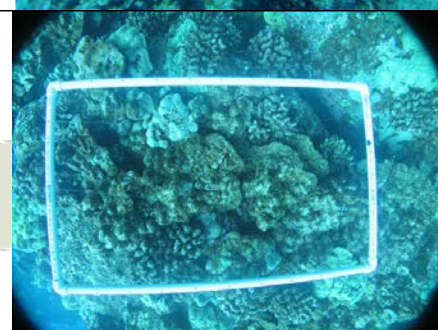
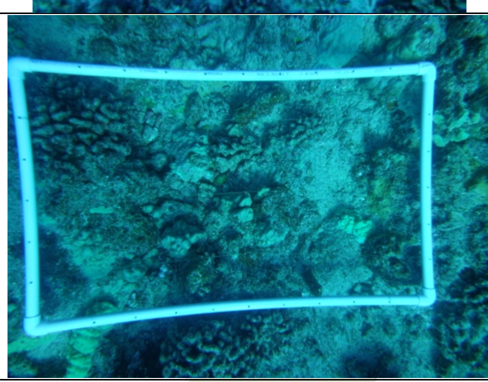
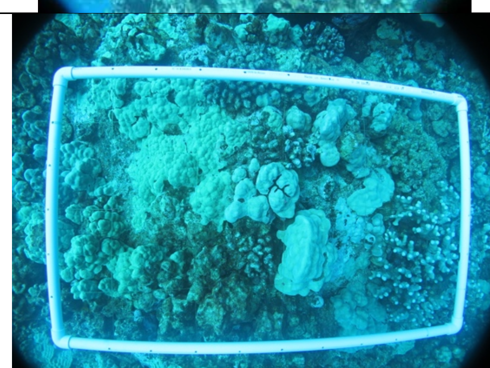
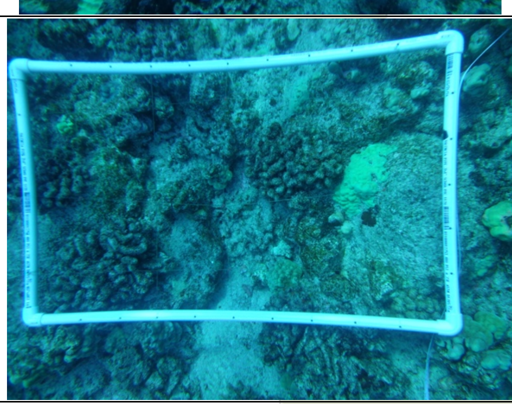
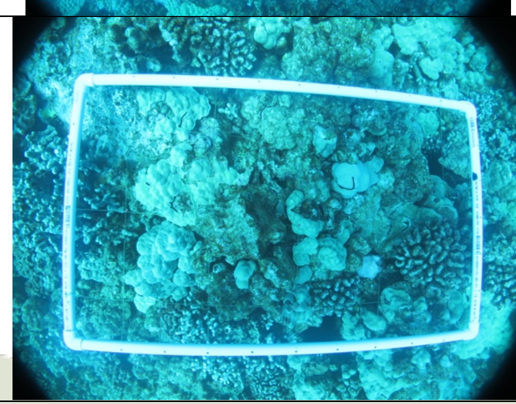
Site: 12 Pipe North Depth: 50fsw	
	
	
	
	
	

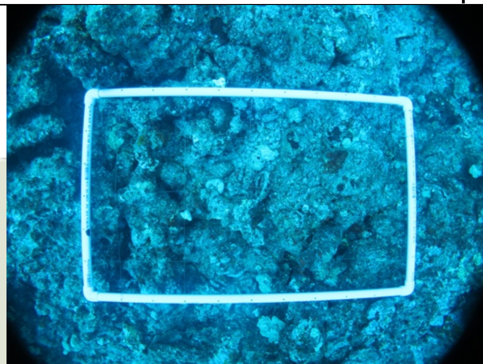
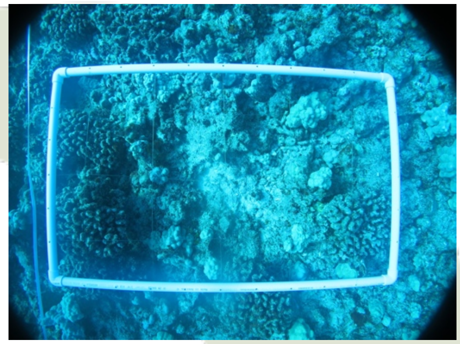
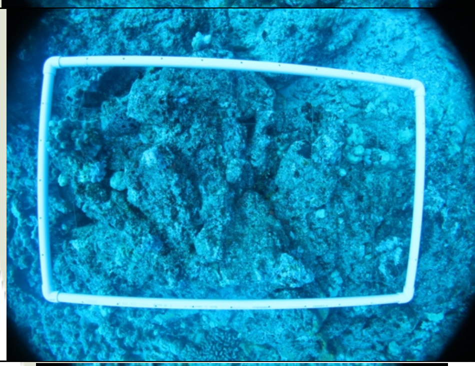
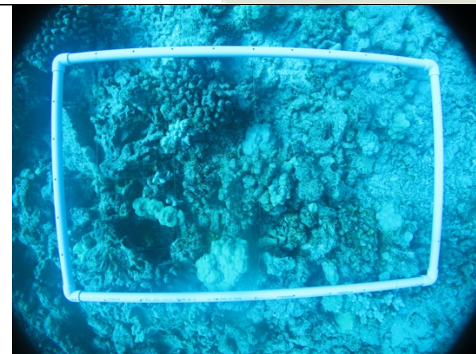
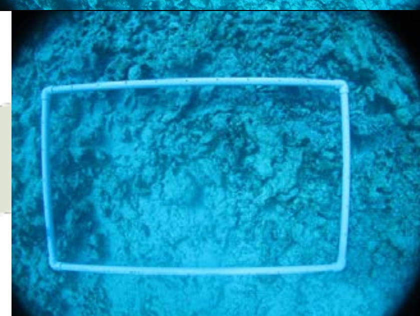
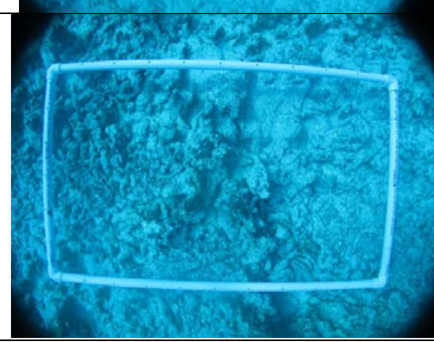
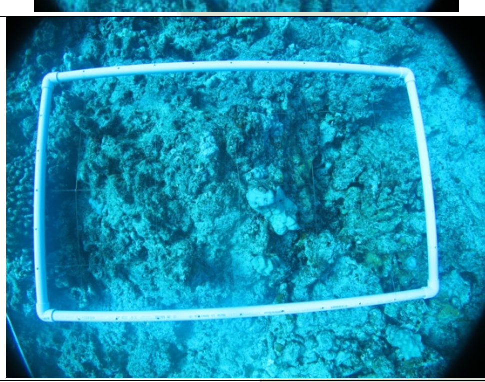
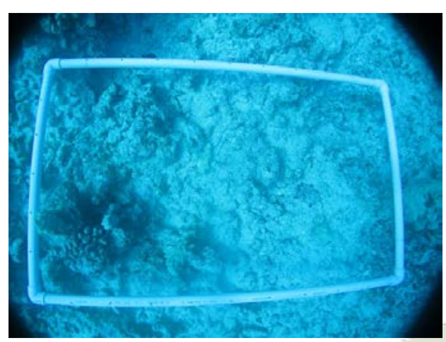
Site: 12 Pipe North	Depth: 30fsw
	
	
	
	
	

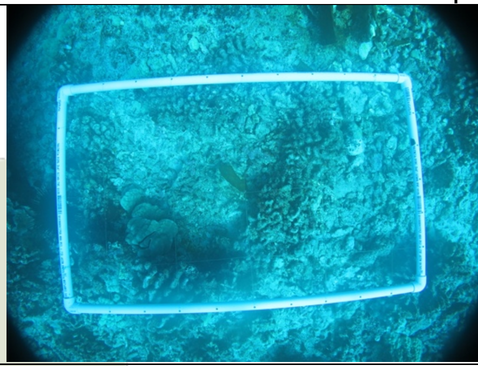
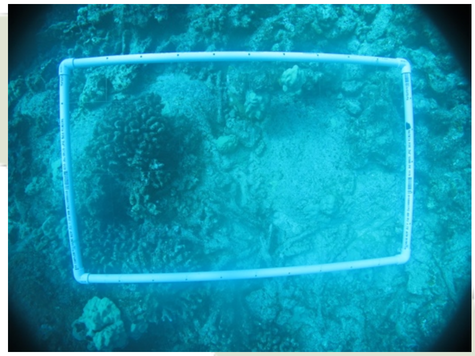
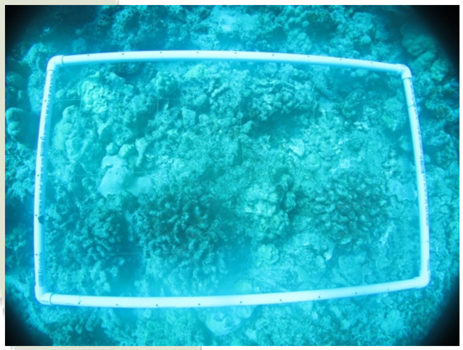
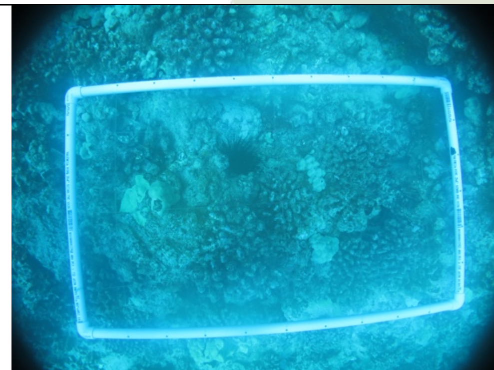
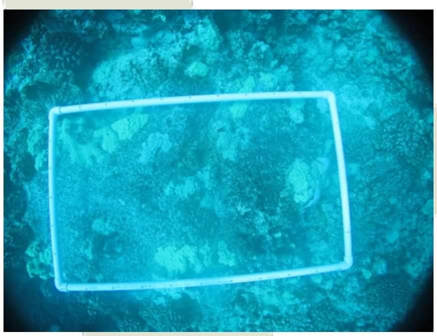
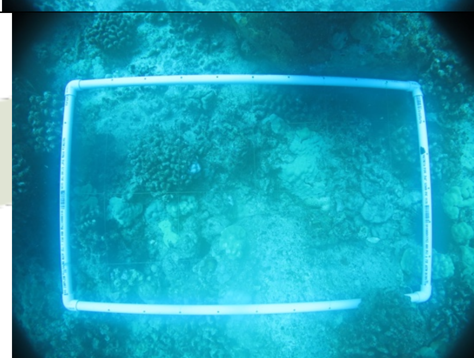
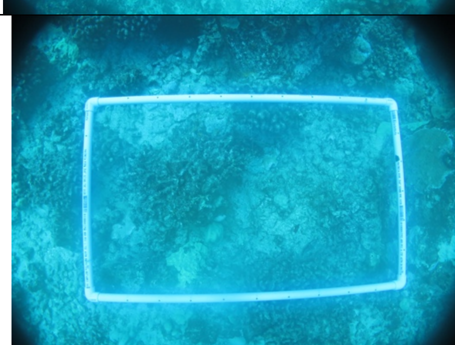
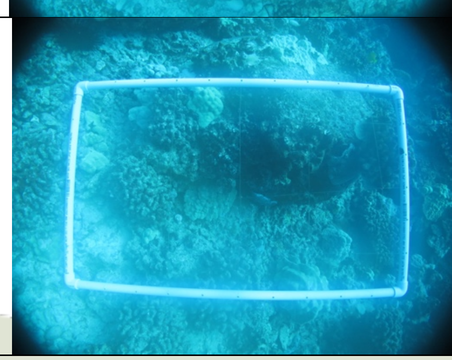
Site: 12 Pipe North	Depth: 15fsw
	
	
	
	
	

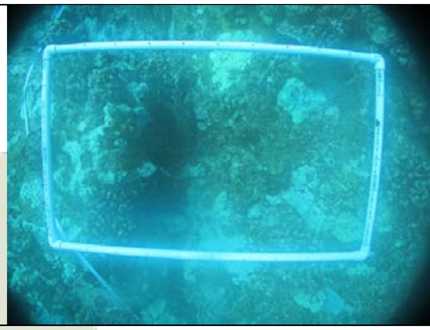
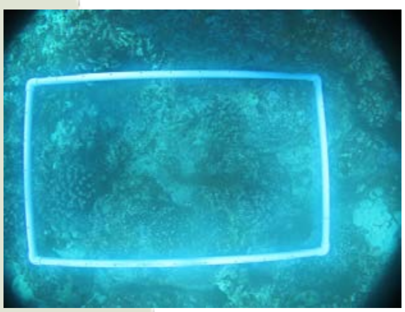
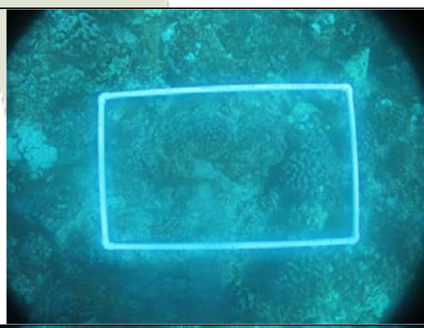
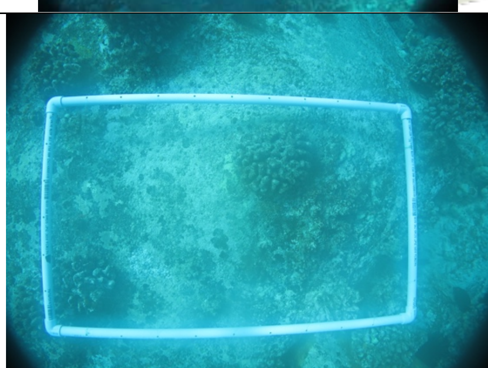
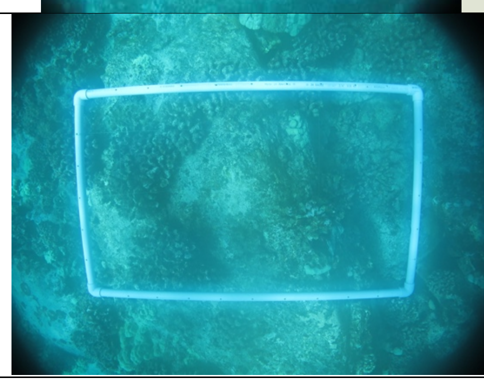
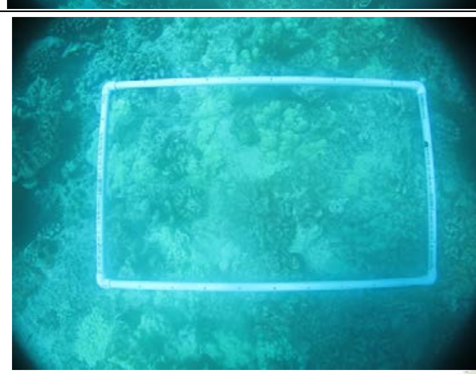
Site: 12 Pipe South	Depth: 50fsw
	
	
	
	
	

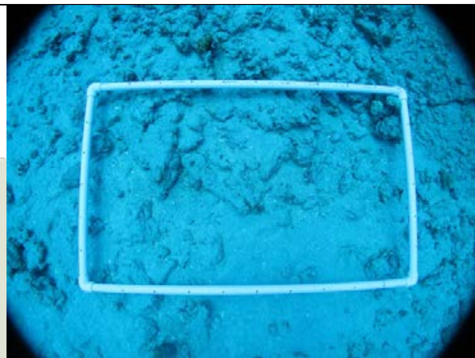
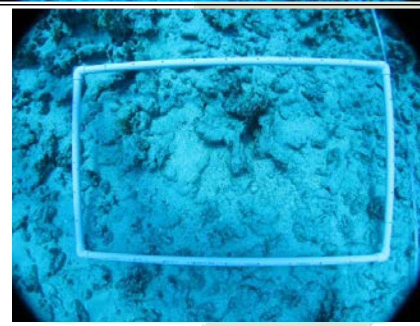
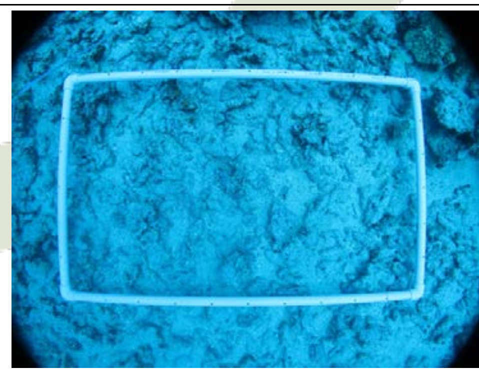
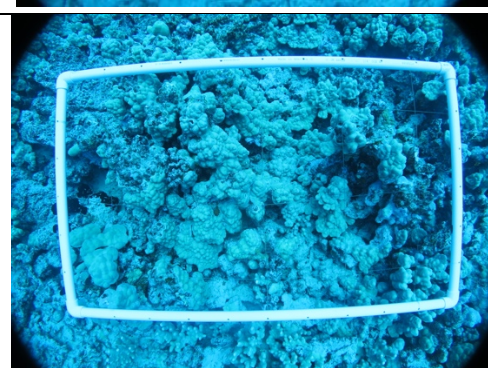
Site: 12 Pipe South	Depth: 30fsw
	
	
	
	
	

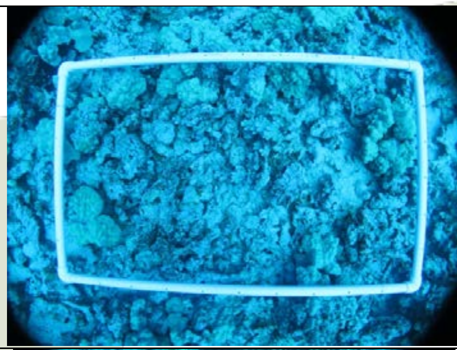
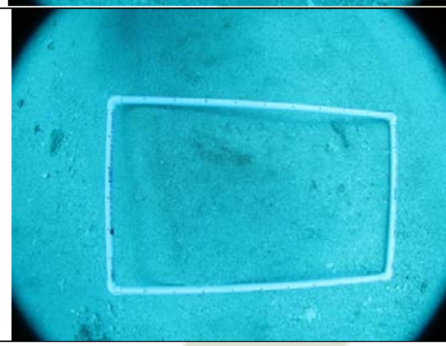
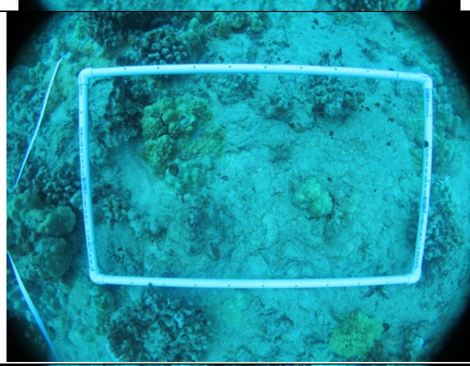
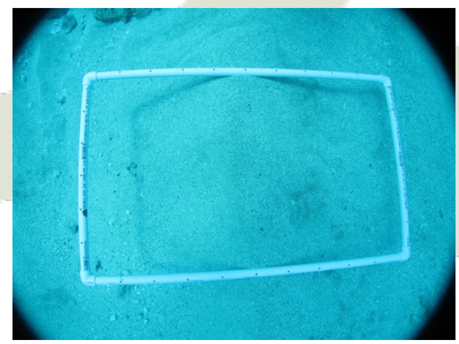
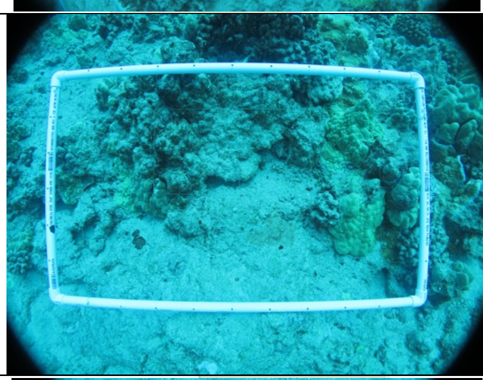
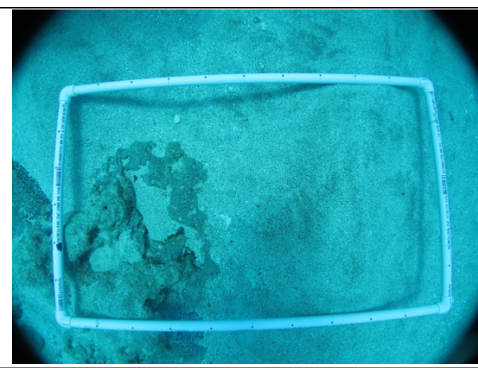
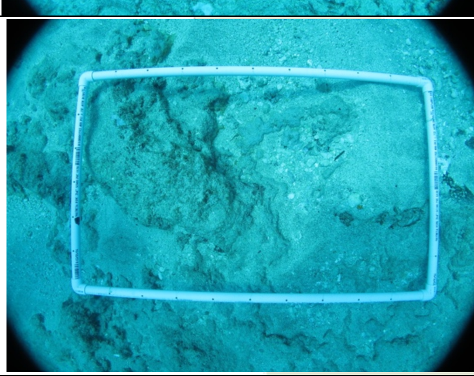
Site: 12 Pipe South	Depth: 15fsw
	
	
	
	
	

Site: 18 Pipe Depth: 50fsw	
	
	
	
	
	

Site: 18 Pipe Depth: 30fsw	
	
	
	
	
	

Site: 18 Pipe Depth: 15fsw	
	
	
	
	
	

Site: Wawaloli Depth: 50fsw	
	
	
	
	
	

Site: Wawaloli Depth: 30fsw	
	
	
	
	
	

Site: Wawaloli	Depth: 15fsw