NELHA BENTHIC AND BIOTA MONITORING PROGRAM

3/31/2021

Annual Survey Report – 2020

Prepared by

PLANB CONSULTANCY

Hawaii Office:
PO Box 578
Papaikou, HI 96781
p: 808.854.4057
f: 503.907.5229
w: planbconsult.net

Main Office:
696 McVey Avenue, Suite 202
Lake Oswego, OR 97034
p: 503.850.9876
f: 503.907.5229
w: planbconsult.net

NELHA BENTHIC AND BIOTA MONITORING PROGRAM

ANNUAL SURVEY REPORT – 2020

PREPARED FOR:

Natural Energy Laboratory of Hawaii Authority (NELHA)

P. O. Box 1749 Kailua-Kona, HI 96745

PREPARED BY:

John HR Burns, Ph.D. | Kaile'a Annandale, M.S. | Kehau Springer, M.S

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

March 2021

EXECUTIVE SUMMARY

The Natural Energy Laboratory 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 surface and 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 48 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 2020 surveys.

The anchialine pools in the vicinity of the NELHA facility are distributed into two main complexes, “Northern” and “Southern”, comprised of five pools in the Northern complex and ten in the Southern complex. The pools within both complexes are relatively clustered, apart from pool S-10, which is situated south of the main Southern complex. A faunal census of each pool was completed from June 20th to September 13th, 2020 during a high-tidal range (+2.07’ to +2.41’). Temperature and salinity were documented, and photographs and visual observations were used to quantify all flora and fauna within and surrounding each pool.

The results of the 2020 survey were generally consistent with previous annual surveys, with observed variances described in the following report. The native red shrimp, ‘ōpae ‘ula (Halocaridina rubra), were found in all pools where invasive fish were absent. ‘Ōpae ‘ula were absent from only one pool, S-1, and this pool was the only pool that invasive fish were present this year. Overall species composition at each pool was similar to previous surveys. Minimal turbidity was observed across sites in 2020, despite the presence of introduced fish in one of the pools. Invasive algae were not observed in any pool. Observations at all pools suggest that the current water quality conditions can sustain a community of native species.

The results of this survey support the conclusion that the surveyed anchialine pools, adjacent to the NELHA facility, are not currently impacted by anthropogenic inputs from local facilities. Pool disturbance due to visitation and the presence of predatory invasive fish were noted as the key drivers of pool degradation. Three pools are already seeing a return to health based on the rapid increase in H. rubra population with the absence of fish within the past year.

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 (fsw = feet salt water) gradients (~15-fsw, ~30-fsw, and ~50-fsw) 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 nine years have found the coral cover to stabilize in the range of ~30.0 – 50.0%. The overall coral cover for 2020 was 37.4%, which is within this range and shows the benthic communities to have exhibited relatively consistent values of coral cover for the last nine years. Permanent pins were established in 2017, which improves the ability to temporally track shifts in benthic composition and structure over time. The data from 2020 were quite consistent to data collected from 2017 – 2019 which indicates the pins are assisting with temporal monitoring of the study sites.

The overall percent coral cover among the six stations was 37.4%, the most dominant corals were *Porites lobata* (23.0%), *Porites compressa (*13.6*%), Porites evermanni* (10.3%), *Pocillopora grandis* (10.3%), *Montipora capitata* (7.3%), *Montipora patula* (5.5%) and *Pocillopora meandrina* (5.1%). These coral species were present among all the stations. Other corals present were *Leptastrea purpurea, Leptastrea bewickensis, Montipora flabellata, Pavona varians, Porites brighami, Porites rus and Fungia scutaria.* These corals accounted for a small percentage of the overall 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 28-year period of this monitoring program. The findings from 2020 show similar values of abundance, diversity, and biomass to 2019. Ultimately, data from the duration of the monitoring program shows the nearshore habitats surrounding NELHA support highly diverse and productive fish assemblages.

An intertidal survey was completed in 2020 to identify and enumerate all species residing within the intertidal habitat surrounding the NELHA facilities. 50-cm wide belt-transects were visually surveyed at each of the six (6) survey site locations used for the marine biota monitoring. The belt transects were deployed perpendicular to the shoreline (mauka to makai) and the surveys were conducted across all intertidal zones from the splash zone, or supratidal zone (above the high-tide line and only exposed to water from wave spray), to the low-tide zone which becomes fully submerged by coastal water. All intertidal organisms within the belt-transect surveys were enumerated to the lowest possible taxonomic level. In addition, targeted nonnative species that are cultivated at NELHA were enumerated in the belt-transect surveys as present or not present. If present, an estimation of abundance was noted. The surveys followed the general guidelines found in the National Park Service, Natural Resource Stewardship and Science, “Long-term Monitoring of Targeted Intertidal Resource Species” report. The intertidal surveys were added to the 2020 monitoring to provide a useful baseline inventory that documents the species occupying this habitat zone to enable detection of alien species or changes in community structure in the future.

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

Table of Contents

ANCHIALINE POOL SURVEY

INTRODUCTION

Anchialine pools are unique ecosystems 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 aquatic species. Hawai'i Island is known for its relatively high concentration of anchialine pools, with many examples at Keāhole Point where the NELHA facility is located. Interest in these ecosystems, previously described by numerous researchers, partially stemmed from the observations of abundant assemblages of tiny, red shrimp (ʻōpae ʻula) that appeared to be restricted to this particular habitat (Holthuis 1973, Maciolek and Brock 1974). Anchialine systems occur globally and can be found on 30 tropical and subtropical islands within the Pacific Ocean, in nearshore areas of the Western Indian Ocean, on Ascension Island in the Atlantic Ocean, and at other inland sites in North America, Mesoamerica, and adjacent to the Red Sea (Chace and Manning 1972, Holthuis 1973, Maciolek 1983, Iliffe 1991, Hobbs 1994, Peck 1994). Anchialine pools are commonly found along the shoreline of West Hawaiʻi, and also occur on Oʻahu, Maui, Molokaʻi, and Kahoʻolawe (Brock et al. 1987, Bailey-Brock and Brock 1993, Yamamoto et al. 2015).

The unusual environmental conditions that shape anchialine pool ecosystems have resulted in the presence of specialized native and endemic species (Bailey-Brock and Brock 1993, Yamamoto et al. 2015). As elsewhere, organisms found within the anchialine pools in Hawaiʻi are uniquely suited to the varying salinity conditions. Specialized species include crustaceans, mollusks, plants, and other taxa. Table 1 summarizes species previously reported from the pools located within and adjacent to the NELHA facility (Brock 2008, Ziemann and Conquest 2008).

Two specialized decapod shrimp species, endemic Halocaridina rubra (ʻōpae ʻula) and indigenous Metabetaeus lohena, are common inhabitants in many of the anchialine pools at NELHA. H. rubra are omnivorous, and preferentially inhabit anchialine pools throughout the day to feed on microalgae, macroalgae, and detritus (Bailey-Brock and Brock 1993). Anchialine pools are typically connected to one another through lava tubes, rock fissures, and micro-cracks in the surrounding basalt substrate. Reproduction and larval dispersal of H. rubra generally occur within these subterranean (hypogeal) sections of anchialine systems. H. rubra have a relatively long lifespan of approximately 10 - 20 years, and are key grazers within anchialine pools, maintaining a controlled standing crop of plants, bacteria, diatoms, and protozoans in the pools through active grazing. This 'gardening' role contributes to the overall health of anchialine pool ecosystems, allowing other species to reside within the sunlit (epigeal) portion of the pools. Because of this critical ecosystem function, H. rubra are thought to be a keystone species within these systems

PLANB CONSULTANCY

(Bailey-Brock and Brock 1993). The relatively larger indigenous shrimp species, M. lohena, is omnivorous occasionally feeding on H. rubra (Yamamoto et al. 2015).

Introduced fish species (e.g. mosquitofish, guppies, tilapia) are a substantial threat to native species within anchialine pools in Hawai'i and can cause rapid and sharp declines in H. rubra abundance due to focused predation. The presence of invasive fish, which are active during the day, can also drive shifts in H. rubra foraging behavior by increasing nocturnal activities (Capps et al. 2009, Carey et al. 2011). Typically, anchialine pools with well-established populations of introduced fish are not able to support H. rubra and other native shrimp assemblages during the day in open, epigeal areas. However, the shrimp are able to take refuge within basalt fissures and cracks within the pool substrate, then emerge after dark to forage.

Several anthropogenic stressors can alter the health of anchialine pool ecosystems. Coastal development and other shoreline alterations can cause structural damage to the pools and/or disrupt surrounding groundwater influx and condition. Increased human presence adjacent to the pools can also lead to invasive species introductions and can alter to pool surroundings and substrate due to visitation and swimming. Additionally, recent sea-level rise forecast models suggest that anchialine pools on Hawaiʻi Island and throughout the state will eventually form larger pool complexes and have more frequent surface connections to the ocean in the coming decades (Marrack and O'Grady 2014). Concurrently, new anchialine pools may emerge further inshore, depending on elevation and groundwater connectivity. These anticipated changes associated with predicted sea-level rise could dramatically impact anchialine pool ecology. Fortunately, submarine connections between pools will likely allow H. rubra and other shrimp species to populate new higher elevation pools.

Recent investigations examining the DNA of H. rubra provided an improved understanding of population dynamics and contributed to more effective monitoring and management of anchialine pools in Hawaiʻi (Santos 2006). This study showed that two distinct lineages of H. rubra exist on the East and West coasts of the Hawaiʻi Island. Also, within small-scale geographic areas, populations were structured with low levels of gene flow, suggesting that local assemblages of H. rubra are genetically unique (Santos 2006). Therefore, local scale monitoring of anchialine pools in Hawaiʻi (e.g. at the level of pools and pool complexes) is appropriate for determining H. rubra population status and is utilized in this survey.

The two groups of pools adjacent to the NELHA facility have been surveyed for more than 30 years (Brock 1995, Brock 2008, Oceanic Institute 1997, Oceanic Institute 2007, Ziemann and Conquest 2008, Bybee et al. 2012, Bybee et al. 2013, Bybee et al. 2014, Whale Environmental Services 2015, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019). Through this continued annual monitoring program at the pools, changes in communities have been noted since 1989, with shrimp becoming absent in certain pools due to

Poeciliid fish (mosquitofish and guppies) introductions (Brock 2008, Ziemann and Conquest 2008). More recently, signs of visitation and usage have been noted for certain easily accessible pools (Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019).

Results of the 2020 survey as part of NELHA's Comprehensive Environmental Monitoring Program (CEMP) are reported subsequently.

METHODS

Anchialine pools located within the NELHA facility form localized complexes, including five pools in the “Northern complex” and ten pools in the “Southern complex” (Figures 1 - 3). The Northern pool complex, including pools N-1 through N-5, is located approximately 100m inland of the cobble beach at Hoʻona Bay (Figure 2), and the Southern pool complex, including pools S-1 to S-10, is located approximately 200 m to 225 m from the shoreline at Wawaloli Beach Park, adjacent to Makako Bay Drive, with the exception of pool S-10, which is located approximately 500m south of the main pool complex (Figure 3).

Table 2 describes the location and size of each pool at the NELHA site. A Garmin 76Cx hand-held GPS unit was used to locate each pool during the 2020 survey based on previously recorded latitudes and longitudes. In 2017, site coordinates were updated to a five-decimal system for improved ease of pool relocation (Table 2). Upon arrival at each site, pool diameter was confirmed from measurements first reported by Brock 2008 (Table 2), except for pool S-10 which was first surveyed in 2015 (Whale Environmental Services 2015). Pool dimensions and basin characteristics for historically surveyed pools are included in Appendix 1.1 (Brock 2008).

Water level, water chemistry, and appearance of the anchialine pools vary with tidal level during the survey. The effect of tidal level is particularly apparent for the Northern pool complex, including pools N-2, N-3, N-4, and N-5. At low tide, these pools are separated by basalt substrate outcrops, however at high tide (> +2.1ft), these pools start to form a single body of water (Burns and Kramer 2018). This interconnectivity is particularly apparent during annual peak tides (also known as King’s tides) during which tidal levels exceed 2.4 ft. While the water level in the Southern group pools is also strongly tidally affected, pools were not observed to be interconnected during the 2020 survey.

Faunal surveys were conducted from June 20th to September 13th, 2020. Faunal observations for the 2020 survey were collected at tide levels just below the daily maximum to provide sufficient water for organismal observations. Sampling of the pools was conducted at tidal levels ranging from +2.07 to +2.41ft . Temperature and salinity measurements were collected concurrently using a hand-held YSI Pro-Series Quatro water quality meter and data logger. Flora and fauna within and surrounding each pool was documented using visual observations and photographs taken with a FujiFilm FinePix XP130 digital waterproof camera. In-situ H. rubra counts were conducted by randomly placing ruler in the pool and counting a 10x10cm area to calculate density. The number of replicate counts depended on pool area and depth and ranged from 3 to 7 replicates. H. rubra density was determined for each quadrat, then averaged for each pool. H. rubra density was calculated for an area of 0.1 m^2 to allow for comparisons with previous survey results (Tables 3 and 4, Appendix 1.2).

RESULTS

Water quality measurements and faunal census results from the 2020 survey are summarized in Tables 3 and 4, and include temperature and salinity observations, H. rubra density, Poeciliid presence, Ruppia maritima presence, and other notes on pool status. Faunal presence at the pools during the 2020 survey was generally consistent with recent previous surveys (Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019). Pool characteristics were partially explained by location, with higher species diversity and higher density vegetation surrounding the Northern pools compared to the Southern pools (Figures 4 - 14). The Southern pools tended to be surrounded by non-vegetated or very sparsely vegetated basalt. Some Southern pools also had more signs of visitation, such as moved rocks, trash, and the presence of people.

Southern pools (with the exception of pool S-10) were less saline and slightly cooler compared to the Northern pools. For the Southern pools S-1 through S-9, temperature ranged from 22.4 to 22.6 °C and salinity ranged from 9.6 to 11 ppt. Slightly higher temperature and salinity readings were recorded for distal pool S-10 (23 °C, 12 ppt., respectively) (Table 4). For the Northern pools, temperature and salinity were relatively higher, ranging from 22.5 to 27.7 °C and from 11.6 to 12.8 ppt. (Table 3). This pattern observed for water quality characteristics corroborates previous surveys and reflects varying degrees of groundwater and marine influence within the pools (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019, Appendix 1.1).

The majority of the Northern anchialine pools hosted higher densities of H. rubra compared to the Southern pools (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Annandale 2019) (Figure 5). During the 2020 survey, H. rubra were observed at all of the Northern Pools. H. rubra were also present in N-4 in 2019 , where they were previously absent in the 2018 survey and H. rubra was now present in N-3 where they were previously absent in the 2018 and 2019 surveys (Burns and Kramer 2018, Burns and Annandale 2019). H. rubra were still observed at a very high densities at pool N-5 similar to 2018 and 2019 surveys, where they were previously absent due to intensive substrate disturbance in 2016 (Burns and Kramer 2016, Burns and Kramer 2018, Burns and Annandale 2019).

Within the Southern complex, three pools (S-7, S-8, and S-5) had very high densities of H. rubra (~ 200 individuals/ 0.1 m2), and three pools (S-3, S-4, and S-6) had high densities of H. rubra (~100 200 individuals/ 0.1 m2) (Table 4). H. rubra were present in very high densities in S-7 where H. rubra had been absent in previous surveys and invasive fish were observed (Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019). H. rubra was also observed in high densities in pools S-5 and S-8 where they had not been observed in previous surveys (Burns and

Kramer 2017, Burns and Kramer 2018) and were observed in very low densities in 2019 (Burns and Annandale 2019). Pool S-1 was the only pool H. rubra was absent (Figures 9).

During the 2020 survey, M. lohena was observed within several Southern pools, including S-3, S-6, S-8, S-9, and S-10, and were noted to be particularly abundant at pool S-10 (Figure 14). M. lohena was also observed at three of the Northern pools (N-1, N-2, and N-5), compared to 2018 where M. lohena was absent from the Northern complex (Burns and Kramer 2018). Macrobrachium grandimanus, an uncommon indigenous species, was not observed at any of the pools during the 2020 surveys compared to previous years (Burns and Kramer 2018, Burns and Annandale 2019). Historically and in more recent surveys, M. grandimanus had been observed in pools S-1, S-5, S-7, S-8, and N-3 (Bybee et al. 2014, Burns and Kramer 2017, Burns and Annandale 2019) (Appendix 1.2).

Introduced Poeciliid fish, including Gambusia affinis and Poecilia spp. were observed at one of the southern area pools, S-1, in 2020 compared to 2019 where they were observed at four of the southern area pools (S-1, S-5, S-7, and S-8). In the 2020 survey, Poeciliid fish were absent from pools S-7, S-8, and S-9 in which they were very abundant in previous surveys and have been recorded since 2002, 2007, and 2008 respectively (Burns and Kramer 2018 , Burns and Kramer 2018, Burns and Annandale 2019). In S-1, where introduced fish were present, shrimp populations, including H. rubra and M. lohena, were absent. As of the survey date in September 2020, introduced fish were not observed in any of the Northern pools (Table 3).

Tables 3 and 4 list additional species observed within and around each pool during in-situ visual observations. Generally, higher species diversity was observed for the Northern pools, which were typically surrounded by dense vegetation (Figures 4 - 7). Similar to previous surveys, Northern pools N-1, N-3, and N-5 hosted assemblages of the aquatic grass, Ruppia maritima (Figures 6 and 8). Thiarid snails (Melanoides tuberculata and Terbia grainers) were observed in three of the five Northern pools (N-2, N-4, and N-5). Similar to previous surveys, very high densities of Thiarid snails were observed within the Northern pool N-4 (Table 3) (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019, Appendix 1.2).

Significant archeological features were noted at several pools in both the Northern and Southern complexes, including pools N-1, N-5, S-5, S-7, S-8, and S-10. Features included water-worn basalt and/or coral stones within or surrounding the pools, walls or structures surrounding the pools, and water-worn stones embedded within trails leading to the pools.

DISCUSSION

The West Hawai'i coastline hosts more than 500 anchialine pools, which are unique, tidally influenced brackish ecosystems that host a specialized array of species (Yamamoto et al. 2015). Two complexes of pools adjacent to the NELHA facility have been monitored for multiple decades (Appendix 1.2), providing a foundation of data for evaluating status and change within these ecosystems. These datasets can help improve management of the pools locally and throughout Hawai'i Island by tracking ecosystem changes overtime and evaluating causative factors.

The anchialine pools at NELHA were resurveyed in June, July, and September 2020, and compared to previous censuses, spanning back to May 1989. The census results from 2020 show the anchialine pool ecology has remained relatively stable in the last several years except for specific changes such as the introduction of Poeciliids (Bybee et al. 2013, Bybee et al. 2014, Whale Environmental Services 2015, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Burns and Annandale 2019). The major drivers of pool ecology were: 1. pool location, either Northern or Southern areas, 2. groundwater influence reflected in temperature and salinity readings, 3. the presence or absence of introduced fish, and 4. the intensity of human visitor impacts to the pools (Tables 3 and 4).

Water quality is a key indicator in assessing anchialine pool ecosystem health and measurements collected in 2020 were consistent with surveys in previous years suggesting that groundwater influence within the pools has remained relatively consistent (Bybee et al. 2014, Whale Environmental Services 2015, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Appendix 1.1). Pool temperatures ranged from 22.5 to 27.7 °C and salinity ranged from 9.6 to 12.8 ppt. The Southern pools were cooler and less saline during the 2020 survey compared to the Northern pools. This suggests Southern pools have a relatively higher groundwater influence or the Northern pools have a greater ocean influence due to the pools' proximity to the shoreline. Pool S-10 did have higher water temperatures than previous years, potentially due to the removal of the Christmas Berry (*Schinus terebinthifolia*) that was recently cut down (Figure 14). The tree previously shaded the pool but was encroaching the pool basin and introduced substantial organic matter to the pool. Under

PLANB CONSULTANCY

the guidance of Hui Loko network, the Christmas Berry was removed to reduce the amount of introduced organic debris from leaf litter accumulating in the pool. The bush was removed on January 9th, 2020 and covered in black landscaping mesh to prevent new growth offshoots from appearing.

All the Northern pools hosted H. rubra and three hosted M. lohena. H. rubra was now present in pool N-3, it was last observed in pool N-3 in the 2017 surveys. In 2018, an unusually dense and partially decaying assemblage of R. maritima was observed in pool N-3, which may have altered water quality (e.g. depleted oxygen levels) within the pool and deterred H. rubra (Approximately 5 gallons of decaying R. maritima material were removed from the pool following the survey). The two nearshore fish present in N-3 in 2019 were also not observed in the 2020 survey which may also be a factor in H. rubra returning. A very high density of H. rubra remains in N-5 in 2020, similar to the 2018 and 2019 surveys. A dramatic increase in H. rubra density was noted in 2018 compared to the 2016 survey in which H. rubra was absent and to the 2017 survey in which a moderate population was observed. In April 2016, obvious signs of visitation and severe physical disturbance were documented (Burns and Kramer 2016).

At very high tides, pools N-2, N-3, N-4 and N-5 become interconnected, which provides a simple mechanism for organismal exchange following depletion events (in addition to submarine/ hypogeal pool connections). This interconnectivity suggests that H. rubra can easily move from pool to pool. This interconnectivity also likely promoted the rapid replenishment of H. rubra within pool N-5 and the return of H. rubra to pool N-3. As documented in previous years, Poeciliid fish were not observed in any Northern pools which allows for the continued diurnal presence of H. rubra (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Burns and Kramer 2018, Appendix 1.2).

The historical introduction of Poeciliid fish within anchialine pools at NELHA has significantly affected pool ecology, but in 2020, these fish were only found in one Southern area pool, S-1 (Figure 9). Where introduced fish were present, shrimp populations, including H. rubra and M. lohena, were absent. H. rubra and M. lohena were not observed in S-1 during the 2020 survey despite the presence of a few individuals within deep cracks and crevices in the 2019 survey. Capps et al. (2009) and Carey et al. (2011) suggest that H. rubra within fish-invaded pools may alter their behavior by only residing within protected areas (inaccessible by fish) of the pool, or by only entering the epigeal regions of the pool at night to feed. During this survey, pools were surveyed during daylight hours and the nocturnal behavior of H. rubra was not assessed.

Poeciliids were not observed in pools S-5, S-7, and S-8 during the 2020 survey, where they were abundant during the 2019 and other past surveys. With the absence of introduced Poeciliid fish in pools S-5, S-7, ad S-8, the *H. rubra* populations dramatically increased. These pools have the highest densities of the southern pools and are comparable to the northern pools in shrimp density. In past reports, S-7 and S-8 have been recommended as good candidates for introduced Poecilild removal to restore native shrimp populations. NELHA staff responded to these recommendations and started a concerted effort to remove the introduced Poeciliids from the four pools impacted by these guppies (S5, S1, S7, and S8). The removal efforts were carried out with support from the Hawaii Island Hui Loko network and Hawaii State Parks. Eradication methods utilized carbon dioxide addition and baited fish traps. Carbon dioxide (CO2) is an emerging alternative to traditional chemical control agents because it has been demonstrated to be toxic to fish but is also naturally occurring and readily neutralized. The increase in *H. rubra* indicates the removal efforts have helped to reduce the impact of this invasive species on the anchialine pools.

Signs of visitor impacts were observed at several of the Southern pools in 2020. Affected pools were generally near access points, including Wawaloli Beach Park and Makako Bay Drive, and were also relatively visible due to minimal surrounding vegetation. Signs of recent visitor impacts were observed at four of the surveyed pools in the Southern complex (S-1, S-3, S-4, and S-5). Modifications in and around the pools included the addition of rocks to pool basins, litter, and the possible removal/addition of Poeciliid fish and H. rubra for fishing bait and other uses. On the visit to the pools on June 20, 2020, a group of people and a dog were observed swimming in pool in pool S-5, so the pool was not surveyed that day. The water appeared more murky than usual after the group left. Overall, visitation and disturbance can cause damaging physical changes to the pools. Local schools arrange field trips to the southern pools to raise awareness of these ecologically important habitats, however this may result in more visitation and disturbance to the sites. Substrate and surrounding rock movements can influence overall pool ecology, by altering light, water depth, turf algal growth, and food availability for H. rubra and other shrimp species. Trash and other refuse present may affect the water quality of the pools.

Predicted sea-level rise is a significant future threat to Hawaiian anchialine pool ecosystems will likely drive substantial changes to pool interconnectedness, depth, location, and water chemistry (Marrack and O'Grady 2014). These physical changes will have a critical influence on faunal composition within the pools. The interconnectedness of pools with sea-level rise can allow Poeciliids to invade nearby pools that currently do not have introduced fish. King Tides or seasonal high tides offer a preliminary view of potential anchialine pool ecosystem changes associated with rising sea-level.

The results of the 2020 anchialine pool survey did not indicate that anthropogenic inputs from local aquaculture and other facilities at NELHA are degrading the pools. Pool disturbance due to visitation and the presence of predatory invasive fish were noted as the key drivers of pool degradation. The majority of the surveyed pools at NELHA had water quality and other ecosystem conditions supporting a healthy native shrimp population.

FIGURES AND TABLES

Figure 1. Overview of the study area, which includes Northern and Southern anchialine pool complexes in the vicinity of the NELHA facility. For this annual report, the pools were surveyed from June 20th through September 13st 2020. (Map generated using Google Earth 7.1.7).

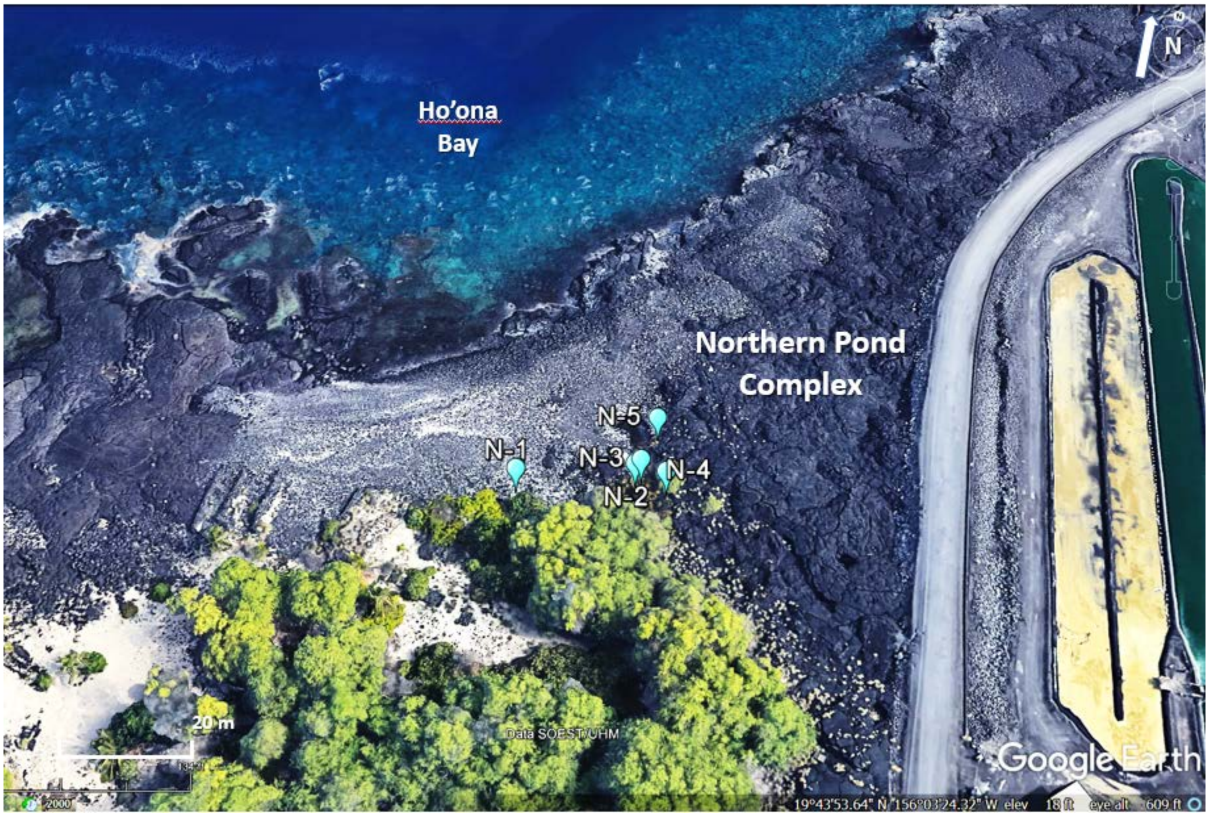


Figure 2. Locations of the Northern complex of anchialine pools (N – 1 through N –5), located inland of the cobble beach at Ho'ona Bay. The Northern pools were surveyed on September 13th, 2020. (Map generated using Google Earth 7.1.7).

Figure 3. The Southern complex of anchialine pools (S-1 through S-10), located inshore and south of the Wawaloli Beach Park facility at NELHA. The Southern pools were surveyed from June 20th through July 19th, 2020. (Map generated using Google Earth 7.1.7).

Figure 4. (left) Northern pool, N - 1 at a tide level of +2.29’, and (right) leaf litter floating on the surface of the pool.   Pools in the Northern group were typically characterized by relatively diverse faunal assemblages and dense surrounding vegetation. Surrounding vegetation has continued to encroach pool N – 1.

Figure 5. (left) Northern pool N-2, at a tide level of +2.24‘, and (right) Halocaridina rubra (‘ōpae ‘ula) and algae within the pool.

Figure 6. (left) Northern pool N-3 at tide level +2.21' in September 2020 and (right) Ruppia maritima comprises a portion of the pool basin.

Figure 7. (left) Northern pool, N-4, at tide level +2.19' in September 2020

Figure 8. Northern pool N-5, at tide level +2.07', continued to show signs of improved health after intensive physical disturbance noted during the 2016 survey.

Figure 9. Southern pool, S-1, at a tide level of + 2.31'

Figure 10. (left) Southern pool, S-3, at a tide level of +2.41. (right) Southern pool, S-4, at a tide level of +2.39.

Figure 11. Southern pool S-5 at a tide level of +2.35 in July 2020.

Figure 12. (right) Southern pool S-6 at a tide level of +2.35 in June 2020. (left) Southern pool, S-9 at a tide level of +2.29 in June 2020

Figure 13. (left) Southern pool, S-7, at a tide level of +2.26’. (right) Southern pool, S-8, at tide level +2.23.

Figure 14. Southern pool, S-10 (left), at a tide level of +2.19’. Christmas berry (Schinus terebinthifolius) that was encroaching on the pool recently cut and covered (right).

Table 1. List of species previously observed in anchialine pools within and surrounding the NELHA facility. (Compiled from previous annual reports).

	Taxon	Common/ Hawaiian Name	Classification
Anchialine pond: Native	*Halocaridina rubra*	Ōpae ʻula/ Ōpae hiki	Shrimp (Decapoda)
	Metabetaeus lohena		Shrimp (Decapoda)
	Macrobrachium grandimanus	Ōpae ʻoehaʻa	Shrimp (Decapoda)
	Ruppia sp.	Widgeon grass	Monocot plant (Ruppiaceae)
	Assiminea sp.	Snail	Aquatic Snail (Gastropoda)
	Theodoxus cariosa	Hihiwai	Limpet (Gastopoda)
	Trichocorixa reticulata	Water boatman	Aquatic insect (Arthropoda)
	Pantala flavescens	Globe skimmer	Dragonfly (Arthropoda)
	Ajax junior	Common green darner	Dragonfly (Arthropoda)
	Oligochaeta sp.	Worm	Aquatic worm (Oligochaeta)
	Palaemon debilis	ʻŌpae hula, Glass shrimp	Shrimp (Decapoda)
	Metopograspus meson	Kukupa	Crab (Decapoda)
	Grasps 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)
	Argiope appensa	Garden spider	Spider (Arthropoda)
	Tramea lacerata	Black saddlebags	Dragonfly (Arthropoda)
	Ischnura posita	Fragile forktail damselfly	Damselfly (Arthropoda)
Terrestrial plants	*Bacopa sp.*	Pickleweed (Invasive)	Plantaginaceae
	Capparis sandwichiana	Maiapilo (Endemic)	Capparaceae
	Cladium sp.	Sedge	Cyperaceae
	Ipomoea pes-caprae	Pōhuehue, Beach morning glory	Convolvulaceae
	Morinda citrifolia	Noni	Rubiaceae
	Pennisetum setaceum	Fountain grass (Invasive)	Poaceae
	Pluchea odorata	Pluchea	Asteraceae
	Prosopis pallida	Kiawe, mesquite tree	Mimoseae
	Scaevola taccada	Naupaka	Goodeniaceae
	Schinus terebinthifolius	Christmas berry (Invasive)	Anacardiaceae
	Sesuvium portulacastrum	ʻĀkulikuli, Pickleweed	Aizoaceae
	Thespesia populnea	Milo	Malvaceae
	Tournefortia argentea	Beach heliotrope	Boraginaceae

Table 2. Coordinates and sizes of anchialine pools located 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	19.73137	-156.05681	93
	N-2	19.73142	-156.05659	1
	N-3	19.73143	-156.05658	22.5
	N-4	19.73141	-156.05653	4
	N-5	19.73153	-156.05656	22.5
Southern Ponds	S-1	19.71676	-156.04893	1.7
	S-2	19.71670	-156.04890	1
	S-3	19.71680	-156.04871	1
	S-4	19.71680	-156.04871	0.01
	S-5	19.71680	-156.04871	5
	S-6	19.71685	-156.04814	0.01
	S-7	19.71660	-156.04810	1.4
	S-8	19.71650	-156.04810	1
	S-9	19.71680	-156.04810	0.01
	S-10	19.71380	-156.04820	0.9**

Table 3. Faunal census data collected for the Northern pool complex of anchialine pools at the NELHA facility. The pool surveys were conducted on September 13th, 2020, at a tidal level ranging from +2.07' to +2.29'. Poeciliid fish and Ruppia maritima were recorded as present or absent, and other organisms in the observed in each pool were noted in the comments. Halocaridina rubra densities are reported as a mean number of individuals per 0.1 square meters (± one standard error unit).

Area	Pond number	Survey Date	Survey Time	Water Quality		Faunal Surveys				
				Temp (C°)	Salinty (ppt)	Substrate	*H. rubra* (Count/0.1m^2) (Mean ± SE)	Poeciliids	*Ruppia maritima*	Comments/ Other Species
Northern Ponds	N-1	9/13/2020	12:26	22.5	12.76	Sandy pebble substrate, some silt and shell fragments, rock wall mauka section	197 ± 37	absent	present	Lots of leaf litter, sticks, and seeds floating on surface. *M. lohena, Scaevola taccada, Cypenus laevigatus, Prosopis pallida, Tournefortia argentea, Thespesia populnea, Sesuvium portulacastrum, Lyngbya sp., Argiope appensa, Anux junius*
	N-2	9/13/2020	12:09	27.1	11.74	Basalt rubble, pahoehoe surroundings, some sediment and silt	188 ± 48	absent	absent	*M. lohena, Sesuvium portulacastrum, Schizothrix clacicola*, Lyngby sp., thiarid snails, ~1in centipede in pool
	N-3	9/13/2020	12:01	24.3	11.63	Silt, sediment, and shell fragments, underlying cobble, pahoehoe surroundings	158 ± 48	absent	present	*Lyngbya sp., Sesuvium portulacastrum, Scaevola taccada, Cypenus laevigatus, Anux junius* mating
	N-4	9/13/2020	11:55	27.7	11.58	Silt bottom with cobble and shells, pahoehoe surroundings	97 ± 31	absent	absent	Thiarid snails, *Sesuvium portulacastrum, Cypenus laevigatus, Schizothrix clacicol, Pennisetum setaceum, Prosopis pallida, Pluchea carolinensis, Anux junius* mating
	N-5	9/13/2020	11:30	24.1	12.73	Water-worn (rounded) basalt cobble and coral, some sediment and silt	290 ± 69	absent	present	*M. lohena, Sesuvium portulacastrum, Anux junius* mating (possibly depositing eggs), *Pantala flavescens*, Thiarid snails

PLANB CONSULTANCY

Table 4. Faunal census data collected for the Southern pool complex of anchialine pools at the NELHA facility. The pool surveys were conducted on June 20th and July 19th, 2020, at a tidal level ranging from +2.19' to +2.40'. Poeciliid fish and Ruppia maritima were recorded as present or absent, and other organisms in the observed in each pool were noted in the comments. Halocaridina rubra densities are reported as a mean number of individuals per 0.1 square meters (± one standard error unit).

Area	Pond number	Survey Date	Survey Time	Water Quality		Faunal Surveys				
				Temp (C°)	Salinty (ppt)	Substrate	*H. rubra* (Count/0.1m^2) (Mean ± SE)	Poeciliids	*Ruppia maritima*	Comments/ Other Species
Southern Ponds	S-1	7/19/2020	14:10	22.5	10.5	Basalt rubble/ pebbles, shell fragments, pahoehoe surroundings	absent	present	absent	*M. lohena*, *Pennisetum setaceum*, *Schinus terebinthifolius*, *Schizothrix clacicola*, *Poecilia* sp. or *Gambusia affinis* (~8 fish < 1cm)
	S-2	7/19/2020	14:40	-	-	-	-	-	-	Pond filled in with rocks
	S-3	7/19/2020	14:32	22.4	10.7	Basalt rubble/ pebbles, mixed pahoehoe surroundings	56 ± 12	absent	absent	*M. lohena*, white amphipod, no surrounding vegetation
	S-4	7/19/2020	14:27	22.4	11.0	Basalt rubble, pahoehoe surroundings	91 ± 24	absent	absent	No surrounding vegetation.
	S-5	7/19/2020	14:18	22.6	10.7	Basalt rubble and coral, mixed pahoehoe surroundings,	196 ± 53	absent	absent	*Pennisetum setaceum*, *Schizothrix clacicola*, Minimal vegetation around pond. Signs of visitation – people and dogs swimming on 6/20/2020
	S-6	6/20/2020	16:10	22.4	10.2	Very narrow basalt crack, a'a surroundings.	103 ± 22	absent	absent	*H. rubra* very small, *M. lohena*, no surrounding vegetation, *Capparis sandwichiana* nearby, Abundant ants at pond edge
	S-7	6/20/2020	16:32	22.5	9.85	Basalt rubble (some rounded), mixed pahoehoe surroundings	204 ± 18	absent	absent	*Pennisetum setaceum*, *Capparis sandwichiana*, *Schizothrix clacicola*, green algae, Opihi shells observed. Rounded stones along basin and trail.
	S-8	6/20/2020	16:40	22.4	10.1	Basalt rubble with a few white coral stones, shell fragments, pahoehoe surroundings	198 ± 38	absent	absent	*M. lohena*, *Pennisetum setaceum*, *Capparis sandwichiana*, *Schizothrix clacicola*, Water-worn wall with rounded corals surrounding pond. Opihi shells observed. Trail to pond.
	S-9	6/20/2020	16:21	22.4	9.64	Basalt crack, a'a surroundings.	133 ± 93	absent	absent	*H. rubra* very small. *M. lohena*, abundant ants at pond edge. No surrounding vegetation.
	S-10	7/19/2020	13:49	23.0	12.0	Pahoehoe with light organic material and some sand, small basalt pebbles	115 ± 37	absent	absent	*M. lohena* (common), *Schinus terebinthifolius* cut and covered, *Pennisetum setaceum*, *Talinum fruticosum*, *Pluchea carolinensis and Leucaena leucocephala* nearby, green algae

MARINE BENTHIC BIOTA SURVEY

INTRODUCTION

The Natural Energy Laboratory 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-related 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 (~2,000 to ~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 48 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 2016, 2017, and 2018 surveys are summarized by Burns and Kramer (Burns and Kramer 2016, 2017, 2018). The 2019 surveys are summarized by Burns and Annandale and the results and findings for the 2020 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 13). 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. Surveys were conducted along the pre-determined isobaths at long-term monitoring pins installed in 2017. The long-term monitoring pins are located at the following coordinates. Coordinates are only recorded for the 50-fsw depth at sites with steep slopes due to the close linear proximity to the moderate and shallow survey depths. The pins can be found by swimming up-slope from the 50-fsw pin along the bearing indicated in the table below:

Site	GPS	Notes
Ho'ona Bay	50: 19.73255, - 156.0578	Mooring located at 30fsw. Pins align across depth gradient on 160-degree bearing and are adjacent to mooring. Surveys conducted along isobaths on west side of each pin.
NPPE	50: 19.73137, -156.0609	Pins align across depth gradient on 90-degree bearing. Surveys conducted along isobaths on west side of each pin.
12" Pipe North	50: 19.72825, -156.0625	Pins are just to south of pipe platform. Chain from pipe aligns with 30fsw pin, and bearing is consistent to 15fsw pin. Surveys conducted along isobaths on southwest side of each pin.
12" Pipe South	50: 19.72627, -156.06159	Pins are located to south of pipe. Follow 50-degree bearing from pipe at each isobaths to the pins. Surveys conducted along isobaths on south side of each pin.
18" Pipe	50: 19.72176, -156.05868	Pins are located to south side of pin at each isobaths. Surveys conducted along isobaths on south side of each pin.
Wawaloli	50: 19.71463, -156.05188 35: 19.7149, - 156.05136 15: 19.71535, - 156.05086	Pins are located at each bearing. Isobaths are much more separated than other sites. Surveys conducted along isobaths on south side of each pin.

PLANB CONSULTANCY

Photographs were taken of each quadrat using an underwater camera. 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, which allows the photos to 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 13. 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. An updated map with aerial imagery is provided on the right with North arrow for spatial reference.

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 5**.**

The overall percent coral cover among the six stations was 37.4%, the most dominant corals were *Porites lobata* (23.0%), *Porites compressa (13.6%), Porites evermanni* (10.3%), *Pocillopora grandis* (10.3%) *Montipora capitata* (7.3%), *Montipora patula* (5.5%) and *Pocillopora meandrina* (5.1%). These coral species were present among all the stations. Other corals present were *Leptastrea purpurea, Leptastrea bewickensis, Montipora flabellata, Pavona varians, Porites brighami, Porites rus and Fungia scutaria.* These corals accounted for a small percentage of the overall relative benthic cover. Values of percent cover for the dominant coral species at each station and depth are provided in Table 5.

P. lobata was the most dominant coral among all three depths throughout the six monitoring stations. *P. lobata, P. evermanni, P. compressa and M. capitata* were the dominant corals in the shallow (~15-fsw) and moderate depths (~35-fsw) among the six stations. *P. lobata* and *P. compressa* were the most dominant corals at the deep depths (~50-fsw) among the six stations. *P. meandrina* was most abundant at the 12” Pipe stations. *P. evermanni* was most abundant at Hoʻona Bay, the 18” Pipe and the Wawaloli stations. *P. compressa* was most abundant at Hoʻona Bay and NPPE stations. *P. lobata* had the highest levels of abundance at Hoʻona Bay, NPPE, and 18” Pipe stations. *P. lobata* had the highest levels of coral cover among all six stations compared to the other observed species of coral. The distribution, abundance, and percent cover of the corals among all stations in 2020 were similar to previous years. Photographs of each photographed quadrat are included in Appendix 4.

Table 5 provides a detailed comparison of the percent cover, species richness, and species diversity of corals among all stations and survey depths. Similar to previous years, the Hoʻona

PLANB CONSULTANCY

Bay, NPPE, and 18” Pipe sites exhibited the highest levels of coral cover (51.0% 42.1%, and 41.5% respectively). Coral cover at these three sites was dominated by *P. lobata, P. evermanni, and P. compressa.* Species richness and species diversity was highest at 12” Pipe and Hoʻona Bay stations. The benthic substrate at these sites were predominantly occupied by *P. lobata, P. evermanni*, *P. compressa*, and *M. capitata (*Table 5). Values of coral cover exhibited statistically significant differences among the sites. Overall coral cover was significantly higher ($p<0.05$, Kruskal-Wallis) at Hoʻona Bay, NPPE and the 18” Pipe compared to the other sites. *P. lobata* and *P. compressa* also exhibited significantly higher values of cover ($p<0.05$, Kruskal-Wallis) at Hoʻona Bay, NPPE and the 18” Pipe compared to the other sites. *M. capitata* exhibited significantly higher values of cover ($p<0.05$, Kruskal-Wallis) at both 12” Pipe and the 18” Pipe stations.

Values of overall coral cover were statistically similar among all depths. Deep depths had the highest cover of 39.18%, with moderate and shallow sites exhibiting 37.3% and 32.8% coral cover. *P. compressa* showed significantly higher values of cover ($p<0.05$, Kruskal-Wallis) at the deep sites compared to moderate and shallow. Among the deep stations, coral was most abundant at NPPE and Ho’ona Bay sites (49.4% and 62.7%). These statistical patterns in coral cover are similar to the 2017 – 2019 survey years with the same species and depths exhibiting higher levels of coral cover compared to the other locations. The general patterns in coral cover and diversity among the surveyed depths and sites are similar to previous years and showed similar patterns in coral cover among sites in 2016-2018 (Burns and Kramer 2016-2018, Burns and Annandale 2019). Coral cover values were very similar to 2019, which indicates stability in coral community structure among the survey locations in the last two years.

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., Echinothrix spp., Tripnuestes spp., Acanthaster spp.*), sponges, flatworms, and sea cucumbers (*Holothurian spp.*) were observed among the study sites. Counts of 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 5: Summary of benthic substrate data and comparative analyses from surveys conducted in August 2020.

Station	Wawaloli				18" Pipe				12" Pipe South		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Overall coral cover	21.40	33.40	18.60		39.10	37.10	48.30		24.60	37.00	24.00
P. lobata	14.30	18.50	10.90		32.30	30.80	32.50		14.70	21.00	14.00
P. evermanni	8.75	11.40	8.00		10.00				8.00	12.00	
P. compressa						15.00	14.78		4.00	9.00	7.75
P. meandrina						3.50				7.50	5.00
P. grandis									5.00	20.00	
M. capitata	6.33	12.50	7.80		6.50	7.75	8.33		5.75	9.60	6.60
M. patula	5.67	8.00	4.20		8.33	10.00			7.66	4.00	
Species count	4.00	4.00	4.00		4.00	5.00	3.00		6.00	7.00	4.00
Species diversity (H)	1.29	1.22	1.18		1.23	1.27	1.34		1.43	1.40	1.26

Station	12" Pipe North				NPPE				Hoona Bay		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Overall coral cover	35.70	24.30	32.10		33.90	43.00	49.40		42.30	48.18	62.70
P. lobata	25.20	15.50	17.50		25.30	28.40	24.90		25.60	31.00	32.10
P. evermanni	18.33	5.75	8.50		8.66	4.00			15.44		15.00
P. compressa	8.00	8.00	6.50		3.00	13.33	24.30			14.30	25.30
P. meandrina	9.00	5.00	10.00			4.00			3.50		
P. grandis			8.00								
M. capitata	3.00	8.67	8.50		5.50	3.50	2.00		6.00	6.75	8.00
M. patula	4.66	3.00			5.50					4.00	
Species count	6.00	6.00	6.00		5.00	5.00	3.00		4.00	4.00	4.00
Species diversity (H)	1.35	1.32	1.36		1.34	1.39	1.36		1.38	1.39	1.41

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	30.70	41.50	28.53	30.70	42.10	50.96	**<0.01**	32.83	37.34	39.18	0.21
P. lobata	14.56	31.86	16.56	19.40	26.20	29.61	**<0.01**	22.90	24.31	21.98	0.40
P. evermanni	10.00	10.00	9.14	9.92	7.50	15.40	0.07	12.03	9.00	9.25	0.16
P. compressa		14.80	7.84	7.33	18.30	19.80	**<0.01**	5.75	12.51	17.49	**<0.05**
P. meandrina		3.50	6.67	8.00	4.00	3.50	0.37	5.33	5.00	7.50	0.57
P. eydouxi			12.50	8.00			0.90	5.00	20.00	8.00	0.36
M. capitata	9.50	7.67	7.42	7.54	4.45	6.90	**<0.05**	5.60	8.50	7.56	0.06
M. patula	5.40	8.75	5.57	4.00	5.50	4.00	0.42	6.43	5.00	4.20	0.30
Species count	4.00	6.00	7.00	7.00	6.00	6.00	0.86	7.00	7.00	7.00	0.92
Species diversity (H)	1.23	1.28	1.37	1.34	1.36	1.38	0.69	1.33	1.34	1.31	0.72

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 2013-2019, and how they compare to the current data from 2020.

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 52.0%. 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 (~25.0 – 50.0%) 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 were 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 2020, 37.4%, is within this range and shows the benthic communities to exhibit consistent values of coral cover for the last 10 years.

Other studies conducted throughout the 18-year period of monitoring have found significant differences in overall coral cover among the six stations and among the three depth gradients (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 Ho‘ona Bay and NPPE exhibiting statistically higher values of coral cover than the 12” Pipe 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. The 2020 data supported this trend in overall coral cover with significantly higher mean values of overall coral cover observed at the Ho‘ona Bay, 18” Pipe, and the NPPE sites compared to the other four monitoring stations. The 2020 data also supported previous studies with *P. compressa* having significantly higher cover values at deeper sites. The 2020 data showed P. lobata to have significantly higher values of cover at all sites among all three depths compared to the other observed coral species. The 2020 data show no significant differences in species richness or species diversity among the six stations and three depth profiles. The levels of overall coral cover were very similar to 2019. These findings indicate all survey locations support coral assemblages of similar diversity and community structure with relatively high levels of coral cover.

Previous reports have 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 30.0%, 29.0%, 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 2020 was 23.0%. This value is similar to the observed coral cover in 2019 (25.2%) and more similar to previous years. While this value is lower than during the years 2013-2015, there was 10.3% cover attributed to *P. evermanni,* which was possibly not identified in previous years due to morphological similarity. This was a high value for *P. evermanni* compared to the past four years, which again is likely due to the morphological similarity between these species. Overall this indicates a high level of mounding *Porites* corals among the survey stations, as the average percent cover of mounding *Porites* coral in 2020 is not statistically different to the previous four years. The differences in coral cover from 2013 to 2019 are less than 5.0%, which indicates consistency in this coral being the dominant coral species. The 2020 values of coral cover for mounding *Porites* were also very similar among surveys conducted during the previous 5-years, thus indicating these are the dominant coral colonies among these stations and this species is exhibiting minimal changes in levels of coral cover.

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 2020 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 (3.9% - 21.6%) and was found to have statistically higher values in shallow sites in 2014 (Bybee et al. 2014). The 2020 data are similar to the generally lower values recorded in 2017 and 2018, and no colonies were observed at a few stations. The overall cover of *P. meandrina* cover did not exhibit statistically significant differences among sites compared to the past three years but increased slightly to 5.1%. Values of *P. meandrina* cover in 2020 were highest at shallow depths. The variability in *P. meandrina* coral cover over the last several years may be associated with the loss of *P. meandrina* corals along leeward coastlines at shallow depths throughout Hawaii due to regional increases 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 relatively higher levels of *P. meandrina* cover in shallow depths observed in 2020, compared to the past four years, suggests some recovery and recruitment of this species may be occurring. Conducting future surveys in the same locations will help to track the community structure of this coral.

The counts of mobile invertebrate species from the 2020 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 showed similar characteristics of coral community structure, with no significant differences among either sites or depths (Burns and Kramer 2016). The general range of coral cover among the dominant species has also remained relatively stable from 2009-2019. The data from 2020 exhibited a slight increase compared to 2018, but patterns in community structure were statistically similar, thus suggesting coral composition has remained similar at these sites. The 2020 data did support the previous findings of statistically significantly higher coral cover at the more northern sites, Hoʻona Bay and NPPE.

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. The values of coral cover of *P. meandrina* were highest at shallow sites in 2020, and elevated from the values in 2019, which suggests potential recruitment and recovery of this species at this depth zone. Future surveys at the same spatial locations will enable documentation of how effectively *P.*

meandrina can re-colonize at the shallow survey stations and how the community structure of this species may change following the prior disturbances.

The results and findings of the surveys conducted over the last 22 years have shown variability in the characterization of coral communities among the six stations. Considering that no permanent markers were 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 will reduce this error and enhance the capability to track changes in reef structure over time. Permanent pins were established in 2017 to help mitigate this problem. Stainless steel pins were placed at the start location for transect surveys at each depth among the six sites. It is promising to see high similarity in values of coral cover from 2017 - 2020, the four years using the permanent pins. While variability will always exist due to the randomly selected locations for quadrats along the transect, the high similarity in values among the previous two years suggest the permanent sites are helping in accurately detecting changes in the benthic communities at these survey sites.

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 dramatic changes over the last two decades. The 2020 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 Laboratory 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-related 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 (~2,000 to ~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 26 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 13). 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).

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

PLANB CONSULTANCY

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 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 6, and the complete dataset is provided in Appendix 3.

Total Number of Individuals

The total number of individual fishes was highest at Hoʻona Bay and the lowest was at Wawaloli, which is similar to patterns seen from 2016-2019 where the northern sites have higher counts of individual fish. This range in individuals was 101 to 407. Habitats at deep and moderate depths had similarity in the total number of individuals (266 and 246 respectively), with shallow sites having the lowest number (195 individuals). While there were differences in the mean values, there were no statistically significant differences in the total number of individual fishes counted among all six stations (p=0.16) or among the three depth gradients (p=0.43). All values are reported in Table 6.

Number of Species

The mean number of species recorded was highest at the 12 Pipe South and lowest at Wawaloli. This range in mean number of species was 15 to 29. The shallow, moderate, and deep habitats had 23-25 species of fish recorded for surveys among these depths. While there were differences in mean values of the number of species recorded, there was no statistically significant difference among the six stations (p=0.07) or among the three depth gradients (p=0.92). All values are reported in Table 6.

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. The patterns in abundance were similar to previous years.

Species Diversity and Biomass

Species diversity ranged from 1.34 at Wawaloli to 3.18 at 12" Pipe South. The mean species diversity among the deep depths was 2.70, 2.58 among moderate depths, and 2.70 among the shallow depths. There were no significant differences in species diversity among the six stations surveyed (p=0.08). There were also no significant differences in species diversity among the three depth gradients (p=0.88)

Fish biomass was highest at the 12" Pipe North (225.39 g/m2) and lowest at Wawaloli (73.20 g/m2). Biomass was lowest at moderate depths (128.67 g/m2), and highest at the shallow depths (154.96 g/m2). No significant differences in mean biomass were detected among the sites (p=0.10) or depth gradients (p=0.86).

Table 6: Summary of fish survey data and comparative analyses from surveys conducted in August 2020.

Station	Wawaloli				18" Pipe				12" Pipe South		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Fish count	46.00	195.00	62.00		170.00	280.00	192.00		261.00	201.00	294.00
Number of species	12.00	25.00	7.00		25.00	23.00	29.00		32.00	25.00	28.00
Diversity	1.15	1.35	1.51		3.39	2.66	3.42		3.02	3.06	2.51
Biomass	71.64	111.10	36.85		121.34	95.85	138.02		98.96	158.28	163.60
Station	12" Pipe North				NPPE				Hoona Bay		
Depth	Shallow	Moderate	Deep		Shallow	Moderate	Deep		Shallow	Moderate	Deep
Fish count	154.00	161.00	207.00		195.00	246.00	348.00		335.00	393.00	493.00
Number of species	23.00	27.00	22.00		24.00	23.00	21.00		27.00	23.00	26.00
Diversity	2.96	3.13	2.99		2.93	2.90	2.75		2.76	2.35	2.99
Biomass	313.63	152.95	209.60		200.65	71.45	131.28		123.56	182.43	148.55
Mean value comparisons	Wawa	18" Pipe	12" Pipe S	12" Pipe N	NPPE	H - Bay	p-value	Shallow	Moderate	Deep	p-value
Fish count	101.00	214.00	252.00	174.00	263.00	407.00	0.16	195.00	246.00	266.00	0.43
Number of species	15.00	26.00	29.00	24.00	23.00	26.00	0.07	24.00	25.00	23.00	0.92
Diversity	1.34	3.16	2.86	3.03	2.86	2.70	0.08	2.70	2.58	2.70	0.88
Biomass	73.20	118.40	140.28	225.39	134.46	151.51	0.10	154.96	128.67	137.98	0.86

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 1992-2016 (Ziemann 2010, Bybee and Barrett 2012, Bybee et al. 2013, 2014, Whale Environmental 2015, Burns and Kramer 2016). This report will discuss the key findings from these previous reports and how they compare to the current data from the 2020 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 showed a marked increase in abundance, diversity, and biomass of the fish assemblages among all stations and depths. The 2020 data exhibited similar patterns and values for all parameters observed from 2016 - 2019 (Burns and Kramer 2016, 2017, 2018, Burns and Annandale 2019). The data from the past five years suggests the sites support very abundant and diverse fish assemblages. The lack of statistically significant variation suggests all study sites support abundance and diverse fish assemblages.

PLANB CONSULTANCY

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 - 2020 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 in 2020 were higher than some previous years, but in the same range as those observed from 2016 - 2019. 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 28-year timespan 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, 2015-2019, and in the 2020 data (Bybee et al. 2014, WHALE Environmental 2015, Burns and Kramer 2016-2018, Burns and Annandale 2019, Table 6). 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. The 2020 data continued to support this trend, with similar values of biomass, count, and diversity in comparison to previous years.

In summary, the reports conducted over the past 28 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.

INTERTIDAL SURVEY

INTRODUCTION

The intertidal zone is an extreme marine environment that is covered with water during high tide and exposed to the air and hot sun during low tide. The species found in the intertidal zone are unique and adapted for these challenging living conditions. The Hawaiian rocky intertidal zone is home to numerous species of limu (algae), pūpū (snails), wana (urchins), pāpaʻi (crabs), heʻe (octopi), ʻōkala (anemones) and ʻopihi (limpets) that have been harvested from these intertidal habitats for many generations and are culturally significant to Native Hawaiians.

Keāhole is the most western point on Hawaiʻi Island, located in the district of North Kona. Keāhole point was formed by the 1801 lava flow from Hualalai volcano. The coastline consists mostly of pāhoehoe lava benches, small boulders, rock and coral rubble beaches. During the winter months, the large swells batter this coastline, and the intertidal zone expands due to the water reaching higher along the coastline.

Surveys were conducted in July 2020 along the Keāhole coastline fronting the Natural Energy Laboratory of Hawaiʻi Authority (NELHA). Since 1974, the State of Hawaiʻi has invested over 100 million dollars to create an outdoor facility to host a demonstration site for renewable and ocean-based technologies. Three sets of pipelines deliver deep sea water from depths up to 3000 ft as well as sea surface water to energy and aquaculture initiatives and businesses at NELHA.

These surveys were initiated by NELHA as it was determined that there is a need for benthic and biota monitoring of the coastal areas adjacent to their facilities. This section includes a summary of the monitoring conducted along six benthic biota survey sites identified by NELHA.

Site Information

Transect #	Site Name	GPS
N1	Wawaloli	19.715744, -156.050052
N2	18” Pipeline	19.722658, -156.057347
N3	12” Pipeline South	19.727016, -156.060803
N4	12” Pipeline North	19.728430, -156.061295
N5	NPPE	19.730759, -156.059941
N6	Ho‘ona Bay	19.731723, -156.057718

METHODS

The following materials were used to conduct intertidal surveys. Google Earth was used to enter GPS points and create a map to locate survey sites. The sites all start on shore in alignment with the same locations used for benthic and fish monitoring (Figure 13). A Garmin GPS unit was also used to enter GPS points to locate the survey sites. A ⅜ nylon utility rope was used to delineate the transects that ran perpendicular to shore. A three-pound weight was tied to the end of the rope and was safely secured below the water's edge and the top end of the rope was secured to a large boulder above the supratidal zone. A 50 cm wide PVC pipe was used as a guide to survey the transect width. A datasheet with the most common invertebrate and limu species was created, along with a list and ID guide of NELHA's cultivated species highlighting the non-native species that should be on the lookout for (see appendix A). A clipboard, datasheets and pencil were used to document the number of species enumerated on the transect. A camera and iPhone were used to photograph transects. Data was entered and analyzed using Microsoft EXCEL.

The intertidal monitoring is conducted by surveying a 50-cm wide belt transect perpendicular to shore (mauka to makai). A ⅜ nylon utility rope was placed along the contour of the substrate from the splash or supratidal zone (above the high-tide line) down to the low-tide zone which becomes fully submerged by coastal water. All intertidal organisms within the 50cm wide belt transect were enumerated to the lowest taxonomic level and recorded on the datasheet. In addition, the transects and adjacent areas were scanned for the targeted nonnative species cultivated at NELHA. This was repeated at the six transects sites identified in the scope of work.

RESULTS

Surveys were conducted over the span of two days on July 4 and 6, 2020. July 4, 2020 was the full moon and surveys were conducted during the low and low-rising tides on both days to identify as many species as possible before the rising tide covered them. This was also the same day as the one of the King Tide events in the summer of 2020. A total of thirty-eight (38) different intertidal species (invertebrates and algae) were identified and enumerated on the six (6) transects (see appendix B with the list of all species).

Transect 1 (N1) - Hoʻona Bay

Transect 1 (N1) is located on the pāhoehoe lava bench just south of Hoʻona Bay which is a mixed ʻiliʻili (pebble), small boulder and coral rubble beach. This transect also had a lava bench with a large, submerged section closer to the water's edge.

Standing at the start of transect N6 looking down toward the ocean.

Standing midway down of transect N6.

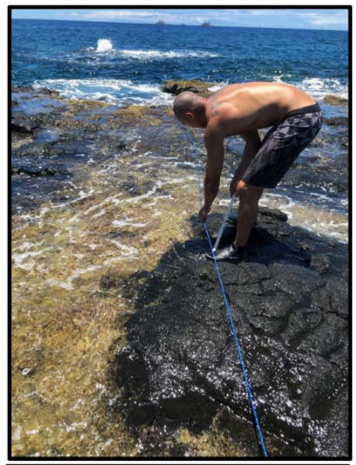
There were 14 different invertebrate species identified and enumerated and five different limu species identified on transect 6. The most dominant species being *Colobocentrotus atratus* with 363 individuals counted. Closely followed by *Echinolittorina hawaiiensis* with 358 individuals counted. The next dominant species was *Nesochthamalus intertextus*, with 71 individuals counted. All other species are noted in the table below.

Transect 1 (N1) – Hoʻona		
Invertebrate Species	**Count**	**Algal Species**
Calcinus spp.	8	*Asteronema spp*
Cellana exarata	9	*Chondrophycus spp*
Cellana sandwicensis	11	*Padina spp*
Colobocentrotus atratus	363	*Sargassum spp*
Drupa ricina	1	Turf
Echinolittorina hawaiiensis	358	
Echinometra mathaei	1	
Echinometra oblonga	39	
Grapsus tenuicrustatus	1	
Littoraria pintado	49	
Morula granulata	2	
Morula uva	2	
Nerita picea	13	
Nesochthamalus intertextus	71	

Transect 2 (N2) - NPPE

Transect 2 (N2) is located on the shoreline right off the large cages, as you can see in the photos below. Like all the other sites, it consisted mostly of pāhoehoe lava bench. There was a small decline in the pāhoehoe lava and a small channel of water. Surveys were conducted where the highest organism (usually *Echinolittorina spp*.) were found.

Standing at the start of transect N5 looking the ocean.



Standing near the water's edge of transect N5 down toward looking down toward the ocean.

There were 11 different invertebrate species identified and enumerated and five different limu species identified on transect 5. The most dominant species being *Nesochthamalus intertextus* or the barnacle with 766 individuals counted. *Echinolittorina hawaiiensis* was the next dominant species with 317 individuals counted. Followed by *Echinometra oblonga* with 73 individuals. There was a large section on the transect that was submerged thus for the higher numbers of *Echinometra oblonga* (as you can see in the picture on the right above). All other species are noted in the table below.

PLANB CONSULTANCY

Transect 2 (N2) - NPPE		
Invertebrate Species	**Count**	**Algal Species**
Calcinus spp.	10	*Colpomenia sinuosa*
Conus spp	1	*Padina spp*
Cypraeidae spp.	1	*Sargassum spp*
Echinolittorina hawaiiensis	317	*Turbinaria ornata*
Echinometra mathaei	6	Turf
Echinometra oblonga	73	
Holothuria spp	1	
Littoraria pintado	60	
Nerita picea	1	
Nesochthamalus intertextus	766	
Smaragdinella calyculata	11	

Transect 3 (N3) - 12” Pipeline North

Transect 3 (N3) is located north of the 12” pipeline. There were small pools of water left behind due to the high tidal fluctuation during the full moon. As the tide rises, the lava bench is submerged with water.

Standing at the starting point of transect N4 looking down toward the ocean.

Transect 3 (N3) - 12" Pipeline North		
Invertebrate Species	**Count**	**Algal Species**
Calcinus spp.	36	*Ahnfeltiopsis concinna*
Echinolittorina hawaiiensis	11	*Asteronema spp*
Grapsus tenuicrustatus	2	*Chaetomorpha antennina*
Isognomon californicum	1	*Padina spp*
Littoraria pintado	6	
Nesochthamalus intertextus	112	
Siphonaria normalis	4	

Transect 4 (N4) - 12" Pipeline South

Transect 4 (N4) is located on a concrete slab, just south of the 12" pipeline. Since surveys were conducted on the full moon and tidal fluctuations highest during these moon phases, there were small pools of water with invertebrates inhabiting them from the previous day's tidal fluctuation.

Standing on concrete slab at the start of transect N3 looking down toward the ocean.

There were 11 different invertebrate species identified and enumerated and five different limu species identified on this transect. The most dominant species found on this transect was *Littoraria pintado*, with 595 individuals counted. Followed by *Echinolittorina hawaiiensis* with 51 individuals counted. There were very low amounts of the other species, which makes sense since this is a manmade substrate with frequent human presence. *Acanthophora spicifera* is an invasive alga that was noted in small amounts on this transect. *A. spicifera* is the most widespread and successful alien alga in Hawaiʻi. This red alga appeared for the first time in Hawaiʻi in the early 1950's and is found on reefs and intertidal habitats. Due to the ubiquitous nature of this invasive alga there is no recommendation for NELHA to attempt to remove or manage this particular invasive species. All other species are noted in the table below.

PLANB CONSULTANCY

Transect 4 (N4) - 12" Pipeline South		
Invertebrate Species	**Count**	**Algal Species**
Calcinus spp.	11	*Acanthophora spicifera*
Colobocentrotus atratus	1	*Ahnfeltiopsis concinna*
Drupa ricina	5	*Asteronema spp*
Echinolittorina hawaiiensis	51	*Chaetomorpha antennina*
Euraphia hembeli	7	*Padina spp*
Isognomon californicum	8	
Littoraria pintado	595	
Morula granulata	2	
Nerita picea	1	
Smaragdinella calyculata	1	
Vermetidae spp	4	

Transect 5 (N5) - 18” Pipeline

Transect 5 (N5) is located just a little north of the 18” pipeline. There were a few tide pools located along this transect and adjacent to the transect. The splash zone consisted of a pāhoehoe bench encrusted with crustose coralline algae.


Standing at start of transect N2 running toward ocean.


Overlooking end of transect N2.

There were 15 different invertebrate species identified and enumerated and five different limu species identified on this transect. Because there was a large supratidal zone that consisted of a few tidepools, the most dominant species identified and enumerated was the Hawaiian periwinkle, *Echinolittorina hawaiiensis*, with 658 individuals counted. The second dominant species found on this transect was *Isognomon californicum* followed by the helmet urchin, *Colobocentrotus atratus*. All other species are noted in the table below.

PLANB CONSULTANCY

Transect 5 (N5) - 18" Pipeline		
Invertebrate Species	**Count**	**Algal Species**
Calcinus spp.	14	*Dictyota spp.*
Cellana exarata	6	*Jania spp.*
Cellana sandwicensis	3	*Padina spp*
Colobocentrotus atratus	82	*Sargassum spp*
Echinolittorina hawaiiensis	658	Turf
Echinometra mathaei	24	
Echinometra oblonga	8	
Haminoea cymbalum	5	
Holothuria atra	1	
Isognomon californicum	93	
Littoraria pintado	20	
Morula granulata	2	
Morula uva	1	
Nerita picea	7	
Nesochthamalus intertextus	27	

Transect 6 (N6) - Wawaloli

Transect 6 (N6) is located at Wawaloli and is the most southern transect surveyed. At this site, there is a small channel that separates the pāhoehoe flat from the beach. During high tide, the channel will be submerged and somewhat difficult to cross if there are large waves. The beginning of the transect is located on the pāhoehoe flat after crossing the small channel.


Standing at start of transect N1 running toward the ocean.


Standing mid-way down transect N1.

There were 13 different invertebrate species identified and enumerated and five different limu species identified on this transect. *Nesochthamalus intertextus*, a barnacle being the most dominant species with 398 individuals counted. The endemic Hawaiian periwinkle, *Echinolittorina hawaiiensis*, was the second most dominant species on this transect with 278 individuals counted. Followed by the larger dotted periwinkle, *Littoraria pintado* with 211 individuals counted. Another dominant species found on this transect was *Isognomon californicum* with 118 individuals. All other species on this transect are noted in the table below.

PLANB CONSULTANCY

Transect 6 (N6) - Wawaloli		
Invertebrate Species	**Count**	**Algal Species**
Cellana exarata	14	*Ahnfeltiopsis concinna*
Colobocentrotus atratus	7	*Chaetomorpha antennina*
Drupa morum	1	*Sargassum spp*
Drupa ricina	1	Turf
Echinolittorina hawaiiensis	278	*Ulva fasciata*
Echinometra oblonga	13	
Isognomon californicum	118	
Littoraria pintado	211	
Morula granulata	2	
Nerita picea	87	
Nesochthamalus intertextus	398	
Smaragdinella calyculata	1	
Vermetidae spp	2	

After surveys were conducted to identify and count all the intertidal species, surveys of NELHA's non-native cultivated species were also inspected. A species identification guide was created and used to look for species that aren't commonly found or native to Hawai'i's intertidal. None of NELHA's non-native cultivated species were found along any of the six transects nor were they found in the general vicinity around the transects. Special care was also made to look for these species while walking along the coastline while in transit to the other transect sites or to/from the general survey area when accessing the study sites.

DISCUSSION

Intertidal species identified and enumerated at the six survey sites along the coastline at Keāhole fronting NELHA are consistent with other intertidal coastal sites found along Hawai‘i Island. Surveys were conducted during the full moon, during the summer of 2020, which meant it coincided with one of the King Tide events. This allowed surveyors to inventory the shoreline during the low, low tide and look for as much species as possible. This also means that organisms will be left dry and exposed to solar radiation for longer periods of time, and in some cases, they will retreat into cracks and crevices.

There was a total of 38 different invertebrate and limu species that were identified on all six transects. All species identified were common invertebrate or limu species found in Hawai‘i. One species to note and be aware of is *Acanthophora spicifera*, an invasive alga that was found on transect 4. *A. spicifera* is the most widespread and successful alien alga in Hawai‘i. This red alga appeared for the first time in Hawai‘i in the early 1950’s and is found on reefs and intertidal habitats. Due to the ubiquitous nature of this invasive alga there is no recommendation for NELHA to attempt to remove or manage this particular invasive species.

There were none of NELHA’s non-native cultivated species identified along the transects and the general area which is important to note. Although each facility should have a closed system and protocols in place in case of spill sand leaks, it is critical that NELHA continue to conduct yearly monitoring to ensure that none of the cultivated species start to inhabit the Keāhole coastline.

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.

Burns, J. H. R., and K. L. Kramer (PlanB Consultancy, Inc.). 2016. NELHA Benthic and Biota Monitoring Study, May 2016. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 86 pp. + Appendices.

Burns, J. H. R., and K. L. Kramer (PlanB Consultancy, Inc.). 2017. NELHA Benthic and Biota Monitoring Study, May 2017. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 86 pp. + Appendices.

Burns, J. H. R., and K. L. Kramer (PlanB Consultancy, Inc.). 2018. NELHA Benthic and Biota Monitoring Study, May 2017. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 86 pp. + Appendices.

Burns, J. H. R., Annandale K., Springer, K. (PlanB Consultancy, Inc.). 2019. NELHA Benthic and Biota Monitoring Study, May 2017. Prepared for Natural Energy Laboratory of Hawaii Authority (NELHA), Kailua-Kona, HI. 86 pp. + Appendices.

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.

Marrack, L. and P. O'Grady. 2014. Predicting impacts of sea level rise for cultural and natural resources in five National Park units on the Island of Hawai'i. Technical Report No. 188. Pacific Cooperative Studies Unit, University of Hawai'i, Honolulu, Hawai'i. 40 pp.

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.

School of ocean and earth science and Technology (SOEST), University of Hawaiʻi at Mānoa website. Accessed May 2017. http://www.soest.hawaii.edu/coasts/sealevel/.

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

Yamamoto, M. N., and A. W. Tagawa. 2000. Hawaii's Freshwater Animals: Native & Exotic. Mutual Publishing: Honolulu Hawaii. 112 pp.

Yamamoto, M. N., T. Y. Iwai, and A. W. Tagawa. 2015. Hawaiian Anchialine Pools. Mutual Publishing: Honolulu Hawaii. 112 pp.

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 – Pool Monitoring

Appendix 1.1. Physical characteristics of Northern and Southern complex anchialine pools, summarized from faunal surveys conducted from May 1989 to October 2008 (Brock 2008, Ziemann and Conquest 2008), and water quality surveys in 2009. Pool S-10 was not included 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. Faunal census data reported for Northern and Southern complex anchialine pools located within and surrounding the NELHA facility, during surveys conducted from May 1989 to August 2008 (Brock 2008). Introduced fish species (Poeciliids) were 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

PLANB CONSULTANCY

Appendix 1.2. (continued)

Survey Date	Pond: N-4 (Count/0.1m²)						Pond: N-5 (Count/0.1m²)					
	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/ sand				dry			
May 2001	55		0	11	dry							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 2 - Nearshore marine habitat characterization data

Table 2.1 Benthic habitat characterization data - Algae

Site	Depth	Location	ıoto Nam	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
12S	50	1									5																		76		
12S	50	4									15																		62		
12S	50	6									20																		61		
12S	50	7									30																		50		
12S	50	8									10																		69		
12S	50	9									10																		62		
12S	50	11									5																		62		
12S	50	13									5																		66		
12S	50	20									1																		69		
12S	50	27									8																		62		
12S	35	2									1																		75		
12S	35	3									1																		61		
12S	35	5									2																		58		
12S	35	6																											75		
12S	35	8																											45		
12S	35	9									5																		60		
12S	35	10									5																		52		
12S	35	13																											59		
12S	35	15																											50		
12S	35	16																											65		
12S	15	1																											73		
12S	15	2																											76		
12S	15	5																											79		
12S	15	6																											81		
12S	15	9																											77		
12S	15	12									1																		74		
12S	15	14																											82		
12S	15	15									1																		81		
12S	15	22									1																		55		
12S	15	25									10																		62		

Site	Depth	Location	ıoto Nam	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	red 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)	
12N	50	1									9																		47		
12N	50	4									2																		68		
12N	50	5																											71		
12N	50	6																											66		
12N	50	9									5																		72		
12N	50	13																											62		
12N	50	14									5																		62		
12N	50	17									9																		62		
12N	50	19																											62		
12N	50	20									5																		56		
12N	35	2									5																		47		
12N	35	3																											79		
12N	35	5																											67		
12N	35	8									1																		61		
12N	35	10																											62		
12N	35	12									1																		79		
12N	35	14																											60		
12N	35	21									1																		80		
12N	35	25																											76		
12N	35	27									1																		80		
12N	15	2									1																		76		
12N	15	3																											77		
12N	15	6									5																		62		
12N	15	8																											52		
12N	15	10																											37		
12N	15	11									1																		41		
12N	15	17																											77		
12N	15	20																											77		
12N	15	26																											61		
12N	15	27																											74		

PLANB CONSULTANCY

Site	Depth	Location	ıoto Nam	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	4									5																		42		
NPPE	50	6									5																		37		
NPPE	50	8									15																		40		
NPPE	50	10									10																		32		
NPPE	50	12									2																		63		
NPPE	50	13									8																		57		
NPPE	50	15									2																		50		
NPPE	50	16									2																		52		
NPPE	50	18									2																		40		
NPPE	50	21									10																		32		
NPPE	35	1									1																		50		
NPPE	35	6									4																		52		
NPPE	35	8									2																		55		
NPPE	35	10																											27		
NPPE	35	12																											52		
NPPE	35	14																											47		
NPPE	35	20																											57		
NPPE	35	22																											77		
NPPE	35	23																											77		
NPPE	35	25																											66		
NPPE	15	1									20																		47		
NPPE	15	4									15																		57		
NPPE	15	5									10																		72		
NPPE	15	9									25																		52		
NPPE	15	10									30																		51		
NPPE	15	11									3																		76		
NPPE	15	12									10																		42		
NPPE	15	14									10																		57		
NPPE	15	15									5																		47		
NPPE	15	24									20																		12		

Site	Depth	Location	hoto Nam	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	2									30																		22		
H-bay	50	6									25																		21		
H-bay	50	7									10																		2		
H-bay	50	8									9																		32		
H-bay	50	4									20																		42		
H-bay	50	9									10																		-8		
H-bay	50	12									10																		42		
H-bay	50	15									10																		12		
H-bay	50	17									10																		2		
H-bay	50	18									5																		-3		
H-bay	35	1																											71		
H-bay	35	2																											81		
H-bay	35	3																											80		
H-bay	35	7									10																		47		
H-bay	35	9									3																		44		
H-bay	35	14									5																		22		
H-bay	35	19									9																		32		
H-bay	35	21																											32		
H-bay	35	24																											61		
H-bay	35	25									5																		37		
H-bay	35	27																											31		
H-bay	15	1									3																		52		
H-bay	15	2									1																		46		
H-bay	15	3									1																		50		
H-bay	15	12																											52		
H-bay	15	14									5																		47		
H-bay	15	15									10																		52		
H-bay	15	21									1																		55		
H-bay	15	24									1																		61		
H-bay	15	25									1																		59		

PLANB CONSULTANCY

Site	Depth	Location	ıoto Nam	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
18	50	2									15																		55		
18	50	4									1																		52		
18	50	5									10																		35		
18	50	6									5																		25		
18	50	10									5																		25		
18	50	11									10																		20		
18	50	12									1																		39		
18	50	14									2																		64		
18	50	16									2																		41		
18	50	18																											63		
18	35	1									9																		55		
18	35	3									2																		65		
18	35	4									1																		64		
18	35	7									1																		58		
18	35	8									2																		66		
18	35	9									1																		65		
18	35	10									2																		63		
18	35	14									3																		51		
18	35	16																											55		
18	35	20									2																		59		
18	15	1									1																		68		
18	15	7																											60		
18	15	8									1																		23		
18	15	10									2																		43		
18	15	14									1																		68		
18	15	15																											65		
18	15	20									10																		59		
18	15	21																											65		
18	15	23									15																		54		
18	15	24																											69		

Site	Depth	Location	hoto Nam	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
Wawa	50	1																											10		
Wawa	50	2																											5		
Wawa	50	4									2																		3		
Wawa	50	8																													
Wawa	50	10																											1		
Wawa	50	11																											3		
Wawa	50	12									1																		4		
Wawa	50	14																											7		
Wawa	50	21																											23		
Wawa	50	22																											16		
Wawa	35	3									3																		57		
Wawa	35	4																											28		
Wawa	35	5																											54		
Wawa	35	7																											45		
Wawa	35	10																											7		
Wawa	35	11									5																		59		
Wawa	35	18																											40		
Wawa	35	20									10																		70		
Wawa	35	21																											83		
Wawa	35	22																													
Wawa	15	1																											90		
Wawa	15	7									2																		58		
Wawa	15	11																											75		
Wawa	15	12																											70		
Wawa	15	13																											90		
Wawa	15	14									6																		90		
Wawa	15	17																											95		
Wawa	15	21																											40		
Wawa	15	24									3																		87		
Wawa	15	25																											70		

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

					cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
Site	Depth	Location	ıoto Nam	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 brighami	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
12S	50	1																		9			10									
12S	50	4																		8			15									
12S	50	6								7													12									
12S	50	7								7									5				8									
12S	50	8																		11			10									
12S	50	9								8										8			12									
12S	50	11								3										10			20									
12S	50	13																		4			15									10
12S	50	20																		8			20									2
12S	50	27								8										4			18									
12S	35	2													1					8			15									
12S	35	3								6													32									
12S	35	5																		14			16									10
12S	35	6								10									10				5									
12S	35	8								10		3							5				35									2
12S	35	9																		4		16	15									
12S	35	10																		10		8	25									
12S	35	13								10		6											25									
12S	35	15								12		4											32									2
12S	35	16										3					20						10									2
12S	15	1										10					5			4			8									
12S	15	2																				14	10									
12S	15	5																				10	11									
12S	15	6																				5	14									
12S	15	9										3										6	14									
12S	15	12										10			4							5	5									1
12S	15	14								3													15									
12S	15	15								2													16									
12S	15	22								10													34									
12S	15	25								8													20									

Site	Depth	Location	ıoto Nam	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 brighami	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
					cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
12N	50	1																	10				34									
12N	50	4								2													28									
12N	50	5								8										1			20									
12N	50	6								4										15			15									
12N	50	9																				8	15									
12N	50	13								12							8					10	8									
12N	50	14								10												3	15									5
12N	50	17								15												9	5									
12N	50	19																		2		6	20									10
12N	50	20																		8		15	15									1
12N	35	2																		10		5	6									27
12N	35	3																				6	15									
12N	35	5								5		4			4								20									
12N	35	8																				8	30									
12N	35	10								6		2											20									10
12N	35	12								15													5									
12N	35	14																					20									20
12N	35	21																				4	15									
12N	35	25																		4			20									
12N	35	27																	5	10			4									
12N	15	2										6											15									2
12N	15	3													5								18									
12N	15	6																		8			25									
12N	15	8										3										20	25									
12N	15	10										5										20	38									
12N	15	11								3												15	40									
12N	15	17																					23									
12N	15	20								3													20									
12N	15	26																	9				30									
12N	15	27																		8			18									

PLANB CONSULTANCY

				cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
Site	Depth	Location ɿoto Nam	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 brighami	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni	Inorganics	Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
NPPE	50	4																	35			18									
NPPE	50	6																	25			33									
NPPE	50	8																	20			25									
NPPE	50	10							2										18			38									
NPPE	50	12																	15			20									
NPPE	50	13																	20			15									
NPPE	50	15																	30			18									
NPPE	50	16																	26			20									
NPPE	50	18																	26			32									
NPPE	50	21																	28			30									
NPPE	35	1							1										18			30									
NPPE	35	6																4	15			25									
NPPE	35	8																4	14			25									
NPPE	35	10																	18			55									
NPPE	35	12																	10			38									
NPPE	35	14																	18			35									
NPPE	35	20							2										12			26									3
NPPE	35	22							3													20									
NPPE	35	23							8										3			12									
NPPE	35	25																	12		4	18									
NPPE	15	1																			10	23									
NPPE	15	4																			6	22									
NPPE	15	5																	3			15									
NPPE	15	9							3													20									
NPPE	15	10							4													15									
NPPE	15	11												9								12									
NPPE	15	12							6		6											36									
NPPE	15	14							3													30									
NPPE	15	15							3		5											40									
NPPE	15	24							14					4							10	40									

PLANB CONSULTANCY

Site	Depth	Location Photo Name	Coral	cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc		Inorganics	Basalt		Limest	Quad	Sand
				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 brighami	Porites evermanni (Porev)	Porites lobata (Porlob)	Porites rus	Tubastrea coccinea (Tubcoc)	Sarcothelia edmondsoni		Basalt (Basalt)	Rubble	Limestone (Limest)	Quad (Quad)	Sand (Sand)
H-bay	50	2																	18			30									
H-bay	50	6													6				15			33									
H-bay	50	7												3					30		15	40									
H-bay	50	8																	4			15									40
H-bay	50	4							8										5			25									
H-bay	50	9																	38			30									30
H-bay	50	12																	28			20									
H-bay	50	15																	30			48									
H-bay	50	17							8					5					40			35									
H-bay	50	18							8										45			45									
H-bay	35	1							12													17									
H-bay	35	2																	4			15									
H-bay	35	3									1								15			4									
H-bay	35	7									6								12			25									
H-bay	35	9									5								18			30									
H-bay	35	14																	18			55									
H-bay	35	19												4					15			40									
H-bay	35	21							8										15			45									
H-bay	35	24							3										16			20									
H-bay	35	25												3					15			40									
H-bay	35	27							4										15			50									
H-bay	15	1							3												15	25									2
H-bay	15	2																			8	45									
H-bay	15	3																6				43									
H-bay	15	12																			14	34									
H-bay	15	14												3							20	25									
H-bay	15	15																			15	23									
H-bay	15	21							5												18	20									1
H-bay	15	24																			12	21									5
H-bay	15	25							10									1			19	10									

				cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
Site	Depth	Location ıoto Nam	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 brighami	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	2																	10			20									
18	50	4				5			5										15			17									5
18	50	5																	10			40									5
18	50	6																	20			30									20
18	50	10																	18			52									
18	50	11																	18			52									
18	50	12																	12			38									10
18	50	14																				32									2
18	50	16							12										20			25									
18	50	18							8										10			19									
18	35	1																6				30									
18	35	3																1				32									
18	35	4																				35									
18	35	7							1													40									
18	35	8							10													22									
18	35	9									10											24									
18	35	10																	15			20									
18	35	14							10													36									
18	35	16																				40									5
18	35	20							10													29									
18	15	1																				31									
18	15	7																				35									5
18	15	8							9		10											57									
18	15	10																			18	37									
18	15	14																			4	27									
18	15	15																			8	27									
18	15	20									3											28									
18	15	21									12											23									
18	15	23																				31									
18	15	24							4													27									

Site	Depth	Location Photo Name	Coral	cypag	cypoc	Funscu	Leppur	Lepbew	Moncap	Monfla	Monpat	Monsp	Pavdue	Pavvar	Pocdam	Poceyd	Poclig	Pocmea	Porcom		Porev	Porlob		Tubcoc			Basalt		Limest	Quad	Sand
				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 brighami	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	1									3											10									77
Wawa	50	2							6		6											6									77
Wawa	50	4							4		4											10									77
Wawa	50	8												3								15									82
Wawa	50	10									3			3								12									81
Wawa	50	11																				18									79
Wawa	50	12							5		5											8									77
Wawa	50	14												3								15									75
Wawa	50	21							12												8	5									52
Wawa	50	22							12													10									62
Wawa	35	3									8										10	22									
Wawa	35	4																				2									70
Wawa	35	5							18													28									
Wawa	35	7																			18	32									5
Wawa	35	10												1								2									90
Wawa	35	11							12													24									
Wawa	35	18							8												15	37									
Wawa	35	20							10		8											2									
Wawa	35	21							12												5	0									
Wawa	35	22							15												9	36									40
Wawa	15	1																				10									
Wawa	15	7																			10	30									
Wawa	15	11									8											17									
Wawa	15	12							5												8	17									
Wawa	15	13							8													2									
Wawa	15	14																				4									
Wawa	15	17																				5									
Wawa	15	21									3										5	42									10
Wawa	15	24									6											4									
Wawa	15	25							6												12	12									

Table 2.3 Benthic habitat characterization data – Mobile Invertebrates

Row Labels	Sum of D. paucispinum	Sum of Echinometra mathaei	Sum of Echinometra oblonga	Sum of Tripneustes gratilla	Sum of Holothuria atra	Sum of C. novaeguineae
18	**4**	**4**		**1**	**1**	
15	2	2				
35	1					
50	1	2		1	1	
12N		**2**				**1**
15						
35		1				
50		1				1
12S	**1**				**1**	
15						
35					1	
50	1					
H-bay	**1**	**5**	**5**	**2**		
15		5				
35			4	1		
50	1		1	1		
NPPE	**4**	**2**		**8**		
15	4					
35						
50		2		8		
Wawa	**5**	**7**				
15	4	4				
35	1	3				
50						
Grand Total	**15**	**20**	**5**	**11**	**2**	**1**

PLANB CONSULTANCY

Appendix 3: Nearshore fish assemblage data

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

Haona Bay	8/8/20							
50'			35'			15'		
Species	Individuals	Size (cm)	Species	Individuals	Size (cm)	Species	Individuals	Size (cm)
M. kuntee	60	15	A. nigrofuscus	4	4	A. nigrofuscus	10	10
M. kuntee	60	12	A. nigrofuscus	4	6	A. nigrofuscus	14	7
N. literatus	1	16	A. nigrofuscus	6	10	A. nigrofuscus	15	9
N. literatus	1	21	A. nigrofuscus	1	13	A. nigrofuscus	11	13
N. literatus	2	19	C. agilis	13	4	G. varius	1	11
N. literatus	2	9	C. agilis	10	5	G. varius	1	4
N. literatus	1	15	C. strigosus	6	4	G. varius	1	13
A. nigrofuscus	3	6	C. strigosus	6	10	C. strigosus	5	8
A. nigrofuscus	4	12	C. strigosus	4	8	C. strigosus	10	10
A. nigrofuscus	3	8	C. vanderbiliti	50	2	C. strigosus	6	12
C. agilis	52	3	C. vanderbiliti	100	3	C. jactator	1	5
C. agilis	50	4	C. vanderbiliti	90	4	C. vanderbiliti	50	2
C. agilis	50	5	C. vanderbiliti	58	5	C. vanderbiliti	56	3
C. agilis	46	6	T. duperrey	1	17	T. duperrey	1	11
C. strigosus	7	10	T. duperrey	1	12	T. duperrey	1	12
C. strigosus	6	6	T. duperrey	1	4	T. duperrey	1	14
C. strigosus	1	14	T. duperrey	1	9	T. duperrey	3	10
C. argus	1	26	C. sordidus	1	20	T. duperrey	1	16
C. potteri	2	6	C. sordidus	2	15	T. duperrey	1	18
C. potteri	1	8	C. multicinctus	1	11	T. duperrey	1	14
C. jactator	1	5	C. multicinctus	1	10	S. bursa	1	18
Z. flavescens	12	6	C. multicinctus	1	4	Z. flavescens	2	15
Z. flavescens	8	5	G. varius	1	14	Z. flavescens	1	10
Z. flavescens	12	10	G. varius	1	8	Z. flavescens	5	13
Z. flavescens	1	12	C. jactator	1	4	C. multicinctus	1	11
C. sordidus	1	17	P. arcatus	1	8	C. multicinctus	1	9
C. sordidus	1	27	P. arcatus	1	9	Z. cornutus	1	14
C. sordidus	1	8	M. vidua	1	23	Z. cornutus	2	12
C. sordidus	2	12	C. ornatissimus	2	16	S. balteata	1	11
C. sordidus	1	14	N. literatus	3	21	S. balteata	1	7
T. duperrey	1	14	N. literatus	1	26	C. ornatissimus	2	17
T. duperrey	1	5	A. abdominalis	2	14	M. grandoculis	1	24
T. duperrey	1	11	A. abdominalis	3	12	F. commersonii	1	12
T. duperrey	1	6	S. balteata	1	12	N. unicornis	1	25
C. ornatissimus	2	12	A. olivaceus	1	16	P. aspricaudus	1	13
C. ornatissimus	1	14	A. olivaceus	1	23	S. rubroviolaceus	1	46
P. johnstonianus	1	8	C. quadrimaculatus	1	12	C. sordidus	1	14
A. abdominalis	27	14	C. gaimard	1	14	A. abdominalis	2	12
A. abdominalis	22	16	H. ornatissimus	1	9	A. vaigiensis	1	14
A. vaigiensis	4	12	P. octotaenia	1	7	A. leucopareius	1	16
A. vaigiensis	4	15	A. chinensis	1	31	C. hawaiiensis	2	20
M. vidua	2	26	Z. flavescens	2	15	C. hawaiiensis	2	23
C. multicinctus	1	10	Z. flavescens	3	14	C. jactator	2	5
C. multicinctus	2	7				L. phthirophagus	1	7
C. multicinctus	1	5				C. vanderbilti	53	3
F. flavissimus	1	12				C. vanderbilti	50	2
F. commersonii	1	60				S. marginatus	1	8
F. commersonii	1	75				S. marginatus	1	11
F. commersonii	1	120				P. ewaensis	1	5
S. spiniferum	1	18						
S. spiniferum	1	15						
Z. cornutus	1	15						
A. olivaceus	4	20						
C. hawaiiensis	1	10						
P. arcatus	1	10						
P. arcatus	1	8						
G. varius	1	8						
C. ovalis	4	7						
C. ovalis	5	9						
P. aspricaudus	1	5						

PLANB CONSULTANCY

NPPE	8/9/20									
50'				35'				*15'*		
Species	**Individuals**	**Size (cm)**		**Species**	**Individuals**	**Size (cm)**		***Species***	**Individuals**	**Size (cm)**
Z. flavescens	5	7		*C. strigosus*	6	6		*A. nigrofuscus*	3	7
Z. flavescens	6	5		*C. strigosus*	6	11		*A. nigrofuscus*	3	12
Z. flavescens	2	6		*C. strigosus*	4	5		*A. nigrofuscus*	4	6
A. nigrofuscus	1	8		*C. strigosus*	5	12		*A. nigrofuscus*	4	11
A. nigrofuscus	8	4		*T. duperrey*	1	8		*A. nigrofuscus*	5	7
C. strigosus	1	10		*T. duperrey*	1	9		*A. nigrofuscus*	8	10
C. strigosus	4	4		*T. duperrey*	2	12		*A. nigrofuscus*	5	12
C. strigosus	5	8		*A. nigrofuscus*	4	6		*C. strigosus*	3	7
C. strigosus	9	7		*A. nigrofuscus*	7	9		*C. strigosus*	4	12
C. sordidus	1	26		*A. nigrofuscus*	5	5		*C. strigosus*	8	13
C. sordidus	1	18		*A. nigrofuscus*	7	11		*C. strigosus*	4	9
C. sordidus	1	16		*C. sordidus*	1	27		*C. strigosus*	4	13
C. sordidus	1	19		*C. sordidus*	1	24		*C. strigosus*	2	11
C. argus	1	29		*C. sordidus*	2	17		*Z. flavescens*	1	12
C. ornatissimus	1	8		*Z. flavescens*	4	14		*Z. flavescens*	7	13
C. ornatissimus	1	7		*Z. flavescens*	3	7		*T. duperrey*	1	12
G. varius	1	6		*Z. flavescens*	1	9		*T. duperrey*	1	5
G. varius	1	7		*Z. flavescens*	4	11		*T. duperrey*	1	14
G. varius	2	8		*Z. flavescens*	4	12		*T. duperrey*	1	12
T. duperrey	2	9		*P. arcatus*	1	5		*T. duperrey*	1	6
T. duperrey	2	7		*S. bursa*	1	19		*C. vanderbilti*	45	3
T. duperrey	1	12		*C. jactator*	2	3		*C. vanderbilti*	37	2
C. multicinctus	1	5		*C. jactator*	1	7		*Z. flavescens*	5	14
C. multicinctus	1	3		*G. varius*	1	10		*M. vidua*	1	25
N. literatus	4	22		*G. varius*	1	5		*M. vidua*	1	22
N. literatus	3	26		*G. varius*	2	6		*H. ornatissimus*	3	8
N. literatus	4	17		*C. multicinctus*	1	7		*C. multicinctus*	2	8
N. literatus	3	19		*C. multicinctus*	1	3		*F. flavissimus*	1	13
P. multifasciatus	1	16		*C. multicinctus*	2	8		*S. rubroviolaceus*	1	40
P. arcatus	1	9		*C. vanderbilti*	29	2		*M. burdti*	4	17
C. hanui	1	3		*C. vanderbilti*	53	3		*M. kuntee*	1	14
C. hanui	1	4		*C. vanderbilti*	34	4		*M. kuntee*	7	13
H. ornatissimus	2	8		*H. ornatissimus*	2	7		*G. varius*	1	11
H. ornatissimus	1	7		*H. ornatissimus*	1	8		*C. jactator*	2	5
C. agilis	30	2		*H. ornatissimus*	2	10		*C. jactator*	3	6
C. agilis	80	3		*A. abdominalis*	14	13		*C. jactator*	1	7
C. agilis	27	4		*A. vaigiensis*	13	13		*A. chinensis*	1	36
C. agilis	80	5		*C. argus*	1	23		*A. chinensis*	1	42
L. phthirophagus	1	6		*C. lunula*	1	15		*A. chinensis*	1	50
L. phthirophagus	2	7		*N. literatus*	1	22		*M. vanicolensis*	2	22
C. vanderbilti	20	3		*N. literatus*	1	25		*P. ewaensis*	1	6
S. bursa	1	9		*P. evanidus*	1	6		*P. ewaensis*	1	4
S. bursa	1	6		*P. ewaensis*	1	9		*P. multifasciatus*	1	17
S. bursa	1	12		*S. balteata*	1	7		*S. marginatus*	1	8
C. strigosus	1	10		*S. rubroviolaceus*	1	9		*S. spiniferum*	1	18
C. strigosus	4	4		*S. spiniferum*	1	17				
C. strigosus	5	8		*M. niger*	8	27				
C. strigosus	9	7								
C. potteri	1	7								
C. loricula	1	7								
C. loricula	1	5								
A. nigricans	1	9								
G. meleagris	1	60								
S. dumerili	1	65								

12 Pipe N 8/8/20

50'

Species	Individuals	Size (cm)
T. duperrey	2	7
T. duperrey	1	11
C. gaimard		24
C. agilis	12	4
A. nigrofuscus	3	9
A. nigrofuscus	6	10
A. nigrofuscus	3	12
C. vanderbiliti	12	2
C. vanderbiliti	20	3
Z. flavescens	16	10
Z. flavescens	8	14
P. octotaenia	1	8
P. octotaenia	2	9
H. ornatissimus	2	7
H. ornatissimus	1	8
H. ornatissimus	1	12
G. varius	1	7
P. multifasciatus	2	21
N. literatus	1	26
N. literatus	1	21
N. literatus	1	31
N. literatus	1	28
C. sordidus	26	26
C. sordidus	20	20
C. sordidus	10	10
C. sordidus	15	15
C. sordidus	23	25
M. vidua	1	24
A. chinensis	1	44
A. olivaceus	1	23
A. thompsoni	2	21
C. ornatissimus	2	16
F. flavissimus	1	12
O. unifasciatus	1	28
Z. cornutus	1	12
C. orthogrammus	3	29
P. pleurostigma	1	20

35'

Species	Individuals	Size (cm)
N. literatus	1	24
N. literatus	1	19
C. vanderbiliti	21	2
C. vanderbiliti	40	3
T. duperrey	5	8
T. duperrey	1	7
T. duperrey	4	12
T. duperrey	1	15
H. ornatissimus	1	6
H. ornatissimus	1	7
A. nigrofuscus	10	12
Z. flavescens	3	9
Z. flavescens	11	13
Z. flavescens	6	16
Z. flavescens	3	12
C. strigosus	4	10
C. strigosus	8	12
C. strigosus	1	20
F. flavissimus	1	13
A. achilles	1	9
A. chinensis	1	40
A. nigricans	1	11
A. olivaceus	1	25
A. olivaceus	1	23
A. thompsoni	1	18
C. argus	1	26
C. hanui	2	5
C. verater	9	14
C. sordidus	1	14
C. sordidus	1	26
C. sordidus	10	22
C. sordidus	2	25
C. sordidus	1	28
C. ornatissimus	1	13
H. polylepis	1	13
M. burdti	2	13
M. burdti	1	15
M. geoffroy	1	3
O. unifasciatus	1	28
P. ewaensis	2	5
S. bursa	2	14
S. rubroviolaceus	1	38
S. spiniferum	1	15
Kyphosus spp.	2	24

15'

Species	Individuals	Size (cm)
A. nigrofuscus	4	13
A. nigrofuscus	3	6
A. nigrofuscus	4	10
C. strigosus	8	9
C. strigosus	5	12
C. strigosus	5	10
C. strigosus	1	16
N. literatus	1	24
N. literatus	1	27
N. literatus	1	26
C. hawaiiensis	1	20
C. hawaiiensis	1	19
T. duperrey	1	7
T. duperrey	2	5
T. duperrey	3	13
T. duperrey	4	9
H. ornatissimus	1	8
C. vanderbiliti	34	2
C. vanderbiliti	30	3
S. rubroviolaceus	1	38
S. rubroviolaceus	1	48
S. rubroviolaceus	1	26
Z. flavescens	11	14
Z. flavescens	14	12
Kyphosus spp.	1	21
A. nigricans	1	15
A. nigricans	3	13
C. jactator	2	5
S. psittacus	1	24
S. psittacus	1	18
S. balteata	1	13
A. furca	1	32
A. olivaceus	1	18
C. melampygus	1	46
C. melampygus	1	40
C. quadrimaculatus	1	12
N. unicornis	1	21
P. multifasciatus	1	13
P. multifasciatus	2	15
S. bursa	1	16
O. meleagris	1	6
Z. cornutus	2	12

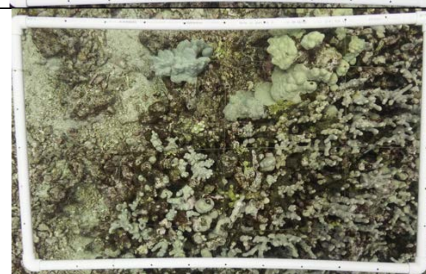
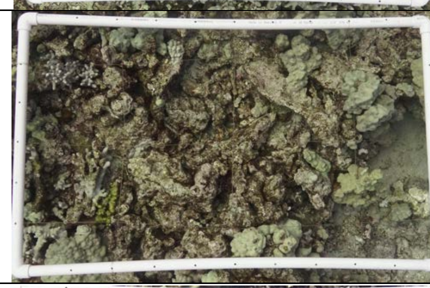
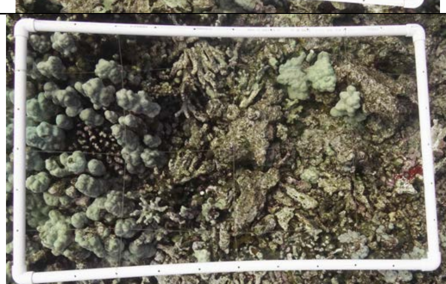
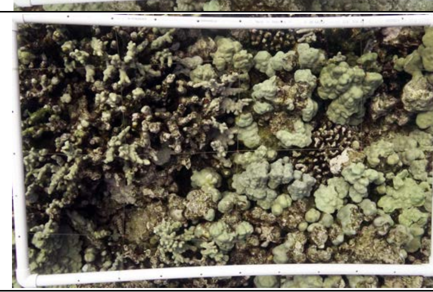
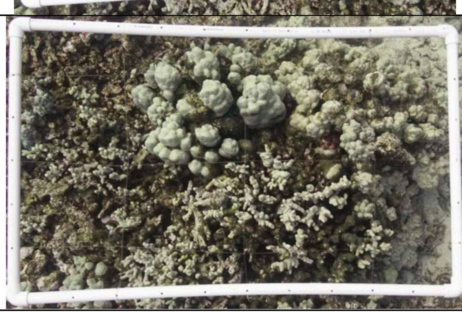
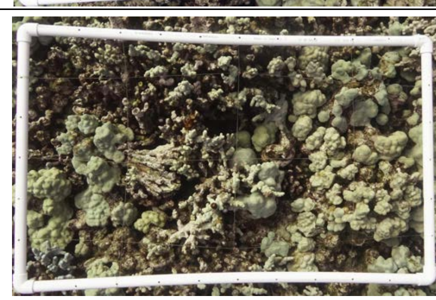
12 Pipe South	8/8/20							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
T. duperrey	1	12	N. literatus	1	23	Z. flavescens	6	13
T. duperrey	1	14	N. literatus	1	26	Z. flavescens	2	15
T. duperrey	1	17	N. literatus	1	20	A. nigrofuscus	6	7
T. duperrey	3	8	Z. flavescens	2	15	A. nigrofuscus	5	12
T. duperrey	1	10	Z. flavescens	4	13	C. vanderbilti	37	2
A. nigrofuscus	3	9	Z. flavescens	1	12	C. vanderbilti	40	3
A. nigrofuscus	8	7	C. strigosus	2	10	N. literatus	1	22
A. nigrofuscus	6	8	C. strigosus	1	6	N. literatus	1	17
C. strigosus	6	14	C. strigosus	9	7	C. sordidus	2	15
C. strigosus	10	9	A. nigrofuscus	3	9	C. sordidus	1	16
C. strigosus	5	5	A. nigrofuscus	3	12	T. duperrey	3	10
Z. flavescens	3	11	A. nigrofuscus	5	4	T. duperrey	5	8
Z. flavescens	2	15	A. nigrofuscus	5	6	T. duperrey	1	13
C. sordidus	1	22	A. nigrofuscus	6	9	T. duperrey	2	7
C. sordidus	1	18	S. bursa	1	20	H. ornatissimus	2	6
C. sordidus	2	14	C. sordidus	1	23	H. ornatissimus	2	7
C. sordidus	1	28	C. sordidus	1	20	H. ornatissimus	1	14
C. multicinctus	1	5	C. sordidus	1	27	S. bursa	1	17
C. vanderbilti	71	2	T. duperrey	1	7	F. flavissimus	2	14
C. vanderbilti	92	3	T. duperrey	5	10	M. niger	1	22
N. literatus	2	19	T. duperrey	1	15	Kyphosus spp.	2	25
N. literatus	1	16	T. duperrey	4	5	Kyphosus spp.	4	32
Z. corntus	1	13	G. varius	1	13	Kyphosus spp.	2	28
C. agilis	20	18	C. ornatissimus	2	14	C. strigosus	6	13
C. agilis	20	34	A. olivaceus	1	23	C. ornatissimus	1	14
C. multicinctus	1	5	A. olivaceus	1	21	A. olivaceus	1	18
H. ornatissimus	1	13	H. polylepis	16	14	A. olivaceus	1	21
H. ornatissimus	2	12	P. multifasciatus	1	22	C. amboinensis	1	6
C. jactator	2	4	P. multifasciatus	2	14	C. amboinensis	1	9
P. arcatus	1	13	P. multifasciatus	1	17	C. carolinus	1	22
P. arcatus	2	11	A. nigroris	1	12	C. hawaiiensis	2	17
G. varius	1	13	C. gaimard	2	9	C. hawaiiensis	1	24
G. varius	2	8	C. gaimard	1	7	C. hawaiiensis	1	14
C. dumerilii	1	10	C. jactator	1	5	C. lunula	3	13
C. hawaiiensis	2	19	C. jactator	2	4	C. lunula	1	16
C. hawaiiensis	1	20	C. vanderbilti	60	2	C. multicinctus	1	10
C. lunula	1	14	C. vanderbilti	20	3	C. multicinctus	1	12
F. flavissimus	1	9	C. vanderbilti	20	4	T. duperrey	3	12
P. cyclostomus	1	26	H. ornatissimus	1	5	T. duperrey	2	16
P. evanidus	1	6	H. ornatissimus	1	10	T. duperrey	2	9
P. ewaensis	1	9	H. ornatissimus	1	13	Z. flavescens	14	14
G. meleagris	1	56	M. vidua	1	19	Z. flavescens	40	12
L.	1	6	P. arcatus	1	12	Z. flavescens	42	9
P. multifasciatus	1	13	P. aspricaudus	1	11	A. triostegus	1	13
P. multifasciatus	1	9	P. aspricaudus	1	8	G. varius	1	13
P. octotaenia	1	8	P. evanidus	1	5	P. cyclostomus	1	14
P. tetrataenia	1	7	P. evanidus	1	4	P. imparipennis	3	3
Z. flavescens	4	10	P. imparipennis	1	4	S. balteata	1	6
			P. octotaenia	2	12	S. balteata	2	9
			P. tetrataenia	1	8	S. psittacus	2	22
			Z. cornutus	1	14	S. rubroviolaceus	1	16
			P. octotaenia	1	10	C. jactator	1	4
			P. octotaenia	1	7	P. multifasciatus	1	13
			O. unifasciatus	1	20	R. rectangulus	1	17
			C. miliaris	1	11			

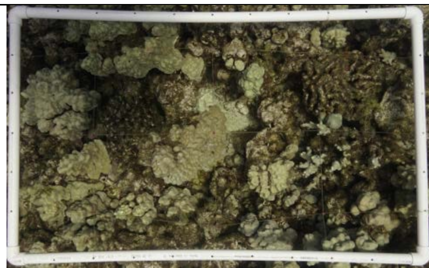
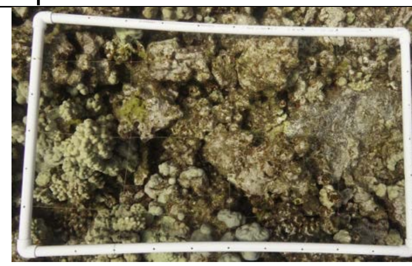
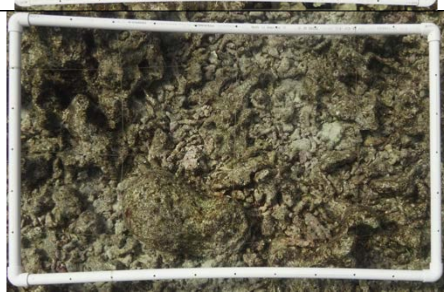
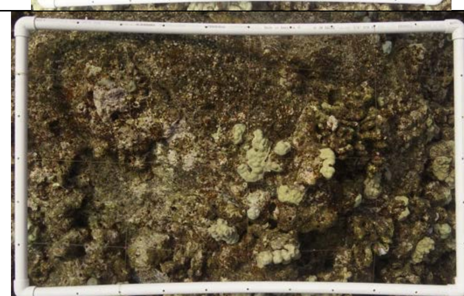
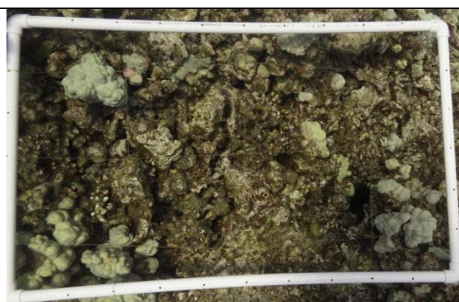
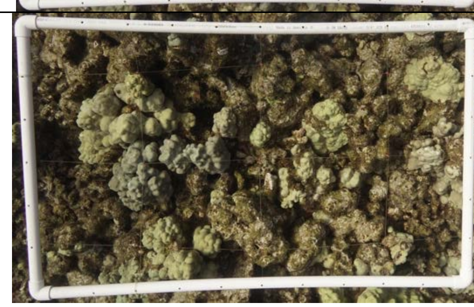
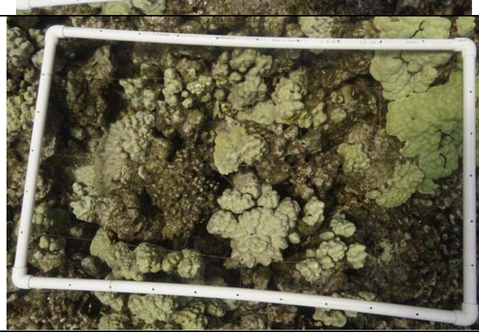
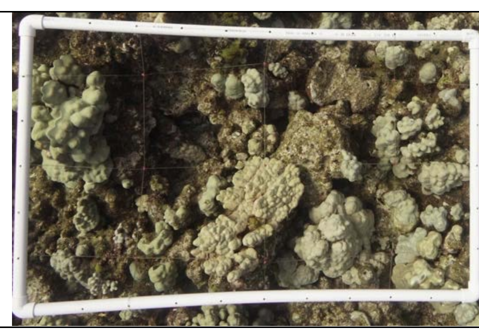
18 Pipe	8/8/20							
50'			35'			15'		
Species	Individuals	Size (cm)	Species	Individuals	Size (cm)	Species	Individuals	Size (cm)
A. nigrofuscus	8	5	N. literatus	2	22	C. jactator	2	4
A. nigrofuscus	6	10	N. literatus	1	21	C. jactator	1	5
A. nigrofuscus	10	6	N. literatus	1	25	A. nigrofuscus	5	10
C. agilis	10	3	Z. flavescens	1	13	A. nigrofuscus	5	14
C. agilis	6	4	Z. flavescens	6	11	A. nigrofuscus	8	13
C. agilis	8	6	Z. flavescens	8	14	T. duperrey	3	12
C. strigosus	10	9	C. strigosus	2	10	T. duperrey	3	7
C. strigosus	15	6	C. strigosus	1	12	T. duperrey	2	10
C. vanderbiliti	21	2	C. strigosus	5	8	Z. flavescens	11	11
C. vanderbiliti	20	3	A. nigrofuscus	8	12	Z. flavescens	18	16
C. vanderbiliti	17	5	A. nigrofuscus	1	13	P. insularis	1	13
N. literatus	2	19	A. nigrofuscus	3	11	P. insularis	1	16
N. literatus	1	20	A. nigrofuscus	4	7	P. insularis	1	17
N. literatus	1	21	A. nigrofuscus	2	6	C. strigosus	4	8
N. literatus	1	26	S. bursa	1	17	C. strigosus	4	12
T. duperrey	2	7	S. bursa	1	15	C. strigosus	2	14
T. duperrey	1	6	T. duperrey	3	8	C. strigosus	2	17
T. duperrey	1	12	T. duperrey	2	5	C. strigosus	1	15
T. duperrey	1	14	T. duperrey	2	9	C. vanderbiliti	18	2
S. bursa	1	15	T. duperrey	1	12	C. vanderbiliti	15	3
C. sordidus	1	26	T. duperrey	1	13	A. olivaceus	1	19
C. sordidus	2	15	G. varius	1	13	A. olivaceus	1	20
C. sordidus	1	21	G. varius	1	7	M. niger	4	26
G. varius	1	14	C. sordidus	2	18	H. ornatissimus	1	11
G. varius	1	15	C. sordidus	16	14	H. ornatissimus	2	7
G. varius	1	8	C. jactator	1	5	H. ornatissimus	1	10
G. varius	1	7	C. vanderbilti	72	2	S. bursa	1	17
Z. flavescens	3	5	C. vanderbilti	75	3	C. hawaiiensis	6	20
Z. flavescens	1	14	H. ornatissimus	20	7	C. hawaiiensis	5	26
Z. flavescens	1	13	H. ornatissimus	1	4	N. literatus	1	33
Z. flavescens	1	12	H. ornatissimus	1	11	N. literatus	1	30
C. jactator	1	3	P. multifasciatus	2	9	N. literatus	1	25
C. multicinctus	2	3	P. multifasciatus	1	3	Z. flavescens	4	12
A. olivaceus	1	24	P. arcatus	1	9	Z. flavescens	4	14
S. rubroviolaceus	1	18	P. arcatus	1	6	C. multicinctus	1	9
C. gaimard	1	12	P. octotaenia	1	7	P. multifasciatus	1	10
C. gaimard	1	8	C. agilis	7	4	C. argus	1	36
C. gaimard	1	7	C. multicinctus	2	9	C. lunula	1	14
C. hanui	1	3	C. multicinctus	2	4	C. sordidus	1	19
C. jactator	1	4	C. quadrimaculatus	1	12	C. strigosus	7	17
C. ornatissimus	1	13	L. phthirophagus	1	6	C. strigosus	8	12
P. arcatus	1	9	P. ewaensis	2	5	M. kuntee	1	11
P. evanidus	2	7	P. ewaensis	1	4	M. kuntee	2	13
P. evanidus	1	6	S. balteata	1	12	P. arcatus	1	9
P. ewaensis	1	7	S. rubroviolaceus	1	12	P. cyclostomus	1	12
P. multifasciatus	1	14	S. rubroviolaceus	1	17	S. marginatus	2	9
P. multifasciatus	1	12	S. rubroviolaceus	1	34	S. marginatus	1	7
P. octotaenia	2	8	T. duperrey	4	7	S. marginatus	1	6
P. octotaenia	1	4	T. duperrey	1	10	Z. corntus	1	12
S. balteata	2	9	T. duperrey	1	15			
S. psittacus	1	20	C. argus	1	31			
C. potteri	1	5	C. argus	1	38			
C. potteri	2	7						
H. ornatissimus	2	7						
H. ornatissimus	1	6						
H. ornatissimus	1	4						
H. ornatissimus	1	10						
L. phthirophagus	1	4						
L. phthirophagus	1	6						
L. phthirophagus	1	7						
M. geoffroy	1	6						

PLANB CONSULTANCY

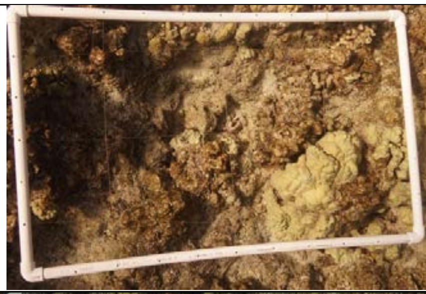
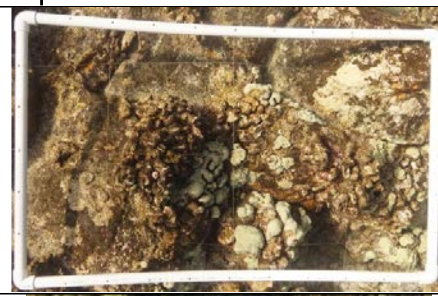
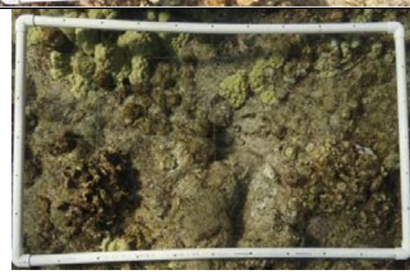
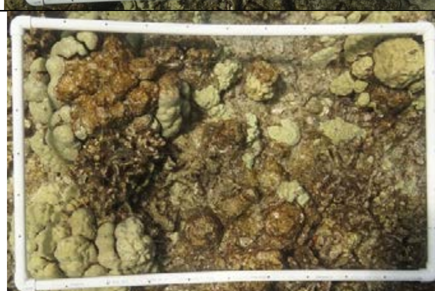
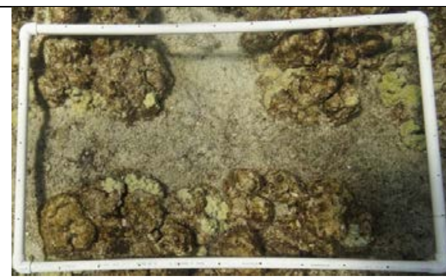
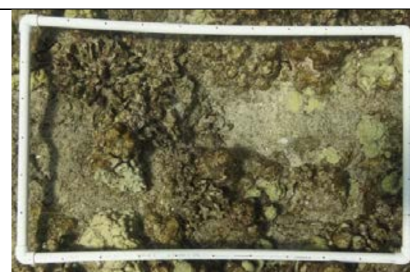
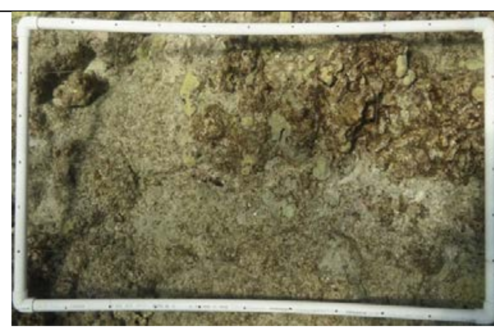
Wawa	8/9/20							
50'			35'			15'		
Species	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**	**Species**	**Individuals**	**Size (cm)**
I. umbrilatus	1	18	*C. vanderbiliti*	40	2	*A. nigrofuscus*	1	10
I. umbrilatus	1	21	*C. vanderbiliti*	63	3	*A. nigrofuscus*	10	12
C. chanos	1	75	*C. vanderbiliti*	20	4	*A. nigrofuscus*	1	11
S. bursa	2	24	*Z. flavescens*	7	16	*T. duperrey*	2	8
C. vanderbiliti	11	3	*Z. flavescens*	5	3	*T. duperrey*	1	14
C. vanderbiliti	18	2	*Z. flavescens*	5	13	*T. duperrey*	1	6
C. gaimard	1	7	*T. duperrey*	2	12	*T. duperrey*	2	7
S. baiteata	1	12	*T. duperrey*	2	8	*T. duperrey*	2	10
P. octotaenia	1	6	*T. duperrey*	1	17	*T. duperrey*	1	11
			T. duperrey	1	4	*Z. flavescens*	1	12
			T. duperrey	2	6	*Z. flavescens*	3	14
			T. duperrey	1	10	*N. literatus*	1	20
			A. nigrofuscus	1	8	*S. bursa*	1	15
			A. nigrofuscus	1	6	*C. quadrimaculatus*	1	3
			A. nigrofuscus	2	5	*A. olivaceus*	1	10
			H. ornatissimus	1	7	*A. olivaceus*	2	20
			H. ornatissimus	1	9	*A. olivaceus*	1	22
			H. ornatissimus	1	6	*C. gaimard*	1	9
			P. octotaenia	1	8	*C. gaimard*	1	14
			P. octotaenia	1	6	*C. jactator*	1	5
			A. olivaceus	2	21	*C. jactator*	1	8
			A. olivaceus	1	19	*C. jactator*	1	6
			A. olivaceus	2	20	*C. ornatissimus*	1	15
			G. varius	2	8	*P. cyclostomus*	1	14
			A. nigroris	1	19	*P. ewaensis*	6	5
			A. nigroris	1	16	*P. ewaensis*	1	6
			C. agilis	2	4			
			C. jactator	1	4			
			C. lunula	1	15			
			C. lunula	1	16			
			C. multicinctus	1	5			
			C. ornatissimus	1	13			
			C. sordidus	1	19			
			C. strigosus	3	5			
			G. meleagris	1	40			
			L. phthirophagus	1	6			
			P. ewaensis	6	5			
			Z. cornutus	1	14			
			C. quadrimaculatus	1	14			
			C. quadrimaculatus	2	6			
			C. quadrimaculatus	1	3			
			P. imparipennis	2	4			
			S. balteata	1	11			
			Cirripectes vanderbi	1	7			

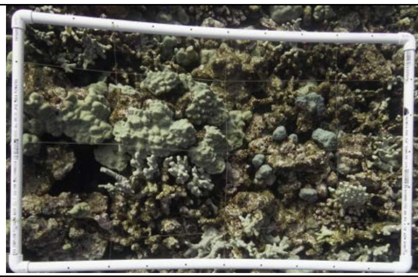
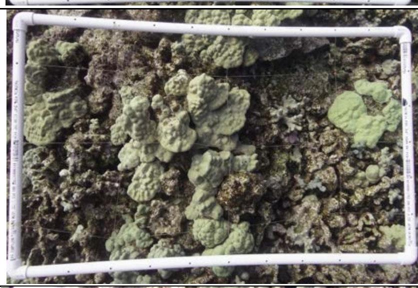
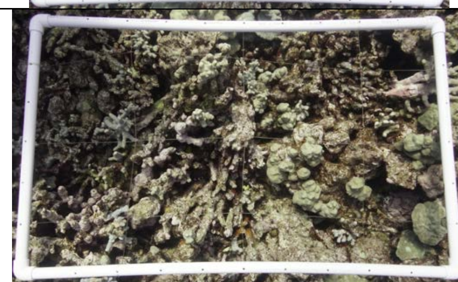
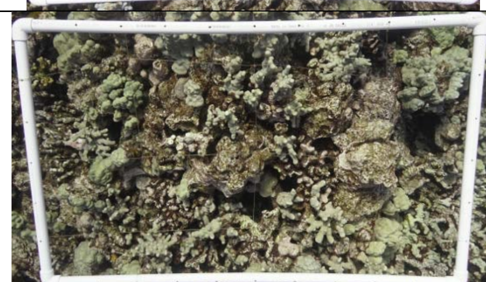
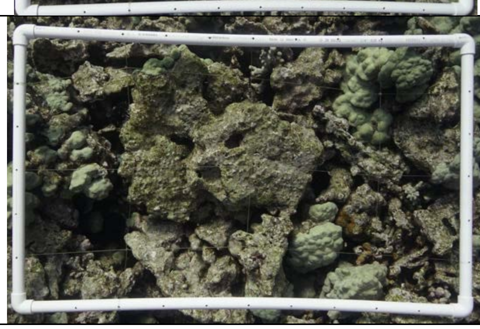
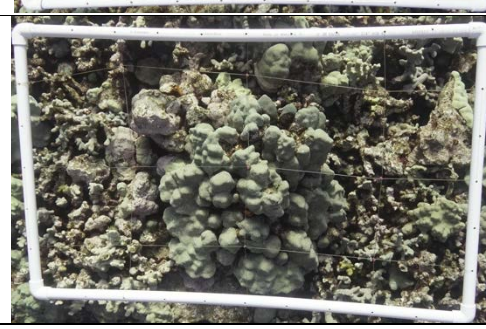
Appendix 4. Digital images of quadrats used for benthic habitat characterization

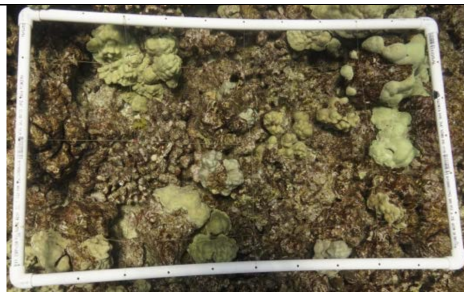
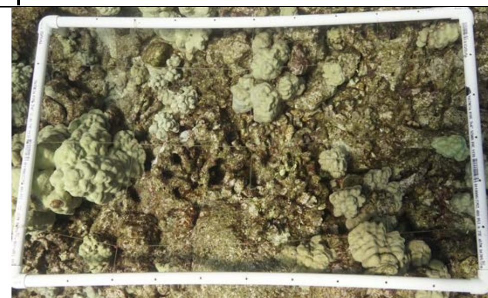
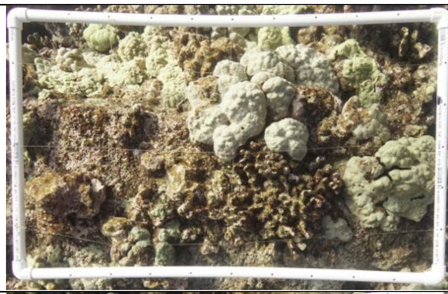
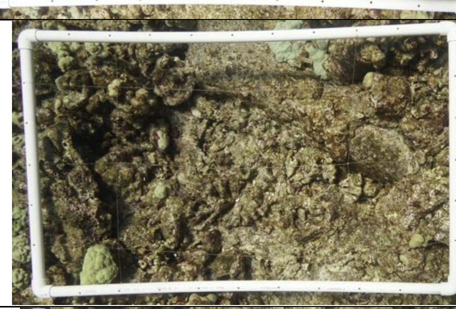
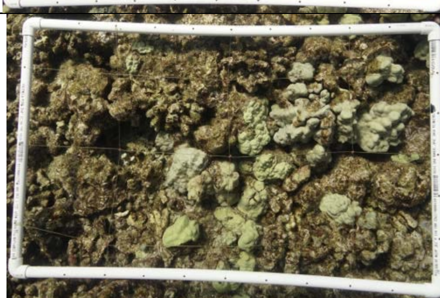
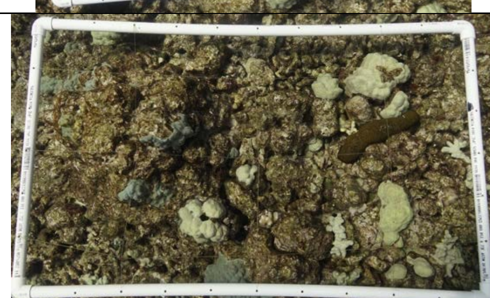
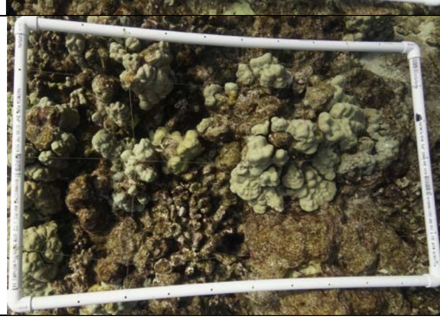
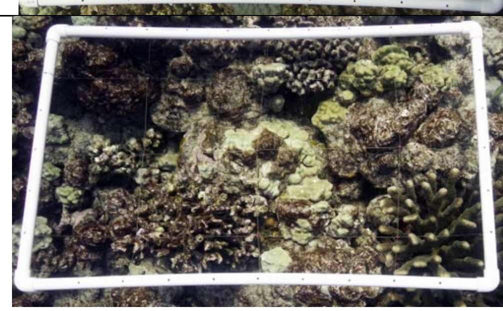
Site: Hoʻona Bay Depth: 50fsw	
	
	
	
	
	

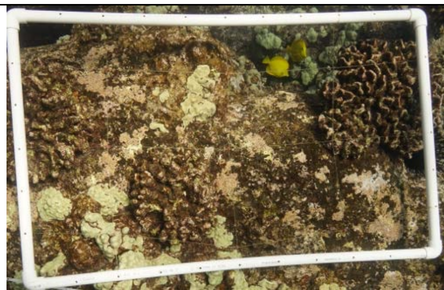
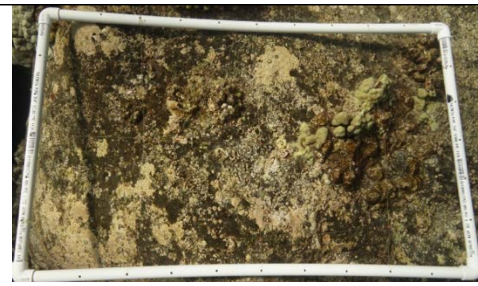
Site: Ho‘ona Bay	Depth: 30fsw
	
	
	
	
	

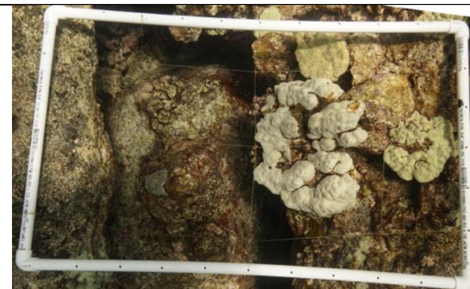
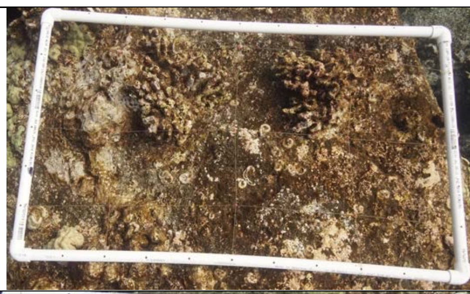
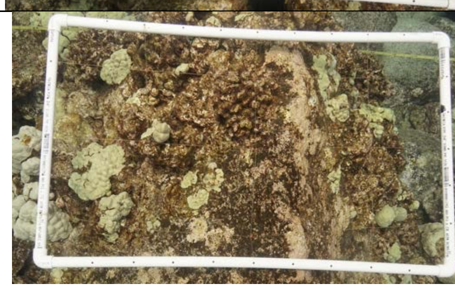
PLANB CONSULTANCY

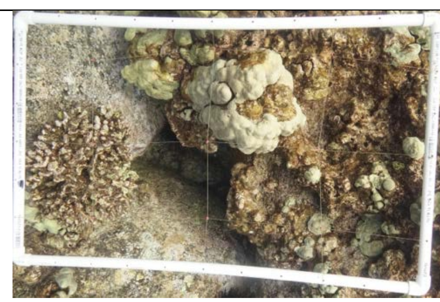
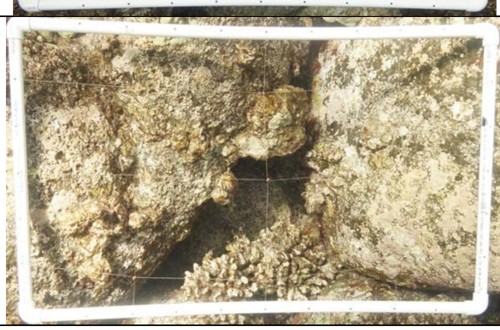
Site: Ho‘ona Bay Depth: 15fsw	
	
	
	
	
	
Site: NPPE Depth: 50sw	

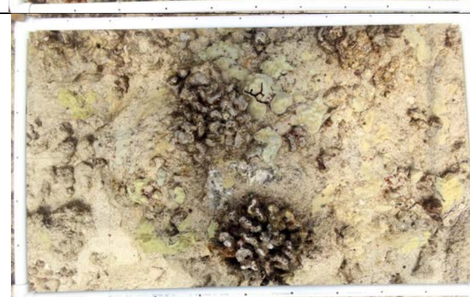
	
	
	
	
	

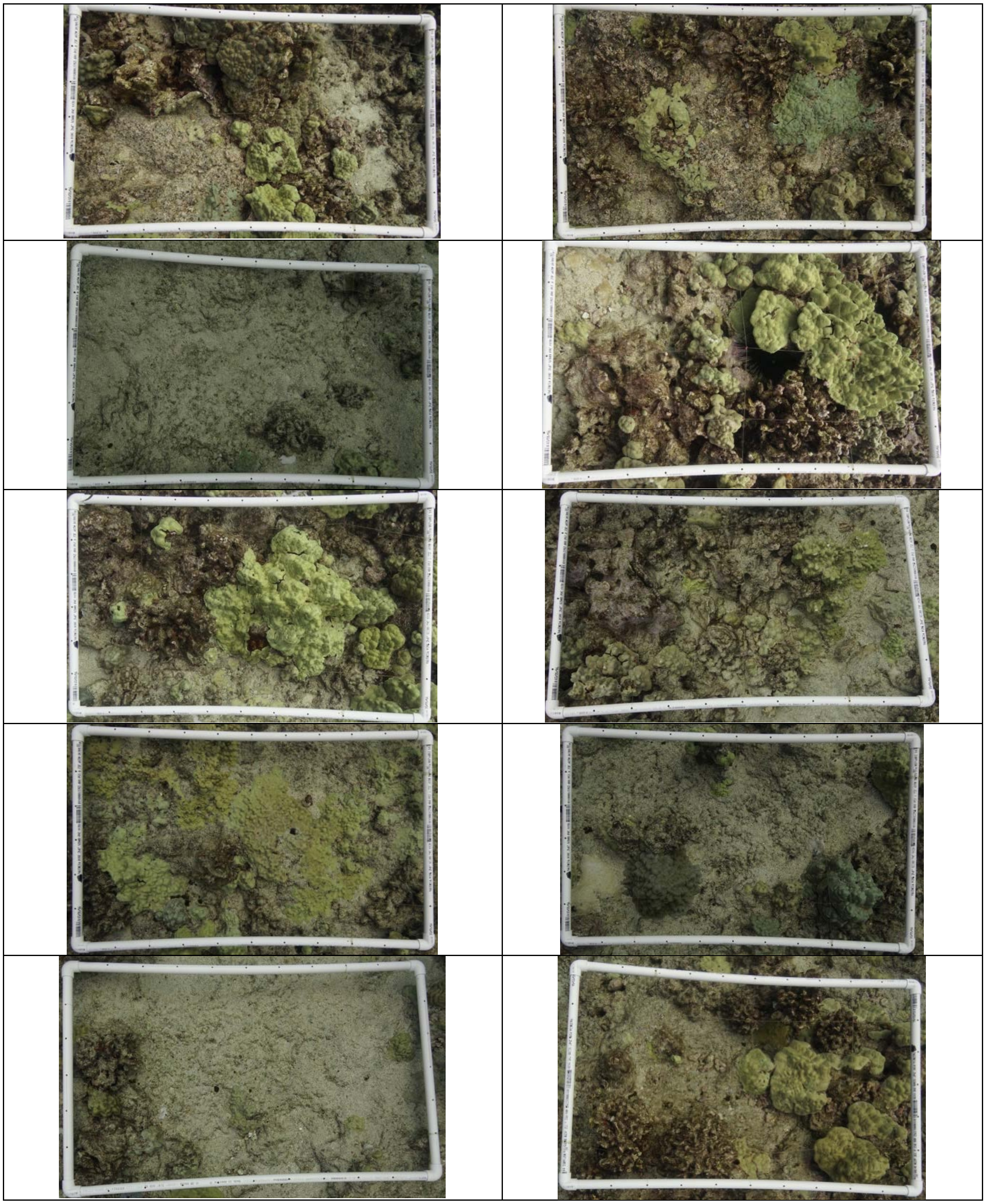
Site: NPPE	Depth: 30fsw
	
	
	
	
	
Site: NPPE	Depth: 15fsw

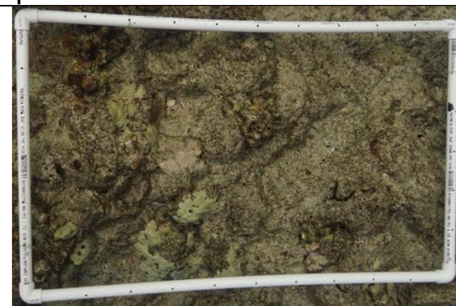
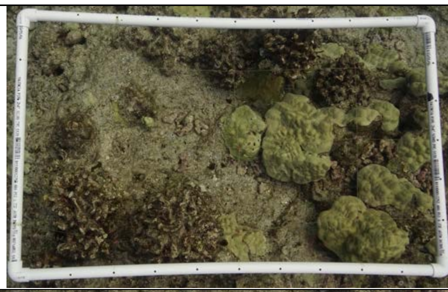
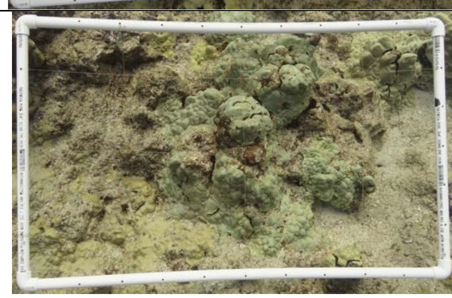
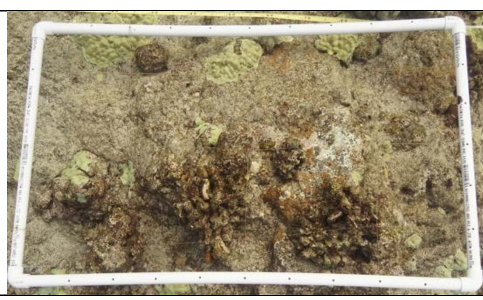
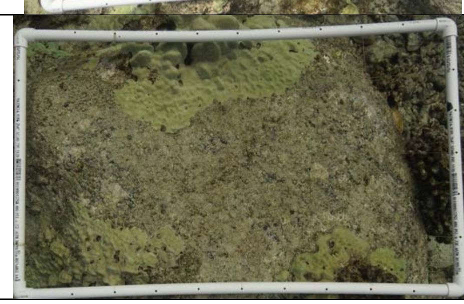



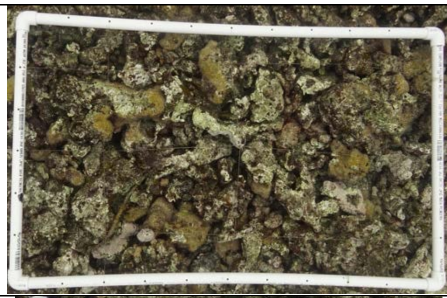
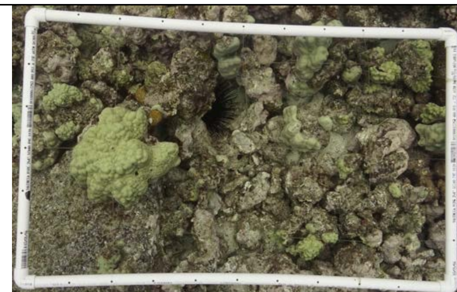
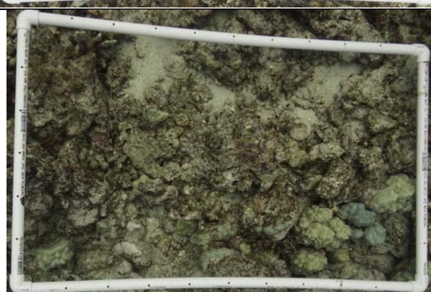
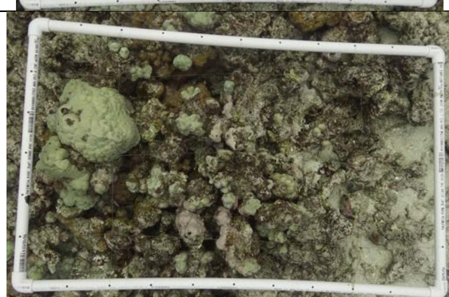
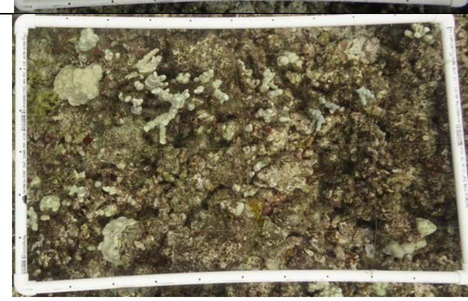
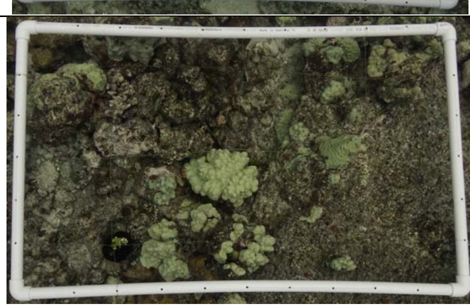
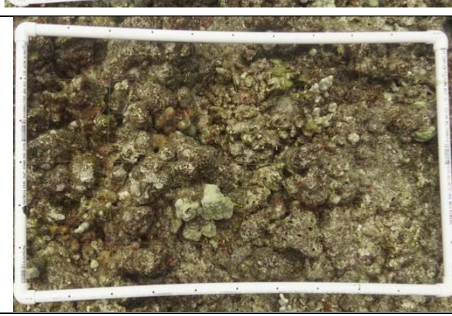




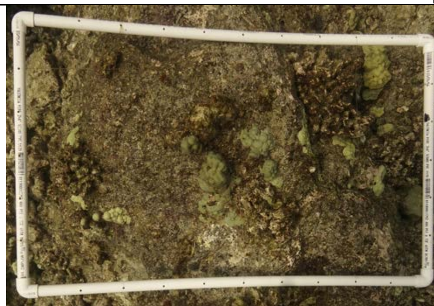
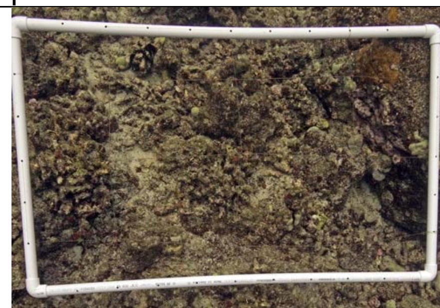
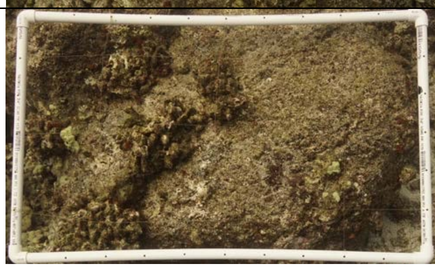
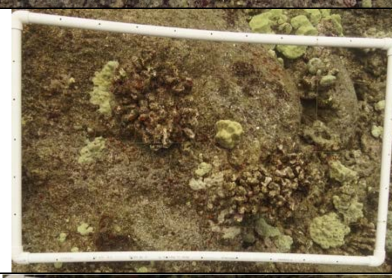
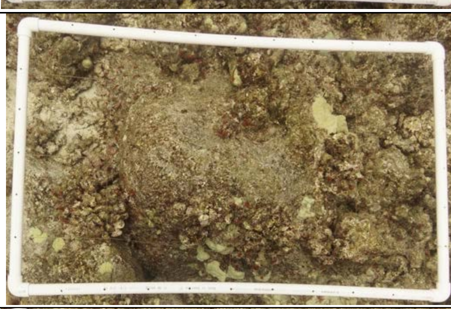
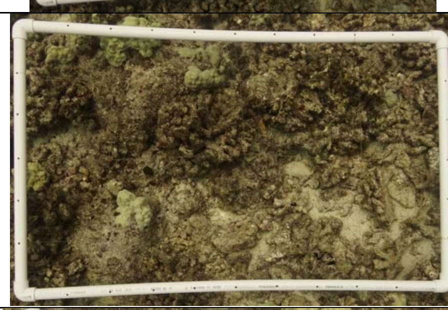
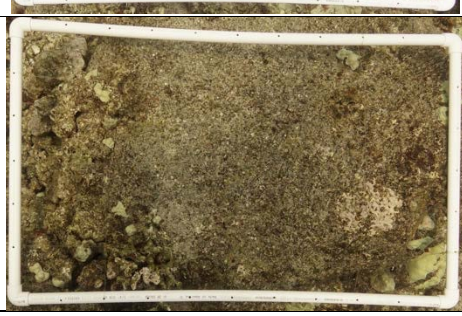
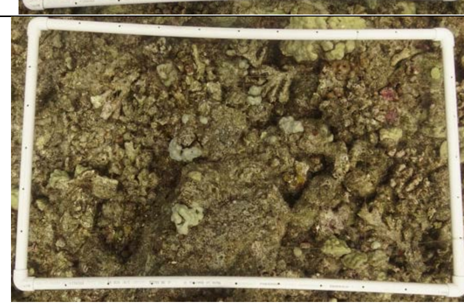



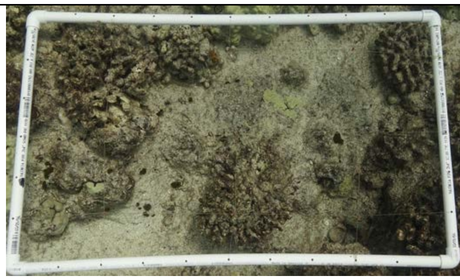
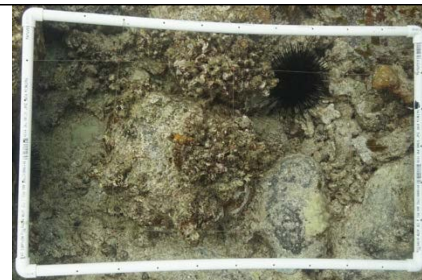
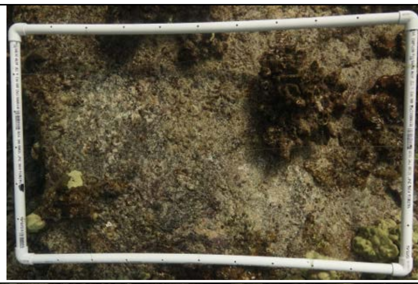
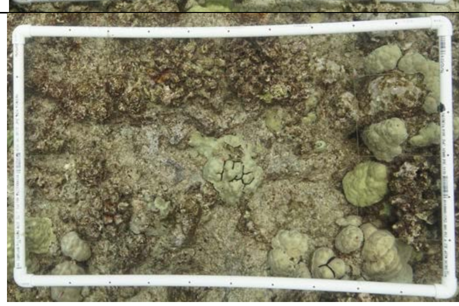
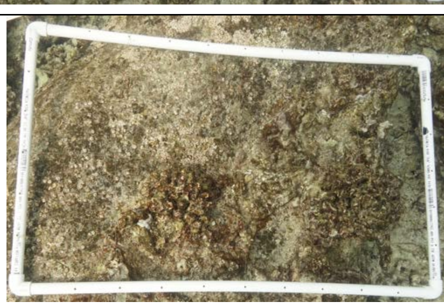
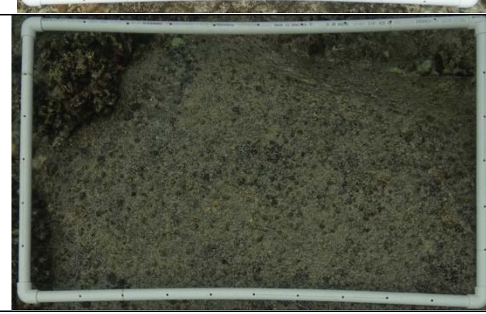

Site: WAWA	Depth: 50fsw
	
	
	
	
	
Site: WAWA	Depth: 30fsw

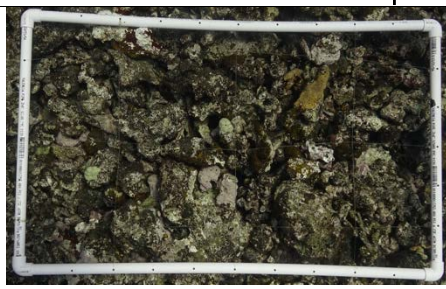
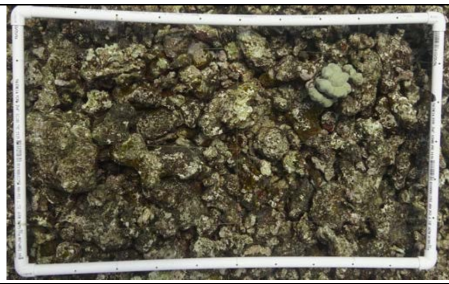
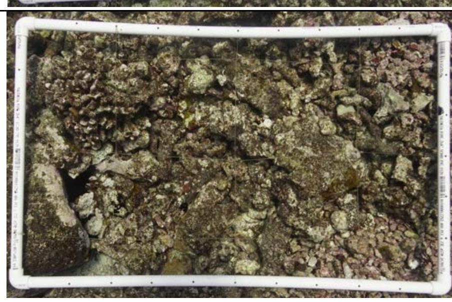
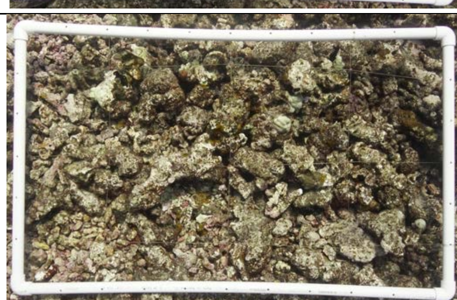
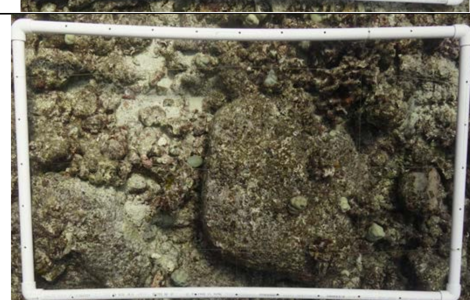
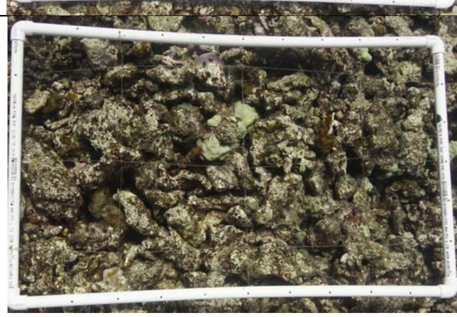
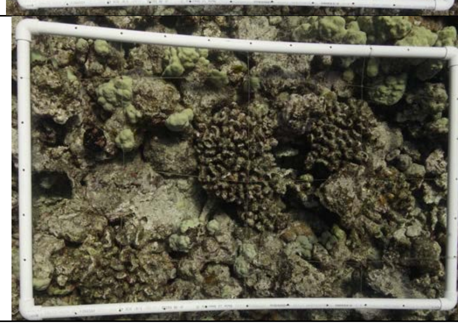


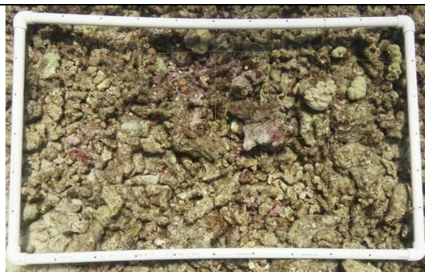
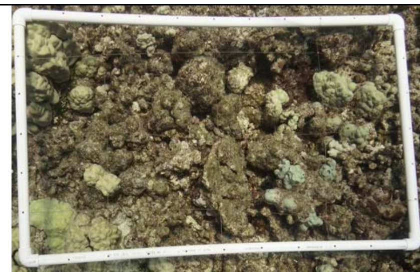
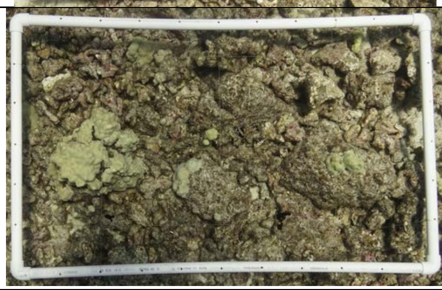
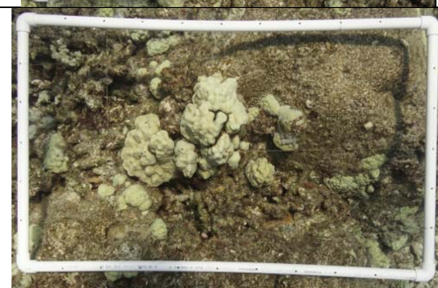
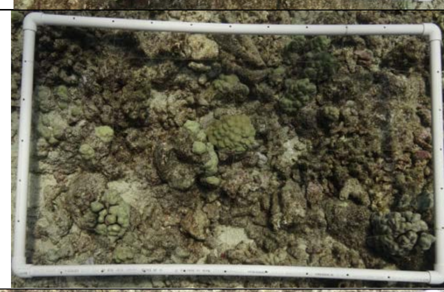
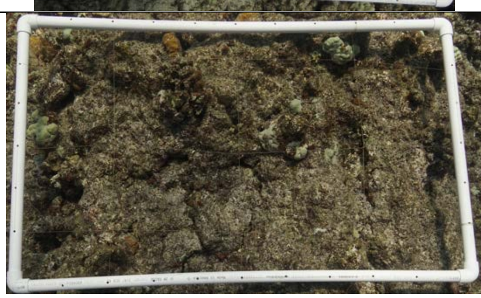
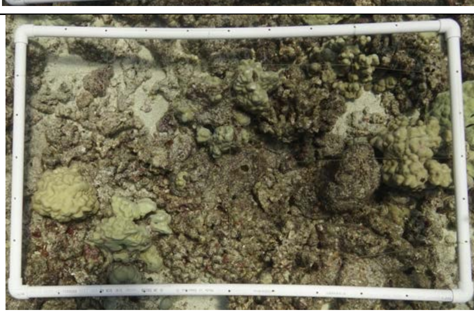
Site: WAWA Depth: 15fsw	
	
	
	
	
	
Site: 18 Pipe Depth: 50fsw	

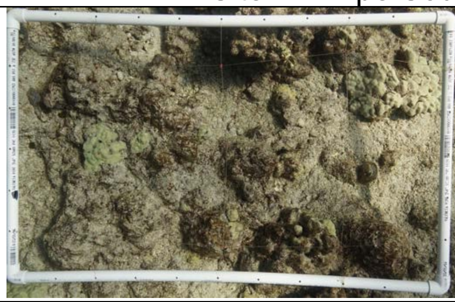
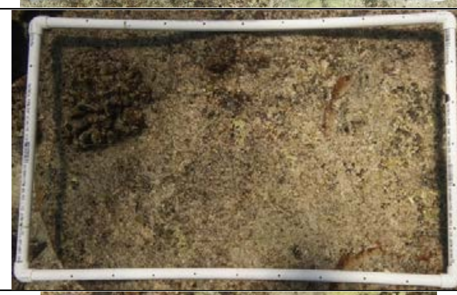
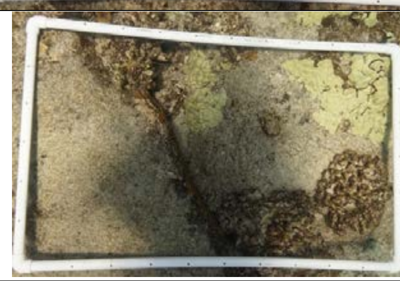
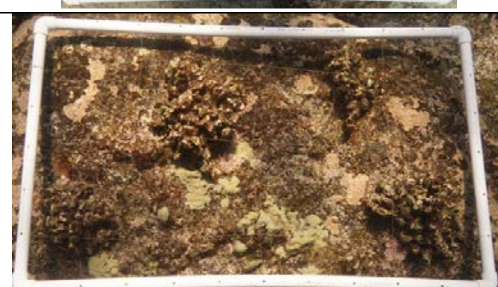
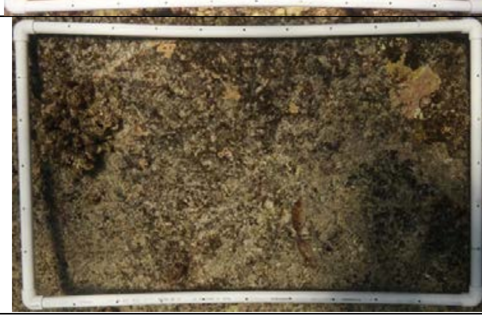
	
	
	
	
	

Site: 18 Pipe Depth: 30fsw	
	
	
	
	
	
Site: 18 Pipe Depth: 15fsw	

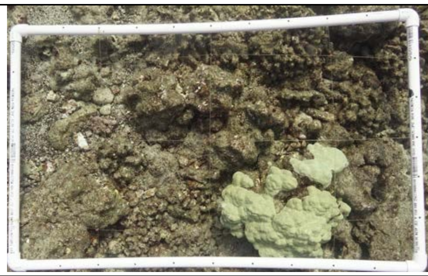
	
	
	
	
	

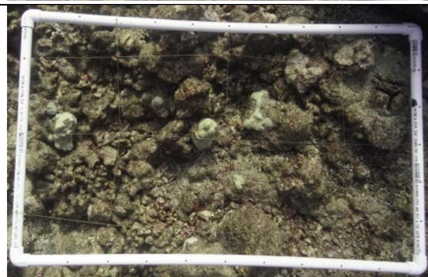
Site: 12 Pipe South Depth: 50fsw	
	
	
	
	
	
Site: 12 Pipe South Depth: 30fsw	

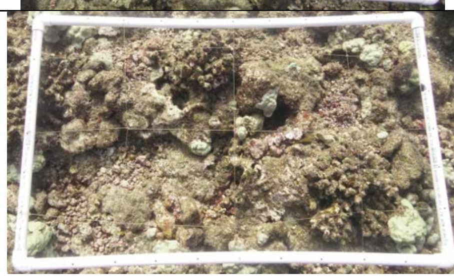
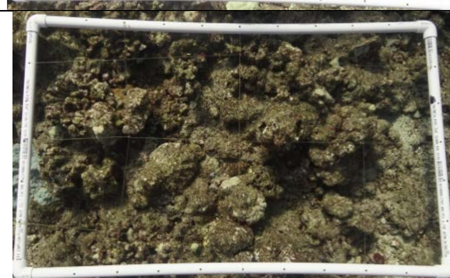
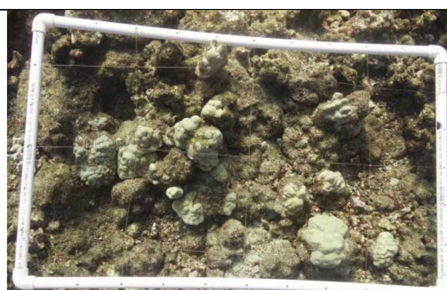
	
	
	
	
	

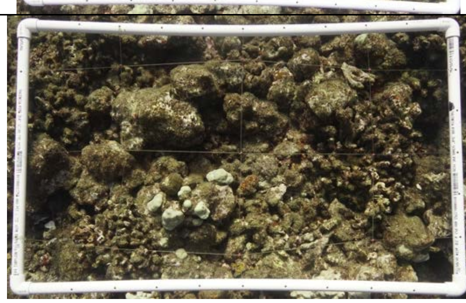
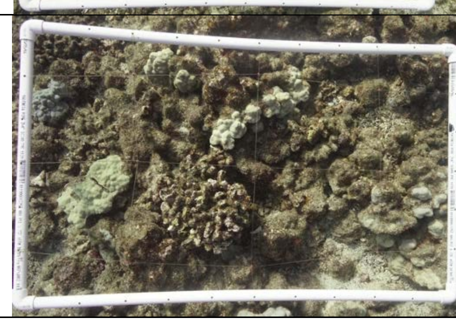
Site: 12 Pipe South	Depth: 15fsw
	
	
	
	
	
Site: 12 Pipe North	Depth: 50fsw

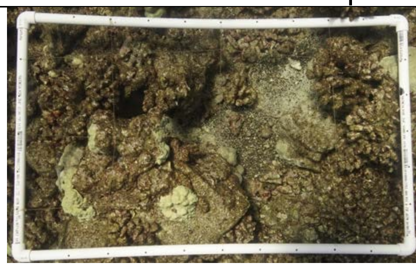
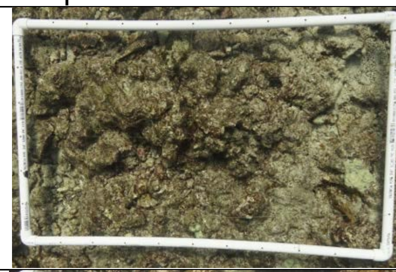
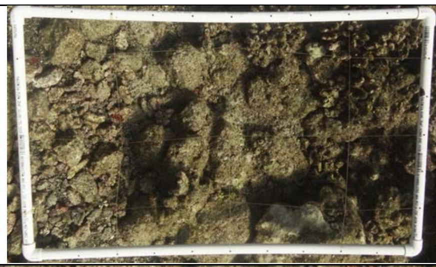
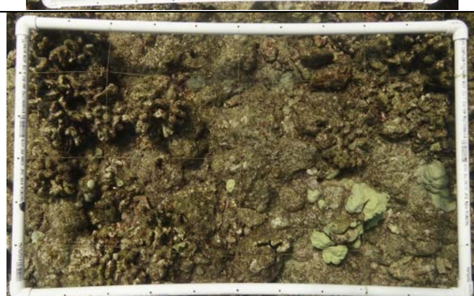
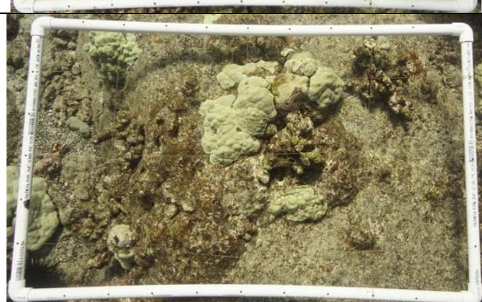
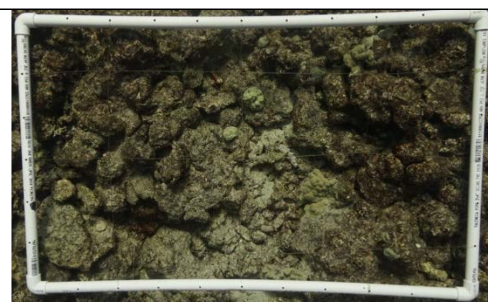
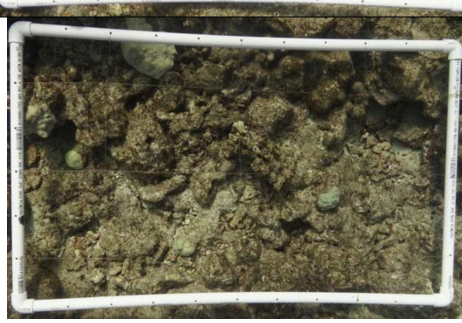
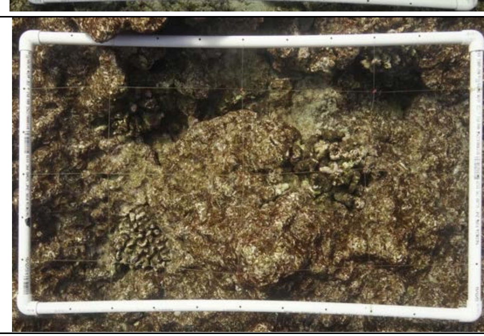
PLANB CONSULTANCY

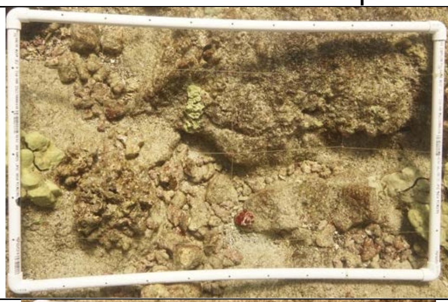
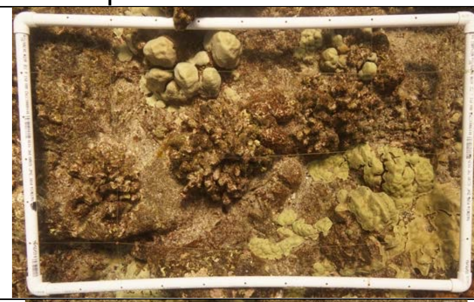
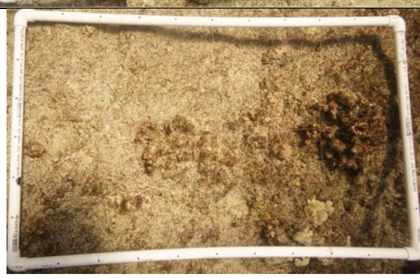
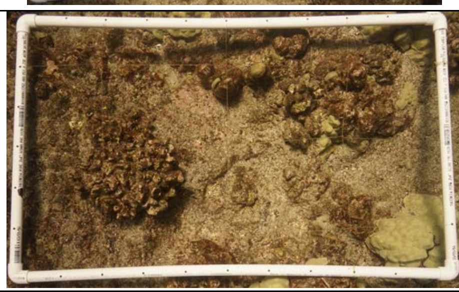
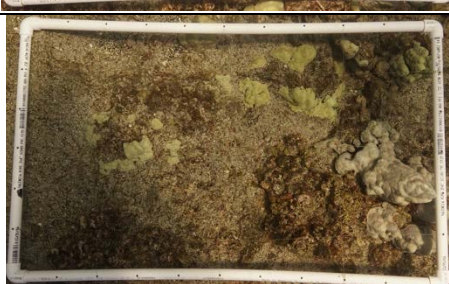
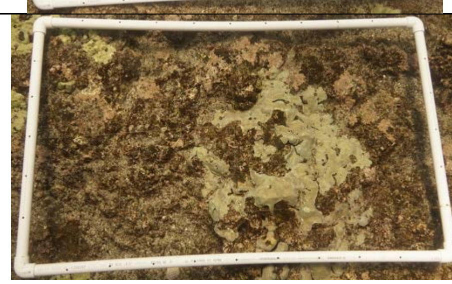
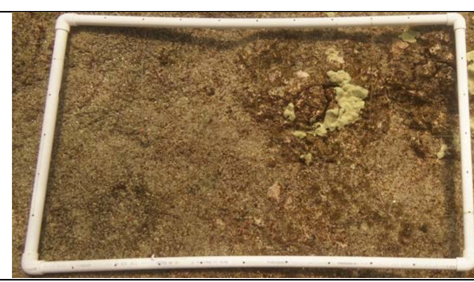




Site: 12 Pipe North	Depth: 30fsw
	
	
	
	
	

Site: 12 Pipe North	Depth: 15fsw
	
	
	
	
	

Appendix 5. Intertidal Species Identification Guide and Full List of Observed Species

Common Invert Species for NELHA surveys

Bubble Snail
Smaragdinella calyculata

Echinolit
Echinolittorina hawaiiensis

Hāʻukeʻuke
Colobocentrotus atratus

Hawaʻe
Tripneustes gratilla

Heʻe
Octopus hawaiiensis

Heʻe Mauli
Octopus cyanea

Heʻe pali
Octopus oliveri

Unauna - Hermit Crab
Calcinus spp.

ʻIna
Echinometra oblonga

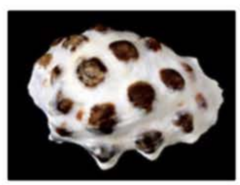
ʻIna Kea
Echinometra mathaei

Kio
Vermetidae spp

Kio Nahawele
Brachidontes crebristriatus

Leho
Cypraeidae spp.

Makaloa
Drupa ricina



Makaloa
Drupa morum

Morula
Morula granulata

Morula Uva
Morula Uva

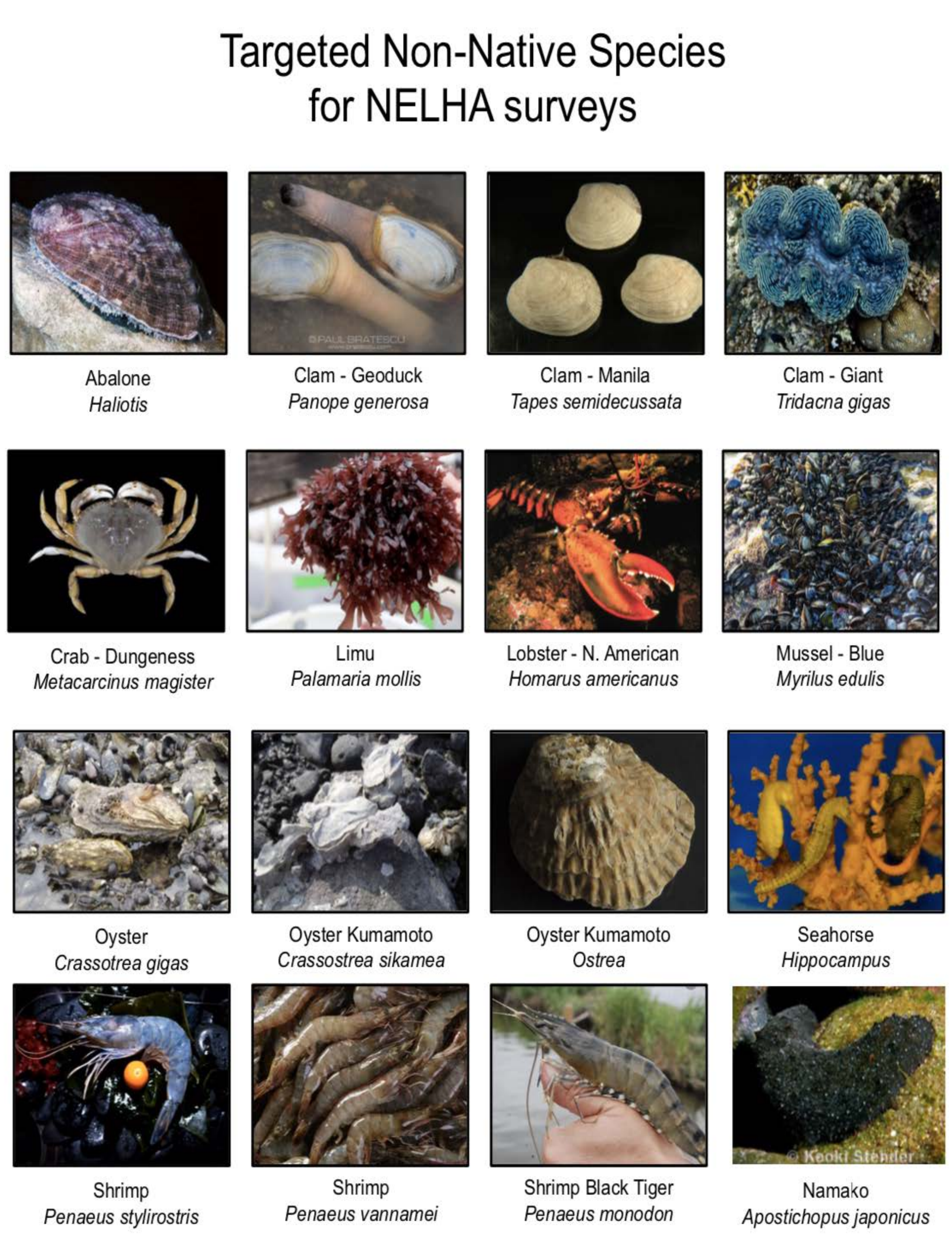
Naepuni
Neothais harpa

Nahawele
isognomon californicum

ʻOkole
Cladactella manni

PLANB CONSULTANCY


Common Invert Species for NELHA surveys
ʻŌpeʻapeʻa
Ophiuroids
ʻOpihi Awa
Siphonaria normalis
ʻOpihi ʻĀlinalina
Cellana sandwicensis
ʻOpihi Kōʻele
Cellana talcosa
ʻOpihi Makaiauli
Cellana exarata
Pīʻoeʻoe
Mytilus californianus
Pipipi
Nerita picea
Pipipi kolea
Littoraria pintado
Thais
Thais aperta
Thais int.
Thais intermedia
Common Limu Species for NELHA surveys
Limu Kala
Sargassum spp.
Limu Kohu
Asparagopsis taxiformis
Limu Kāhili
Turbinaria ornata
Limu ʻakiʻaki
Ahnfeltiopsis spp.
Limu Pālahalaha
Ulva lactuca
Limu ʻOhe
Chaetomorpha antennina
Chnoospora minima
Pterocladiella spp.


Targeted Non-Native Species
for NELHA surveys
Abalone
Haliotis
Clam - Geoduck
Panope generosa
Clam - Manila
Tapes semidecussata
Clam - Giant
Tridacna gigas
Crab - Dungeness
Metacarcinus magister
Limu
Palamaria mollis
Lobster - N. American
Homarus americanus
Mussel - Blue
Myrilus edulis
Oyster
Crassotrea gigas
Oyster Kumamoto
Crassostrea sikamea
Oyster Kumamoto
Ostrea
Seahorse
Hippocampus
Shrimp
Penaeus stylirostris
Shrimp
Penaeus vannamei
Shrimp Black Tiger
Penaeus monodon
Namako
Apostichopus japonicus

	Scientific Names	Hawaiian / Common Name
1	Acanthophora spicifera	
2	Ahnfeltiopsis concinna	
3	Asteronema spp	limu hulu ʻīlio
4	Calcinus spp.	unauna / hermit crab
5	Cellana exarata	makaiauli
6	Cellana sandwicensis	ʻālinalina
7	Chaetomorpha antennina	limu ʻohe
8	Chondrophycus spp	
9	Colobocentrotus atratus	hāʻukeʻuke / helmet urchin
10	Colpomenia sinuosa	
11	Conus spp	pūpū alā / cone shell
12	Cypraeidae spp.	leho / cowry shell
13	Dictyota spp.	
14	Drupa morum	makaloa
15	Drupa ricina	makaloa
16	Echinolittorina hawaiiensis	
17	Echinometra mathaei	ina kea
18	Echinometra oblonga	ina uli
19	Euraphia hembeli	
20	Grapsus tenuicrustatus	ʻaʻama
21	Haminoea cymbalum	bubble snail
22	Holothuria atra	loli
23	Holothuria spp	loli

24	Isognomon californicum	nahawele
25	Jania spp.	
26	Littoraria pintado	pipipi kolea
27	Morula granulata	
28	Morula uva	
29	Nerita picea	pipipi
30	Nesochthamalus intertextus	piʻoeʻoe
31	Padina spp	limu pepeiao
32	Sargassum spp	limu kala
33	Siphonaria normalis	ʻopihi ʻawa
34	Smaragdinella calyculata	calyx bubble shell
35	Turbinaria ornata	limu kahili
36	Turf	turf limu
37	Ulva fasciata	limu pālahalaha
38	Vermetidae spp	kio