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# Benthic and Biota Monitoring Program

# Natural Energy Laboratory of Hawaii Authority

# Survey Report – 2018

Prepared for:

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# EXECUTIVE SUMMARY

The Natural Energy Lab of Hawaii Authority (NELHA) is a Hawaii state agency that operates an Ocean Science and Technology Park at Kailua-Kona on the West side of Hawaii Island. The purpose of the NELHA facility is to promote research, education, and commercial activities that focus on development of sustainable industries. The nearshore marine environment surrounding NELHA, known as Keahole Point, is known for supporting abundant and diverse benthic and fish communities. The development of NELHA included the installment of pipeline infrastructure on the reef in order to pump 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 46 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 2018 surveys.

The anchialine ponds in the vicinity of the NELHA facility are distributed into two main complexes, “Northern” and “Southern”, comprised of five ponds in the Northern complex and ten in the Southern complex. The ponds within both complexes are relatively clustered, with the exception of pond S-10, which is situated south of the main Southern complex. A faunal census of each pond was completed from May 13th to May 21st, 2018 during a mid-tidal range (+0.5’ to +2.0’). Temperature and salinity were documented, and photographs, high-definition videos, and visual observations were used to quantify all flora and fauna within and surrounding each pond.

The results of the 2018 survey were generally consistent with previous annual surveys, with observed variances described in the following report. Native organisms, including the native red shrimp, ‘ōpae ‘ula (Halocaridina rubra), were found in most ponds where invasive fish were absent, with the exception of two Northern area ponds (N-3 and N-4). Similarly, the presence of invasive fish within the ponds almost always precluded native shrimp presence. Overall species composition at each pond was similar to previous surveys. Minimal turbidity was observed across sites in 2018, despite the presence of introduced fish in a portion (26%) of the ponds. Relative to 2017, fewer signs of public visitation were observed at the Southern complex ponds adjacent to the Wawaloli Beach park. Invasive algae were not observed in any pond. Observations at all ponds 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 ponds, adjacent to the NELHA facility, are not currently impacted by anthropogenic inputs from local facilities. Because of their relatively small size and enclosed nature, several of the Southern ponds are ideal candidates for invasive fish removal programs, which would likely further enhance the presence of Halocaridina rubra and other native shrimp species within the ponds.

The marine surveys are conducted at six stations along the coastline adjacent to the NELHA facilities. At each station, transects are conducted at three depth gradients (~15-fsw, ~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 eight years have found the coral cover to stabilize in the range of ~30-50%. The overall coral cover for 2018 was 35.37%, which is within this range and shows the benthic communities to have exhibited relatively consistent values of coral cover for the last eight 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 2018 were quite consistent to 2017 which indicates the pins will assist with temporal monitoring of the study sites.

The overall percent coral cover among the six stations was 35.87%, the most dominant corals were *Porites lobata* (22.49%), *Porites compressa (6.36%), Porites evermanni* (2.61%), *Montipora capitata* (2.52%), and *Pocillopora meandrina* (1.53%). These coral species were present among all the stations. Other corals present were *Pocillopora grandis (*previously *eydouxi)*, *Leptastrea purpurea, Leptastrea bewickensis, Montipora patula, Montipora flabellata, Pavona varians, Pocillopora eydouxi, 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 2018 show similar values of abundance, diversity, and biomass to 2017. Ultimately, data from the duration of the monitoring program shows the nearshore habitats surrounding NELHA support highly diverse and productive fish assemblages.

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

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# ANCHIALINE POND SURVEY

## INTRODUCTION

Anchialine ponds 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 ponds, with many examples at Keāhole Point where the NELHA facility is located. Interest in these ecosystems, previously described by numerous researchers (Holthuis 1973, Maciolek and Brock 1974), partially stemmed from the observations of abundant assemblages of tiny, red shrimp (‘ōpae ‘ula) that appeared to be restricted to this particular habitat. Anchialine systems occur globally and can be found on 30 tropical and subtropical islands within in 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 ponds are commonly found along the shoreline of West Hawai‘i, and also occur on O‘ahu, Maui, Moloka‘i, and Kaho‘olawe (Brock et al. 1987, Bailey-Brock and Brock 1993, Yamamoto et al. 2015).

The unusual environmental conditions that shape anchialine pond 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 ponds in Hawai‘i 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 ponds located within and adjacent to the NELHA facility (Brock 2008, Ziemann and Conquest 2008).

Two specialized decapod shrimp species, endemic Halocaridina rubra (‘ōpae ‘ula) and indigenous Metabetaeus lohena, are common inhabitants in many of the anchialine ponds at NELHA. H. rubra are omnivorous, and preferentially inhabit anchialine ponds throughout the day to feed on microalgae, macroalgae, and detritus (Bailey-Brock and Brock 1993). Anchialine ponds are typically connected to one another through lava tubes, rock fissures, and micro-cracks in the surrounding basalt substrate, and reproduction and larval dispersal of H. rubra generally occur within the subterranean (hypogeal) sections of anchialine systems. H. rubra have a relatively long lifespan of approximately 10 - 20 years, and are key grazers within anchialine ponds, maintaining a controlled standing crop of plants, bacteria, diatoms, and protozoans in the ponds through active grazing. This ‘gardening’ role contributes to the overall health of anchialine pond ecosystems, allowing other species to reside within the sunlit (epigeal) portion of the ponds. Because of this critical ecosystem function, H. rubra (‘ōpae ‘ula) are thought to be a keystone species within these systems (Bailey-Brock and Brock 1993). The relatively larger indigenous shrimp species, M. lohena, is also omnivorous, but can also sometimes consume H. rubra (Yamamoto et al. 2015).

Introduced fish species (e.g. mosquitofish, guppies, tilapia) are a substantial threat to native species within anchialine ponds 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 ponds 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 pond substrate, then emerge after dark to forage.

Several anthropogenic stressors can alter the health of anchialine pond ecosystems. Coastal development and other shoreline alterations can cause structural damage to the ponds and/or disrupt surrounding groundwater influx and condition. Increased human-presence adjacent to the ponds can also lead to invasive species introductions (e.g. guppies and tilapia), and to alterations to the pond surroundings and substrate due to visitation and swimming. Additionally, recent sea- level rise forecast models suggest that anchialine ponds 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 ponds may emerge further inshore, depending on elevation and groundwater connectivity. These anticipated changes associated with predicted sea-level rise could dramatically impact anchialine pond ecology. Fortunately, submarine connections between ponds will likely allow H. rubra and other shrimp species to populate new higher elevation ponds.

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 ponds 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 ponds in Hawaiʻi (e.g. at the level of ponds and pond complexes), is appropriate for determining H. rubra population status, and is utilized in this survey.

The two groups of ponds 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). Through this continued annual monitoring program at the ponds, changes in communities have been noted since 1989, with shrimp becoming absent in certain ponds due to Poeciliid fish introductions (Brock 2008, Ziemann and Conquest 2008). More recently, signs of visitation and usage have been noted for certain easily accessible ponds (Burns and Kramer 2016, Burns and Kramer 2017). Results of the May 2018 survey as part of

NELHA's Comprehensive Environmental Monitoring Program (CEMP) are reported subsequently.

## METHODS

Anchialine ponds located within the NELHA facility form localized complexes, including five ponds in the "Northern complex" and ten ponds in the "Southern complex" (Figures 1 - 3). The Northern pond complex, including ponds N-1 through N-5, is located approximately 100 m inland of the cobble beach at Hoʻona Bay (Figure 2), and the Southern pond complex, including ponds 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 pond S-10, which is located approximately 500 m south of the main pond complex (Figure 3).

Table 2 describes the location and size of each pond at the NELHA site. A Garmin 76Cx hand-held GPS unit was used to locate each pond during the May 2018 survey based on previously recorded latitudes and longitudes. In 2017, site coordinates were updated to a five-decimal system for improved ease of pond relocation (Table 2). Upon arrival at each site, pond diameter was confirmed from measurements first reported by Brock 2008 (Table 2), except for pond S-10, which was first surveyed in 2015 (Whale Environmental Services 2015). Pond dimensions and basin characteristics for historically surveyed ponds are included in Appendix 1.1 (Brock 2008).

Because anchialine pond ecosystems are significantly influenced by tide, the water level, chemistry, and appearance of the surveyed ponds were expected to vary with tidal level during the survey. The effect of tidal level was particularly apparent for the Northern pond complex, including ponds N-2, N-3, N-4 and N-5. At low tide, these ponds were separated by basalt substrate outcrops, however at high tide (> +2.1'), these pools formed a single body of water. This interconnectivity was particularly apparent during annual peak tides (or "King's tides") during which tidal levels exceeded + 2.2 ft. in May 2018. While the water level in the Southern group ponds was also strongly tidally affected, ponds were not observed to be interconnected during the 2018 survey.

Faunal observations for the May 2018 survey were collected at tide levels below the daily maximum to provide sufficient water for organismal observations and photo-quadrat sampling if possible, while avoiding pond interconnection. Sampling of the ponds was conducted at tidal levels ranging from +0.5' to +2.0'. For pond "complexes," such as in the Northern complex, each pond was surveyed only when it was physically separated from other adjacent ponds (well below the daily maximum tide).

Faunal surveys were conducted from May 13th to May 21th, 2018. 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 pond was documented using visual observations, photographs, and high-definition videos taken with a Canon G12 1080p digital waterproof camera. Images and videos were reviewed within two weeks of the surveys. Randomly selected photo-quadrats ranged in size from 0.02 $m^2$ to 0.09 $m^2$ (based on feasibility according to pond size and depth).

Individual photo-quadrats (including scale in cm) were isolated from video footage for H. rubra quantification. The number of replicate photo-quadrats analyzed for H. rubra density depended on pond area and depth and ranged from 3 to 7 replicates. H. rubra density was determined for each recorded photo-quadrat, then averaged for each pond.

Three ponds with low water levels (S-4, S-6, S-9) were surveyed visually in-situ for H. rubra density. H. rubra density for each photo-quadrat 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).

Two to five-minute videos were recorded at each pond to document the environmental surroundings and organisms present in the ponds and were later examined to qualitatively assess the biological community. Video surveys were designed to include less common, cryptic, or highly mobile species, as well as surrounding vegetation. Only the presence or absence of non-native organisms was recorded for this survey.

## RESULTS

Water quality measurements and faunal census results from the May 2018 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 pond status. Faunal presence at the ponds during the 2018 survey was generally consistent with recent previous surveys (Burns and Kramer 2016, Burns and Kramer 2017). Pond characteristics were partially explained by location, with higher species diversity and higher density vegetation surrounding the Northern ponds compared to the Southern ponds (Figures 4 - 10). The Southern ponds tended to be surrounded by non-vegetated or very sparsely vegetated basalt, and were more likely to host introduced fish, likely because of their relative conspicuousness and accessibility (Figures 8 - 10). Similar to previous surveys, certain Southern ponds had more signs of visitation, likely due to their proximity to Wawaloli Beach Park and Makako Bay Drive.

Similar to recent surveys, the Southern ponds (with the exception of pond S-10) were less saline and slightly cooler during the May 2018 survey compared to the Northern ponds. This finding suggests that relatively higher groundwater influence occurs within the Southern complex. For the Southern ponds S-1 through S-9, temperature ranged from 21.2 – 22.3 C°, and salinity ranged from 10.9 to 11.7 ppt. Slightly higher readings were recorded for distal pond S-10 (23.0 C°, 14.1 ppt., respectively) (Table 4). For the Northern ponds, temperature and salinity were relatively higher, ranging from 22.8 - 25.7 C° and from 13.3 – 14.7 ppt. (Table 3). This pattern observed for water quality characteristics corroborates previous surveys (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Appendix 1.1), and reflects varying degrees of groundwater and marine influence within the ponds.

In previous surveys, the majority of the Northern anchialine ponds hosted higher densities of H. rubra compared to the Southern ponds (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017) (Figures 4, 5, 7, and 10). However, during the May 2018 survey, H. rubra were not observed at two Northern ponds, N-3 and N-4. In previous surveys, H. rubra were also absent or nearly absent from pond N-3, including the 2014 survey (Bybee et al. 2014), and the 2016 survey (Burns and Kramer 2016). In 2018, a dense and partially decaying bloom of Ruppia maritima and one large (> 15 cm) āholehole (Kuhlia spp.) were also recorded in pond N-3, which may have precluded H. rubra presence. Alternately, H. rubra were observed at a very high density at pond

N-5, where they were previously absent due to intensive substrate disturbance (Burns and Kramer 2016). Within N-5, H. rubra density had increased exponentially since the 2017 survey, increasing from absent in April 2016, to 23 ± 9 in May 2017, to 332 ± 59 individuals/ 0.1 m2 in the present survey. Improvements to substrate and habitat quality within N-5 are discussed below.

Within the Southern complex, two ponds (S-9 and S-10) had very high densities of H. rubra (> 100 individuals/ 0.1 m2), and several ponds had low to moderate densities of H. rubra (S-1, S-3, S-4, and S-6) (Table 4). In the four ponds where invasive fish were present in the Southern complex, H. rubra were absent (S-5, S-7, S-8) or observed at a very low density (S-1) (Figures 8 - 10).

During the May 2018 survey, the somewhat uncommon indigenous shrimp species, Metabetaeus lohena, was observed within several Southern complex ponds, including S-1, S-4, S-6, S-9, and S- 10, and were noted to be particularly abundant at pond S-10 (Figure 10). However, M. lohena was noticeably absent from the Northern complex, where the species had previously been observed at ponds N-1 and N-2 (Burns and Kramer 2016, Burns and Kramer 2017).

Only one individual of the uncommon indigenous species, Macrobrachium grandimanus, was observed during the May 2018 survey at Pond S-8 (Table 4). Historically and in more recent surveys, M. grandimanus had also been observed in ponds S-1, S-5, and S-7 (Bybee et al. 2014, Burns and Kramer 2017, Appendix 1.2).

Similar to previous surveys, several Northern ponds hosted assemblages of the aquatic grass, Ruppia maritima including ponds N-1, N-3, and N-5 (Figures 6 and 7). In previous surveys, H. rubra has varied in its presence or absence within R. maritima beds, suggesting a more complex relationship exists between these two species. In May 2018, R. maritima was present at pond N- 3 as in past surveys, however, it formed a dense bloom with substantial decaying organic material floating at the pond's surface (removed following the survey). H. rubra were not observed in pond N-3 during the May 2018 survey, which may have been related to the presence of this decaying material.

A healthy stand of R. maritima had continued to grow within pond N-5, and minimal signs of visitation and disturbance were observed during the May 2018 survey, in contrast to the May 2016 survey in which intensive disturbance was noted. As mentioned above, H. rubra density increased exponentially within N-5, likely due to this improved habitat availability. A non-native damselfly, Ischnura posita, was observed within emergent Ruppia maritima in this and previous surveys at Northern complex ponds N-1, N-3, and N-5 (Table 3). This finding suggests that these ponds might also provide habitat for the rare native damselfly species, Megalagrion spp.

Introduced Poeciliid fish, including Gambusia affinis and Poecilia spp. were observed in four of the Southern area ponds, including S-1, S-5, S-7, and S-8 (Figures 8 and 9, Table 4). For pond S-3, Poeciliids were not noted in the May 2018 survey, but were recorded previously in 1994, 2007, 2008, and 2017 surveys (Burns and Kramer 2017, Appendix 1.2). Where introduced fish were present, shrimp populations, including H. rubra and M. lohena, were dramatically reduced or absent. As of the survey date in May 2018, introduced fish were not observed in any of the

Northern area ponds (Table 3). However, one individual nearshore fish species, Kuhlia spp.

(āholehole), was observed in pond N-3, and had increased in size since the May 2016 survey.

Tables 3 and 4 list additional species observed within and around each pond during video surveys and in-situ visual observations. Generally, higher species diversity was observed for the Northern area ponds, which were typically surrounded by dense vegetation (Figures 4 - 7). Thiarid snails (Melanoides tuberculata and Terbia grainers) were observed in three of the five Northern ponds, with a just few individuals observed in one Southern pond, S-7. Similar to previous surveys, very high densities of Thiarid snails were observed within the Northern pond, N-4 (Table 3) (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Appendix 1.2). The 2018 survey was the first in which metallic skink lizards (Lampropholis delicata) were noted along the edges of several ponds, particularly in the Northern complex.

Significant archeological features were noted at several ponds in both the Northern and Southern complexes, including ponds N-5, S-5, S-7, S-8, and S-10 (Figure 9). Features included water-worn basalt and/or coral stones within or surrounding the ponds, walls or structures surrounding the ponds, and water-worn stones embedded within trails leading to the ponds.

Signs of recent visitor impacts were observed at four of the surveyed ponds in the Southern complex, including ponds S-1, S-3, S-4, and S-5. At pond N-2, blue and white aquarium gravel was noted along the pond bank and was removed after the survey (Figure 5). No unusual species were observed in pond N-2 during the survey. Modifications from visitors included visible trash along pond edges, the addition of rocks to pond basins (leading to increased shading and pond depth reduction) and refuse addition to ponds and surroundings. Notably, relatively less trash and other signs of disturbance were noted during the May 2018 survey compared to May 2017.

## DISCUSSION

The West Hawai'i coastline hosts more than 500 anchialine ponds, which are unique, tidally influenced brackish ecosystems that host a specialized array of species (Yamamoto et al. 2015). Two complexes of ponds 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 ponds locally and throughout Hawai'i Island by tracking ecosystem changes overtime and evaluating causative factors.

The anchialine ponds at NELHA were resurveyed in May 2018, and compared to previous censuses, spanning back to May 1989. The census results from May 2018 were relatively similar to previous recent surveys (Bybee et al. 2013, Bybee et al. 2014, Whale Environmental Services 2015, Burns and Kramer 2016, Burns and Kramer 2017), yet highlighted specific changes in the ponds when compared to historical data. The major drivers of pond ecology were: 1) pond location, either Northern or Southern areas, 2) groundwater influence reflected in temperature and salinity readings, 3) the presence or absence of introduced fish (Figures 8 and 9), and 4) the intensity of human visitor impacts to the ponds (Tables 3 and 4).

Water quality is a key indicator in assessing anchialine pond ecosystem health, and measurements collected in May 2018 were consistent with surveys in previous years (Bybee et al. 2014, Whale Environmental Services 2015, Burns and Kramer 2016, Burns and Kramer 2017, Appendix 1.1), suggesting that groundwater influence within the ponds has remained relatively consistent. Pond temperatures ranged from 21 C° to 25 C° and salinity ranged from 10 ppt to 15 ppt. The Southern ponds were cooler and less saline during the May 2018 survey compared to the Northern ponds, suggesting that relatively higher groundwater influence occurs within the Southern ponds. This finding complemented previous surveys (Appendix 1.1).

Three of the five of the Northern ponds hosted Halocaridina rubra ('ōpae 'ula) assemblages, and in contrast to 2017, no H. rubra were observed ponds N-3 and N-4. An unusually dense and partially decaying assemblage of Ruppia maritima was observed in pond N-3, which may have altered water quality (e.g. depleted oxygen levels) within the pond and deterred H. rubra. (Approximately 5 gallons of decaying R. maritima material were removed from the pond following the survey). In previous surveys, H. rubra has varied in its presence or absence within R. maritima beds (Bybee et al. 2014, Burns and Kramer 2016, Appendix 1.2), suggesting a more complex relationship exists between these two species. At pond N-4, water level was relatively low at the time of the survey (~ 5cm), and the substrate was relatively silty within the main pond basin. Both of these factors may have deterred H. rubra presence at the time of the survey.

A dramatic increase in H. rubra density was noted at Northern complex pond N-5 in May 2018, compared to the April 2016 survey in which H. rubra was absent and to the May 2017 survey in which a moderate population was observed. In April 2016, obvious signs of visitation and severe physical disturbance were documented, including pond substrate disruption, high turbidity, trampled R. maritima and H. rubra absence (Burns and Kramer 2016). During the May 2017 and May 2018 faunal surveys, the condition of pond N-5 had improved substantially, with improved

water clarity, R. maritima regrowth, and abundant H. rubra observed. These findings suggest that visitation and physical disturbance at pond N-5 were minimal within the past two years.

At very high tides, ponds 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 pond connections). This interconnectivity suggests that H. rubra can easily move from pond to pond, and H. rubra presence at N-3 and N-4 is likely in future surveys. This interconnectivity also likely promoted the rapid replenishment of H. rubra within pond N-5. As documented in previous years, Poeciliid fish were not observed in any Northern ponds (Bybee et al. 2014, Burns and Kramer 2016, Burns and Kramer 2017, Appendix 1.2), which allows for the continued diurnal presence of H. rubra.

The historical introduction of Poeciliid fish within anchialine ponds at NELHA has significantly affected pond ecology, and continues to alter four Southern area ponds including, S-1, S-5, S-7, and S-8 (Figures 8 and 9). Poeciliids were not observed in pond S-3 during the May 2018 or April 2016 surveys, but were recorded in 1994, 2007, 2008, and 2017 (Burns and Kramer 2017, Appendix 1.2). For ponds S-5, S-7, and S-8, H. rubra and Metabataeus lohena were not observed in May 2018, despite the presence of these shrimp in nearby uninvaded ponds. For pond S-1, a few individual H. rubra and M. lohena were observed within deep cracks and crevices in the pond, which likely provided a spatial refuge from predation by the Poeciliids present.

Capps et al. (2009) and Carey et al. (2011) suggest that H. rubra within fish-invaded ponds may alter their behavior by only residing within protected areas (inaccessible by fish) of the pond, or by only entering the epigeal regions of the pond at night to feed. During this survey, ponds were surveyed during daylight hours, and the nocturnal behavior of H. rubra was not assessed. While H. rubra was the dominant community member within ponds uninvaded by Poeciliids, M. lohena was also frequently observed in uninvaded ponds (Tables 3 and 4).

Ponds S-7 and S-8 are good candidates for introduced Poeciliid removal in order to restore native shrimp populations, due to their small overall size and secluded nature (minimal signs of recent visitation were observed). However, any proposed fish removal activities must consider the effects of treatments on Macrobrachium grandimanus present in the ponds. One individual of the nearshore fish species, Kuhlia spp. (āholehole), was observed in pond N-3, and corresponded with the absence H. rubra in the pond. Removal of this āholehole from the pond is recommended to promote H. rubra recovery.

Despite the presence of introduced fish in certain ponds, water clarity was high and invasive macroalgae was absent within the invaded ponds, according to visual, qualitative surveys (Tables 3 and 4). This suggests that water quality characteristics have remained relatively consistent, and/or that grazing activities within the invaded ponds are still able to adequately control any macroalgal growth. Because of the subterranean (hypogeal) connections between the Southern area ponds, recolonization by H. rubra and other crustacean species would likely be rapid if Poeciliids were to be removed.

Video observations of the ponds allowed for qualitative documentation of less common, more motile species, and also provided a record of the vegetation surrounding each pond (Tables 3 and 4). Generally, Northern area ponds tended to host a more diverse assemblage of pond inhabitants and surrounding vegetation (Figures 4-7, Table 3). The less common anchialine pond shrimp species, M. lohena, was observed in May 2018 at ponds S-1, S-4, S-6, S-9, and S-10. One individual Macrobrachium grandimanus was observed in pond S-8, and was approximately 10 cm in length. Despite the presence of Poeciliids in S-8, M. grandimanus has been able to coinhabit the pond, likely by reaching a size that precludes consumption.

To a lesser extent than observed in the April 2016 and May 2017 surveys, signs of visitor impacts were observed at several of the Southern ponds in May 2018. Affected ponds were generally near access points, including Wawaloli Beach Park and Makako Bay Drive, and were also relatively visible due to minimal surrounding vegetation. Modifications in and around the ponds included the addition of rocks to pond basins, rubbish additions, and the possible removal/addition of Poeciliid fish and H. rubra for fishing bait and other uses. Signs of disturbance were also noted at pond N-2, including the presence of several new boulders in the pond and blue and white aquarium gravel noted along the pond bank (which was removed after the survey). Fortunately, no guppies or unusual species were observed in pond N-2 during the survey. Overall, visitation and disturbance can cause damaging physical changes to the ponds. Substrate and surrounding rock movements can influence overall pond ecology, by altering light, water depth, turf algal growth, and food availability for H. rubra and other shrimp species. Rubbish and other refuse present may affect the water quality of the ponds, while faunal removal and additions can affect the overall ecology of the ponds.

Predicted sea-level rise is a significant future threat to Hawaiian anchialine pond ecosystems, and will likely drive substantial changes to pond interconnectedness, depth, location, and water chemistry (Marrack and O'Grady 2014). These physical changes will have a critical influence on faunal composition within the ponds. Notably, the highest tides of the year (referred to as the "King's tides") occurred throughout the Hawaiian Islands in May 2017 and May 2018, just prior to the faunal surveys. These seasonal high tides offer a preliminary view of potential anchialine pond ecosystem changes associated with rising sea-level (SOEST website, Accessed May 2018, <www.soest.hawaii.edu/coasts/sealevel/>).

The results of the May 2018 anchialine pond survey did not indicate that anthropogenic inputs from local aquaculture and other facilities at NELHA are degrading the ponds. Pond disturbance due to visitation and the presence of predatory invasive fish were noted as the key drivers of pond degradation. The majority of the surveyed ponds 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 pond complexes in the vicinity of the NELHA facility. For this annual report, the ponds were surveyed from May 13th through May 21st, 2018. (Map generated using Google Earth 7.1.7).

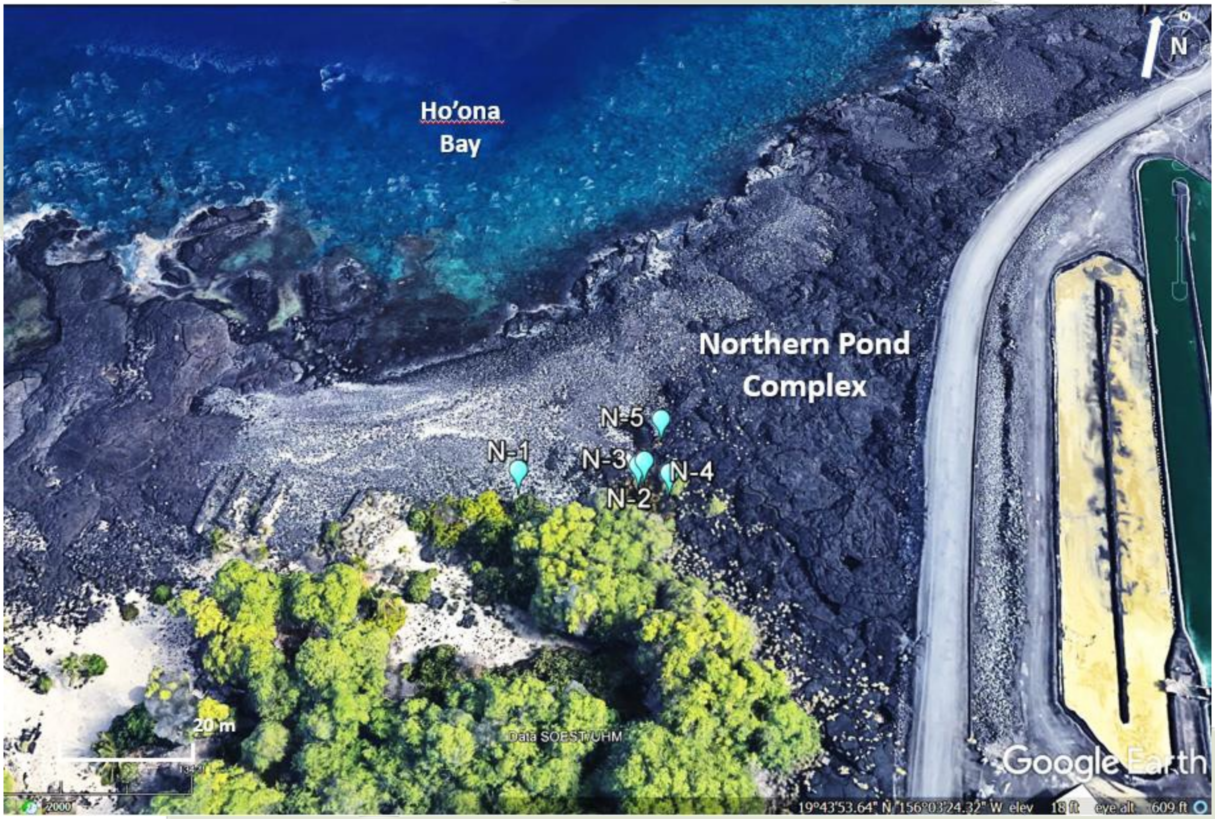


Figure 2. Locations of the Northern complex of anchialine ponds (N – 1 through N –5), located inland of the cobble beach at Ho'ona Bay. The Northern ponds were surveyed on May 19th and May 20th. (Map generated using Google Earth 7.1.7).


Figure 3. The Southern complex of anchialine ponds (S-1 through S-10), located inshore and south of the Wawaloli Beach Park facility at NELHA. The Southern ponds were surveyed from May 13th to May 21st. (Map generated using Google Earth 7.1.7).

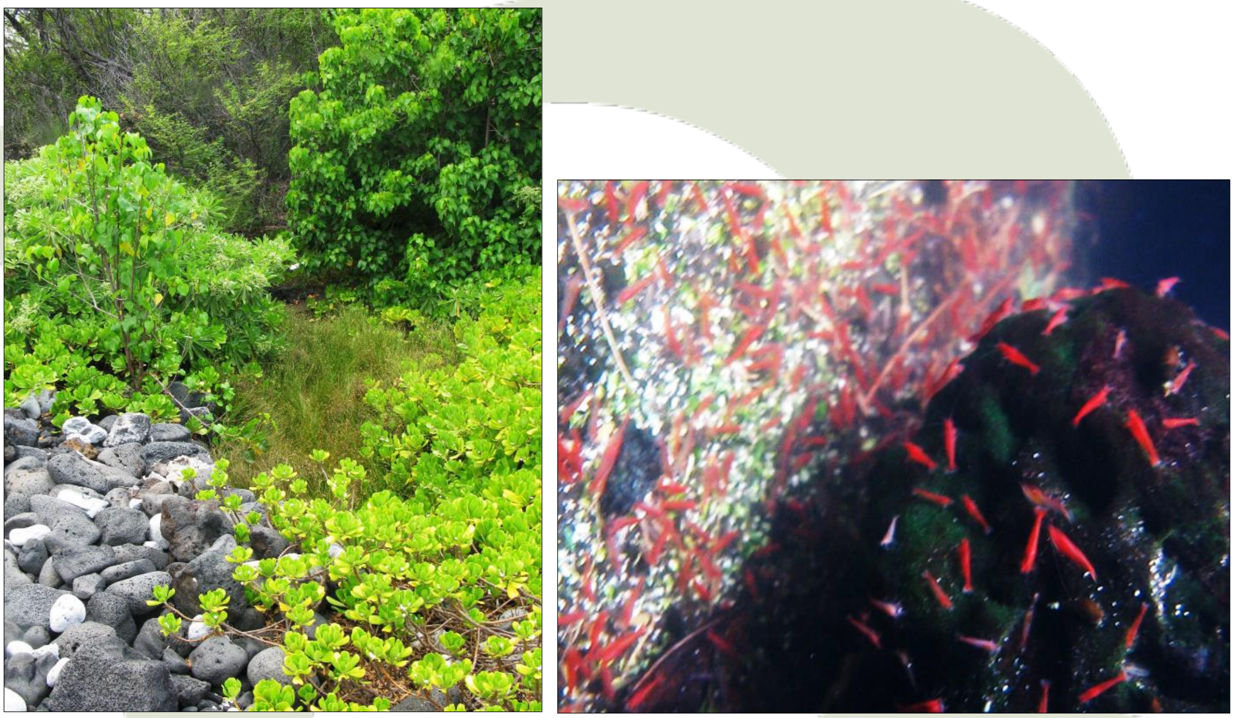

Figure 4. (left) Northern group pond, N - 1 at a tide level of +1.17’, and (right) a typical section of the N-1 basin, hosting a high density of *Halocaridina rubra* (‘ōpae ‘ula). Ponds in the Northern group were typically characterized by relatively diverse faunal assemblages and dense surrounding vegetation. Surrounding vegetation has continued to encroach pond N – 1, and *Ruppia maritima* comprises a portion of the pond basin.

Figure 5. (left) A Northern group pond, N-2, at a tide level of +0.85‘, and (right) *Halocaridina rubra* (‘ōpae ‘ula) within the pond. The circle in the lower right of the left image highlights unusual gravel deposited along the bank of the pond (removed after the survey). No introduced species were observed within this pond during the May 2018 survey.

Figure 6. During the May 2018 survey, Northern group pond, N-3, had a dense and partially decaying stand of the aquatic grass, *Ruppia maritima* (circled in the lower left of the left image). *Halicaridina rubra* were not observed in the pond during the survey, suggesting that this decaying material may have been a deterrent to native shrimp assemblages.

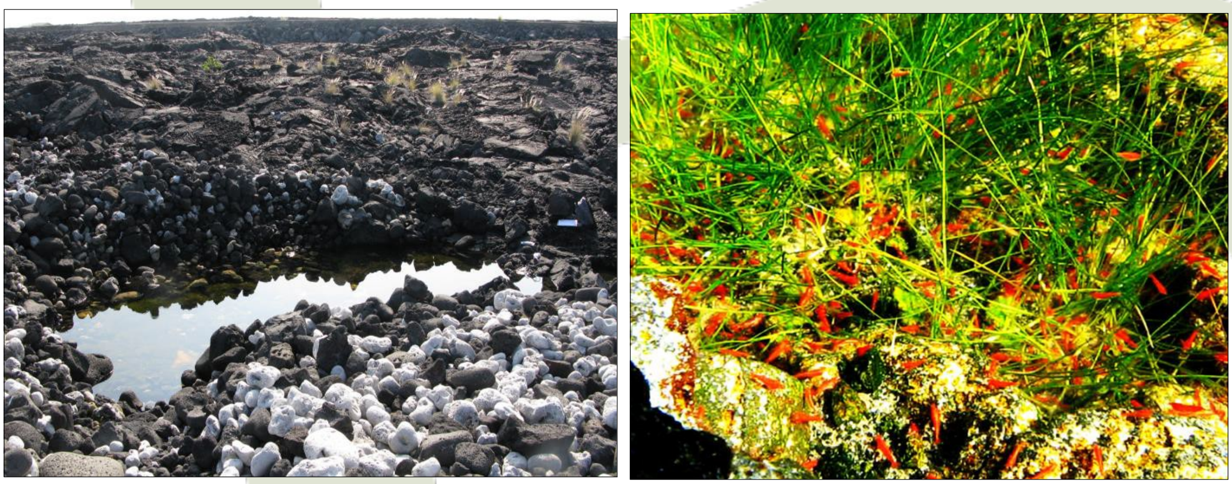

Figure 7. The Northern complex pond, N-5 (left), continued to show signs of improved health after intensive physical disturbance was noted during the April 2016 survey. A healthy stand of the aquatic grass, *Ruppia maritima*, was observed in the pond.

Figure 8. Southern complex pond, S-1, at a tide level of + 0.59‘ (left), and introduced Poeciliids near the water quality instrument deployed within the pond on May 13, 2018. Four ponds in the Southern complex hosted introduced fish, which was correlated with very low or absent *Halocaridina rubra* assemblages.

Figure 9. Southern group pond, S-8 (left), at a tide level of +0.50’ on May 13th, 2018. Archaeological features surround this pond, including a water-worn stone trail leading to the pond (center) and an adjacent rock wall. Introduced Poeciliids were abundant within pond S-8 (right), and *Halocaridina rubra* were not observed during the survey.

Figure 10. Southern group pond, S-10 (left), at a tide level of +1.60'. Christmas berry (*Schinus terebinthifolius*) encroaches the pond basin and introduces substantial organic matter to the pond, which hosts an abundant assemblage of *Halocaridina rubra* and *Metabetaeus lohena* (right).

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

| | Taxon | Common/ Hawaiian Name | Classification |
|---|---|---|---|
| Anchialine pond: | *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) |
| | *Rantala 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 | *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 ponds 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 pond complex of anchialine ponds at the NELHA facility. The pond surveys were conducted from May 19th 2018 to May 20th 2018, at a tidal level ranging from +0.5' to +2.0'. Poeciliid fish and *Ruppia maritima* were recorded as present or absent, and other organisms in the observed in each pond were noted in the comments. *Halocaridina rubra* densities are reported as a mean number of individuals per 0.1 square meters (± one standard error unit). If the water level was too shallow for the photo-quadrat placement, the presence or absence of *H. rubra* was noted with a density estimate based on *in-situ* visual surveys.

| Area | Pond number | Survey Date | Survey Time | Water Quality | | Faunal Surveys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Temp (C°) | Salinty (ppt) | Substrate | *H. rubra* (Count/0.1m²) (Mean ± SE) | Poeciliids | *Ruppia maritima* | Comments/ Other Species |
| Northern Ponds | **N-1** | 5/20/2018 | 11:11 | 25.6 | 14.2 | Water-worn (rounded) basalt cobble, some silt, shell hash and sand, rock wall mauka section | 287 ± 63 | absent | present | Also observed: Thiarid snails, *Scaevola taccada, Prosopis pallida, Tournefortia argentea, Thespesia populnea, Sesuvium portulacastrum, Ischnura posita, Lampropholis delicata, Lyngbya sp.* |
| | **N-2** | 5/19/2018 | 9:45 | 25.3 | 14.0 | Basalt rubble, pahoehoe surroundings | 68 ± 14 | absent | absent | Also observed: Thiarid snails, *Pantala flavescens, Sesuvium portulacastrum, Schizothrix clacicola, Lampropholis delicata* |
| | **N-3** | 5/19/2018 | 9:20 | 24.4 | 13.3 | *Ruppia* dominant, underlying cobble, pahoehoe surroundings | 0 ± 0 | absent | present | Also observed: *Lyngbya sp., Sesuvium portulacastrum, Prosopis pallida, Pantala flavescens, Ischnura posita, Kuhlia sp.*(1) |
| | **N-4** | 5/19/2018 | 9:00 | 25.7 | 13.7 | Silt bottom with cobble and shells, pahoehoe surroundings | 0 ± 0 | absent | absent | Also observed: Thiarid snails (high density), *Sesuvium portulacastrum, Ischnura posita, Schizothrix clacicol, Lyngbya* sp., *Lampropholis delicata, Ruppia maritima* approaching bank of pond |
| | **N-5** | 5/19/2018 | 8:35 | 22.8 | 14.5 | Water-worn (rounded) basalt cobble and coral rock | 332 ± 59 | absent | present | Also observed: *Pantala flavescen*, *Schizothrix clacicola*, *Lyngbya* sp., *Lampropholis delicata* |

Table 4. Faunal census data collected for the Southern pond complex of anchialine ponds at the NELHA facility. The pond surveys were conducted from May 13th 2018 to May 20th 2018, at a tidal level ranging from +0.5' to +2.0'. Poeciliid fish and *Ruppia maritima* were recorded as present or absent, and other organisms in the observed in each pond were noted in the comments. *Halocaridina rubra* densities are reported as a mean number of individuals per 0.1 square meters (± one standard error unit). If the water level was too shallow for the photo-quadrat placement, the presence or absence of *H. rubra* was noted with a density estimate based on *in-situ* visual surveys.

| Area | Pond number | Survey Date | Survey Time | Water Quality | | Faunal Surveys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Temp (C°) | Salinty (ppt) | Substrate | *H. rubra* (Count/0.1m²) (Mean + SE) | Poeciliids | *Ruppia maritima* | Comments/ Other Species |
| Southern Ponds | S-1 | 5/13/2018 | 7:28 | 21.8 | 11.3 | Basalt rubble/ pebbles, pahoehoe surroundings | 2.7 + 2.7 | present | absent | Also observed: *M. lohena*, *Pennisetum setaceum*, *Schinus terebinthifolius*, ~ 5% cover *Schizothrix clacicola Poecilia* sp., *Gambusia affinis*, *Pantala flavescens* |
| | S-2 | 5/13/2018 | 8:02 | - | - | - | - | - | - | Pond filled in with rocks |
| | S-3 | 5/14/2018 | 18:15 | 22.2 | 11.7 | Basalt rubble/ pebbles, mixed pahoehoe surroundings | 54 + 16 | absent | absent | Also observed: no surrounding vegetation, a few new rocks added to pond |
| | S-4 | 5/14/2018 | 18:30 | 22.3 | 11.7 | Basalt rubble, pahoehoe surroundings | present (*In-situ*= 40 + 8) | absent | absent | Too shallow for photoquadrats. *In-situ* visual surveys used. Also observed: *M. lohena*, no surrounding vegetation. Additional rocks observed in pond |
| | S-5 | 5/13/2018 | 8:05 | 21.7 | 11.6 | Basalt rubble, mxied pahoehoe surroundings | absent (0 + 0) | present (abundant) | absent | Also observed: *Pantala flavescens*, *Pennisetum setaceum*, *Schizothrix clacicola* (~5% cover), light algal turf cover, *Poecilia* sp. and *Gambusia affinis present*. Minimal vegetation around pond. Signs of visitation (base cobbles moved since 2017). |
| | S-6 | 5/21/2018 | 18:30 | 21.2 | 10.9 | Very narrow basalt crack, a'a surroundings. | present (*In-situ*= 80 + 37) | absent | absent | Too shallow for photoquadrats. In-situ visual surveys used. Also observed: *M. lohena*, No surrounding vegetation. *Capparis sandwichiana* nearby, Abundant ants at pond edge. |
| | S-7 | 5/13/2018 | 8:45 | 21.3 | 11.3 | Basalt rubble (some rounded), mixed pahoehoe surroundings | absent (0 + 0) | present (abundant) | absent | Also observed: Thiarid snails, *Capparis sandwichiana*, *Pennisetum setaceum*, *Schizothrix clacicola* (~20% cover), both *Poecilia sp.* (occasional) and *Gambusia affinis* (abundant). Rounded stones along basin and trail. |
| | S-8 | 5/13/2018 | 9:05 | 21.3 | 11.3 | Basalt rubble with a few white coral stones, pahoehoe surroundings | absent (0 + 0) | present (abundant) | absent | Also observed: *Macrobrachium grandimanus* (1), *Pennisetum setaceum*, *Argiope appensa*, *Schizothrix clacicola* (~50% cover), both *Poecilia* sp. and *Gambusia affinis*. Water-worn wall with rounded corals surrounding pond. Opihi shells observed. Trail to pond. |
| | S-9 | 5/20/2018 | 8:45 | 21.6 | 11.1 | Basalt crack, a'a surroundings. | present (*In-situ*=135 + 21) | absent | absent | Too shallow for photoquadrats. *In-situ* visual survey used. *H. rubra* very small. Also observed: *M. lohena*, abundant ants at pond edge. No surrounding vegetation. |
| | S-10 | 5/14/2018 | 17:50 | 23.0 | 14.1 | Pahoehoe with light organic material and some sand, small basalt pebbles | 132 + 25 | absent | absent | Also observed: *M. lohena* (common), *Schinus terebinthifolius*, *Sesuvium portulacastrum*, *Pennisetum setaceum*, *Argiope appens* |

# MARINE BENTHIC BIOTA SURVEY

## INTRODUCTION

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

One of the utilities provided by the NELHA is the pumping of cold seawater from deep ocean depths (~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 46 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 and 2017 surveys are summarized by Burns and Kramer (Burns and Kramer 2016 & 2017), and the results and findings for the 2018 surveys are reported here.

## METHODS

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

| 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<br>35: 19.7149, - 156.05136<br>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. |

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).

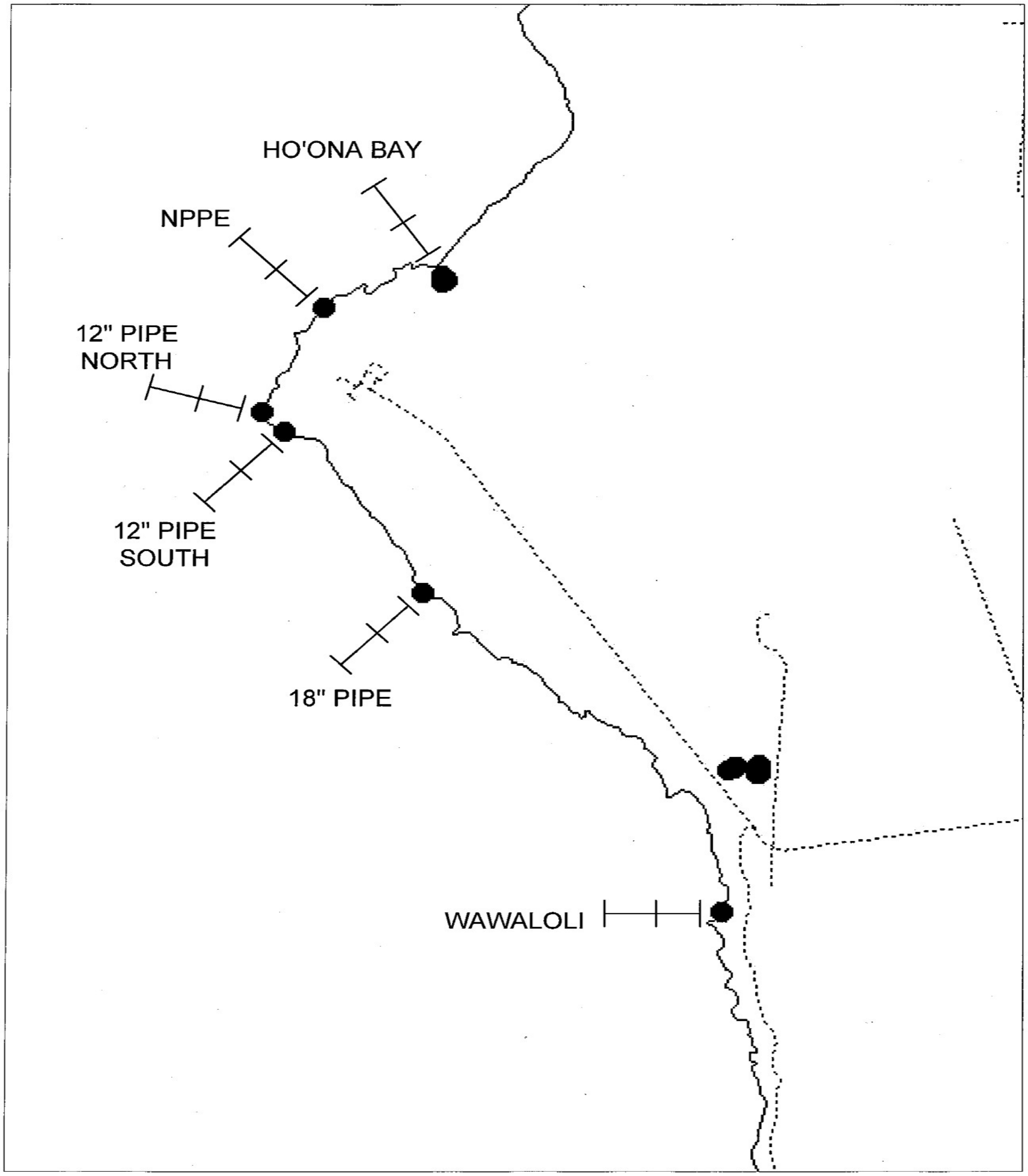


Figure 10. Six stations with three transects per station at deep (~50-fsw), moderate (~35-fsw), and shallow (~15-fsw) depths along the NELHA coastline. A total of 18 transects are completed for both the benthic monitoring and fish assemblage monitoring.

## RESULTS

*Benthic substrate characterization*

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

The overall percent coral cover among the six stations was 35.87%, the most dominant corals were *Porites lobata* (22.49%), *Porites compressa (6.36%), Porites evermanni* (2.61%), *Montipora capitata* (2.52%), and *Pocillopora meandrina* (1.53%). These coral species were present among all the stations. Other corals present were *Pocillopora grandis (*previously *eydouxi)*, *Leptastrea purpurea, Leptastrea bewickensis, Montipora patula, Montipora flabellata, Pavona varians, Pocillopora eydouxi, 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 4.

*P. lobata* was the most dominant coral in the shallow depths (~15-fsw) among all six stations. *P. lobata, P. evermanni, P. comressa and M. capitata* were the dominant corals in the 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. P. meandrina* was most abundant at the Wawaloli station, 12” Pipe South station, and Hoona Bay. *P. evermanni* was most abundant at the 12” Pipe South station. *P. compressa* was most abundant at Hoona Bay and NPPE stations. *P. lobata* had the highest levels of abundance at Hoona Bay and NPPE 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 2017 were similar to previous years. Photographs of each photographed quadrat are included in Appendix 4.

Table 4 provides a detailed comparison of the percent cover, species richness, and species diversity of corals among all stations and survey depths. Similar to previous years, the Hoona Bay and NPPE sites exhibited the highest levels of coral cover (43.73% and 41.20% respectively). Coral cover at these two sites was dominated by *P. lobata and, P. compressa.* Species richness and species diversity was highest at Hoona Bay. The benthic substrate at this site was also predominantly occupied by *P. lobata* (27.03%), and also had high values of coral cover for *P. compressa* (12.10%). Values of coral cover exhibited statistically significant differences among the sites. Overall coral cover was significantly higher ($p<0.05$, Kruskal-Wallis) at Hoona Bay and NPPE compared to the other sites. *P. lobata* and *P. compressa* also exhibited significantly higher values of cover (p<0.05, Kruskal-Wallis) at Hoona Bay and NPPE compared to the other sites.

Values of overall coral cover were statistically similar among all depths. Deep depths had the highest cover of 38.55%, with moderate and shallow sites exhibiting 35.22% and 32.33% coral cover. *P. lobata* showed significantly lower (p<0.05, Kruskal-Wallis) values of coral cover at the deep sites compared to shallow and moderate, whereas *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 (49.70% and 49.50%), which was also seen in 2017. The observed patterns in coral cover among the surveyed depths are similar to previous years and showed similar patterns in coral cover among sites in 2016 and 2017 (Burns and Kramer 2016, Burns and Kramer 2017).

*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 4: Summary of benthic substrate data and comparative analyses from surveys conducted in April 2017*

| Station | Wawaloli | | | | 18" Pipe | | | | 12" Pipe South | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Shallow | Moderate | Deep | | Shallow | Moderate | Deep | | Shallow | Moderate | Deep |
| Overall coral cover | 27.40 | 32.90 | 27.30 | | 30.30 | 31.70 | 33.70 | | 31.40 | 37.70 | 36.90 |
| *P. lobata* | 21.80 | 23.20 | 12.00 | | 23.90 | 21.20 | 15.00 | | 19.70 | 23.40 | 22.30 |
| *P. evermanni* | | | 3.50 | | 2.20 | 2.30 | | | 4.30 | 5.90 | 7.50 |
| *P. compressa* | | | | | | 1.60 | 12.80 | | | 1.50 | 1.70 |
| *P. meandrina* | 3.00 | 3.00 | 3.00 | | | 2.00 | | | 6.40 | 1.00 | 1.00 |
| *P. eydouxi* | | | | | | 1.00 | 3.20 | | | 3.00 | |
| *M. capitata* | 1.40 | 4.60 | 4.80 | | 4.20 | 3.60 | 2.70 | | 1.00 | 1.90 | 1.40 |
| *M. patula* | 1.20 | 2.10 | 4.00 | | | | | | | 1.00 | 3.00 |
| Species count | 4.00 | 4.00 | 7.00 | | 3.00 | 6.00 | 5.00 | | 2.00 | 4.00 | 7.00 |
| Species diversity (H) | 1.41 | 1.45 | 0.83 | | 1.32 | 1.37 | 1.21 | | 1.39 | 1.45 | 1.17 |

| Station | 12" Pipe North | | | | NPPE | | | | Hoona Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Shallow | Moderate | Deep | | Shallow | Moderate | Deep | | Shallow | Moderate | Deep |
| Overall coral cover | 30.20 | 28.10 | 34.20 | | 41.40 | 32.50 | 49.70 | | 33.30 | 48.40 | 49.50 |
| *P. lobata* | 23.70 | 19.10 | 20.20 | | 30.60 | 24.60 | 23.00 | | 25.50 | 35.80 | 19.80 |
| *P. evermanni* | 4.10 | | 1.00 | | 5.00 | | 2.50 | | 2.60 | | |
| *P. compressa* | | 4.00 | 9.50 | | | 2.10 | 19.00 | | 3.00 | 8.30 | 25.00 |
| *P. meandrina* | | | | | 1.10 | 1.00 | 2.00 | | | | 3.00 |
| *P. eydouxi* | | | | | | | | | 1.20 | | |
| *M. capitata* | 2.40 | 2.80 | 1.20 | | 2.40 | 1.80 | 2.20 | | 1.00 | 4.30 | 1.70 |
| *M. patula* | | 2.20 | 2.30 | | 2.30 | 3.00 | 1.00 | | | | |
| Species count | 3.00 | 7.00 | 6.00 | | 4.00 | 7.00 | 7.00 | | 5.00 | 4.00 | 7.00 |
| Species diversity (H) | 1.35 | 1.31 | 1.45 | | 1.29 | 1.35 | 1.48 | | 1.36 | 1.43 | 1.51 |

| 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 | 30.20 | 31.90 | 35.33 | 32.83 | 41.20 | 43.73 | **0.01** | 32.33 | 35.22 | 38.55 | 0.13 |
| *P. lobata* | 19.00 | 20.03 | 21.80 | 21.00 | 26.07 | 27.03 | **0.01** | 24.20 | 24.55 | 18.72 | **0.01** |
| *P. evermanni* | 3.50 | | 5.90 | 2.55 | 3.75 | | 0.28 | 3.64 | 4.10 | 3.63 | 0.21 |
| *P. compressa* | | 7.20 | 1.60 | 6.75 | 10.55 | 12.10 | **0.01** | 3.00 | 3.50 | 13.60 | **0.01** |
| *P. meandrina* | 3.00 | 2.00 | 2.80 | | 1.37 | 3.00 | 0.22 | 3.50 | 1.75 | 2.25 | 0.89 |
| *P. eydouxi* | | 2.10 | 3.00 | | | 1.20 | 0.40 | 1.20 | 2.00 | 3.20 | 0.17 |
| *M. capitata* | 3.60 | 3.50 | 1.43 | 2.13 | 2.13 | 2.33 | 0.10 | 2.07 | 3.17 | 2.33 | 0.11 |
| *M. patula* | 2.43 | | 2.00 | 2.25 | 2.10 | | 0.08 | 1.75 | 2.08 | 2.58 | 0.14 |
| Species count | 8.00 | 7.00 | 8.00 | 7.00 | 8.00 | 8.00 | 0.44 | 6.00 | 7.00 | 7.00 | 0.62 |
| Species diversity (H) | 1.23 | 1.30 | 1.34 | 1.38 | 1.37 | 1.43 | 0.18 | 1.35 | 1.40 | 1.28 | 0.31 |

## 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 2013-2017, and how they compare to the current data from 2018.

Reports from previous years (1992-2008) showed a pattern of increase in overall coral cover ranging from 16.9% to 54.7%. Surveys conducted in the following years (2009-2015) reported estimates of overall coral cover fluctuating from 39.5% to 52%. While several of the changes in overall coral cover among these years were noted as significant (ANOVA, $p<0.01$), the last six years have provided a consistent range (~40-50%) for which coral cover can be expected among the survey stations and depth gradients. The fluctuations in observed overall coral cover should be expected, as the surveys 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 2018, 35.37%, is within this range and shows the benthic communities to exhibit consistent values of coral cover for the last 9 years.

Other studies conducted throughout the 18-year period of monitoring have found significant differences in overall coral cover among the six stations, and the depth gradient (Ziemann 2010, Bybee et al. 2014). The statistical differences observed among the sites showed that coral cover increased from the Southern to Northern sites, with Hoona Bay and NPPE exhibiting statistically higher values of coral cover than the 12” and 18” Pipe sites, and all sites exhibiting higher coral cover than Wawaloli. *P. meandrina* has also been shown to have significantly higher coral cover at shallow depths compared to deep depths, and *P. compressa* to have higher coral cover at deep depths compared to shallow depths. The 2018 data supported this trend in overall coral cover with significantly higher mean values of overall coral cover observed at the Hoona Bay and NPPE sites compared to the other four monitoring stations. The 2018 data also supported previous studies with *P. compressa* having significantly higher cover values at deeper sites. The 2018 data also showed P. lobata to have significantly higher values of cover at moderate and shallow depths. The 2018 data also show no significant differences in species richness or species diversity among the six stations and three depth profiles. These findings indicate all survey locations support coral assemblages of similar diversity and community structure with relatively high coral cover.

Previous reports have documented a pattern of increase in percent cover of *P. lobata* among the six survey stations. The average percent cover of *P. lobata* increased from 10.0% to 30.7% from the years 1992-2012. The 2013 survey report documented significant increases (ANOVA, $p<0.05$) in coral cover at the 18” Pipe station and NPPE station compared to the 2010 and 2012 data (Ziemann 2010). The average percent cover of *P. lobata* among all stations was 30%, 29%, and 25.8% for 2013, 2014, and 2015 respectively (Bybee et al. 2014, WHALE Environmental 2015). The average percent cover of *P. lobata* among all stations in 2018 was 22.49%. This value is higher than observed in 2017 and more similar to previous years. While this value is lower, there was 3.79% cover attributed to *P. evermanni,* which was possibly not identified in previous years due to morphological similarity.  The overall percent cover of mounding *Porites* coral in 2018 is not statistically different to the previous three years. The 2018 values of coral cover for mounding *Porites* was also very similar among surveys conducted the previous 5-year, thus indicating these are the dominant coral colonies among these stations, and this species is exhibiting minimal changes in community structure.

The average values of *P. compressa* cover have not fluctuated significantly over the last several years and show a consistent trend of higher percent cover at deeper depths. The 2017 data also support this trend; with nearly all the *P. compressa* coral cover being observed at the deeper sites. This is expected, as this coral has a delicate morphology and typically grows at deeper depths along the reef slope throughout Hawaii.

The average values of *P. meandrina* have also shown a general increase from 1992 – 2014 (Ziemann 2010). The percent cover of *P. meandrina* exhibited a wide range in coral cover in 2013 (3.98% - 21.59%), and was found to have statistically higher values in shallow sites in 2014 (Bybee et al. 2014). The 2018 data are similar to the generally lower values recorded in 2017 and no colonies were observed at a few stations. The range in percent cover of this species was larger than previous years (0-25%), and overall *P. meandrina* cover did not decrease significantly among all sites compared to previous years. Values of *P. meandrina* cover in 2018 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 elevations in seawater temperature seen in 2014 and 2015. This coral species is fast growing and relatively short-lived, thus the fluctuations seen throughout the survey years are expected considering its life history traits. The relatively higher levels of *P. meandrina* cover in shallow depths, compared to 2017, 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 2018 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 2009-2017. The data from 2018 exhibited a slight increase compared to 2017, but patterns in community structure were similar, thus suggesting coral composition has remained similar at these sites. The 2018 data did support the previous findings of significantly higher coral cover at the more northern sites, Hoona 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 2018, 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 20 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 would 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 in 2017 and 2018, the two 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 will help 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 2018 data show no significant variation in benthic composition among the stations and depths, and no significant changes compared to the last several years of monitoring. These findings indicate the nearshore marine benthic communities are not exhibiting any signs of detrimental impacts associated with the NELHA facility.

# MARINE FISH BIOTA SURVEY

## INTRODUCTION

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

One of the utilities provided by the NELHA is the pumping of cold seawater from deep ocean depths (~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 25 years to ensure that any impacts to water quality, associated with activities conducted on the NELHA facility, are not causing detrimental changes to the nearshore fish assemblages in this area.

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

## METHODS

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

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

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

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

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

## RESULTS

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

*Total Number of Individuals*

The total number of individual fishes was highest at 12" Pipe South and the lowest was at Wawaloli, which was the same pattern detected in 2016 and 2017. This range in individuals was 132 to 388. Moderate and deep habitats had similarity in the total number of individuals (335 and 309 respectively), with shallow sites having the lowest number (211 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=0.44) or among the three depth gradients (p=0.26). All values are reported in Table 5.

*Number of Species*

The mean number of species recorded was highest at the 12" Pipe North, and lowest at Wawaloli. This range in mean number of species was 26 to 46. The shallow, moderate, and deep habitats had 34-41 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=0.08) or among the three depth gradients (p=0.36). All values are reported in Table 5.

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

*Species Diversity and Biomass*

Species diversity ranged from 2.47 at Wawaloli to 3.42 at 18" Pipe. The mean species diversity among the deep depths was 3.03, 2.95 among moderate depths, and 3.00 among the shallow depths. There were no significant differences in species diversity among the six stations surveyed (p=0.09). There were also no significant differences in species diversity among the three depth gradients (p=0.79)

Fish biomass was highest at the 18" Pipe (272.41 g/m2) and lowest at Hoona Bay (111.61 g/m2). Biomass was lowest at deep depths (147.04 g/m2), and highest at the moderate depths (229.87 g/m2). No significant differences in mean biomass were detected among the sites (p=0.45) or depth gradients (p=0.70).

*Table 5: Summary of fish survey data and comparative analyses from surveys conducted in May 2017*

| Station | Wawaloli | | | | 18" Pipe | | | | 12" Pipe South | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Shallow | Moderate | Deep | | Shallow | Moderate | Deep | | Shallow | Moderate | Deep |
| Fish count | 62.00 | 263.00 | 70.00 | | 220.00 | 149.00 | 355.00 | | 172.00 | 584.00 | 409.00 |
| Number of species | 20.00 | 36.00 | 22.00 | | 31.00 | 36.00 | 42.00 | | 31.00 | 37.00 | 42.00 |
| Diversity | 2.29 | 2.50 | 2.64 | | 3.47 | 3.52 | 3.27 | | 2.91 | 2.70 | 3.30 |
| Biomass | 74.20 | 127.75 | 262.03 | | 263.14 | 421.47 | 132.61 | | 88.67 | 356.51 | 153.13 |

| Station | 12" Pipe North | | | | NPPE | | | | Hoona Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Shallow | Moderate | Deep | | Shallow | Moderate | Deep | | Shallow | Moderate | Deep |
| Fish count | 345.00 | 374.00 | 224.00 | | 185.00 | 247.00 | 580.00 | | 283.00 | 391.00 | 217.00 |
| Number of species | 42.00 | 48.00 | 47.00 | | 43.00 | 49.00 | 43.00 | | 38.00 | 42.00 | 39.00 |
| Diversity | 3.10 | 3.12 | 3.36 | | 3.04 | 2.82 | 2.44 | | 3.20 | 3.08 | 3.21 |
| Biomass | 176.26 | 245.26 | 116.04 | | 213.45 | 112.05 | 127.84 | | 128.03 | 116.22 | 90.61 |

| Mean value comparisons | Wawa | 18" Pipe | 12" Pipe S | 12" Pipe N | NPPE | H - Bay | p-value | Shallow | Moderate | Deep | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fish count | 132.00 | 241.00 | 388.00 | 314.00 | 337.00 | 297.00 | 0.44 | 211.00 | 335.00 | 309.00 | 0.26 |
| Number of species | 26.00 | 36.00 | 37.00 | 46.00 | 45.00 | 39.00 | 0.08 | 34.00 | 41.00 | 39.00 | 0.36 |
| Diversity | 2.47 | 3.42 | 2.97 | 3.19 | 2.76 | 3.16 | 0.09 | 3.00 | 2.95 | 3.03 | 0.79 |
| Biomass | 154.66 | 272.41 | 199.43 | 179.18 | 151.11 | 111.61 | 0.45 | 157.29 | 229.87 | 147.04 | 0.70 |

## 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 2018 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 2018 data exhibited similar patterns and values for all parameters to the 2016 and 2017 data (Burns and Kramer 2016, Burns and Kramer 2017). The data from the past three years suggests the sites support very abundant and diverse fish assemblages.

## 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 2018 surveys were conducted using the standardized approaches that are utilized by multiple agencies for monitoring and assessing fish assemblages throughout Hawaii (e.g., NOAA, DAR, UH). Values were higher than some previous years, but in the same range as those observed in 2010, 2016, and 2017. 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 26-year time-span of the monitoring program is effective for noticing any substantial detrimental changes that may be associated with acute or long-term disturbances.

A general pattern that has been detected in previous years was that fish assemblages exhibited higher abundance, diversity, and biomass near the Pipe sites and lower values off Wawaloli Beach. This pattern is still evident, as values at Wawaloli were lowest in 2014, 2015, 2016 and in the 2017 data (Bybee et al. 2014, WHALE Environmental 2015, Burns and Kramer 2016 & 2017, Table 5). The reason of this pattern is likely habitat differences. Both the northern sites and those adjacent to the pipes display steep topographic relief with highly complex basalt substrate. Complex habitat is a known driver of fish abundance and diversity. The Wawaloli Beach site is in an embayment, and the substrate not occupied by live coral is predominantly sand (Appendix 2 and 4). These differences in habitat composition may be driving the consistent differences in fish assemblages seen at Wawaloli, and they will likely remain evident in future surveys. The 2018 data continued to support this trend, except a higher biomass was found compared to previous years. This was likely caused by the presence of larger bodied fish during the survey, as the overall count and diversity were lower compared to the other sites.

In summary, the reports conducted over the past 26 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.

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# B

# APPENDICES

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

Appendix 1.1. Physical characteristics of northern and southern anchialine ponds, summarized from surveys conducted from May 1989 to October 2008 (Brock 2008, Ziemann and Conquest 2008), and water quality surveys in 2009. Pond S-10 was not surveyed during these surveys.

| Area | Pond number | Dimensions (m) | Basin Characteristics | Salinity (2009) (ppt) |
|---|---|---|---|---|
| Northern Ponds | N-1 | 15.5 x 6 | Deep mud substrate; in pahoehoe/basalt cobble | 10 |
| | N-2 | 1 x 1 | Rubble basin substrate; in pahoehoe | 10 |
| | N-3 | 7.5 x 3 | Cobble basin substrate; in pahoehoe | 9 |
| | N-4 | 2 x 2 | Rubble and mud substrate; in pahoehoe | 9 |
| | N-5 | 7.5 x 3 | Two inter-connected basins in cobble | 10 |
| Southern Ponds | S-1 | 1.4 x 1.2 | Pahoehoe and rubble substrate | 5 |
| | S-2 | 1 x 1 | Pahoehoe and rubble substrate | 7 |
| | S-3 | 1 x 1 | Pahoehoe and rubble substrate | 8 |
| | S-4 | 0.075 x 0.075 | Pahoehoe and rubble substrate | 8 |
| | S-5 | 2 x 2.5 | Pahoehoe and rubble substrate | 8 |
| | S-6 | 0.2 x 0.05 | Pahoehoe and rubble substrate | 8 |
| | S-7 | 1 x 1.4 | Pahoehoe and rubble substrate | 9 |
| | S-8 | 1 x 1 | Pahoehoe and rubble substrate | 8 |
| | S-9 | 0.2 x 0.05 | Small a'a crack | 8 |

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

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

Appendix 1.2. (continued)

| Survey Date | Pond: N-4 (Count/0.1m²) | | | | | | 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 1.3. The anchialine ponds census data for the survey conducted October 2008. In addition to quantitative counts, qualitative abundances were noted as follows: + few animals; scattered plants, ++ animals common; plants abundant in patches, +++ animals too numerous to count; plants covering substrate, and – none observed (Ziemann and Conquest 2008).

| **Area** | **Pond number** | ***Ruppia maritima*** | **Thiarid Snails** | ***Assiminea sp.*** | ***Theodoxus cariosa*** | ***Graspsus tenuicrustatus*** | ***Halocaridina rubra*** | ***Metabataeus lohena*** | **Poecilia sp.** | **Other Species, Comments** |
|---|---|---|---|---|---|---|---|---|---|---|
| | N-1 | | | | + | | ++ | - | - | Ruppia absent |
| | N-2 | | | | | | + | - | - | Ruppia absent |
| **Northern Ponds** | N-3 | + | + | | | | +++ | - | - | Ruppia absent |
| | N-4 | | | | | | +++ | - | - | Ruppia absent |
| | N-5 | + | + | | | | ++ | - | - | Ruppia absent |
| | S-1 | | | | | | - | 2 | + | |
| | S-2 | | | | | | 100 | - | - | |
| | S-3 | | | | | | 200 | 1 | - | |
| | S-4 | | | | | | 5 | - | - | |
| **Southern Ponds** | S-5 | | | | | | - | - | + | |
| | S-6 | | | | | | 20 | 1 | - | |
| | S-7 | | | | | | - | - | ++ | |
| | S-8 | | | | | | 75 | 15 | - | |
| | S-9 | | | | | | - | - | - | |

B

# Appendix 2: Nearshore marine habitat characterization data

Table 2.1 Benthic habitat characterization data - Algae

| Site | Depth | Location | Photo Name | 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 | 2 | | | | | | | | 50 | 10 | | | | | | | | | | | | | | | | | 30 | | |
| 12S | 50 | 3 | | | | | | | | 60 | 5 | | | | | | | | | | | | | | | | | 28 | | |
| 12S | 50 | 4 | | | | | | | | 40 | 5 | | | | | | | | | | | | | | | | | 47 | | |
| 12S | 50 | 6 | | | | | | | | 45 | 7 | | | | | | | | | | | | | | | | | 30 | | 1 |
| 12S | 50 | 11 | | | | | | | | 35 | | | | | | | | | | | | | | | | | | 19 | | 3 |
| 12S | 50 | 17 | | | | | | | | 15 | 10 | | | | | | | | | | | 1 | | | | | | 67 | | 1 |
| 12S | 50 | 19 | | | | | | | | 5 | 10 | | | | | | | | | | | 1 | | | | | | 53 | | 1 |
| 12S | 50 | 21 | | | | | | | | 20 | 20 | | | | | | | | | | | | | | | | | 52 | | |
| 12S | 50 | 23 | | | | | | | | | 3 | | | | | | | 1 | | | | | | | | | | 79 | | |
| 12S | 50 | 25 | | | | | | | | 10 | 6 | | | | | | | 4 | | | | | | | | | | 60 | | |
| 12S | 35 | 2 | | | | | | | | 10 | 5 | | | | | | | | | | | 1 | | | | | | 56 | | |
| 12S | 35 | 3 | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 31 | | |
| 12S | 35 | 4 | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 52 | | |
| 12S | 35 | 8 | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 63 | | 2 |
| 12S | 35 | 14 | | | | | | | | 10 | 15 | | | | | | | | | | | | | | | | | 48 | | |
| 12S | 35 | 16 | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 43 | | |
| 12S | 35 | 19 | | | | | | | | 15 | 10 | | | | | | | 1 | | | | | | | | | | 49 | | |
| 12S | 35 | 20 | | | | | | | | 8 | 18 | | | | | | | | | | | | | | | | | 32 | | |
| 12S | 35 | 27 | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 40 | | |
| 12S | 35 | 28 | | | | | | | | 5 | 3 | | | | | | | | | | | | | | | | | 71 | | |
| 12S | 15 | 1 | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 68 | | |
| 12S | 15 | 5 | | | | | | | | 5 | 3 | | | | | | | | | | | | | | | | | 68 | | |
| 12S | 15 | 6 | | | | | | | | | 7 | | | | | | | | | | | | | | | | | 77 | | |
| 12S | 15 | 8 | | | | | | | | 5 | 7 | | | | | | | | | | | | | | | | | 65 | | 1 |
| 12S | 15 | 12 | | | | | | | | 5 | 3 | | | | | | | | | | | | | | | | | 84 | | |
| 12S | 15 | 17 | | | | | | | | 10 | 3 | | | | | | | | | | | | | | | | | 67 | | |
| 12S | 15 | 21 | | | | | | | | 10 | 2 | | | | | | | | | | | | | | | | | 72 | | 1 |
| 12S | 15 | 23 | | | | | | | | 10 | 6 | | | | | | | | | | | | | | | | | 73 | | |
| 12S | 15 | 26 | | | | | | | | 20 | 5 | | | | | | | | | | | | | | | | | 39 | | |
| 12S | 15 | 29 | | | | | | | | 12 | | | | | | | | | | | | | | | | | | 72 | | 1 |

| | | | | | | Asptax | Caurac | Causer | Caulsert | Codara | CCA | BG | Dasyir | Dichmar | Dictcav | Dictver | Dicty | Gibhaw | Halop | Lobvar | Marfiab | Marfrag | Neoman | Padina | Porhor | Prewel | Sarg | Turbor | Turf | venven | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Depth | Location | Photo Name | Sub-Categories | Algae | Asparagopsis taxiformis (Asptax) | Caulerpa racemosa (Caurac) | Caulerpa serrulata (Caulser) | Caulerpa sertularioides (Caulsert) | Codium arabicum (Codara) | Crustose Coralline (CCA) | Cyanophyta (BG) | Dasya iridescens (Dasyir) | Dichotomaria marginata (Dichmar) | Dictyospaeria cavernosa (Dictcav) | Dictyosphaeria versluysii (Dictver) | Dictyota species (Dicty) | Gibsmithia hawaiiensis (Gibhaw) | Halimeda opuntia (Halop) | Lobophora variegata (Lobvar) | Martensia flabelliformis (Marfiab) | Martensia fragilis (Marfrag) | Neomeris annulata (Neoman) | Padina species (Padina) | Portieria hornemanii (Porhor) | Predaea weldii (Prewel) | Sargassum (Sarg) | Turbinaria ornata (Turbor) | Turf (Turf) | Ventricaria ventricosa (venven) | red algae |
| 12N | 50 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 53 | | |
| 12N | 50 | 2 | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | 52 | | |
| 12N | 50 | 6 | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | 66 | | 1 |
| 12N | 50 | 9 | | | | | | | | | 5 | 1 | | | | | | | 1 | | | | | | | | | | 60 | | 1 |
| 12N | 50 | 13 | | | | | | | | | 10 | 6 | | | | | | | | | | | | | | | | | 60 | | |
| 12N | 50 | 15 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 59 | | |
| 12N | 50 | 19 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 63 | | 1 |
| 12N | 50 | 21 | | | | | | | | | | 2 | | | | | | | 5 | | | | 1 | | | | | | 47 | | 3 |
| 12N | 50 | 23 | | | | | | | | | 5 | 2 | | | | | | | | | | | | | | | | | 50 | | |
| 12N | 50 | 24 | | | | | | | | | 10 | 2 | | | | | | | 3 | | | | | | | | | | 60 | | |
| 12N | 35 | 1 | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | 78 | | |
| 12N | 35 | 2 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 62 | | |
| 12N | 35 | 7 | | | | | | | | | 8 | | | | | | | | | | | | | | | | | | 66 | | |
| 12N | 35 | 9 | | | | | | | | | 7 | 5 | | | | | | | | | | | | | | | | | 47 | | |
| 12N | 35 | 11 | | | | | | | | | 8 | 5 | | | | | | | | | | | | | | | | | 60 | | |
| 12N | 35 | 12 | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | 57 | | |
| 12N | 35 | 13 | | | | | | | | | 5 | 5 | | | | | | | | | | | | | | | | | 65 | | |
| 12N | 35 | 17 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 85 | | |
| 12N | 35 | 18 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 58 | | |
| 12N | 35 | 21 | | | | | | | | | 5 | 10 | | | | | | | | | | | 1 | | | | | | 62 | | |
| 12N | 15 | 2 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 75 | | |
| 12N | 15 | 4 | | | | | | | | | 30 | | | | | | | | | | | | | | | | | | 50 | | |
| 12N | 15 | 5 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 58 | | |
| 12N | 15 | 9 | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | 45 | | |
| 12N | 15 | 11 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 65 | | |
| 12N | 15 | 13 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 70 | | |
| 12N | 15 | 15 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 63 | | |
| 12N | 15 | 16 | | | | | | | | | 30 | 5 | | | | | | | | | | | | | | | | | 53 | | |
| 12N | 15 | 21 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 66 | | |
| 12N | 15 | 23 | | | | | | | | | 7 | 5 | | | | | | | | | | | | | | | | | 41 | | |

# B

| Site | Depth | Location | Photo Name | Sub-Categories | Algae | Asptax | Caurac | Caulser | Caulsert | Codara | CCA | BG | Dasyir | Dichmar | Dictcav | Dictver | Dicty | Gibhaw | Halop | Lobvar | Marflab | Marfrag | Neoman | Padina | Porhor | Prewel | Sarg | Turbor | Turf | venven | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Asparagopsis taxiformis (Asptax) | Caulerpa racemosa (Caurac) | Caulerpa serrulata (Caulser) | Caulerpa sertularioides (Caulsert) | Codium arabicum (Codara) | Crustose Coralline (CCA) | Cyanophyta (BG) | Dasya iridescens (Dasyir) | Dichotomaria marginata (Dichmar) | Dictyospaeria cavernosa (Dictcav) | Dictyosphaeria versluysii (Dictver) | Dictyota species (Dicty) | Gibsmithia hawaiiensis (Gibhaw) | Halimeda opuntia (Halop) | Lobophora variegata (Lobvar) | Martensia flabelliformis (Marflab) | Martensia fragilis (Marfrag) | Neomeris annulata (Neoman) | Padina species (Padina) | Portieria hornemanii (Porhor) | Predaea weldii (Prewel) | Sargassum (Sarg) | Turbinaria ornata (Turbor) | Turf (Turf) | Ventricaria ventricosa (venven) | red algae |
| NPPE | 50 | 0 | | | | | | | | | 3 | | | | | | | 1 | | | | | | | | | | | 11 | | 5 |
| NPPE | 50 | 1 | | | | | | | | | 5 | 6 | | | | | | | | | | | | | | | | | 48 | | |
| NPPE | 50 | 5 | | | | | | | | | 5 | 3 | | | | | | | | | | | 1 | | | | | | 54 | | |
| NPPE | 50 | 7 | | | | | | | | | 10 | 2 | | | | | | | | | | | | | | | | | 61 | | |
| NPPE | 50 | 8 | | | | | | | | | 10 | 3 | | | | | | | | | | | | | | | | | 47 | | |
| NPPE | 50 | 19 | | | | | | | | | 15 | 2 | | | | | | | | | | | | | | | | | 40 | | |
| NPPE | 50 | 23 | | | | | | | | | 20 | 5 | | | | | | | | | | | | | | | | | 29 | | 2 |
| NPPE | 50 | 24 | | | | | | | | | 20 | | | | | | | 1 | | | | | | | | | | | 23 | | |
| NPPE | 50 | 27 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 32 | | 1 |
| NPPE | 50 | 29 | | | | | | | | | 10 | | | | | | | | | | | | 1 | | | | | | 58 | | 1 |
| NPPE | 35 | 0 | | | | | | | | | 7 | 2 | | | | | | | | | | | 1 | | | | | | 58 | | |
| NPPE | 35 | 1 | | | | | | | | | 5 | 5 | | | | | | | | | | | | | | | | | 49 | | |
| NPPE | 35 | 2 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 75 | 1 | |
| NPPE | 35 | 5 | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | 53 | | 1 |
| NPPE | 35 | 12 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | 67 | | |
| NPPE | 35 | 14 | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | 56 | | |
| NPPE | 35 | 17 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 52 | | |
| NPPE | 35 | 19 | | | | | | | | | 6 | 5 | | | | | | | | | | | | | | | | | 53 | | |
| NPPE | 35 | 21 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 66 | | |
| NPPE | 35 | 22 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | 45 | | |
| NPPE | 15 | 0 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 70 | | |
| NPPE | 15 | 1 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 52 | | |
| NPPE | 15 | 6 | | | | | | | | | 8 | 2 | | | | | | | | | | | | | | | | | 62 | | |
| NPPE | 15 | 8 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 60 | | |
| NPPE | 15 | 12 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 65 | | |
| NPPE | 15 | 13 | | | | | | | | | 5 | 2 | | | | | | | | | | | | | | | | | 47 | | |
| NPPE | 15 | 15 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 68 | | |
| NPPE | 15 | 19 | | | | | | | | | 5 | 2 | | | | | | | | | | | | | | | | | 64 | | |
| NPPE | 15 | 22 | | | | | | | | | 15 | 2 | | | | | | | | | | | | | | | | | 71 | | |
| NPPE | 15 | 25 | | | | | | | | | 3 | 1 | | | | | | | | | | | | | | | | | 30 | | |

| Site | Depth | Location | Photo Name | 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 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | 28 | | |
| H-bay | 50 | 13 | | | | | | | | | 30 | | | | | | | 1 | | | | | | | | | | | 17 | | |
| H-bay | 50 | 15 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | 25 | | |
| H-bay | 50 | 18 | | | | | | | | | 30 | | | | | | | | | | | | | | | | | | 23 | | 1 |
| H-bay | 50 | 22 | | | | | | | | | 5 | 15 | | | | | | | | | | | | | | | | | 26 | | |
| H-bay | 50 | 29 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 15 | | |
| H-bay | 50 | 31 | | | | | | | | | 25 | 1 | | | | | | | | | | | | | | | | | 8 | | |
| H-bay | 50 | 33 | | | | | | | | | 12 | 8 | | | | | | | | | | | | | | | | | 15 | | |
| H-bay | 50 | 37 | | | | | | | | | 10 | 3 | | | | | | | | | | | | | | | | | 27 | | |
| H-bay | 50 | 41 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 36 | | |
| H-bay | 35 | 1 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 42 | | |
| H-bay | 35 | 6 | | | | | | | | | 25 | | | | | | | | | | | | 1 | | | | | | 53 | | |
| H-bay | 35 | 11 | | | | | | | | | 10 | 2 | | | | | | | | | | | | | | | | | 36 | | |
| H-bay | 35 | 13 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 60 | | |
| H-bay | 35 | 18 | | | | | | | | | 20 | 5 | | | | | | | | | | | | | | | | | 29 | | |
| H-bay | 35 | 21 | | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 45 | | |
| H-bay | 35 | 23 | | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 57 | | |
| H-bay | 35 | 27 | | | | | | | | | 10 | 5 | | | | | | | | | | | 1 | | | | | | 34 | | 2 |
| H-bay | 35 | 32 | | | | | | | | | 10 | | | | | | | | | | | | 1 | | | | | | 33 | | |
| H-bay | 35 | 35 | | | | | | | | | | | | | | | | | | | | | | | | | | | 46 | | |
| H-bay | 15 | 0 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 47 | | |
| H-bay | 15 | 4 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 52 | | |
| H-bay | 15 | 6 | | | | | | | | | 30 | | | | | | | | | | | | 1 | | | | | | 45 | | |
| H-bay | 15 | 10 | | | | | | 3 | | | 10 | 3 | | | | | | | | | | | | | | | | | 59 | | |
| H-bay | 15 | 14 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | 40 | | |
| H-bay | 15 | 16 | | | | | | | | | 30 | 5 | | | | | | | | | | | | | | | | | 50 | | |
| H-bay | 15 | 18 | | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 33 | | |
| H-bay | 15 | 20 | | | | | | | | | 20 | 3 | | | | | | | | | | | | | | | | | 67 | | |
| H-bay | 15 | 21 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | 58 | | |
| H-bay | 15 | 25 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 43 | | |

| Site | Depth | Location | Photo Name | 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 | 1 | | | | | | | | | 7 | 5 | | | | | | | | | | | | | | | | | 56 | | |
| 18 | 50 | 2 | | | | | | | | | 25 | 15 | | | | | | | | | | | | | | | | | 54 | | |
| 18 | 50 | 3 | | | | | | | | | 50 | 5 | | | | | | | | | | | | | | | | | 33 | | |
| 18 | 50 | 4 | | | | | | | | | 60 | 5 | | | | | | | | | | | | | | | | | 12 | | |
| 18 | 50 | 5 | | | | | | | | | 20 | 15 | | | | | | | 3 | | | | | | | | | | 22 | | |
| 18 | 50 | 10 | | | | | | | | | 40 | 5 | | | | | | | 1 | | | | | | | | | | 6 | | |
| 18 | 50 | 20 | | | | | | | | | 5 | 15 | | | | | | | 2 | | | | | | | | | | 43 | | |
| 18 | 50 | 23 | | | | | | | | | | 15 | | | | | | | | | | | 1 | | | | | | 61 | | |
| 18 | 50 | 25 | | | | | | | | | 5 | | | | | | | | 2 | | | | 1 | | | | | | 71 | | 1 |
| 18 | 50 | 27 | | | | | | | | | 3 | 5 | | | | | | | | | | | 1 | | | | | | 67 | | |
| 18 | 35 | 0 | | | | | | | | | 20 | 5 | | | | | | | | | | | 1 | | | | | | 46 | | 1 |
| 18 | 35 | 4 | | | | | | | | | 5 | 2 | | | | | | | | | | | | | | | | | 55 | | |
| 18 | 35 | 5 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 33 | | |
| 18 | 35 | 10 | | | | | | | | | 5 | 3 | | | | | | | 1 | | | | | | | | | | 54 | | |
| 18 | 35 | 13 | | | | | | | | | 20 | 10 | | | | | | | 1 | | | | | | | | | | 66 | | |
| 18 | 35 | 19 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 32 | | |
| 18 | 35 | 20 | | | | | | | | | 15 | | | | | | | | | | | | | | | | | | 33 | | |
| 18 | 35 | 23 | | | | | | | | | 25 | 5 | | | | | | | 1 | | | | | | | | | | 48 | | |
| 18 | 35 | 27 | | | | | | | | | 15 | 10 | | | | | | | | | | | | | | | | | 40 | | |
| 18 | 35 | 30 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 38 | | |
| 18 | 15 | 2 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | 30 | | |
| 18 | 15 | 5 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 42 | | |
| 18 | 15 | 6 | | | | | | | | | 5 | 3 | | | | | | | | | | | | | | | | | 61 | | |
| 18 | 15 | 8 | | | | | | | | | 20 | 5 | | | | | | | | | | | | | | | | | 58 | | |
| 18 | 15 | 10 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 44 | | |
| 18 | 15 | 12 | | | | | | | | | 15 | 10 | | | | | | | | | | | | | | | | | 62 | | |
| 18 | 15 | 19 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 35 | | |
| 18 | 15 | 25 | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | 77 | | |
| 18 | 15 | 26 | | | | | | | | | 30 | 5 | | | | | | | | | | | | | | | | | 30 | | |
| 18 | 15 | 27 | | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 73 | | |

| Site | Depth | Location | Photo Name | Sub-Categories | Algae | Asparagopsis taxiformis (Asptax) | Caulerpa racemosa (Caurac) | Caulerpa serrulata (Caulser) | Caulerpa sertularioides (Caulsert) | Codium arabicum (Codara) | Crustose Coralline (CCA) | Cyanophyta (BG) | Dasya iridescens (Dasyir) | Dichotomaria marginata (Dichmar) | Dictyospaeria cavernosa (Dictcav) | Dictyosphaeria versluysii (Dictver) | Dictyota species (Dicty) | Gibsmithia hawaiiensis (Gibhaw) | Halimeda opuntia (Halop) | Lobophora variegata (Lobvar) | Martensia flabelliformis (Marflab) | Martensia fragilis (Marfrag) | Neomeris annulata (Neoman) | Padina species (Padina) | Portieria hornemanii (Porhor) | Predaea weldii (Prewel) | Sargassum (Sarg) | Turbinaria ornata (Turbor) | Turf (Turf) | Ventricaria ventricosa (venven) | red algae |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Asptax | Caurac | Caulser | Caulsert | Codara | CCA | BG | Dasyir | Dichmar | Dictcav | Dictver | Dicty | Gibhaw | Halop | Lobvar | Marflab | Marfrag | Neoman | Padina | Porhor | Prewel | Sarg | Turbor | Turf | venven | |
| Wawa | 50 | 0 | | | | | | | | | 20 | 1 | | | | | | | | | | | | | | | | | 33 | | |
| Wawa | 50 | 2 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | 27 | | |
| Wawa | 50 | 3 | | | | | | | | | 10 | 3 | | | | | | | | | | | | | | | | | 33 | | 2 |
| Wawa | 50 | 6 | | | | | | | | | 10 | 3 | | | | | | | | | | | | | | | | | 45 | | |
| Wawa | 50 | 7 | | | | | | | | | 10 | 2 | | | | | | | | | | | | | | | | | 42 | | 1 |
| Wawa | 50 | 10 | | | | | | | | | 15 | 5 | | | | | | | | | | | | | | | | | 36 | | 1 |
| Wawa | 50 | 15 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 40 | | |
| Wawa | 50 | 17 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 15 | | 1 |
| Wawa | 50 | 21 | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | 63 | | 2 |
| Wawa | 50 | 24 | | | | | | | | | 5 | 6 | | | | | | | | | | | | | | | | | 67 | | |
| Wawa | 35 | 0 | | | | | | | | | 20 | 5 | | | | | | | | | | | | | | | | | 44 | | |
| Wawa | 35 | 3 | | | | | | | | | 3 | 5 | | | | | | | | | | | | | | | | | 61 | | |
| Wawa | 35 | 5 | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | 54 | | |
| Wawa | 35 | 10 | | | | | | | | | 10 | 5 | | | | | | | | | | | | | | | | | 55 | | |
| Wawa | 35 | 12 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 58 | | |
| Wawa | 35 | 18 | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | 59 | | |
| Wawa | 35 | 20 | | | | | | | | | 20 | 10 | | | | | | | | | | | | | | | | | 30 | | |
| Wawa | 35 | 22 | | | | | | | | | 10 | 7 | | | | | | | | | | | | | | | | | 44 | | |
| Wawa | 35 | 26 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | 57 | | |
| Wawa | 35 | 27 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | 49 | | |
| Wawa | 15 | 0 | | | | | | | | | 6 | 1 | | | | | | | | | | | | | | | | | 49 | | |
| Wawa | 15 | 4 | | | | | | | | | 5 | 10 | | | | | | | | | | | | | | | | | 58 | | |
| Wawa | 15 | 6 | | | | | | | | | 20 | 4 | | | | | | | | | | | | | | | | | 32 | | |
| Wawa | 15 | 10 | | | | | | | | | 8 | 5 | | | | | | | | | | | | | | | | | 71 | | |
| Wawa | 15 | 11 | | | | | | | | | 3 | 5 | | | | | | | | | | | | | | | | | 62 | | |
| Wawa | 15 | 15 | | | | | | | | | 3 | 1 | | | | | | | | | | | | | | | | | 73 | | |
| Wawa | 15 | 17 | | | | | | | | | 10 | 4 | | | | | | | | | | | | | | | | | 68 | | |
| Wawa | 15 | 21 | | | | | | | | | 5 | 5 | | | | | | | | | | | | | | | | | 55 | | |
| Wawa | 15 | 22 | | | | | | | | | 3 | 5 | | | | | | | | | | | | | | | | | 62 | | |
| Wawa | 15 | 24 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 70 | | 1 |

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

| Site | Depth | Location | Photo Name | Sponge (Sponge) | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12S | 50 | 2 | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| 12S | 50 | 3 | | | | | | | | | | 1 | | | | | | | | | | | | | 6 | | | | | | | | | |
| 12S | 50 | 4 | | | | | | | | | | 3 | | | | | | | | | | | | | 5 | | | | | | | | | |
| 12S | 50 | 6 | | | | | | | | | | | 2 | | | | | | | | | | | | 15 | | | | | | | | | |
| 12S | 50 | 11 | | | | | | | | | | | | | | | | 1 | | | | | 7 | | 30 | | | | | | | | | 5 |
| 12S | 50 | 17 | | | | | | | | | | | 1 | | | | | | | | | | | | 5 | | | | | | | | | |
| 12S | 50 | 19 | | | | | | | | | | | 10 | | | | | | | | | | | | 20 | | | | | | | | | |
| 12S | 50 | 21 | | | | | | | | | | 1 | | | | | | | | | | | | | 7 | | | | | | | | | |
| 12S | 50 | 23 | | | | | | | | | | | 1 | | | | | | | | | 1 | | | 10 | | | | | | | | | 5 |
| 12S | 50 | 25 | | | | | | | | | | 5 | | | | | | | | | | | | | 15 | | | | | | | | | |
| 12S | 35 | 2 | | | | | | | | | | | 1 | | | | | | | | | | | 10 | 12 | | | | | | | | | 5 |
| 12S | 35 | 3 | | 1 | | | | | | | | | 3 | | | | | | | 20 | | | | | 25 | | | | | | | | | 5 |
| 12S | 35 | 4 | | | | | | | | | | | 2 | | | | | | | | | 1 | | | 25 | | | | | | | | | |
| 12S | 35 | 8 | | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | |
| 12S | 35 | 14 | | | | | | | | | | | | | | | | | | | | | | 6 | 20 | | | | | | | | | 1 |
| 12S | 35 | 16 | | 2 | | | | | | | | | 8 | | | | | | | | | | | | 17 | | | | | | | | | 20 |
| 12S | 35 | 19 | | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | 5 |
| 12S | 35 | 20 | | 2 | | | | | | | | | 5 | | | | | | | 10 | | | | | 10 | | | | | | | | | 15 |
| 12S | 35 | 27 | | 2 | | | | | | | | | | | | | | | | | | | 5 | 23 | 10 | | | | | | | | | 5 |
| 12S | 35 | 28 | | | | | | | | | | | | | 1 | | | | | | | | | | 20 | | | | | | | | | |
| 12S | 15 | 1 | | | | | | | | | | | 1 | | | | | | | | | 1 | | | 10 | | | | | | | | | |
| 12S | 15 | 5 | | | | | | | | | | | 1 | | | | | | | | | | | | 20 | | | | | | | | | 3 |
| 12S | 15 | 6 | | | | | | | | | | | 1 | | | | | | | | | | | | 10 | | | | | | | | | 5 |
| 12S | 15 | 8 | | | | | | | | | | | 1 | | | | | | | | | 1 | | | 15 | | | | | | | | | 5 |
| 12S | 15 | 12 | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | 3 |
| 12S | 15 | 17 | | | | | | | | | | | 5 | | | | | | | | | | | | 12 | | | | | | | | | 3 |
| 12S | 15 | 21 | | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | |
| 12S | 15 | 23 | | | | | | | | | | | | | | | | | | | | 1 | | | 10 | | | | | | | | | |
| 12S | 15 | 26 | | | | | | | | | | | | | | | | | | | | 1 | | | 35 | | | | | | | | | |
| 12S | 15 | 29 | | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | |

| Site | Depth | Location | Photo Name | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
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| 12N | 50 | 0 | | | | | | | | | | 5 | | 3 | | | | | | | | 7 | | 20 | | | | | | | | | 10 |
| 12N | 50 | 2 | | | | | | | | | | 1 | | | | | | | | | | 20 | | 25 | | | | | | | | | |
| 12N | 50 | 6 | | | | | | | | | | | | | | | | | | | | 10 | | 22 | | | | | | | | | |
| 12N | 50 | 9 | | | | | | | | | | | | | | | 1 | | | | | 10 | | 15 | | | | | | | | | 6 |
| 12N | 50 | 13 | | | | | | | | | | 2 | | | | | | | | | | 5 | | 17 | | | | | | | | | |
| 12N | 50 | 15 | | | | | | | | | 1 | | | | | | | | | | | 15 | | 15 | | | | | | | | | |
| 12N | 50 | 19 | | | | | | | | | | | | | | | | | | | | 5 | 10 | 12 | | | | | | | | | 3 |
| 12N | 50 | 21 | | | | | | | | | | 2 | | | | | | | | | | 13 | | 25 | | | | | | | | | 2 |
| 12N | 50 | 23 | | | | | | | | | | | | | | | | | | | | 10 | | 28 | | | | | | | | | 5 |
| 12N | 50 | 24 | | | | | | | | | | 2 | | | | | | | | | | | | 23 | | | | | | | | | |
| 12N | 35 | 1 | | | | | | | | | | 3 | | | | | | | | | | | | 10 | | | | | | | | | 5 |
| 12N | 35 | 2 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | 3 |
| 12N | 35 | 7 | | | | | | | | | | | | | | | | | | | | 5 | | 17 | | | | | | | | | 4 |
| 12N | 35 | 9 | | | | | | | | | | 2 | | | | | | | | | | | | 35 | | | | | | | | | 4 |
| 12N | 35 | 11 | | | | | | | | | | | | 2 | | | | | | | | | | 25 | | | | | | | | | |
| 12N | 35 | 12 | | | | | | | | | | 3 | | | | | | | | | | | | 10 | | | | | | | | | 25 |
| 12N | 35 | 13 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | 5 |
| 12N | 35 | 17 | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| 12N | 35 | 18 | | | | | | | | | | | | | | | | | | | | 5 | | 27 | | | | | | | | | |
| 12N | 35 | 21 | | | | | | | | | | | | | | | | | | | | | | 17 | | | | | | | | | 5 |
| 12N | 15 | 2 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | |
| 12N | 15 | 4 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | |
| 12N | 15 | 5 | | | | | | | | | | 1 | | | | | | | | | | | | 30 | | | | | | | | | 5 |
| 12N | 15 | 9 | | | | | | | | | | 5 | | | | | | | | | | | | 35 | | | | | | | | | 10 |
| 12N | 15 | 11 | | | | | | | | | | 5 | | | | | | | | | | | | 25 | | | | | | | | | |
| 12N | 15 | 13 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | |
| 12N | 15 | 15 | | | | | | | | | | 2 | | | | | | | | | | | | 30 | | | | | | | | | |
| 12N | 15 | 16 | | | | | | | | | | | | | | | | | | | | | | 12 | | | | | | | | | |
| 12N | 15 | 21 | | | 1 | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | 2 |
| 12N | 15 | 23 | | | | | | | | | | 1 | | | | | | | | | | | | 30 | | | | | | | | | 15 |

| Site | Depth | Location | Photo Name | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
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| NPPE | 50 | 0 | | | | | | | | | | | | | | | | | | | | 50 | | 30 | | | | | | | | | |
| NPPE | 50 | 1 | | | | | | | | | | 5 | | 1 | | | | | | | | 10 | | 25 | | | | | | | | | |
| NPPE | 50 | 5 | | | | | | | | | | 7 | | | | | | | | | | | | 30 | | | | | | | | | |
| NPPE | 50 | 7 | | | | | | | | | | 2 | | | | | | | | | | 5 | | 20 | | | | | | | | | |
| NPPE | 50 | 8 | | | | | | | | | | 3 | | | | | | | | | | 7 | | 30 | | | | | | | | | |
| NPPE | 50 | 19 | | | | | | | | | | | | | | | | | | | | 25 | | 18 | | | | | | | | | |
| NPPE | 50 | 23 | | | | | | | | | | | | | | | | | | | 2 | 30 | | 12 | | | | | | | | | |
| NPPE | 50 | 24 | | | | | | | | | | | | | | | 1 | | | | | 35 | | 20 | | | | | | | | | |
| NPPE | 50 | 27 | | | | | | | | | | | | | | | | | | | | 25 | | 32 | | | | | | | | | |
| NPPE | 50 | 29 | | | | | | | | | | 5 | | | | | | | | | | 3 | 5 | 13 | | | | | | | | | 3 |
| NPPE | 35 | 0 | | | 1 | | | | | | | 1 | | | | | | | | | | | | 30 | | | | | | | | | |
| NPPE | 35 | 1 | | | | | | | | | | | | 1 | | | | | | | | | | 25 | | | | | | 5 | | | 10 |
| NPPE | 35 | 2 | | | | | | | | | | | | | | | 2 | | | | | | | 12 | | | | | | | | | |
| NPPE | 35 | 5 | | | | | | | | | 1 | 2 | | | | | | | | | | | | 35 | | | | | | | | | 2 |
| NPPE | 35 | 12 | | | | | | | | | | | | 1 | | | | | | | | | | 12 | | | | | | | | | |
| NPPE | 35 | 14 | | | | | | | | | | | | 1 | | | | | | | | 3 | | 25 | | | | | | | | | 3 |
| NPPE | 35 | 17 | | | | | | | | | | 3 | | | | | | | | | | | | 30 | | | | | | | | | |
| NPPE | 35 | 19 | | | | | | | | | | | | | | | | | | | 1 | 3 | | 32 | | | | | | | | | |
| NPPE | 35 | 21 | | | | | | | | | | 2 | | | | | | | | | | 15 | | 10 | | | | | | 2 | | | |
| NPPE | 35 | 22 | | | | | | | | | | | | | | | | | | | | | | 35 | | | | | | | | | |
| NPPE | 15 | 0 | | | | | | | | | | | | 2 | | | | | | | | | | 18 | | | | | | | | | |
| NPPE | 15 | 1 | | | | | | | | | | | | | | | | | | | | | | 38 | | | | | | | | | |
| NPPE | 15 | 6 | | | | | | | | | | 2 | | | | | | | | | 1 | | | 25 | | | | | | | | | |
| NPPE | 15 | 8 | | | | | | | | | | | | | | | | | | | | | | 35 | | | | | | | | | |
| NPPE | 15 | 12 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | |
| NPPE | 15 | 13 | | | | | | | | | | 2 | | 1 | | | | | | | | | | 50 | | | | | | 3 | | | |
| NPPE | 15 | 15 | | | | | | | | | | | | | | | | | | | | | | 17 | | | | | | | | | |
| NPPE | 15 | 19 | | | | | | | | | | | | | | | | | | | | | | 26 | | | | | | | | | 3 |
| NPPE | 15 | 22 | | | | | | | | | | | | | | | | | | | | | | 12 | | | | | | | | | |
| NPPE | 15 | 25 | | | | | | | | | | | | | | | | | | | | | | 65 | | | | | | | | | 1 |

| Site | Depth | Location | Photo Name | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H-bay | 50 | 2 | | | | | | | | | | | | | | | 2 | | | | | 25 | | 20 | | | | | | | | | |
| H-bay | 50 | 13 | | | | | | | | | | 5 | | | | | | | | | 2 | 15 | | 30 | | | | | | | | | |
| H-bay | 50 | 15 | | | | | | | | | 1 | 4 | | | | | | | | | | 25 | | 25 | | | | | | | | | |
| H-bay | 50 | 18 | | | | | | | | | | 2 | | | | | | | | | 1 | | | 3 | | | | | | 10 | | | 30 |
| H-bay | 50 | 22 | | | | | | | | | | 4 | | | | | | | | | | 15 | | 10 | | | | | | | | | 25 |
| H-bay | 50 | 29 | | | | | | | | | | | | | | | | | | | | 20 | | 50 | | | | | | | | | |
| H-bay | 50 | 31 | | | | | | | | | | 1 | | | | | | | | | | 20 | | 40 | 5 | | | | | | | | |
| H-bay | 50 | 33 | | | | | | | | | | | | | | | | | | | | 45 | | 20 | | | | | | | | | |
| H-bay | 50 | 37 | | | | | | | | | | | | | | | | | | | | 40 | | 20 | | | | | | | | | |
| H-bay | 50 | 41 | | | | | | | | | | 1 | | | | | | | | | | 45 | | 10 | | | | | | | | | 3 |
| H-bay | 35 | 1 | | | | | | | | | | 10 | | | | | | | | | | 2 | | 35 | | | | | | | | | 5 |
| H-bay | 35 | 6 | | | | | | | | | | 1 | | | | | | | | | | 5 | | 15 | | | | | | | | | |
| H-bay | 35 | 11 | | | | | | | | | | 2 | | | | | | | | | | | | 50 | | | | | | | | | |
| H-bay | 35 | 13 | | | | | | | | | 1 | 2 | | | | | | | | | | | | 30 | | | | | | | | | 2 |
| H-bay | 35 | 18 | | | | | | | | | | 1 | | | | | | | | | | | | 45 | | | | | | | | | |
| H-bay | 35 | 21 | | | | | | | | | | 5 | | | | | | | | | | | | 30 | | | | | | | | | |
| H-bay | 35 | 23 | | | | | | | | | | 3 | | | | | | | | | | | | 20 | | | | | | | | | |
| H-bay | 35 | 27 | | | | | | | | | | 3 | | | | | | | | | | | | 45 | | | | | | | | | |
| H-bay | 35 | 32 | | | | | | | | | | 8 | | | | | | | | | | | | 48 | | | | | | | | | |
| H-bay | 35 | 35 | | | | | | | | | | 8 | | | | | | | | | | 6 | | 40 | | | | | | | | | |
| H-bay | 15 | 0 | | | | | | | | | | 3 | | | | | | | | | | | | 35 | | | | | | | | | |
| H-bay | 15 | 4 | | | | | | | | | 3 | | | | | | | | | | | | | 35 | | | | | | | | | 5 |
| H-bay | 15 | 6 | | | 1 | | | | | | | 1 | | | | | | | | | | | | 20 | | | | | | | | | 2 |
| H-bay | 15 | 10 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | 5 |
| H-bay | 15 | 14 | | | | | | | | | 1 | 5 | | | | | 1 | | | | | | | 25 | | | | | | | | | 3 |
| H-bay | 15 | 16 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | |
| H-bay | 15 | 18 | | | 2 | | | | | | | | | | | | | | | | | | | 45 | | | | | | | | | |
| H-bay | 15 | 20 | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| H-bay | 15 | 21 | | | | | | | | | | | | | | | | | 12 | | | | | 10 | | | | | | | | | |
| H-bay | 15 | 25 | | | | | | | | | 1 | 1 | | | | | | | | | | | | 40 | | | | | | | | | |

# B

| Site | Depth | Location | Photo Name | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 50 | 1 | | | | | | | | | | 2 | | | | | | | | | | | | 10 | | | | | | | | | 20 |
| 18 | 50 | 2 | | | | | | | 1 | | | | | | | | | | | | | | | 5 | | | | | | | | | |
| 18 | 50 | 3 | | | 2 | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| 18 | 50 | 4 | | | 1 | | | | | | | 2 | | | | | | | | | | | | 20 | | | | | | | | | |
| 18 | 50 | 5 | | | | | | | | | | | | | | | | | | | | 5 | | 25 | | | | | | | | | 10 |
| 18 | 50 | 10 | | | 1 | | | | | | | 6 | | | | | | | | | | | | 25 | | | | | | | | | 15 |
| 18 | 50 | 20 | | | | | | | | | | 2 | | | | | | | | | | 3 | | 25 | | | | | | | | | 5 |
| 18 | 50 | 23 | | | | | | | | | | 3 | | | | | | | | | | | | 10 | | | | | | | | | 10 |
| 18 | 50 | 25 | | | | | | | | | | 5 | | | | | | | | | | | | 10 | | | | | | | | | 5 |
| 18 | 50 | 27 | | | | | | | | | 1 | 7 | | | | | | | | | | | | 10 | | | | | | | | | 5 |
| 18 | 35 | 0 | | | | | | | | | 2 | | | | | | | | | | | 5 | | 20 | | | | | | | | | |
| 18 | 35 | 4 | | | | | | | | | | 5 | | | | | | | | | 1 | | | 25 | | | | | | | | | 5 |
| 18 | 35 | 5 | | | | | | | | | | 3 | | | | | | | | | 1 | 1 | | 20 | | | | | | | | | 25 |
| 18 | 35 | 10 | | | | | | | | | 1 | 1 | | | | | | | 10 | | | | | 25 | | | | | | | | | |
| 18 | 35 | 13 | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | 2 | | | |
| 18 | 35 | 19 | | | | | | | | | | 6 | | | | | | | | | | | | 25 | | | | | | | | | 20 |
| 18 | 35 | 20 | | | | | | | | | 2 | 10 | | | | | | | | | | | | 40 | | | | | | | | | |
| 18 | 35 | 23 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | 5 | | | 1 |
| 18 | 35 | 27 | | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | 10 |
| 18 | 35 | 30 | | | | | | | | | | 10 | | | | | | | | | | | | 17 | | | | | | | | | 20 |
| 18 | 15 | 2 | | | | | | | | | | | | | | | | | | | | | | 45 | | | | | | | | | |
| 18 | 15 | 5 | | | | | | | | | | | | | | | | | | | | | | 50 | | | | | | | | | |
| 18 | 15 | 6 | | | | | | | | | | 1 | | | | | | | | | | | | 25 | | | | | | | | | 5 |
| 18 | 15 | 8 | | | | | | | | | 1 | 1 | | | | | | | | | | | | 15 | | | | | | | | | |
| 18 | 15 | 10 | | | | | | | | | 1 | | | | | | | | | | | | | 15 | | | | | | | | | 25 |
| 18 | 15 | 12 | | | | | | | | | | | | | | | | | | | | | | 13 | | | | | | | | | |
| 18 | 15 | 19 | | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | 25 |
| 18 | 15 | 25 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | 5 |
| 18 | 15 | 26 | | | | | | | | | | 5 | | | | | | | | | | | | 30 | | | | | | | | | |
| 18 | 15 | 27 | | | 1 | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | |

| Site | Depth | Location | Photo Name | Spirastrealla vagabunda | Palythoa tuberculosa | Coral | Cyphastrea agassizi (cypag) | Cyphastrea ocellina (cypoc) | Fungia scutaria (Funscu) | Leptastrea purpurea (Leppur) | Leptoseris bewickensis (Lepbew) | Montipora capitata (Moncap) | Montipora flabellata (Monfla) | Montipora patula (Monpat) | Montipora species (Monsp) | Pavona duerdeni (Pavdue) | Pavona varians (Pavvar) | Pocillopora damicornis (Pocdam) | Pocillopora eydouxi (Poceyd) | Pocillopora ligulata (Poclig) | Pocillopra meandrina (Pocmea) | Porites compressa (Porcom) | Porites evermanni (Porev) | Porites lobata (Porlob) | Porites rus | Tubastrea coccinea (Tubcoc) | Sarcothelia edmondsoni | Inorganics | Basalt (Basalt) | Rubble | Limestone (Limest) | Quad (Quad) | Sand (Sand) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawa | 50 | 0 | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | 45 |
| Wawa | 50 | 2 | | | | | | | | | | 2 | | | | | | | | | | | | 6 | | | | | | | | | 45 |
| Wawa | 50 | 3 | | | | | | | 1 | | | 1 | 1 | | | | | | | | 1 | | 15 | 3 | | | | | | | | | 30 |
| Wawa | 50 | 6 | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | 40 |
| Wawa | 50 | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | 40 |
| Wawa | 50 | 10 | | | | | | | | | 3 | | | | | | | | | | | | | 5 | | | | | | | | | 35 |
| Wawa | 50 | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 45 |
| Wawa | 50 | 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 79 |
| Wawa | 50 | 21 | | | | | | | | | | 3 | | | | | | | | | | | | 20 | | | | | | | | | 5 |
| Wawa | 50 | 24 | | | | | | | | | | 2 | | | | | | | | | | | | 15 | | | | | | | | | 5 |
| Wawa | 35 | 0 | | | 3 | | | | | | | | | | | | | | | | 1 | | | 25 | | | | | | | | | 2 |
| Wawa | 35 | 3 | | | | | | | | | | 5 | | 6 | | | | | | | | | | 15 | | | | | | | | | 5 |
| Wawa | 35 | 5 | | | | | | | | | | 10 | | 7 | | | | | | | 1 | | | 20 | | | | | | | | | 1 |
| Wawa | 35 | 10 | | | | | | | | | | 2 | | | | | | | | | | | | 28 | | | | | | | | | |
| Wawa | 35 | 12 | | | | | | | | | | 12 | | | | | | | | | | | | 25 | | | | | | | | | |
| Wawa | 35 | 18 | | | 1 | | | | | | | 4 | | | | | | | | | | | | 30 | | | | | | | | | 3 |
| Wawa | 35 | 20 | | | | | | | | | | 2 | | 8 | | | | | | | | | | 15 | | | | | | | | | 15 |
| Wawa | 35 | 22 | | | | | | | | | | 2 | | | | | | | | | | | | 35 | | | | | | | | | 2 |
| Wawa | 35 | 26 | | | 1 | | | | | | | 4 | | | | | | | | | | | | 27 | | | | | | | | | 5 |
| Wawa | 35 | 27 | | | | | | | | | | 5 | | | | | | | | | 1 | | | 12 | | | | | | | | | 25 |
| Wawa | 15 | 0 | | | | | | | | | | 3 | | 6 | | | | | | | | | | 35 | | | | | | | | | |
| Wawa | 15 | 4 | | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | 2 |
| Wawa | 15 | 6 | | | | | | | | | | 3 | | | | | | | | | | | | 25 | | | | | | 10 | | | 6 |
| Wawa | 15 | 10 | | | | | | | | | | | | | | | | | | | 1 | | | 15 | | | | | | | | | |
| Wawa | 15 | 11 | | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | 5 |
| Wawa | 15 | 15 | | | | | | | | | | | | | | | | | | | | | | 18 | | | | | | | | | 5 |
| Wawa | 15 | 17 | | | | | | | | | | 3 | | | | | | | | | | | | 15 | | | | | | | | | |
| Wawa | 15 | 21 | | | | | | | | | | | | 5 | | | | | | | | | | 20 | | | | | | | | | 10 |
| Wawa | 15 | 22 | | | | | | | | | | 3 | | 1 | | | | | | | 1 | | | 25 | | | | | | | | | |
| Wawa | 15 | 24 | | | | | | | | | | 3 | | | | | | | | | 1 | | | 15 | | | | | | | | | |

Table 2.3 Benthic habitat characterization data – Mobile Invertebrates

| Row Labels | Count of Site | Count of sponges | Count of Hermit Crab | Count of flatworms | Count of Conus sp. | Count of Hydroid sp. | Count of S. giganteus |
|---|---|---|---|---|---|---|---|
| ⊟ 15 | 60 | 6 | | 1 | 2 | | 3 |
| 18 | 10 | 2 | | 1 | | | |
| 12N | 10 | 4 | | | | | 1 |
| 12S | 10 | | | | | | 1 |
| H-bay | 10 | | | | 1 | | |
| NPPE | 10 | | | | 1 | | |
| Wawa | 10 | | | | | | 1 |
| ⊟ 35 | 60 | 11 | 3 | | 3 | | 1 |
| 18 | 10 | 3 | | | | | |
| 12N | 10 | 1 | 1 | | | | |
| 12S | 10 | 4 | 1 | | | | |
| H-bay | 10 | 1 | | | | | |
| NPPE | 10 | | 1 | | | | |
| Wawa | 10 | 2 | | | 3 | | 1 |
| ⊟ 50 | 60 | 6 | | | 1 | 1 | 1 |
| 18 | 10 | 2 | | | | | |
| 12N | 10 | 2 | | | 1 | 1 | |
| 12S | 10 | | | | | | |
| H-bay | 10 | | | | | | |
| NPPE | 10 | 1 | | | | | 1 |
| Wawa | 10 | 1 | | | | | |
| **Grand Total** | **180** | **23** | **3** | **1** | **6** | **1** | **5** |

# Appendix 3: Nearshore fish assemblage data

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

| Haona Bay | 6/9/18 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 50' | | | 35' | | | 15' | | |
| **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** |
| *M. kuntee* | 13 | 20 | *A. nigrofuscus* | 7 | 7 | *A. nigrofuscus* | 17 | 8 |
| *M. kuntee* | 10 | 18 | *A. nigrofuscus* | 1 | 9 | *A. nigrofuscus* | 13 | 12 |
| *M. kuntee* | 10 | 14 | *A. nigrofuscus* | 5 | 12 | *A. nigrofuscus* | 25 | 10 |
| *M. kuntee* | 10 | 17 | *A. nigrofuscus* | 7 | 8 | *A. nigrofuscus* | 12 | 14 |
| *M. kuntee* | 10 | 16 | *A. nigrofuscus* | 7 | 10 | *Kyphosus spp.* | 2 | 16 |
| *M. kuntee* | 12 | 15 | *C. agilis* | 40 | 2 | *G. varius* | 1 | 5 |
| *A. nigrofuscus* | 6 | 7 | *C. agilis* | 24 | 3 | *C. lunula* | 1 | 13 |
| *A. nigrofuscus* | 1 | 9 | *C. agilis* | 35 | 4 | *C. lunula* | 1 | 14 |
| *A. nigrofuscus* | 1 | 8 | *C. agilis* | 20 | 5 | *C. strigosus* | 7 | 8 |
| *A. nigrofuscus* | 2 | 5 | *C. agilis* | 20 | 6 | *C. strigosus* | 11 | 12 |
| *C. agilis* | 30 | 2 | *C. strigosus* | 6 | 8 | *C. strigosus* | 9 | 14 |
| *C. agilis* | 35 | 3 | *C. strigosus* | 10 | 12 | *C. strigosus* | 6 | 16 |
| *C. agilis* | 20 | 4 | *C. strigosus* | 3 | 7 | *C. jactator* | 2 | 7 |
| *C. strigosus* | 1 | 11 | *C. strigosus* | 6 | 10 | *C. jactator* | 2 | 5 |
| *C. strigosus* | 1 | 12 | *C. strigosus* | 3 | 9 | *C. vanderbiliti* | 48 | 2 |
| *C. strigosus* | 1 | 8 | *C. vanderbiliti* | 5 | 3 | *C. vanderbiliti* | 20 | 4 |
| *C. strigosus* | 4 | 5 | *C. vanderbiliti* | 4 | 4 | *T. duperrey* | 2 | 14 |
| *C. potteri* | 1 | 9 | *N. literatus* | 1 | 23 | *T. duperrey* | 3 | 8 |
| *C. potteri* | 1 | 11 | *N. literatus* | 1 | 19 | *T. duperrey* | 1 | 10 |
| *D. albisella* | 2 | 10 | *N. literatus* | 1 | 22 | *T. duperrey* | 2 | 6 |
| *D. albisella* | 2 | 11 | *N. literatus* | 1 | 27 | *T. duperrey* | 2 | 7 |
| *D. albisella* | 1 | 12 | *N. literatus* | 2 | 17 | *S. bursa* | 1 | 18 |
| *D. albisella* | 1 | 9 | *T. duperrey* | 2 | 6 | *P. arcatus* | 1 | 12 |
| *N. literatus* | 1 | 19 | *T. duperrey* | 2 | 5 | *Z. flavescens* | 2 | 14 |
| *N. literatus* | 1 | 17 | *T. duperrey* | 1 | 7 | *Z. flavescens* | 1 | 16 |
| *N. literatus* | 1 | 9 | *T. duperrey* | 1 | 13 | *Z. flavescens* | 1 | 17 |
| *N. literatus* | 1 | 12 | *Z. flavescens* | 3 | 14 | *Z. flavescens* | 10 | 10 |
| *N. literatus* | 1 | 16 | *Z. flavescens* | 1 | 15 | *Z. flavescens* | 10 | 15 |
| *C. gaimard* | 1 | 13 | *Z. flavescens* | 1 | 7 | *C. multicinctus* | 1 | 11 |
| *C. jactator* | 1 | 4 | *Z. flavescens* | 2 | 13 | *C. multicinctus* | 2 | 12 |
| *C. jactator* | 1 | 6 | *Z. flavescens* | 1 | 10 | *Z. cornutus* | 1 | 13 |
| *S. bursa* | 1 | 15 | *C. sordidus* | 1 | 26 | *S. fasciolatus* | 2 | 9 |
| *Z. flavescens* | 5 | 9 | *C. sordidus* | 1 | 22 | *S. fasciolatus* | 2 | 10 |
| *Z. flavescens* | 4 | 7 | *C. sordidus* | 3 | 14 | *C. carolinus* | 1 | 16 |
| *Z. flavescens* | 1 | 4 | *C. sordidus* | 1 | 17 | *N. literatus* | 2 | 20 |
| *C. sordidus* | 1 | 17 | *C. sordidus* | 2 | 18 | *N. literatus* | 1 | 30 |
| *C. sordidus* | 2 | 16 | *C. multicinctus* | 1 | 7 | *N. literatus* | 2 | 28 |
| *C. sordidus* | 1 | 9 | *C. multicinctus* | 1 | 10 | *M. vidua* | 1 | 19 |
| *H. thompsoni* | 1 | 14 | *C. multicinctus* | 2 | 9 | *Z. flavescens* | 4 | 12 |
| *P. arcatus* | 1 | 12 | *P. multifasciatus* | 1 | 10 | *C. hawaiiensis* | 1 | 16 |
| *P. arcatus* | 1 | 8 | *G. varius* | 1 | 16 | *C. dumerilii* | 1 | 21 |
| *T. duperrey* | 1 | 14 | *G. varius* | 1 | 12 | *C. dumerilii* | 1 | 24 |
| *T. duperrey* | 1 | 15 | *G. varius* | 1 | 13 | *C. quadrimaculat* | 1 | 14 |
| *T. duperrey* | 1 | 13 | *M. niger* | 1 | 24 | *P. johnstonianus* | 2 | 7 |
| *M. flavolineatus* | 1 | 22 | *C. jactator* | 1 | 6 | *C. sordidus* | 1 | 18 |
| *P. multifasciatus* | 2 | 17 | *C. jactator* | 2 | 5 | *C. sordidus* | 3 | 17 |
| *C. multicinctus* | 1 | 11 | *S. bursa* | 1 | 17 | *C. sordidus* | 1 | 15 |
| *F. flavissimus* | 1 | 11 | *P. arcatus* | 1 | 10 | *P. multifasciatus* | 1 | 14 |
| *F. flavissimus* | 1 | 14 | *P. insularis* | 1 | 21 | *F. flavissimus* | 4 | 12 |
| *M. berndti* | 1 | 14 | *Z. cornutus* | 1 | 11 | *F. flavissimus* | 1 | 14 |
| *P. octotania* | 1 | 11 | *Z. cornutus* | 1 | 14 | *F. flavissimus* | 1 | 11 |
| *P. evanidus* | 1 | 5 | *C. ornatissimus* | 1 | 15 | *A. triostegus* | 1 | 14 |
| *P. evanidus* | 1 | 2 | *C. hanui* | 3 | 4 | *C. carolinus* | 1 | 16 |
| *P. evanidus* | 3 | 7 | *C. argus* | 1 | 31 | *C. melampygus* | 1 | 32 |
| *C. ornatissimus* | 1 | 13 | *T. duperrey* | 1 | 8 | | | |
| | | | *T. duperrey* | 1 | 14 | | | |
| | | | *A. furca* | 1 | 29 | | | |
| | | | *Kyphosus spp.* | 61 | 20 | | | |
| | | | *Kyphosus spp.* | 61 | 24 | | | |
| | | | *H. ornatissimus* | 1 | 12 | | | |
| | | | *O. unifasciatus* | 1 | 12 | | | |
| | | | *A. chinensis* | 1 | 42 | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NPPE | 6/10/18 | | | | | | | | | |
| 50' | | | | 35' | | | | 15' | | |
| **Species** | **Individuals** | **Size (cm)** | | **Species** | **Individuals** | **Size (cm)** | | **Species** | **Individuals** | **Size (cm)** |
| *A. nigrofuscus* | 13 | 10 | | *A. nigrofuscus* | 16 | 12 | | *A. nigrofuscus* | 10 | 8 |
| *A. nigrofuscus* | 10 | 12 | | *A. nigrofuscus* | 5 | 10 | | *A. nigrofuscus* | 10 | 12 |
| *A. nigrofuscus* | 5 | 6 | | *A. nigrofuscus* | 5 | 8 | | *A. nigrofuscus* | 10 | 10 |
| *C. strigosus* | 8 | 12 | | *C. strigosus* | 10 | 12 | | *C. strigosus* | 6 | 10 |
| *C. strigosus* | 9 | 8 | | *C. strigosus* | 6 | 14 | | *C. strigosus* | 9 | 13 |
| *C. strigosus* | 5 | 10 | | *C. strigosus* | 4 | 13 | | *C. strigosus* | 4 | 12 |
| *A. scritus* | 1 | 45 | | *P. johnstonianus* | 1 | 6 | | *C. strigosus* | 4 | 14 |
| *A. scritus* | 1 | 55 | | *C. sordidus* | 1 | 32 | | *Z. flavescens* | 17 | 14 |
| *C. sordidus* | 63 | 15 | | *C. sordidus* | 1 | 15 | | *Z. flavescens* | 6 | 16 |
| *C. sordidus* | 63 | 18 | | *T. duperrey* | 1 | 16 | | *T. duperrey* | 1 | 17 |
| *C. sordidus* | 1 | 24 | | *T. duperrey* | 1 | 6 | | *T. duperrey* | 1 | 8 |
| *A. furca* | 1 | 36 | | *T. duperrey* | 1 | 12 | | *T. duperrey* | 1 | 15 |
| *A. furca* | 1 | 26 | | *T. duperrey* | 1 | 4 | | *T. duperrey* | 1 | 10 |
| *A. furca* | 1 | 28 | | *T. duperrey* | 1 | 13 | | *T. duperrey* | 2 | 7 |
| *G. varius* | 1 | 17 | | *T. duperrey* | 1 | 8 | | *C. vanderbilti* | 30 | 2 |
| *T. duperrey* | 1 | 7 | | *Z. flavescens* | 11 | 14 | | *C. vanderbilti* | 30 | 3 |
| *T. duperrey* | 3 | 11 | | *Z. flavescens* | 1 | 11 | | *N. literatus* | 1 | 28 |
| *Z. flavescens* | 2 | 13 | | *P. arcatus* | 1 | 10 | | *Z. cornutus* | 1 | 14 |
| *Z. flavescens* | 8 | 9 | | *S. bursa* | 1 | 18 | | *Z. flavescens* | 7 | 12 |
| *C. multicinctus* | 2 | 12 | | *C. jactator* | 2 | 6 | | *A. olicaceus* | 1 | 18 |
| *C. multicinctus* | 2 | 10 | | *C. jactator* | 1 | 4 | | *M. niger* | 1 | 22 |
| *C. multicinctus* | 1 | 6 | | *C. jactator* | 1 | 5 | | *N. literatus* | 1 | 28 |
| *P. multifasciatus* | 1 | 13 | | *N. literatus* | 1 | 18 | | *A. guttatus* | 2 | 14 |
| *N. literatus* | 1 | 18 | | *N. literatus* | 1 | 21 | | *C. ornatissimus* | 1 | 16 |
| *N. literatus* | 1 | 5 | | *N. literatus* | 5 | 20 | | *N. literatus* | 4 | 20 |
| *N. literatus* | 1 | 20 | | *N. literatus* | 4 | 24 | | *N. literatus* | 3 | 25 |
| *N. literatus* | 1 | 8 | | *P. multifasciatus* | 1 | 10 | | *N. literatus* | 1 | 17 |
| *P. arcatus* | 1 | 9 | | *P. multifasciatus* | 1 | 16 | | *N. literatus* | 1 | 30 |
| *S. bursa* | 1 | 14 | | *P. multifasciatus* | 1 | 17 | | *S. balteata* | 1 | 10 |
| *S. bursa* | 1 | 12 | | *P. multifasciatus* | 1 | 24 | | *G. varius* | 1 | 12 |
| *S. balteata* | 2 | 12 | | *M. niger* | 2 | 28 | | *C. jactator* | 2 | 6 |
| *S. balteata* | 1 | 9 | | *C. lunula* | 2 | 16 | | *C. jactator* | 1 | 5 |
| *C. ornatissimus* | 1 | 15 | | *A. furca* | 1 | 26 | | *C. jactator* | 1 | 4 |
| *F. flavissimus* | 2 | 12 | | *P. octotaenia* | 1 | 12 | | *A. nigricans* | 1 | 11 |
| *C. argus* | 1 | 20 | | *H. polylepis* | 2 | 14 | | *A. nigricans* | 1 | 14 |
| *P. johnstonianus* | 1 | 7 | | *A. abdominalis* | 26 | 15 | | *S. fasciolatus* | 2 | 10 |
| *F. commersonii* | 1 | 110 | | *C. vanderbilti* | 35 | 2 | | *S. fasciolatus* | 1 | 9 |
| *C. agilis* | 125 | 3 | | *C. vanderbilti* | 39 | 3 | | *C. carolinus* | 1 | 14 |
| *C. agilis* | 125 | 4 | | *C. vanderbilti* | 28 | 4 | | *M. grandoculis* | 1 | 38 |
| *C. agilis* | 50 | 5 | | *C. vanderbilti* | 5 | 5 | | *O. melagris* | 1 | 5 |
| *C. agilis* | 50 | 6 | | *G. varius* | 1 | 12 | | *F. commersonii* | 1 | 55 |
| *O. unifasciatus* | 1 | 26 | | *A. nigrofuscus* | 4 | 14 | | *A. achilles* | 1 | 11 |
| *L. phthirophagus* | 1 | 8 | | *M. vidua* | 1 | 21 | | *C. amboinensis* | 1 | 10 |
| *A. thompsoni* | 9 | 18 | | *A. olicaceus* | 1 | 25 | | *C. chanos* | 2 | 80 |
| | | | | *L. phthirophagus* | 1 | 7 | | | | |
| | | | | *P. insularis* | 1 | 21 | | | | |
| | | | | *M. favolineatus* | 7 | 23 | | | | |
| | | | | *M. kuntee* | 1 | 17 | | | | |
| | | | | *P. forestri* | 1 | 18 | | | | |

| 12 Pipe North | 6/10/18 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 50' | | | | 35' | | | | 15' | | |
| **Species** | **Individuals** | **Size (cm)** | | **Species** | **Individuals** | **Size (cm)** | | **Species** | **Individuals** | **Size (cm)** |
| A. nigrofuscus | 4 | 8 | | Z. flavescens | 2 | 15 | | Z. flavescens | 15 | 12 |
| A. nigrofuscus | 11 | 10 | | Z. flavescens | 11 | 13 | | Z. flavescens | 10 | 17 |
| A. nigrofuscus | 5 | 12 | | Z. flavescens | 5 | 10 | | Z. flavescens | 4 | 10 |
| A. nigrofuscus | 6 | 7 | | Z. flavescens | 17 | 16 | | Z. flavescens | 14 | 14 |
| C. strigosus | 4 | 5 | | Z. flavescens | 2 | 17 | | C. strigosus | 14 | 13 |
| C. strigosus | 10 | 10 | | N. literatus | 1 | 21 | | C. strigosus | 10 | 16 |
| C. strigosus | 6 | 12 | | P. | 1 | 16 | | C. strigosus | 6 | 12 |
| T. duperrey | 1 | 14 | | C. jactator | 1 | 6 | | C. strigosus | 10 | 14 |
| T. duperrey | 2 | 9 | | C. strigosus | 15 | 10 | | A. nigrofuscus | 6 | 10 |
| T. duperrey | 1 | 10 | | C. strigosus | 6 | 16 | | A. nigrofuscus | 6 | 14 |
| Z. flavescens | 2 | 8 | | C. strigosus | 8 | 14 | | A. nigrofuscus | 7 | 12 |
| Z. flavescens | 7 | 10 | | A. nigrofuscus | 10 | 8 | | P. insularis | 1 | 17 |
| Z. flavescens | 7 | 14 | | A. nigrofuscus | 7 | 14 | | C. vanderbilti | 24 | 2 |
| Z. flavescens | 1 | 13 | | A. nigrofuscus | 6 | 10 | | C. vanderbilti | 50 | 3 |
| P. johnstonianu | 1 | 7 | | S. bursa | 1 | 15 | | N. literatus | 2 | 21 |
| C. multicinctus | 1 | 11 | | S. bursa | 1 | 18 | | N. literatus | 1 | 26 |
| C. multicinctus | 2 | 12 | | C. multicinctus | 2 | 9 | | N. nigricans | 1 | 11 |
| G. varius | 1 | 10 | | C. multicinctus | 1 | 10 | | N. nigricans | 2 | 10 |
| G. varius | 1 | 11 | | C. multicinctus | 1 | 11 | | N. nigricans | 1 | 15 |
| P. arcatus | 1 | 10 | | A. furca | 1 | 28 | | C. multicinctus | 2 | 12 |
| C. jactator | 2 | 4 | | C. gaimard | 1 | 16 | | C. sordidus | 1 | 30 |
| C. jactator | 1 | 6 | | C. sordidus | 1 | 28 | | C. sordidus | 1 | 18 |
| C. agilis | 6 | 5 | | C. sordidus | 14 | 14 | | Z. cornutus | 2 | 14 |
| C. agilis | 1 | 6 | | C. sordidus | 3 | 18 | | Z. cornutus | 2 | 10 |
| C. agilis | 4 | 4 | | C. sordidus | 2 | 19 | | T. duperrey | 2 | 10 |
| P. forestri | 1 | 19 | | T. duperrey | 1 | 10 | | T. duperrey | 2 | 15 |
| H. ornatissimus | 2 | 12 | | T. duperrey | 1 | 12 | | T. duperrey | 1 | 16 |
| H. ornatissimus | 1 | 4 | | C. agilis | 15 | 3 | | C. ornatissimus | 1 | 14 |
| H. ornatissimus | 2 | 7 | | C. lunula | 1 | 16 | | C. ornatissimus | 1 | 16 |
| P. multifasciatu | 1 | 16 | | S. balteata | 1 | 12 | | H. ornatissimus | 1 | 6 |
| C. vanderbilti | 32 | 2 | | H. ornatissimus | 1 | 5 | | S. bursa | 1 | 14 |
| C. vanderbilti | 20 | 4 | | H. ornatissimus | 1 | 12 | | H. polylepis | 30 | 12 |
| C. vanderbilti | 20 | 3 | | C. vanderbilti | 67 | 2 | | H. polylepis | 30 | 16 |
| A. olivaceus | 1 | 17 | | C. vanderbilti | 50 | 3 | | A. chinensis | 1 | 40 |
| N. literatus | 1 | 19 | | C. vanderbilti | 35 | 4 | | C. quadrimaculatu | 1 | 10 |
| N. literatus | 1 | 23 | | M. niger | 4 | 26 | | C. lunula | 30 | 12 |
| N. literatus | 1 | 20 | | V. vidua | 1 | 22 | | C. lunula | 33 | 15 |
| M. vidua | 1 | 22 | | F. flavissimus | 1 | 17 | | C. jactator | 1 | 5 |
| P. insularis | 1 | 21 | | C. agilis | 6 | 4 | | F. flavissimus | 1 | 13 |
| P. aspricaudus | 1 | 7 | | C. agilis | 6 | 5 | | O. unifasciatus | 1 | 21 |
| C. gaimard | 1 | 17 | | N. literatus | 2 | 28 | | S. psittacus | 1 | 32 |
| P. octotaenia | 1 | 9 | | N. literatus | 1 | 34 | | S. fasciolatus | 1 | 9 |
| A. achilles | 1 | 10 | | C. ornatissimus | 1 | 10 | | S. fasciolatus | 1 | 10 |
| A. achilles | 1 | 8 | | C. ornatissimus | 1 | 12 | | M. vanicolensis | 1 | 18 |
| S. bursa | 1 | 19 | | H. polylepis | 18 | 14 | | M. grandoculis | 1 | 28 |
| S. bursa | 1 | 23 | | H. polylepis | 18 | 15 | | M. grandoculis | 1 | 32 |
| C. sordidus | 1 | 34 | | C. argus | 1 | 40 | | M. grandoculis | 1 | 40 |
| C. sordidus | 11 | 24 | | Z. cornutus | 1 | 16 | | M. vidua | 1 | 22 |
| C. sordidus | 16 | 15 | | H. thompsoni | 6 | 15 | | M. vidua | 1 | 25 |
| C. sordidus | 8 | 30 | | N. hexacanthus | 4 | 18 | | M. vidua | 1 | 20 |
| S. psittacus | 1 | 26 | | A. chinensis | 1 | 35 | | H. thompsoni | 4 | 16 |
| A. chinensis | 1 | 40 | | A. chinensis | 1 | 50 | | C. reticulatus | 1 | 12 |
| C. ornatissimus | 1 | 14 | | G. varius | 1 | 11 | | A. guttatus | 1 | 17 |
| C. quadrimacula | 1 | 12 | | G. varius | 1 | 7 | | | | |
| C. potteri | 1 | 9 | | A. olivaceus | 1 | 20 | | | | |
| H. polylepis | 1 | 14 | | A. olivaceus | 1 | 24 | | | | |
| C. hanui | 1 | 5 | | N. unicornis | 1 | 45 | | | | |
| S. spiniferum | 1 | 19 | | A. xanthopterus | 1 | 36 | | | | |
| | | | | F. logirostris | 2 | 17 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 Pipe South | 6/9/18 | | | | | | | |
| 50' | | | 35' | | | 15' | | |
| **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** |
| A. nigrofuscus | 9 | 10 | A. nigrofuscus | 5 | 8 | A. nigrofuscus | 13 | 10 |
| A. nigrofuscus | 7 | 8 | A. nigrofuscus | 6 | 10 | A. nigrofuscus | 8 | 14 |
| A. nigrofuscus | 4 | 12 | P. arcatus | 1 | 5 | P. imparipennis | 1 | 4 |
| C. agilis | 40 | 3 | A. scriptus | 1 | 45 | N. literatus | 1 | 32 |
| C. agilis | 50 | 6 | N. literatus | 1 | 28 | N. literatus | 1 | 25 |
| C. agilis | 30 | 4 | N. literatus | 1 | 18 | N. literatus | 1 | 23 |
| C. agilis | 60 | 5 | C. vanderbilti | 50 | 2 | P. insularis | 1 | 13 |
| C. strigosus | 6 | 8 | C. vanderbilti | 55 | 3 | C. multicinctus | 2 | 11 |
| C. strigosus | 6 | 14 | T. duperrey | 3 | 12 | C. multicinctus | 1 | 13 |
| C. strigosus | 18 | 12 | T. duperrey | 1 | 14 | C. strigosus | 3 | 12 |
| C. vanderbilti | 10 | 2 | C. sordidus | 1 | 30 | C. strigosus | 9 | 14 |
| C. vanderbilti | 25 | 3 | C. sordidus | 1 | 24 | C. vanderbilti | 41 | 2 |
| C. vanderbilti | 10 | 4 | C. sordidus | 1 | 7 | C. vanderbilti | 26 | 3 |
| N. literatus | 1 | 30 | H. polylepis | 18 | 12 | C. vanderbilti | 12 | 4 |
| N. literatus | 1 | 34 | H. polylepis | 15 | 14 | Z. flavescens | 7 | 14 |
| N. literatus | 1 | 27 | H. ornatissimus | 1 | 9 | Z. flavescens | 6 | 16 |
| N. literatus | 1 | 20 | F. flavissimus | 1 | 14 | A. olivaceus | 1 | 23 |
| T. duperrey | 1 | 13 | F. flavissimus | 2 | 9 | A. olivaceus | 1 | 18 |
| T. duperrey | 2 | 12 | Z. flavescens | 8 | 14 | A. abdominalis | 1 | 16 |
| T. duperrey | 2 | 11 | Z. flavescens | 7 | 12 | A. abdominalis | 1 | 13 |
| T. duperrey | 1 | 9 | Z. flavescens | 7 | 6 | S. bursa | 1 | 20 |
| S. bursa | 1 | 15 | S. bursa | 1 | 21 | T. duperrey | 2 | 14 |
| S. bursa | 2 | 18 | S. bursa | 1 | 19 | T. duperrey | 1 | 13 |
| C. sordidus | 3 | 16 | C. hawaiiensis | 1 | 20 | T. duperrey | 1 | 12 |
| C. sordidus | 1 | 31 | S. psittacus | 1 | 28 | T. duperrey | 2 | 4 |
| C. sordidus | 1 | 20 | N. hexacanthus | 1 | 45 | T. duperrey | 1 | 5 |
| C. sordidus | 1 | 11 | N. hexacanthus | 1 | 50 | T. duperrey | 1 | 8 |
| H. ornatissimus | 1 | 12 | N. hexacanthus | 4 | 28 | C. | 1 | 13 |
| H. ornatissimus | 1 | 8 | N. brevirostris | 1 | 24 | C. | 2 | 12 |
| G. varius | 1 | 13 | N. brevirostris | 1 | 30 | C. jactator | 1 | 4 |
| G. varius | 2 | 9 | G. varius | 1 | 9 | C. jactator | 1 | 5 |
| G. varius | 1 | 10 | G. varius | 1 | 7 | G. varius | 1 | 14 |
| G. varius | 1 | 12 | A. thompsoni | 5 | 18 | P. aspricaudus | 1 | 10 |
| P. arcatus | 1 | 6 | A. thompsoni | 5 | 20 | P. aspricaudus | 1 | 15 |
| P. arcatus | 1 | 9 | P. multifasciatus | 1 | 22 | C. lunula | 1 | 17 |
| Z. cornutus | 1 | 14 | P. multifasciatus | 1 | 12 | C. hawaiiensis | 1 | 20 |
| A. furca | 1 | 30 | H. thompsoni | 14 | 14 | C. gaimard | 1 | 15 |
| A. furca | 1 | 36 | H. thompsoni | 14 | 18 | C. gaimard | 1 | 13 |
| C. potteri | 1 | 9 | C. ornatissimus | 2 | 16 | C. gaimard | 1 | 18 |
| C. potteri | 1 | 7 | C. ornatissimus | 2 | 14 | C. gaimard | 1 | 16 |
| C. ornatissimus | 1 | 11 | C. hawaiiensis | 1 | 22 | P. octotaenia | 1 | 6 |
| C. | 1 | 6 | S. balteata | 1 | 12 | C. sordidus | 4 | 14 |
| P. multifasciatus | 1 | 12 | A. meleagris | 1 | 28 | C. sordidus | 5 | 16 |
| C. gaimard | 1 | 16 | C. jactator | 1 | 6 | F. flavissimus | 2 | 14 |
| C. gaimard | 1 | 21 | O. unifasciatus | 1 | 30 | | | |
| C. argus | 1 | 26 | S. balteata | 1 | 10 | | | |
| C. argus | 1 | 20 | P. octotaenia | 1 | 8 | | | |
| Z. flavescens | 4 | 7 | A. abdominalis | 16 | 12 | | | |
| Z. flavescens | 6 | 12 | A. abdominalis | 16 | 14 | | | |
| Z. flavescens | 1 | 8 | A. virescens | 1 | 55 | | | |
| Z. flavescens | 8 | 10 | D. macarellus | 100 | 24 | | | |
| Z. flavescens | 6 | 16 | D. macarellus | 100 | 27 | | | |
| O. unifasciatus | 1 | 34 | D. macarellus | 100 | 30 | | | |
| A. olivaceus | 1 | 26 | | | | | | |
| L. phthirophagus | 1 | 9 | | | | | | |
| L. phthirophagus | 1 | 6 | | | | | | |
| N. hexacanthus | 8 | 30 | | | | | | |
| N. hexacanthus | 4 | 23 | | | | | | |
| N. hexacanthus | 15 | 28 | | | | | | |
| N. hexacanthus | 15 | 24 | | | | | | |
| N. hexacanthus | 9 | 34 | | | | | | |
| C. multicinctus | 3 | 10 | | | | | | |
| F. flavissimus | 1 | 9 | | | | | | |
| A. achilles | 1 | 8 | | | | | | |
| C. jactator | 1 | 6 | | | | | | |
| C. jactator | 1 | 4 | | | | | | |
| P. forsteri | 1 | 18 | | | | | | |
| C. lunula | 1 | 16 | | | | | | |
| P. octotaenia | 1 | 9 | | | | | | |
| Z. veliferum | 1 | 8 | | | | | | |
| P. insularis | 1 | 21 | | | | | | |
| P. aspricaudus | 1 | 6 | | | | | | |
| P. aspricaudus | 1 | 8 | | | | | | |

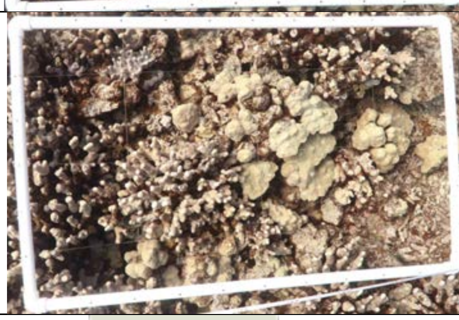
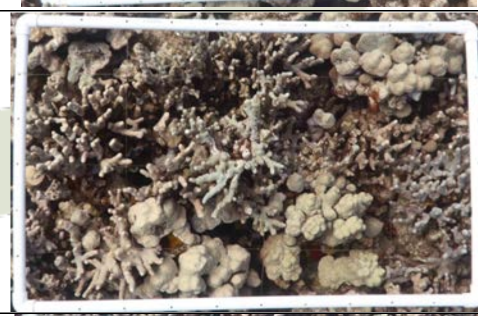
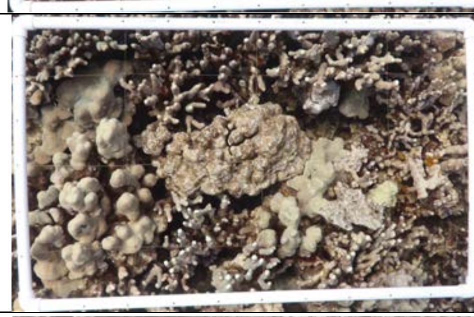
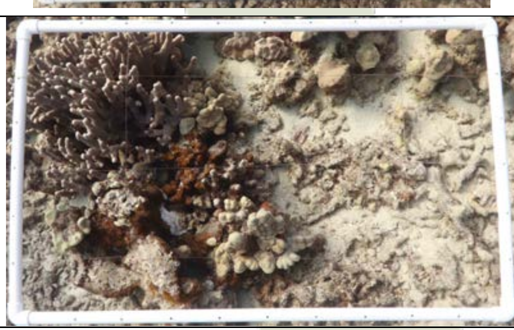
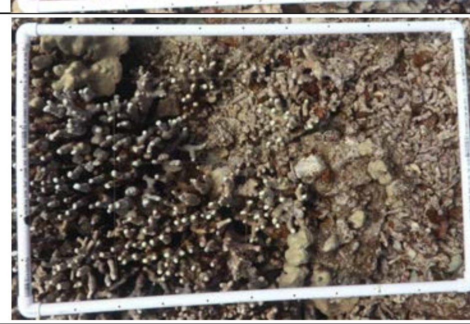
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 18 | 6/9/18 | | | | | | | |
| 50' | | | 35' | | | 15' | | |
| **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** | **Species** | **Individuals** | **Size (cm)** |
| *T. duperrey* | 3 | 7 | *M. grandoculis* | 2 | 36 | *A. nigrofuscus* | 5 | 10 |
| *T. duperrey* | 1 | 8 | *M. grandoculis* | 1 | 30 | *A. nigrofuscus* | 12 | 14 |
| *T. duperrey* | 1 | 10 | *M. grandoculis* | 1 | 27 | *A. nigrofuscus* | 11 | 12 |
| *T. duperrey* | 2 | 14 | *M. grandoculis* | 1 | 28 | *A. nigrofuscus* | 8 | 16 |
| *C. potteri* | 1 | 5 | *M. grandoculis* | 1 | 22 | *C. strigosus* | 5 | 8 |
| *C. gaimard* | 1 | 8 | *M. grandoculis* | 2 | 25 | *C. strigosus* | 5 | 10 |
| *C. gaimard* | 1 | 5 | *M. grandoculis* | 1 | 44 | *C. strigosus* | 11 | 14 |
| *C. agilis* | 15 | 3 | *N. unicornis* | 1 | 30 | *C. strigosus* | 4 | 3 |
| *C. agilis* | 20 | 4 | *N. unicornis* | 1 | 39 | *C. strigosus* | 5 | 16 |
| *C. agilis* | 20 | 5 | *N. unicornis* | 1 | 33 | *N. literatus* | 2 | 23 |
| *C. agilis* | 10 | 6 | *N. literatus* | 2 | 20 | *N. literatus* | 3 | 20 |
| *A. nigrofuscus* | 10 | 8 | *N. literatus* | 3 | 28 | *N. literatus* | 1 | 24 |
| *A. nigrofuscus* | 5 | 7 | *N. literatus* | 1 | 30 | *N. literatus* | 1 | 28 |
| *A. nigrofuscus* | 4 | 6 | *N. literatus* | 2 | 22 | *N. literatus* | 1 | 30 |
| *P. ewaensis* | 1 | 6 | *N. literatus* | 3 | 24 | *C. hawaiiensis* | 3 | 21 |
| *C. vanderbiliti* | 20 | 2 | *C. agilis* | 9 | 4 | *C. hawaiiensis* | 5 | 22 |
| *C. vanderbiliti* | 64 | 3 | *A. furca* | 1 | 28 | *T. duperrey* | 1 | 11 |
| *C. vanderbiliti* | 50 | 4 | *H. thompsoni* | 4 | 17 | *T. duperrey* | 2 | 14 |
| *C. strigosus* | 12 | 6 | *N. hexacanthus* | 2 | 32 | *T. duperrey* | 3 | 12 |
| *C. strigosus* | 17 | 8 | *C. vanderbiliti* | 34 | 3 | *C. multicinctus* | 2 | 10 |
| *C. jactator* | 1 | 6 | *C. vanderbiliti* | 2 | 33 | *C. multicinctus* | 1 | 12 |
| *C. hanui* | 4 | 3 | *T. duperrey* | 1 | 12 | *C. multicinctus* | 1 | 11 |
| *C. hanui* | 3 | 5 | *T. duperrey* | 1 | 16 | *P. multifasciatus* | 1 | 14 |
| *C. hanui* | 4 | 5 | *T. duperrey* | 1 | 5 | *P. forsteri* | 1 | 17 |
| *L. phthirophagus* | 1 | 6 | *T. duperrey* | 1 | 14 | *G. varius* | 1 | 13 |
| *L. phthirophagus* | 1 | 11 | *T. duperrey* | 1 | 8 | *H. ornatissimus* | 1 | 14 |
| *P. octotaenia* | 1 | 7 | *T. duperrey* | 1 | 9 | *C. melampygus* | 1 | 43 |
| *P. octotaenia* | 1 | 8 | *G. varius* | 1 | 7 | *C. melampygus* | 2 | 40 |
| *P. octotaenia* | 2 | 9 | *H. ornatissimus* | 2 | 9 | *C. melampygus* | 1 | 35 |
| *P. octotaenia* | 1 | 11 | *C. strigosus* | 1 | 7 | *S. fasciolatus* | 2 | 9 |
| *C. multicinctus* | 2 | 4 | *A. nigrofuscus* | 4 | 11 | *C. lunula* | 1 | 14 |
| *C. multicinctus* | 2 | 8 | *A. nigrofuscus* | 3 | 14 | *C. lunula* | 3 | 16 |
| *S. bursa* | 1 | 14 | *A. nigrofuscus* | 6 | 10 | *C. ornatissimus* | 1 | 13 |
| *F. flavissimus* | 1 | 14 | *A. nigrofuscus* | 5 | 12 | *C. vanderbiliti* | 28 | 3 |
| *A. olivaceus* | 1 | 32 | *C. multicinctus* | 2 | 8 | *C. vanderbiliti* | 20 | 2 |
| *Z. flavescens* | 9 | 7 | *Z. flavescens* | 7 | 13 | *C. vanderbiliti* | 15 | 4 |
| *Z. flavescens* | 1 | 13 | *Z. flavescens* | 6 | 17 | *C. sordidus* | 1 | 20 |
| *Z. flavescens* | 2 | 12 | *C. multicinctus* | 3 | 7 | *M. kuntee* | 1 | 14 |
| *P. arcatus* | 1 | 9 | *P. multifasciatus* | 2 | 12 | *S. rubroviolaceus* | 1 | 48 |
| *P. mulloidichthys* | 2 | 7 | *P. multifasciatus* | 1 | 14 | *L. phthirophagus* | 1 | 11 |
| *P. mulloidichthys* | 1 | 12 | *L. phthirophagus* | 1 | 7 | *S. bursa* | 1 | 17 |
| *P. mulloidichthys* | 2 | 14 | *C. argus* | 1 | 22 | *M. vanicolensis* | 7 | 19 |
| *P. mulloidichthys* | 1 | 17 | *C. argus* | 1 | 40 | *Z. flavescens* | 7 | 11 |
| *N. literatus* | 1 | 18 | *A. olivaceus* | 1 | 24 | *Z. flavescens* | 7 | 15 |
| *N. literatus* | 1 | 26 | *A. olivaceus* | 1 | 28 | *Kyphosus spp.* | 4 | 20 |
| *N. literatus* | 1 | 17 | *A. olivaceus* | 1 | 16 | *Kyphosus spp.* | 4 | 22 |
| *N. literatus* | 4 | 23 | *A. olivaceus* | 1 | 20 | *Kyphosus spp.* | 1 | 28 |
| *N. literatus* | 3 | 28 | *C. quadrimaculatu* | 2 | 12 | *Kyphosus spp.* | 5 | 24 |
| *N. literatus* | 1 | 32 | *C. melampygus* | 1 | 62 | *A. furca* | 1 | 28 |
| *G. varius* | 1 | 9 | *C. melampygus* | 1 | 40 | *A. furca* | 1 | 22 |
| *H. ornatissimus* | 1 | 14 | *C. melampygus* | 1 | 48 | *L. kasmira* | 1 | 19 |
| *H. ornatissimus* | 1 | 7 | *Z. flavescens* | 1 | 10 | *M. niger* | 1 | 23 |
| *H. ornatissimus* | 1 | 8 | *Z. flavescens* | 1 | 13 | *A. chinensis* | 1 | 28 |
| *Z. cornutus* | 1 | 13 | *Z. flavescens* | 1 | 14 | *A. chinensis* | 1 | 35 |
| *P. kallopterus* | 1 | 11 | *C. sordidus* | 1 | 9 | *A. nigricans* | 1 | 11 |
| *D. hystrix* | 1 | 38 | *M. vidua* | 1 | 23 | *A. abdominalis* | 3 | 13 |
| *A. xanthopterus* | 1 | 33 | *C. jactator* | 1 | 5 | | | |
| *O. unifasciatus* | 1 | 35 | *C. jactator* | 1 | 7 | | | |
| *O. unifasciatus* | 1 | 8 | *S. rubroviolaceus* | 1 | 27 | | | |
| *C. argus* | 1 | 26 | *S. rubroviolaceus* | 1 | 35 | | | |
| *C. carolinus* | 1 | 11 | *Z. cornutus* | 1 | 11 | | | |
| *C. carolinus* | 1 | 8 | *P. octotaenia* | 1 | 9 | | | |
| *C. carolinus* | 2 | 9 | *P. forsteri* | 1 | 13 | | | |
| *C. sordidus* | 10 | 18 | *B. albotaeniatus* | 1 | 28 | | | |
| *C. sordidus* | 1 | 17 | | | | | | |
| *C. sordidus* | 7 | 10 | | | | | | |
| *A. furca* | 1 | 27 | | | | | | |
| *A. furca* | 1 | 29 | | | | | | |
| *N. hexacanthus* | 6 | 29 | | | | | | |

| Wawa | 6/9/18 | |
|---|---|---|
| 50' | | |
| **Species** | **Individuals** | **Size (cm)** |
| *A. xanthopterus* | 1 | 35 |
| *N. brevirostris* | 1 | 38 |
| *N. literatus* | 1 | 22 |
| *A. olivaceus* | 1 | 28 |
| *A. olivaceus* | 1 | 30 |
| *C. vanderbiliti* | 3 | 2 |
| *S. bursa* | 1 | 17 |
| *P. evanidus* | 1 | 5 |
| *P. evanidus* | 1 | 6 |
| *C. ornatissimus* | 1 | 14 |
| *C. quadrimaculatus* | 1 | 12 |
| *Z. flavescens* | 3 | 12 |
| *Z. flavescens* | 3 | 14 |
| *A. nigrofuscus* | 1 | 5 |
| *A. nigrofuscus* | 1 | 6 |
| *C. melampygus* | 1 | 24 |

| 35' | | |
|---|---|---|
| **Species** | **Individuals** | **Size (cm)** |
| *C. vanderbiliti* | 70 | 2 |
| *C. vanderbiliti* | 107 | 3 |
| *C. vanderbiliti* | 20 | 40 |
| *Z. flavescens* | 5 | 14 |
| *Z. flavescens* | 6 | 16 |
| *Z. flavescens* | 4 | 15 |
| *A. nigrofuscus* | 5 | 8 |
| *A. nigrofuscus* | 5 | 7 |
| *A. nigrofuscus* | 1 | 14 |
| *A. nigrofuscus* | 2 | 12 |
| *T. duperrey* | 2 | 7 |
| *T. duperrey* | 1 | 9 |
| *C. argus* | 1 | 25 |
| *A. olivaceus* | 1 | 25 |
| *A. olivaceus* | 2 | 17 |
| *A. olivaceus* | 1 | 28 |
| *A. olivaceus* | 3 | 18 |
| *N. literatus* | 1 | 25 |
| *N. literatus* | 1 | 21 |
| *S. brursa* | 1 | 21 |
| *H. ornatissimus* | 2 | 5 |
| *H. ornatissimus* | 1 | 7 |
| *H. ornatissimus* | 1 | 9 |
| *H. ornatissimus* | 1 | 11 |
| *C. jactator* | *1* | 6 |
| *C. jactator* | 1 | 7 |
| *A. nigroris* | 1 | 16 |
| *A. nigroris* | 1 | 14 |
| *C. lunula* | 2 | 14 |
| *P. octotaenia* | 1 | 8 |
| *P. octotaenia* | 1 | 7 |
| *C. gaimard* | 1 | 8 |
| *C. agilis* | 5 | 4 |
| *P. mulloidichthys* | 1 | 11 |
| *P. mulloidichthys* | 1 | 24 |
| *P. imparipennis* | 2 | 4 |
| *P. imparipennis* | 1 | 6 |

| 15' | | |
|---|---|---|
| **Species** | **Individuals** | **Size (cm)** |
| *A. nigrofuscus* | 9 | 10 |
| *A. nigrofuscus* | 18 | 12 |
| *A. nigrofuscus* | 6 | 8 |
| *A. nigrofuscus* | 5 | 14 |
| *T. duperrey* | 1 | 7 |
| *Z. flavescens* | 4 | 15 |
| *Z. flavescens* | 3 | 13 |
| *N. literatus* | 1 | 17 |
| *S. bursa* | 1 | 16 |
| *A. nigrofuscus* | 4 | 13 |
| *C. vanderbiliti* | 5 | 2 |
| *C. vanderbiliti* | 6 | 3 |
| *R. rectangulus* | 1 | 19 |
| *A. nigroris* | 1 | 15 |
| *A. olivaceus* | 1 | 26 |
| *C. gaimard* | 1 | 18 |
| *C. gaimard* | 1 | 14 |
| *C. jactator* | 1 | 6 |
| *C. quadrimaculatus* | 1 | 12 |

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

| Site: Hoona | Depth: 50fsw |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

| Site: Hoona | Depth: 30fsw |
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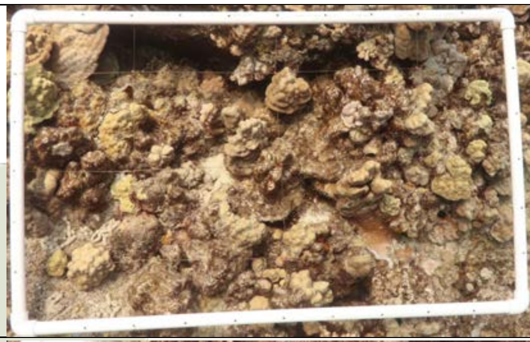
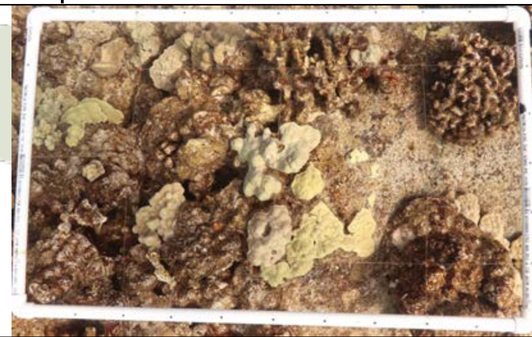
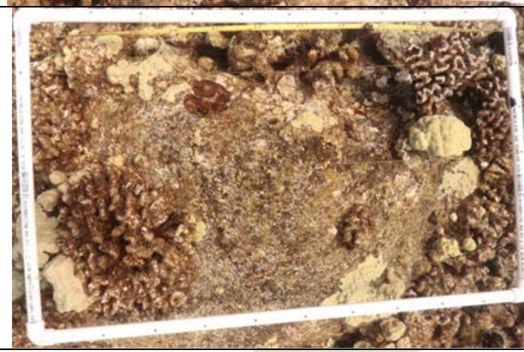
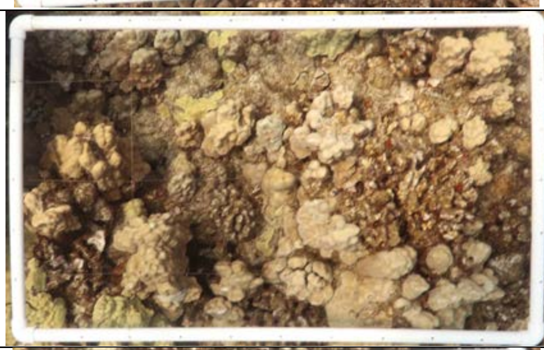
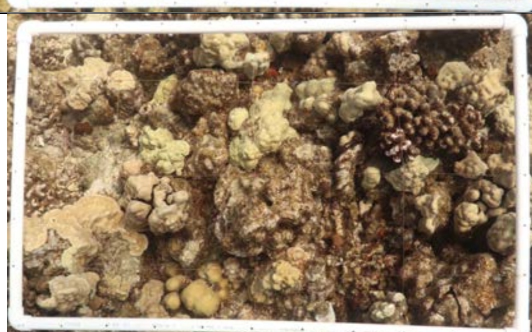
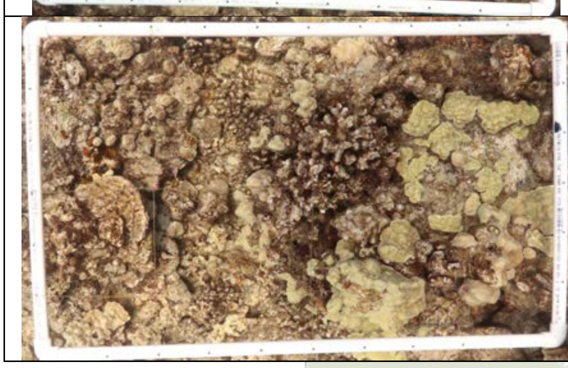
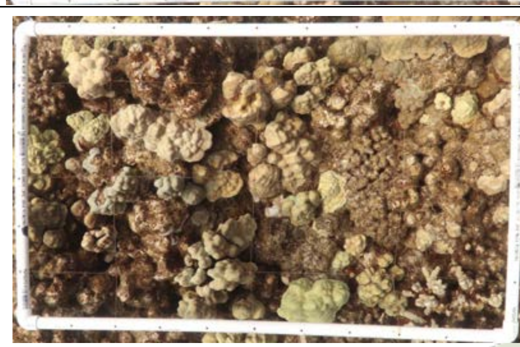
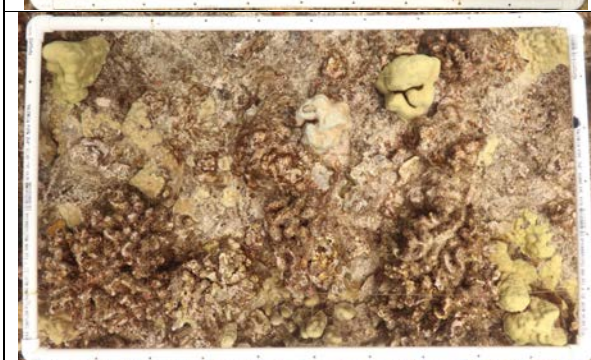
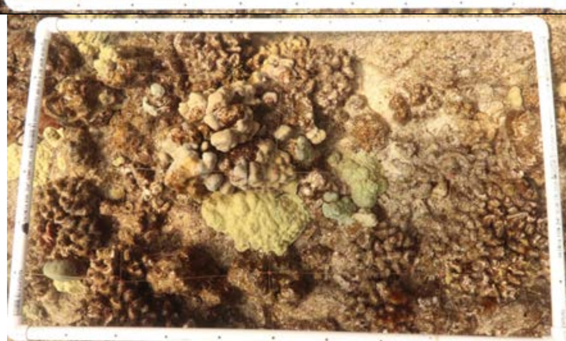
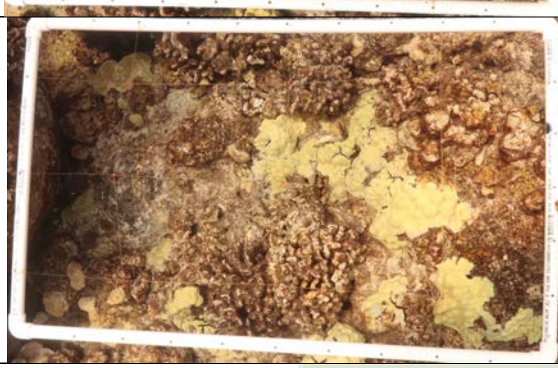
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

| Site: Hoona | Depth: 15fsw |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

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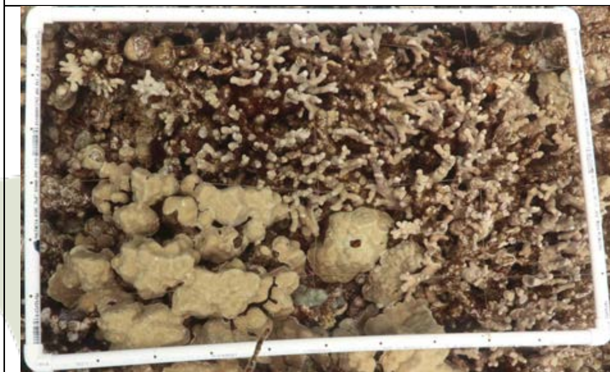
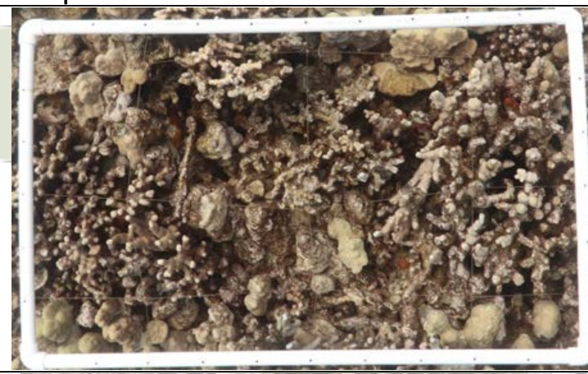
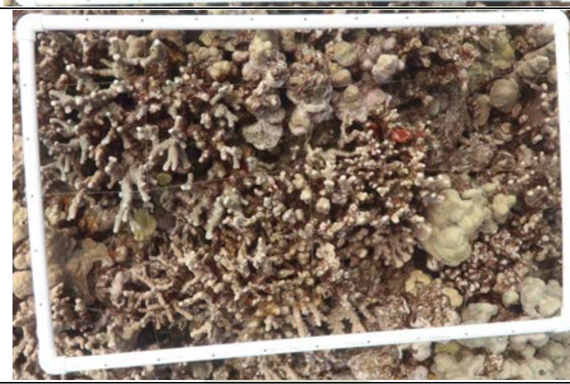
|  |  |
|  |  |
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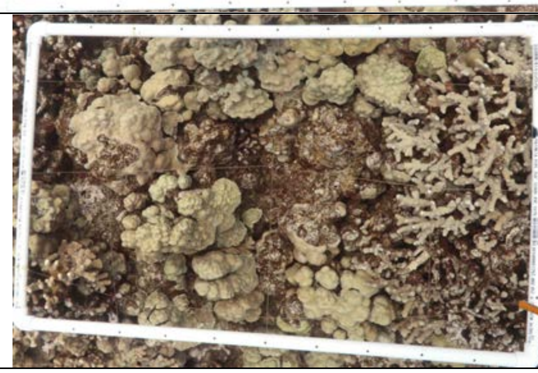
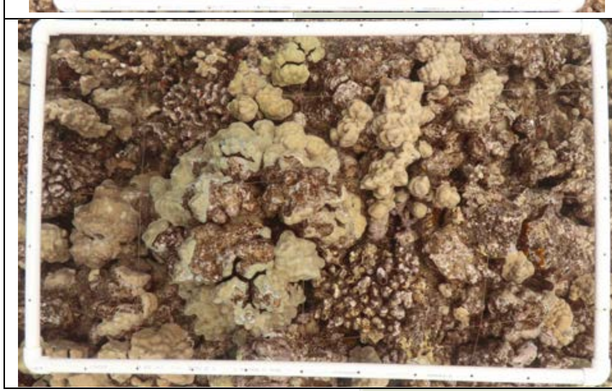
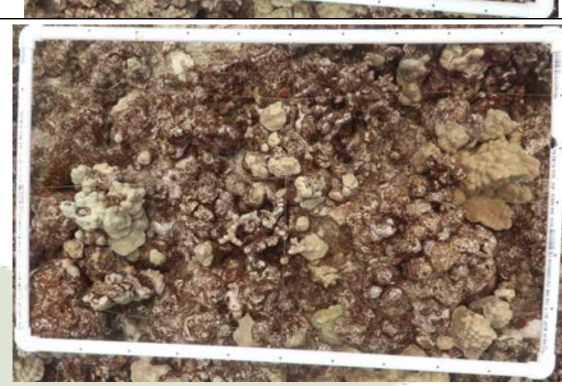
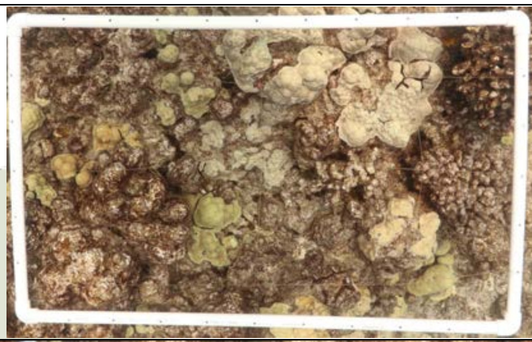
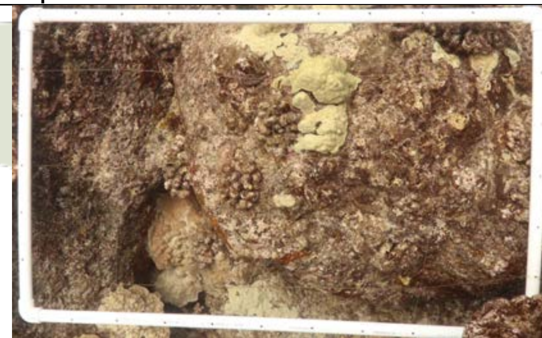
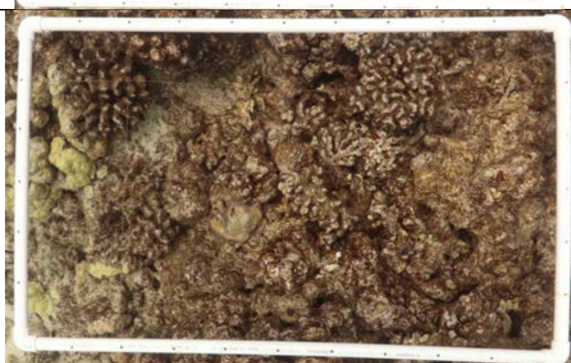
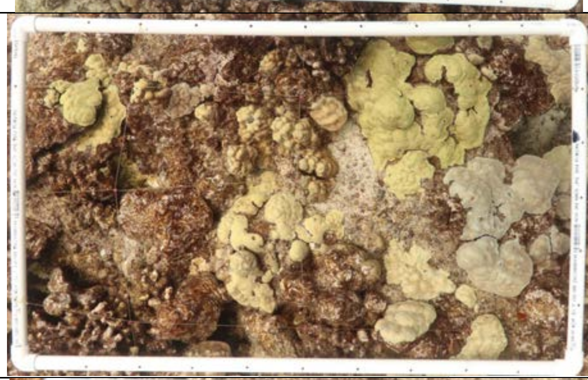
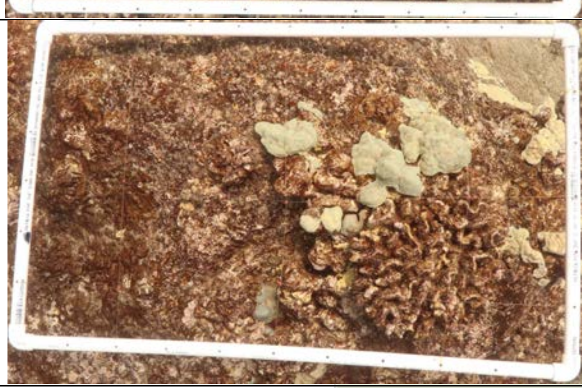
|  |  |
|  |  |

Site: NPPE Depth: 30fsw






| Site: NPPE | Depth: 15fsw |
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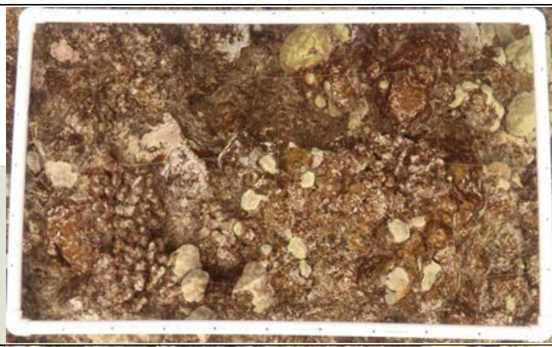
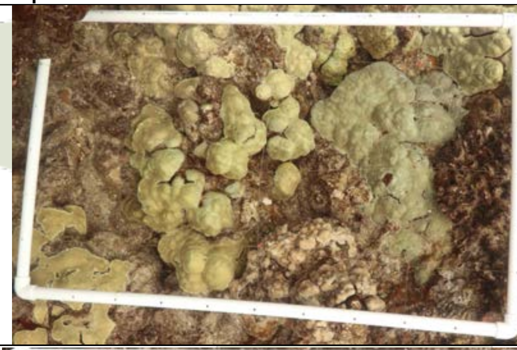
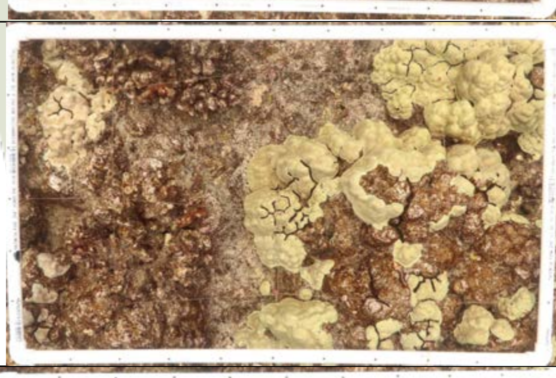
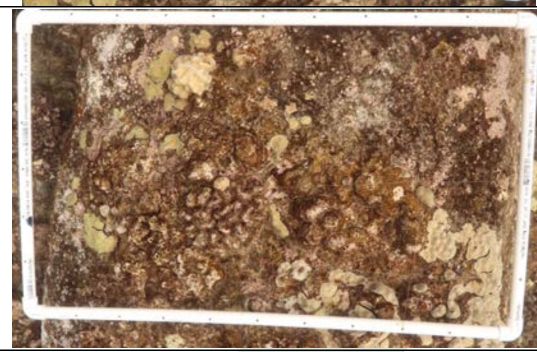
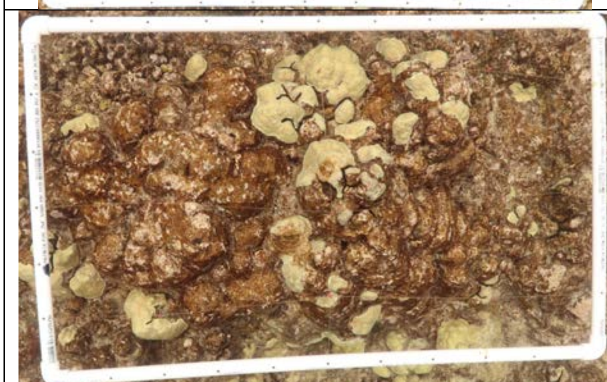
|  |  |
|  |  |
|  |  |
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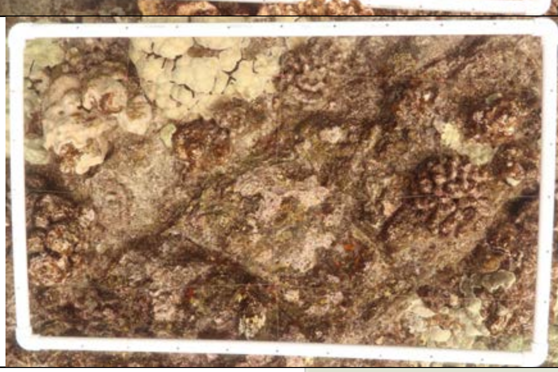
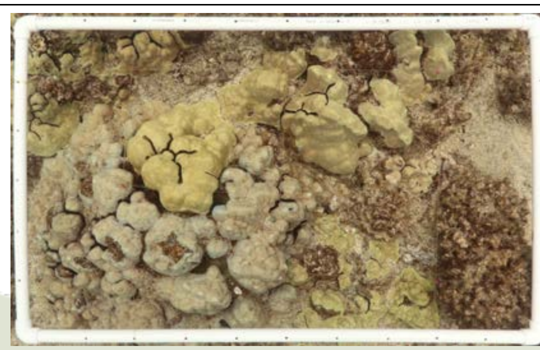
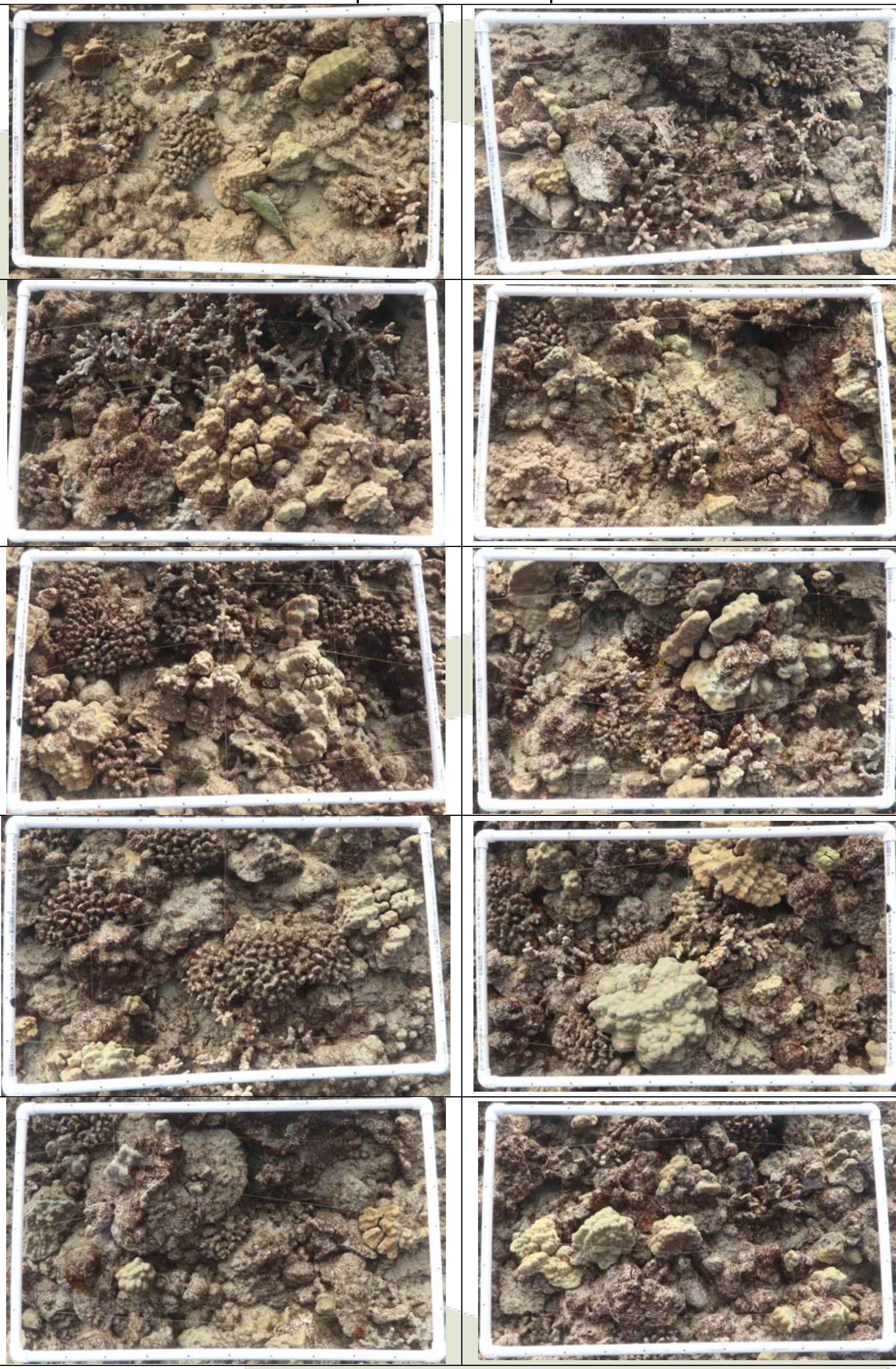
|  |  |

Site: 12 Pipe North Depth: 50fsw



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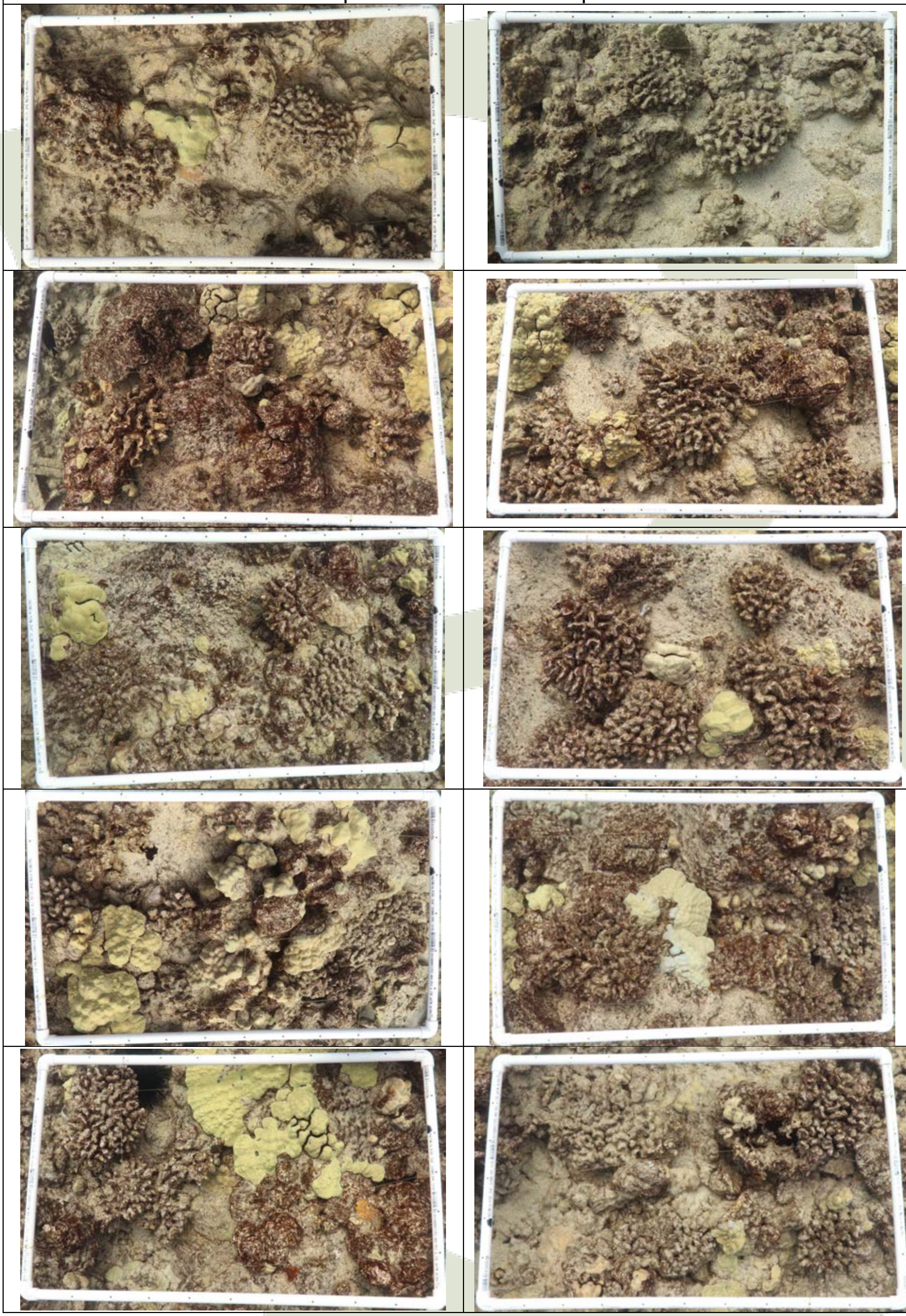

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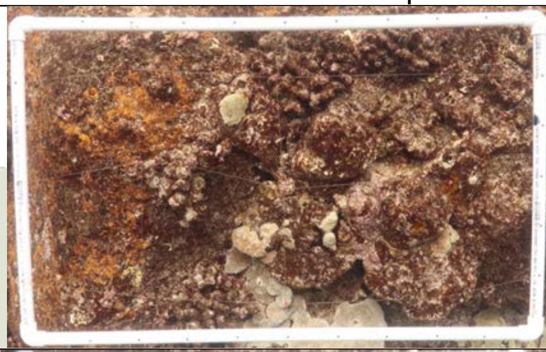
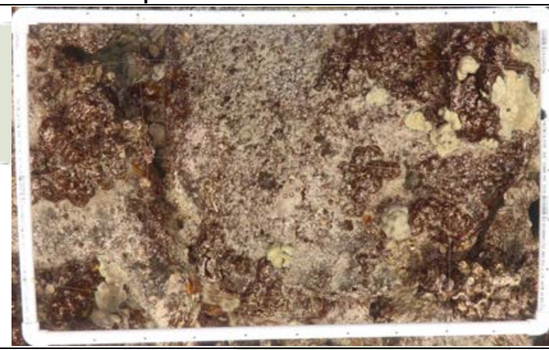
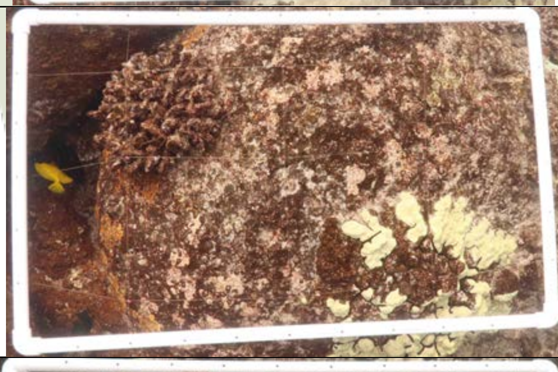
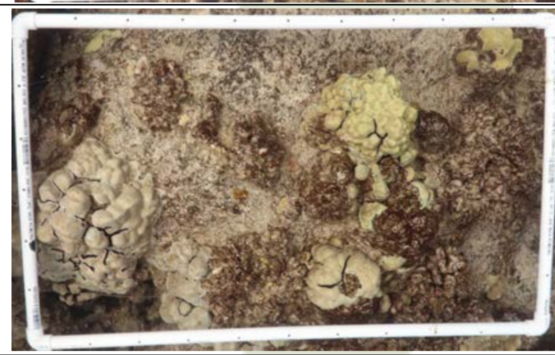
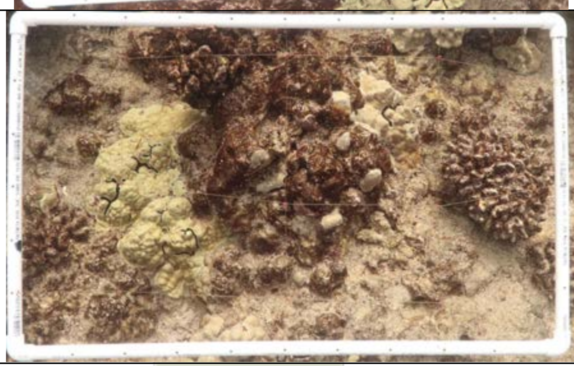
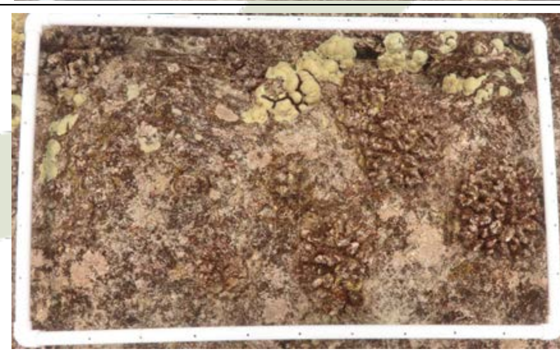
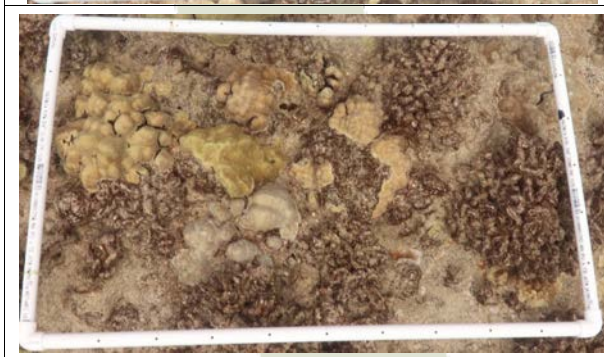
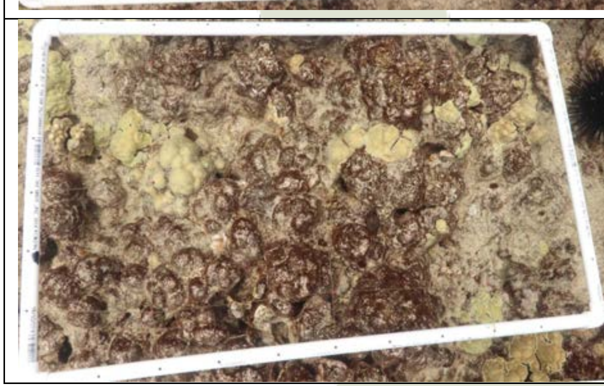
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

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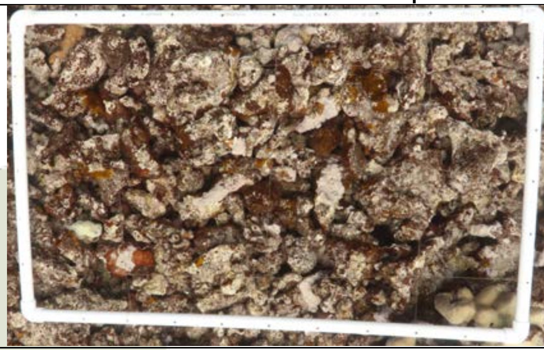
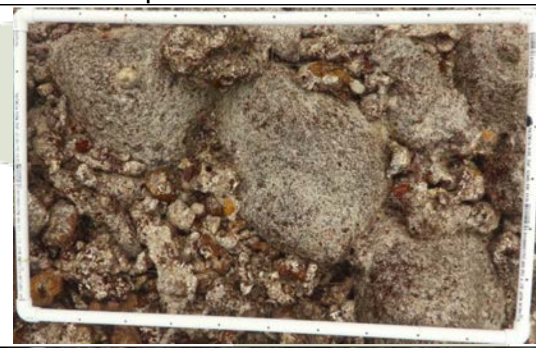
|  |  |
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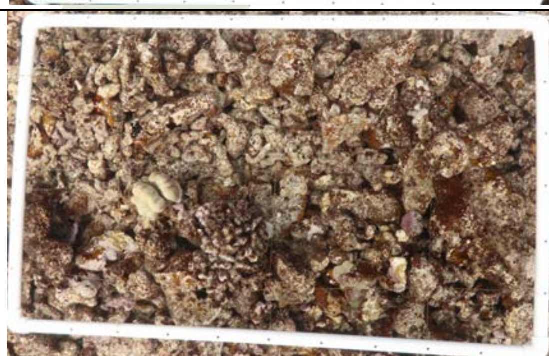
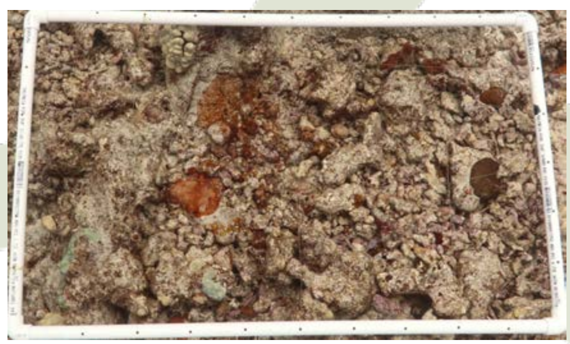
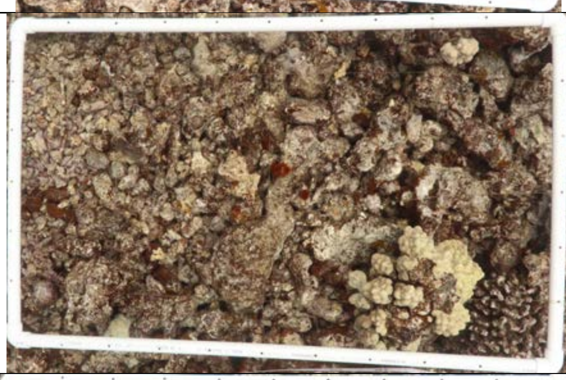
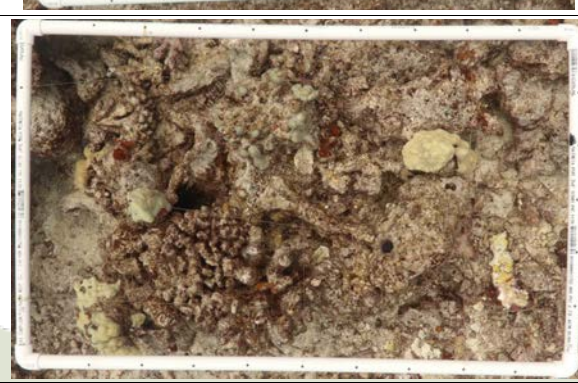
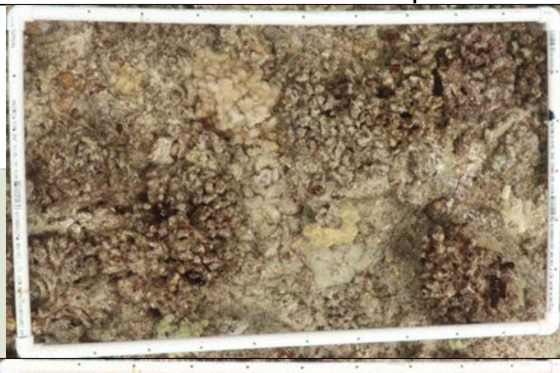
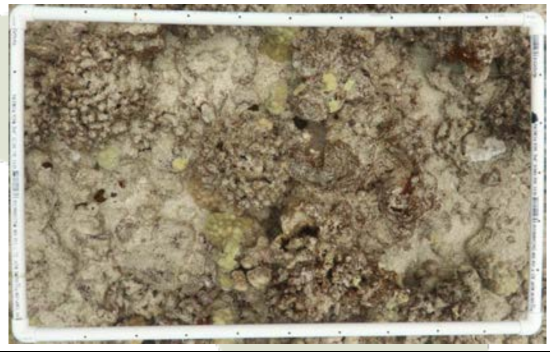
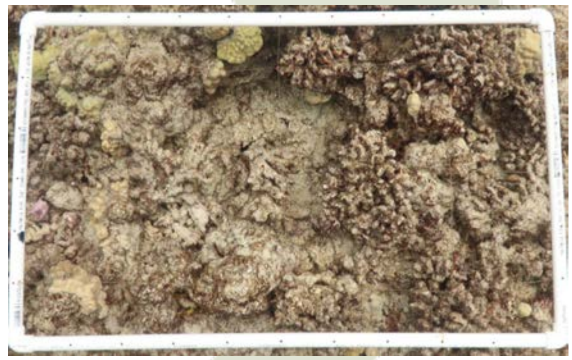
|  |  |
|  |  |
|  |  |

| Site: 12 Pipe South | Depth: 30fsw |
| --- | --- |
|  |  |
|  |  |
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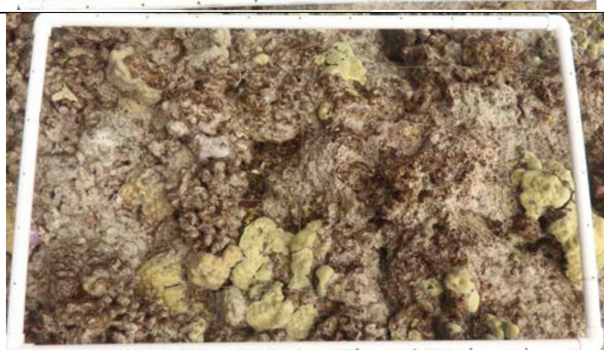
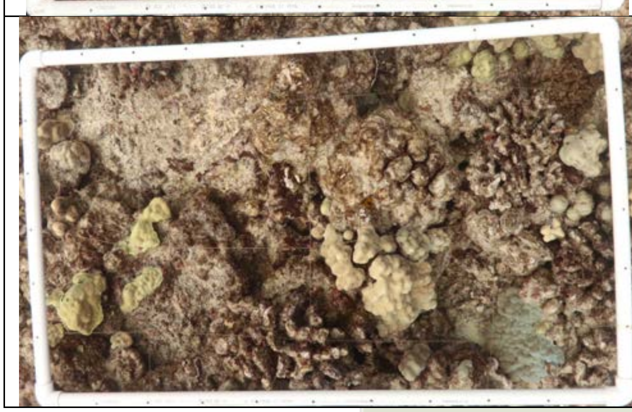
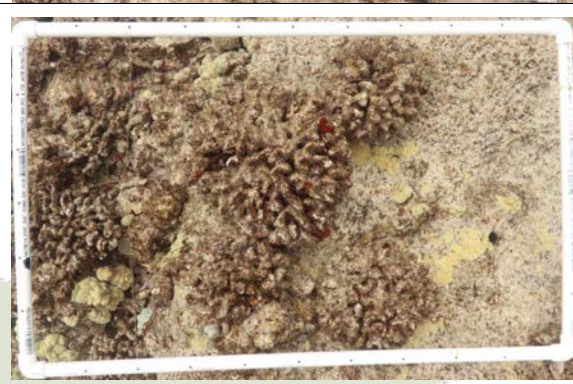
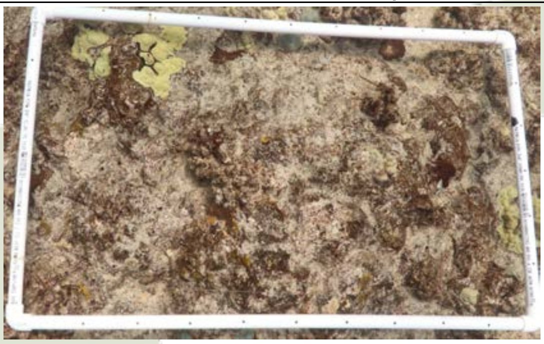
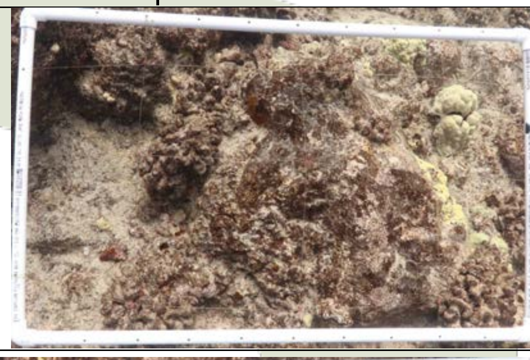
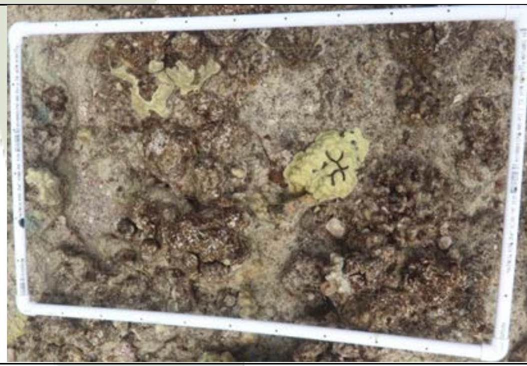
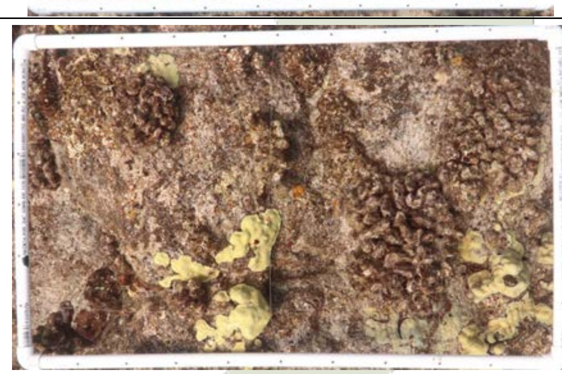
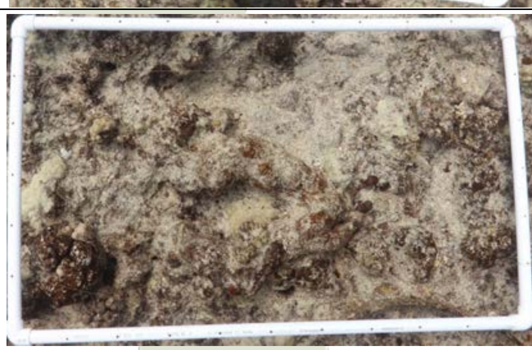
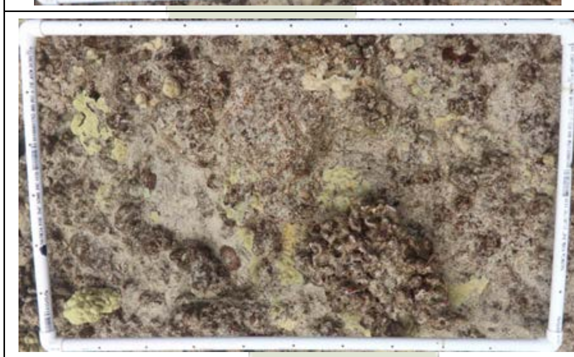
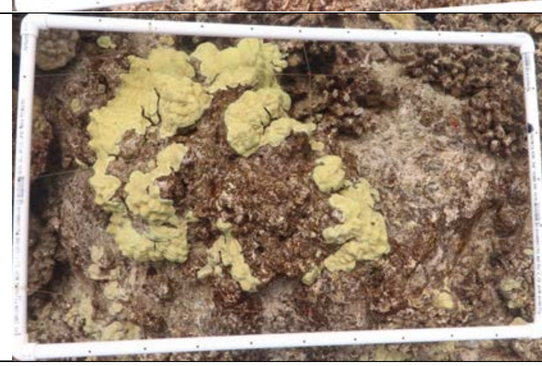
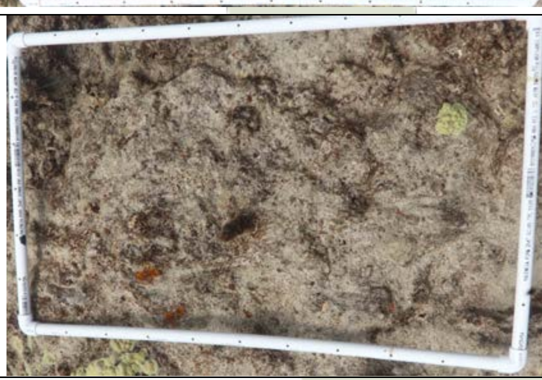
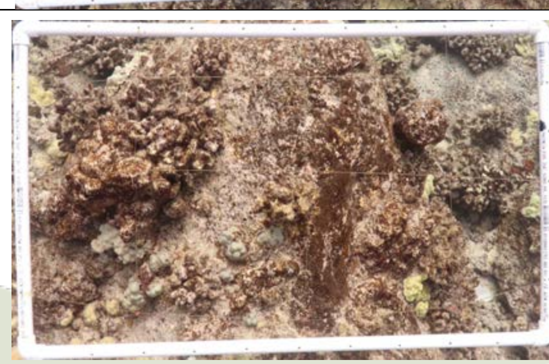
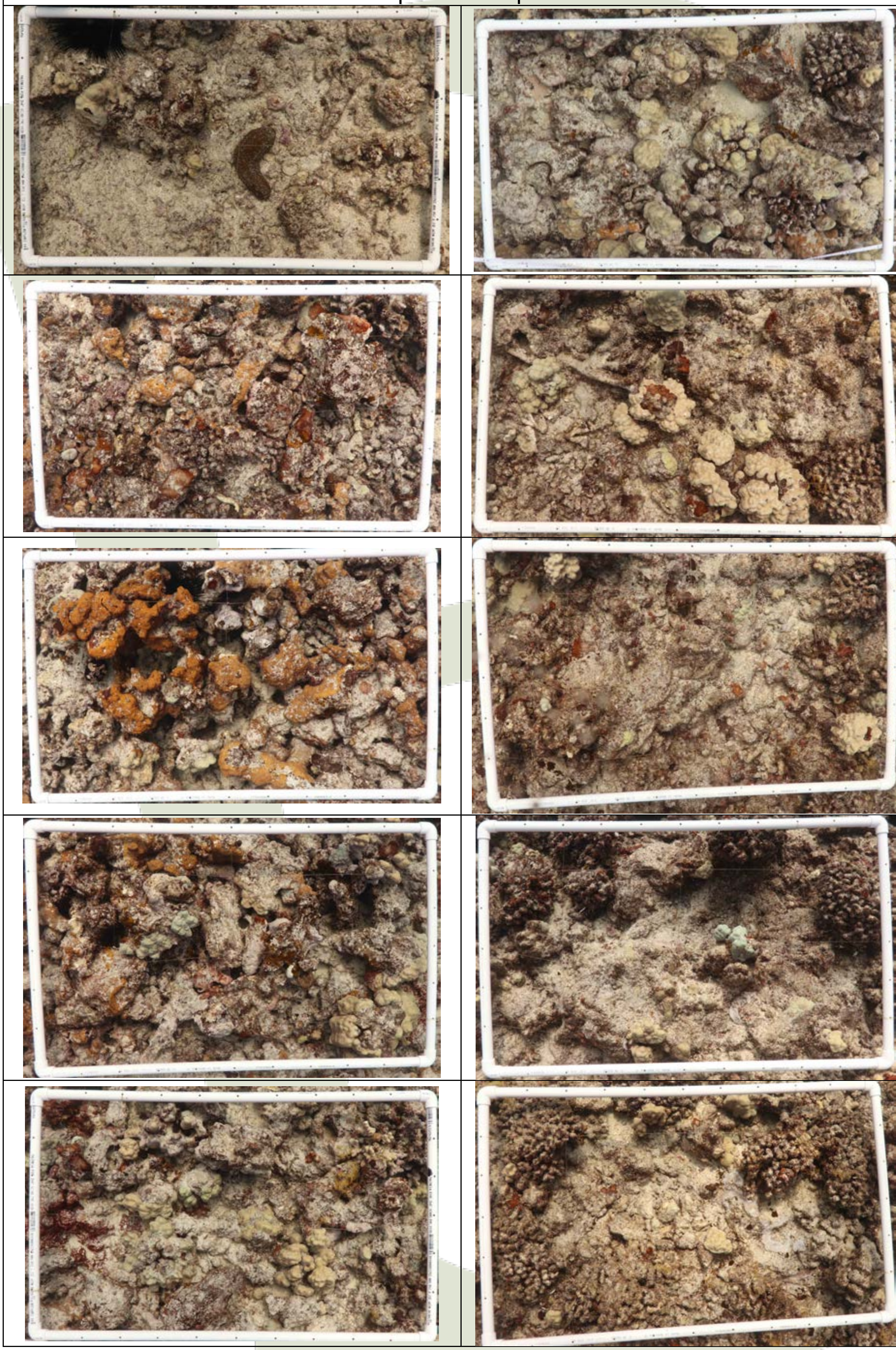
|  |  |
|  |  |

| Site: 12 Pipe South | Depth: 15fsw |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Site: 18 Pipe Depth: 50fsw



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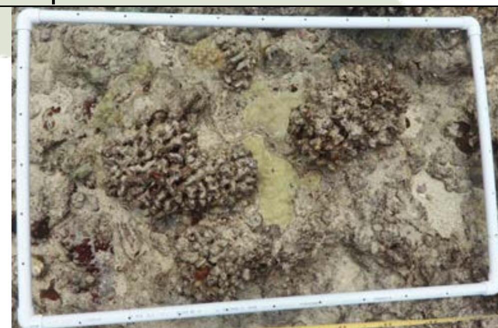
|  |  |
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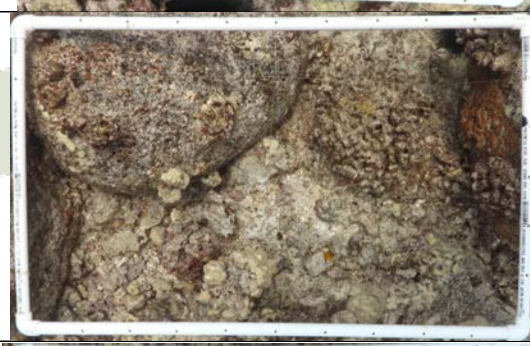
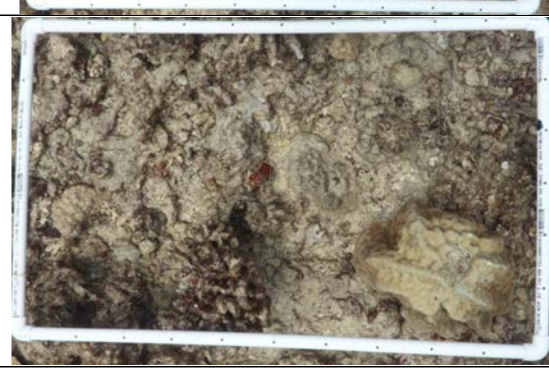
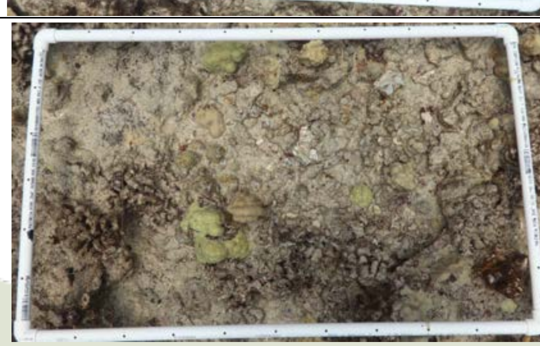
|  |  |
|  |  |
|  |  |

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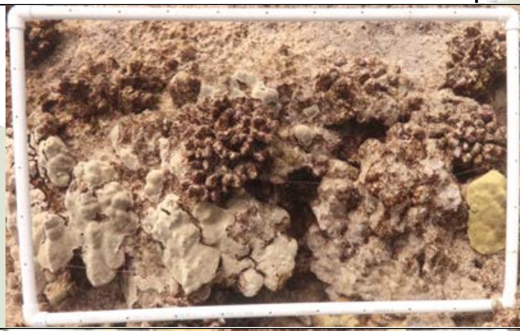
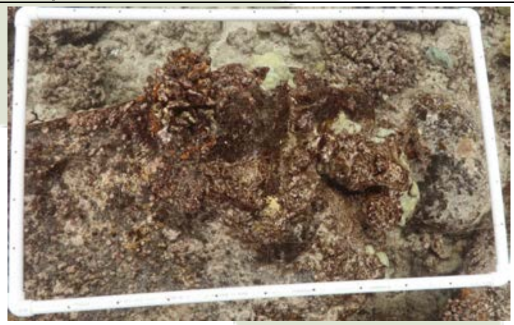
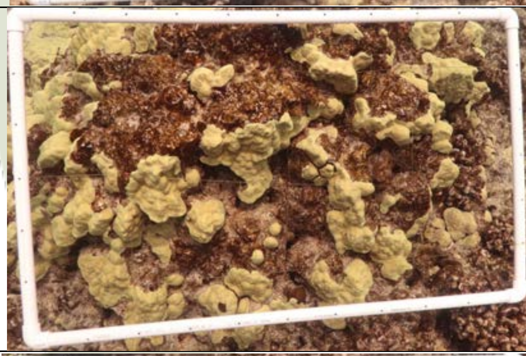
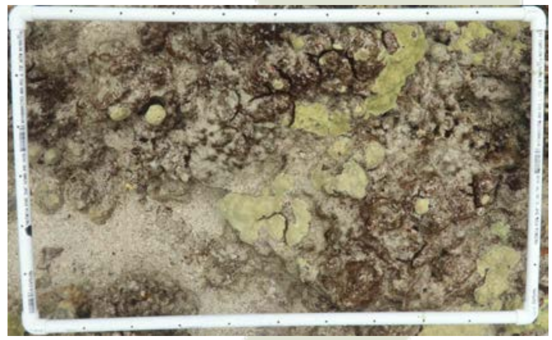
|  |  |
|  |  |
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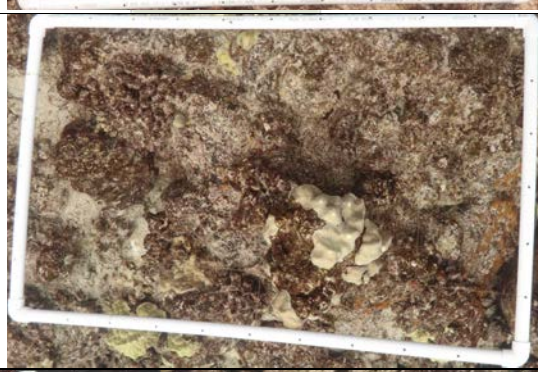
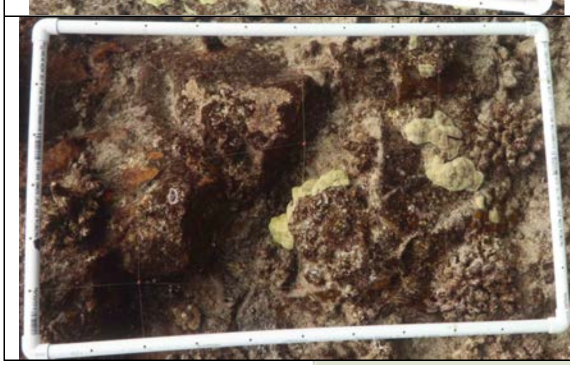
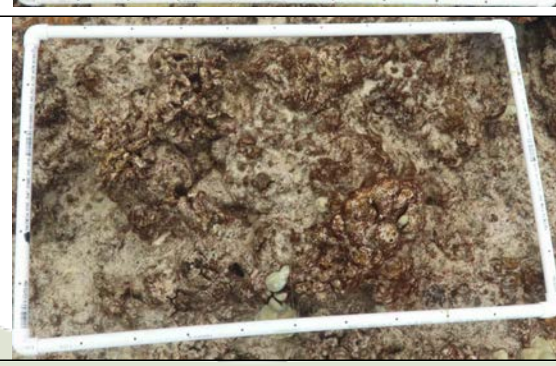
|  |  |
|  |  |

| Site: Wawaloli | Depth: 50fsw |
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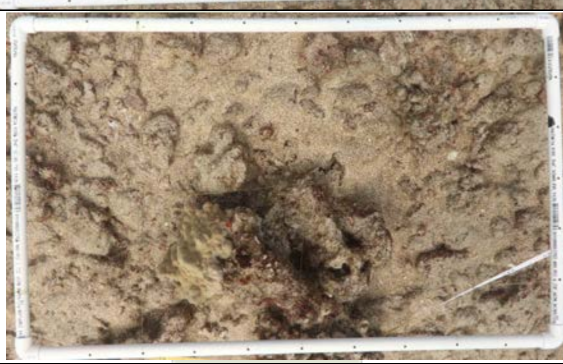
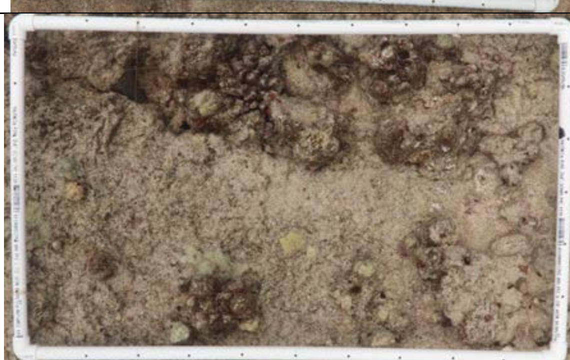
|  |  |
|  |  |
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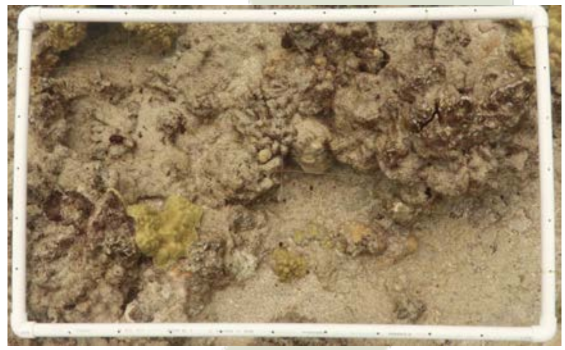
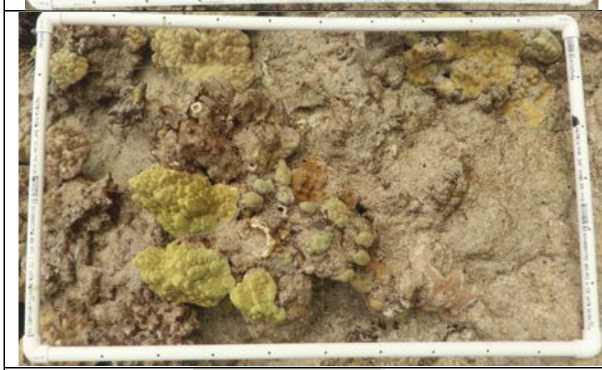
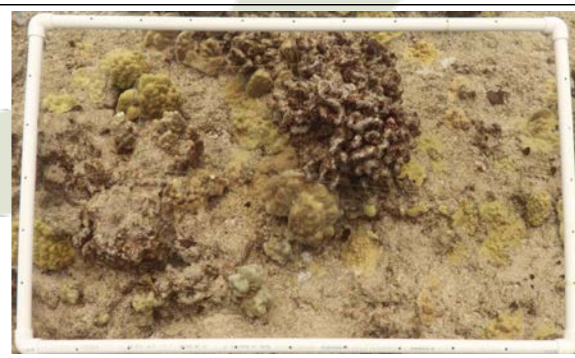
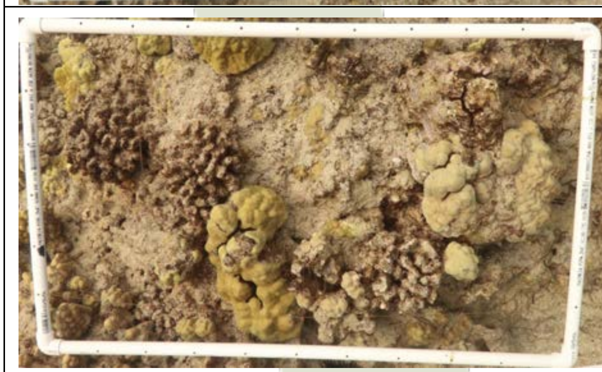
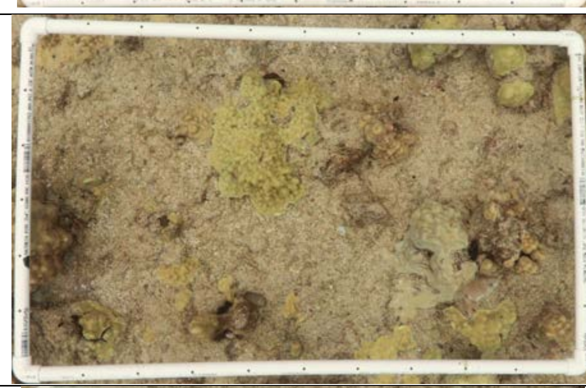
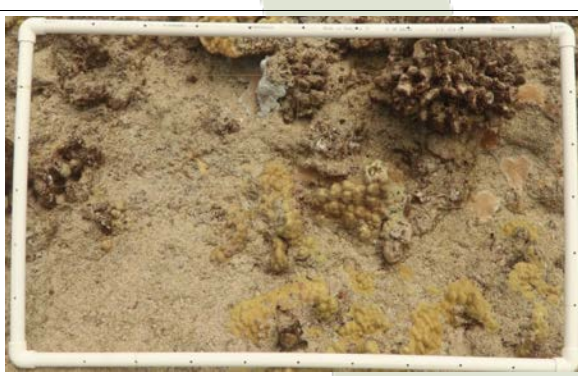
Site: Wawaloli Depth: 30fsw




Site: Wawaloli Depth: 15fsw