# MARINE BIOTA MONITORING PROGRAM
# FOR
# NATURAL ENERGY LABORATORY
# OF HAWAII AUTHORITY
# KEAHOLE POINT, DISTRICT OF NORTH KONA
# ISLAND OF HAWAII

SURVEY REPORT
May 2009

Prepared for

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NELHA MARINE BIOTA MONITORING PROGRAM

EXECUTIVE SUMMARY

The Natural Energy Laboratory of Hawaii Authority (NELHA) and the Hawaii Ocean Science and Technology (HOST) Park are located at Keahole Point, North Kona, Hawaii. These State of Hawaii facilities share infrastructure for the delivery of water from a variety of sources, including wells and offshore pipelines; water is disposed of primarily via discharge into open trenches in the shore side lava. In order to fulfill the requirements of permits to discharge, NELHA/HOST established the Comprehensive Environmental Monitoring Program (CEMP; G. K. & Associates, 1989). The objectives of the CEMP are to protect the environmental resources of the Keahole Point area and to provide the information necessary to comply with the permit requirements of county, state and federal agencies.

The CEMP is divided into two components: the water quality monitoring component and the marine resources component. The water quality monitoring component is being performed by staff of NELHA, and technical reports from that effort are prepared periodically. The marine biota monitoring component has been performed under contract by technical consultants. David A. Ziemann, Ph.D. is the current recipient of the contract award. Monitoring addresses three marine biotic components: anchialine ponds, nearshore benthic communities and nearshore fish communities. This report presents the results of monitoring surveys conducted in May 2009.

The ponds at NELHA exhibit both groups with high abundance of *Halocaridina rubra* (a unique brackish water shrimp locally known as opae ula), and others where *H. rubra* is excluded by the presence of exotic fishes. In the past, exotic fish had been present in all of the northern ponds and about one-third of the southern ponds. Some modifications to several of the northern ponds were made between November 2005 and July 2006. *Ruppia* has been removed from Ponds N2, N3 and N4 and replanted in the deeper portions of N5. Also, poecillids were apparently successfully removed, at least temporarily, from the northern ponds; their presence was noted in our January 2007 survey, but none were observed during the October 2008 survey, and they remain absent in the present survey. As an apparent consequence of the removal of exotic fishes, *Halocaridina rubra* were seen in all the northern ponds in abundance, along with *Metabataeus lohena*. These observations suggest that selective removal of exotic fish can be accomplished, and that the native anchialine pond crustaceans can return to ponds from which they were excluded; however, these changes may be short-lived if constant maintenance is not undertaken.

None of the ponds exhibit any conditions which might be attributable to anthropogenic inputs of material to the ponds. Water clarity remains high, and macroalgal growth is minimal even in ponds containing exotic fish. There is no evidence of any long term changes attributable to facility operations on the anchialine ponds at NELHA.

Total coral cover, *Porites lobata* cover, *Pocillopora meandrina* cover and coral species diversity have been monitored over the period from May 1992 to May 2009. The data suggest that there may have been systematic differences in monitoring protocols between contractors prior to May 1997 and after November 1997. Independent of these differences, the data suggest that total coral cover and cover of individual species have gradually increased over the period May 1992 to May

2009. This increase is the result of the continued growth of existing corals, the settlement and growth of new corals, or a combination of the two processes. No other significant changes in benthic communities have been observed. There is no evidence that the operational activities at NELHA have had any impact on the benthic communities in the region.

The fish community in the NELHA region has remained relatively constant over a period of seventeen years and through several significant storm events. Analysis of variance of number of species, number of individuals and biomass over the period from May 1992 to May 2009 showed no significant change with time. There is no evidence that the NELHA operations have resulted in any significant changes to the fish communities in the region.

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# NELHA ANCHIALINE POND MONITORING PROGRAM
May 2009

## INTRODUCTION

Anchialine ponds are brackish water bodies separated from the ocean but responding to the rise and fall of the tides. In Hawaii, anchialine ponds are found predominantly on low lying coastal lava where depressions in the lava extend below the water table. Anchialine ponds are inhabited by a community of unique organisms adapted for life in these conditions. The predominant species include several crustaceans, mollusks and other invertebrates. Because these unique ecosystems are found at the distal edge of the groundwater lens, they are potentially sensitive indicators of pollution to groundwater and the marine environment by terrestrial activities and processes.

The anchialine ponds at NELHA were first surveyed by Maciolek and Brock (1974). They observed pond systems which were relatively pristine, with typical communities of aquatic plants and animals. Subsequent surveys by OI Consultants, Inc. (Ziemann, 1985) and G.K. & Associates (G.K. & Assoc., 1986) found essentially unchanged conditions, with generally the same flora and fauna. Notably absent in all these surveys were exotic fish.

Since 1989, the anchialine ponds at NELHA have been surveyed as part of the CEMP. Between 1989 and the present, 31 surveys of the ponds have been completed. The results of the first 12 surveys (through June 1995) are summarized in Brock, 1995; for November 1995 through May 1997 in Oceanic Institute, 1997; for December 1997 through May 2002 in Brock 2002; for July 2005 – January 2007 in Oceanic Institute 2007; for December 2007 and August 2008 in Brock 2008; and for October 2008 in Ziemann 2008. Results of the pond monitoring survey conducted in May 2009 are presented below.

## METHODS

Anchialine ponds are located in two groups on the NELHA site (Figure 1): Prior to 2008, five ponds were located near the shoreline to the north of NELHA (Figure 2 upper). Sometime in 2008 an additional pond was dug in the sandy back-beach area adjacent to Pond N1; this pond has been labeled N6. Nine ponds are located to the south, inland of the NELHA access road (Figure 2 lower). A survey of the general conditions and biota within the ponds was conducted for this project on May 19, 2009. At each pond, water temperature was determined with a mercury thermometer and salinity was determined with a hand-held refractometer calibrated against distilled water. From one to four 0.1 $m^2$ quadrats were placed in each pond, in areas of different substrate, if possible. After five minutes, the number of organisms within each quadrat was counted and recorded. The presence of organisms not within the quadrats was noted and abundance estimated.

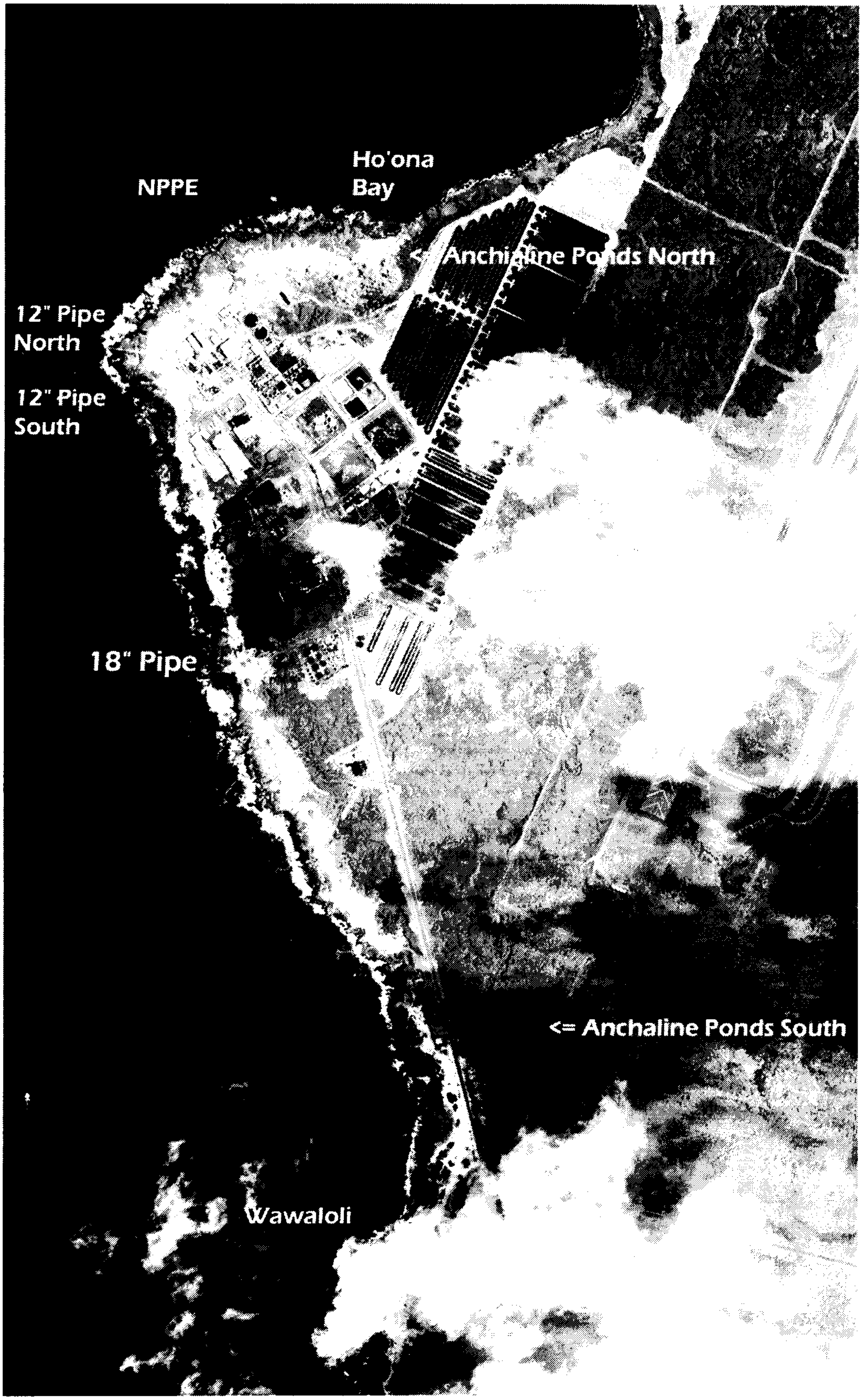


Figure 1. Locations of anchialine ponds and marine biota monitoring transects off NELHA.

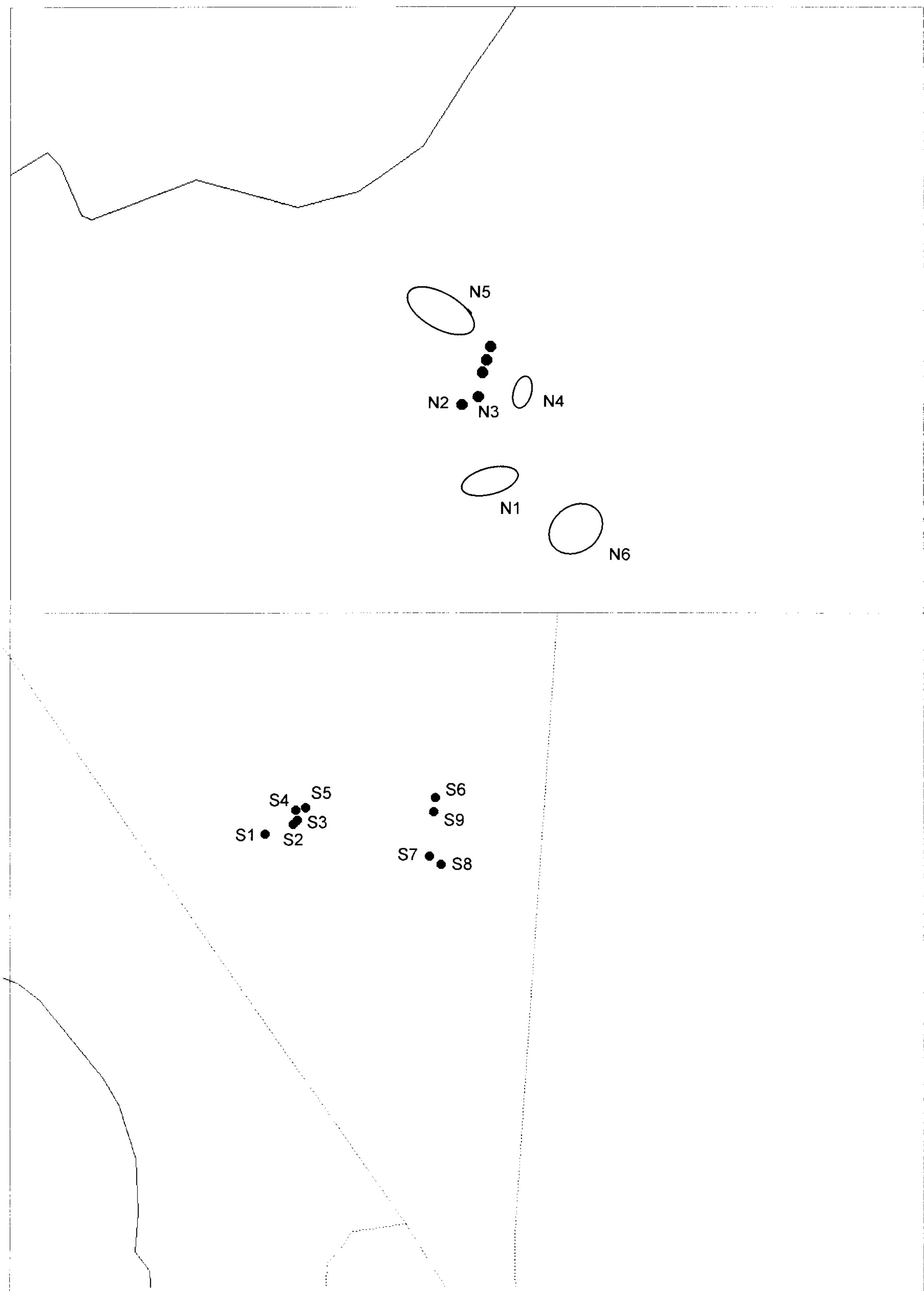


Figure 2. Locations of northern (upper) and southern (lower) anchialine pond groups at NELHA. Figures not to the same scale.

## RESULTS

The results of the survey of the anchialine ponds at NELHA performed on October 30, 2008 are presented in Table 1. The distribution and abundance of organisms in the northern and southern pond complexes were very different, but generally similar to the conditions observed in previous surveys (Brock, 1995; Oceanic Institute, 1997; Brock, 2002; Oceanic Institute, 2007; Brock 2008; Ziemann 2008), with the exception of apparent changes to several ponds in the northern complex. The northern ponds are shallow and located near the shoreline (Figure 2 upper). Ponds N1 – N4 are formed in depressions in the low-lying lava; Pond N5 is at least partially man-made, consisting of a depression in the back-beach rubble formed by manual removal of rubble material. Pond N5 is closest to the shoreline and separated from the ocean by the rubble back-beach. Pond N6 was recently dug in the sandy back-beach area adjacent to Pond N1. Salinity during the May 2009 survey was similar in the five northern ponds (8 - 10 ppt). Temperature was lowest (23.5 deg C) in pond N1 and elevated (27 - 28 deg C) in Ponds N3, N4 and N6.

Data for surveys conducted between 1989 and the present are compiled in Appendix A. In surveys prior to July 2006, ponds N2, N3 and N4 contained growths of the marine grass *Ruppia maratima*, and while this plant is typically used as shelter by the anchialine shrimp *Halocaridina rubra*, no shrimp were seen in the *Ruppia* growths. In July 2006, however, the *Ruppia* had been manually removed from these ponds and replanted in pond N5. Large numbers of *Halocaridina rubra* and *Metabateaus lohena* were seen in the now-barren Ponds N4a and N4b, where they had not been seen in prior surveys. During the January 2007 survey, neither *H. rubra* nor *M. lohena* were seen in any of the northern ponds, a return to conditions observed prior to July 2006.

No crustaceans were observed in the northern ponds in the survey conducted by Brock in December 2007. Notably, all exotic fish were absent in the northern ponds as well. Many of the northern ponds have been characterized by the presence of exotic fishes (*Poecilia* sp.), which exclude the red shrimp, *Halocaridina rubra*. With the removal of exotic fishes from the ponds, native crustaceans returned. *Halocaridina rubra* were observed in all five northern ponds in the August 2008 survey (Brock 2008) and in greater numbers during the October 2008 survey (Ziemann 2008). The numbers and distributions of *H. rubra* in the northern ponds in the present survey were very similar to those observed in October 2008.

Historically, the small snail, *Melania* sp., was common in these ponds, primarily on the sediment covered pond bottoms of Ponds N1, N3 and N4, and less so on the rocky sides. Since the survey conducted by Brock in 2006, however, snails have been notably absent from all of the northern ponds.

The southern ponds are located inland at some distance from the shoreline (Figure 2 lower). Water temperature in the northern group of ponds (S1 – S5) was similar (19 - 20 deg C) to the southern group (S6 – S9), where temperatures were uniformly 19.5 - 20 deg C. Salinity in the southern ponds was lower than in the northern ponds and consistent at 8 - 9 ppt.

The first exotic fishes were recorded in the southern ponds in the May 2002 survey (Brock, 2002) in Pond S7. Subsequently, exotic fishes expanded to all the southern ponds (except S6, which is dry at low tide) by January 2007. As a result, no anchialine pond crustaceans were observed in surveys conducted in December 2007 and August 2008 (Brock 2008). During the October 2008 survey (Ziemann 2008) and the present survey, however, exotic fishes were observed in only three ponds (S1, S5 and S7). *Halocaridina rubra* were present in the ponds which did not contain exotic fish. Another common pond crustacean, *Metabateaus lohena*, was seen only in Pond S8, a deeper pond previously overgrown with beach heliotrope, but which had been cleared of overgrowth between October 2008 and May 2009.

DISCUSSION

On the island of Hawaii, anchialine ponds are found along the west and south coasts. Studies of the ecology of these unique communities have established that the populations are generally hardy and apparently unaffected by nearby terrestrial activities, including the development of residences, hotels and golf courses. The major impact to the anchialine pond communities has been the inadvertent or purposeful introduction of exotic fishes into the ponds. From 1972 to 1985, exotic fish spread from 15% to 46% of the ponds along the Kona coast (Brock, 1985; Bailey-Brock and Brock, 1993); recent estimates suggest that over 90% of the ponds are now infested (Brock, unpublished data). With the introduction of exotic fishes comes the decline or complete absence of the ubiquitous small red shrimp (*Halocaridina rubra* or opae ula). These shrimp constantly graze on the microalgae which grow in the brightly-lit, high nutrient ponds. With the removal of the shrimp, ponds often become overgrown with mats of filamentous algae.

The ponds at NELHA exhibit both groups of ponds with high abundance of *H. rubra*, and others where *H. rubra* is excluded by the presence of exotic fishes. Attempts to eradicate the exotic fish in the northern ponds have been only temporarily successful (Brock, 1995).

For several years, exotic fish were present in most of the northern ponds and one-third of the southern ponds. During surveys conducted from December 2007 to the present, however, exotic fishes were not observed in any of the northern ponds and only three of the southern ponds, the decrease presumably the result of eradication efforts. Concurrently, the ponds without exotic fish all contained populations of the common red shrimp *Halocaridina rubra*.

None of the anchialine ponds on the NELHA site exhibit any conditions which might be attributable to anthropogenic inputs of material to the ponds. Water clarity remains high, and macroalgal growth is minimal even in ponds containing exotic fish. There is no evidence of any long term changes attributable to operational activities of NELHA on the anchialine ponds at NELHA.

Table 1. Physical and biological data collected in anchialine ponds within the NELHA facility in May 2009. Pond locations are given in Figure 2. Surveys were conducted at or near high tide (+1.0 feet).

| Pond | Temp (deg C) | Salinity (ppt) | *Ruppia maratima* | *Melania* | *Assemenia* | *Theodoxus cariosa* | *Grapsus tenuicrustatus* | *Halocaridina rubra* | *Metabataeus lohena* | *Poecilia sp.* | other species, comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N1 | 23.5 | 10 | ++ | | | + | | +++ | - | - | *H. rubra* 50-100 in quads; 100-200 in gravel along pond edge; dense aggregations in *Ruppia* . |
| N2 | 25.0 | 8 | | | | | | ++ | + | - | *H. rubra* 20/quad on rocks; 50/quad on rubble; 2 *M. lohena.* |
| N3 | 27.0 | 8 | +++ | + | | | | +++ | - | - | *H. rubra* 200/quad on rock shelf; TNTC/quad on *Ruppia; Ruppia* covers 80% of central basin |
| N4 | 27.5 | 9 | | | | | | + | - | - | *H. rubra* 10/quad on rocks; 5/quad on sand. |
| N5 | 24.5 | 10 | + | + | | | | ++ | - | - | *H. rubra* 75/quad on rock shelf; TNTC/quad on *Ruppia; Ruppia* covers 50% of central basin |
| N6 | 27.0 | 8 | | | | | | | | | Newly-created pond; no vegetation, no animals observed. |
| S1 | 21.5 | 9 | | | | | | - | - | + | Poecilids present, no shrimp |
| S2 | 21.5 | 9 | | | | | | + | - | - | *H. rubra* 15 - 20/quad on rocks. |
| S3 | 21.0 | 9 | | | | | | + | - | - | *H. rubra* 10 - 13/quad on rocks. |
| S4 | 21.0 | 8 | | | | | | + | - | - | *H. rubra* 15 - 20/quad on rocks. |
| S5 | 21.0 | 9 | | | | | | - | - | + | Poecilids present, no shrimp |
| S6 | 19.0 | 9 | | | | | | - | - | - | |
| S7 | 20.0 | 7 | | | | | | - | - | ++ | Poecilids present, no shrimp |
| S8 | 21.0 | 8 | | | | | | ++ | + | - | *H. rubra* 45 - 60/quad on rocks; 5 *M. lohena* Beach heliotrope previously covering pond now cut back. |
| S9 | 21.5 | 8 | | | | | | - | - | - | *H. rubra* 30/pond, 2 *M. lohena* |

Qualitative abundance:
+ ls; scattered plants
++ plants abundant in patches
+++ ˌ count; plants covering substrate
- ıe observed

## BENTHIC MARINE BIOTA MONITORING PROGRAM

### INTRODUCTION

Benthic communities are considered to be the potentially most useful and sensitive indicators of the environmental impact of terrestrial activities because the components of these communities are fixed in place and cannot move from an area undergoing impact; thus their exposure to potentially harmful materials has components of both concentration and duration. Changes in coral community abundance or diversity may result from changes in the quantity or quality of groundwater discharged along the coastline. In the Hawaiian Islands, the structure of coral communities is also a response to the periodic physical impacts of storm- or hurricane-generated waves (Dollar, 1975, 1982; Dollar and Tribble, 1993).

Between 1991 and the present, 33 surveys of the benthic communities have been completed. The results of surveys between 1991 and 1995 are summarized in Marine Research Consultants, 1995; for surveys between 1995 and 1997 in Oceanic Institute 1997; for surveys performed from 1997 to 2002 in Marine Research Consultants, 2002; for surveys from July 2005 to January 2007 in Oceanic Institute 2007; for October 2007 and July 2008 surveys in Marine Research Consultants 2008; and for the October 2008 survey in Ziemann 2008. Results of the survey conducted in May 2009 are reported here.

### METHODS

A survey to examine the nearshore benthic marine biota was performed using SCUBA between May 16 – 18, 2009. Surveys were performed at six locations along the NELHA coastline (Figure 3): Ho'ona Bay, the NPPE site, 12" Pipe - North, 12" Pipe - South, 18" Pipe, and Wawaloli. At each location, a series of three transects was laid out. Transects were performed in the shallow (~5m) boulder zone, the intermediate depth (~8-10 m) reef bench, and the deeper (15-20 m) reef slope. These station locations and transect depths have been chosen as representative of major biotopes along the Kona coast (Dollar, 1975, 1982; Dollar and Tribble, 1993), and are the same locations visited in previous surveys (Marine Research Consultants, 2008; Brock, 2008; Ziemann 2008). At each location, a 50 m transect line was laid out parallel to the depth contours. At ten randomly selected points along the transect line, photographs of a 0.6 x 1.0 m quadrat frame were taken using a digital camera with a wide angle lens in an underwater housing with a dome port. Lighting was provided by underwater strobes. Digital quadrat photos were analyzed using Coral Point Count with Excel extensions (CPCe v3.6; National Coral Reef Institute, Nova Southeastern University, 2006). On the computer screen, each digital photo was overlaid with a 20 (vertical) x 10 (horizontal) grid of equally spaced points, and the biotic components and substrate type under each point was recorded. Point count data were exported into Excel spreadsheets for compilation and analysis. For each transect, the mean abundance (as percent cover) of coral species and substrate type was tabulated, and the species diversity (Shannon-Weaver Index) of the coral community (Shannon and Weaver, 1949; Pielou, 1969) calculated:

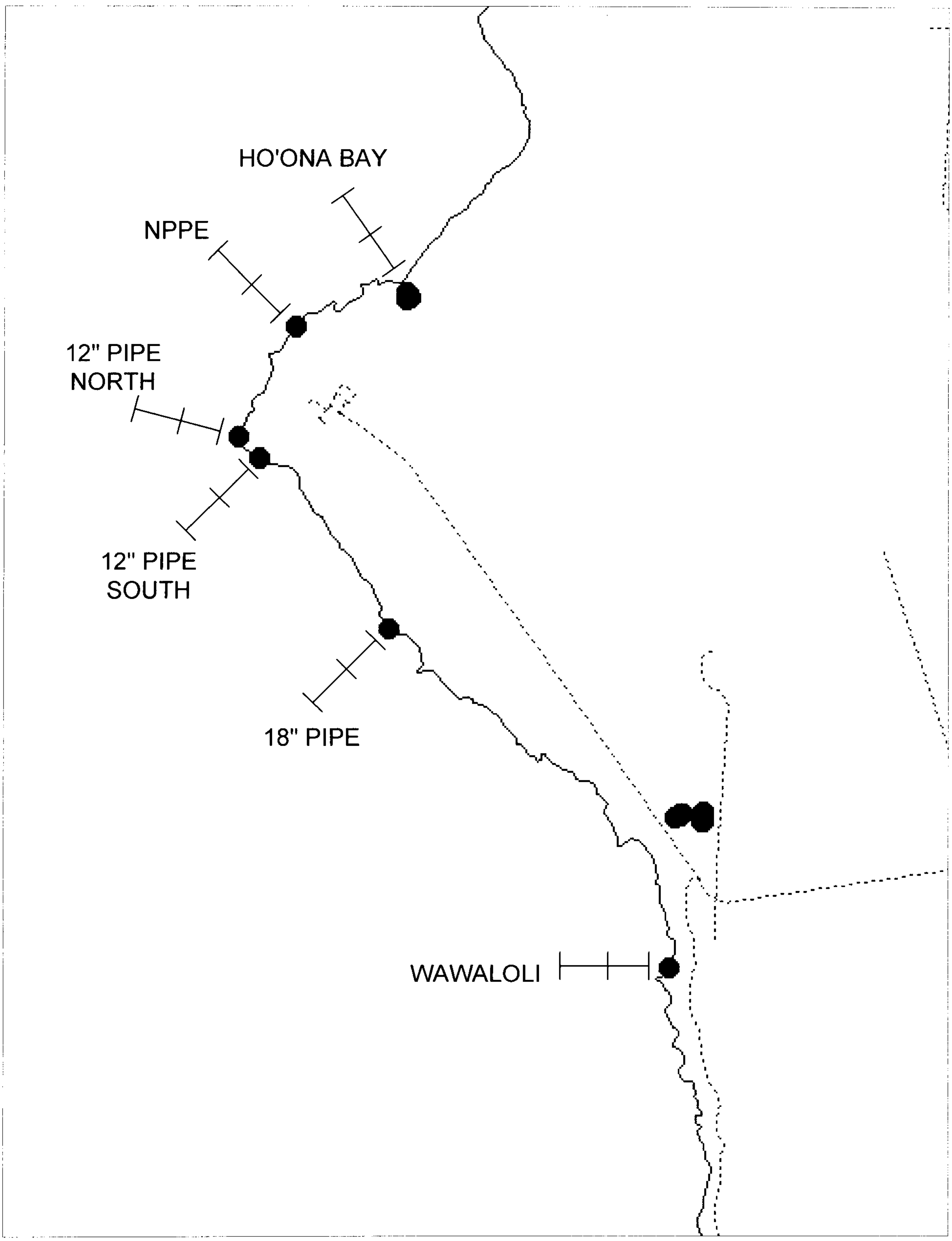


Figure 3. Locations of marine biota monitoring survey transects.

$$H' = -\sum_{i=1}^{n} (p_i \ln p_i)$$

where $p_i$ = the proportion of the coral population of the $i^{th}$ species.

RESULTS

Coral species abundance and coral diversity as well as non-coral benthic cover from the October 2008 survey off NELHA are presented in detail in Appendix B and summarized in Table 2. Color prints of digital quadrat photos are presented in Appendix E. Two species, *Porites lobata* and *Pocillopora meandrina*, comprised the majority of the coral observed, constituting over 25.9% and 8.1%, respectively. Other stony coral species (*Montipora capitata* [previously *verrucosa*], *M. patula, Pavona varians, Leptastrea purpurea, Fungia scutaria*) made up generally less than 2% of the benthic cover. *Porites lobata* and *Pocillopora meandrina* were found throughout all stations and habitat types. *Porites compressa* was abundant only at the deepest reef slope transects at stations 12" Pipe North, NPPE and Ho'ona Bay, the three most northern stations.

The percent cover of all coral species in the three habitat types and the individual distribution of the three dominant coral species, *Porites lobata, P. compressa*, and *Pocillopora meandrina*, are presented in Table 2. There were significant differences in coral abundance both between habitat types and also between sites. Total coral cover was significantly higher at the NPPE site (53.2%) than at the Wawaloli site (31.9%); differences between other pairs of sites were not significant ($p = 0.11$; two-way ANOVA; Holm-Sladek pairwise comparison test). Total coral cover in the deep reef slope habitat was significantly higher (45.6%) than the middle reef slope habitat (33.3%; $p = 0.027$, two-way ANOVA; Holm-Sladek pairwise comparison test). Among the deep reef slope stations, coral abundance was highest at Ho'ona Bay, NPPE and 12" Pipe North sites. At Ho'ona Bay this was due to the high abundance of *Porites compressa* (nearly 16% cover). At the NPPE site, the reef slope was dominated by *P. lobata* (36.7%) and *Porites compressa* (14.2%). At the other four deep reef slope stations, *P. lobata* and *Pocillopora meandrina* accounted for the high coral abundance (combined average cover of 25 - 56%).

Between areas, the highest mean and also maximum coral was found in the two most northern areas, Ho'ona Bay and the NPPE site. The most southern area, Wawaloli had the lowest overall coral coverage. The highest mean *Porites lobata* coverage was found in the 12" Pipe North station, with somewhat lower coverage at the NPPE and Ho'ona Bay boulder, bench, and slope stations. For *Pocillopora meandrina*, the 12" Pipe North and South stations had the highest mean abundance of all the stations. None of the differences in coverage for these species were statistically significant ($p > 0.05$).

The number of coral species observed in photoquadrats was significantly different between sites and habitats. The mean number of species observed at the 18" Pipe site (6.3) was significantly higher than that observed at the 12 " Pipe South site (4.0). None of the other pair-wice comparison were significantly different ($p = 0.034$; two-way ANOVA; Holm-Sladek pairwise comparison test). The mean number of species observed at the deep habitats (5.8) was significantly greater than at the shallow habitat (4.2; p = 0.031; two-way ANOVA; Holm-Sladek pairwise comparison test).

Other Benthic Invertebrates

Results of the benthic invertebrate surveys are presented in Appendix C. The primary benthic invertebrates, other than corals, were echinoderms (sea urchins). The most visible invertebrate and most abundant echinoderm species was *E. mathaei*, found at all stations, with highest abundance in the shallow boulder zone and in the intermediate reef bench areas. The other urchin species occurred infrequently throughout the three different habitat zones. *Diadema paucispinum*, *Echinothrix diadema* and *Tripneustes gratilla* were generally observed most frequently in the deeper reef bench and reef slope areas.

Comparative Analysis - Benthic Marine Resources

Data for the NELHA benthic marine resources monitoring program has been collected since May 1989. However, the current arrangement of six stations with three transects at each station was not established until May 1992. Since that time, 31 surveys have been conducted. The balanced design and complete coverage afforded by the current survey arrangement provides a powerful database for statistical analysis. Although the three surveys performed between May 1989 and March 1992 provide additional temporal scale, their incomplete coverage provides little statistical power. Therefore, the statistical analyses which follow incorporate data only from May 1992 to October 2008, inclusive.

The surveys for benthic marine resources provided data for a number of variables (total coral cover, and cover for two dominant coral species per transect) for three sources of variance (date, location [stations] and habitat [transects]). Three-way analysis of variance (ANOVA) tests were performed on three sources of variance (date x location x habitat) for 31 surveys from May 1992 to May 2009 for total coral cover, *Porites lobata* abundance and *Pocillopora meandrina* abundance using SigmaStat for Windows, a PC-based statistical analysis program. However, all data sets failed the test of normality, in raw form or after transformations (log, exp, arc-sine). Therefor, one-way ANOVA tests utilizing ranked data ( Kruskal-Wallis analysis of variance on ranks) were conducted on each factor independently; pairwise comparison comparisons on ranked data using the Tukey test were performed to identify significant differences between all pairs. The level of significance for all tests was p = 0.05.

Results of the one-way K-S analysis of variance (ANOVA) on ranks for total coral cover, *Porites lobata* abundance and *Pocillopora meandrina* abundance are summarized below and presented in detail in Tables 3 – 5, respectively. Mean total coral, *P. lobata* and *Poc. meandrina* cover were all significantly different for date, location and habitat.

Table 2. Summary of quantitative coral photoquadrat surveys conducted off Natural Energy Laboratory of Hawaii on May 16 - 18, 2009. Locations of transects are shown in Figure 3. Quantitative data are presented in Appendix B.

| Station | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep |
| % Total coral | 27.4 | 38.6 | 29.8 | 39.5 | 31.8 | 41.4 | 21.8 | 32.8 | 31.2 |
| % *P. lobata* | 18.5 | 30.3 | 21.6 | 25.8 | 16.3 | 24.5 | 11.7 | 20.9 | 16.1 |
| % *P. compressa* | | | 0.6 | | 0.1 | 0.4 | | | 0.1 |
| % *Poc. meandrina* | 6.5 | 3.9 | 2.9 | 11.1 | 9.0 | 13.5 | 10.2 | 10.4 | 12.0 |
| Species | 5 | 5 | 5 | 4 | 8 | 7 | 2 | 4 | 6 |
| Diversity | 0.88 | 0.77 | 0.88 | 0.85 | 1.27 | 1.00 | 0.69 | 0.82 | 1.04 |

| Station | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep |
| % Total coral | 29.5 | 41.8 | 57.2 | 42.5 | 52.1 | 65.1 | 39.0 | 41.0 | 49.1 |
| % *P. lobata* | 18.4 | 18.6 | 48.8 | 29.7 | 37.1 | 36.7 | 31.1 | 29.2 | 31.4 |
| % *P. compressa* | | 0.1 | 5.4 | | 0.6 | 14.2 | | 0.5 | 15.9 |
| % *Poc. meandrina* | 6.0 | 14.1 | 7.8 | 7.6 | 7.8 | 7.1 | 6.9 | 8.1 | |
| Species | 4 | 5 | 5 | 6 | 7 | 7 | 4 | 4 | 5 |
| Diversity | 1.03 | 1.22 | 0.92 | 0.98 | 0.88 | 1.23 | 0.58 | 0.81 | 0.79 |

| Survey Means | Wawaloli Beach | 18" Pipe | 12" Pipe South | 12" Pipe North | NPPE | Ho'ona Bay | p level | Shallow | Middle | Deep | p level |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Total coral | 31.9 | 37.6 | 28.6 | 42.8 | 53.2 | 43.0 | **0.01** | 33.3 | 39.7 | 45.6 | **0.03** |
| | b | ab | b | ab | a | ab | | b | ab | a | |
| % *P. lobata* (note 1) | 23.5 | 22.2 | 16.2 | 28.7 | 34.5 | 30.6 | 0.17 | 22.5 | 25.4 | 29.9 | 0.33 |
| % *Poc. meandrina* | 4.4 | 11.2 | 10.9 | 9.3 | 7.5 | 5.0 | 0.07 | 8.1 | 8.8 | 7.2 | 0.63 |
| Species | 5.0 | 6.3 | 4.0 | 4.7 | 6.7 | 4.3 | **0.03** | 4.2 | 5.5 | 5.8 | **0.03** |
| | ab | a | b | ab | ab | ab | | b | ab | a | |
| Diversity | 0.84 | 1.04 | 0.82 | 1.06 | 1.03 | 0.73 | 0.12 | 0.82 | 0.96 | 0.98 | 0.22 |

note 1 ln-transformed data

Summary of three-way analysis of variance on ranked data (Kruskal-Wallis test) for quantitative benthic community abundance for the period May 1992 – May 2009.

| TEST | Source of Variance | Probability | Significance |
|---|---|---|---|
| Total coral cover | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | <0.001 | highly significant |
| *Porites lobata* abundance | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | <0.001 | highly significant |
| *Pocillopora meandrina* abundance | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | <0.001 | highly significant |

The mean total coral cover for each date, location and habitat and the results of the pairwise comparisons (Tukey tests) from the one-way ANOVA on ranks are presented in Table 3. Total coral abundance showed a clear pattern over time. Mean total coral abundance did not change significantly from May 1992 through May 1997, although there was a generally increasing trend, with values ranging from 16.9 to 27.0%. Mean cover almost doubled, from 27% to 42.5%, between surveys conducted in May 1997 and November 1997. Mean total coral cover remained high (40.7% to 52.5%) through June 2002. In July and November 2005, after a nearly three-year hiatus in monitoring, the mean total coral cover was 30.8 and 30.2%, respectively, significantly higher than during the May 1992 to May 1997 period, but significantly lower than during the November 1997 – June 2002 period. Mean coral cover was reported as 52.4% and 54.7% for surveys in October 2007 and July 2008. Mean total coral cover was 39.5% in the survey conducted in October 2008, and 39.5% in the present survey.

Mean total coral cover was significantly different between all sites except the 12" Pipe North, 12" Pipe South and 18" Pipe sites. Mean total coral cover was highest (51.7%) at the NPPE site, decreasing through the Ho'ona Bay, 12" Pipe S and N, and 18" Pipe sites to a minimum of 21.1% at the Wawaloli site. Mean total coral cover was not significantly different between the deep reef slope (41.4%) and reef bench stations (36.4%), and significantly lower (26.0%) at the shallow boulder stations.

The mean *P. lobata* cover for each date, location and habitat and the results of the pairwise comparisons (Tukey tests) from the one-way ANOVA on ranks are presented in Table 4. In general, the patterns of *P. lobata* distribution were similar to the patterns for total coral cover. *Porites lobata* cover was low and similar between May 1992 and May 1997, ranging from 10.0 to 14.6%. *Porites lobata* cover increased between surveys conducted in May 1997 and November 1997 from 13.7% to 20.6%, values that were significantly different. *Porites lobata* cover remained high and not statistically different from November 1997 through the present survey, ranging from 16.7 – 30.7%.

As for total coral cover, *P. lobata* cover was highest at the NPPE station (30.4%) and lowest at Wawaloli (12.6%) and the 18" Pipe (11.5%) sites, and increased from lowest values (12.5%) in the shallow boulder habitat to highest values (21.7%) in the deep reef slope habitat.

The mean *Pocillopora meandrina* cover for each date, location and habitat and the results of the pairwise comparisons (Tukey tests) from the one-way ANOVA on ranks are presented in Table 5. In general, the patterns of *Poc. meandrina* distribution were similar to the patterns for total coral cover. *Poc. meandrina* cover was low and similar between May 1992 and December 1996, ranging from 3.7 to 6.3%. Mean *Poc. meandrina* cover increased between surveys conducted in May 1997 and November 1997 from 8.0% to 13.0%, values that were significantly different. *Pocillopora meandrina* cover increased between surveys conducted in December 1996 and November 1997 from 6.3% to 13.0%, values that were significantly different. *Pocillopora meandrina* cover remained high and not statistically different from November 1997 through the present survey, ranging from 8.1 – 20.3%.

Mean *Poc. meandrina* cover was similar (10.2 – 13.6%) at the NPPE, 18" Pipe, 12" Pipe South and 12" Pipe North sites. The Wawaloli and Ho'ona Bay sites showed significantly lower cover (3.7 – 5.5%). Mean *Poc. meandrina* cover was similar at the shallow boulder (10.2%) and middle reef shelf (11.5%) sites, and significantly lower at the deep reef slope (7.7%).

## DISCUSSION

The distributions of the predominant coral species appear to define particular biotopes which fit the general descriptions (Dollar, 1975, 1982; Dollar and Tribble, 1993) of typical coral zonation: the area of high energy where *Porites lobata* and *Pocillopora meandrina* dominated; the intermediate bench zone where *P. lobata* was more abundant than *Poc. meandrina*; and the deeper reef slope zone dominated by *P. compressa*. The distribution of these biotopes along the NELHA coastline was not uniform, however, and the location of the survey transects is not uniform within these zones. For example, only the deepest transects at Ho'ona Bay and the NPPE station actually covered the deep *P. compressa* zone; all other deep transects were more shallow and located within the reef bench zone where *P. lobata* dominated or the shallow boulder zone where *P. lobata* and *Poc. meandrina* dominated.

Overall total coral cover and *Porites lobata* abundance showed the same general patterns of distribution, increasing in abundance from south to north along the NELHA coastline, and increasing in abundance from shallow to deep.

*Pocillopora meandrina* was dominant in the boulder zone along part of the coastline, but was found in low abundance in the boulder zone at the northern-most and southern-most stations. The low abundance of *Poc. meandrina* at these stations is likely due to the decreased wave action experienced there, a result of the orientation and bathymetry, which appears to provide some level of shelter from predominant storm waves.

Table 3. Summary of one-way analysis of variance (ANOVA) of total coral abundance (percent cover) for surveys conducted off NELHA from 1992 - 2009. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

| | | Mean | group | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | | | | | | | | | |
| | May-92 | 17.4 | | | | | | f | g |
| | Oct-92 | 16.9 | | | | | | | g |
| | May-93 | 19.3 | | | | | e | f | g |
| | Oct-93 | 21.0 | | | | | e | f | g |
| | Mar-94 | 21.0 | | | | | e | f | g |
| | May-94 | 19.4 | | | | | e | f | g |
| | Sep-94 | 23.3 | | | c | d | e | f | g |
| | Jan-95 | 23.5 | | | c | d | e | f | g |
| | May-95 | 21.7 | | | | d | e | f | g |
| | Nov-95 | 25.1 | | b | c | d | e | f | g |
| | Jun-96 | 19.6 | | | | | e | f | g |
| | Dec-96 | 21.6 | | | | | e | f | g |
| | May-97 | 27.0 | | b | c | d | e | f | g |
| | Nov-97 | 42.5 | a | b | c | d | e | | |
| | May-98 | 49.4 | a | b | c | | | | |
| | Nov-98 | 46.1 | a | b | c | d | | | |
| | May-99 | 40.7 | a | b | c | d | e | f | g |
| | Dec-99 | 48.0 | a | b | c | | | | |
| | Jun-00 | 47.5 | a | b | c | | | | |
| | Feb-01 | 51.0 | a | | | | | | |
| | May-01 | 52.5 | a | | | | | | |
| | Dec-01 | 48.6 | a | b | | | | | |
| | Jun-02 | 48.2 | a | b | c | | | | |
| | Jul-05 | 30.8 | a | b | c | d | e | f | g |
| | Nov-05 | 30.2 | a | b | c | d | e | f | g |
| | Jul-06 | 35.8 | a | b | c | d | e | f | g |
| | Jan-07 | 38.5 | a | b | c | d | e | f | |
| | Oct-07 | 52.4 | a | | | | | | |
| | Jul-08 | 54.7 | a | | | | | | |
| | Oct-08 | 39.5 | a | b | c | d | e | f | |
| | May-09 | 39.5 | a | b | c | d | e | | |
| Location | | | | | | | | | |
| | Wawaloli | 21.1 | | | | | e | | |
| | 18-inch Pipe | 29.2 | | | c | d | | | |
| | 12-inch South | 32.4 | | | c | | | | |
| | 12-inch North | 31.6 | | | c | d | | | |
| | NPPE | 51.7 | a | | | | | | |
| | Ho'ona Bay | 41.6 | | b | | | | | |
| Biotope | | | | | | | | | |
| | Shallow | 26.0 | | b | | | | | |
| | Middle | 36.4 | a | | | | | | |
| | Deep | 41.4 | a | | | | | | |

Table 4. Summary of three-way analysis of variance (ANOVA) of mean *Porites lobata* abundance (percent cover) for surveys conducted off NELHA from 1992 - 2009. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

| | | Mean | | | group | | |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |
| | May-92 | 10.3 | | | | | e |
| | Oct-92 | 10.0 | | | | | e |
| | May-93 | 10.9 | | | | | e |
| | Oct-93 | 11.4 | | | | | e |
| | Mar-94 | 12.2 | | | | d | e |
| | May-94 | 10.4 | | | | | e |
| | Sep-94 | 13.1 | | | | d | e |
| | Jan-95 | 14.6 | | b | c | d | e |
| | May-95 | 12.2 | | | | | e |
| | Nov-95 | 13.3 | | | c | d | e |
| | Jun-96 | 10.4 | | | | | e |
| | Dec-96 | 11.0 | | | | | e |
| | May-97 | 13.7 | | | c | d | e |
| | Nov-97 | 20.6 | a | b | c | d | e |
| | May-98 | 22.9 | a | b | c | d | e |
| | Nov-98 | 20.9 | a | b | c | d | e |
| | May-99 | 18.9 | a | b | c | d | e |
| | Dec-99 | 21.5 | a | b | c | d | e |
| | Jun-00 | 20.9 | a | b | c | d | e |
| | Feb-01 | 22.5 | a | b | c | d | e |
| | May-01 | 22.5 | a | b | c | d | e |
| | Dec-01 | 22.5 | a | b | c | d | e |
| | Jun-02 | 22.7 | a | b | c | d | e |
| | Jul-05 | 16.7 | a | b | c | d | e |
| | Nov-05 | 17.7 | a | b | c | d | e |
| | Jul-06 | 19.8 | a | b | c | d | e |
| | Jan-07 | 22.3 | a | b | c | d | e |
| | Oct-07 | 30.7 | a | b | | | |
| | Jul-08 | 29.8 | a | | | | |
| | Oct-08 | 25.8 | a | b | c | d | |
| | May-09 | 25.9 | a | b | c | | |
| Location | | | | | | | |
| | Wawaloli | 12.6 | | b | | | |
| | 18-inch Pipe | 11.5 | | b | | | |
| | 12-inch South | 14.6 | | b | | | |
| | 12-inch North | 15.8 | | b | | | |
| | NPPE | 30.4 | a | | | | |
| | Ho'ona Bay | 21.7 | a | | | | |
| Biotope | | | | | | | |
| | Shallow | 12.5 | | | b | | |
| | Middle | 19.0 | | a | | | |
| | Deep | 21.7 | | a | | | |

Table 5. Summary of three-way analysis of variance (ANOVA) of mean *Pocillopora meandrina* abundance (percent cover) for surveys conducted off NELHA from 1992 - 2009. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

| | | Mean | group | | | | |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |
| | May-92 | 4.3 | | | | | e |
| | Oct-92 | 3.7 | | | | | e |
| | May-93 | 4.3 | | | | | e |
| | Oct-93 | 5.0 | | | | d | e |
| | Mar-94 | 4.0 | | | | | e |
| | May-94 | 4.5 | | | | d | e |
| | Sep-94 | 4.9 | | | | d | e |
| | Jan-95 | 4.5 | | | | d | e |
| | May-95 | 4.8 | | | | d | e |
| | Nov-95 | 7.0 | | b | c | d | e |
| | Jun-96 | 5.3 | | | | d | e |
| | Dec-96 | 6.3 | | | c | d | e |
| | May-97 | 8.0 | a | b | c | d | e |
| | Nov-97 | 13.0 | a | b | c | d | e |
| | May-98 | 14.9 | a | b | c | d | |
| | Nov-98 | 13.6 | a | b | c | d | e |
| | May-99 | 12.3 | a | b | c | d | e |
| | Dec-99 | 17.5 | a | b | c | | |
| | Jun-00 | 17.8 | a | b | c | | |
| | Feb-01 | 20.0 | a | b | | | |
| | May-01 | 20.3 | a | | | | |
| | Dec-01 | 16.7 | a | b | c | | |
| | Jun-02 | 16.1 | a | b | c | | |
| | Jul-05 | 8.6 | a | b | c | d | e |
| | Nov-05 | 8.0 | a | b | c | d | e |
| | Jul-06 | 9.0 | a | b | c | d | e |
| | Jan-07 | 9.4 | a | b | c | d | e |
| | Oct-07 | 10.2 | a | b | c | d | e |
| | Jul-08 | 11.8 | a | b | c | d | e |
| | Oct-08 | 7.3 | a | b | c | d | e |
| | May-09 | 8.1 | a | b | c | d | e |
| Location | | | | | | | |
| | Wawaloli | 5.5 | | b | | | |
| | 18-inch Pipe | 13.6 | a | | | | |
| | 12-inch South | 13.0 | a | | | | |
| | 12-inch North | 10.2 | a | | | | |
| | NPPE | 12.4 | a | | | | |
| | Ho'ona Bay | 3.7 | | b | | | |
| Biotope | | | | | | | |
| | Shallow | 10.2 | a | | | | |
| | Middle | 11.5 | a | | | | |
| | Deep | 7.7 | | b | | | |

All three coral variables (total coral cover, *Porites lobata* abundance and *Pocillopora meandrina* abundance) showed the same temporal pattern: levels that were statistically similar between May 1992 and May 1997, with some suggestion of small increases over that period; a sudden increase on the order of 60 - 100% between the May 1997 and November 1997 surveys; relatively similar levels between November 1997 and May 2002; decreases in the July 2005 – January 2007 surveys to levels slightly higher but not statistically significantly different from those observed in May 1997; increases to the highest levels observed in surveys conducted in October 2007 and July 2008 and decreases in October 2008 to levels similar to January 2007. Increases in coral cover, whether for individual species or for total coral, on the order of 60 – 100% over a 6-month period are likely not reflections of actual increase in coral abundance; rather, they may represent basic changes in the manner or area in which surveys were conducted.

Benthic monitoring surveys have been conducted by different parties over the course of the CEMP program: Marine Research Consultants (MRC, Dr. Steven Dollar) from August 1991 – May 1995; Oceanic Institute (OI, Dr. David Ziemann), four surveys from November 1995 – May 1997; Marine Research Consultants (MRC, Dr. Steven Dollar), ten surveys from November 1997 – June 2002; Oceanic Institute (OI, Dr. David Ziemann), four surveys between July 2005 and January 2007; Marine Research Consultants (MRC, Dr. Steven Dollar), two surveys in October 2007 and July 2008; and Dr. David Ziemann, the surveys in October 2008 and May 2009. In their report (Marine Research Consultants, 1998) of the results of the November 1997 survey, the first conducted by MRC following the two-year period during which surveys were conducted by OI, the MRC authors choose not to include the data from the OI surveys of November 1995 – May 1997 in their analysis, speculating "it appears that locations of the monitoring sites were not identical between the two investigators", but the present analysis shows the results of the four OI surveys between November 1995 and May 1997 were not significantly different from those conducted by MRC up to May 1995. Table 6 of the MRC report for the November 1997 survey (Marine Research Consultants, 1998) clearly shows highly significant differences between the coral abundances found in their prior surveys (through 1995) and their November 1997 survey. While the significant difference between surveys conducted up to May 1995 and after November 1997 is recognized (Marine Research Consultants, 1998), it is attributed to "increased coral cover at many of the survey sites directly off the NELHA facility."

The overall mean total coral cover, mean *Porites lobata* cover, and mean *Pocillopora meandrina* cover for six periods during which monitoring was conducted by different contractors are presented below. Figures in bold type represent mean values that are significantly different from the remaining means (see Tables 3 – 5 and accompanying text for details). Mean total coral cover and cover for *P. lobata* and *Poc. meandrina* was not significantly different between monitoring conducted by MRC in 1992 – 1995, by OI between 1995 – 1997, by OI in 2005 – 2007 and by Ziemann between 2008 - 2009. Mean values were significantly higher, however, for the monitoring conducted by MRC between 1997 - 2002 and 2007 - 2008.

| Dates | Monitor | Mean Total Coral Cover | Mean *Porites lobata* cover | Mean *Pocillopora meandrina* cover |
|---|---|---|---|---|
| May 1992 – May 1995 | Marine Research Consultants | 20.4 | 11.7 | 4.5 |
| Nov 1995 – May 1997 | Oceanic Institute | 23.4 | 12.1 | 6.7 |
| Nov 1997 – Jun 2002 | Marine Research Consultants | **47.4** | **21.6** | **11.2** |
| Jul 2005 - Jan 2007 | Oceanic Institute | 33.3 | 19.1 | 8.8 |
| Oct 2007 – July 2008 | Marine Research Consultants | **53.6** | **30.3** | **11.0** |
| Oct 2008 – May 2009 | David A. Ziemann | 39.5 | 25.8 | 7.3 |

Mean total coral cover, and cover for *P. lobata* and *Poc. meandrina* increased by 19.1, 14.1 and 2.8%, respectively, over the approximately 24-year period 1992-1995 and 2008. These rates of increase are consistent with natural increases in coral cover on Hawaiian reefs. These data suggest that there have been no significant changes in coral abundance that might be attributable to operations at NELHA, or to natural disturbances such as storm surf.

MARINE NEARSHORE FISH RESOURCES MONITORING PROGRAM

INTRODUCTION

The fish community at NELHA has long been recognized as being particularly abundant and speciose (Brock, 1985; Brock, 1995). Nearshore fish communities might be expected to respond in a quantifiable way to changes in the natural input of material via groundwater, either directly or in response to changes at lower trophic levels. It is upon this expectation that the CEMP has focused activities on the nearshore fish communities at NELHA. Between 1989 and the present, 32 surveys of the fish communities have been completed. The results of the first 12 surveys through May 1995 are summarized in Brock, 1995; for November 1995 through May 1997 surveys in Oceanic Institute 1997; for surveys conducted between November 1997 and June 2002 in Brock, 2002; for July 2005 – January 2007 in Oceanic Institute 2007; for December 2007 and August 2008 in Brock 2008; for October 2008 in Ziemann 2008. Results from the current survey performed in May 2009 are presented below. The data from the 31 complete surveys (May 1992 – May 2009) are used in the subsequent analysis of long-term trends.

METHODS

Surveys to examine the nearshore fish populations were performed using SCUBA between May 16 – 18, 2009. Surveys were performed at six locations along the NELHA coastline (Figure 3): Ho'ona Bay, the NPPE site, 12" Pipe - North, 12" Pipe - South, 18" Pipe, and Wawaloli. At each location, a series of three transects were laid out, starting at permanently placed markers or facility features (NELHA supply pipes). Transects were performed in the shallow (~5m) boulder zone, the intermediate depth (~8-10 m) reef bench, and the deeper (15-20 m) reef slope. These station locations and transect depths have been chosen as representative of major biotopes along the Kona coast (Dollar, 1975, 1982; Dollar and Tribble, 1993), and are the same locations occupied in previous surveys (Marine Research Consultants, 1995, 2002, 2008; Brock, 1995, 2002, 2008; Oceanic Institute, 1997, 2007; Ziemann 2008). At each location, a 25 m transect was laid out parallel to the depth contours, and all the fish within a 4 m wide corridor, from the bottom to the surface, were identified and counted. The size of each fish was also estimated for calculation of biomass (Maynard, 1988).

The results of the survey were tabulated and basic statistics generated: the total number of species observed, the total number of individuals observed, and the total biomass calculated from species, number of individuals, size of individuals, and tables of weights for representative sizes for each species. Species diversity for fish was calculated using Shannon's Index (Ludwig and Reynolds, 1988).

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

where $n_i$ = the number of individuals in the $i^{th}$ species and n = the total number of individuals on the transect.

## RESULTS

The results of the fish surveys conducted off NELHA in May 2009 in terms of number of species, individual abundance, biomass, and species diversity are summarized in Table 6 and Figure 4 and presented in detail in Appendix D.1 – D.5.

### Numerical Abundance and Habitat Distribution

The number of individuals per transect for the May 2009 fish survey off NELHA are summarized in Table 6. Numerical abundance varied widely between locations and habitats (Fig. 4A). Highest number of individuals occurred at the 12" Pipe South and NPPE location, deep transect (535 and 543, respectively). The number of individuals at the other five locations ranged from 139 to 386. The mean number of fish observed was not significantly different between locations ($p = 0.295$), or between biotope types ($p = 0.356$; two-way ANOVA on raw data, Tukey test on interactions).

### Number of Species

The number of species per transect for the May 2009 survey off NELHA is summarized in Table 6 and Figure 4B. The mean number of species observed per transect ranged from 21.7 at Wawaloli to 29.7 at the 12" Pipe South site. The number of species observed at the 18" Pipe, 12" Pipe South and 12" Pipe North locations were significantly higher than the number observed at the other three locations. ($p = 0.002$; two-way ANOVA on raw data, Tukey test on interactions, $p = 0.05$). The mean number of species per transect ranged from 21.8 in the shallow boulder habitats to 27.3 in the deep reef slope habitat. The number of species observed in the shallow habitat was significant different from the number of species observed in the middle and deep habitats ($p = 0.001$; two-way ANOVA on raw data, Tukey test on interactions).

In all areas and habitat zones, most of the species were from two families, the pomacentrids (damsel fish) and acanthurids (surgeon fish). The specific composition of these families varied somewhat between the habitat zones. Seven species were widely distributed throughout all three habitat zones: *Chromis vanderbilti, Acanthurus nigrofuscus, Ctenochaetus strigosus, Zebrasoma flavescens, Paracirrhites arcatus, Thalassoma duperrey* and *Chaetodon multicinctus.* Many of these species were usually found dispersed throughout the area, although *Chromis vanderbilti* and *Zebrasoma flavescens* often congregated in schools. *C. vanderbilti* was ubiquitous at all stations except the reef bench and slope habitats at Ho'ona Bay, where it was absent or rare.

### Species Diversity

Shannon's Index for species diversity for the May 2009 survey off NELHA is summarized in Table 6. Mean species diversity ranged from 1.78 at the 18" Pipe station to 2.11 at the 12" Pipe North station, but there were no significant differences between locations ($p = 0.543$). Mean species diversity was not significantly different between habitats ($p = 0.708$).

Table 6. Summary of quantitative fish transects conducted off Natural Energy Laboratory of Hawaii on May 16 - 18, 2009. Locations of transects are shown in Figure 3. Quantitative data are presented in Appendix D.

| Station | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep |
| Total number | 240 | 139 | 174 | 343 | 366 | 347 | 207 | 386 | 535 |
| Number of species | 21 | 20 | 24 | 25 | 26 | 30 | 25 | 31 | 33 |
| Diversity | 1.84 | 2.05 | 1.72 | 1.70 | 1.85 | 1.80 | 2.02 | 1.66 | 1.91 |
| Biomass ($g/m^2$) | 268 | 34 | 70 | 88 | 198 | 94 | 110 | 146 | 82 |

| Station | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep |
| Total number | 326 | 260 | 199 | 203 | 186 | 543 | 229 | 177 | 235 |
| Number of species | 22 | 29 | 28 | 19 | 22 | 26 | 19 | 25 | 23 |
| Diversity | 1.88 | 2.00 | 2.45 | 2.11 | 2.03 | 1.45 | 2.03 | 2.37 | 1.88 |
| Biomass ($g/m^2$) | 114 | 74 | 60 | 122 | 100 | 66 | 119 | 95 | 75 |

| Survey Means | Wawaloli Beach | 18" Pipe | 12" Pipe South | 12" Pipe North | NPPE | Ho'ona Bay | p level | Shallow | Middle | Deep | p level |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total number | 184.3 | 352.0 | 376.0 | 261.7 | 310.7 | 213.7 | 0.30 | 258.0 | 252.3 | 338.8 | 0.36 |
| Number of species | 21.7 b | **27.0** a | **29.7** a | **26.3** a | 22.3 b | 22.3 b | **0.002** | 21.8 b | **25.5** a | **27.3** a | **0.001** |
| Diversity | 1.87 | 1.78 | 1.86 | 2.11 | 1.86 | 2.09 | 0.54 | 1.93 | 1.99 | 1.87 | 0.71 |
| Biomass ($g/m^2$) | 123.8 | 126.6 | 112.7 | 82.8 | 96.2 | 96.3 | 0.75 | 136.9 a | 107.8 ab | 74.5 b | **0.04** |

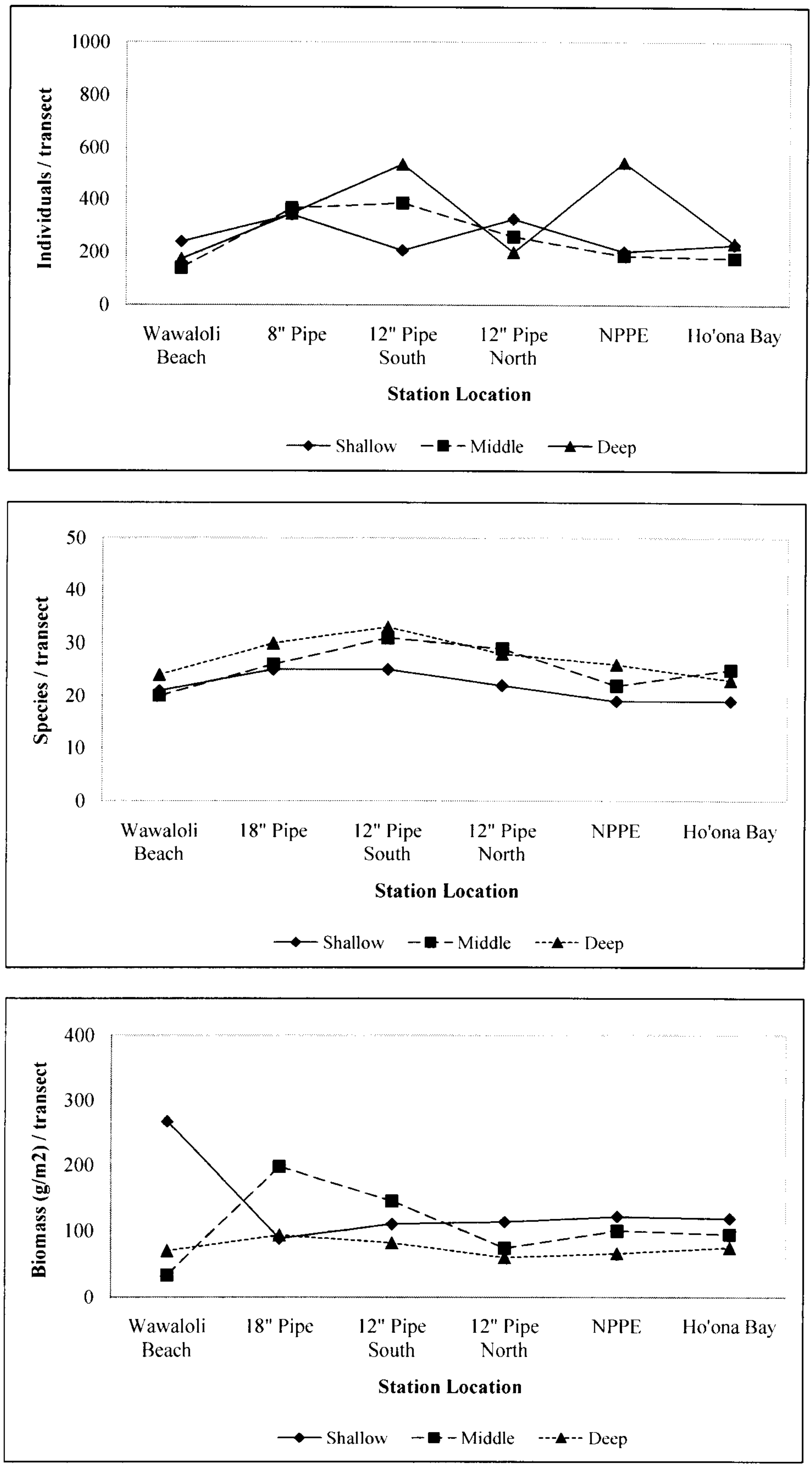


Figure 4. Plots of A: numerical abundance; B: number of species; and C: biomass ($g/m^2$) per transect for fish surveys conducted of NELHA in May 2009. Station locations are shown in Figure 3.

Biomass

The distribution of fish biomass per transect for the May 2009 survey off NELHA is summarized in Table 6 and presented in Figure 4C. There were no significant differences between mean biomass per transect for locations ($p = 0.749$) but differences were significant between habitats ($p = 0.040$). Mean biomass was highest at the 18" Pipe site (127 $g/m^2$); differences between other locations were not significant. Mean biomass was significantly different between habitats, lowest in the deep reef slope habitat (74.5 $g/m^2$) and highest in the shallow boulder habitat (136.9 $g/m^2$).

The acanthurid (surgeonfish) family made the largest contribution to biomass because of their large size, schooling tendencies and wide distribution. Pomacentrids (damselfishes), despite their high abundance, contributed only a fraction of the biomass because of their small size (<5 cm).

Comparative Analysis

Data for the NELHA fish monitoring program have been collected since May 1989. However, the current arrangement of six stations with three transects at each station was not established until May 1992. Since that time, 31 surveys, including the present survey, have been conducted. The balanced design and complete coverage afforded by the current survey arrangement provides a powerful database for statistical analysis. Although the three surveys performed between May 1989 and March 1992 provide additional temporal scale, their incomplete coverage provides little statistical power. In addition, the free swimming nature of the fish populations means that they can leave and return to areas of disturbance rapidly, compared to the sessile benthic organisms which are relatively permanently located. Therefore, the statistical analyses which follow incorporate data only from May 1992 to May 2009, inclusive.

The surveys for fish populations provided data for three variables (number of species, number of individuals and biomass per transect) for three sources of variance (date, location [stations] and habitat [transects]). Summary data for these parameters for 32 surveys from May 1992 to May 2009 are presented in Appendix D.3 – D.5, respectively. Three-way analyses of variance (ANOVA) tests were performed on data for each of the three fish population variables using SigmaStat for Windows, a PC-based statistical analysis program. Three-way ANOVA provides an estimate of the significance of the differences between levels for each source of variance, while post hoc pair-wise analyses provides details of which pairs of data are significantly different. If the data failed either the test that the data were normally distributed (normality test) or that the variances were equally distributed, the tests were performed using the rank-transformed data rather that the untransformed data. The ANOVA test utilizing ranked data is known as the Kruskal-Wallis analysis of variance on ranks (K-W test), while the multiple pairwise comparison test on ranked data is known as the Student-Newman-Keuls Method (SNK test). The level of significance for all tests was $p = 0.05$.

Results of the three-way ANOVA on rank-transformed data for number of individuals per transect, number of species per transect and biomass per transect by date, location and habitat are summarized below and presented in detail in Tables 7 – 9, respectively. Mean number of individuals, species and biomass were all significantly different for date, location and habitat.

Summary of three-way analysis of variance on ranked data (Kruskal-Wallis test) for date of survey, number of individuals, number of fish species and biomass per transect for survey conducted between November 1992 and May 2009.

| Parameter | Source of Variance | Probability | Significance |
|---|---|---|---|
| Individuals | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | <0.001 | highly significant |
| Species | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | 0.001 | highly significant |
| Biomass | Date | <0.001 | highly significant |
| | Location | <0.001 | highly significant |
| | Habitat | <0.001 | highly significant |

A summary of the post-hoc S-N-K test for pair-wise comparisons on numbers of individuals per transect for date, location and habitat is presented in Table 7. While the ANOVA indicated significant differences between mean abundance by date, mean abundance showed no temporal pattern of differences that would suggest impacts due to anthropogenic influences (Figure 5). The fourteen surveys with highest abundance levels were significantly higher than the eleven surveys with lowest abundances, but these high levels were separated in time by one to two years, and periods with significantly lower abundances, and are likely due to seasonal variability or the occasional presence of large schools of fish within the transect area. Surveys conducted between May 1992 and October 2008 fell within a group of data that were not significantly different, suggesting that no change in fish abundance has taken place over the 16-year monitoring period.

Mean abundance (Figure 6) was significantly higher at the 18" Pipe site (457 individuals per transect) than at the next highest site (12" Pipe South – 420 individuals per transect). Mean abundance at the remaining four locations were not significantly different (283 – 324 individuals per transect). Abundance was significantly higher at the deep reef slope habitat (388 individuals per transect) than at the other two habitats (330 – 335 individuals per transect).

A summary of the post-hoc S-N-K test for pair-wise comparisons on numbers of species per transect for date, location and habitat is presented in Table 8. While the ANOVA indicated significant differences between mean number of species by date, mean species per transect showed no pattern of differences that would suggest impacts due to anthropogenic influences (Figure 7). Mean number of species per transect ranged from 24.2 to 33.2, and data for surveys conducted between May 1992 and October 2008 fell within a group of data that were not significantly different, suggesting that no change in the number of fish species in the NELHA area has taken place over the 16-year monitoring period. Mean species per transect (Figure 8) were similar and significantly higher at the 18" Pipe site (32.4 species per transect) and 12" Pipe

South site (31.0 species per transect). The fewest species were seen at the Wawaloli site (23.1 species per transect). Significantly fewer species were seen in the reef bench habitat (27.5 species per transect) than in the deep reef slope habitat (29.0 species per transect) or the shallow boulder habitat (28.5 species per transect).

A summary of the post-hoc S-N-K test for pair-wise comparisons on mean biomass per transect for date, location and habitat is presented in Table 9. While the ANOVA indicated significant differences between mean biomass by date, mean biomass showed no pattern of differences that would suggest impacts due to anthropogenic influences (Figure 9). A single survey in November 1998 (Figure 10) had biomass levels higher than the remaining 26 surveys, but this high level is likely due to the presence of large schools of fish within the transect area. Biomass for surveys conducted between May 1992 and October 2008 fell within a group of data that were not significantly different (ranging from 120 – 620 $g/m^2$), suggesting that no change in fish biomass has taken place over the 15-year monitoring period. Mean biomass (Figure 10) was significantly highest at the 12" Pipe South site (303 $g/m^2$). Biomass at the 18" Pipe and 12" Pipe North sites were lower and not significantly different (232 – 237 $g/m^2$). Biomass at NPPE, Wawaloli and Ho'ona Bay were lowest (143 – 178 $g.m^2$). Biomass was significantly higher at the shallow boulder habitat (250 $g/m^2$) than at the other two habitats (170 – 205 $g/m^2$).

Table 7. Summary of three-way analysis of variance (ANOVA) of number of individuals per transect for surveys conducted off NELHA from 1992 - 2008. Data ln-transformed to pass normality test. All pair-wise comparisons tested by Holm-Sidak method. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

| Date | Mean | group | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| May-92 | 318.2 | | | | d | e | f | g | h |
| Oct-92 | 341.2 | | b | c | d | e | f | g | h |
| May-93 | 295.3 | | | | | | f | g | h |
| Dec-93 | 389.4 | a | b | c | d | e | f | g | h |
| May-94 | 351.6 | | b | c | d | e | f | g | h |
| Jun-94 | 359.1 | a | b | c | d | e | f | g | h |
| Oct-94 | 379.7 | a | b | c | d | e | f | g | h |
| Mar-95 | 278.9 | | | | | | | g | h |
| Jun-95 | 477.2 | a | b | | | | | | |
| Nov-95 | 241.2 | | | | | | | | h |
| Jun-96 | 297.2 | | | | | | f | g | h |
| Dec-96 | 284.6 | | | | | | f | g | h |
| May-97 | 302.4 | | | | d | e | f | g | h |
| Dec-97 | 473.7 | a | b | c | | | | | |
| Jun-98 | 301.7 | | | | | e | f | g | h |
| Nov-98 | 510.6 | a | | | | | | | |
| May-99 | 320.6 | | | c | d | e | f | g | h |
| Dec-99 | 352.3 | | b | c | d | e | f | g | h |
| Jun-00 | 313.6 | | | | d | e | f | g | h |
| Nov-00 | 452.0 | a | b | c | d | e | | | |
| May-01 | 359.5 | a | b | c | d | e | f | g | h |
| Nov-01 | 286.3 | | | | | | f | g | h |
| May-02 | 364.3 | a | b | c | d | e | f | g | h |
| Jul-05 | 249.6 | | | | | | | | h |
| Nov-05 | 376.8 | a | b | c | d | e | f | g | h |
| Jul-06 | 465.1 | a | b | c | d | | | | |
| Jan-07 | 345.2 | | b | c | d | e | f | g | h |
| Dec-07 | 436.3 | a | b | c | d | e | f | | |
| Aug-08 | 452.7 | a | b | c | d | e | | | |
| Oct-08 | 412.8 | a | b | c | d | e | f | g | |
| May-09 | 283.1 | | | | | | f | g | h |

| Location | Mean | | | |
|---|---|---|---|---|
| Wawaloli | 306.5 | | | c |
| 18-inch Pipe | 468.2 | a | | |
| 12-inch South | 430.6 | a | b | |
| 12-inch North | 305.5 | | | c |
| NPPE Site | 318.3 | | | c |
| Ho'ona Bay | 314.0 | | | c |

| Biotope | Mean | | |
|---|---|---|---|
| Shallow | 335.3 | | b |
| Middle | 332.9 | | b |
| Deep | 403.3 | a | |

Table 8. Summary of three-way analysis of variance (ANOVA) of number of species per transect for surveys conducted off NELHA from 1992 - 2008. All pair-wise comparisons tested by Holm-Sidak method. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

| Date | Mean | group | | | | | | |
|---|---|---|---|---|---|---|---|---|
| May-92 | 29.8 | a | b | c | d | | | |
| Oct-92 | 28.7 | | b | c | d | e | f | |
| May-93 | 27.1 | | | c | d | e | f | g |
| Dec-93 | 29.9 | a | b | c | d | | | |
| May-94 | 28.8 | | b | c | d | e | f | |
| Jun-94 | 29.8 | a | b | c | d | | | |
| Oct-94 | 27.7 | | b | c | d | e | f | g |
| Mar-95 | 25.1 | | | | | e | f | g |
| Jun-95 | 29.9 | a | b | c | d | | | |
| Nov-95 | 27.1 | | | c | d | e | f | g |
| Jun-96 | 27.4 | | b | c | d | e | f | g |
| Dec-96 | 24.2 | | | | | | | g |
| May-97 | 26.1 | | | | d | e | f | g |
| Dec-97 | 28.4 | | b | c | d | e | f | g |
| Jun-98 | 26.6 | | | c | d | e | f | g |
| Nov-98 | 31.1 | a | b | c | | | | |
| May-99 | 31.7 | a | b | | | | | |
| Dec-99 | 26.9 | | | c | d | e | f | g |
| Jun-00 | 33.2 | a | | | | | | |
| Nov-00 | 30.3 | a | b | c | d | | | |
| May-01 | 31.0 | a | b | c | | | | |
| Nov-01 | 29.1 | a | b | c | d | e | | |
| May-02 | 31.1 | a | b | c | | | | |
| Jul-05 | 24.6 | | | | | | f | g |
| Nov-05 | 25.3 | | | | | e | f | g |
| Jul-06 | 26.3 | | | | d | e | f | g |
| Jan-07 | 25.9 | | | | d | e | f | g |
| Dec-07 | 29.2 | a | b | c | d | e | | |
| Aug-08 | 29.3 | a | b | c | d | e | | |
| Oct-08 | 28.7 | | b | c | d | e | f | |
| May-09 | | | | | | | | |

| Location | Mean | | | | |
|---|---|---|---|---|---|
| Wawaloli | 23.1 | | | | d |
| 18-inch Pipe | 32.4 | a | | | |
| 12-inch South | 31.0 | a | | | |
| 12-inch North | 29.9 | | b | | |
| NPPE Site | 27.4 | | | c | |
| Ho'ona Bay | 26.3 | | | c | |

| Biotope | Mean | | |
|---|---|---|---|
| Shallow | 28.5 | a | |
| Middle | 27.5 | | b |
| Deep | 29.0 | a | |

Table 9. Summary of three-way analysis of variance (ANOVA) of biomass (g/m$^2$) per transect for surveys conducted off NELHA from 1992 - 2008. Data rank-transformed to pass normality test. All pair-wise comparisons tested by Holm-Sidak method. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

| Date | Mean | | | group | | |
|---|---|---|---|---|---|---|
| May-92 | 159.8 | a | b | c | d | e |
| Oct-92 | 177.7 | a | b | c | d | e |
| May-93 | 154.1 | | b | c | d | e |
| Dec-93 | 289.8 | a | b | c | | |
| May-94 | 173.8 | a | b | c | d | e |
| Jun-94 | 157.0 | | b | c | d | e |
| Oct-94 | 205.6 | a | b | c | d | e |
| Mar-95 | 193.4 | a | b | c | d | e |
| Jun-95 | 185.7 | a | b | c | d | e |
| Nov-95 | 148.3 | | | | d | e |
| Jun-96 | 137.5 | | | | | e |
| Dec-96 | 187.6 | a | b | c | d | e |
| May-97 | 183.7 | a | b | c | d | e |
| Dec-97 | 408.1 | a | b | | | |
| Jun-98 | 160.6 | a | b | c | d | e |
| Nov-98 | 620.1 | a | | | | |
| May-99 | 170.9 | a | b | c | d | e |
| Dec-99 | 261.2 | a | b | c | d | |
| Jun-00 | 314.6 | a | b | | | |
| Nov-00 | 284.6 | a | b | c | d | |
| May-01 | 177.1 | a | b | c | d | e |
| Nov-01 | 144.1 | | | | d | e |
| May-02 | 153.3 | | | c | d | e |
| Jul-05 | 119.2 | | | | | e |
| Nov-05 | 173.9 | a | b | c | d | e |
| Jul-06 | 178.6 | a | b | c | d | e |
| Jan-07 | 233.3 | a | b | c | d | |
| Dec-07 | 213.5 | a | b | c | d | e |
| Aug-08 | 162.9 | a | b | c | d | e |
| Oct-08 | 130.5 | | | | | e |
| | | | | | | |
| **Location** | **Mean** | | | | | |
| Wawaloli | 159.0 | | | c | | |
| 18-inch Pipe | 237.0 | | b | | | |
| 12-inch South | 302.8 | a | | | | |
| 12-inch North | 231.7 | | b | | | |
| NPPE Site | 178.4 | | | c | | |
| Ho'ona Bay | 143.2 | | | c | | |
| | | | | | | |
| **Biotope** | **Mean** | | | | | |
| Shallow | 250.1 | a | | | | |
| Middle | 170.1 | | | c | | |
| Deep | 205.8 | | b | | | |

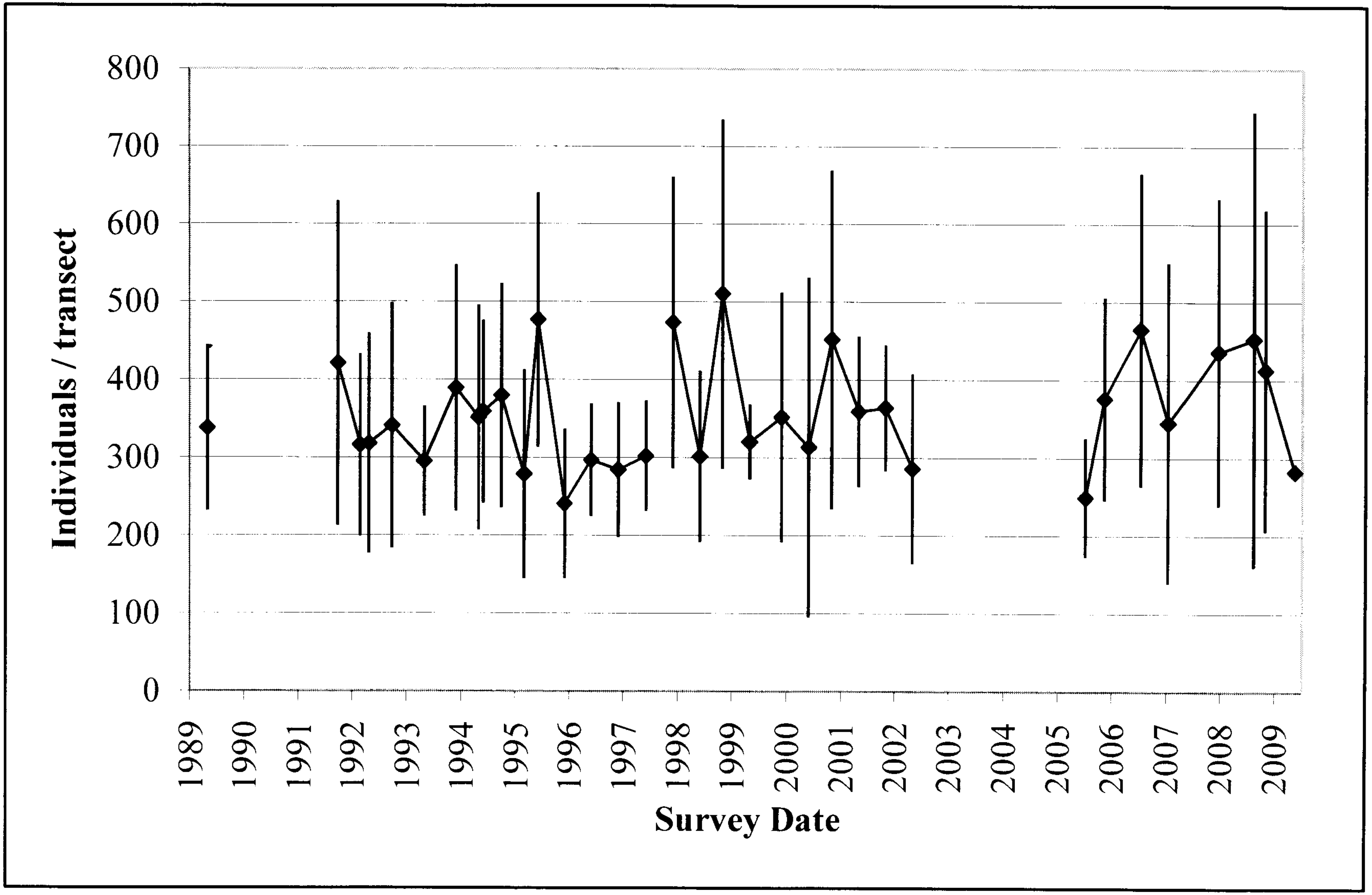


Figure 5. Plot of mean number of individuals (with standard deviation) per transect for each survey from 1989 through 2009 off NELHA.

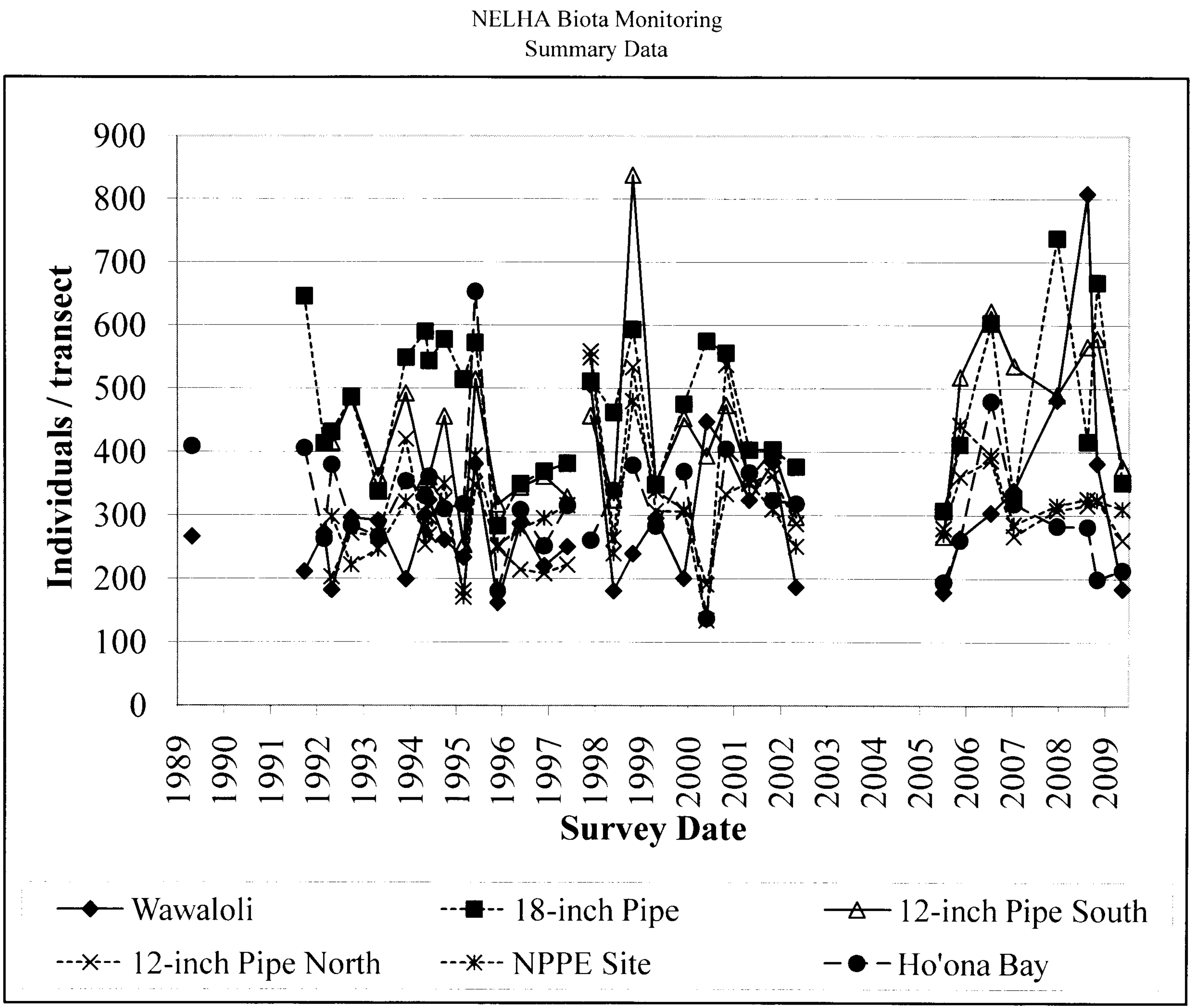


Figure 6. Plot of mean number of individuals per transect across the three biotopes at each of six survey locations off NELHA between 1989 and 2009.

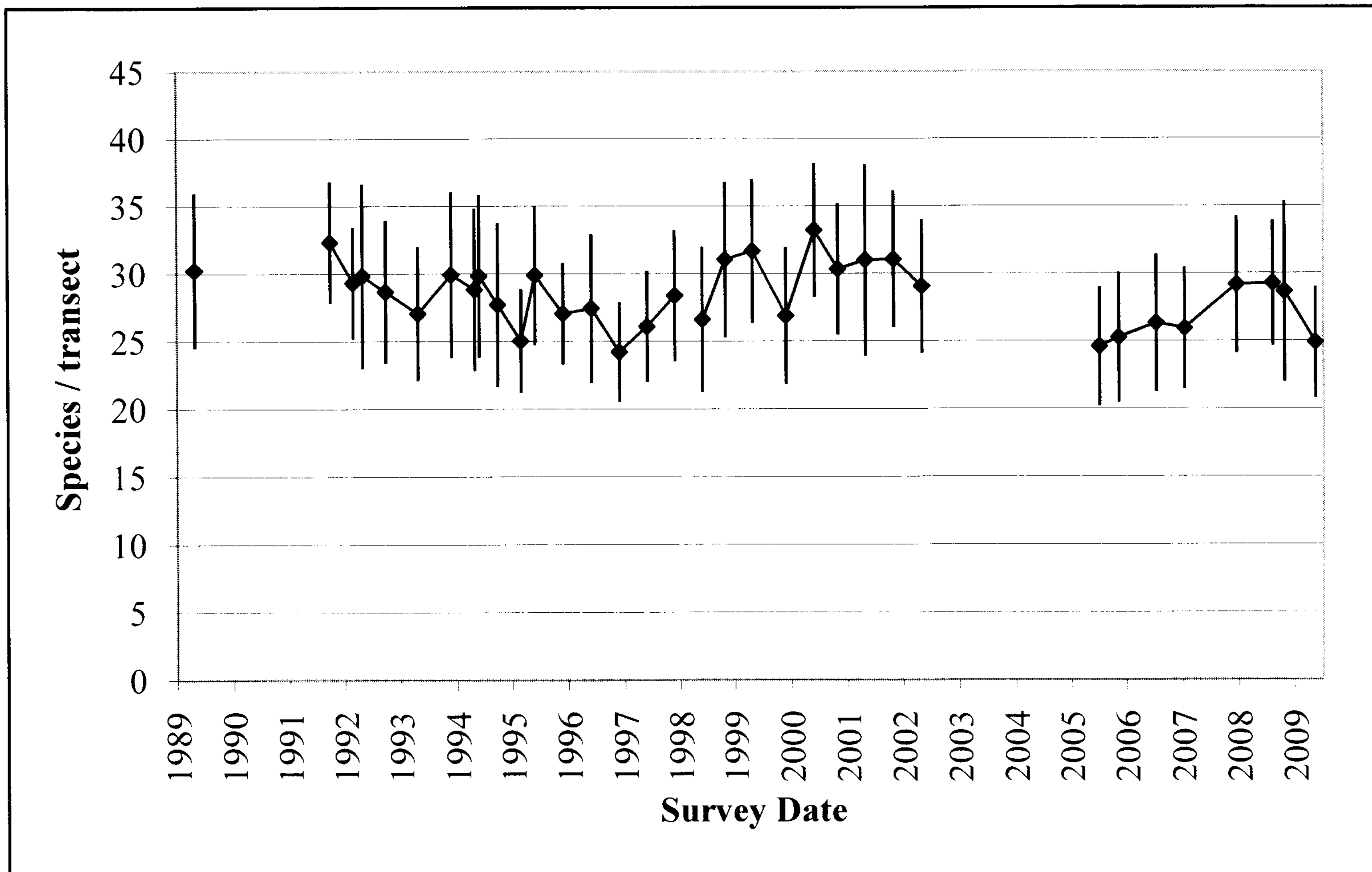


Figure 7. Plot of mean number of species (with standard deviation) per transect for each survey off NELHA from 1989 through 2009.

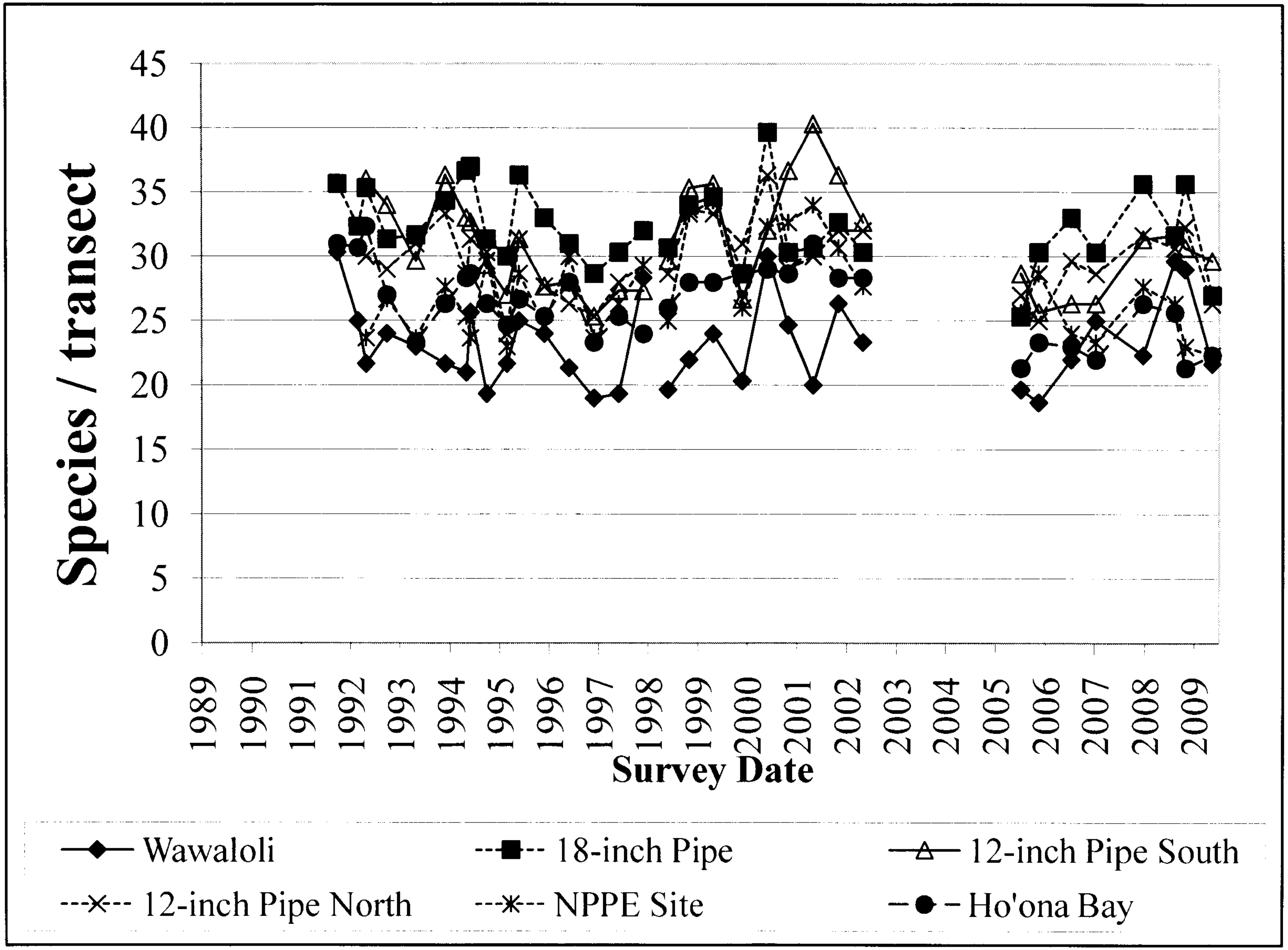


Figure 8. Plot of mean number of species per transect across the three biotopes at six survey locations off NELHA from 1989 through 2009.

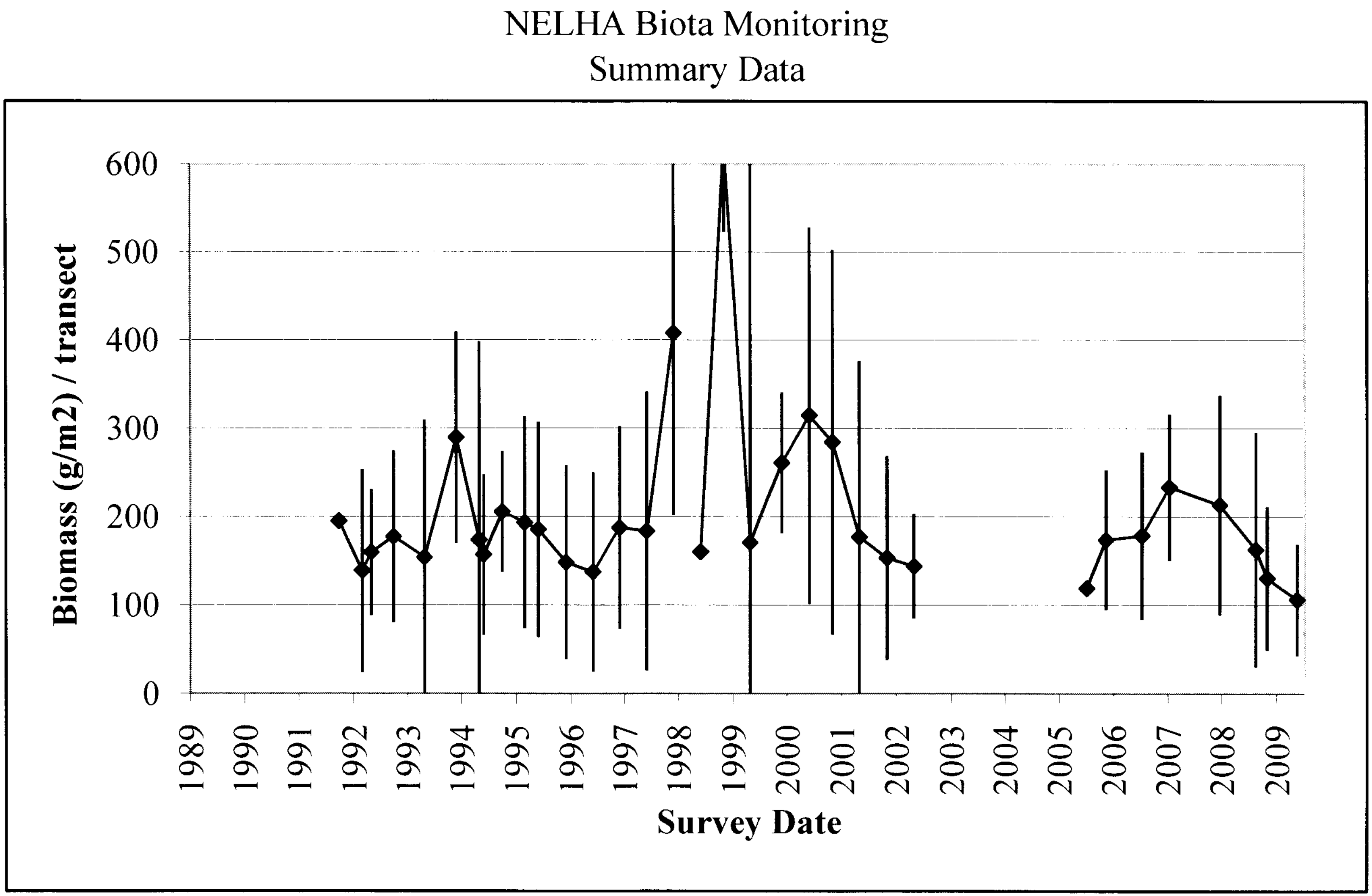


Figure 9. Plot of mean (standard deviation) biomass per transect for surveys off the NELHA site from 1992 - 2009.

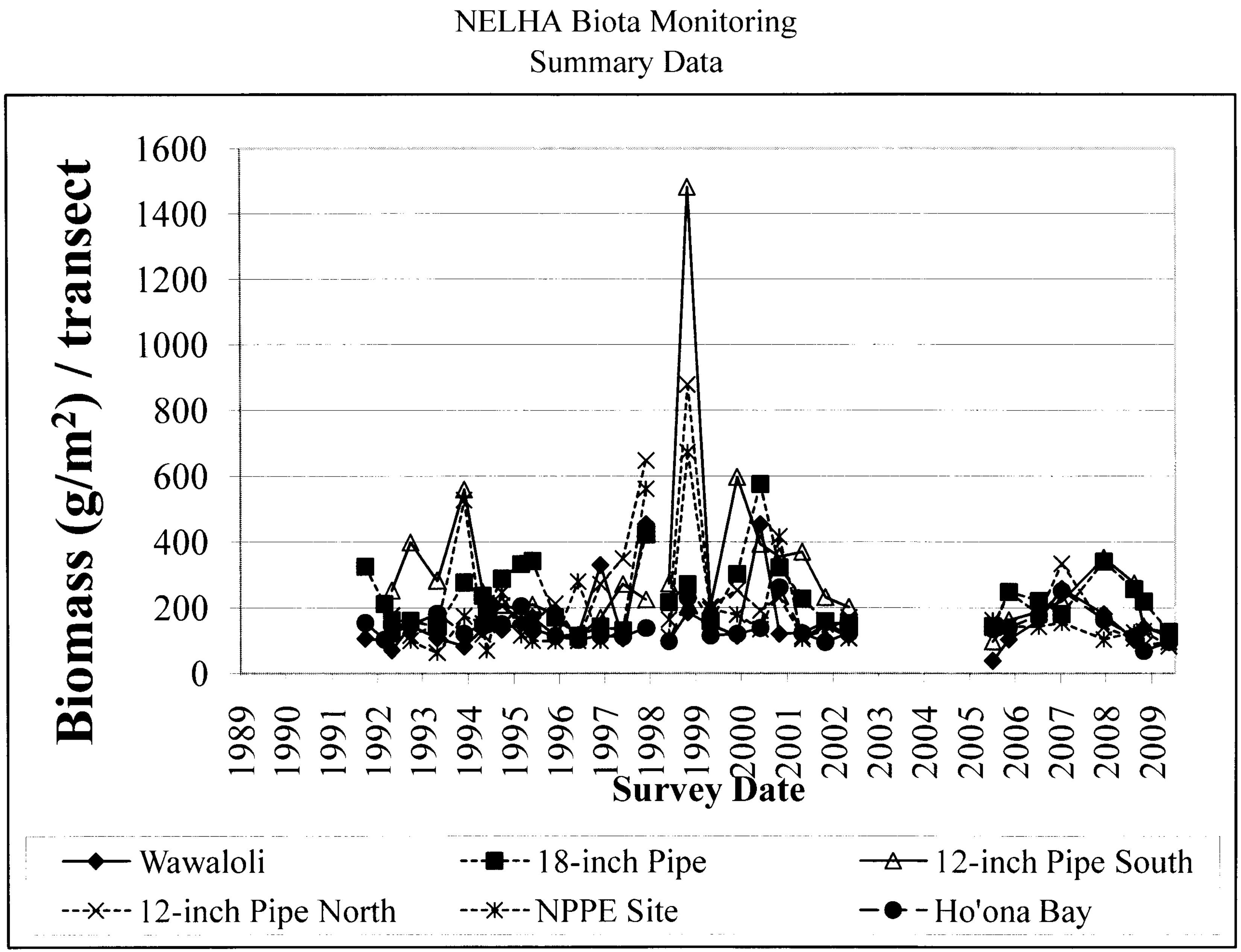


Figure 10. Plot of mean biomass on transects across three biotopes at six locations off NELHA from 1989 through 2009.

## DISCUSSION

In all areas and habitat zones, most of the fish species observed during the monitoring surveys off NELHA were from two families, the pomacentrids (damsel fish) and acanthurids (surgeon fish). The composition of the species within these families varied slightly between the habitat zones. In contrast, several species were found only within one of the three habitat types. The distributions of these two groups of fish reflect, in the first group, their ability to utilize a wide range of habitat types and resources, while in the second group, the fact that their habitat requirements are much narrower. It is likely that environmental impacts would not be reflected in changes in the first group, since they are able to utilize a wide range of habitat and could easily move away from a source of disturbance. Species located only in the boulder zone, however, would seem to be limited in their capacity to move to other habitats and might therefore be more subject to influence from terrestrial activities.

Throughout the survey area, schools of fish, mainly opelu (*Decapterus macarellus*), A*canthurus blochii*, *A. olivaceous*, and *Naso literatus* roamed between the habitat zones, especially between the reef bench and slope zones. These schools can have a dramatic impact on the abundance and biomass calculations when they pass through the transect area (e.g., in December 1997 when a spawning aggregation of surgeonfish [pualu, *Acanthurus mata* or *xanthopterus*] which passed over the shallow transect at the 12" Pipe South station comprised 81% of the biomass for that transect [Brock, 2002]). In addition, we observed that the fish communities in the opposite direction from the transect direction (e.g., to the south, whereas our transect ran to the north) were often significantly different, in terms of species abundance and diversity. These factors illustrate the highly variable nature of the fish communities over very small time and space scales, and imply that any conclusions of change in fish community abundance or distribution needs to be examined carefully in the context of natural variability.

In general, the fish community appears to be most well developed (in terms of number of species, abundance and biomass) in the area from Keahole Point south to the location of the 18" Pipe. The fish community appears to be least well developed off Wawaloli.

The fish community in the NELHA region has remained relatively constant over a period of sixteen years and through several significant storm events. Analysis of variance of number of individuals, number of species and biomass per transect showed no significant changes with time. There is no evidence that the NELHA operations have resulted in any significant changes to the fish communities in the region.

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# APPENDIX A

# ANCHIALINE POND SURVEY RESULTS

Appendix A.1. Summary of the census data of the anchialine pools of the northern complex (N-1 - N-5) sampled between 1998 and 2008.
Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | May-89 | Oct-91 | Mar-92 | May-92 | Oct-92 | May-93 | Dec-93 | May-94 | Jun-94 | Oct-94 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N-1 | *Melania* (mean) | 75 | 44 | 40 | 43 | 43 | 43 | 51 | 52 | 56 | 82 |
| | *Theodoxus cariosa* | | | | | | | | | | |
| | *Halocaridina rubra* | | | | | | | | | | 0 |
| | *Macrobrachium grandimanus* | | | | | | | | | 2 | 0 |
| | *Palaemon debilis* | | | | | | | | | | |
| | *Metopograpsus* | | | | | | | | | | |
| | *Poecilia* | x | x | x | x | x | x | x | x | x | x |
| N-2 | *Melania* | 36 | 42 | 72 | 85 | 41 | 22 | 27 | 31 | 28 | 19 |
| | *Halocaridina rubra* | 22 | 15 | 3 | 0 | 72 | 0 | 0 | 0 | 4 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Poecilia* | - | - | - | x | - | x | x | x | x | x |
| N-3 | *Melania* (mean) | 42 | 7 | 30 | 23 | 15 | 15 | 19 | 24 | 30 | 41 |
| | *Theodoxus cariosa* | | | | | | | | | | |
| | *Halocaridina rubra* (mean) | 8 | 14 | 0 | 0 | 26.5 | 0 | 0 | 1 | 0 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Palaemon debilis* | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 1 |
| | *Macrobrachium lar* | | | | | | | | | 1 | 0 |
| | *Poecilia* | - | - | x | x | - | x | x | x | x | x |
| N-4 | *Melania* (mean) | 77 | 2 | 5 | 9 | 48 | 26 | 23 | 33 | 38 | 22 |
| | *Halocaridina rubra* (mean) | 12 | 11.5 | 0 | 0 | 21.5 | 0 | 0 | 0 | 0 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | | | | | | | | | | |
| | *Poecilia* | - | - | x | x | - | x | x | x | x | x |
| N-5 | *Melania* (mean) | 3 | 3 | 22 | 5 | 5 | 7 | 20 | 23 | 17 | 40 |
| | *Theodoxus cariosa* | | | | | | | | | | |
| | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 41 | 0 | 0 | 0 | 0 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | | | | | | | | | | |
| | *Metopograpsus* | | | | | | | | | | |
| | *Poecilia* | - | - | x | x | - | x | x | x | x | x |
| N-6 | | | | | | | | | | | |

Appendix A.1 (cont.). Summary of the census data of the anchialine pools of the northern complex (N-1 - N-5) sampled between 1998 and 2008. Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | Mar-95 | Jun-95 | Dec-97 | Jun-98 | Nov-98 | May-99 | Dec-99 | Jun-00 | Nov-00 | May-01 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N-1 | *Melania* (mean) | 46 | 57 | 53 | 47 | 45 | 38 | 52 | 40 | 45 | 33 |
| | *Theodoxus cariosa* | | | | 6 | 2 | 6 | 3 | 2 | 4 | 3 |
| | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Palaemon debilis* | | 2 | | | | | 0 | 0 | 0 | 0 |
| | *Metopograpsus* | | | 4 | 7 | 9 | 6 | 8 | 9 | 5 | 4 |
| | *Poecilia* | x | x | x | x | x | x | x | x | x | x |
| N-2 | *Melania* | 31 | 28 | 33 | 44 | 56 | 47 | 47 | 39 | 51 | 79 |
| | *Halocaridina rubra* | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| | *Poecilia* | - | x | x | x | x | x | x | x | x | x |
| N-3 | *Melania* (mean) | 24 | 29 | 33 | 38 | 22 | 28 | 27 | 34 | 24 | 22 |
| | *Theodoxus cariosa* | | | | | | | | | | |
| | *Halocaridina rubra* (mean) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Palaemon debilis* | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Macrobrachium lar* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | x | x | x | x | x | x | x | x | x | x |
| N-4 | *Melania* (mean) | 23 | 24 | 22 | 27 | 28 | 23 | 33 | 23 | 24 | |
| | *Halocaridina rubra* (mean) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | *Macrobrachium grandimanus* | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | *Poecilia* | x | x | x | x | x | x | x | x | x | |
| N-5 | *Melania* (mean) | 20 | 23 | 23 | 35 | 21 | 18 | 18 | 19 | 19 | 17 |
| | *Theodoxus cariosa* | | | | | | | | | | |
| | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *Metopograpsus* | | | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 7 |
| | *Poecilia* | x | x | x | x | x | x | x | x | x | x |
| N-6 | | | | | | | | | | | |

Appendix A.1 (cont.). Summary of the census data of the anchialine pools of the northern complex (N-1 - N-5) sampled between 1998 and 2008. Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | Nov-01 | May-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Dec-07 | Aug-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N-1 | *Melania* (mean) | 30 | 38 | 53 | 43 | 0 | 0 | 0 | 4 | 0 | 0 |
| | *Theodoxus cariosa* | 2 | 9 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 |
| | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 200+ | 200+ |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Palaemon debilis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metopograpsus* | 6 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | x | x | x | x | x | x | - | - | - | - |
| N-2 | *Melania* | 66 | 72 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| | *Halocaridina rubra* | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 10 | 40 | 35 |
| | *Metabataeus lohena* | | | | | | | | | | 2 |
| | *Poecilia* | x | x | x | x | x | x | - | - | - | - |
| N-3 | *Melania* (mean) | 25 | 17 | 60 | 35 | 2 | 0 | 0 | 2 | 0 | 0 |
| | *Theodoxus cariosa* | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Halocaridina rubra* (mean) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 200+ | 200+ |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | *Palaemon debilis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Macrobrachium lar* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | x | x | x | x | x | x | - | - | - | - |
| N-4 | *Melania* (mean) | 23 | 26 | 100+ | 100+ | 100+ | 100+ | dry | 2 | 0 | 0 |
| | *Halocaridina rubra* (mean) | 0 | 0 | 0 | 0 | 40 | 0 | | 20 | 100+ | 10 |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 10 | 0 | | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| | *Poecilia* | x | x | x | x | - | - | | - | - | - |
| N-5 | *Melania* (mean) | 15 | 20 | 0 | 0 | 10 | 10 | 0 | 4 | 0 | 0 |
| | *Theodoxus cariosa* | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Halocaridina rubra* | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 170 | 150 |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metopograpsus* | 5 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | x | x | x | x | x | x | - | - | - | - |
| N-6 | | | | | | | | | | | - |

Appendix A.2. Summary of the census data of the anchialine pools of the southern complex (S-1 - S-9) sampled between 1998 and 2008.
Non-native species (the introduced fish *Poecilia* ) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | May-89 | Oct-91 | Mar-92 | May-92 | Oct-92 | May-93 | Dec-93 | May-94 | Jun-94 | Oct-94 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-1 | *Halocaridina rubra* | 56 | 29 | 31 | 61 | 29 | 49 | 37 | 47 | 52 | 84 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 |
| | Amphipoda | 0 | 0 | 0 | 6 | 19 | 12 | 15 | 21 | 18 | 26 |
| | *Poecilia* | | | | | | | | | | |
| S-2 | *Halocaridina rubra* | 71 | 31 | 40 | 14 | 34 | 54 | Dry | Dry | Dry | 42 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | Amphipoda | 185 | 32 | 6 | 2 | 9 | 2 | | | | 9 |
| | *Poecilia* | | | | | | | | | | |
| S-3 | *Halocaridina rubra* | 38 | 21 | 43 | 64 | 56 | Dry | 49 | 37 | 86 | 94 |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 0 |
| | Amphipoda | 54 | 14 | 9 | 12 | 9 | | 12 | 14 | 3 | 16 |
| | *Poecilia* | | | | | | | | | | |
| S-4 | *Halocaridina rubra* | 9 | 42 | 6 | 9 | 7 | Dry | Dry | 21 | Dry | 39 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | Amphipoda | 0 | 0 | 0 | 2 | 12 | | | 6 | | 12 |
| | *Poecilia* | | | | | | | | | | |
| S-5 | *Halocaridina rubra* | 43 | 121 | 131 | 92 | 107 | 113 | 0 | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 1 |
| | Amphipoda | 94 | 65 | 48 | 27 | 34 | 7 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | | | | | | | | | |
| S-6 | *Halocaridina rubra* | 3 | 3 | 1 | 1 | 7 | 5 | 4 | 7 | 4 | 23 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | Amphipoda | 0 | 9 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| | Amphipod (white) | 0 | 2 | 0 | 0 | 2 | 1 | 1 | 3 | 1 | 2 |
| S-7 | *Halocaridina rubra* | 97 | 95 | 87 | 96 | 49 | 72 | 68 | 82 | 94 | 113 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | 0.5 | 0.5 | 0.5 | 0.75 | 1 | 0.5 | 1 | 2 | 1 | 1 |
| | Amphipoda | 11 | 17 | 12 | 10 | 13 | 9 | 10 | 18 | 23 | 39 |
| | *Poecilia* | | | | | | | | | | |
| S-8 | *Halocaridina rubra* | | | | 65 | 72 | 81 | 71 | 68 | 81 | 80 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | | | | 0.5 | 0.75 | 1 | 1 | 2 | 1 | 1 |
| | *Poecilia* | | | | | | | | | | |
| S-9 | *Halocaridina rubra* | | | | | 3 | Dry | Dry | Dry | Dry | 14 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Poecilia* | | | | | | | | | | |

Appendix A.2 (cont.). Summary of the census data of the anchialine pools of the southern complex (S-1 - S-9) sampled between 1998 and 2008. Non-native species (the introduced fish *Poecilia* ) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | Mar-95 | Jun-95 | Dec-97 | Jun-98 | Nov-98 | May-99 | Dec-99 | Jun-00 | Nov-00 | May-01 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-1 | *Halocaridina rubra* | 61 | 57 | 73 | 49 | 81 | 63 | 65 | 35 | 35 | 55 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 23 | 27 | 24 | 23 | 14 | 12 | 14 | 16 | 9 | 11 |
| | *Poecilia* | | | | | | | | | | |
| S-2 | *Halocaridina rubra* | Dry | 39 | Dry | 62 | Dry | 52 | Dry | 6 | Dry | Dry |
| | *Metabataeus lohena* | | | | | | | | | | |
| | Amphipoda | | | | 12 | | 14 | | 0 | | |
| S-3 | *Halocaridina rubra* | Dry | 78 | Dry | 14 | Dry | 29 | 8 | 17 | Filled | Filled |
| | *Metabataeus lohena* | | 2 | | 0 | | 0 | 0 | 0 | | |
| | Amphipoda | | 21 | | 17 | | 10 | 12 | 9 | | |
| S-4 | *Halocaridina rubra* | Dry | 16 | Dry | 0 | Dry | 0 | 15 | 31 | Dry | Dry |
| | Amphipoda | | 3 | | 2 | | 3 | 4 | 8 | | |
| | *Poecilia* | | | | | | | | | | |
| S-5 | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| | *Macrobrachium grandimanus* | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | | | | | | | | | |
| S-6 | *Halocaridina rubra* | Dry | 17 | Dry | 12 | Dry | 6 | Dry | 4 | Dry | Dry |
| | *Metabataeus lohena* | | | | | | | | | | |
| | Amphipoda | | 0 | | 2 | | 3 | | 0 | | |
| | Amphipod (white) | | 0 | | 0 | | 0 | | 0 | | |
| S-7 | *Halocaridina rubra* | 77 | 121 | 86 | 79 | 87 | 59 | 43 | 41 | 56 | 47 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | 1 | 3 | 0 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |
| | Amphipoda | 25 | 29 | 21 | 31 | 20 | 18 | 14 | 22 | 6 | 9 |
| | *Poecilia* | | | | | | | | | | |
| S-8 | *Halocaridina rubra* | 52 | 61 | 55 | 57 | 63 | 72 | 30 | 38 | 48 | 80 |
| | *Metabataeus lohena* | | | | | | | | | | |
| | *Macrobrachium grandimanus* | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| S-9 | *Halocaridina rubra* | Dry | 9 | Dry | 12 | Dry | 10 | 4 | 1 | 7 | Dry |

Appendix A.2 (cont.). Summary of the census data of the anchialine pools of the southern complex (S-1 - S-9) sampled between 1998 and 2008. Non-native species (the introduced fish *Poecilia* ) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

| Pond | Species | Nov-01 | May-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Dec-07 | Aug-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-1 | *Halocaridina rubra* | 40 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 12 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | | X | X | X | X | X | X | X | X |
| S-2 | *Halocaridina rubra* | 35 | 9 | 65 | 150 | 40 | 200 | 0 | 0 | 100 | 17 |
| | *Metabataeus lohena* | 0 | 0 | 2 | 5 | 6 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | X | X | - | - |
| S-3 | *Halocaridina rubra* | 45 | 55 | 85 | 185 | 100 | 100 | 0 | 0 | 200 | 12 |
| | *Metabataeus lohena* | 0 | 0 | 6 | 8 | 2 | 0 | 0 | 0 | 1 | 0 |
| | Amphipoda | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | X | X | - | - |
| S-4 | *Halocaridina rubra* | 31 | 12 | 0 | 4 | 60 | 0 | 8 | 0 | 5 | 17 |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 4 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | | X | X | - | X | - | - | - | - |
| S-5 | *Halocaridina rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | | X | X | X | X | | X | X | X |
| S-6 | *Halocaridina rubra* | 0 | 12 | 4 | 0 | 1 | 50 | dry | 5 | 20 | 0 |
| | *Metabataeus lohena* | 0 | 0 | 1 | 0 | 0 | 0 | | 0 | 1 | 0 |
| | Amphipoda | 0 | 2 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| | Amphipod (white) | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| S-7 | *Halocaridina rubra* | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metabataeus lohena* | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Macrobrachium grandimanus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Amphipoda | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Poecilia* | | X | X | | X | X | X | X | X | X |
| S-8 | *Halocaridina rubra* | 81 | 45 | 30 | 115 | 50 | 50 | 0 | 0 | 75 | 50 |
| | *Metabataeus lohena* | 0 | 0 | 3 | 30 | 6 | 1 | 0 | 0 | 15 | 5 |
| | *Macrobrachium grandimanus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | X | X | - | - |
| S-9 | *Halocaridina rubra* | 20 | 3 | 2 | 0 | 50 | 80 | 0 | 0 | 0 | 30 |
| | *Metabataeus lohena* | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 2 |
| | | | | | | | | X | X | - | - |

# APPENDIX B

# MARINE BENTHIC COMMUNITY SURVEY RESULTS

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | Ho'ona Bay Shallow | | | Ho'ona Bay Middle | | | Ho'ona Bay Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora capitata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.01 |
| *Montipora flabellata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 16 | 0.8 | 0.08 | 64 | 3.2 | 0.20 | 29 | 1.5 | 0.10 |
| *Pavona varians* | 4 | 0.2 | 0.03 | 0 | 0.0 | 0.00 | 5 | 0.3 | 0.03 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Pocillopora meandrina* | 138 | 6.9 | 0.31 | 161 | 8.1 | 0.32 | 0 | 0.0 | 0.00 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 10 | 0.5 | 0.05 | 318 | 15.9 | 0.37 |
| *Porites lobata* | 621 | 31.1 | 0.18 | 584 | 29.2 | 0.24 | 628 | 31.4 | 0.29 |
| Total coral cover / index | | 39.0 | 0.59 | | 41.0 | 0.81 | | 49.1 | 0.79 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sponge (SPO) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 346 | 17.3 | 0.36 | 239 | 12.0 | 0.33 | 1 | 0.1 | 0.01 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Limestone (L) | 806 | 40.3 | 0.25 | 825 | 41.3 | 0.21 | 799 | 40.0 | 0.19 |
| Rock (R) | 6 | 0.3 | 0.03 | 21 | 1.1 | 0.08 | 203 | 10.2 | 0.32 |
| Sand (S) | 1 | 0.1 | 0.01 | 0 | 0.0 | 0.00 | 9 | 0.5 | 0.04 |

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | NPPE Shallow | | | NPPE Middle | | | NPPE Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 22 | 1.1 | 0.09 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora capitata* | 49 | 2.5 | 0.16 | 125 | 6.3 | 0.25 | 57 | 2.9 | 0.14 |
| *Montipora flabellata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 3 | 0.2 | 0.02 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 29 | 1.5 | 0.12 | 2 | 0.1 | 0.01 | 5 | 0.3 | 0.02 |
| *Pavona varians* | 5 | 0.3 | 0.03 | 4 | 0.2 | 0.02 | 1 | 0.1 | 0.01 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 79 | 4.0 | 0.17 |
| *Pocillopora meandrina* | 152 | 7.6 | 0.31 | 155 | 7.8 | 0.28 | 142 | 7.1 | 0.24 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 11 | 0.6 | 0.05 | 284 | 14.2 | 0.33 |
| *Porites lobata* | 593 | 29.7 | 0.25 | 742 | 37.1 | 0.24 | 734 | 36.7 | 0.32 |
| Total coral cover / index | | 42.5 | 0.96 | | 52.1 | 0.88 | | 65.1 | 1.23 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sponge (SPO) | 1 | 0.1 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 612 | 30.6 | 0.32 | 43 | 2.2 | 0.16 | 0 | 0.0 | 0.00 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Limestone (L) | 455 | 22.8 | 0.36 | 747 | 37.4 | 0.06 | 567 | 28.4 | 0.00 |
| Rock (R) | 2 | 0.1 | 0.01 | 8 | 0.4 | 0.05 | 0 | 0.0 | 0.00 |
| Sand (S) | 1 | 0.1 | 0.01 | 1 | 0.1 | 0.01 | 0 | 0.0 | 0.00 |

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | 12" Pipe North Shallow | | | 12"Pipe North Middle | | | 12"Pipe North Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora capitata* | 32 | 1.6 | 0.16 | 80 | 4.0 | 0.22 | 84 | 4.2 | 0.17 |
| *Montipora flabellata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 70 | 3.5 | 0.25 | 100 | 5.0 | 0.25 | 20 | 1.0 | 0.06 |
| *Pavona varians* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Pocillopora meandrina* | 119 | 6.0 | 0.32 | 282 | 14.1 | 0.37 | 156 | 7.8 | 0.25 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.01 | 108 | 5.4 | 0.20 |
| *Porites lobata* | 368 | 18.4 | 0.29 | 372 | 18.6 | 0.36 | 976 | 48.8 | 0.23 |
| Total coral cover / index | | 29.5 | 1.03 | | 41.8 | 1.22 | | 67.2 | 0.92 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 1 | 0.1 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 31 | 1.6 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sponge (SPO) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 0 | 0.0 | 0.00 | 118 | 5.9 | 0.26 | 0 | 0.0 | 0.00 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Limestone (L) | 1374 | 68.7 | 0.00 | 826 | 41.3 | 0.12 | 601 | 30.1 | 0.00 |
| Rock (R) | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.01 | 0 | 0.0 | 0.00 |
| Sand (S) | 0 | 0.0 | 0.00 | 8 | 0.4 | 0.04 | 0 | 0.0 | 0.00 |

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | 12" Pipe South Shallow | | | 12" Pipe South Middle | | | 12" Pipe South Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora capitata* | 0 | 0.0 | 0.00 | 21 | 1.1 | 0.11 | 31 | 1.6 | 0.15 |
| *Montipora flabellata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 0 | 0.0 | 0.00 | 9 | 0.5 | 0.06 | 4 | 0.2 | 0.03 |
| *Pavona varians* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 26 | 1.3 | 0.13 |
| *Pocillopora meandrina* | 203 | 10.2 | 0.36 | 207 | 10.4 | 0.36 | 239 | 12.0 | 0.37 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.02 |
| *Porites lobata* | 233 | 11.7 | 0.33 | 418 | 20.9 | 0.29 | 322 | 16.1 | 0.34 |
| Total coral cover / index | | 21.8 | 0.69 | | 32.8 | 0.82 | | 31.2 | 1.04 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 4 | 0.2 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sponge (SPO) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 0 | 0.0 | 0.00 | 134 | 6.7 | 0.27 | 0 | 0.0 | 0.00 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 25 | 1.3 | 0.09 | 0 | 0.0 | 0.00 |
| Limestone (L) | 1478 | 73.9 | 0.00 | 843 | 42.2 | 0.16 | 1286 | 64.3 | 0.02 |
| Rock (R) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 33 | 1.7 | 0.09 |
| Sand (S) | 0 | 0.0 | 0.00 | 23 | 1.2 | 0.09 | 0 | 0.0 | 0.00 |

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | 18" Pipe Shallow | | | 18" Pipe Middle | | | 18" Pipe Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 1 | 0.1 | 0.01 |
| *Montipora capitata* | 9 | 0.5 | 0.05 | 57 | 2.9 | 0.22 | 44 | 2.2 | 0.16 |
| *Montipora flabellata* | 0 | 0.0 | 0.00 | 10 | 0.5 | 0.07 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 5 | 0.3 | 0.04 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 44 | 2.2 | 0.16 | 54 | 2.7 | 0.21 | 12 | 0.6 | 0.06 |
| *Pavona varians* | 0 | 0.0 | 0.00 | 3 | 0.2 | 0.03 | 0 | 0.0 | 0.00 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 5 | 0.3 | 0.03 |
| *Pocillopora meandrina* | 221 | 11.1 | 0.36 | 179 | 9.0 | 0.36 | 270 | 13.5 | 0.37 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.02 | 7 | 0.4 | 0.04 |
| *Porites lobata* | 515 | 25.8 | 0.28 | 325 | 16.3 | 0.34 | 489 | 24.5 | 0.31 |
| Total coral cover / index | | 39.5 | 0.85 | | 31.8 | 1.27 | | 41.4 | 0.97 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 2 | 0.1 | 0.00 | 3 | 0.2 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 0 | 0.0 | 0.00 | 7 | 0.4 | 0.00 | 0 | 0.0 | 0.00 |
| Sponge (SPO) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 36 | 1.8 | 0.10 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Limestone (L) | 1175 | 58.8 | 0.03 | 1356 | 67.8 | 0.00 | 1169 | 58.5 | 0.00 |
| Rock (R) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sand (S) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in May 2009. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

| | Wawaloli Shallow | | | Wawaloli Middle | | | Wawaloli Deep | | |
|---|---|---|---|---|---|---|---|---|---|
| **CATEGORIES** | # Points | % | SW Index | # Points | % | SW Index | # Points | % | SW Index |
| **Coral** | | | | | | | | | |
| *Leptastrea purpurea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora capitata* | 35 | 1.8 | 0.18 | 40 | 2.0 | 0.15 | 11 | 0.6 | 0.07 |
| *Montipora flabellata* | 2 | 0.1 | 0.02 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora incrassata* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Montipora patula* | 10 | 0.5 | 0.07 | 38 | 1.9 | 0.15 | 0 | 0.0 | 0.00 |
| *Pavona varians* | 0 | 0.0 | 0.00 | 9 | 0.5 | 0.05 | 0 | 0.0 | 0.00 |
| *Pocillopora eydouxi* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 84 | 4.2 | 0.28 |
| *Pocillopora meandrina* | 130 | 6.5 | 0.34 | 78 | 3.9 | 0.23 | 57 | 2.9 | 0.22 |
| *Porites compressa* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 11 | 0.6 | 0.07 |
| *Porites lobata* | 370 | 18.5 | 0.26 | 606 | 30.3 | 0.19 | 432 | 21.6 | 0.23 |
| Total coral cover / index | | 27.4 | 0.88 | | 38.6 | 0.77 | | 29.8 | 0.88 |
| **Zoanthids** | | | | | | | | | |
| *Palythoa* sp. | 0 | 0.0 | 0.00 | 1 | 0.1 | 0.00 | 0 | 0.0 | 0.00 |
| **Macroalgae** | | | | | | | | | |
| Macroalgae (MACA) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Other live** | | | | | | | | | |
| Other (O) | 3 | 0.2 | 0.00 | 0 | 0.0 | 0.00 | 17 | 0.9 | 0.00 |
| Sponge (SPO) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| **Sand, pavement, rubble** | | | | | | | | | |
| Boulder (B) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Coral Rubble (CR) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Limestone (L) | 1450 | 72.5 | 0.00 | 1228 | 61.4 | 0.00 | 1388 | 69.4 | 0.00 |
| Rock (R) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| Sand (S) | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Dec-91 | May-92 | Oct-92 | May-93 | Oct-93 | Mar-94 | May-94 | Sep-94 |
|---|---|---|---|---|---|---|---|---|---|---|
| WAWALOLI | Shallow | % CORAL | 12.5 | 5.5 | 5.1 | 4.7 | 7.6 | 2.5 | 5 | 6.9 |
| | | % P.I. | 10.8 | 4.4 | 2.9 | 1.9 | 5.7 | 1.3 | 2.8 | 3.0 |
| | | % P.c. | | | | | | | 0.1 | |
| | | % P.m. | 1.7 | 1.0 | 2.2 | 2.5 | 1.7 | 0.4 | 0.7 | 1.8 |
| | | Sp. # | 2 | 4 | 2 | 3 | 4 | 4 | 8 | 6 |
| | | Sp. Div. | 0.39 | 0.57 | 0.68 | 0.87 | 0.67 | 1.19 | 1.41 | 1.32 |
| | Middle | % CORAL | 1.7 | 23.6 | 10.8 | 12.1 | 17.7 | 8.7 | 14.9 | 23.3 |
| | | % P.I. | 1.4 | 22.2 | 9.8 | 11.4 | 16.5 | 4.1 | 13.3 | 21.7 |
| | | % P.c. | 0.2 | | | | 0.1 | 0.1 | | |
| | | % P.m. | 0.1 | 1.1 | 0.5 | 0.2 | 0.5 | 3.9 | 0.6 | 0.2 |
| | | Sp. # | 4 | 6 | 3 | 3 | 5 | 5 | 3 | 5 |
| | | Sp. Div. | 0.57 | 0.27 | 0.37 | 0.23 | 0.33 | 0.99 | 0.41 | 0.32 |
| | Deep | % CORAL | 23.9 | 2.9 | 2.5 | 2.2 | 5.3 | 8.5 | 8.4 | 8.9 |
| | | % P.I. | 14.7 | 2.5 | 2.2 | 1.5 | 2.9 | 3.6 | 6.3 | 7.1 |
| | | % P.c. | 9.2 | 0.3 | | 0.3 | 1.0 | 0.5 | | |
| | | % P.m. | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 | 3.3 | 1.6 | 1.3 |
| | | Sp. # | 3 | 3 | 3 | 5 | 4 | 7 | 4 | 3 |
| | | Sp. Div. | 0.68 | 0.42 | 0.44 | 1.05 | 1.15 | 1.32 | 0.74 | 0.62 |
| 18" PIPE | Shallow | % CORAL | 12.5 | 15.6 | 19.2 | 15.8 | 18.6 | 10.0 | 15.5 | 15.1 |
| | | % P.I. | 5.8 | 2.8 | 5.2 | 6.4 | 4.9 | 4.1 | 6.1 | 3.8 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 6.2 | 10.0 | 11.2 | 5.7 | 11.8 | 3.9 | 8.4 | 6.2 |
| | | Sp. # | 4 | 7 | 5 | 6 | 3 | 5 | 5 | 5 |
| | | Sp. Div. | 0.84 | 1.01 | 1 | 1.24 | 0.87 | 1.21 | 0.95 | 1.34 |
| | Middle | % CORAL | 14.3 | 13 | 9.1 | 13.1 | 11.8 | 16.0 | 17.3 | 13.2 |
| | | % P.I. | 5.2 | 4.4 | 3.9 | 2.6 | 3.4 | 4.8 | 3.7 | 3.3 |
| | | % P.c. | | | | | | 0.3 | | 0.5 |
| | | % P.m. | 8.5 | 8.0 | 3.2 | 8.9 | 6.0 | 5.9 | 10.7 | 6.9 |
| | | Sp. # | 6 | 6 | 4 | 5 | 6 | 8 | 5 | 6 |
| | | Sp. Div. | 0.84 | 0.85 | 1.15 | 0.89 | 1.17 | 1.56 | 1.06 | 1.27 |
| | Deep | % CORAL | 12.4 | 7.4 | 5.5 | 16.2 | 10.7 | 12.9 | 12..9 | 8.4 |
| | | % P.I. | 9.2 | 6.0 | 4.0 | 13.3 | 8.0 | 11.9 | 9.3 | 7.7 |
| | | % P.c. | 2.5 | 1.3 | 1.3 | 1.3 | 2.4 | 0.6 | 2.7 | 0.4 |
| | | % P.m. | 0.1 | 0.5 | 0.1 | | 0.2 | 0.2 | | 0.3 |
| | | Sp. # | 6 | 4 | 4 | 3 | 4 | 5 | 3 | 3 |
| | | Sp. Div. | 0.58 | 0.54 | 0.72 | 59 | 0.67 | 0.36 | 0.75 | 0.34 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Dec-91 | May-92 | Oct-92 | May-93 | Oct-93 | Mar-94 | May-94 | Sep-94 |
|---|---|---|---|---|---|---|---|---|---|---|
| 12" PIPE SOUTH | Shallow | % CORAL | | 8.9 | 8.7 | 8.5 | 6.5 | 6.5 | 9.4 | 12 |
| | | % P.l. | | 1.4 | 1.4 | 2.0 | 2.4 | 1.9 | 2.5 | 4.1 |
| | | % P.c. | | 0.3 | | | | 0.1 | | |
| | | % P.m. | | 6.9 | 7.1 | 6.6 | 4.1 | 3.4 | 5.1 | 7.5 |
| | | Sp. # | | 5 | 4 | 2 | 2 | 4 | 4 | 3 |
| | | Sp. Div. | | 0.70 | 0.56 | 0.54 | 0.66 | 1.04 | 1.10 | 0.77 |
| | Middle | % CORAL | | 20.2 | 13.7 | 21.2 | 16.8 | 20.5 | 18.8 | 19.2 |
| | | % P.l. | | 8.5 | 7.3 | 14.3 | 9.9 | 12.6 | 7.8 | 6.9 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | | 7.2 | 3.6 | 4.6 | 2.8 | 5.1 | 5.2 | 8.5 |
| | | Sp. # | | 6 | 6 | 6 | 5 | 4 | 5 | 4 |
| | | Sp. Div. | | 1.28 | 1.28 | 0.95 | 1.21 | 1.01 | 1.36 | 1.14 |
| | Deep | % CORAL | | 15.0 | 17.9 | 22.2 | 31.0 | 22.9 | 14.3 | 30.8 |
| | | % P.l. | | 11.5 | 14.1 | 16.8 | 19.1 | 17.9 | 10.1 | 18.9 |
| | | % P.c. | | 0.5 | 0.2 | 0.9 | 0.7 | 0.4 | 1 | 1.4 |
| | | % P.m. | | 0.9 | 1.2 | 2.3 | 2.8 | 1.3 | 0.8 | 2.8 |
| | | Sp. # | | 6 | 6 | 6 | 9 | 7 | 7 | 6 |
| | | Sp. Div. | | 0.86 | 0.78 | 0.84 | 1.22 | 0.83 | 1.00 | 1.20 |
| 12" PIPE NORTH | Shallow | % CORAL | | 8.3 | 4.5 | 7.6 | 14.8 | 10.0 | 10.2 | 9.6 |
| | | % P.l. | | 3.2 | 2.2 | 2.5 | 5.0 | 3.0 | 3.3 | 3.4 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | | 4.3 | 2.3 | 3.1 | 6.3 | 3.5 | 3.9 | 5.1 |
| | | Sp. # | | 7 | 3 | 6 | 6 | 6 | 5 | 4 |
| | | Sp. Div. | | 1.02 | 0.78 | 1.30 | 1.33 | 1.58 | 1.40 | 1.03 |
| | Middle | % CORAL | | 13.8 | 12.5 | 14.1 | 17.8 | 20.8 | 23.7 | 22.7 |
| | | % P.l. | | 9.2 | 9.9 | 7.1 | 7.0 | 9.2 | 9.0 | 10.4 |
| | | % P.c. | | 0.4 | 0.1 | | 0.1 | | | |
| | | % P.m. | | 3.4 | 1.3 | 4.0 | 3.0 | 3.5 | 7.7 | 5.5 |
| | | Sp. # | | 6 | 6 | 6 | 7 | 7 | 6 | 5 |
| | | Sp. Div. | | 0.95 | 0.79 | 1.26 | 1.48 | 1.47 | 1.39 | 1.18 |
| | Deep | % CORAL | | 17.4 | 13.2 | 17.7 | 27.1 | 21.8 | 19.4 | 22.5 |
| | | % P.l. | | 14.1 | 10.5 | 13.9 | 15.3 | 16.4 | 14.0 | 14.4 |
| | | % P.c. | | 1.2 | 0.3 | 0.8 | 0.6 | 0.4 | 0.2 | 0.5 |
| | | % P.m. | | 0.1 | 0.5 | 0.5 | 3.6 | 0.8 | 1.0 | 2.0 |
| | | Sp. # | | 6 | 4 | 6 | 5 | 5 | 6 | 5 |
| | | Sp. Div. | | 0.70 | 0.67 | 0.77 | 1.13 | 0.75 | 0.87 | 1.07 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Dec-91 | May-92 | Oct-92 | May-93 | Oct-93 | Mar-94 | May-94 | Sep-94 |
|---|---|---|---|---|---|---|---|---|---|---|
| NPPE | Shallow | % CORAL | | 18.6 | 21.7 | 20.6 | 25.6 | 22.9 | 26.4 | 33.7 |
| | | % P.l. | | 6.9 | 6.1 | 5.9 | 9.4 | 7.4 | 8.7 | 11.0 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | | 8.8 | 10.2 | 11.8 | 10.7 | 11.8 | 15.0 | 13.6 |
| | | Sp. # | | 6 | 7 | 6 | 5 | 7 | 5 | 6 |
| | | Sp. Div. | | 1.21 | 1.43 | 1.13 | 1.25 | 1.25 | 0.99 | 1.40 |
| | Middle | % CORAL | | 29.5 | 33.9 | 36.6 | 51.3 | 44.1 | 45.3 | 47.2 |
| | | % P.l. | | 10.4 | 16.6 | 14.1 | 18.7 | 19.3 | 22.1 | 23 |
| | | % P.c. | | 0.3 | 0.3 | 1.6 | 0.8 | | 2.8 | 1.6 |
| | | % P.m. | | 17.6 | 15.8 | 18.8 | 26.2 | 22.0 | 17.0 | 19.1 |
| | | Sp. # | | 6 | 7 | 6 | 7 | 5 | 5 | 6 |
| | | Sp. Div. | | 0.88 | 0.9 | 1.05 | 1.13 | 0.95 | 1.13 | 1.09 |
| | Deep | % CORAL | | 28.0 | 38.3 | 45.5 | 40.5 | 47.7 | 40.5 | 60.3 |
| | | % P.l. | | 23.2 | 30.1 | 34.2 | 32.4 | 41.1 | 31.6 | 47.7 |
| | | % P.c. | | 1.9 | 1.4 | 3.5 | 1.4 | 1.7 | 3.8 | 2.1 |
| | | % P.m. | | 1.5 | 3.0 | 3.8 | 4.4 | 2.1 | 1.0 | 5.7 |
| | | Sp. # | | 6 | 7 | 6 | 6 | 5 | 5 | 6 |
| | | Sp. Div. | | 0.68 | 0.83 | 0.91 | 0.74 | 0.56 | 0.78 | 0.78 |
| HO'ONA BAY | Shallow | % CORAL | 15.1 | 15.1 | 24.8 | 12.0 | 7.5 | 9.0 | 6.8 | 10.9 |
| | | % P.l. | 12.3 | 10.0 | 18.3 | 7.5 | 4.8 | 7.2 | 4.7 | 6.2 |
| | | % P.c. | | 0.2 | | 0.3 | | | | |
| | | % P.m. | 2.4 | 4.4 | 3.9 | 3.9 | 1.5 | 1.1 | 0.9 | 2.1 |
| | | Sp. # | 3 | 4 | 5 | 6 | 3 | 5 | 6 | 3 |
| | | Sp. Div. | 0.55 | 0.79 | 0.85 | 0.87 | 0.90 | 0.73 | 1.02 | 0.98 |
| | Middle | % CORAL | 42.1 | 30.8 | 27.8 | 30.7 | 26.0 | 38.1 | 18.6 | 25.7 |
| | | % P.l. | 37.4 | 25.4 | 22.1 | 22.8 | 21.3 | 35.2 | 13.1 | 23.0 |
| | | % P.c. | 4.1 | 3.5 | 5.0 | 6.8 | 2.3 | 2.1 | 4.1 | 1.1 |
| | | % P.m. | 0.6 | 1.7 | 0.6 | 1.0 | 2.3 | 0.3 | 1.2 | |
| | | Sp. # | 3 | 4 | 3 | 3 | 4 | 6 | 5 | 4 |
| | | Sp. Div. | 0.39 | 0.58 | 0.57 | 0.66 | 0.61 | 0.35 | 0.81 | 0.44 |
| | Deep | % CORAL | 34.7 | 39.1 | 35.1 | 45.9 | 40.8 | 55.0 | 41.5 | 49.0 |
| | | % P.l. | 12.5 | 20.0 | 12.7 | 18.8 | 18.7 | 18.9 | 19.2 | 20.8 |
| | | % P.c. | 20.0 | 18.0 | 21.7 | 25.3 | 19.9 | 35.2 | 19.1 | 25.3 |
| | | % P.m. | 0.5 | 0.3 | 0.1 | 0.3 | 1.1 | 0.1 | 0.7 | 0.4 |
| | | Sp. # | 7 | 5 | 5 | 6 | 4 | 5 | 7 | 5 |
| | | Sp. Div. | 0.93 | 0.83 | 0.76 | 0.86 | 0.90 | 0.74 | 1.02 | 0.92 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jan-95 | May-95 | Nov-95 | Jun-96 | Dec-96 | May-97 | Nov-97 | May-98 |
|---|---|---|---|---|---|---|---|---|---|---|
| WAWALOLI | Shallow | % CORAL | 5.8 | 5.7 | 9.4 | 9.5 | 5.9 | 12.7 | 24.3 | 30.2 |
| | | % P.l. | 3.8 | 2.9 | 6.4 | 5.7 | 1.4 | 9.6 | 11.3 | 17.8 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 1.6 | 1.9 | 2.6 | 2.7 | 4.2 | 2.8 | 12.5 | 9.9 |
| | | Sp. # | 5 | 4 | 5 | 6 | 5 | 6 | 4 | 4 |
| | | Sp. Div. | 0.89 | 1.1 | 0.81 | 1.06 | 0.76 | 0.65 | 0.79 | 0.93 |
| | Middle | % CORAL | 15.6 | 15.9 | 20.5 | 13.2 | 12.4 | 19.3 | 32.0 | 37.9 |
| | | % P.l. | 13.8 | 14.2 | 17.9 | 10 | 10.2 | 16.1 | 20.6 | 21.7 |
| | | % P.c. | | | | | 0.1 | | | |
| | | % P.m. | 0.3 | 1.1 | 2.4 | 1.9 | 0.6 | 2.6 | 7.0 | 11.8 |
| | | Sp. # | 4 | 3 | 5 | 6 | 6 | 6 | 4 | 6 |
| | | Sp. Div. | 0.47 | 0.41 | 0.43 | 0.85 | 0.72 | 0.56 | 0.98 | 1.03 |
| | Deep | % CORAL | 9.9 | 14.2 | 10.3 | 4.6 | 7.6 | 13.8 | 13.9 | 15.1 |
| | | % P.l. | 7.5 | 8.2 | 9.8 | 1.4 | 4.9 | 4.2 | 7.7 | 7 |
| | | % P.c. | | | 0.6 | 0.6 | 0.8 | | 0.6 | 1.7 |
| | | % P.m. | 1.2 | 4.8 | 0.1 | 2.5 | 1.9 | 9.3 | 5.3 | 4.5 |
| | | Sp. # | 3 | 5 | 5 | 5 | 3 | 3 | 4 | 5 |
| | | Sp. Div. | 0.72 | 0.94 | 0.26 | 1.08 | 0.86 | 0.7 | 0.91 | 1.25 |
| 18" PIPE | Shallow | % CORAL | 15.2 | 24.5 | 24.7 | 19.7 | 21.6 | 22.9 | 35.2 | 54.5 |
| | | % P.l. | 6.7 | 7 | 5.3 | 11.6 | 10.4 | 16.6 | 14.5 | 21.8 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 6.8 | 9.3 | 13.1 | 5.5 | 10.7 | 3.9 | 15.7 | 20.08 |
| | | Sp. # | 5 | 6 | 7 | 6 | 5 | 5 | 4 | 5 |
| | | Sp. Div. | 1.06 | 1.44 | 1.28 | 1.1 | 0.81 | 0.85 | 1.03 | 1.26 |
| | Middle | % CORAL | 23.0 | 20.4 | 22.9 | 22.3 | 19.3 | 21.7 | 39.6 | 53.5 |
| | | % P.l. | 12.6 | 8.6 | 5 | 7.5 | 7.6 | 6.9 | 12.2 | 15.5 |
| | | % P.c. | | 0.4 | 0.3 | 0.1 | | | | |
| | | % P.m. | 6.4 | 9.0 | 16.2 | 13.7 | 10.5 | 13.1 | 23.5 | 25.8 |
| | | Sp. # | 4 | 5 | 7 | 6 | 5 | 6 | 6 | 5 |
| | | Sp. Div. | 1.04 | 1.13 | 0.87 | 0.86 | 0.92 | 0.94 | 1.03 | 1.22 |
| | Deep | % CORAL | 12.5 | 4.3 | 7.7 | 7.2 | 8.2 | 5.2 | 18.9 | 22.0 |
| | | % P.l. | 11.8 | 2.4 | 2.5 | 3.5 | 2.8 | 3.3 | 8.0 | 7.7 |
| | | % P.c. | 0.2 | 0.7 | 0.1 | 0.3 | | | | 3.7 |
| | | % P.m. | 0.4 | 0.9 | 4.9 | 0.8 | 2.8 | 1.3 | 9.9 | 10.4 |
| | | Sp. # | 4 | 4 | 7 | 5 | 3 | 4 | 3 | 4 |
| | | Sp. Div. | 0.27 | 1.13 | 0.87 | 1.13 | 1.1 | 1 | 0.86 | 1.06 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jan-95 | May-95 | Nov-95 | Jun-96 | Dec-96 | May-97 | Nov-97 | May-98 |
|---|---|---|---|---|---|---|---|---|---|---|
| 12" PIPE SOUTH | Shallow | % CORAL | 10.7 | 5.9 | 14.1 | 24.9 | 25.1 | 21.1 | 31.8 | 15.0 |
| | | % P.l. | 2.2 | 1.3 | 6.3 | 11.7 | 15.2 | 12.3 | 17.3 | 3.5 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 7.7 | 4.6 | 6.6 | 10.8 | 9.2 | 7.5 | 12.2 | 7.7 |
| | | Sp. # | 4 | 2 | 5 | 5 | 4 | 5 | 4 | 6 |
| | | Sp. Div. | 0.81 | 0.53 | 1.01 | 0.99 | 0.78 | 0.9 | 0.92 | 1.27 |
| | Middle | % CORAL | 23.4 | 17.6 | 22.6 | 17 | 16.9 | 19.8 | 42.7 | 42.2 |
| | | % P.l. | 12.9 | 5.1 | 8.6 | 9.2 | 6.5 | 6.8 | 12.9 | 15.0 |
| | | % P.c. | | | | | 0.1 | | | 1.4 |
| | | % P.m. | 6.1 | 7.5 | 12.8 | 7.5 | 9.8 | 11.7 | 26.2 | 20.7 |
| | | Sp. # | 5 | 5 | 5 | 4 | 5 | 5 | 6 | 5 |
| | | Sp. Div. | 1.17 | 1.27 | 0.9 | 0.79 | 0.82 | 0.91 | 0.95 | 1.12 |
| | Deep | % CORAL | 28.9 | 26.1 | 38.6 | 24 | 30.4 | 37.1 | 50.4 | 75.6 |
| | | % P.l. | 18.3 | 16.7 | 19.8 | 9.5 | 8.9 | 12.3 | 15.5 | 28.9 |
| | | % P.c. | | 0.4 | 1.1 | 1 | 0.5 | 0.2 | 0.5 | 1 |
| | | % P.m. | 4.4 | 4.6 | 14.8 | 12.6 | 19.6 | 22.3 | 27.3 | 35.3 |
| | | Sp. # | 4 | 6 | 6 | 6 | 5 | 6 | 6 | 7 |
| | | Sp. Div. | 1.04 | 1.08 | 1.09 | 1 | 0.88 | 0.91 | 1.17 | 1.16 |
| 12" PIPE NORTH | Shallow | % CORAL | 7.5 | 15.1 | 14.3 | 10.7 | 7.8 | 12.5 | 35.9 | 32.0 |
| | | % P.l. | 4.6 | 3.5 | 6.6 | 5.2 | 2.8 | 2 | 9.7 | 11.9 |
| | | % P.c. | | | | | | | | 0.2 |
| | | % P.m. | 1.5 | 8.1 | 6.5 | 3.8 | 4.3 | 9.5 | 22.1 | 18.7 |
| | | Sp. # | 5 | 7 | 6 | 5 | 5 | 5 | 3 | 5 |
| | | Sp. Div. | 1.13 | 1.35 | 1.02 | 1.19 | 0.99 | 0.79 | 0.90 | 0.85 |
| | Middle | % CORAL | 19.1 | 16.2 | 15.6 | 25.6 | 14.2 | 20 | 29.8 | 45.9 |
| | | % P.l. | 9.3 | 10.1 | 9.9 | 17.5 | 8.9 | 13.2 | 14.8 | 23.9 |
| | | % P.c. | | | 2.2 | 0.1 | | 0.3 | 2.2 | |
| | | % P.m. | 6.8 | 4.3 | 5.2 | 7.6 | 4.9 | 6.4 | 12.1 | 16.1 |
| | | Sp. # | 4 | 6 | 4 | 6 | 5 | 6 | 4 | 4 |
| | | Sp. Div. | 1.10 | 1.01 | 0.78 | 0.72 | 0.79 | 0.76 | 0.99 | 1.04 |
| | Deep | % CORAL | 30.4 | 29.9 | 10.8 | 17.5 | 22.6 | 17.1 | 40.6 | 63.6 |
| | | % P.l. | 24.8 | 23.9 | 4.2 | 12.2 | 13.8 | 9.5 | 23.5 | 32.0 |
| | | % P.c. | 0.8 | 0.5 | 0.1 | 0.5 | 0.7 | 0.4 | 2.3 | 1.4 |
| | | % P.m. | 0.8 | 1.8 | 5.6 | 3.3 | 6.1 | 6.1 | 7.1 | 14.6 |
| | | Sp. # | 5 | 5 | 6 | 5 | 5 | 5 | 6 | 6 |
| | | Sp. Div. | 0.67 | 0.74 | 1.03 | 0.89 | 1.01 | 0.98 | 1.22 | 1.22 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jan-95 | May-95 | Nov-95 | Jun-96 | Dec-96 | May-97 | Nov-97 | May-98 |
|---|---|---|---|---|---|---|---|---|---|---|
| NPPE | Shallow | % CORAL | 24.5 | 19.6 | 28.2 | 13.2 | 17.5 | 12.1 | 62.0 | 46.7 |
| | | % P.I. | 8.2 | 6.6 | 16.3 | 8.5 | 10 | 5.1 | 33.8 | 20.5 |
| | | % P.c. | | | 0.6 | | | | 0.6 | 0.6 |
| | | % P.m. | 9.6 | 8.6 | 9.1 | 4.1 | 5.3 | 5.1 | 21.2 | 20.0 |
| | | Sp. # | 6 | 5 | 5 | 4 | 6 | 6 | 6 | 7 |
| | | Sp. Div. | 1.45 | 1.28 | 0.98 | 0.82 | 1.11 | 1.21 | 1.06 | 1.19 |
| | Middle | % CORAL | 51.7 | 42.1 | 46.4 | 9.6 | 20.9 | 43.8 | 61.6 | 75.3 |
| | | % P.I. | 28.1 | 26.5 | 27.1 | 2.3 | 13.8 | 26.2 | 24.9 | 31.9 |
| | | % P.c. | 1.7 | 0.2 | 2.7 | | 0.4 | 0.3 | 2.8 | 1.2 |
| | | % P.m. | 19.7 | 13.2 | 11.5 | 7 | 5.2 | 13.8 | 19.1 | 33.1 |
| | | Sp. # | 6 | 6 | 8 | 5 | 6 | 5 | 7 | 7 |
| | | Sp. Div. | 0.98 | 0.89 | 1.18 | 0.74 | 0.96 | 0.94 | 1.50 | 1.17 |
| | Deep | % CORAL | 58.4 | 55.1 | 60.7 | 22.4 | 49.3 | 63.3 | 83.8 | 83.9 |
| | | % P.I. | 41.7 | 37.8 | 47.1 | 14.1 | 23.1 | 43.5 | 57.1 | 55.4 |
| | | % P.c. | 5.4 | 7.6 | 3.9 | 0.8 | 5.1 | 2.4 | 11.1 | 6.3 |
| | | % P.m. | 5.5 | 3.8 | 7 | 6.2 | 12.4 | 16.2 | 8.3 | 10.6 |
| | | Sp. # | 6 | 7 | 6 | 5 | 6 | 6 | 7 | 7 |
| | | Sp. Div. | 0.96 | 1.04 | 0.79 | 0.96 | 1.3 | 0.82 | 1.05 | 1.15 |
| HO'ONA BAY | Shallow | % CORAL | 10.8 | 11.0 | 8.7 | 14.2 | 14.4 | 18.5 | 17.6 | 24.0 |
| | | % P.I. | 9.1 | 6.3 | 6.6 | 12.5 | 13.4 | 13.9 | 12.0 | 16.5 |
| | | % P.c. | | | | 0.5 | | | | |
| | | % P.m. | 1.7 | 2.4 | 0.4 | 0.9 | 0.8 | 4.2 | 4.3 | 6.8 |
| | | Sp. # | 2 | 3 | 5 | 6 | 3 | 4 | 5 | 4 |
| | | Sp. Div. | 0.44 | 0.98 | 0.78 | 0.53 | 0.29 | 0.64 | 0.86 | 0.74 |
| | Middle | % CORAL | 28.7 | 23.4 | 40.3 | 40.5 | 45.8 | 59.4 | 68.0 | 82.6 |
| | | % P.I. | 24.9 | 20.3 | 21.6 | 23.9 | 26.9 | 28.8 | 46.4 | 51.0 |
| | | % P.c. | 3.5 | 3.0 | 8.4 | 12 | 10.8 | 13.7 | 18.9 | 29.4 |
| | | % P.m. | 0.1 | 0.1 | 6.2 | 3.5 | 4.4 | 7.6 | 0.6 | 1.1 |
| | | Sp. # | 4 | 3 | 7 | 6 | 6 | 7 | 7 | 5 |
| | | Sp. Div. | 0.43 | 0.41 | 1.27 | 1.00 | 1.16 | 1.44 | 0.80 | 0.79 |
| | Deep | % CORAL | 46.3 | 43.4 | 56.7 | 57.5 | 49.7 | 65.2 | 77.1 | 88.9 |
| | | % P.I. | 23.3 | 17.4 | 18.2 | 21.6 | 17.2 | 16.9 | 27.9 | 30.4 |
| | | % P.c. | 21.8 | 23.3 | 36.3 | 33.1 | 29.6 | 458 | 44.7 | 54.3 |
| | | % P.m. | 0.3 | 0.5 | 1.1 | 0.7 | 0.9 | | | 0.3 |
| | | Sp. # | 6 | 6 | 6 | 6 | 6 | 6 | 4 | 6 |
| | | Sp. Div. | 0.82 | 0.95 | 0.82 | 0.89 | 0.92 | 0.76 | 0.88 | 0.85 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Nov-98 | May-99 | Dec-99 | Jun-00 | Feb-01 | May-01 | Dec-01 | Jun-02 |
|---|---|---|---|---|---|---|---|---|---|---|
| WAWALOLI | Shallow | % CORAL | 19.4 | 16.9 | 21.2 | 24.1 | 34.1 | 32.4 | 23.5 | 42.3 |
| | | % P.l. | 7.6 | 8.1 | 10.9 | 12.3 | 17.8 | 15.5 | 7.5 | 27.3 |
| | | % P.c. | | 0.6 | | | | 0.1 | | 0.8 |
| | | % P.m. | 11.0 | 5.3 | 9.4 | 9.5 | 14.1 | 14.3 | 14.3 | 11.6 |
| | | Sp. # | 4 | 6 | 3 | 5 | 4 | 5 | 5 | 7 |
| | | Sp. Div. | 0.85 | 1.27 | 0.84 | 1.01 | 0.92 | 0.94 | 0.93 | 0.93 |
| | Middle | % CORAL | 35.5 | 23.9 | 45.9 | 26.3 | 31.4 | 44.8 | 33.7 | 34.7 |
| | | % P.l. | 16.5 | 11.4 | 25.8 | 13.2 | 14.4 | 14.4 | 14.3 | 16.3 |
| | | % P.c. | 0.6 | 0.3 | 1.1 | | | 0.3 | 0.3 | 0.3 |
| | | % P.m. | 13.7 | 9.1 | 13.1 | 8.5 | 12.0 | 22.1 | 16.6 | 14.1 |
| | | Sp. # | 7 | 5 | 5 | 5 | 4 | 6 | 5 | 6 |
| | | Sp. Div. | 1.16 | 1.13 | 1.11 | 1.20 | 1.08 | 1.18 | 0.97 | 1.12 |
| | Deep | % CORAL | 32.0 | 22.7 | 23.2 | 29.4 | 29.5 | 28.3 | 8.5 | 14.6 |
| | | % P.l. | 19.7 | 10.4 | 10.4 | 13.5 | 13.8 | 15.2 | 4.9 | 5.8 |
| | | % P.c. | 0.9 | 1.5 | 0.3 | 0.6 | | 1.2 | 0.6 | 2.6 |
| | | % P.m. | 10.8 | 8.9 | 10.8 | 11.5 | 13.0 | 9.9 | 1.8 | 4.4 |
| | | Sp. # | 5 | 4 | 4 | 5 | 4 | 5 | 5 | 4 |
| | | Sp. Div. | 0.85 | 1.11 | 0.96 | 1.15 | 0.95 | 1.07 | 1.15 | 1.29 |
| 18" PIPE | Shallow | % CORAL | 49.8 | 36.8 | 46.4 | 45.9 | 49.5 | 46.3 | 54.7 | 41.7 |
| | | % P.l. | 17.7 | 17.9 | 11.9 | 15.1 | 20.1 | 16.3 | 22.9 | 14.2 |
| | | % P.c. | 0.8 | | | | 0.3 | | | |
| | | % P.m. | 26.2 | 13.8 | 27.4 | 27.4 | 24.7 | 29.3 | 25.2 | 22.6 |
| | | Sp. # | 5 | 5 | 6 | 6 | 7 | 4 | 7 | 4 |
| | | Sp. Div. | 1.05 | 1.11 | 1.13 | 0.96 | 1.04 | 0.73 | 1.11 | 0.97 |
| | Middle | % CORAL | 44.9 | 44.9 | 49.5 | 43.2 | 53.1 | 59.0 | 40.1 | 52.9 |
| | | % P.l. | 20.0 | 19.2 | 8.2 | 8.4 | 12.7 | 16.7 | 8.2 | 21.2 |
| | | % P.c. | | | | 0.7 | | 0.2 | | |
| | | % P.m. | 18.9 | 20.9 | 38.8 | 30.7 | 32.0 | 32.6 | 24.2 | 23.5 |
| | | Sp. # | 5 | 5 | 4 | 7 | 7 | 5 | 6 | 5 |
| | | Sp. Div. | 1.10 | 1.03 | 0.67 | 0.89 | 1.11 | 1.11 | 1.15 | 1.12 |
| | Deep | % CORAL | 22.6 | 12.6 | 27.0 | 36.9 | 40.8 | 36.4 | 41.4 | 31.6 |
| | | % P.l. | 10.6 | 3.5 | 2.5 | 4.6 | 5.3 | 9.6 | 15.7 | 16.4 |
| | | % P.c. | 1.1 | 0.1 | 0.1 | | 0.2 | | 0.4 | 1.6 |
| | | % P.m. | 10.1 | 8.7 | 22.6 | 31.4 | 31.2 | 26.6 | 22.1 | 10.9 |
| | | Sp. # | 7 | 5 | 7 | 4 | 6 | 3 | 6 | 5 |
| | | Sp. Div. | 1.02 | 0.75 | 0.65 | 0.50 | 0.80 | 0.61 | 0.99 | 1.12 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Nov-98 | May-99 | Dec-99 | Jun-00 | Feb-01 | May-01 | Dec-01 | Jun-02 |
|---|---|---|---|---|---|---|---|---|---|---|
| 12" PIPE SOUTH | Shallow | % CORAL | 21.6 | 13.2 | 21.5 | 29.6 | 39.0 | 51.3 | 28.7 | 28.7 |
| | | % P.l. | 7.8 | 7.5 | 7.8 | 9.0 | 19.9 | 23.1 | 10.8 | 9.2 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | | 4.7 | 13.5 | 19.6 | 18.1 | 18.8 | 15.7 | 15.4 |
| | | Sp. # | 6 | 3 | 3 | 3 | 5 | 6 | 4 | 5 |
| | | Sp. Div. | 0.93 | 0.88 | 0.70 | 0.75 | 0.82 | 1.28 | 0.93 | 1.13 |
| | Middle | % CORAL | 50.9 | 36.9 | 57.5 | 57.5 | 56.9 | 60.9 | 56.7 | 52.0 |
| | | % P.l. | 32.9 | 18.8 | 30.0 | 20.4 | 15.3 | 23.3 | 14.1 | 20.1 |
| | | % P.c. | | | | 0.4 | | 0.2 | | |
| | | % P.m. | | 13.1 | 17.0 | 26.5 | 37.7 | 27.1 | 28.4 | 24.2 |
| | | Sp. # | 4 | 4 | 6 | 5 | 5 | 8 | 5 | 6 |
| | | Sp. Div. | 0.77 | 1.05 | 1.14 | 1.18 | 0.86 | 1.23 | 1.28 | 1.19 |
| | Deep | % CORAL | 68.2 | 36.3 | 65 | 65.3 | 71.7 | 76.6 | 72.2 | 68 |
| | | % P.l. | 23.1 | 15.9 | 26 | 20.08 | 30.6 | 28.6 | 45 | 28 |
| | | % P.c. | 1.1 | 1.4 | 0.6 | 0.7 | 1.8 | 5.8 | 5.3 | 2.1 |
| | | % P.m. | 35.7 | 5 | 30.3 | 34.5 | 27 | 32.1 | 14.7 | 24.9 |
| | | Sp. # | 6 | 7 | 7 | 8 | 7 | 6 | 6 | 7 |
| | | Sp. Div. | 1.12 | 1.41 | 1.16 | 1.20 | 1.32 | 1.30 | 1.14 | 1.32 |
| 12" PIPE NORTH | Shallow | % CORAL | 36.2 | 27.2 | 37.1 | 34.1 | 40.5 | 43.4 | 41.9 | 32.0 |
| | | % P.l. | 10.0 | 6.6 | 10.9 | 8.0 | 14.9 | 11.8 | 16.1 | 9.2 |
| | | % P.c. | 0.2 | | | | | | | 0.1 |
| | | % P.m. | 22.9 | 20.2 | 24.1 | 22.8 | 22.9 | 26.4 | 21.1 | 18.4 |
| | | Sp. # | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 7 |
| | | Sp. Div. | 0.88 | 0.64 | 0.81 | 0.90 | 0.93 | 0.94 | 1.05 | 1.07 |
| | Middle | % CORAL | 41.5 | 53.0 | 33.7 | 33.2 | 50.9 | 40.5 | 51.0 | 49.2 |
| | | % P.l. | 22.5 | 15.7 | 16.3 | 20.6 | 21.7 | 16.1 | 19.1 | 23.6 |
| | | % P.c. | | 1.2 | 1.2 | | | 0.8 | 2.2 | 0.3 |
| | | % P.m. | 14.4 | 31.1 | 12.5 | 11.1 | 21.5 | 18.9 | 21.6 | 16.2 |
| | | Sp. # | 4 | 7 | 7 | 5 | 7 | 6 | 8 | 7 |
| | | Sp. Div. | 0.95 | 1.09 | 1.19 | 0.85 | 1.20 | 1.17 | 1.35 | 1.28 |
| | Deep | % CORAL | 47.3 | 58.1 | 59.8 | 63.7 | 66.6 | 60.1 | 60.4 | 64.8 |
| | | % P.l. | 26.6 | 36.0 | 32.2 | 36.2 | 35.4 | 29.0 | 27.7 | 38.1 |
| | | % P.c. | 1.7 | 0.9 | 1.8 | 2.3 | 2.8 | 3.2 | 1.9 | 5.6 |
| | | % P.m. | 8.0 | 13.7 | 15.4 | 13.7 | 17.8 | 21.0 | 14.4 | 10.8 |
| | | Sp. # | 5 | 5 | 7 | 5 | 6 | 6 | 6 | 6 |
| | | Sp. Div. | 1.23 | 1.03 | 1.23 | 1.17 | 1.19 | 1.22 | 1.35 | 1.24 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Nov-98 | May-99 | Dec-99 | Jun-00 | Feb-01 | May-01 | Dec-01 | Jun-02 |
|---|---|---|---|---|---|---|---|---|---|---|
| NPPE | Shallow | % CORAL | 42.5 | 47.8 | 66.8 | 53.7 | 37.7 | 48.1 | 52.9 | 45.3 |
| | | % P.l. | 15.4 | 19.1 | 31.9 | 25.3 | 12.6 | 21.1 | 28.4 | 19.7 |
| | | % P.c. | | | | | | 0.8 | | |
| | | % P.m. | 16.3 | 21.8 | 24.6 | 22.1 | 22.9 | 24.3 | 19.8 | 22.1 |
| | | Sp. # | 6 | 5 | 6 | 4 | 5 | 5 | 4 | 7 |
| | | Sp. Div. | 1.37 | 1.12 | 1.17 | 1.05 | 0.87 | 0.92 | 0.98 | 0.97 |
| | Middle | % CORAL | 64.8 | 75.3 | 85.4 | 71.3 | 77.2 | 71.7 | 70.2 | 59.2 |
| | | % P.l. | 27.1 | 35.6 | 46.9 | 39.6 | 33.4 | 38.0 | 41.5 | 28.7 |
| | | % P.c. | 1.3 | 1.6 | 1.9 | 4.5 | 2.8 | 2.4 | 6.4 | |
| | | % P.m. | 30.4 | 27.7 | 30.6 | 22.8 | 35.2 | 22.6 | 17.2 | 22.4 |
| | | Sp. # | 6 | 7 | 6 | 5 | 6 | 7 | 6 | 6 |
| | | Sp. Div. | 1.11 | 1.23 | 1.04 | 1.08 | 1.10 | 1.20 | 1.13 | 1.11 |
| | Deep | % CORAL | 77.2 | 79.8 | 74.7 | 89.8 | 77.7 | 89.6 | 76.6 | 90.3 |
| | | % P.l. | 47.7 | 49.7 | 48.8 | 56.3 | 45.5 | 62.0 | 41.9 | 61.1 |
| | | % P.c. | 14.3 | 20.5 | 11.7 | 14.5 | 17.2 | 17.0 | 10.3 | 21.4 |
| | | % P.m. | 8.9 | 5.3 | 6.3 | 9.0 | 8.2 | 6.3 | 15.2 | 5.1 |
| | | Sp. # | 4 | 7 | 7 | 6 | 5 | 5 | 7 | 5 |
| | | Sp. Div. | 1.06 | 1.01 | 1.11 | 1.17 | 1.15 | 0.93 | 1.29 | 0.89 |
| HO'ONA BAY | Shallow | % CORAL | 27.7 | 15.3 | 32.2 | 35.2 | 46.9 | 41.9 | 43.6 | 35.2 |
| | | % P.l. | 13.5 | 7.0 | 15.2 | 19.0 | 24.2 | 15.9 | 22.7 | 4.4 |
| | | % P.c. | 0.2 | | 0.2 | | | | | |
| | | % P.m. | 10.1 | 8.3 | 12.7 | 14.9 | 17.6 | 21.2 | 19.1 | 30.8 |
| | | Sp. # | 4 | 2 | 4 | 3 | 5 | 6 | 4 | 2 |
| | | Sp. Div. | 1.03 | 0.69 | 1.02 | 0.82 | 1.03 | 1.08 | 0.85 | 0.38 |
| | Middle | % CORAL | 64.9 | 48.0 | 48.4 | 44.0 | 49.5 | 30.6 | 42.1 | 38.9 |
| | | % P.l. | 28.7 | 28.1 | 24.2 | 29.3 | 29.9 | 16.1 | 30.3 | 26.3 |
| | | % P.c. | 28.7 | 12.6 | 17.8 | 10.1 | 16.1 | | 2.9 | 0.9 |
| | | % P.m. | 6.7 | 3.2 | 5.2 | 3.6 | 2.9 | 12.0 | 7.2 | 11.6 |
| | | Sp. # | 5 | 5 | 6 | 6 | 4 | 4 | 6 | 4 |
| | | Sp. Div. | 1.02 | 1.10 | 1.06 | 0.92 | 0.89 | 0.95 | 0.88 | 0.73 |
| | Deep | % CORAL | 82.0 | 83.4 | 69.5 | 72.0 | 65.0 | 82.9 | 76.8 | 86.5 |
| | | % P.l. | 28.3 | 28.8 | 27.0 | 24.6 | 38.2 | 32.9 | 33.0 | 39.3 |
| | | % P.c. | 49.4 | 52.6 | 38.7 | 43.8 | 22.4 | 43.8 | 38.4 | 39.7 |
| | | % P.m. | 0.2 | | 0.5 | | 1.1 | | 1.6 | 0.4 |
| | | Sp. # | 6 | 6 | 6 | 4 | 6 | 5 | 6 | 6 |
| | | Sp. Div. | 0.88 | 0.78 | 0.91 | 0.85 | 0.95 | 0.97 | 0.98 | 1.04 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Oct-07 | Jul-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|
| WAWALOLI | Shallow | % CORAL | 25.3 | 17.7 | 20.9 | 28.3 | 41.2 | 29.1 | 21.0 | 27.4 |
| | | % P.l. | 17.5 | 9.9 | 13.1 | 18.4 | 24.9 | 22.2 | 16.0 | 18.5 |
| | | % P.c. | | | 0.2 | | 0.2 | | | |
| | | % P.m. | 6.1 | 5.0 | 5.4 | 5.7 | 11.0 | 1.6 | 3.0 | 6.5 |
| | | Sp. # | 4 | 4 | 6 | 5 | 6 | 5 | 4 | 5 |
| | | Sp. Div. | 0.82 | 0.92 | 1.02 | 0.85 | 0.97 | 0.80 | 0.77 | 0.88 |
| | Middle | % CORAL | 22 | 15.7 | 34.1 | 23.0 | 59.1 | 46.3 | 34.3 | 38.6 |
| | | % P.l. | 13.4 | 11.2 | 24.2 | 11.7 | 38.9 | 39.7 | 29.4 | 30.3 |
| | | % P.c. | | | | | 5.1 | 0.2 | | |
| | | % P.m. | 6.6 | 3.5 | 5.8 | 9.3 | 12.6 | 4.5 | 3.5 | 3.9 |
| | | Sp. # | 4 | 3 | 4 | 4 | 5 | 4 | 5 | 5 |
| | | Sp. Div. | 0.87 | 0.76 | 0.85 | 0.93 | 0.97 | 0.51 | 0.52 | 0.77 |
| | Deep | % CORAL | 22.2 | 18.6 | 32.5 | 19.0 | 67.4 | 47.9 | 13.4 | 29.8 |
| | | % P.l. | 16.9 | 13.3 | 25.2 | 12.9 | 30.7 | 21.7 | 9.8 | 21.6 |
| | | % P.c. | 0.3 | | 0.5 | 2.1 | 36.1 | 26.2 | 0.3 | 0.6 |
| | | % P.m. | 7.7 | 2.2 | 5.9 | 2.7 | 0.4 | | 3.1 | 2.9 |
| | | Sp. # | 5 | 4 | 4 | 5 | 4 | 2 | 6 | 5 |
| | | Sp. Div. | 0.69 | 0.7 | 0.68 | 0.96 | 0.74 | 0.69 | 0.73 | 0.88 |
| 18" PIPE | Shallow | % CORAL | 37.4 | 40.3 | 39.9 | 47.5 | 47.8 | 56.7 | 43.1 | 39.5 |
| | | % P.l. | 18.8 | 23.7 | 22.7 | 29.3 | 24.7 | 33.4 | 29.9 | 25.8 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 11.4 | 14 | 14.2 | 12.4 | 20.3 | 19.9 | 9.8 | 11.1 |
| | | Sp. # | 5 | 6 | 3 | 5 | 4 | 5 | 4 | 4 |
| | | Sp. Div. | 1.13 | 0.93 | 0.88 | 0.66 | 0.91 | 0.89 | 0.81 | 0.85 |
| | Middle | % CORAL | 23 | 35.2 | 28.7 | 29.8 | 32.3 | 57.1 | 40.9 | 31.8 |
| | | % P.l. | 9.5 | 16.5 | 13.9 | 10.8 | 12.1 | 27.1 | 26.6 | 16.3 |
| | | % P.c. | | | | | | | | 0.1 |
| | | % P.m. | 11.5 | 15.4 | 12.9 | 16.5 | 18.8 | 18.7 | 9.9 | 9.0 |
| | | Sp. # | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 8 |
| | | Sp. Div. | 1 | 0.96 | 0.97 | 0.85 | 0.86 | 1.2 | 0.94 | 1.27 |
| | Deep | % CORAL | 31.9 | 35.5 | 32.8 | 29.8 | 34.6 | 35.1 | 32.8 | 41.4 |
| | | % P.l. | 9.7 | 14.5 | 11.1 | 9.1 | 15.7 | 15.0 | 18.1 | 24.5 |
| | | % P.c. | | 0.1 | 0.3 | 0.6 | 0.2 | 0.2 | 0.1 | 0.4 |
| | | % P.m. | 20.1 | 18.1 | 17.4 | 16.2 | 14.9 | 18.5 | 13.0 | 13.5 |
| | | Sp. # | 3 | 6 | 6 | 6 | 5 | 5 | 5 | 7 |
| | | Sp. Div. | 0.84 | 1.0 | 1.07 | 1.1 | 1.07 | 0.88 | 0.9 | 1.0 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Oct-07 | Jul-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 12" PIPE SOUTH | Shallow | % CORAL | 14.5 | 18.1 | 16.4 | 22.9 | 61.1 | 27.1 | 23.4 | 21.8 |
| | | % P.I. | 8.3 | 7.9 | 4.6 | 10.5 | 31.7 | 9.8 | 15.2 | 11.7 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 6.1 | 6.6 | 10.2 | 10.6 | 25.1 | 15.8 | 5.9 | 10.2 |
| | | Sp. # | 3 | 6 | 4 | 4 | 4 | 5 | 5 | 2 |
| | | Sp. Div. | 0.73 | 1.22 | 0.89 | 0.89 | 0.94 | 0.9 | 0.95 | 0.69 |
| | Middle | % CORAL | 36.4 | 29.4 | 33.9 | 35.5 | 32.6 | 60.1 | 33.1 | 32.8 |
| | | % P.I. | 16.7 | 15.1 | 19.9 | 19.6 | 18.7 | 24.9 | 20.1 | 20.9 |
| | | % P.c. | | | | | | | | |
| | | % P.m. | 15.3 | 11.8 | 11.9 | 15.0 | 12.2 | 20.8 | 10.1 | 10.4 |
| | | Sp. # | 5 | 3 | 5 | 3 | 4 | 5 | 4 | 4 |
| | | Sp. Div. | 1.08 | 0.92 | 0.91 | 0.79 | 0.87 | 1.25 | 0.87 | 0.82 |
| | Deep | % CORAL | 27.5 | 17.4 | 29.4 | 36.4 | 74.8 | 75.2 | 31.9 | 31.2 |
| | | % P.I. | 9.2 | 5.8 | 13.6 | 11.9 | 41.4 | 37.0 | 12.9 | 16.1 |
| | | % P.c. | | | 0.1 | | 10.7 | 8.8 | | 0.1 |
| | | % P.m. | 14.7 | 10.3 | 14.2 | 23.5 | 14.3 | 15.2 | 17.4 | 12.0 |
| | | Sp. # | 6 | 4 | 5 | 5 | 5 | 6 | 4 | 6 |
| | | Sp. Div. | 1.09 | 0.9 | 0.91 | 0.72 | 1.24 | 1.44 | 0.86 | 1.04 |
| 12" PIPE NORTH | Shallow | % CORAL | 17.8 | 36.7 | 27.5 | 33.0 | 26.5 | 39.2 | 21.5 | 29.5 |
| | | % P.I. | 10.9 | 17.2 | 15.3 | 20.0 | 12.0 | 20.3 | 13.6 | 18.4 |
| | | % P.c. | | 0.3 | | | | 0.2 | | |
| | | % P.m. | 6.1 | 10.6 | 6.3 | 7.7 | 12.8 | 12.7 | 5.7 | 6.0 |
| | | Sp. # | 4 | 6 | 6 | 5 | 3 | 5 | 4 | 4 |
| | | Sp. Div. | 0.84 | 1.31 | 1.28 | 0.82 | 0.89 | 1.1 | 0.93 | 1.03 |
| | Middle | % CORAL | 26.7 | 19.1 | 33.3 | 35.1 | 50.8 | 55.3 | 35.9 | 41.8 |
| | | % P.I. | 14 | 9.3 | 16.0 | 19.0 | 20.9 | 27.3 | 17.1 | 18.6 |
| | | % P.c. | | | | 0.1 | | 0.3 | | 0.1 |
| | | % P.m. | 10 | 8.4 | 11.3 | 9.8 | 15.1 | 18.6 | 13.9 | 14.1 |
| | | Sp. # | 3 | 4 | 7 | 6 | 6 | 6 | 5 | 5 |
| | | Sp. Div. | 0.94 | 0.95 | 1.22 | 0.90 | 1.37 | 1.15 | 1.07 | 1.22 |
| | Deep | % CORAL | 33.8 | 19.6 | 44.3 | 41.3 | 72.0 | 74.8 | 55.3 | 57.2 |
| | | % P.I. | 18.6 | 11.8 | 20.4 | 23.7 | 46.6 | 41.5 | 37.8 | 48.8 |
| | | % P.c. | | | 0.1 | | 4.7 | 16.2 | 2.8 | 5.4 |
| | | % P.m. | 9.9 | 6.3 | 14.8 | 13 | 16.2 | 12 | 11.2 | 7.8 |
| | | Sp. # | 4 | 3 | 6 | 4 | 5 | 5 | 5 | 5 |
| | | Sp. Div. | 1.07 | 0.87 | 1.28 | 0.91 | 0.99 | 1.17 | 0.95 | 0.92 |

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and October 2008. Locations of transects are shown in Figure 3.

| SITE | DEPTH | PARAMETER | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Oct-07 | Jul-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|
| NPPE | Shallow | % CORAL | 34.5 | 37 | 20.5 | 51.7 | 41.1 | 50.6 | 53.8 | 42.5 |
| | | % P.l. | 24 | 29.2 | 13.7 | 39.9 | 26.3 | 23.4 | 40.5 | 29.7 |
| | | % P.c. | 0.2 | | | | 12.7 | 2.8 | 0.3 | |
| | | % P.m. | 3.7 | 6.7 | 2.2 | 7.8 | | 14.8 | 6.7 | 7.6 |
| | | Sp. # | 6 | 4 | 5 | 6 | 3 | 8 | 5 | 6 |
| | | Sp. Div. | 1.04 | 0.62 | 1.01 | 0.60 | 0.80 | 1.43 | 0.78 | 0.98 |
| | Middle | % CORAL | 56.8 | 40.5 | 43.8 | 53.6 | 77.3 | 75.8 | 53.0 | 52.1 |
| | | % P.l. | 37.5 | 29.2 | 31.5 | 41.2 | 47.5 | 40.2 | 41.3 | 37.1 |
| | | % P.c. | 1.8 | | 0.1 | | 10.1 | 4.8 | | 0.6 |
| | | % P.m. | 11.5 | 8.3 | 9.7 | 7 | 11.1 | 15.9 | 7.0 | 7.8 |
| | | Sp. # | 5 | 4 | 6 | 4 | 6 | 5 | 5 | 7 |
| | | Sp. Div. | 1.02 | 0.8 | 0.79 | 0.57 | 1.19 | 1.29 | 0.71 | 0.88 |
| | Deep | % CORAL | 64.5 | 69 | 72.1 | 69.1 | 88.6 | 87.5 | 75.2 | 65.1 |
| | | % P.l. | 40.2 | 54.3 | 49.9 | 46.1 | 65.9 | 55.5 | 46.2 | 36.7 |
| | | % P.c. | 13.4 | 7.6 | 12.7 | 14.7 | 16.0 | 24.5 | 20.4 | 14.2 |
| | | % P.m. | 7.6 | 6.1 | 7.0 | 6.6 | 5.6 | 4.7 | 6.1 | 7.1 |
| | | Sp. # | 5 | 5 | 6 | 5 | 5 | 5 | 5 | 7 |
| | | Sp. Div. | 1.04 | 0.72 | 0.93 | 0.88 | 0.77 | 0.93 | 0.99 | 1.23 |
| HO'ONA BAY | Shallow | % CORAL | 6.7 | 16.9 | 38.5 | 33.9 | 34.9 | 46.2 | 32.5 | 39.0 |
| | | % P.l. | 4.2 | 12.7 | 29.2 | 28.6 | 26.6 | 28.1 | 27.9 | 31.1 |
| | | % P.c. | | | | | | | 0.5 | |
| | | % P.m. | 2.5 | 3.2 | 8.4 | 4.2 | 8.3 | 15.4 | 3.6 | 6.9 |
| | | Sp. # | 2 | 3 | 4 | 3 | 2 | 4 | 3 | 4 |
| | | Sp. Div. | 0.61 | 0.69 | 0.64 | 0.52 | 0.55 | 0.86 | 0.43 | 0.58 |
| | Middle | % CORAL | 21.3 | 21.6 | 25.8 | 46.3 | 39.1 | 60.6 | 62.2 | 41.0 |
| | | % P.l. | 16.8 | 16.4 | 17.7 | 35.6 | 32.6 | 33.2 | 33.0 | 29.2 |
| | | % P.c. | 0.3 | | 2.9 | 9.5 | 1.2 | 21.9 | 27.3 | 0.5 |
| | | % P.m. | 4 | 4.5 | 4.2 | 1.0 | 4.3 | 3.6 | 1.4 | 8.1 |
| | | Sp. # | 4 | 3 | 6 | 6 | 5 | 5 | 5 | 4 |
| | | Sp. Div. | 0.66 | 0.65 | 0.97 | 0.62 | 0.61 | 0.99 | 0.83 | 0.81 |
| | Deep | % CORAL | 52.4 | 55.2 | 71.1 | 57.7 | 61.2 | 59.5 | 47.6 | 49.1 |
| | | % P.l. | 13.8 | 19.9 | 15.6 | 13.6 | 36.0 | 35.6 | 28.3 | 31.4 |
| | | % P.c. | 37.7 | 34.1 | 53.8 | 42.3 | 23.5 | 22.2 | 18.6 | 15.9 |
| | | % P.m. | | | | 0.1 | 0.2 | 0.2 | 0.6 | |
| | | Sp. # | 4 | 3 | 4 | 7 | 5 | 6 | 4 | 5 |
| | | Sp. Div. | 0.65 | 0.75 | 0.64 | 0.59 | 0.80 | 0.81 | 0.75 | 0.79 |

# APPENDIX C

# SEA URCHIN SURVEY RESULTS

Appendix C. Summary of the quantitative counts of sea urchins within 0.6 x 1.0 m photo-quadrats for surveys conducted between December 1991 and May 2009. Locations of transects are shown in Figure 3.

| Location | Site | Species | Dec-91 | May-92 | Oct-92 | May-93 | Oct-93 | Mar-94 | May-94 | Sep-94 | Jan-95 | May-95 | Nov-97 | May-98 | Nov-98 | May-99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | *E. mathaei* | 36 | 14 | 8 | 11 | 24 | 14 | 20 | 24 | 31 | 26 | 22 | 31 | 27 | 34 |
| | | *H. mammilatus* | | | 1 | | 1 | | | | | 2 | | 1 | 1 | 2 |
| | | *T. gratilla* | | | 1 | | | | | | | 1 | 1 | 2 | 3 | 3 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | 9 | 40 | 30 | 17 | 34 | 29 | 25 | 31 | 35 | 41 | 35 | 39 | 42 | 31 |
| | | *H. mammilatus* | | | | 1 | 1 | | | | | | | | | |
| | | *E. calamaris* | | | | | | | | | | | | | | |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | | *T. gratilla* | | | | | | | | | | | | | | |
| | Slope | *E. mathaei* | 5 | | 3 | 1 | 1 | 6 | 3 | 4 | 5 | 3 | 2 | 1 | 2 | 3 |
| | | *H. mammilatus* | 1 | | | | | | | | | | 1 | 1 | 1 | 2 |
| | | *T. gratilla* | | 2 | | 1 | | | | | | | | | | 1 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| 18" Pipe | Boulder | *E. mathaei* | 19 | 2 | 4 | 3 | 8 | 4 | 6 | 3 | 2 | 4 | 3 | 5 | 4 | 2 |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | 8 | 5 | 3 | 11 | 13 | 6 | 14 | 21 | 28 | 24 | 27 | 32 | 35 | 39 |
| | | *E. aciculatus* | | | | 1 | | 1 | 1 | | | | | | | 1 |
| | | *E. calimaris* | | | | | | | | | | | | | | |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | | *T. gratilla* | | | | | | | | | | | | | | |
| | Slope | *E. mathaei* | 4 | 9 | 8 | 7 | 6 | 2 | 11 | 7 | 5 | 4 | 4 | 2 | 2 | 2 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | | *T. gratilla* | | | | | | | | | | | | | | |
| 12" Pipe S | Boulder | *E. mathaei* | | 2 | 3 | 2 | 1 | | 1 | 2 | 1 | 2 | 3 | 4 | 2 | 6 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | | *E. oblongata* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | | 15 | 4 | 6 | 11 | 8 | 5 | 3 | 2 | 2 | 2 | 3 | 3 | 4 |
| | Slope | *E. mathaei* | | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 2 | 1 | 1 |
| | | *E. diadema* | | | | | | | | | | | 1 | 2 | 2 | 3 |
| | | *T. gratilla* | | | | | | | | | | | | | | |

Appendix C. Summary of the quantitative counts of sea urchins within 0.6 x 1.0 m photo-quadrats for surveys conducted between December 1991 and May 2009. Locations of transects are shown in Figure 3.

| Location | Site | Species | Dec-91 | May-92 | Oct-92 | May-93 | Oct-93 | Mar-94 | May-94 | Sep-94 | Jan-95 | May-95 | Nov-97 | May-98 | Nov-98 | May-99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12" Pipe N | Boulder | *E. mathaei* | | 3 | 2 | 7 | 4 | 2 | 4 | 3 | 4 | 4 | 2 | 2 | 1 | 2 |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | | 9 | 15 | 7 | 11 | 6 | 6 | 4 | 3 | 2 | 4 | 3 | 2 | 3 |
| | | *E. calimaris* | | | | | | | | | | | | | | |
| | Slope | *E. mathaei* | | 2 | | 1 | 1 | 1 | 4 | 2 | 2 | 3 | 3 | 5 | 3 | 4 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| NPPE | Boulder | *E. mathaei* | | 7 | 7 | 7 | 4 | 4 | 3 | 1 | 2 | 5 | 4 | 6 | 2 | 6 |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | | 1 | 4 | 1 | 1 | 6 | 8 | 3 | 4 | 41 | 27 | 38 | 26 | 28 |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | | *H. mammilatus* | | | | | | | | | | | | | | |
| | Slope | *E. mathaei* | | 1 | 4 | | | 2 | 4 | 1 | 3 | | | | | |
| | | *E. calimaris* | | | | | | | | | | | | | | |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| Ho'ona Bay | Boulder | *E. mathaei* | 4 | 23 | 9 | 4 | 12 | 6 | 11 | 16 | 19 | 12 | 11 | 14 | 12 | 16 |
| | | *H. mammilatus* | 2 | 2 | | 2 | 1 | 2 | | | | | | | | |
| | | *E. diadema* | | | | 1 | | | | | | | | | | |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | | *T. gratilla* | | | | | | | | | | | | | | |
| | Bench | *E. mathaei* | 39 | 20 | 4 | 1 | 9 | 7 | 6 | 3 | 4 | 3 | 2 | 3 | 2 | 3 |
| | | *H. mammilatus* | 7 | 3 | 4 | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 5 | 2 |
| | | *T. gratilla* | | | | | | | | | | | | | | |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | | *E. diadema* | | | | | | | | | | | | | | |
| | Slope | *E. mathaei* | 7 | | | 1 | 1 | | | 1 | 3 | 4 | 2 | 2 | 4 | 4 |
| | | *H. mammilatus* | 4 | | 1 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 2 |
| | | *T. gratilla* | | | | 3 | 1 | | | | | | | | | |
| | | *E. aciculatus* | | | | | | | | | | | | | | |
| | | *E. diadema* | | | | | | | | | | | | | | |

Appendix C. Summary of the quantitative counts of sea urchins within 0.6 x 1.0 m photo-quadrats for surveys conducted between December 1991 and May 2009. Locations of transects are shown in Figure 3.

| Location | Site | Species | Dec-99 | May-00 | Feb-01 | May-01 | Dec-01 | Jun-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Oct-07 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | *E. mathaei* | 38 | 29 | 41 | 29 | 32 | 21 | 39 | 38 | 63 | 24 | 29 | 30 | 12 |
| | | *H. mammilatus* | | 2 | | | | | | | | | | | |
| | | *T. gratilla* | | | | | | 1 | 14 | 2 | 2 | | 2 | 2 | |
| | | *E. diadema* | 2 | 1 | | | | 1 | | 2 | | 5 | 1 | 1 | 1 |
| | Bench | *E. mathaei* | 29 | 32 | 26 | 24 | 37 | 26 | 18 | 74 | 40 | 58 | 31 | 22 | 12 |
| | | *H. mammilatus* | | | | | | | | | | | | | |
| | | *E. calamaris* | | | | | | | 1 | | | | | | |
| | | *E. diadema* | | | | 1 | 1 | 1 | | | | | 2 | 1 | 3 |
| | | | | | | | | | | | | 2 | | 1 | 1 |
| | Slope | *E. mathaei* | 4 | 2 | 5 | 4 | 4 | 2 | 2 | 8 | 6 | 14 | 6 | 6 | |
| | | *H. mammilatus* | | 2 | | | | | | | | | 1 | | 1 |
| | | *T. gratilla* | | | | | | | 13 | | 2 | | | 1 | |
| | | *E. diadema* | | 1 | | | | | | | | | 2 | 3 | |
| 18" Pipe | Boulder | *E. mathaei* | 5 | 6 | 8 | 11 | 12 | 14 | 9 | 28 | 17 | 26 | 8 | 17 | 8 |
| | | | | | | | | | | | | | | | 1 |
| | Bench | *E. mathaei* | 19 | 32 | 31 | 29 | 19 | 21 | 4 | 13 | 25 | 17 | 22 | 14 | 8 |
| | | *E. aciculatus* | | | | | | | 1 | | 4 | | | | 2 |
| | | *E. calimaris* | | | | | | | 1 | | | | | | |
| | | *E. diadema* | 1 | 2 | | | | | | | | | | 2 | 4 |
| | | *T. gratilla* | | | | | | | 1 | | | | 1 | | |
| | Slope | *E. mathaei* | 11 | 4 | 21 | 18 | 13 | 11 | 4 | 1 | 9 | 5 | 15 | 7 | 10 |
| | | | | | | | | | | | | | 2 | | |
| | | *T. gratilla* | | | | | | | 1 | | | 1 | | | |
| 12" Pipe S | Boulder | *E. mathaei* | 5 | 11 | 16 | 21 | 19 | 12 | 8 | 9 | 18 | 7 | 16 | 11 | 7 |
| | | | | | | | | | | | | | 1 | | |
| | | *E. oblongata* | | | | | | | 1 | | | | | | |
| | Bench | *E. mathaei* | 4 | 8 | 11 | 14 | 15 | 11 | 14 | 4 | 16 | 3 | 16 | 9 | 1 |
| | Slope | *E. mathaei* | 5 | 5 | 8 | 6 | 11 | 9 | 4 | 2 | 5 | 1 | 4 | 5 | 3 |
| | | *E. diadema* | | | | | | | | 1 | | | 1 | 3 | |
| | | *T. gratilla* | | | | | | | 1 | | | | | 1 | |

Appendix C. Summary of the quantitative counts of sea urchins within 0.6 x 1.0 m photo-quadrats for surveys conducted between December 1991 and May 2009. Locations of transects are shown in Figure 3.

| Location | Site | Species | Dec-99 | May-00 | Feb-01 | May-01 | Dec-01 | Jun-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Oct-07 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12" Pipe N | Boulder | *E. mathaei* | 5 | 6 | 11 | 13 | 12 | 21 | 11 | 8 | 15 | 5 | 8 | 12 | 7 |
| | | | | | | | | | | | | | | | 2 |
| | Bench | *E. mathaei* | 5 | 7 | 12 | 16 | 15 | 18 | 6 | 3 | 23 | 9 | 13 | 10 | 5 |
| | | *E. calimaris* | | | | | | | 2 | | | | | | |
| | Slope | *E. mathaei* | 4 | 7 | 14 | 21 | 13 | 15 | 5 | 3 | 6 | 7 | 11 | 9 | 8 |
| | | | | | | | | | | | | | 2 | | |
| NPPE | Boulder | *E. mathaei* | 8 | 11 | 21 | 25 | 18 | 11 | 14 | 14 | 27 | 21 | 12 | 16 | 3 |
| | | | | | | | | | | | | | 3 | | |
| | | | | | | | | | | | | | | | 1 |
| | Bench | *E. mathaei* | 18 | 31 | 43 | 32 | 21 | 16 | 15 | 16 | 13 | 5 | 28 | 15 | 2 |
| | | *E. aciculatus* | | | | 1 | | | 1 | | | | | 2 | 1 |
| | | | | | | | | | | | | | 1 | | |
| | Slope | *E. mathaei* | 5 | 2 | 9 | 11 | 13 | 7 | 2 | 2 | 13 | 15 | | 8 | |
| | | *E. calimaris* | | | | | | | 1 | | | | | | |
| | | *E. aciculatus* | | | | | | | 3 | | | | | 2 | 2 |
| Ho'ona Bay | Boulder | *E. mathaei* | 7 | 5 | 9 | 13 | 11 | 11 | 56 | 2 | 53 | 25 | 14 | 21 | 14 |
| | | *H. mammilatus* | | | | | | | | | | | | | |
| | | *E. diadema* | | | | 1 | | | | | 1 | | | | |
| | | *E. aciculatus* | | | | | | | 1 | | | 1 | | | |
| | | | | | | | | | | | | | | 5 | |
| | Bench | *E. mathaei* | 5 | 5 | 11 | 21 | 15 | 14 | 59 | 46 | 33 | 51 | 13 | 37 | 28 |
| | | *H. mammilatus* | | | | | | | | | 1 | 1 | | | |
| | | *T. gratilla* | | 1 | | | | | | | 1 | 2 | | 1 | 1 |
| | | *E. aciculatus* | | | | | | | 7 | | 2 | | | | |
| | | | | | | | | | | | | | | | 5 |
| | Slope | *E. mathaei* | 3 | 6 | 12 | 19 | 12 | 9 | 10 | 60 | 6 | 7 | 15 | 20 | 2 |
| | | *H. mammilatus* | | | | | | | | | 2 | 2 | | | |
| | | *T. gratilla* | | | | | | 1 | 1 | | 11 | 16 | | 4 | |
| | | *E. aciculatus* | | | | | | | 13 | | | | | | 4 |
| | | | | | | | | | | | | | 2 | | 6 |

# APPENDIX D

# MARINE FISH COMMUNITY SURVEY SUMMARY

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on May 16-18, 2009. Transect locations are shown in Figure 3. Species listed in taxonomic order.

| | | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Species | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | |
| Muraenidae | *Gymnomuraena zebra* | | | | | | | | | | | | | 1 | | | | | | 1 |
| | *Gymnothorax meleagris* | | 1 | | | | | | | 1 | | | | | | | | | | 2 |
| Holocentridae | *Myripristis berndti* | | | | | | | | | | | 35 | | | | | | | 48 | 83 |
| Aulostomidae | *Aulostomus chinensis* | | | | | | | | | | | | | 1 | | | | | | 1 |
| Serranidae | *Cephalopholis argus* | | | 1 | | | | | | | | | | | | | 1 | | 1 | 3 |
| Cirrhitidae | *Cirrhitus pinnulatus* | | | | 1 | | | | | | | | | | | | | | | 1 |
| | *Paracirrhites arcatus* | 7 | 11 | 10 | 22 | 9 | 25 | 13 | 11 | 18 | 2 | 9 | 12 | | 8 | 10 | 12 | 9 | | 188 |
| | *Paracirrhites fosteri* | | | | | | | | | 1 | | | | | 1 | | | | | 2 |
| Carangidae | *Caranx melampygus* | | | | | | | 1 | | | | | | | | | | | | 1 |
| Lutjanidae | *Lutjanus kasmira* | | | | | | 1 | | | | | | | | | | | | | 1 |
| Lethirinidae | *Monotaxis grandoculis* | | | | | 1 | | | | | | | | | | | | | | 1 |
| Mullidae | *Parupeneus bifasciatus* | 1 | | | | | 1 | | 1 | | 1 | | 1 | | | | 1 | | | 6 |
| | *Parupeneus chrysonemus* | | | | | | | | | | | | | | | | | 1 | | 1 |
| | *Parupeneus multifasciatus* | | 1 | 1 | | | 4 | | 1 | 1 | 1 | 1 | 1 | | | 1 | | | 2 | 14 |
| Kyphosidae | *Kyphosus bigibbus* | | | | 2 | | | | | | | | | 1 | | | | | | 3 |
| Chaetodontidae | *Chaetodon auriga* | 2 | | | | 1 | | | | | | | | | | 2 | | | | 5 |
| | *Chaetodon kleini* | | | | | | | | | 2 | | | | | | | | | | 2 |
| | *Chaetodon lineolatus* | | | | | 4 | | | | | | | | | | | | | | 4 |
| | *Chaetodon lunula* | | | | 1 | | | | 1 | | 1 | | | | | 1 | 2 | | | 6 |
| | *Chaetodon lunulatus* | | | | | | | | | | | | | | | | | | 2 | 2 |
| | *Chaetodon multicinctus* | 2 | 1 | | 5 | 6 | 5 | | 3 | 7 | 3 | 6 | 6 | | 2 | 6 | 4 | 3 | 1 | 60 |
| | *Chaetodon ornatissimus* | | | | | 3 | | 1 | | 2 | | 2 | | | | | | | 2 | 10 |
| | *Chaetodon quadrimaculatus* | | 3 | 2 | 1 | 4 | 2 | 1 | 3 | 1 | 1 | 1 | | 1 | | | | 1 | | 21 |
| | *Chaetodon unimaculatus* | | | | | | | | | 1 | 2 | | | | | | | | 1 | 4 |
| | *Forcipiger flavissimus* | | | | 2 | 2 | 1 | | 3 | 1 | | 5 | 1 | 5 | 2 | 2 | | 1 | 4 | 29 |
| | *Hemitaurichthys polylepis* | | | | | 9 | 6 | | | 4 | 35 | | | | | | | | | 54 |
| | *Hemitaurichthys thompsoni* | | | | | | | | | | 40 | | | | | | | | | 40 |
| Pomacanthidae | *Centropyge potteri* | | | | | | 1 | | | 3 | | 1 | 1 | | | 1 | | | 3 | 10 |
| Pomacentridae | *Abudefduf abdominalis* | | | | | | | | 21 | | | | | | | | | | | 21 |
| | *Chromis agilis* | | | | | | 6 | | | 272 | | | 52 | | | 96 | | 14 | 112 | 552 |
| | *Chromis hanui* | | | | | | 3 | | | 13 | | | 16 | | | 5 | | | | 37 |
| | *Chromis vanderbilti* | 124 | 58 | 108 | 198 | 203 | 209 | 101 | 247 | 90 | 156 | 132 | 49 | 55 | 80 | 340 | 77 | 26 | | 2253 |
| Pomacentridae | *Dascyllus albisella* | | | | | | | | | | | | | | 1 | | | 4 | 8 | 13 |
| | *Plectroglyphidodon imparipenis* | | 2 | | 2 | | | 1 | | | | | | | | | | | | 5 |

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on May 16-18, 2009. Transect locations are shown in Figure 3. Species listed in taxonomic order.

| | | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Species | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | |
| | *Plectroglyphidodon johnstonianus* | | | 3 | 2 | | 4 | | 5 | 4 | | 3 | 4 | | 1 | 5 | 2 | 1 | 1 | 35 |
| | *Pomacanthus jenkinsi* | | | | 1 | | | | | | | | | | | | | | | 1 |
| | *Stegastes fasciolatus* | 1 | 6 | | 4 | | | 1 | 1 | | | 1 | | 1 | | | 2 | | | 17 |
| Labridae | *Bodianus bilunulatus* | | | 1 | | | | | | | | | | | | | | | | 1 |
| | *Cheilio inermis* | | | | 1 | | | | | | | | | | | | | | | 1 |
| | *Cheilio inermis* | | | | 1 | | | | | | | | | | | | | | | 1 |
| | *Coris gaimard* | | 2 | 2 | | | | 1 | | 4 | | | | | | | | | | 9 |
| | *Gomphosus varius* | | 1 | | | 3 | 1 | 1 | 1 | 4 | 1 | 1 | | | | 2 | | 1 | 1 | 17 |
| | *Halichoeres ornatissimus* | 5 | 4 | 5 | 1 | 4 | 3 | | 4 | 4 | | 1 | 3 | | 2 | 2 | 2 | 1 | | 41 |
| | *Labroides phthirophagus* | | | | | | 4 | | 2 | 2 | | | | | | 1 | | | | 9 |
| | *Oxycheilinus bimaculatus* | | | 1 | | | | | | | | | | | | | | | | 1 |
| | *Oxycheilinus unifasciatus* | | | 1 | | | | 1 | | | | | | | | | | 1 | | 3 |
| | *Pseudocheilinus evanidus* | | | 4 | | | | | | | | | | | | 3 | | | 4 | 11 |
| | *Pseudocheilinus octotaenia* | | | 2 | | 1 | 3 | | | 2 | | | 4 | | | 3 | | | | 15 |
| | *Pseudocheilinus tetrataenia* | 1 | | 2 | | 3 | 4 | | 5 | 4 | | 2 | 2 | | 1 | | | | | 24 |
| | *Stenojulis balteata* | | 3 | 1 | | | 7 | | | 2 | | 3 | | | | 1 | | | | 17 |
| | *Thalassoma ballieui* | | | 1 | | | | | | 1 | | | | | | | | | | 2 |
| | *Thalassoma duperrey* | 14 | 15 | 12 | 18 | 6 | 12 | 16 | 23 | 7 | 12 | 8 | 5 | 17 | 11 | 11 | 17 | 11 | 3 | 218 |
| Scaridae | *Calotomus carolinus* | | | | | | | | | | | | 1 | | | | | | | 1 |
| | *Scarus sordidus* | | | | 3 | 4 | 3 | 6 | | 6 | 2 | 2 | 2 | 2 | 4 | 5 | | 7 | 7 | 53 |
| | *Scarus sp.juvenile* | | | | | 3 | | 10 | | | 15 | | 1 | | | | | 2 | | 31 |
| Blennidae | *Cirripectes vanderbilti* | | | | | | | | | | | | | | 1 | | | | | 1 |
| | *Plagiotremus goslinei* | 1 | 1 | | 1 | | | 1 | | | | | | | | | | | | 4 |
| Zanclidae | *Zanclus cornutus* | 3 | | | 3 | 5 | 3 | 2 | 2 | 1 | | 1 | 2 | 3 | | | | 3 | | 28 |
| Acanthuridae | *Acanthurus achilles* | | | | | | | | | 1 | | 2 | | | | | | | | 3 |
| | *Acanthurus blochii* | 1 | | | | | | | 4 | | | | 4 | | | | | | | 9 |
| | *Acanthurus leucoparieus* | 23 | | | | | | | | | 1 | | | 1 | | | 33 | | | 58 |
| | *Acanthurus nigricans* | | | | | | | | | | | 2 | | | | | | | | 2 |
| | *Acanthurus nigrofuscus* | 23 | 22 | 4 | 29 | 39 | | 16 | 21 | 22 | 20 | 9 | | 41 | 27 | 20 | 49 | 36 | 15 | 393 |
| | *Acanthurus nigroris* | | | | 1 | | 27 | | | | | | 11 | | | | | | | 39 |
| Acanthuridae | *Acanthurus olivaceus* | 1 | | 2 | | 1 | | 3 | | | | 1 | | | 1 | | | | 1 | 10 |
| | *Acanthurus thompsoni* | | | | | 4 | | | | | | | 2 | | | | | | | 6 |
| | *Ctenochaetus hawaiiensis* | | | | | | | 1 | 2 | | | 1 | | 10 | 2 | | 2 | | 1 | 19 |
| | *Ctenochaetus strigosus* | | | | 14 | 9 | 2 | | 5 | 40 | | 11 | 7 | 23 | 6 | 16 | 11 | 44 | 11 | 199 |

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on May 16-18. 2009. Transect locations are shown in Figure 3.
Species listed in taxonomic order.

| | | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Species | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | |
| | *Naso lituratus* | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | | 2 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 25 |
| | *Naso unicornis* | 8 | | | | | | | | | | | | | | | | | | 8 |
| | *Zebrasoma flavescens* | 17 | 2 | 1 | 28 | 34 | 2 | 17 | 9 | 10 | 21 | 15 | 5 | 33 | 24 | 6 | 9 | 4 | 4 | 241 |
| | *Zebrasoma veliferum* | | | | | | | | | | | | | | | | 2 | 1 | | 3 |
| Balistidae | *Melichthys vidua* | | 1 | | | | 1 | 1 | | | | | 1 | | 1 | 1 | | | | 6 |
| | *Sufflamen bursa* | 2 | 1 | | 1 | | 1 | 3 | 1 | | 2 | 1 | 1 | 2 | 1 | 1 | | 2 | 1 | 20 |
| | *Sufflamen fraenatus* | | | 2 | | | | | | | | | | | | | | | | 2 |
| | *Xanthichthys auromarginatus* | | | 4 | | | | | | | | | | | | | | | | 4 |
| Monacanthidae | *Cantherhines dumerilii* | | | | | | 3 | | 1 | | | | | | | | | | | 4 |
| | *Catherhines sanwichiensis* | | | | | | | | 1 | 1 | 1 | | | | | | | 1 | | 4 |
| | *Pervagor aspricaudus* | | | | | | | | 1 | | | | 1 | | | | 1 | | | 3 |
| | *Pervagor spilosoma* | | | | | | | | | | 6 | | | | | | | | | 6 |
| Ostraciidae | *Ostracion memeagris* | 1 | | | | | | | 1 | | | | | | 1 | | | | | 3 |
| Tetraodontidae | *Arothron meleagris* | | | | | 1 | 1 | | 2 | | | | | 1 | | | | | | 5 |
| | *Canthigaster amboinensis* | | | | 1 | | | 2 | | | | | | | | | | | | 3 |
| | *Canthigaster jactator* | 1 | 3 | 3 | | 6 | | | 1 | 3 | | 2 | 3 | 4 | 5 | 1 | 1 | 1 | | 34 |
| Cheloniidae | *Chelonia midas* | | | | | | | | | | 1 | | | | | | | | | 1 |

Appendix D.2. Abundance of fish observed along 25 m transects off NELHA on May 16-18, 2009. Transect locations are shown in Figure 3. Species ordered by total abundance.

| | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | |
| *Chromis vanderbilti* | 124 | 58 | 108 | 198 | 203 | 209 | 101 | 247 | 90 | 156 | 132 | 49 | 55 | 80 | 340 | 77 | 26 | | 2253 |
| *Chromis agilis* | | | | | | 6 | | | 272 | | | 52 | | | 96 | | 14 | 112 | 552 |
| *Acanthurus nigrofuscus* | 23 | 22 | 4 | 29 | 39 | | 16 | 21 | 22 | 20 | 9 | | 41 | 27 | 20 | 49 | 36 | 15 | 393 |
| *Zebrasoma flavescens* | 17 | 2 | 1 | 28 | 34 | 2 | 17 | 9 | 10 | 21 | 15 | 5 | 33 | 24 | 6 | 9 | 4 | 4 | 241 |
| *Thalassoma duperrey* | 14 | 15 | 12 | 18 | 6 | 12 | 16 | 23 | 7 | 12 | 8 | 5 | 17 | 11 | 11 | 17 | 11 | 3 | 218 |
| *Ctenochaetus strigosus* | | | | 14 | 9 | 2 | | 5 | 40 | | 11 | 7 | 23 | 6 | 16 | 11 | 44 | 11 | 199 |
| *Paracirrhites arcatus* | 7 | 11 | 10 | 22 | 9 | 25 | 13 | 11 | 18 | 2 | 9 | 12 | | 8 | 10 | 12 | 9 | | 188 |
| *Myripristis berndti* | | | | | | | | | | | 35 | | | | | | | 48 | 83 |
| *Chaetodon multicinctus* | 2 | 1 | | 5 | 6 | 5 | | 3 | 7 | 3 | 6 | 6 | | 2 | 6 | 4 | 3 | 1 | 60 |
| *Acanthurus leucopareius* | 23 | | | | | | | | | 1 | | | 1 | | | 33 | | | 58 |
| *Hemitaurichthys polylepis* | | | | | 9 | 6 | | | 4 | 35 | | | | | | | | | 54 |
| *Scarus sordidus* | | | | 3 | 4 | 3 | 6 | | 6 | 2 | 2 | 2 | 2 | 4 | 5 | | 7 | 7 | 53 |
| *Halichoeres ornatissimus* | 5 | 4 | 5 | 1 | 4 | 3 | | 4 | 4 | | 1 | 3 | | 2 | 2 | 2 | 1 | | 41 |
| *Hemitaurichthys thompsoni* | | | | | | | | | | 40 | | | | | | | | | 40 |
| *Acanthurus nigroris* | | | | 1 | | 27 | | | | | | 11 | | | | | | | 39 |
| *Chromis hanui* | | | | | | 3 | | | 13 | | | 16 | | | 5 | | | | 37 |
| *Plectroglyphidodon johnstonianus* | | | 3 | 2 | | 4 | | 5 | 4 | | 3 | 4 | | 1 | 5 | 2 | 1 | 1 | 35 |
| *Canthigaster jactator* | 1 | 3 | 3 | | 6 | | | 1 | 3 | | 2 | 3 | 4 | 5 | 1 | 1 | 1 | | 34 |
| *Scarus sp.juvenile* | | | | | 3 | | 10 | | | 15 | | 1 | | | | | 2 | | 31 |
| *Forcipiger flavissimus* | | | | 2 | 2 | 1 | | 3 | 1 | | 5 | 1 | 5 | 2 | 2 | | 1 | 4 | 29 |
| *Zanclus cornutus* | 3 | | | 3 | 5 | 3 | 2 | 2 | 1 | | 1 | 2 | 3 | | | | 3 | | 28 |
| *Naso lituratus* | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | | 2 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 25 |
| *Pseudocheilinus tetrataenia* | 1 | | 2 | | 3 | 4 | | 5 | 4 | | 2 | 2 | | 1 | | | | | 24 |
| *Chaetodon quadrimaculatus* | | 3 | 2 | 1 | 4 | 2 | 1 | 3 | 1 | 1 | 1 | | 1 | | | | 1 | | 21 |
| *Abudefduf abdominalis* | | | | | | | | 21 | | | | | | | | | | | 21 |
| *Sufflamen bursa* | 2 | 1 | | 1 | | 1 | 3 | 1 | | 2 | 1 | 1 | 2 | 1 | 1 | | 2 | 1 | 20 |
| *Ctenochaetus hawaiiensis* | | | | | | | 1 | 2 | | | 1 | | 10 | 2 | | 2 | | 1 | 19 |
| *Stegastes fasciolatus* | 1 | 6 | | 4 | | | 1 | 1 | | | 1 | | 1 | | | 2 | | | 17 |
| *Gomphosus varius* | | 1 | | | 3 | 1 | 1 | 1 | 4 | 1 | 1 | | | | 2 | | 1 | 1 | 17 |
| *Stenojulis balteata* | | 3 | 1 | | | 7 | | | 2 | | 3 | | | | 1 | | | | 17 |
| *Pseudocheilinus octotaenia* | | | 2 | | 1 | 3 | | | 2 | | | 4 | | | 3 | | | | 15 |
| *Parupeneus multifasciatus* | | 1 | 1 | | | 4 | | 1 | 1 | 1 | 1 | 1 | | | 1 | | | 2 | 14 |
| *Dascyllus albisella* | | | | | | | | | | | | | | 1 | | | 4 | 8 | 13 |
| *Pseudocheilinus evanidus* | | | 4 | | | | | | | | | | | | 3 | | | 4 | 11 |
| *Chaetodon ornatissimus* | | | | | 3 | | 1 | | 2 | | 2 | | | | | | | 2 | 10 |
| *Centropyge potteri* | | | | | | 1 | | | 3 | | 1 | 1 | | | 1 | | | 3 | 10 |
| *Acanthurus olivaceus* | 1 | | 2 | | 1 | | 3 | | | | 1 | | | 1 | | | | 1 | 10 |
| *Coris gaimard* | | 2 | 2 | | | | 1 | | 4 | | | | | | | | | | 9 |
| *Labroides phthirophagus* | | | | | | 4 | | 2 | 2 | | | | | | 1 | | | | 9 |
| *Acanthurus blochii* | 1 | | | | | | | 4 | | | | 4 | | | | | | | 9 |
| *Naso unicornis* | 8 | | | | | | | | | | | | | | | | | | 8 |
| *Parupeneus bifasciatus* | 1 | | | | | 1 | | 1 | | 1 | | 1 | | | | 1 | | | 6 |

Appendix D.2. Abundance of fish observed along 25 m transects off NELHA on May 16-18, 2009. Transect locations are shown in Figure 3. Species ordered by total abundance.

| | Wawaloli Beach | | | 18" Pipe | | | 12" Pipe South | | | 12" Pipe North | | | NPPE | | | Ho'ona Bay | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | Shallow | Mid | Deep | |
| *Chaetodon lunula* | | | | 1 | | | | 1 | | 1 | | | | | 1 | 2 | | | 6 |
| *Acanthurus thompsoni* | | | | | 4 | | | | | | | 2 | | | | | | | 6 |
| *Melichthys vidua* | | 1 | | | | 1 | 1 | | | | | 1 | | 1 | 1 | | | | 6 |
| *Pervagor spilosoma* | | | | | | | | | | 6 | | | | | | | | | 6 |
| *Chaetodon auriga* | 2 | | | | 1 | | | | | | | | | | 2 | | | | 5 |
| *Plectroglyphidodon imparipenis* | | 2 | | 2 | | | 1 | | | | | | | | | | | | 5 |
| *Arothron meleagris* | | | | | 1 | 1 | | 2 | | | | | 1 | | | | | | 5 |
| *Chaetodon lineolatus* | | | | | 4 | | | | | | | | | | | | | | 4 |
| *Chaetodon unimaculatus* | | | | | | | | | 1 | 2 | | | | | | | | 1 | 4 |
| *Plagiotremus goslinei* | 1 | 1 | | 1 | | | 1 | | | | | | | | | | | | 4 |
| *Xanthichthys auromarginatus* | | | 4 | | | | | | | | | | | | | | | | 4 |
| *Cantherhines dumerilii* | | | | | | 3 | | 1 | | | | | | | | | | | 4 |
| *Catherhines sanwichiensis* | | | | | | | | 1 | 1 | 1 | | | | | | | 1 | | 4 |
| *Cephalopholis argus* | | | 1 | | | | | | | | | | | | | 1 | | 1 | 3 |
| *Kyphosus bigibbus* | | | | 2 | | | | | | | | | 1 | | | | | | 3 |
| *Oxycheilinus unifasciatus* | | | 1 | | | | 1 | | | | | | | | | | 1 | | 3 |
| *Acanthurus achilles* | | | | | | | | | 1 | | 2 | | | | | | | | 3 |
| *Zebrasoma veliferum* | | | | | | | | | | | | | | | | 2 | 1 | | 3 |
| *Pervagor aspricaudus* | | | | | | | | 1 | | | | 1 | | | | 1 | | | 3 |
| *Ostracion meleagris* | 1 | | | | | | | 1 | | | | | | 1 | | | | | 3 |
| *Canthigaster amboinensis* | | | | 1 | | | 2 | | | | | | | | | | | | 3 |
| *Gymnothorax meleagris* | | 1 | | | | | | | 1 | | | | | | | | | | 2 |
| *Paracirrhites fosteri* | | | | | | | | | 1 | | | | | 1 | | | | | 2 |
| *Chaetodon kleini* | | | | | | | | | 2 | | | | | | | | | | 2 |
| *Chaetodon lunulatus* | | | | | | | | | | | | | | | | | | 2 | 2 |
| *Thalassoma ballieui* | | | 1 | | | | | | 1 | | | | | | | | | | 2 |
| *Acanthurus nigricans* | | | | | | | | | | | 2 | | | | | | | | 2 |
| *Sufflamen fraenatus* | | | 2 | | | | | | | | | | | | | | | | 2 |
| *Gymnomuraena zebra* | | | | | | | | | | | | | 1 | | | | | | 1 |
| *Aulostomus chinensis* | | | | | | | | | | | | | 1 | | | | | | 1 |
| *Cirrhitus pinnulatus* | | | | 1 | | | | | | | | | | | | | | | 1 |
| *Caranx melampygus* | | | | | | | 1 | | | | | | | | | | | | 1 |
| *Lutjanus kasmira* | | | | | | 1 | | | | | | | | | | | | | 1 |
| *Monotaxis grandoculis* | | | | | 1 | | | | | | | | | | | | | | 1 |
| *Parupeneus chrysonemus* | | | | | | | | | | | | | | | | | 1 | | 1 |
| *Pomacanthus jenkinsi* | | | | 1 | | | | | | | | | | | | | | | 1 |
| *Bodianus bilunulatus* | | | 1 | | | | | | | | | | | | | | | | 1 |
| *Cheilio inermis* | | | | 1 | | | | | | | | | | | | | | | 1 |
| *Cheilio inermis* | | | | 1 | | | | | | | | | | | | | | | 1 |
| *Oxycheilinus bimaculatus* | | | 1 | | | | | | | | | | | | | | | | 1 |
| *Calotomus carolinus* | | | | | | | | | | | | 1 | | | | | | | 1 |
| *Cirripectes vanderbilti* | | | | | | | | | | | | | | 1 | | | | | 1 |

Appendix D.3. Number of individuals counted along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2009.

| Site | Biotope | May-89 | Oct-91 | Mar-92 | May-92 | Oct-92 | May-93 | Dec-93 | May-94 | Jun-94 | Oct-94 | Mar-95 | Jun-95 | Dec-95 | Jun-96 | Dec-96 | Jun-97 | Dec-97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | 187 | 209 | 204 | 154 | 434 | 336 | 175 | 230 | 242 | 221 | 256 | 454 | 106 | 279 | 224 | 269 | 371 |
| | Bench | 346 | 237 | 341 | 227 | 80 | 339 | 227 | 413 | 351 | 218 | 214 | 281 | 157 | 326 | 231 | 250 | 636 |
| | Slope | | 188 | 272 | 166 | 375 | 200 | 196 | 258 | 378 | 345 | 232 | 407 | 224 | 255 | 206 | 233 | 510 |
| 18-inch Pipe | Boulder | | 510 | 274 | 357 | 420 | 398 | 434 | 455 | 480 | 526 | 417 | 493 | 196 | 276 | 315 | 369 | 471 |
| | Bench | | 604 | 467 | 447 | 355 | 310 | 350 | 499 | 423 | 505 | 430 | 387 | 310 | 259 | 320 | 323 | 598 |
| | Slope | | 824 | 499 | 491 | 682 | 305 | 862 | 816 | 728 | 701 | 698 | 836 | 346 | 514 | 473 | 453 | 465 |
| - 12-inch Pipe South | Boulder | | | | 350 | 709 | 317 | 524 | 421 | 363 | 650 | 309 | 406 | 213 | 378 | 353 | 302 | 678 |
| | Bench | | | | 541 | 392 | 446 | 565 | 386 | 384 | 446 | 226 | 521 | 439 | 296 | 347 | 308 | 535 |
| | Slope | | | | 353 | 361 | 322 | 388 | 260 | 333 | 272 | 227 | 616 | 300 | 359 | 384 | 376 | 157 |
| 12-inch Pipe North | Boulder | | | | 204 | 243 | 268 | 441 | 255 | 287 | 339 | 168 | 258 | 243 | 199 | 213 | 227 | 523 |
| | Bench | | | | 248 | 267 | 214 | 424 | 327 | 383 | 421 | 189 | 487 | 229 | 203 | 182 | 188 | 364 |
| | Slope | | | | 157 | 306 | 320 | 396 | 178 | 222 | 210 | 188 | 302 | 275 | 243 | 232 | 252 | 790 |
| NPPE Site | Boulder | | | | 443 | 297 | 308 | 330 | 271 | 326 | 454 | 195 | 342 | 148 | 290 | 283 | 246 | 834 |
| | Bench | | | | 357 | 229 | 290 | 400 | 345 | 289 | 329 | 177 | 417 | 436 | 265 | 195 | 272 | 467 |
| | Slope | | | | 93 | 140 | 143 | 235 | 223 | 191 | 266 | 142 | 424 | 175 | 282 | 408 | 429 | 346 |
| Ho'ona Bay | Boulder | 389 | 339 | 263 | 319 | 307 | 315 | 383 | 329 | 354 | 272 | 376 | 473 | 159 | 293 | 217 | 300 | 252 |
| | Bench | 430 | 399 | 144 | 248 | 282 | 257 | 292 | 343 | 311 | 307 | 281 | 706 | 249 | 278 | 193 | 295 | 269 |
| | Slope | | 481 | 382 | 573 | 263 | 228 | 387 | 320 | 418 | 352 | 296 | 780 | 136 | 355 | 347 | 351 | 261 |
| Mean | | 338 | 421 | 316 | 318 | 341 | 295 | 389 | 352 | 359 | 380 | 279 | 477 | 241 | 297 | 285 | 302 | 474 |
| Stdev | | 106 | 208 | 117 | 141 | 157 | 71 | 158 | 144 | 118 | 144 | 134 | 164 | 96 | 72 | 87 | 71 | 187 |

Appendix D.3. Number of individuals counted along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2008.

| Site | Biotope | Jun-98 | Nov-98 | May-99 | Dec-99 | Jun-00 | Nov-00 | May-01 | Nov-01 | May-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Dec-07 | Aug-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | 223 | 248 | 315 | 198 | 673 | 375 | 350 | 514 | 202 | 112 | 197 | 291 | 228 | 464 | 265 | 184 | 240 |
| | Bench | 177 | 295 | 255 | 231 | 424 | 540 | 234 | 339 | 200 | 193 | 241 | 305 | 260 | 327 | 690 | 397 | 139 |
| | Slope | 143 | 176 | 316 | 174 | 246 | 299 | 389 | 298 | 159 | 231 | 353 | 315 | 528 | 655 | 1470 | 565 | 174 |
| 18-inch Pipe | Boulder | 453 | 448 | 376 | 344 | 596 | 314 | 250 | 419 | 280 | 207 | 345 | 591 | 349 | 716 | 476 | 406 | 343 |
| | Bench | 400 | 485 | 321 | 484 | 312 | 336 | 289 | 299 | 172 | 298 | 314 | 521 | 231 | 620 | 274 | 761 | 366 |
| | Slope | 533 | 848 | 349 | 599 | 818 | 1019 | 671 | 493 | 678 | 416 | 576 | 698 | 397 | 878 | 500 | 835 | 347 |
| 12-inch Pipe South | Boulder | 289 | 654 | 295 | 246 | 359 | 731 | 423 | 493 | 349 | 146 | 434 | 400 | 200 | 401 | 427 | 408 | 207 |
| | Bench | 302 | 937 | 396 | 294 | 549 | 371 | 343 | 324 | 227 | 327 | 493 | 506 | 302 | 341 | 565 | 559 | 386 |
| | Slope | 381 | 922 | 357 | 819 | 274 | 319 | 309 | 391 | 316 | 327 | 627 | 960 | 1105 | 728 | 707 | 770 | 535 |
| 12-inch Pipe North | Boulder | 231 | 530 | 257 | 338 | 124 | 336 | 305 | 336 | 213 | 240 | 433 | 267 | 294 | 269 | 284 | 351 | 326 |
| | Bench | 260 | 468 | 321 | 301 | 107 | 315 | 415 | 347 | 219 | 302 | 291 | 506 | 179 | 231 | 273 | 356 | 260 |
| | Slope | 300 | 603 | 344 | 279 | 344 | 351 | 338 | 404 | 429 | 297 | 359 | 387 | 329 | 425 | 392 | 268 | 199 |
| NPPE Site | Boulder | 308 | 660 | 391 | 385 | 150 | 379 | 343 | 350 | 187 | 277 | 271 | 286 | 306 | 412 | 330 | 308 | 203 |
| | Bench | 305 | 425 | 375 | 250 | 93 | 313 | 410 | 186 | 294 | 210 | 478 | 413 | 304 | 249 | 313 | 273 | 186 |
| | Slope | 107 | 355 | 252 | 292 | 162 | 922 | 299 | 393 | 272 | 324 | 578 | 486 | 246 | 287 | 335 | 390 | 543 |
| Ho'ona Bay | Boulder | 237 | 314 | 258 | 332 | 140 | 385 | 431 | 332 | 277 | 193 | 270 | 385 | 314 | 293 | 280 | 232 | 229 |
| | Bench | 418 | 317 | 322 | 267 | 150 | 323 | 365 | 309 | 356 | 202 | 259 | 221 | 281 | 247 | 192 | 137 | 177 |
| | Slope | 364 | 506 | 270 | 509 | 124 | 508 | 307 | 330 | 323 | 190 | 253 | 833 | 361 | 310 | 375 | 230 | 235 |
| Mean | | 302 | 511 | 321 | 352 | 314 | 452 | 360 | 364 | 286 | 250 | 376 | 465 | 345 | 436 | 453 | 413 | 283 |
| Stdev | | 110 | 225 | 48 | 160 | 218 | 218 | 97 | 81 | 122 | 76 | 130 | 201 | 206 | 198 | 293 | 207 | 118 |

Appendix D.4. Number of species counted along 25 m transects within three biotopes (Shallow, Middle, Deep) at six locations off NELHA between 1989 and 2009.

| Site | Biotope | May-89 | Oct-91 | Mar-92 | May-92 | Oct-92 | May-93 | Dec-93 | May-94 | Jun-94 | Oct-94 | Mar-95 | Jun-95 | Dec-95 | Jun-96 | Dec-96 | Jun-97 | Dec-97 | Jun-98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | 25 | 30 | 25 | 20 | 25 | 22 | 22 | 21 | 22 | 18 | 23 | 24 | 22 | 22 | 20 | 18 | 27 | 18 |
| | Bench | 37 | 33 | 26 | 21 | 19 | 22 | 18 | 17 | 26 | 16 | 23 | 22 | 24 | 18 | 17 | 18 | 29 | 23 |
| | Slope | | 28 | 24 | 24 | 28 | 25 | 25 | 25 | 29 | 24 | 19 | 29 | 26 | 24 | 20 | 22 | 29 | 18 |
| 18-inch Pipe | Boulder | | 39 | 37 | 40 | 40 | 36 | 38 | 38 | 37 | 36 | 30 | 38 | 28 | 24 | 28 | 31 | 26 | 36 |
| | Bench | | 32 | 31 | 30 | 28 | 25 | 26 | 36 | 38 | 28 | 27 | 30 | 36 | 30 | 27 | 29 | 32 | 36 |
| | Slope | | 36 | 29 | 36 | 26 | 34 | 39 | 36 | 36 | 30 | 33 | 41 | 35 | 39 | 31 | 31 | 38 | 20 |
| 12-inch Pipe South | Boulder | | | | 30 | 30 | 28 | 39 | 34 | 27 | 29 | 32 | 32 | 28 | 31 | 26 | 29 | 33 | 29 |
| | Bench | | | | 42 | 32 | 29 | 33 | 36 | 32 | 24 | 22 | 26 | 28 | 23 | 22 | 23 | 29 | 27 |
| | Slope | | | | 36 | 40 | 32 | 37 | 29 | 39 | 35 | 27 | 36 | 27 | 30 | 28 | 30 | 20 | 33 |
| 12-inch Pipe North | Boulder | | | | 34 | 27 | 25 | 33 | 26 | 35 | 33 | 26 | 28 | 25 | 21 | 23 | 26 | 33 | 27 |
| | Bench | | | | 28 | 30 | 34 | 36 | 33 | 34 | 35 | 24 | 36 | 28 | 30 | 26 | 26 | 21 | 29 |
| | Slope | | | | 28 | 30 | 34 | 31 | 27 | 25 | 23 | 22 | 30 | 30 | 28 | 27 | 32 | 34 | 30 |
| NPPE Site | Boulder | | | | 31 | 31 | 22 | 29 | 27 | 31 | 35 | 20 | 26 | 23 | 30 | 24 | 27 | 32 | 30 |
| | Bench | | | | 20 | 27 | 27 | 26 | 28 | 23 | 30 | 25 | 30 | 27 | 23 | 20 | 26 | 30 | 23 |
| | Slope | | | | 20 | 22 | 22 | 28 | 21 | 17 | 24 | 24 | 30 | 24 | 37 | 27 | 26 | 26 | 22 |
| Ho'ona Bay | Boulder | 26 | 24 | 32 | 36 | 25 | 22 | 26 | 33 | 30 | 20 | 27 | 26 | 27 | 25 | 21 | 23 | 22 | 26 |
| | Bench | 33 | 34 | 28 | 30 | 31 | 22 | 27 | 24 | 29 | 30 | 25 | 30 | 26 | 32 | 26 | 25 | 24 | 27 |
| | Slope | | 35 | 32 | 31 | 25 | 26 | 26 | 28 | 27 | 29 | 22 | 24 | 23 | 27 | 23 | 28 | 26 | 25 |
| Mean | | 30 | 32 | 29 | 30 | 29 | 27 | 30 | 29 | 30 | 28 | 25 | 30 | 27 | 27 | 24 | 26 | 28 | 27 |
| Stdev | | 6 | 5 | 4 | 7 | 5 | 5 | 6 | 6 | 6 | 6 | 4 | 5 | 4 | 6 | 4 | 4 | 5 | 5 |

Appendix D.4. Number of species counted along 25 m transects within three biotopes (Shallow, Middle, Deep) at six locations off NELHA between 1989 and 2009.

| Site | Biotope | Nov-98 | May-99 | Dec-99 | Jun-00 | Nov-00 | May-01 | Nov-01 | May-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Dec-07 | Aug-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | 26 | 27 | 20 | 34 | 23 | 20 | 31 | 26 | 17 | 17 | 18 | 23 | 20 | 24 | 26 | 21 |
| | Bench | 22 | 18 | 19 | 27 | 24 | 20 | 24 | 24 | 25 | 17 | 20 | 22 | 23 | 26 | 27 | 20 |
| | Slope | 18 | 27 | 22 | 29 | 27 | 20 | 24 | 20 | 17 | 22 | 28 | 30 | 24 | 39 | 34 | 24 |
| 18-inch Pipe | Boulder | 38 | 41 | 34 | 45 | 27 | 28 | 38 | 34 | 26 | 32 | 32 | 29 | 38 | 34 | 28 | 25 |
| | Bench | 32 | 31 | 25 | 36 | 31 | 28 | 24 | 24 | 26 | 25 | 33 | 28 | 33 | 27 | 37 | 26 |
| | Slope | 32 | 32 | 27 | 38 | 33 | 36 | 36 | 33 | 24 | 34 | 34 | 34 | 36 | 34 | 42 | 30 |
| 12-inch Pipe South | Boulder | 36 | 35 | 26 | 30 | 42 | 34 | 33 | 37 | 32 | 25 | 29 | 22 | 27 | 32 | 28 | 25 |
| | Bench | 32 | 34 | 21 | 29 | 35 | 45 | 37 | 27 | 25 | 24 | 28 | 28 | 29 | 31 | 29 | 31 |
| | Slope | 38 | 38 | 33 | 37 | 33 | 42 | 39 | 34 | 29 | 28 | 22 | 29 | 38 | 32 | 35 | 33 |
| 12-inch Pipe North | Boulder | 40 | 32 | 29 | 33 | 25 | 27 | 35 | 27 | 31 | 25 | 31 | 26 | 30 | 31 | 26 | 22 |
| | Bench | 32 | 34 | 34 | 38 | 34 | 34 | 34 | 33 | 27 | 26 | 32 | 25 | 32 | 34 | 33 | 29 |
| | Slope | 29 | 34 | 30 | 38 | 28 | 29 | 27 | 36 | 23 | 24 | 26 | 35 | 33 | 27 | 38 | 28 |
| NPPE Site | Boulder | 35 | 31 | 29 | 37 | 32 | 37 | 30 | 29 | 27 | 35 | 24 | 18 | 29 | 21 | 26 | 19 |
| | Bench | 35 | 39 | 25 | 31 | 30 | 35 | 32 | 30 | 23 | 27 | 20 | 25 | 27 | 26 | 20 | 22 |
| | Slope | 30 | 33 | 24 | 29 | 36 | 30 | 30 | 24 | 27 | 24 | 28 | 27 | 27 | 32 | 23 | 26 |
| Ho'ona Bay | Boulder | 25 | 28 | 29 | 27 | 32 | 32 | 32 | 34 | 17 | 23 | 20 | 22 | 28 | 24 | 25 | 19 |
| | Bench | 31 | 27 | 22 | 32 | 29 | 26 | 23 | 26 | 26 | 23 | 22 | 23 | 24 | 25 | 16 | 25 |
| | Slope | 28 | 29 | 35 | 28 | 25 | 35 | 30 | 25 | 21 | 24 | 27 | 21 | 27 | 28 | 23 | 23 |
| Mean | | 31 | 32 | 27 | 33 | 30 | 31 | 31 | 29 | 25 | 25 | 26 | 26 | 29 | 29 | 29 | 25 |
| Stdev | | 6 | 5 | 5 | 5 | 5 | 7 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 7 | 4 |

Appendix D.5. Estimated biomass (g/m$^2$) along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2009.

| Site | Biotope | Date May-89 | Oct-91 | Mar-92 | May-92 | Oct-92 | May-93 | Dec-93 | May-94 | Jun-94 | Oct-94 | Mar-95 | Jun-95 | Dec-95 | Jun-96 | Dec-96 | Jun-97 | Dec-97 | Jun-98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | | 210 | 113 | 91 | 251 | 171 | 85 | 151 | 276 | 188 | 154 | 184 | 121 | 174 | 482 | 211 | 280 | 144 |
| | Bench | | 51 | 138 | 83 | 67 | 105 | 58 | 104 | 87 | 62 | 112 | 142 | 103 | 103 | 445 | 44 | 891 | 76 |
| | Slope | | 57 | 54 | 37 | 117 | 46 | 102 | 151 | 100 | 150 | 191 | 187 | 121 | 74 | 62 | 64 | 190 | 78 |
| 18-inch Pipe | Boulder | | 379 | 230 | 223 | 285 | 193 | 362 | 342 | 208 | 394 | 555 | 303 | 205 | 94 | 196 | 180 | 518 | 307 |
| | Bench | | 327 | 158 | 175 | 85 | 106 | 255 | 169 | 153 | 380 | 288 | 173 | 210 | 122 | 146 | 124 | 319 | 308 |
| | Slope | | 271 | 248 | 86 | 110 | 128 | 213 | 200 | 217 | 91 | 156 | 551 | 97 | 129 | 83 | 92 | 430 | 37 |
| 12-inch Pipe South | Boulder | | | | 258 | 727 | 483 | 700 | 318 | 286 | 314 | 244 | 214 | 116 | 109 | 240 | 538 | 385 | 177 |
| | Bench | | | | 364 | 259 | 222 | 626 | 288 | 170 | 191 | 130 | 268 | 348 | 101 | 141 | 84 | 211 | 312 |
| | Slope | | | | 136 | 210 | 142 | 351 | 136 | 229 | 121 | 207 | 148 | 74 | 125 | 126 | 193 | 77 | 331 |
| 12-inch Pipe North | Boulder | | | | 122 | 137 | 153 | 610 | 160 | 162 | 311 | 154 | 131 | 98 | 64 | 140 | 104 | 1637 | 178 |
| | Bench | | | | 108 | 125 | 103 | 246 | 124 | 149 | 204 | 119 | 222 | 50 | 120 | 76 | 58 | 123 | 114 |
| | Slope | | | | 298 | 85 | 187 | 726 | 74 | 132 | 105 | 212 | 116 | 490 | 116 | 599 | 886 | 183 | 200 |
| NPPE Site | Boulder | | | | 316 | 149 | 66 | 217 | 95 | 89 | 478 | 146 | 125 | 58 | 179 | 121 | 146 | 912 | 195 |
| | Bench | | | | 171 | 78 | 68 | 118 | 316 | 74 | 113 | 116 | 74 | 163 | 80 | 60 | 150 | 143 | 93 |
| | Slope | | | | 45 | 71 | 55 | 186 | 48 | 47 | 150 | 85 | 99 | 73 | 579 | 115 | 96 | 631 | 47 |
| Ho'ona Bay | Boulder | | 105 | 108 | 131 | 251 | 88 | 151 | 241 | 181 | 209 | 413 | 198 | 141 | 119 | 170 | 112 | 201 | 129 |
| | Bench | | 187 | 36 | 54 | 67 | 44 | 68 | 77 | 93 | 125 | 143 | 101 | 165 | 125 | 53 | 89 | 82 | 85 |
| | Slope | | 170 | 166 | 178 | 124 | 414 | 143 | 134 | 173 | 115 | 57 | 106 | 36 | 62 | 122 | 135 | 132 | 79 |
| Mean | | | 195 | 139 | 160 | 178 | 154 | 290 | 174 | 157 | 206 | 193 | 186 | 148 | 138 | 188 | 184 | 408 | 161 |
| Stdev | | | 115 | 71 | 97 | 156 | 120 | 225 | 91 | 69 | 120 | 122 | 110 | 113 | 115 | 158 | 206 | 399 | 97 |

Appendix D.5. Estimated biomass (g/m$^2$) along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2009.

| Site | Biotope | Nov-98 | May-99 | Dec-99 | Jun-00 | Nov-00 | May-01 | Nov-01 | May-02 | Jul-05 | Nov-05 | Jul-06 | Jan-07 | Dec-07 | Aug-08 | Oct-08 | May-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wawaloli | Boulder | 311 | 274 | 100 | 673 | 143 | 115 | 228 | 155 | 30 | 143 | 107 | 314 | 189 | 84 | 119 | 268 |
| | Bench | 76 | 61 | 91 | 424 | 115 | 148 | 128 | 82 | 48 | 92 | 139 | 114 | 111 | 84 | 84 | 34 |
| | Slope | 168 | 110 | 151 | 264 | 103 | 108 | 110 | 110 | 37 | 76 | 241 | 346 | 242 | 139 | 212 | 70 |
| 18-inch Pipe | Boulder | 346 | 251 | 400 | 596 | 297 | 227 | 170 | 207 | 199 | 204 | 256 | 194 | 297 | 321 | 138 | 88 |
| | Bench | 297 | 103 | 239 | 312 | 414 | 185 | 120 | 86 | 139 | 153 | 230 | 163 | 212 | 213 | 288 | 198 |
| | Slope | 169 | 125 | 270 | 818 | 258 | 274 | 189 | 145 | 95 | 388 | 179 | 187 | 514 | 234 | 231 | 94 |
| 12-inch Pipe South | Boulder | 1382 | 281 | 437 | 359 | 578 | 523 | 190 | 227 | 148 | 270 | 227 | 268 | 261 | 251 | 119 | 110 |
| | Bench | 1255 | 168 | 361 | 549 | 180 | 373 | 293 | 166 | 68 | 101 | 231 | 246 | 297 | 308 | 147 | 146 |
| | Slope | 1809 | 162 | 994 | 274 | 308 | 214 | 213 | 214 | 75 | 116 | 106 | 146 | 497 | 265 | 163 | 82 |
| 12-inch Pipe North | Boulder | 265 | 135 | 183 | 124 | 198 | 116 | 212 | 133 | 226 | 349 | 150 | 352 | 222 | 125 | 158 | 114 |
| | Bench | 219 | 149 | 238 | 107 | 204 | 93 | 86 | 118 | 96 | 94 | 270 | 149 | 79 | 100 | 101 | 74 |
| | Slope | 2152 | 328 | 340 | 344 | 293 | 127 | 89 | 259 | 94 | 298 | 120 | 502 | 120 | 96 | 128 | 60 |
| NPPE Site | Boulder | 1816 | 269 | 148 | 150 | 108 | 161 | 122 | 110 | 330 | 171 | 245 | 231 | 115 | 97 | 70 | 122 |
| | Bench | 121 | 219 | 122 | 93 | 836 | 81 | 153 | 134 | 89 | 180 | 100 | 83 | 135 | 109 | 94 | 100 |
| | Slope | 83 | 96 | 267 | 162 | 303 | 73 | 172 | 77 | 65 | 74 | 84 | 149 | 60 | 170 | 92 | 66 |
| Ho'ona Bay | Boulder | 201 | 150 | 131 | 140 | 169 | 127 | 111 | 163 | 224 | 143 | 87 | 492 | 296 | 151 | 109 | 119 |
| | Bench | 94 | 69 | 77 | 150 | 548 | 82 | 74 | 98 | 101 | 188 | 76 | 150 | 90 | 105 | 36 | 95 |
| | Slope | 398 | 126 | 152 | 124 | 67 | 161 | 100 | 109 | 82 | 90 | 367 | 114 | 106 | 81 | 60 | 75 |
| Mean | | 620 | 171 | 261 | 315 | 285 | 177 | 153 | 144 | 119 | 174 | 179 | 233 | 214 | 163 | 131 | 106 |
| Stdev | | 706 | 80 | 213 | 218 | 200 | 115 | 59 | 53 | 79 | 95 | 83 | 124 | 133 | 81 | 63 | 54 |

# APPENDIX E

# DIGITAL QUADRAT PHOTOS

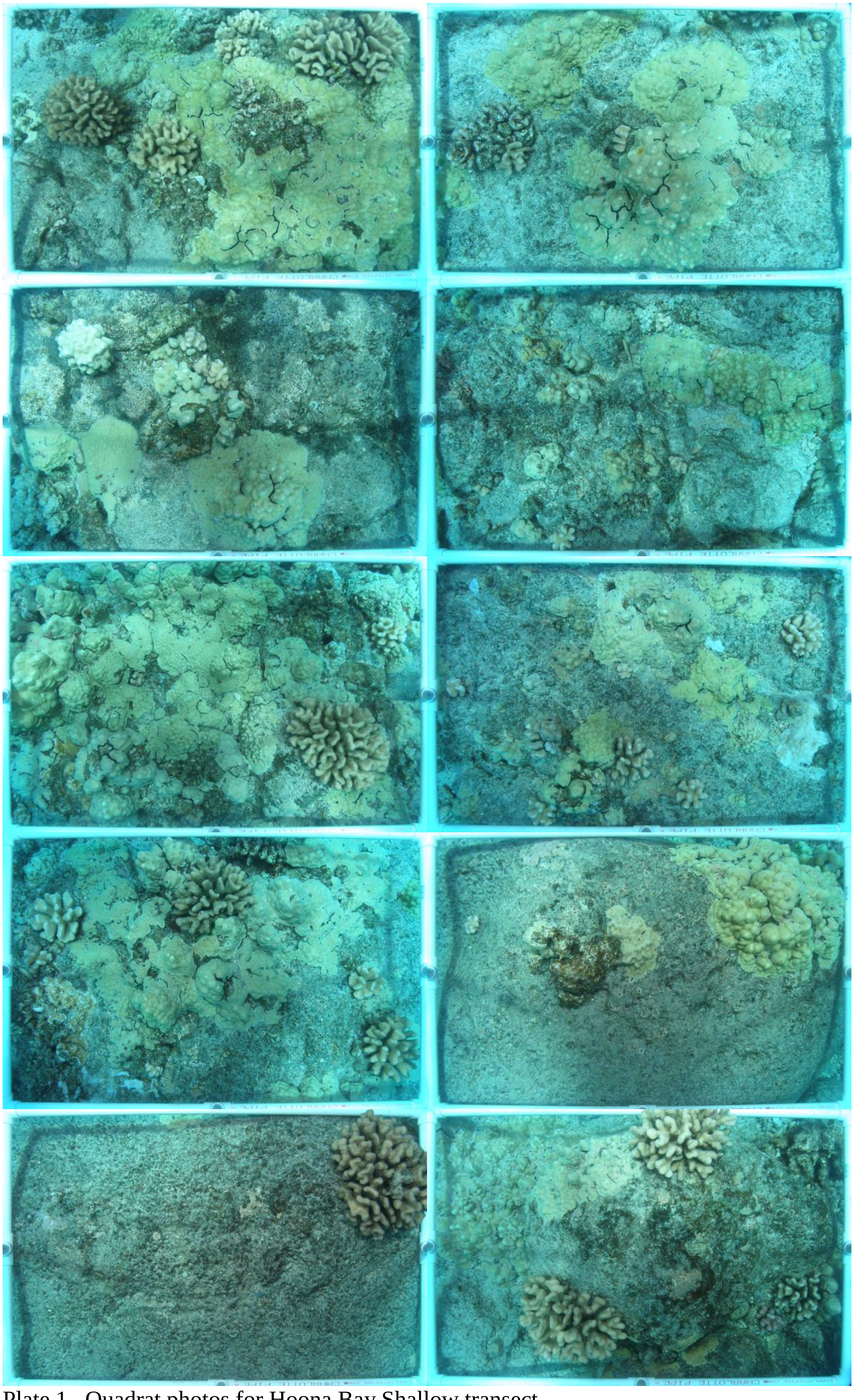

Plate 1.  Quadrat photos for Hoona Bay Shallow transect.

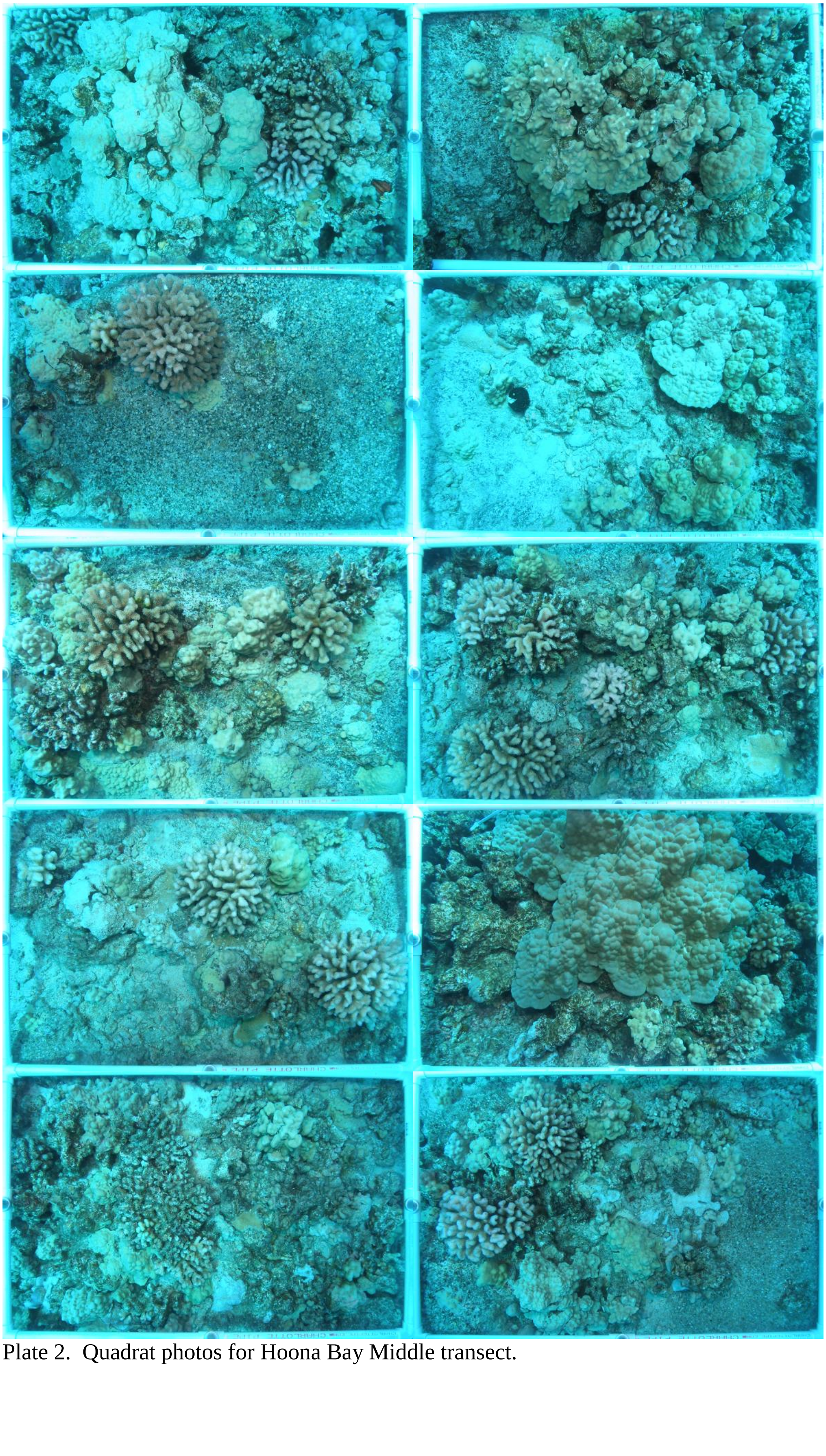

Plate 2. Quadrat photos for Hoona Bay Middle transect.

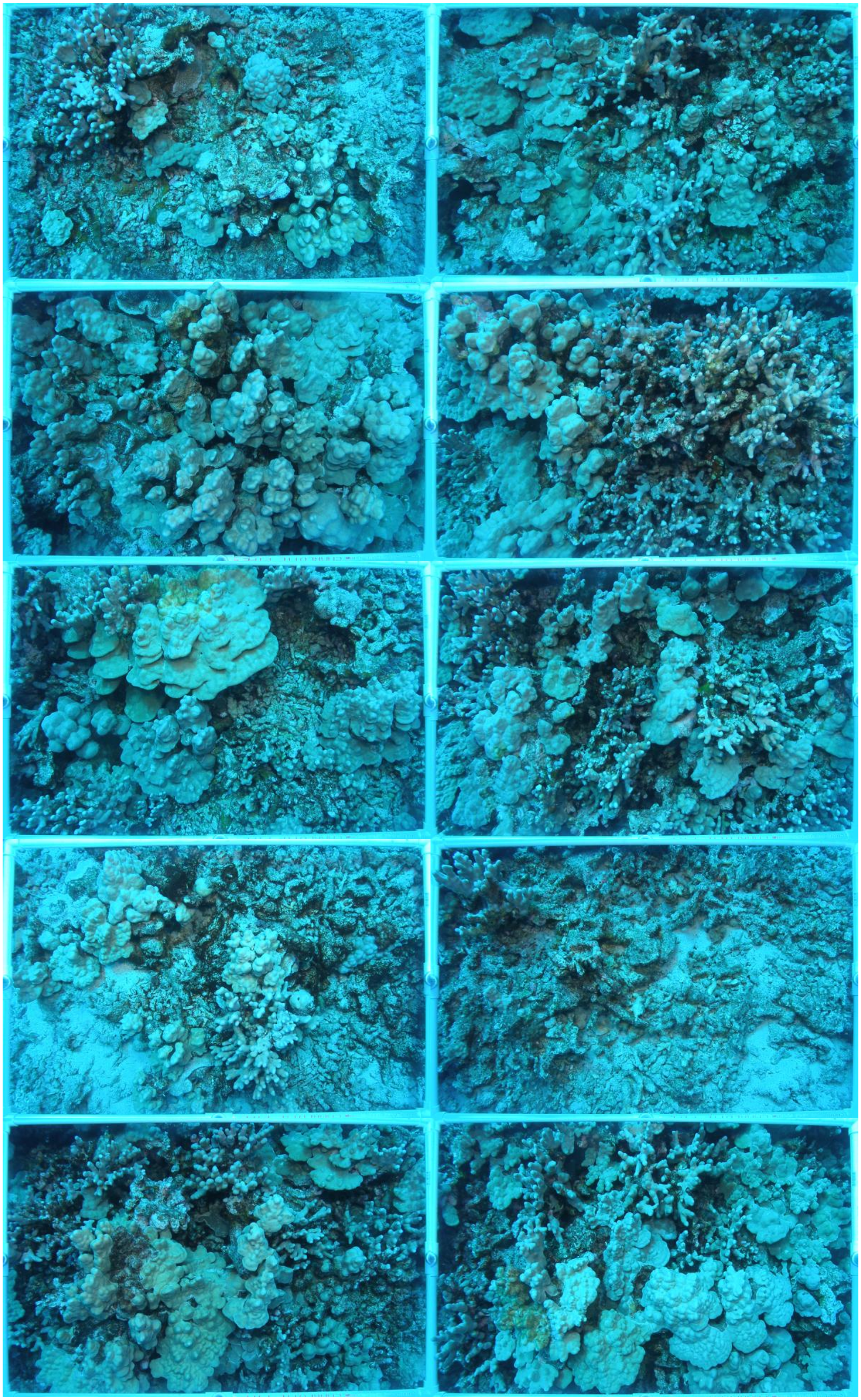

Plate 3.  Quadrat photos for Hoona Bay Deep transect.

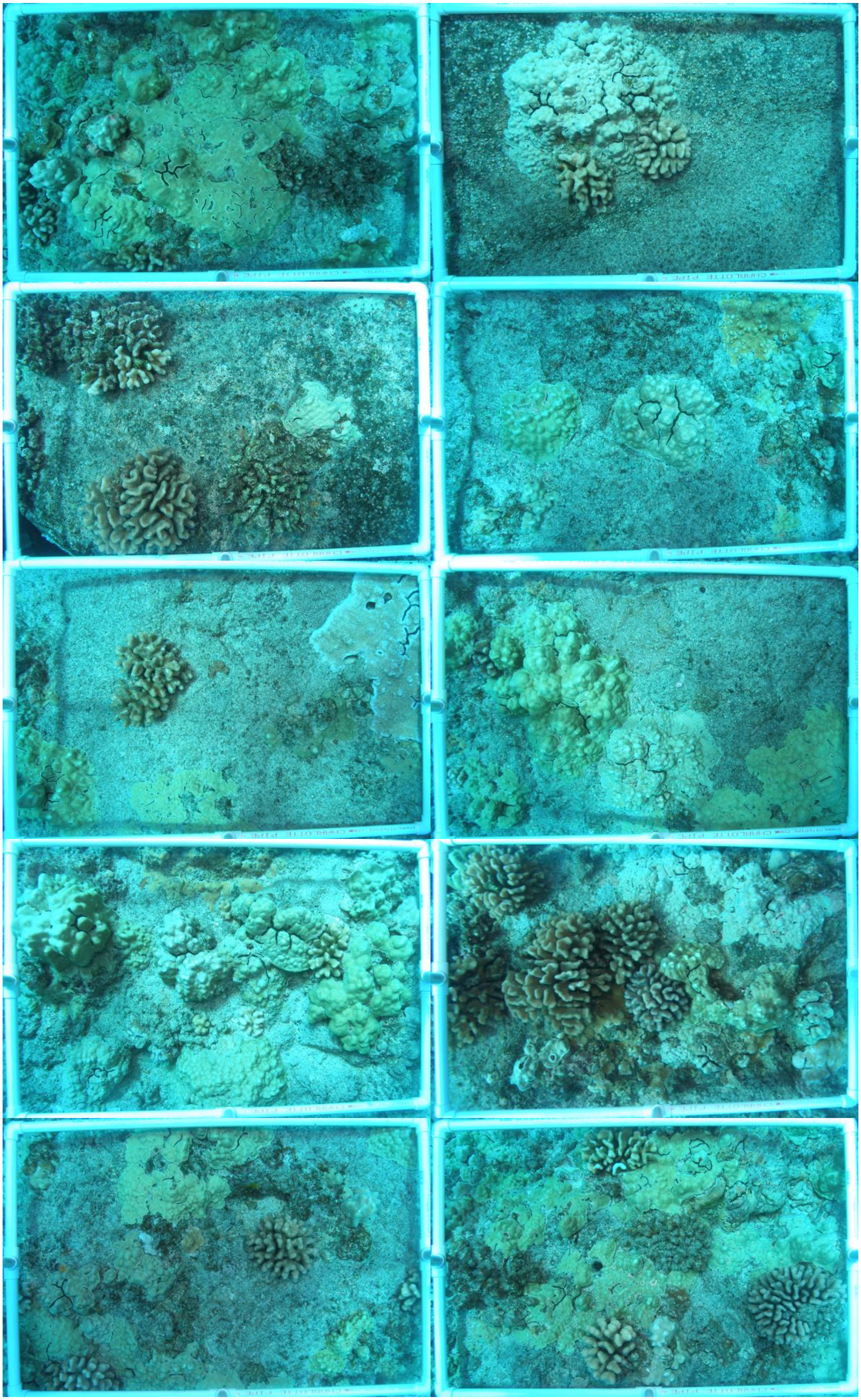

Plate 4.  Quadrat photos for NPPE Shallow transect.

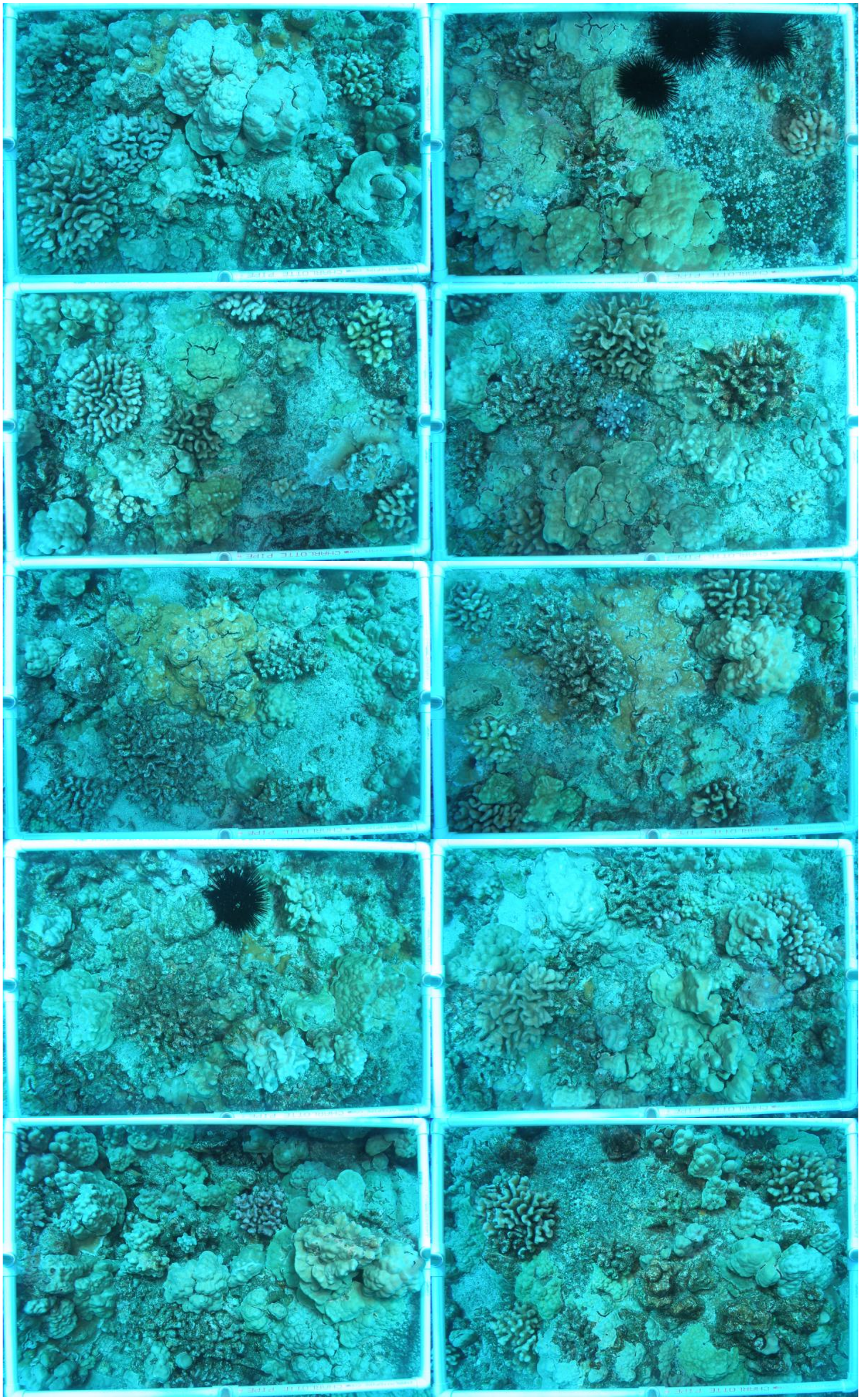

Plate 5.  Quadrat photos for NPPE Middle transect.

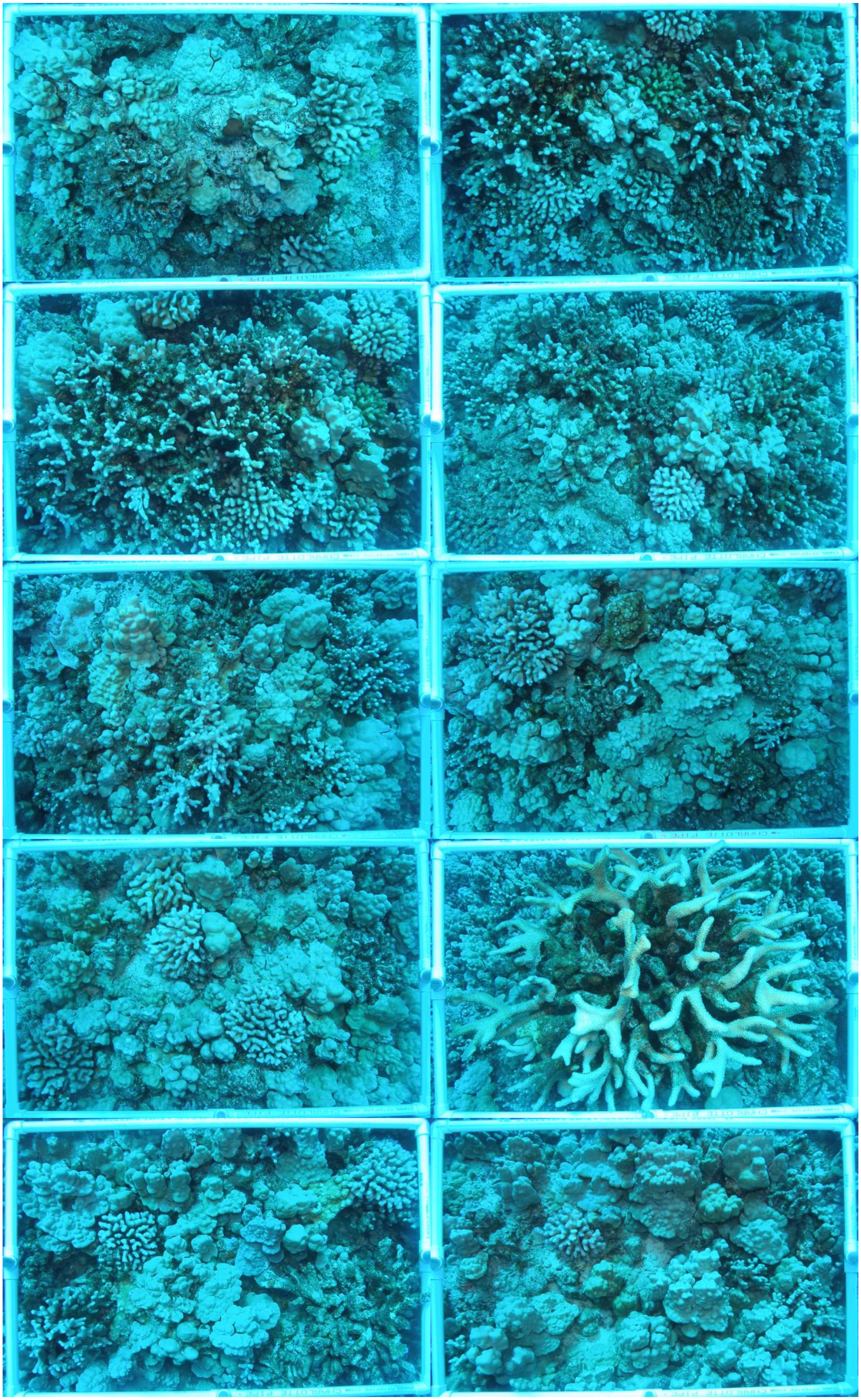

Plate 6.  Quadrat photos for NPPE Deep transect.

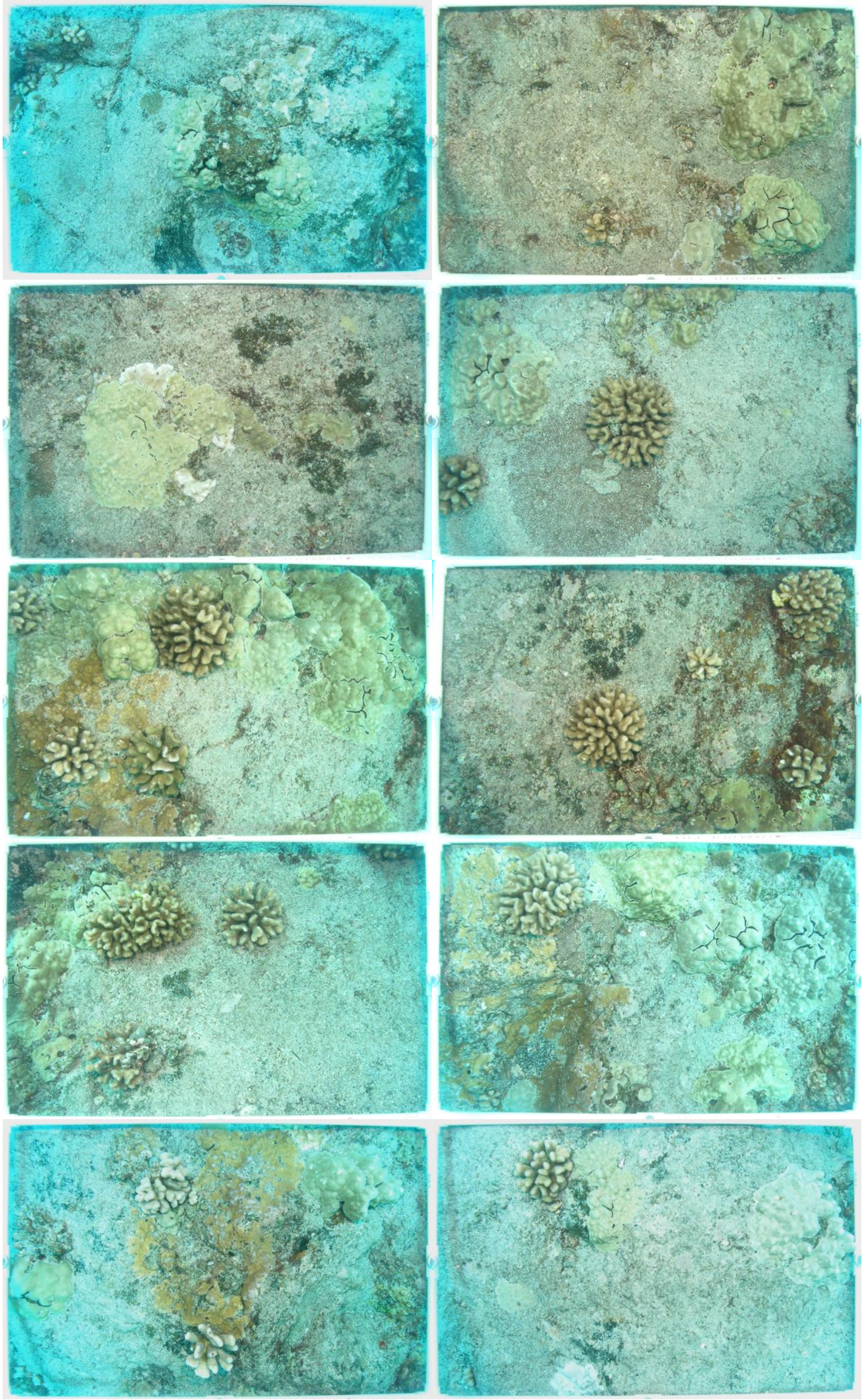

Plate 7.  Quadrat photos for 12” Pipe North Shallow transect.

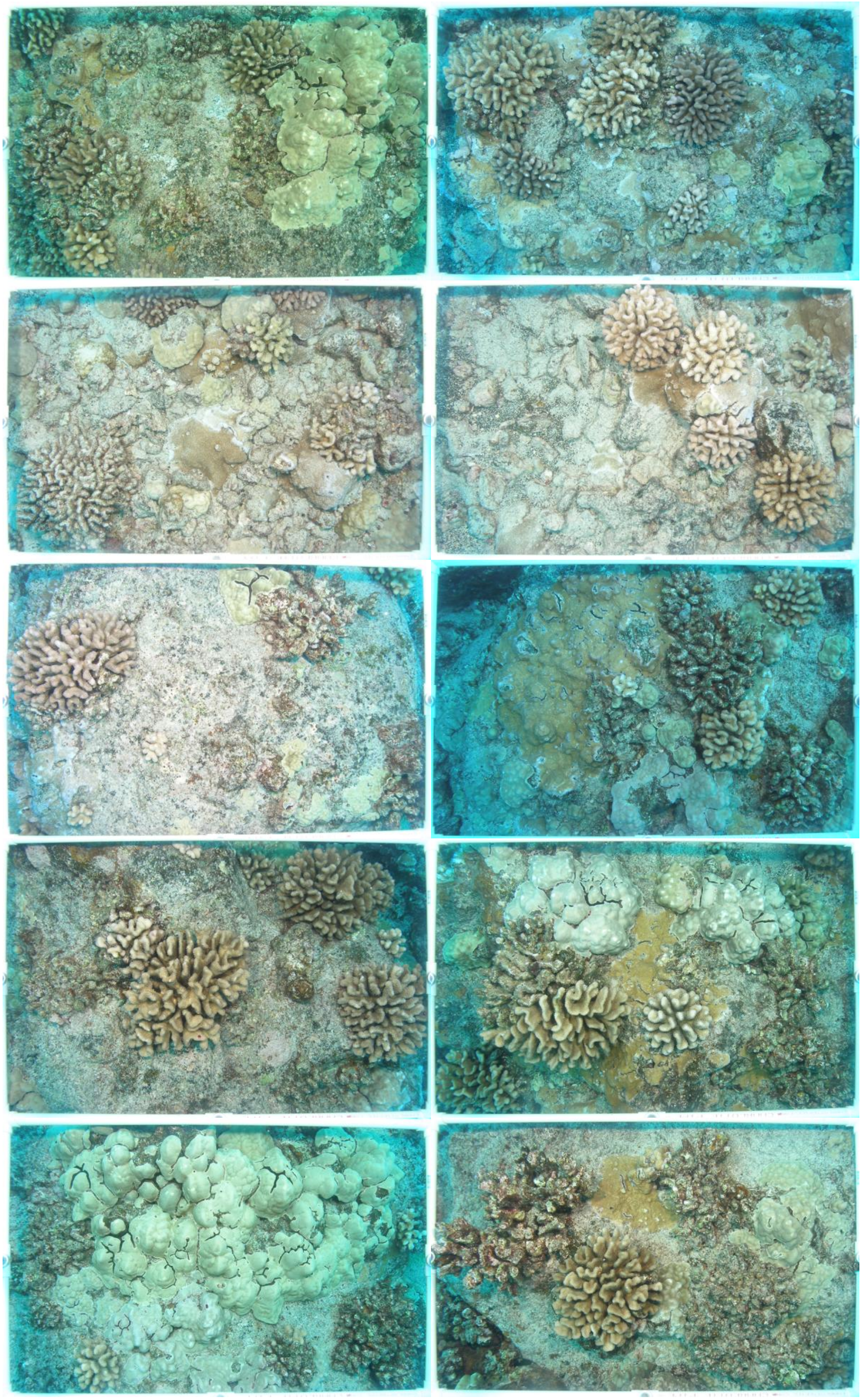

Plate 8. Quadrat photos for 12" Pipe North Middle transect.

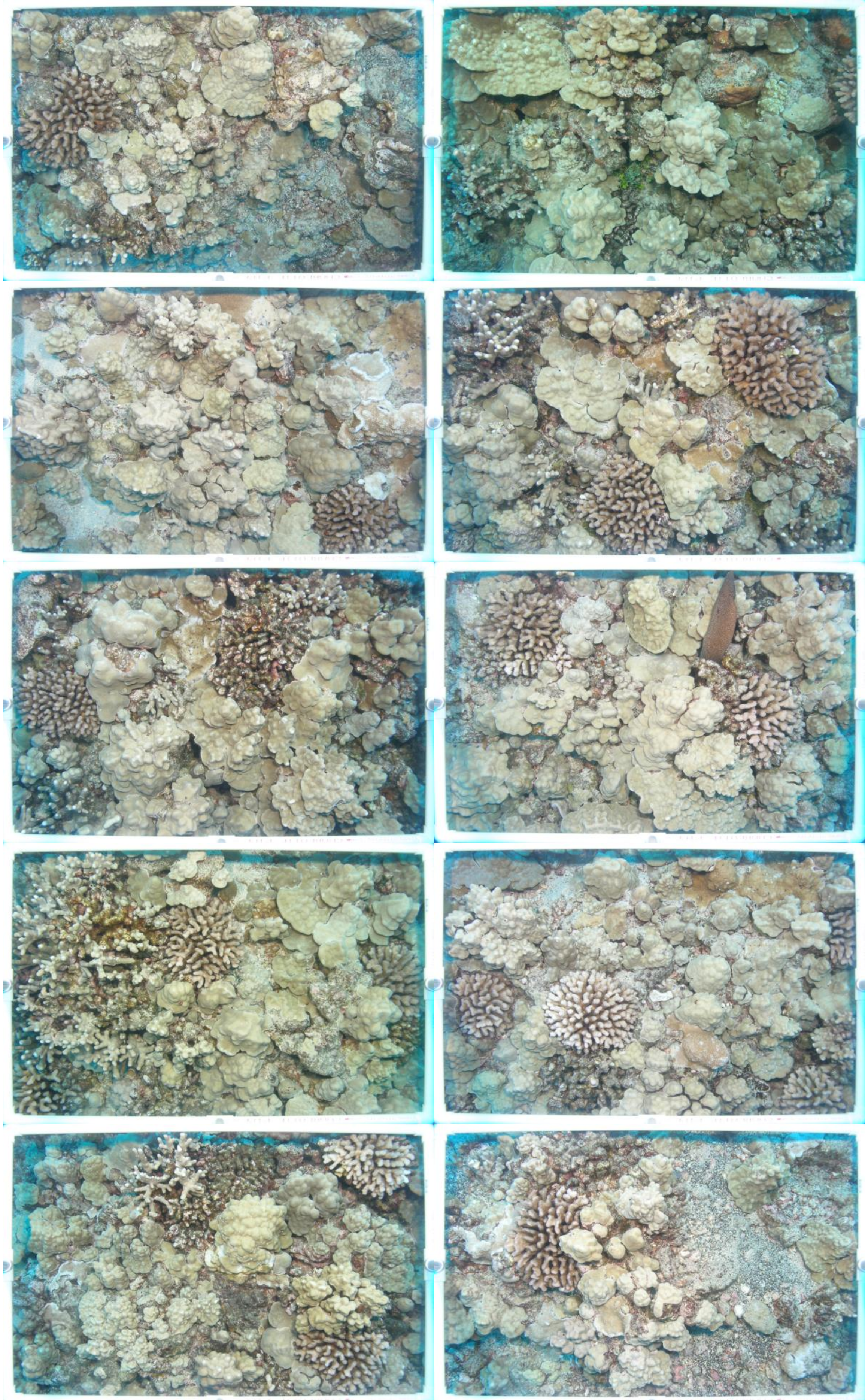

Plate 9.  Quadrat photos for 12" Pipe North Deep transect.

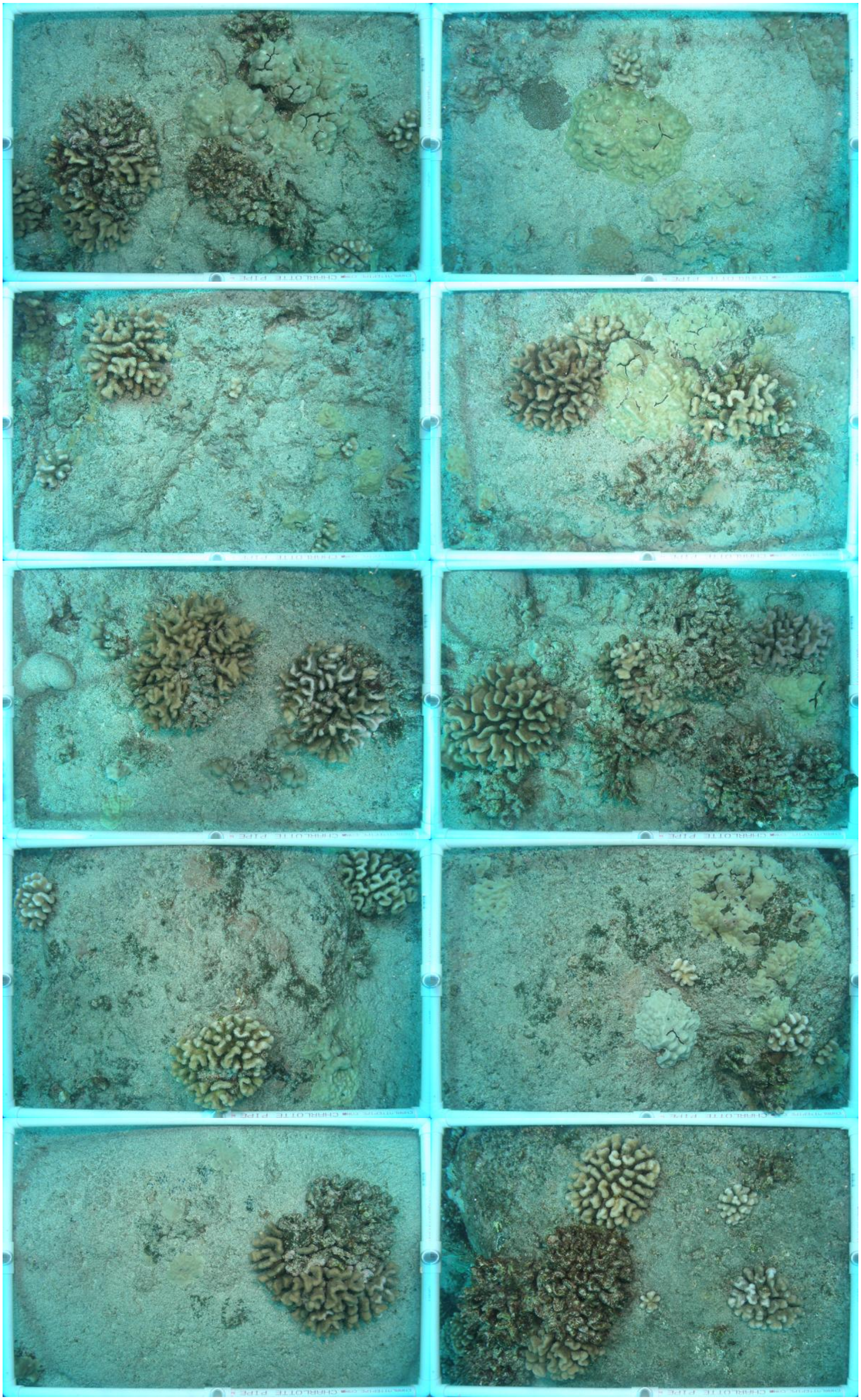

Plate 10. Quadrat photos for 12" Pipe South Shallow transect.

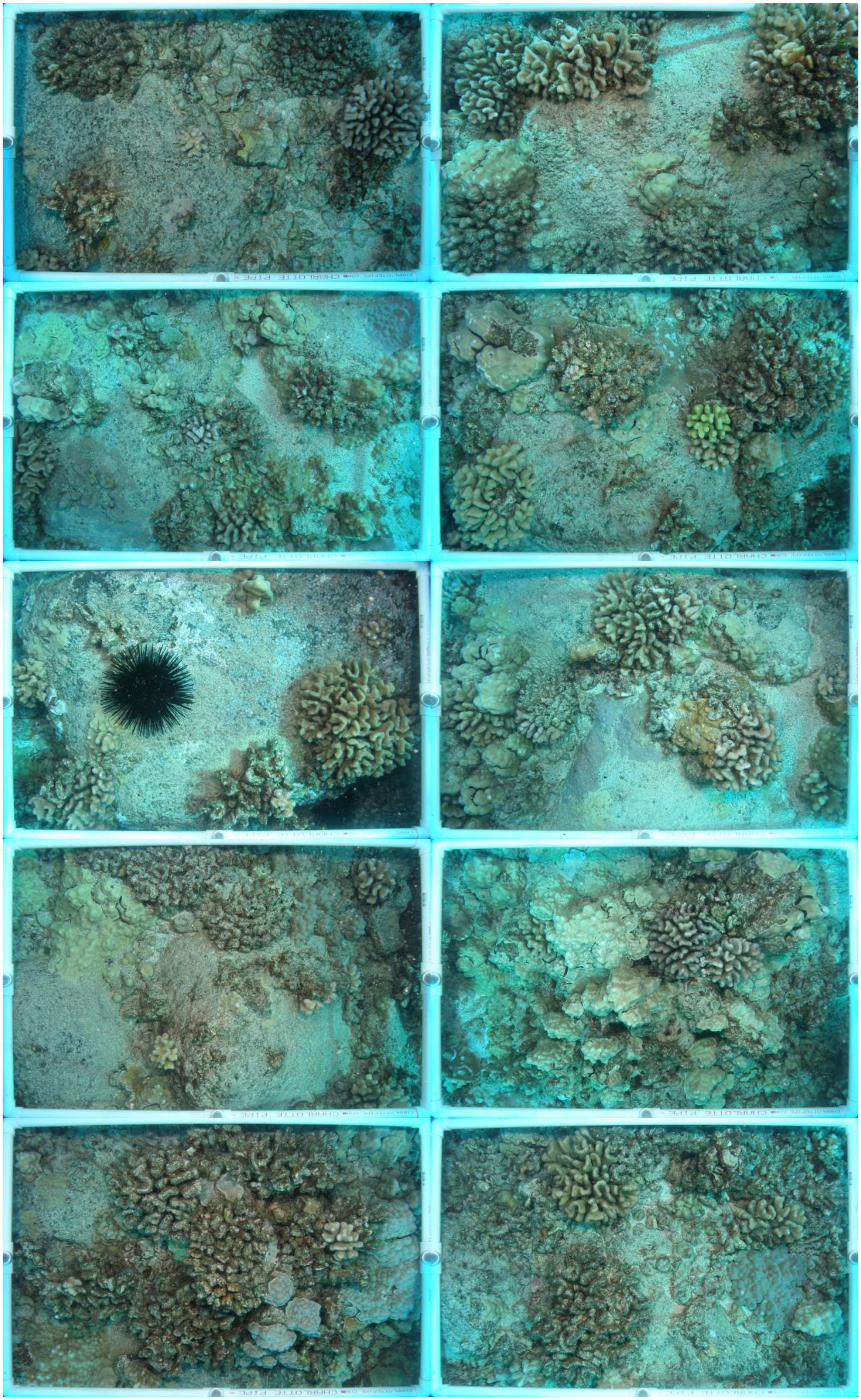

Plate 11. Quadrat photos for 12" Pipe South Middle transect.

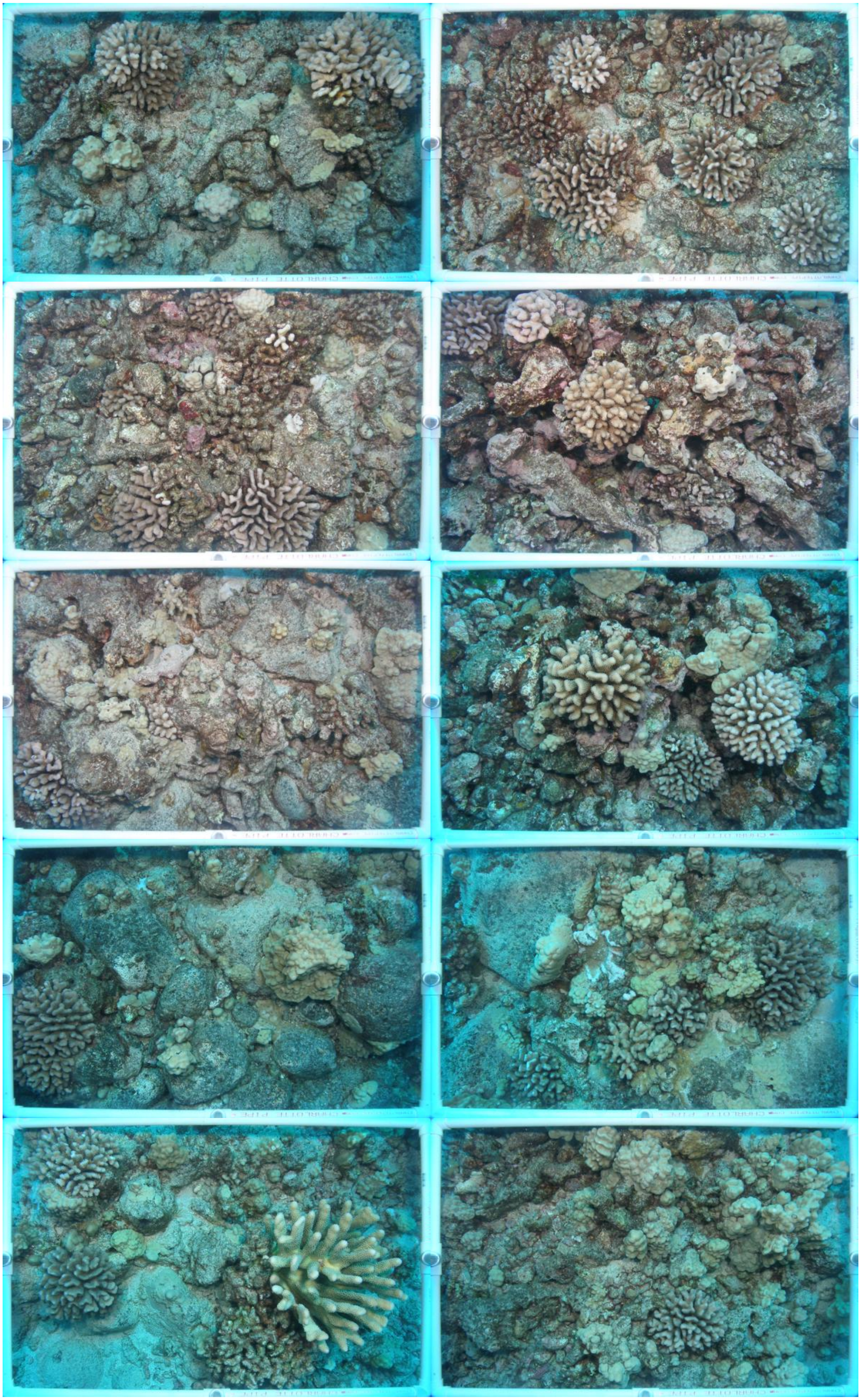

Plate 12.  Quadrat photos for 12” Pipe South Deep transect.

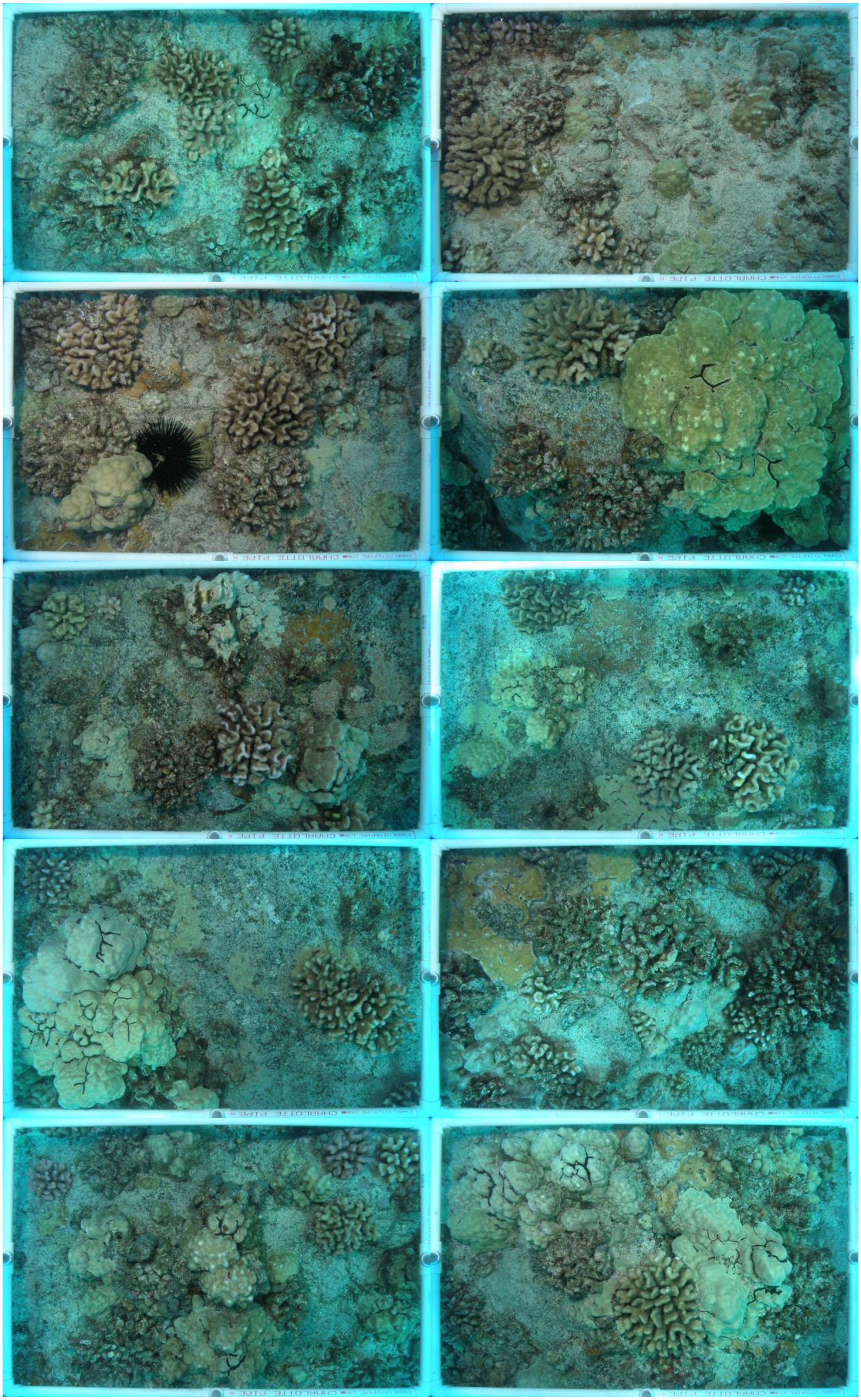

Plate 13.  Quadrat photos for 18" Pipe Shallow transect.

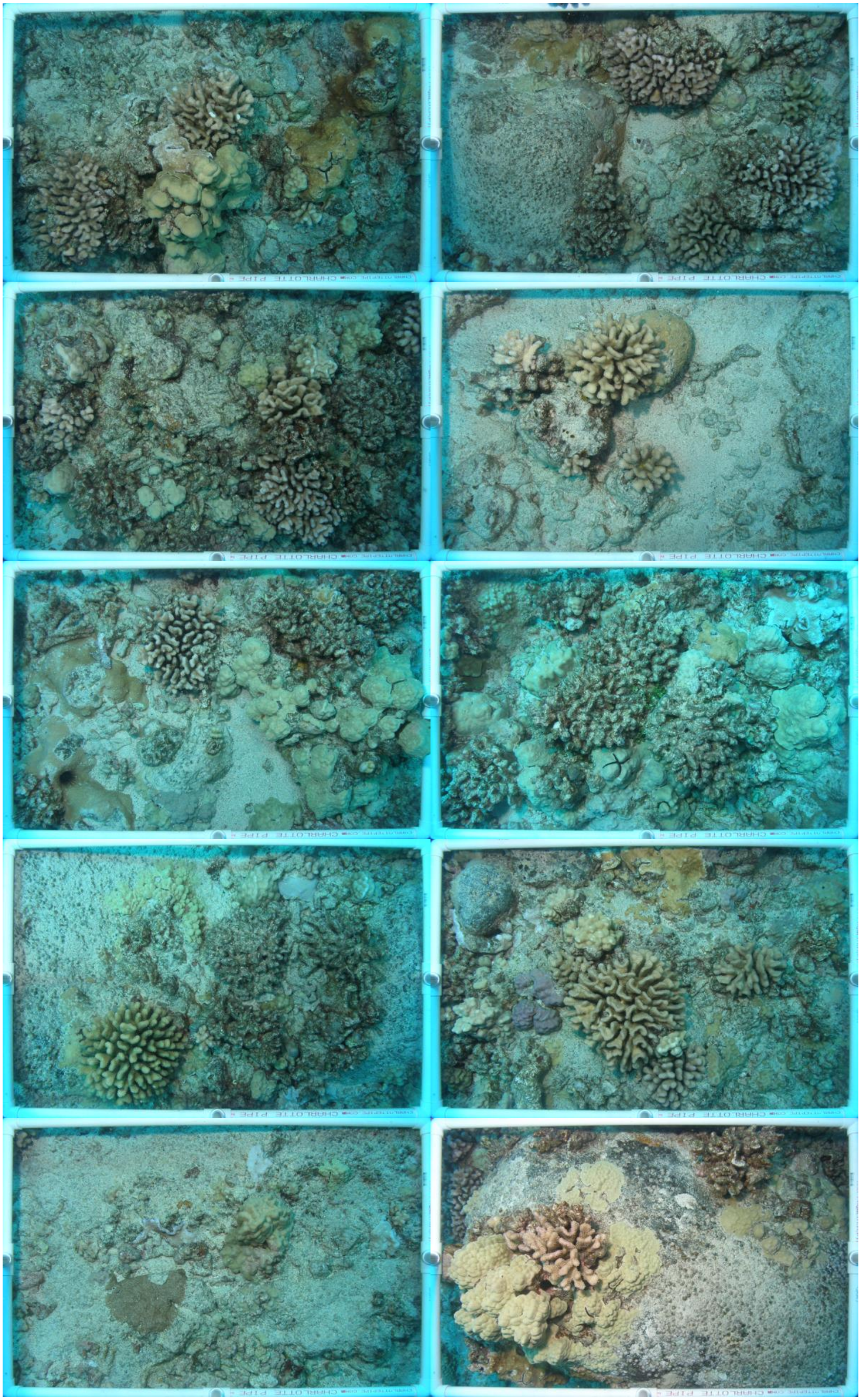

Plate 14.  Quadrat photos for 18" Pipe Middle transect.

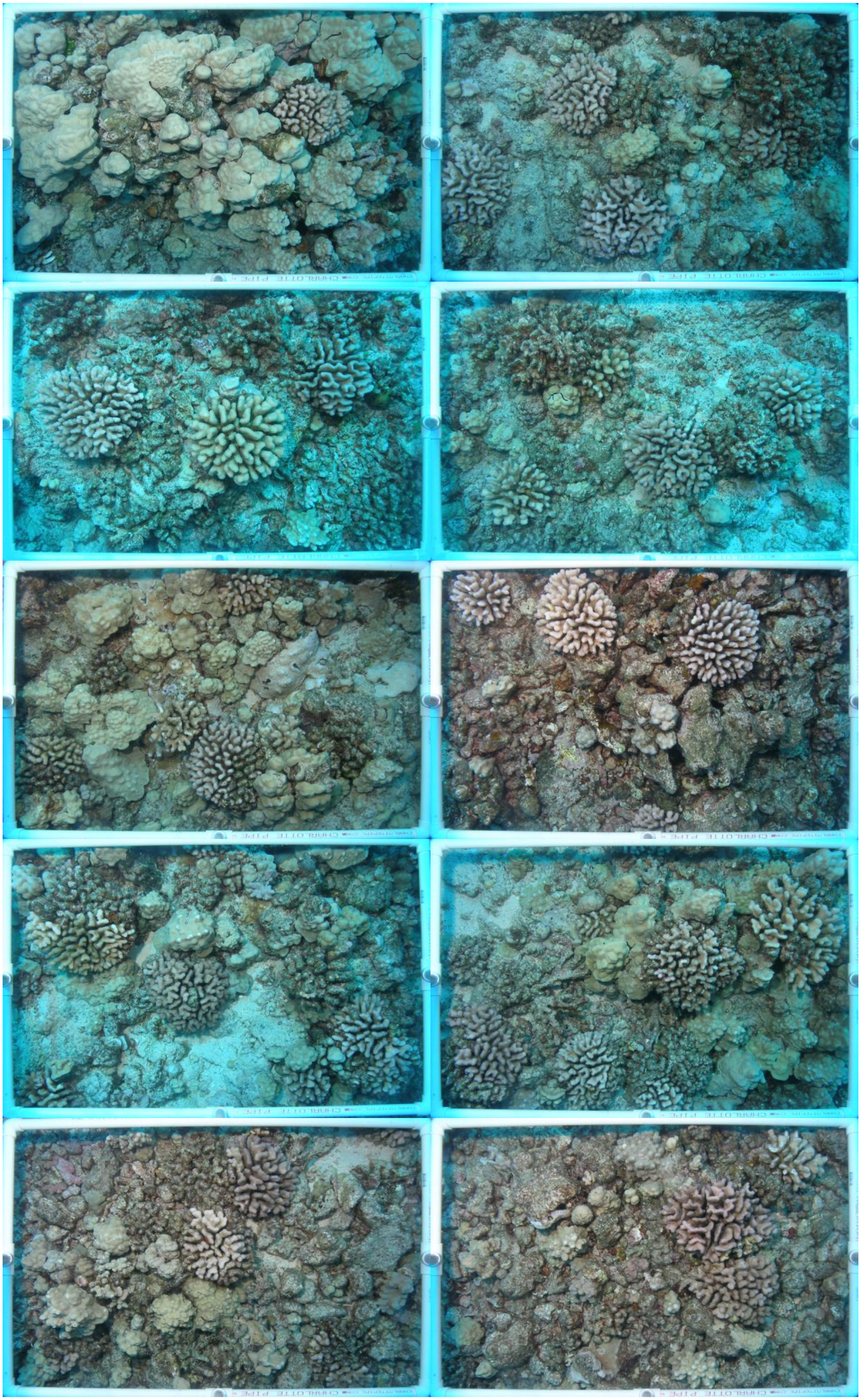

Plate 15.  Quadrat photos for 18” Pipe Deep transect.

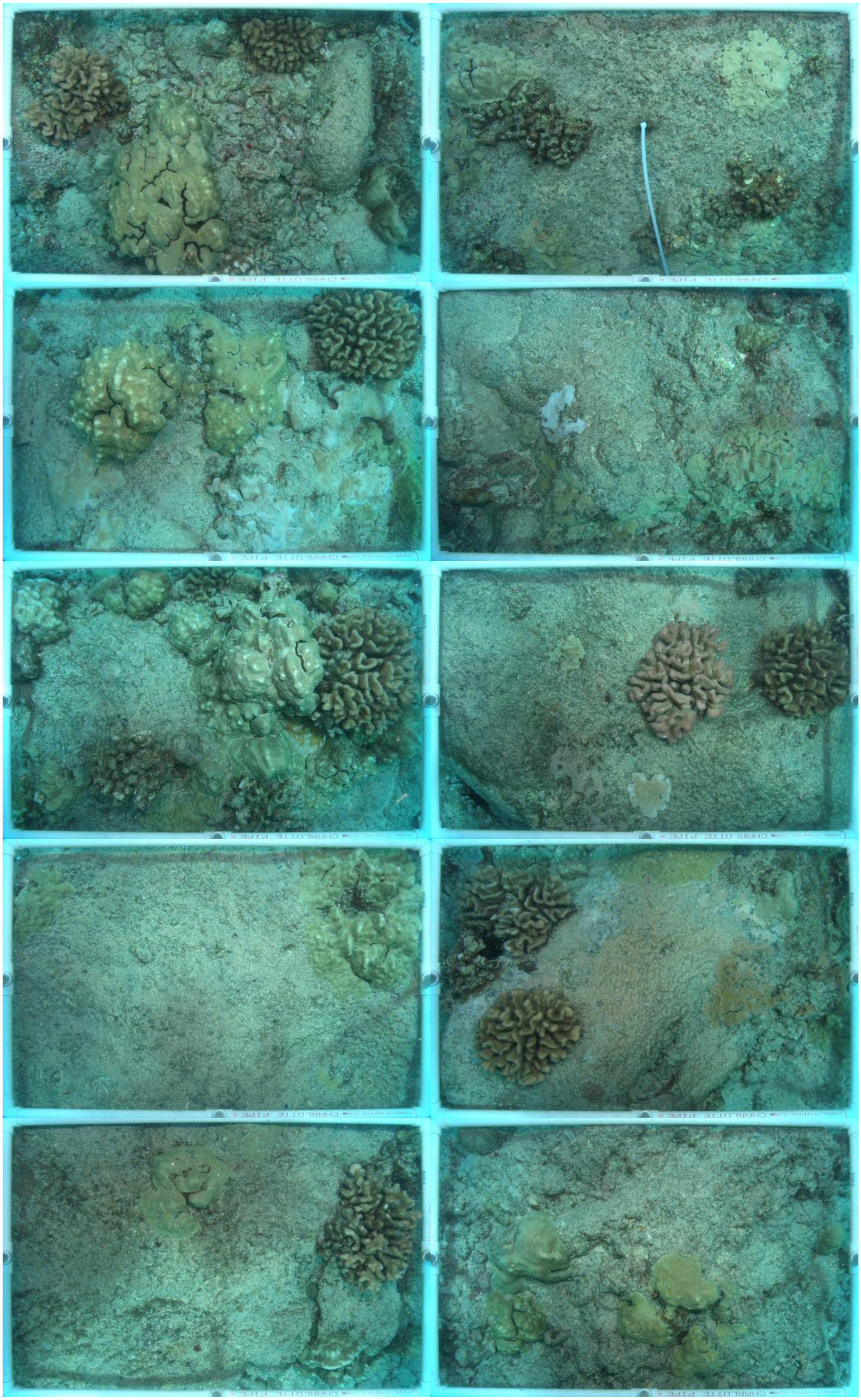

Plate 16.  Quadrat photos for Wawaloli Shallow transect.

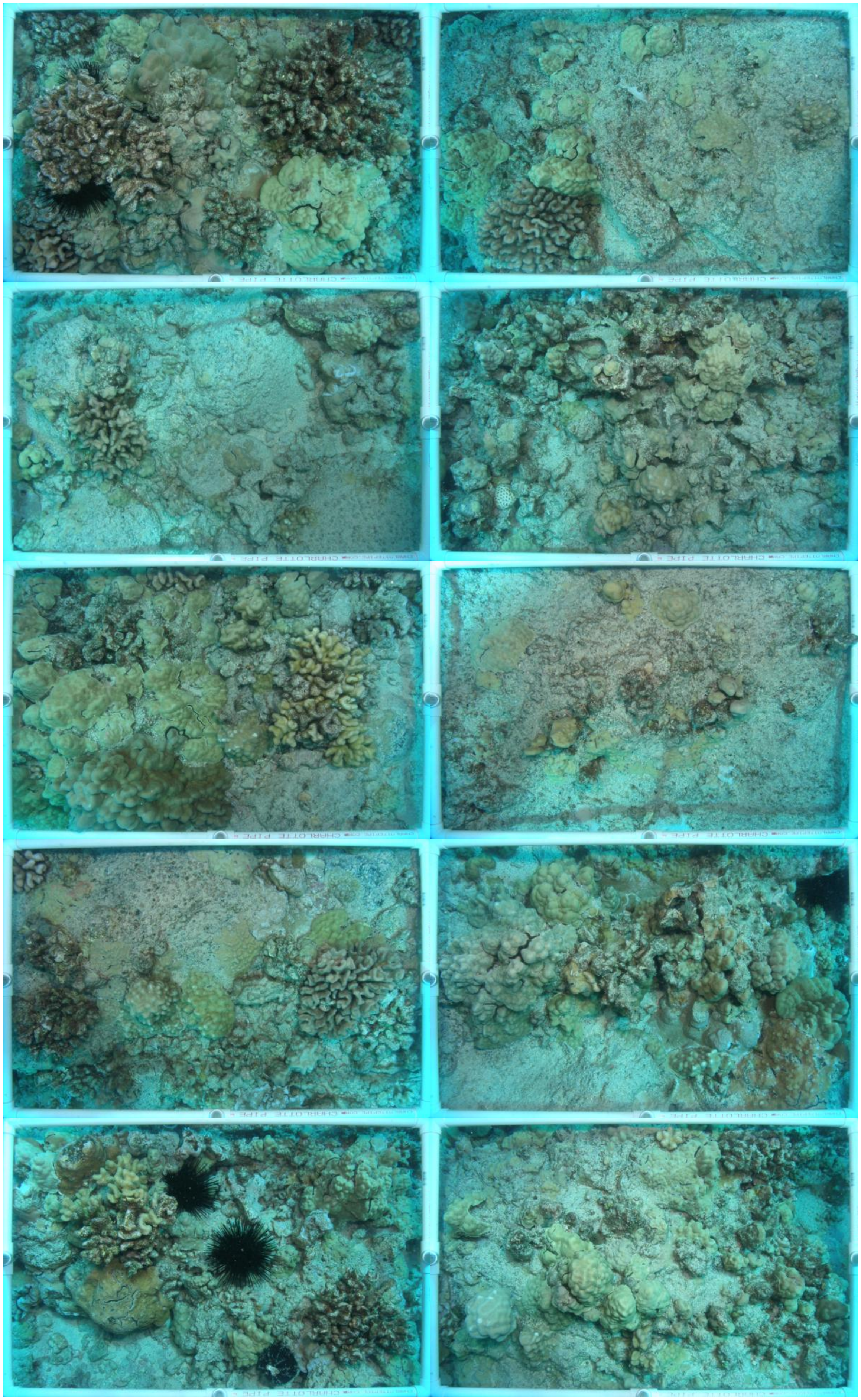

Plate 17.  Quadrat photos for Wawaloli Middle transect.

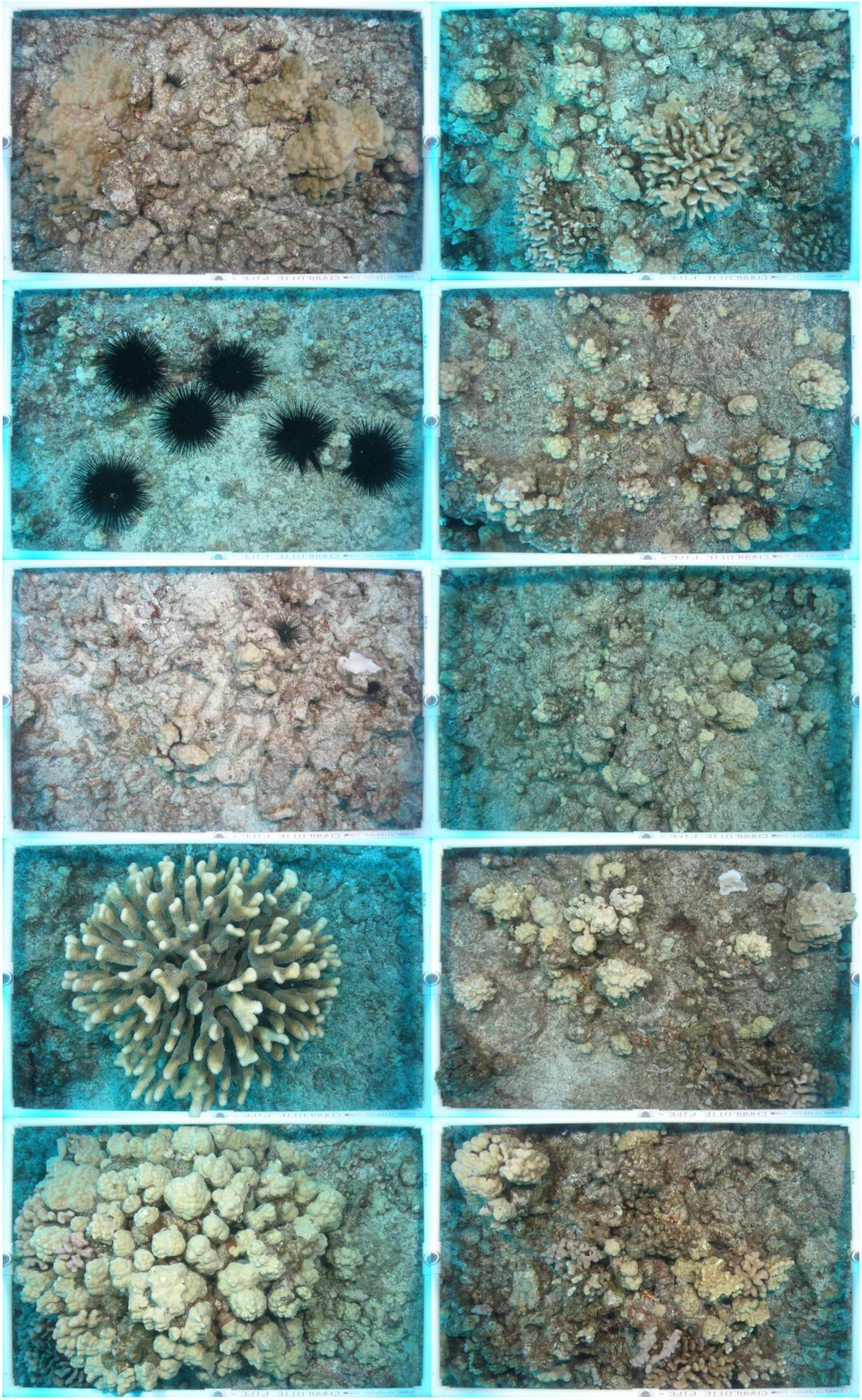

Plate 18.  Quadrat photos for Wawaloli Deep transect.