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

SURVEY REPORT
OCTOBER 2008

Prepared for

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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 October 2008.

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. As an apparent consequency of the removal of exotic fishes, *Halocaridina rubra*, was 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 anthropogenic impacts 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 October 2008. 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 October 2008. 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 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 sixteen 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 October 2008 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
October 2008

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, 30 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; and for December 2007 and August 2008 in Brock 2008. Results of the pond monitoring survey conducted in October 2008 are presented below.

METHODS

Anchialine ponds are located in two groups on the NELHA site (Figure 1): five ponds are located near the shoreline to the north of NELHA (Figure 2 upper), and 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 October 30, 2008 At each pond, water temperature and salinity were determined. Temperature was determined with a mercury thermometer; salinity 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.

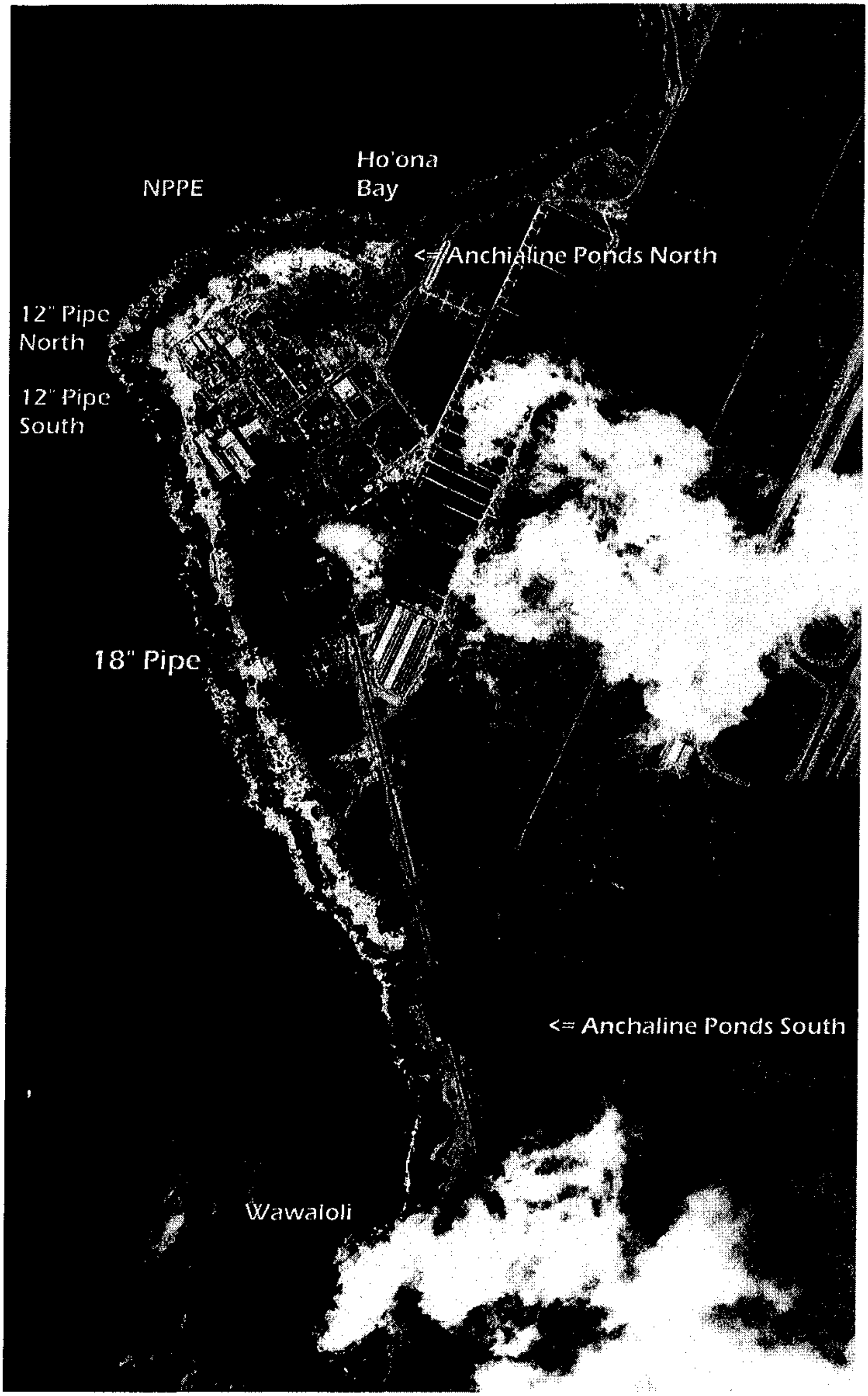


Figure 1. Locations of anchialine ponds and marine biota monitoring transects off NELHA.

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), 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. Salinity during the October 2008 survey was similar in the five northern ponds (9 - 10 ppt). Temperature was similar (22 - 23 deg C) in pondsN1, N2 and N5, but elevated (27 - 28 deg C).

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 reported here.

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 present survey, however, exotic fishes were observed in only three ponds (S1, S5 and S7). *Halocaridina rubra* were abundant in the ponds which did not contain exotic fish. Another common pond crustacean *Metabateaus lohena* was seen in the same southern ponds as *H. rubra.*

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).

Exotic fish were present in most of the northern ponds and one third of the southern ponds. During the present survey, 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.

None of the ponds, however, 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 anthropogenic impacts on the anchialine ponds at NELHA.

Table 1. Physical and biological data collected in anchialine ponds within the NELHA facility in October 2008. 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	23.0	10				+		++	-	-	*Ruppia* absent
N2	22.0	10						+	-	-	*Ruppia* absent
N3	28.0	9	+	+				+++	-	-	*Ruppia* present
N4	27.0	9						+++	-	-	*Ruppia* absent
N5	22.5	10	+	+				++	-	-	*Ruppia* present
S1	20.0	5						-	2	+	
S2	19.5	7						100	-	-	
S3	20.0	8						200	1	-	
S4	20.0	8						5	-	-	
S5	19.0	8						-	-	+	
S6	19.5	8						20	1	-	
S7	20.0	9						-	-	++	
S8	20.0	8						75	15	-	
S9	20.0	8						-	-	-	

Qualitative abundance:

+	few animals; scattered plants
++	animals common; plants abundant in patches
+++	animals too numerous to count; plants covering substrate
-	none 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, 32 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. Results of the survey conducted in October 2008 are reported here.

METHODS

A survey to examine the nearshore benthic marine biota was performed using SCUBA between October 28 – 29, 2008. 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). 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 an underwater strobe. Digital quadrat photos were analyzed using Coral Point Count with Excel extensions (CPCe v3.4; 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:

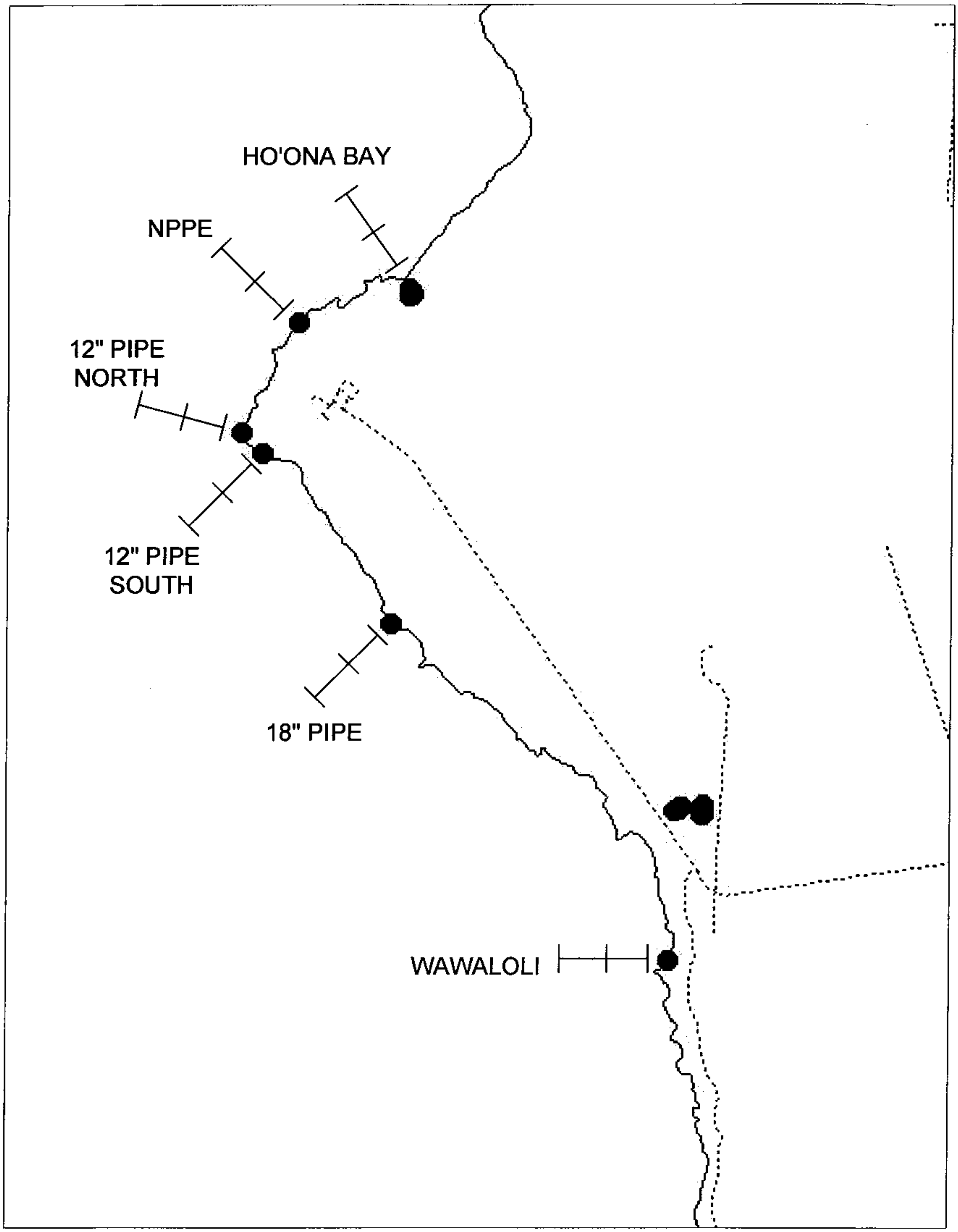


Figure 3. Locations of marine biota monitoring survey transects.

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

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 25.8% and 7.3%, 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 stations at NPPE and the middle and deep stations at Ho'ona Bay, the most northern area.

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 areas. Total coral cover in the inshore boulder habitat was generally lower than in the deeper reef bench or reef slope habitats at the northern stations, but higher in the boulder zone at the two southern stations (18" Pipe, Wawaloli). Among the deep reef slope stations, coral abundance was highest at Ho'ona Bay and the NPPE site. At Ho'ona Bay this was due to the high abundance of *Porites compressa* (over 18 - 27% cover). At the NPPE site, the reef slope was dominated by *P. lobata* (46.2%) and *Porites compressa* (20.4%). At the other four deep reef slope stations, *P. lobata* and *Pocillopora meandrina* accounted for the high coral abundance (combined average cover of 25 - 52%).

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 NPPE boulder, bench, and slope stations. For *Pocillopora meandrina,* the 12" Pipe North and South stations had the highest mean abundance of all the stations.

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.

Table 2. Summary of percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in October 2008. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

	12"Pipe South			18" Pipe			Wawaloli		
TRANSECT NAME: NELHA 0810	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep
Number of frames	10	10	10	10	10	10	10	10	10
Total points	2000	2000	2000	2000	2000	2000	2000	2000	2000
MAJOR CATEGORY (% of transect)									
CORAL	23.4	33.1	31.9	43.1	40.9	32.8	21.0	34.3	13.4
DEAD CORAL WITH ALGAE	1.2	13.7	6.7	12.0	16.0	8.2	3.0	3.8	1.3
SAND, PAVEMENT, RUBBLE	74.3	53.3	61.4	45.0	43.2	59.1	76.1	62.0	85.4
SUBCATEGORIES (% of transect)									
CORAL									
Porites lobata	15.2	20.8	12.9	29.9	26.6	18.1	16.0	29.4	9.8
Porites compressa						0.1			0.3
Pocillopora meandrina	5.9	10.1	17.4	9.8	9.9	13.0	3.0	3.5	3.1
Pocillopora eydouxi	1.2								
Montipora patula	1.0	1.7	1.6	3.2	2.9	1.6	1.3	1.2	0.1
Montipora capitata	0.2	0.6	0.1	0.2	1.5	0.2	0.8	0.3	0.1
Pavona varians								0.1	
Fungia scuratia					0.1				
Leptastrea purpurea									0.1
Species	5	4	4	4	5	5	4	5	6
Diversity	0.95	0.87	0.86	0.81	0.94	0.88	0.77	0.52	0.73
DEAD CORAL WITH ALGAE									
Old dead coral	1.1	13.7	6.7	12.0	16.0	8.2	3.0	3.8	1.3
SAND, PAVEMENT, RUBBLE									
Boulder	0.0	27.4	3.4	0.0	4.4	0.0	30.4	7.0	0.0
Coral Rubble	0.1	3.4	10.6	0.4	0.8	11.5	0.4	4.2	9.5
Limestone	2.7	22.4	46.1	43.4	35.4	45.8	37.4	46.7	73.4
Rock	71.5	0.0	0.0	0.0	0.0	0.1	7.7	2.4	0.0
Sand	0.0	0.1	1.4	1.3	2.7	1.7	0.3	1.7	2.6

Table 2. Summary of percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in October 2008. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

	Ho'ona Bay			NPPE			12" Pipe North		
TRANSECT NAME: NELHA 0810	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep
Number of frames	10	10	10	10	10	10	10	9	10
Total points	2000	2000	2000	2000	2000	2000	2000	1800	2000
MAJOR CATEGORY (% of transect)									
CORAL	32.5	62.2	47.6	53.8	53.0	75.2	21.5	35.9	55.3
DEAD CORAL WITH ALGAE	3.5	0.6	1.9	1.3	9.0	4.2	1.6	6.4	4.9
SAND, PAVEMENT, RUBBLE	62.8	37.2	50.4	44.9	37.6	20.7	76.4	57.7	39.9
SUBCATEGORIES (% of transect)									
CORAL									
Porites lobata	27.9	33.0	28.3	40.5	41.3	46.2	13.6	17.1	37.8
Porites compressa	0.5	27.3	18.6	0.3		20.4			2.8
Pocillopora meandrina	3.6	1.4	0.6	6.7	7.0	6.1	5.7	13.9	11.2
Pocillopora eydouxi						1.6			
Montipora patula				5.9	4.3	1.0	1.8	3.9	2.6
Montipora capitata		0.5	0.2	0.5	0.5		0.5	1.0	1.0
Pavona varians		0.1						0.1	
Fungia scuratia					0.1				
Leptastrea purpurea									
Species	3	5	4	5	5	5	4	5	5
Diversity	0.43	0.83	0.75	0.78	0.71	0.99	0.93	1.07	0.95
DEAD CORAL WITH ALGAE									
Old dead coral	3.5	0.6	1.9	1.3	9.0	4.2	1.6	6.4	4.9
SAND, PAVEMENT, RUBBLE									
Boulder	0.0	0.0	0.0	0.0	14.9	0.0	16.2	29.0	0.0
Coral Rubble	0.6	6.0	19.1	0.0	0.0	0.0	0.0	3.2	7.4
Limestone	0.0	31.1	30.8	44.9	20.8	20.4	60.2	15.7	30.4
Rock	62.3	0.2	0.0	0.0	0.2	0.0	0.0	9.6	1.0
Sand	0.0	0.0	0.6	0.0	1.8	0.4	0.0	0.1	1.1

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, 30 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 30 surveys from May 1992 to October 2008 for total coral cover, *Porites lobata* abundance and *Pocillopora meandrina* abundance using SigmaStat for Windows, a PC-based statistical analysis program. Three-way analysis of variance provides estimates of the significance of the differences between variables, taking into account the variability of the other sources, whereas one-way or two-way ANOVA assume that the remaining variables are replicates, an assumption that is incorrect if all variables exhibit significant variability. If factors are significantly different, the level of significance for each level or interaction is determined by multiple comparison procedures. Since in most cases the data failed either the test that the data were normally distributed or that the variances were equally distributed, or both, the tests were performed using ranked data rather than raw 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 analysis of variance (ANOVA) examining 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.

Summary of three-way analysis of variance on ranked data (Kruskal-Wallis test) for quantitative benthic community abundance for the period May 1992 – October 2008.			
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 multiple comparisons (SNK tests) from the three-way ANOVA 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 present survey conducted in October 2008.

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 20.7% at the Wawaloli site. Mean total coral cover was significantly different between all three habitat types, being highest (41.3%) at the deep reef slope, intermediate (36.3%) at the reef bench stations, and lowest (25.8%) at the shallow boulder stations.

The mean *P. lobata* cover for each date, location and habitat and the results of the pairwise multiple comparisons (SNK tests) from the three-way ANOVA are presented in Table 4. In general, the patterns of *P. lobata* distribution were similar to the patterns for total coral cover. *P. lobata* cover was low and similar between May 1992 and May 1997, ranging from 10.0 to 14.6%. *P. lobata* cover increased between surveys conducted in May 1997 and November 1997

Table 3. Summary of three-way analysis of variance (ANOVA) of total coral abundance (percent cover) for surveys conducted off NELHA from 1992 - 2008. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

		Mean	group								
Date											
	May-92	17.4									i
	Oct-92	16.9									i
	May-93	19.3								h	i
	Oct-93	21.0								h	i
	Mar-94	21.0								h	i
	May-94	19.4								h	i
	Sep-94	23.3							g	h	i
	Jan-95	23.5							g	h	i
	May-95	21.7								h	i
	Nov-95	25.1							g	h	i
	Jun-96	19.6								h	i
	Dec-96	21.6								h	i
	May-97	27.0							g	h	
	Nov-97	42.5		b	c	d	e				
	May-98	49.4	a	b							
	Nov-98	46.1	a	b	c	d					
	May-99	40.7			c	d	e				
	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						f	g		
	Nov-05	30.2						f	g		
	Jul-06	35.8					e	f			
	Jan-07	38.5					e				
	Oct-07	52.4	a								
	Jul-08	54.7	a								
	Oct-08	39.5				d	e				
Location											
	Wawaloli	20.7					e				
	18-inch Pipe	28.9				d					
	12-inch South	32.6			c						
	12-inch North	31.2			c	d					
	NPPE	51.7	a								
	Ho'ona Bay	41.5		b							
Biotope											
	Shallow	25.8			c						
	Middle	36.3		b							
	Deep	41.3	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 - 2008. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

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

from 13.7% to 20.6%, values that were significantly different. *P. lobata* cover remained high from November 1997 through May 2002, ranging from 18.9 – 22.9%. *P. lobata* cover was 16.7 and 17.7% in July and November 2005, respectively, significantly lower than during the prior survey in May 2002, but not significantly different from the levels observed in May 1997. *P. lobata* cover was 22.3% in January 2007, higher but not significantly different from the prior three surveys. Estimates of *P. lobata* coverage increased to 30.7 and 29.8% in surveys conducted in October 2007 and July 2008. Coverage for *P. lobata* in the present October 2008 survey was 25.8%

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 levels of significance of the differences in the mean values among the three sources of variance in three two-way ANOVA tests of *Pocillopora meandrina* cover 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 May 1997, ranging from 3.7 to 8.0%. 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. Mean *Poc. meandrina* cover increased from November 1997 through December 1999, then remained relatively consistent (16.1 – 20.3%) through May 2002. Mean *Poc. meandrina* cover increased from 8.0 to 11.8% between July 2005 and July 2008, significantly lower than during the prior survey in May 2002, but not significantly different from the levels observed between May 1992 and May 1997. Mean *Poc. meandrina* coverage was 7.3% during the present October 2008 survey.

Mean *Poc. meandrina* cover was similar (12.4 – 13.6%) at the NPPE, 18" Pipe and 12" Pipe South sites, then decreased from the 12" Pipe North and Wawaloli sites to a minimum of 3.7% at the Ho'ona Bay site. Mean *Poc. meandrina* cover was highest at the middle reef shelf (11.5%), lower at the shallow boulder sites (10.2%) and lowest at the deep reef slope (7.6%).

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.

Table 5. Summary of three-way analysis of variance (ANOVA) of mean *Pocillopora meandrina* abundance (percent cover) for surveys conducted off NELHA from 1992 - 2008. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

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

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.

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 present survey in October 2008. 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, and by OI in 2005 - 2007. Mean values were significantly higher, however, for the monitoring conducted by MRC between 1997 and 2002.

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	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. Results from the current survey performed in October 2008 are presented below. The data from the 30 complete surveys (May 1992 – January 2007) are used in the subsequent analysis of long-term trends.

METHODS

Surveys to examine the nearshore fish populations were performed using SCUBA between October 27-28, 2008. 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). 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 October 2008 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 Table 7 and Appendix D.

Numerical Abundance and Habitat Distribution

The number of individuals per transect for the October 2008 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 18" Pipe location, deep transect (835). The number of individuals at the other five locations ranged from 137 to 761. The mean number of fish obesrved at the 18" Pipe and 12" Pipe South stations were significantly higher than the means observed at the other four locations. The deep reef slope habitat had the highest mean number of individuals per transect (509), while the middle reef bench habitat (414) and the shallow boulder habitat (315) had lower but not significantly different numbers.

Number of Species

The number of species per transect for the October 2008 survey off NELHA is summarized in Table 6 and Figure 4B. The mean number of species observed per transect ranged from 21.3 at Ho'ona Bay to 35.7 at the 18" Pipe site. The number of species observed at the 18" pipe and 12" Pipe South locations were significantly higher than the number observed at the other four locations. Mean number of species per transect ranged from 26.5 in the shallow boulder habitats to 32.5 in the deep reef slope habitat. There were no significant differences ($p = 0.05$) in number of species observed between habitats.

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 October 2008 survey off NELHA is summarized in Table 6. Mean species diversity ranged from 1.42 at the 18" Pipe station to 2.28 at the 12" Pipe North station, but there were no significant differences between locations ($p = 0.12$). Mean species diversity was not significantly different between habitats ($p = 0.28$), with the shallow boulder habitat (1.92) higher that the reef bench (1.63), and the deep reef slope (1.68).

Table 6. Summary of quantitative fish transects conducted off Natural Energy Laboratory of Hawaii on October 28-29, 2008. 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	184	397	565	406	761	835	408	559	770
Number of species	26	27	34	28	37	42	28	29	35
Diversity	2.35	1.22	1.18	1.68	1.45	1.14	1.61	1.67	1.53
Biomass (g/m^2)	119	84	212	138	288	231	119	147	163

Station	12" Pipe North			NPPE			Ho'ona Bay		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total number	351	356	268	308	273	390	232	137	230
Number of species	26	33	38	26	20	23	25	16	23
Diversity	1.92	2.06	2.86	1.71	1.39	1.65	2.27	1.97	1.72
Biomass (g/m^2)	158	101	128	70	94	92	109	36	60

Table 7. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. Transect locations are shown in Figure 3. Species listed in taxonomic order.

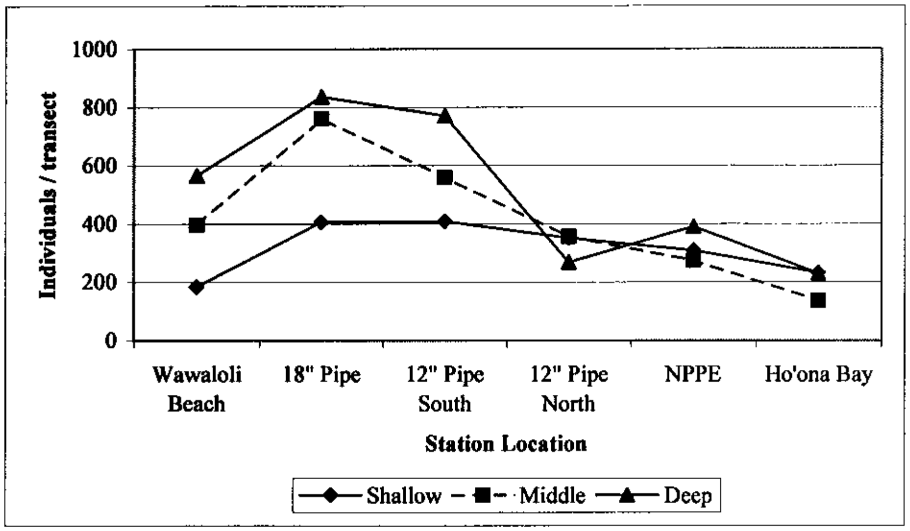
		Wawaloli Beach			18" Pipe			12" Pipe South			12" Pipe North			NPPE			Ho'ona Bay			TOTAL
Family	Species	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Muraenidae	*Gymnothorax flavimarginatus*														1					1
	Gymnothorax meleagris													1			1			2
Synodontidae	*Synodus variegatus*		1																	1
Holocentridae	*Myripristis berndti*											1							4	5
	Neoniphon sammara																		1	1
Aulostomidae	*Aulostomus chinensis*									1									3	4
Fistularidae	*Fistularia petimba*						1					1							1	3
Serranidae	*Cephalopholis argus*			1		1	2			2			1			3			1	11
Cirrhitidae	*Paracirrhites arcatus*	6	16	15	8	18	10		10	26	10	18	14	9	9	6	6	5	1	187
	Paracirrhites fosteri				1	1	1						1	2						6
Carangidae	*Decapterus macarellus*								60											60
	Scombroides lysan							1												1
Lutjanidae	*Alphareus furca*			1			1			1						1				4
Lethirinidae	*Monotaxis grandoculis*					3														3
Mullidae	*Mulloides vanicolensis*											2								2
	Parupeneus bifasciatus	1					1	2				1	1							6
	Parupeneus chrysonemus									1										1
	Parupeneus chyrserydros	1																		1
	Parupeneus multifasciatus			4	1	2				2			1			2	2			14
	Parupeneus porphyreus					1														1
Kyphosidae	*Kyphosus bigibbus*				1															1
Chaetodontidae	*Chaetodon auriga*			2												2				4
	Chaetodon ephippium						1													1
	Chaetodon fremblii										1									1
	Chaetodon kleini			1																1
	Chaetodon lunula					1		1		2	1		2				1			8
	Chaetodon miliaris						4													4
	Chaetodon multicinctus	1	2	4	6	2	7	5	7	9	2	7	7	5	2	14	2	2		84
	Chaetodon ornatissimus	1		2	1					2	2		1			2			3	14
	Chaetodon quadrimaculatus	1	1		6	3	2	6	1		1	2	1	2	3		1			30
	Chaetodon unimaculatus											2								2
	Forcipiger flavissimus				21	2	4	1		11		1	5		5	3	2		4	59
Chaetodontidae	*Forcipiger longirostris*									2										2
	Hemitaurichthys polylepis						2					1								3

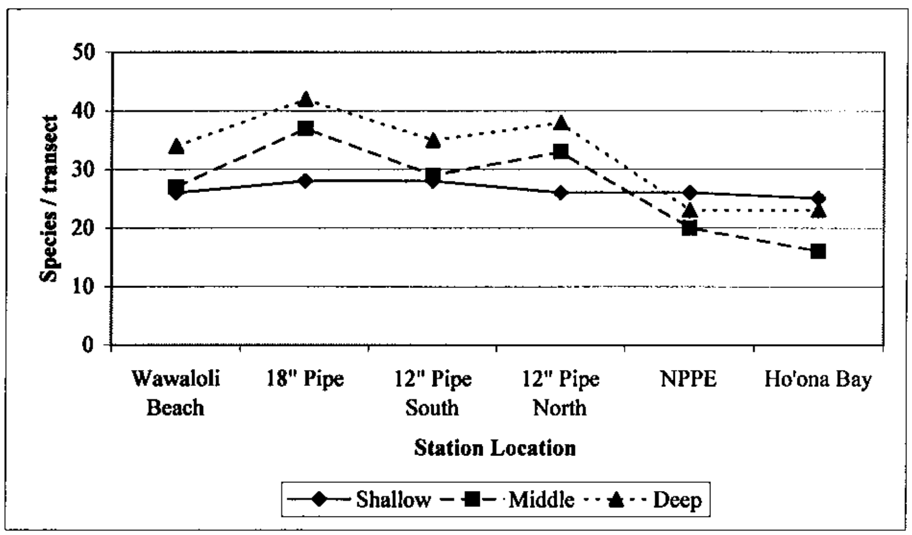
Table 7. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. Transect locations are shown in Figure 3. Species listed in taxonomic order.

Family	Species	Wawaloli Beach			18" Pipe			12" Pipe South			12" Pipe North			NPPE			Ho'ona Bay			TOTAL
		Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Chaetodontidae	*Hemitaurichthys thompsoni*												3							3
Pomacanthidae	*Centropyge potteri*									7		1	3					2	2	15
Pomacentridae	*Abudefduf abdominalis*					12		1										9		22
	Chromis agilis					4	15			500		8	34			208		40	138	947
	Chromis hanui					1				6		1	18							26
	Chromis vanderbilti	52	296	441	255	540	670	260	340	105	170	177	62	185	190	89	81		5	3918
	Dascyllus albisella								1										1	2
	Plectroglyphidodon imparipenis	1	4		2			1						3			1			12
	Plectroglyphidodon johnstonianus	1	1	3		1	5	2	4	1		4	4	2		5	1	1	1	36
	Stegastes fasciolatus	1	2		5	4		1						1			6			20
Labridae	*Anampses chrysocephalus*			1			1													2
	Cheilinus unifasciatus								1	1										2
	Coris gaimard		1	1	1		2			1	2	1								9
	Gomphosus varius			1	6	1	4	5	4	1		3	3	3	1		1	1	1	35
	Halichoeres ornatissimus	5	5	5	7	5	2	3	4	4		2	3	3	7	3	3	2		63
	Labroides phthirophagus		1				1			5		1						3		11
	Macropharyngodon geoffroy													1						1
	Pseudocheilinus evanidus			13									5			2				20
	Pseudocheilinus octotaenia		1	4		1	4			3			1			7				21
	Pseudocheilinus tetrataenia		1	5		7	5		4	1	2	1	4	1	8	1		2		42
	Stenojulis balteata	1	1	2	4		1		2	2	3	1	1				1			19
	Thalassoma duperrey	26	8	12	29	11	8	19	18	13	14	9	6	9	5	3	16	1		207
	Thalassoma purpureum										1									1
Scaridae	*Calotomus carolinus*						1													1
	Scarus psittacus	6	1	1							1									9
	Scarus rubroviolaceus					1	1						1							3
	Scarus sordidus			1	3	6	3	1	2	9	5	11	2	8		1	1		9	62
	Scarus sp.juvenile	6					4	6	5		20	6		1	1		9			58
Blennidae	*Cirripectes vanderbilti*		1			1														2
	Plagiotremus goslinei	2	2	1	2			1						1						9
Zanclidae	*Zanclus cornutus*	2			2	3	1	2	2			4	3	2	1				1	23
Acanthuridae	*Acanthurus achilles*					1														1
	Acanthurus blochii					14	3													17
	Acanthurus guttatus										3									3

Table 7. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. 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	
Acanthuridae	*Acanthurus leucoparieus*	13						2			5						26			46
	Acanthurus nigricans										2	1								3
	Acanthurus nigrofuscus					15	1											14	7	37
	Acanthurus nigroris	28	30	13	24	32	22	31	37	8	29	25	14	27	14	7	23			364
	Acanthurus olivaceus	2	3	15		3	1		1	14	3	2	2		1		1			48
	Acanthurus thompsoni						1		8	1									4	14
	Acanthurus triostegus					2											1			3
	Acanthurus xanthopterus			1																1
	Ctenochaetus hawaiiensis							2												2
	Ctenochaetus strigosus		7	2	4	23	13	15	15	11	13	21	14	18	2	9	31	42	23	263
	Naso brevirostris			1			6													7
	Naso hexacanthus								3				19							22
	Naso lituratus				2	2	1	2	5	1		1	3	1	2	2		1	3	26
	Naso unicornis		2								1									3
	Zebrasoma flavescens	21	3	2		33	14	19	16	12	56	38	18	17	14	18	7	11	12	311
	Zebrasoma veliferum				2															2
Balistidae	*Melichthys niger*	1		2	3			1						1			5			13
	Melichthys vidua			1					1		1		1							4
	Sufflamen bursa	1	1	1	3	2	2	3		1	2	1	4	3		1			3	28
	Sufflamen fraenatus			1																1
	Xanthichthys auromarginatus						3								1					4
Monacanthidae	*Cantherhines dumerilii*	2			1										2					5
	Catherhines sanwichiensis	1							1	1										3
	Pervagor aspricaudus								3											3
Ostraciidae	*Ostracion memeagris*					1					1			1						3
Tetraodontidae	*Arothron meleagris*	1							1											2
	Canthigaster jactator								2	3										5





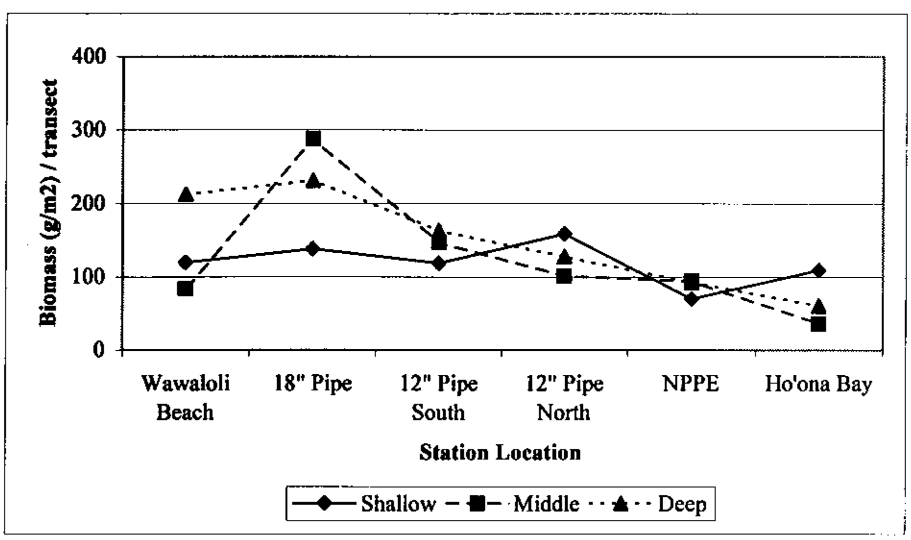


Figure 4. Plots of A: numerical abundance: B: number of species and C: biomass (g/m2) per transect for fish surveys conducted off NELHA in October 2008. Station locations are shown in Figure 3.

Biomass

The distribution of fish biomass per transect for the October 2008 survey off NELHA is summarized in Table 6 and presented in Figure 4C. There were significant differences betweem mean biomass per transect for locations ($p = 0.40$) but not for habitats ($p = 0.57$). Mean biomass was highest at the 18" Pipe site (219 g/m^2); differences between other locations were not significant. Mean biomass was not significantly different between habitats, but was highest in the deep reef slope habitat (147 g/m^2) and lowest in the shallow boulder habitat (118 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, 30 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 October 2008, 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 October 2008 are presented in Appendix D.2 – D.4, 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. Since in most cases 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 8 – 10, 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 January 2007.

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 8. 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 9. 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 10. 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 8. 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						f	g	h	i	j	k
Oct-92	341.2				d	e	f	g	h	i	j	
May-93	295.3							g	h	i	j	k
Dec-93	389.4	a	b	c	d	e	f	g				
May-94	351.6			c	d	e	f	g	h	i	j	
Jun-94	359.1	a	b	c	d	e	f	g	h	i		
Oct-94	379.7	a	b	c	d	e	f	g	h			
Mar-95	278.9									i	j	k
Jun-95	477.2	a	b									
Nov-95	241.2											k
Jun-96	297.2							g	h	i	j	k
Dec-96	284.6								h	i	j	k
May-97	302.4							g	h	i	j	k
Dec-97	473.7	a	b	c								
Jun-98	301.7							g	h	i	j	k
Nov-98	510.6	a										
May-99	320.6					e	f	g	h	i	j	
Dec-99	352.3		b	c	d	e	f	g	h	i		
Jun-00	313.6						f	g	h	i	j	k
Nov-00	452.0	a	b	c	d	e	f					
May-01	359.5	a	b	c	d	e	f	g	h			
Nov-01	286.3							g	h	i	j	k
May-02	364.3	a	b	c	d	e	f	g	h			
Jul-05	249.6										j	k
Nov-05	376.8	a	b	c	d	e	f	g	h			
Jul-06	465.1	a	b	c	d							
Jan-07	345.2			c	d	e	f	g	h	i	j	
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				

Location	Mean			
Wawaloli	283.1			c
18-inch Pipe	457.1	a		
12-inch South	419.9		b	
12-inch North	305.9			c
NPPE Site	318.1			c
Ho'ona Bay	324.2			c

Biotope	Mean		
Shallow	335.2		b
Middle	330.9		b
Deep	388.0	a	

Table 9. 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	
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 10. 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			

NELHA Biota Monitoring
Summary Data

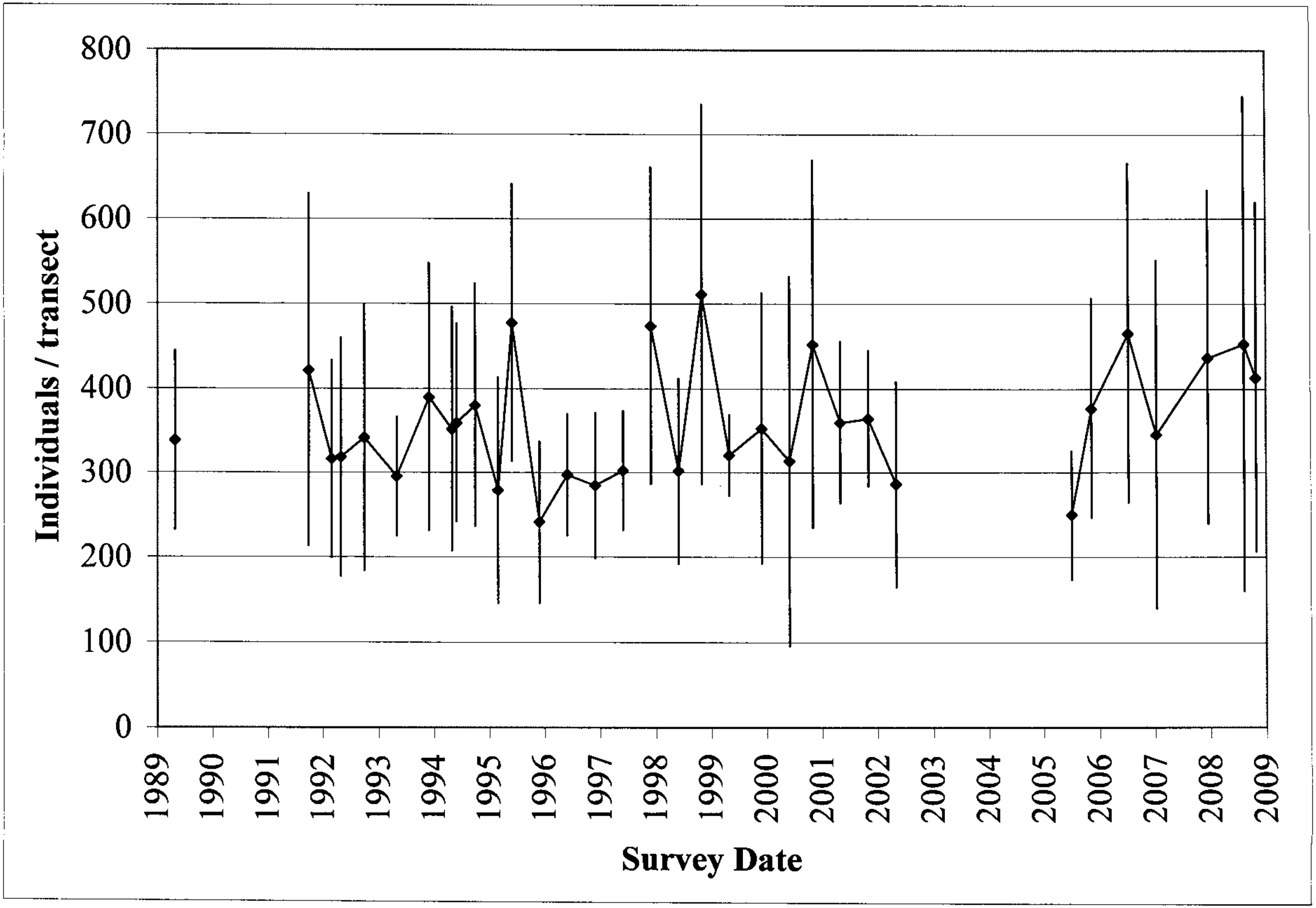


Figure 5. Plot of mean number of individuals (with standard deviation) per transect for each survey from 1989 through 2008 off NELHA.

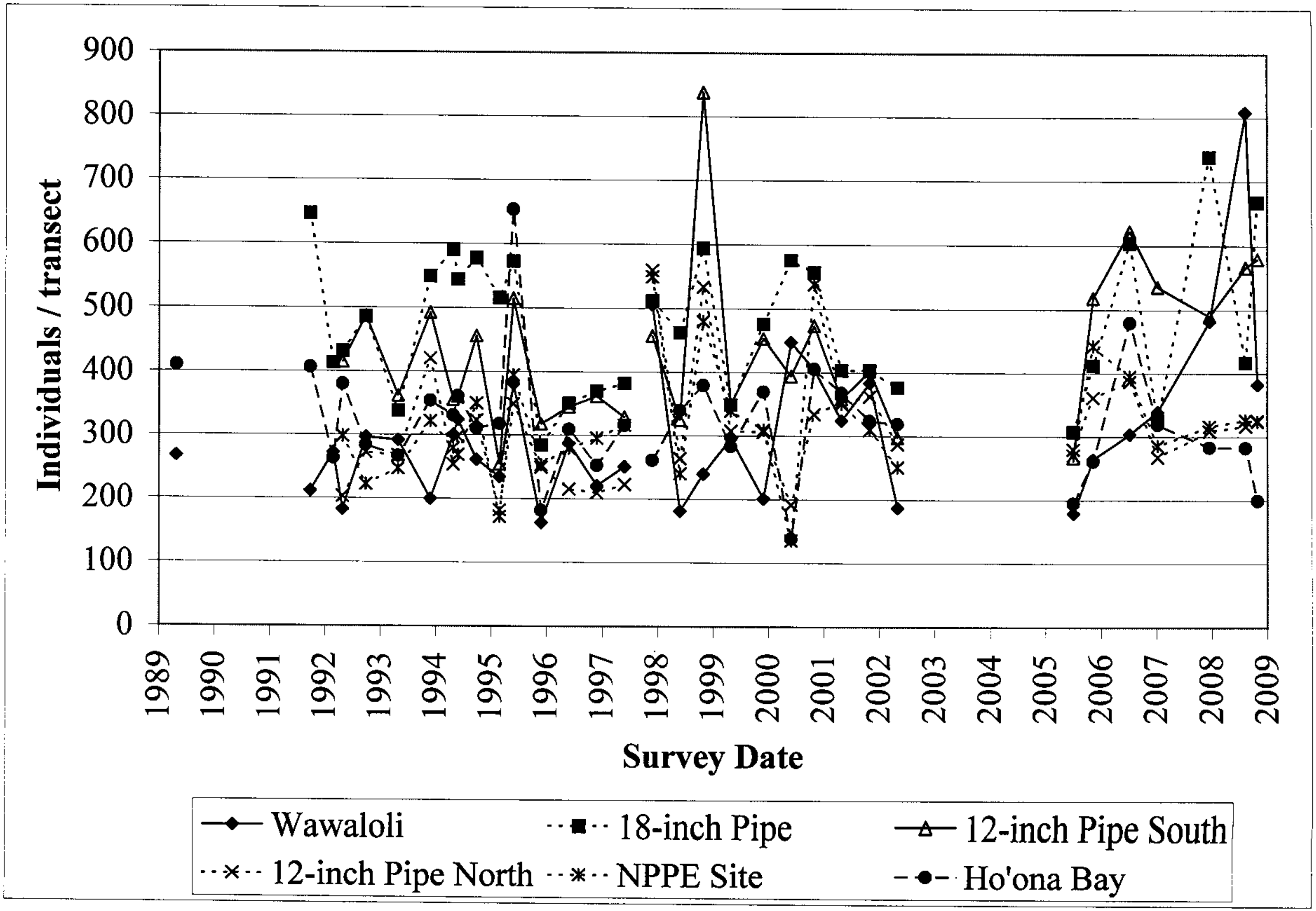


Figure 6. Plot of mean number of individuals per transect across the three biotopes at each of six survey locations off NELHA between 1989 and 2008.

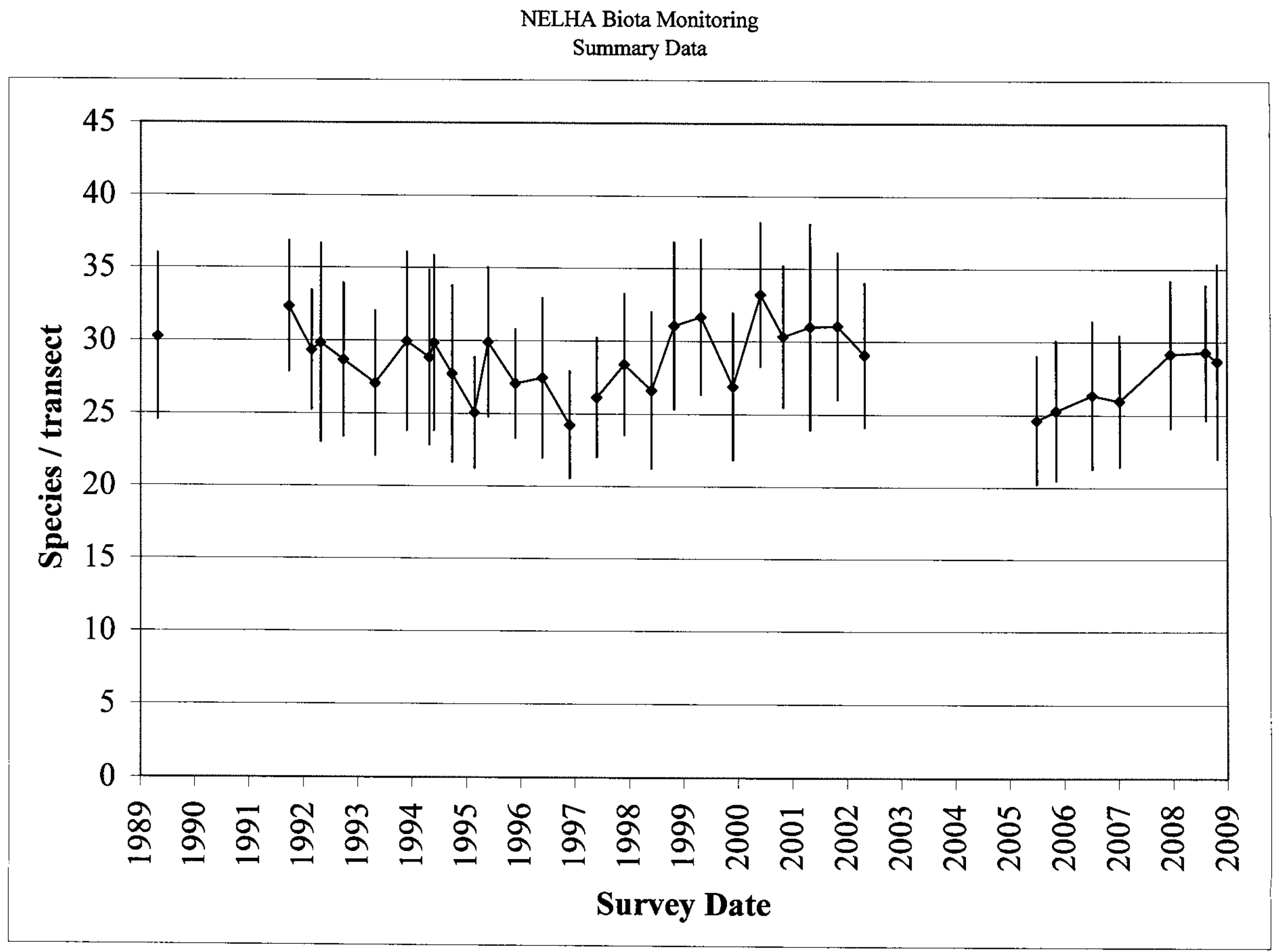


Figure 7. Plot of mean number of species (with standard deviation) per transect for each survey off the NELHA site from 1989 through 2008.

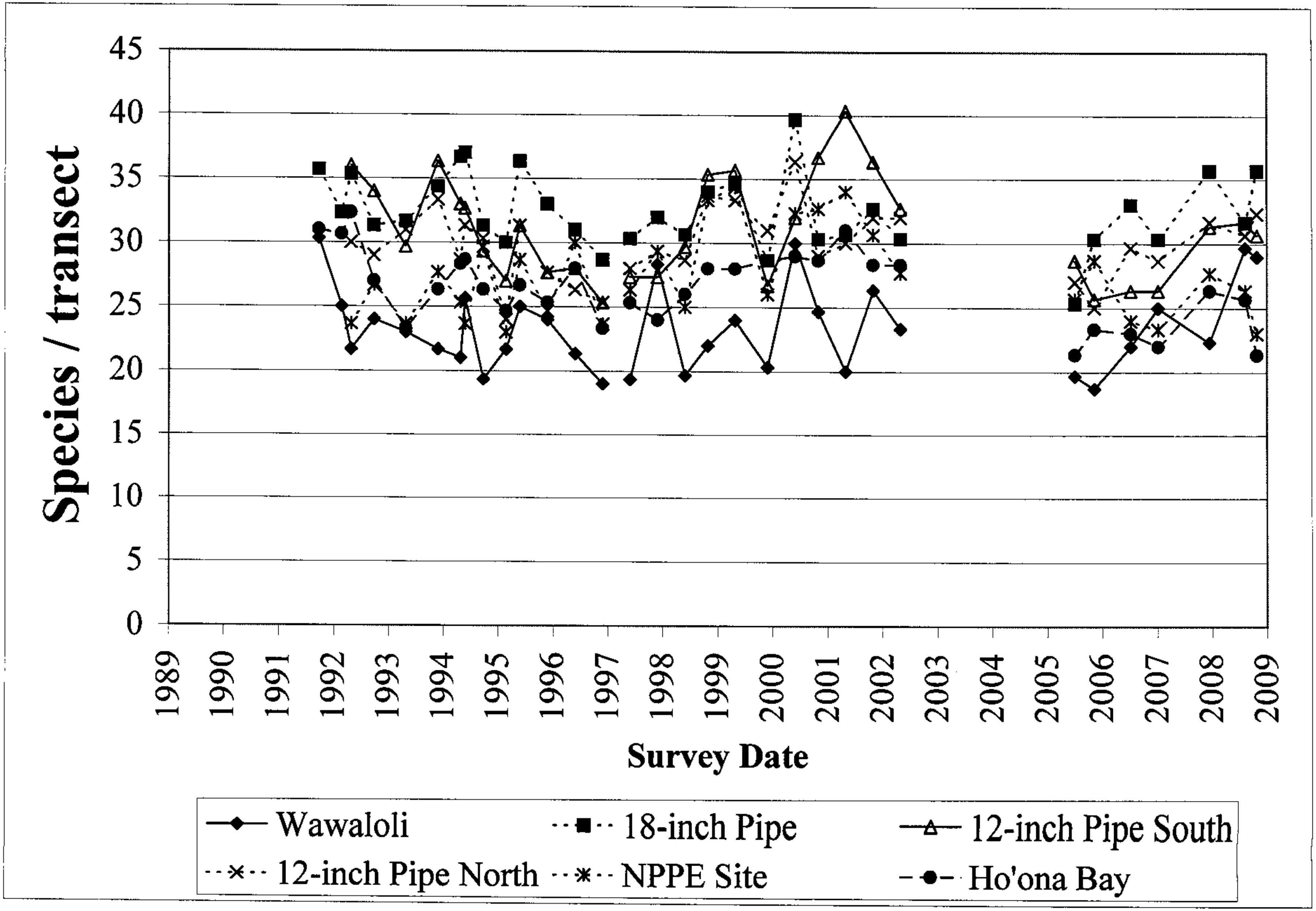


Figure 8. Plot of mean number of species per transect across the three biotopes at each of six survey locations off NELHA between 1989 and 2008.

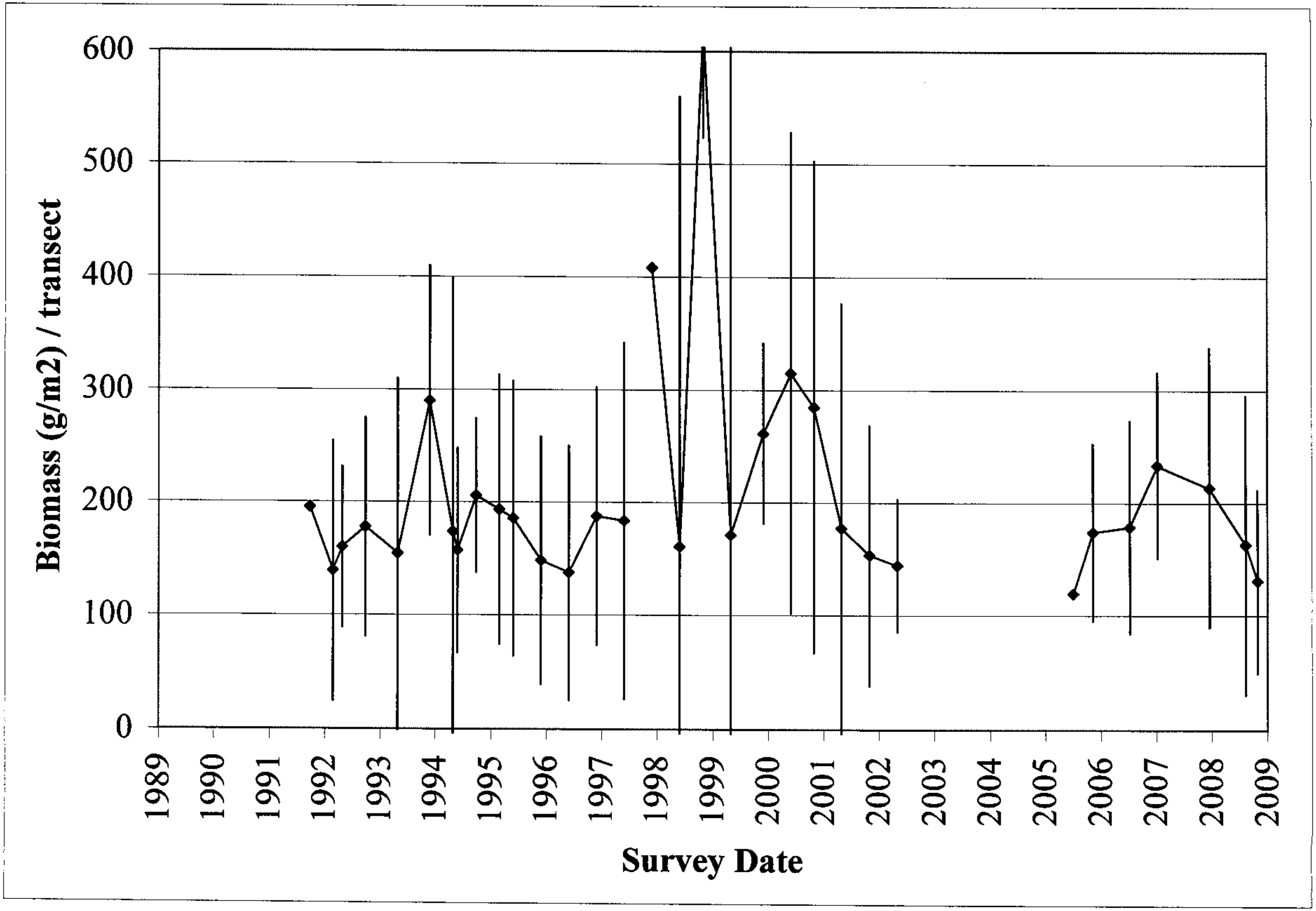


Figure 9. Plot of mean (standard deviation) biomass per transect for each survey off the NELHA site from 1992 through 2008.

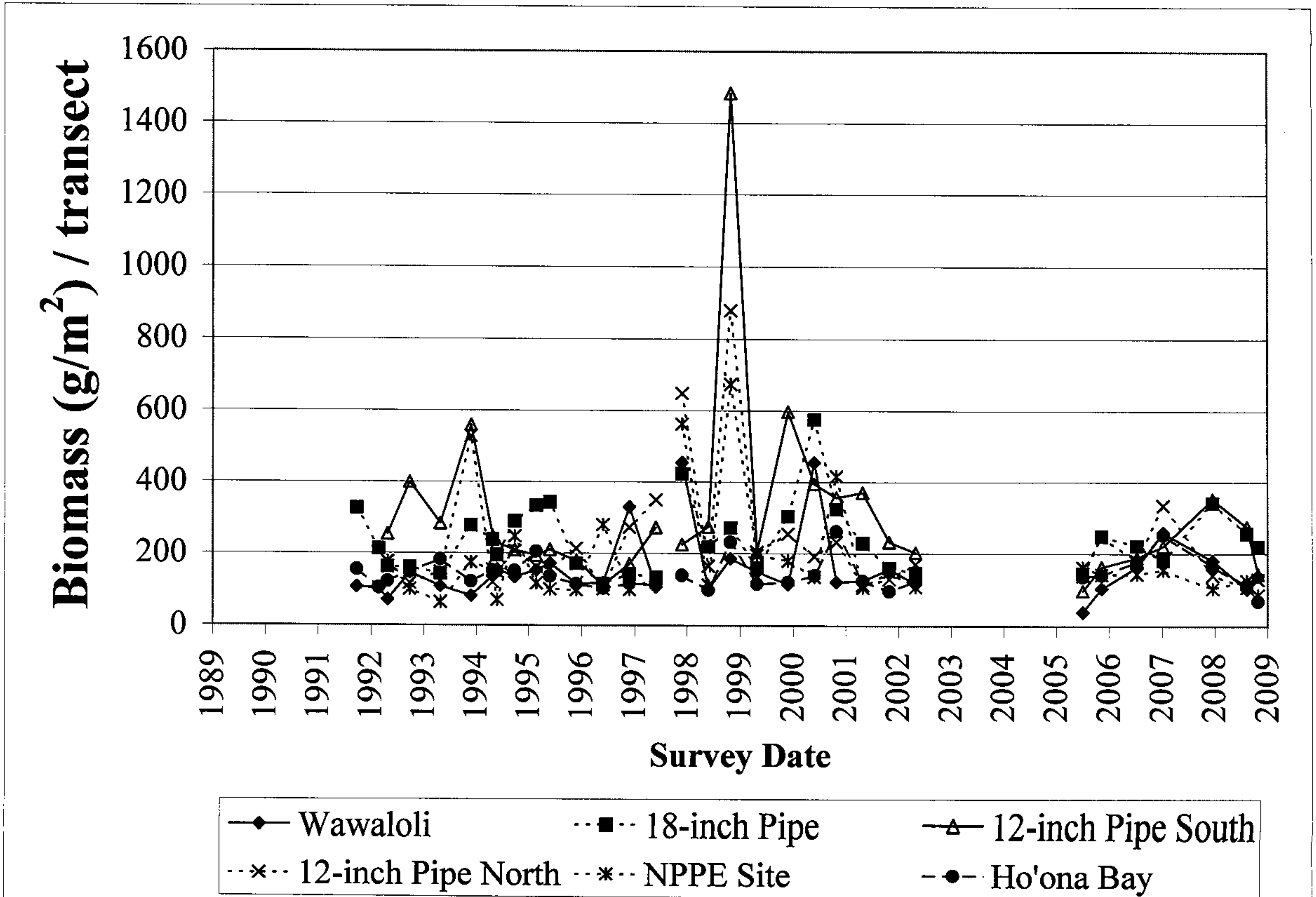


Figure 10. Plot of the estimated biomass (g/m2) on transects across the three biotopes at each of six survey locations off NELHA between 1989 and 2008.

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
	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

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

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
N-1	*Melania* (mean)	30	38	53	43	0	0	0	4	0
	Theodoxus cariosa	2	9	1	3	0	1	0	0	0
	Halocaridina rubra	0	0	0	0	0	0	0	100	200+
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0
	Palaemon debilis	0	0	0	0	0	0	0	0	0
	Metopograpsus	6	5	1	1	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	-	-	-
N-2	*Melania*	66	72	0	0	0	0	0	3	0
	Halocaridina rubra	4	5	0	0	0	0	0	10	40
	Poecilia	x	x	x	x	x	x	-	-	-
N-3	*Melania* (mean)	25	17	60	35	2	0	0	2	0
	Theodoxus cariosa	0	0	4	0	0	0	0	0	0
	Halocaridina rubra (mean)	0	0	0	0	0	0	0	22	200+
	Metabataeus lohena	0	0	0	0	2	0	0	0	0
	Palaemon debilis	0	0	0	0	0	0	0	0	0
	Macrobrachium lar	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
	Halocaridina rubra (mean)	0	0	0	0	40	0		20	100+
	Metabataeus lohena	0	0	0	0	10	0		0	0
	Macrobrachium grandimanus	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
	Theodoxus cariosa	0	0	3	0	0	0	0	0	0
	Halocaridina rubra	8	0	0	0	0	0	0	80	170
	Metabataeus lohena	0	0	0	0	5	0	0	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0
	Metopograpsus	5	6	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	-	-	-

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
S-1	*Halocaridina rubra*	40	35	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	2
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0
	Amphipoda	12	11	0	0	0	0	0	0	0
	Poecilia			X	X	X	X	X	X	X
S-2	*Halocaridina rubra*	35	9	65	150	40	200	0	0	100
	Metabataeus lohena	0	0	2	5	6	0	0	0	0
	Amphipoda	4	3	0	0	0	0	0	0	0
								X	X	
S-3	*Halocaridina rubra*	45	55	85	185	100	100	0	0	200
	Metabataeus lohena	0	0	6	8	2	0	0	0	1
	Amphipoda	6	5	0	0	0	0	0	0	0
								X	X	-
S-4	*Halocaridina rubra*	31	12	0	4	60	0	8	0	5
	Metabataeus lohena	0	0	0	0	3	0	0	0	0
	Amphipoda	4	7	0	0	0	0	0	0	0
	Poecilia			X	X	-	X			-
S-5	*Halocaridina rubra*	0	0	0	0	0	0	3	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0
	Poecilia			X	X	X	X		X	X
S-6	*Halocaridina rubra*	0	12	4	0	1	50	dry	5	20
	Metabataeus lohena	0	0	1	0	0	0		0	1
	Amphipoda	0	2	0	0	0	0		0	0
	Amphipod (white)	0	0	0	0	0	0		0	0
S-7	*Halocaridina rubra*	60	0	0	0	0	0	0	0	0
	Metabataeus lohena	0	0	3	0	0	0	0	0	0
	Macrobrachium grandimanus	1	0	0	0	0	0	0	0	0
	Amphipoda	8	0	0	0	0	0	0	0	0
	Poecilia		X	X		X	X	X	X	X
S-8	*Halocaridina rubra*	81	45	30	115	50	50	0	0	75
	Metabataeus lohena	0	0	3	30	6	1	0	0	15
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0
								X	X	
S-9	*Halocaridina rubra*	20	3	2	0	50	80	0	0	0
	Metabataeus lohena	0	0	0	0	3	0	X	X	0

APPENDIX B

MARINE BENTHIC COMMUNITY SURVEY RESULTS

Appendix B. 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	Jan-95	May-95
WAWALOLI	Shallow	% CORAL	12.5	5.5	5.1	4.7	7.6	2.5	5	6.9	5.8	5.7
		% P.l.	10.8	4.4	2.9	1.9	5.7	1.3	2.8	3.0	3.8	2.9
		% P.c.							0.1			
		% P.m.	1.7	1.0	2.2	2.5	1.7	0.4	0.7	1.8	1.6	1.9
		Sp. #	2	4	2	3	4	4	8	6	5	4
		Sp. Div.	0.39	0.57	0.68	0.87	0.67	1.19	1.41	1.32	0.89	1.1
	Middle	% CORAL	1.7	23.6	10.8	12.1	17.7	8.7	14.9	23.3	15.6	15.9
		% P.l.	1.4	22.2	9.8	11.4	16.5	4.1	13.3	21.7	13.8	14.2
		% 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	0.3	1.1
		Sp. #	4	6	3	3	5	5	3	5	4	3
		Sp. Div.	0.57	0.27	0.37	0.23	0.33	0.99	0.41	0.32	0.47	0.41
	Deep	% CORAL	23.9	2.9	2.5	2.2	5.3	8.5	8.4	8.9	9.9	14.2
		% P.l.	14.7	2.5	2.2	1.5	2.9	3.6	6.3	7.1	7.5	8.2
		% 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	1.2	4.8
		Sp. #	3	3	3	5	4	7	4	3	3	5
		Sp. Div.	0.68	0.42	0.44	1.05	1.15	1.32	0.74	0.62	0.72	0.94
18" PIPE	Shallow	% CORAL	12.5	15.6	19.2	15.8	18.6	10.0	15.5	15.1	15.2	24.5
		% P.l.	5.8	2.8	5.2	6.4	4.9	4.1	6.1	3.8	6.7	7
		% P.c.										
		% P.m.	6.2	10.0	11.2	5.7	11.8	3.9	8.4	6.2	6.8	9.3
		Sp. #	4	7	5	6	3	5	5	5	5	6
		Sp. Div.	0.84	1.01	1	1.24	0.87	1.21	0.95	1.34	1.06	1.44
	Middle	% CORAL	14.3	13	9.1	13.1	11.8	16.0	17.3	13.2	23.0	20.4
		% P.l.	5.2	4.4	3.9	2.6	3.4	4.8	3.7	3.3	12.6	8.6
		% P.c.						0.3		0.5		0.4
		% P.m.	8.5	8.0	3.2	8.9	6.0	5.9	10.7	6.9	6.4	9.0
		Sp. #	6	6	4	5	6	8	5	6	4	5
		Sp. Div.	0.84	0.85	1.15	0.89	1.17	1.56	1.06	1.27	1.04	1.13
	Deep	% CORAL	12.4	7.4	5.5	16.2	10.7	12.9	12..9	8.4	12.5	4.3
		% P.l.	9.2	6.0	4.0	13.3	8.0	11.9	9.3	7.7	11.8	2.4
		% P.c.	2.5	1.3	1.3	1.3	2.4	0.6	2.7	0.4	0.2	0.7
		% P.m.	0.1	0.5	0.1		0.2	0.2		0.3	0.4	0.9
		Sp. #	6	4	4	3	4	5	3	3	4	4
		Sp. Div.	0.58	0.54	0.72	59	0.67	0.36	0.75	0.34	0.27	1.13

Appendix B. 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	Jan-95	May-95
12" PIPE SOUTH	Shallow	% CORAL		8.9	8.7	8.5	6.5	6.5	9.4	12	10.7	5.9
		% P.l.		1.4	1.4	2.0	2.4	1.9	2.5	4.1	2.2	1.3
		% P.c.		0.3				0.1				
		% P.m.		6.9	7.1	6.6	4.1	3.4	5.1	7.5	7.7	4.6
		Sp. #		5	4	2	2	4	4	3	4	2
		Sp. Div.		0.70	0.56	0.54	0.66	1.04	1.10	0.77	0.81	0.53
	Middle	% CORAL		20.2	13.7	21.2	16.8	20.5	18.8	19.2	23.4	17.6
		% P.l.		8.5	7.3	14.3	9.9	12.6	7.8	6.9	12.9	5.1
		% P.c.										
		% P.m.		7.2	3.6	4.6	2.8	5.1	5.2	8.5	6.1	7.5
		Sp. #		6	6	6	5	4	5	4	5	5
		Sp. Div.		1.28	1.28	0.95	1.21	1.01	1.36	1.14	1.17	1.27
	Deep	% CORAL		15.0	17.9	22.2	31.0	22.9	14.3	30.8	28.9	26.1
		% P.l.		11.5	14.1	16.8	19.1	17.9	10.1	18.9	18.3	16.7
		% P.c.		0.5	0.2	0.9	0.7	0.4	1	1.4		0.4
		% P.m.		0.9	1.2	2.3	2.8	1.3	0.8	2.8	4.4	4.6
		Sp. #		6	6	6	9	7	7	6	4	6
		Sp. Div.		0.86	0.78	0.84	1.22	0.83	1.00	1.20	1.04	1.08
12" PIPE NORTH	Shallow	% CORAL		8.3	4.5	7.6	14.8	10.0	10.2	9.6	7.5	15.1
		% P.l.		3.2	2.2	2.5	5.0	3.0	3.3	3.4	4.6	3.5
		% P.c.										
		% P.m.		4.3	2.3	3.1	6.3	3.5	3.9	5.1	1.5	8.1
		Sp. #		7	3	6	6	6	5	4	5	7
		Sp. Div.		1.02	0.78	1.30	1.33	1.58	1.40	1.03	1.13	1.35
	Middle	% CORAL		13.8	12.5	14.1	17.8	20.8	23.7	22.7	19.1	16.2
		% P.l.		9.2	9.9	7.1	7.0	9.2	9.0	10.4	9.3	10.1
		% P.c.		0.4	0.1		0.1					
		% P.m.		3.4	1.3	4.0	3.0	3.5	7.7	5.5	6.8	4.3
		Sp. #		6	6	6	7	7	6	5	4	6
		Sp. Div.		0.95	0.79	1.26	1.48	1.47	1.39	1.18	1.10	1.01
	Deep	% CORAL		17.4	13.2	17.7	27.1	21.8	19.4	22.5	30.4	29.9
		% P.l.		14.1	10.5	13.9	15.3	16.4	14.0	14.4	24.8	23.9
		% P.c.		1.2	0.3	0.8	0.6	0.4	0.2	0.5	0.8	0.5
		% P.m.		0.1	0.5	0.5	3.6	0.8	1.0	2.0	0.8	1.8
		Sp. #		6	4	6	5	5	6	5	5	5
		Sp. Div.		0.70	0.67	0.77	1.13	0.75	0.87	1.07	0.67	0.74

Appendix B. 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	Jan-95	May-95
NPPE	Shallow	% CORAL		18.6	21.7	20.6	25.6	22.9	26.4	33.7	24.5	19.6
		% P.l.		6.9	6.1	5.9	9.4	7.4	8.7	11.0	8.2	6.6
		% P.c.										
		% P.m.		8.8	10.2	11.8	10.7	11.8	15.0	13.6	9.6	8.6
		Sp. #		6	7	6	5	7	5	6	6	5
		Sp. Div.		1.21	1.43	1.13	1.25	1.25	0.99	1.40	1.45	1.28
	Middle	% CORAL		29.5	33.9	36.6	51.3	44.1	45.3	47.2	51.7	42.1
		% P.l.		10.4	16.6	14.1	18.7	19.3	22.1	23	28.1	26.5
		% P.c.		0.3	0.3	1.6	0.8		2.8	1.6	1.7	0.2
		% P.m.		17.6	15.8	18.8	26.2	22.0	17.0	19.1	19.7	13.2
		Sp. #		6	7	6	7	5	5	6	6	6
		Sp. Div.		0.88	0.9	1.05	1.13	0.95	1.13	1.09	0.98	0.89
	Deep	% CORAL		28.0	38.3	45.5	40.5	47.7	40.5	60.3	58.4	55.1
		% P.l.		23.2	30.1	34.2	32.4	41.1	31.6	47.7	41.7	37.8
		% P.c.		1.9	1.4	3.5	1.4	1.7	3.8	2.1	5.4	7.6
		% P.m.		1.5	3.0	3.8	4.4	2.1	1.0	5.7	5.5	3.8
		Sp. #		6	7	6	6	5	5	6	6	7
		Sp. Div.		0.68	0.83	0.91	0.74	0.56	0.78	0.78	0.96	1.04
HO'ONA BAY	Shallow	% CORAL	15.1	15.1	24.8	12.0	7.5	9.0	6.8	10.9	10.8	11.0
		% P.l.	12.3	10.0	18.3	7.5	4.8	7.2	4.7	6.2	9.1	6.3
		% P.c.		0.2		0.3						
		% P.m.	2.4	4.4	3.9	3.9	1.5	1.1	0.9	2.1	1.7	2.4
		Sp. #	3	4	5	6	3	5	6	3	2	3
		Sp. Div.	0.55	0.79	0.85	0.87	0.90	0.73	1.02	0.98	0.44	0.98
	Middle	% CORAL	42.1	30.8	27.8	30.7	26.0	38.1	18.6	25.7	28.7	23.4
		% P.l.	37.4	25.4	22.1	22.8	21.3	35.2	13.1	23.0	24.9	20.3
		% P.c.	4.1	3.5	5.0	6.8	2.3	2.1	4.1	1.1	3.5	3.0
		% P.m.	0.6	1.7	0.6	1.0	2.3	0.3	1.2		0.1	0.1
		Sp. #	3	4	3	3	4	6	5	4	4	3
		Sp. Div.	0.39	0.58	0.57	0.66	0.61	0.35	0.81	0.44	0.43	0.41
	Deep	% CORAL	34.7	39.1	35.1	45.9	40.8	55.0	41.5	49.0	46.3	43.4
		% P.l.	12.5	20.0	12.7	18.8	18.7	18.9	19.2	20.8	23.3	17.4
		% P.c.	20.0	18.0	21.7	25.3	19.9	35.2	19.1	25.3	21.8	23.3
		% P.m.	0.5	0.3	0.1	0.3	1.1	0.1	0.7	0.4	0.3	0.5
		Sp. #	7	5	5	6	4	5	7	5	6	6
		Sp. Div.	0.93	0.83	0.76	0.86	0.90	0.74	1.02	0.92	0.82	0.95

Appendix B. 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-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99	Dec-99	Jun-00
WAWALOLI	Shallow	% CORAL	9.4	9.5	5.9	12.7	24.3	30.2	19.4	16.9	21.2	24.1
		% P.I.	6.4	5.7	1.4	9.6	11.3	17.8	7.6	8.1	10.9	12.3
		% P.c.								0.6		
		% P.m.	2.6	2.7	4.2	2.8	12.5	9.9	11.0	5.3	9.4	9.5
		Sp. #	5	6	5	6	4	4	4	6	3	5
		Sp. Div.	0.81	1.06	0.76	0.65	0.79	0.93	0.85	1.27	0.84	1.01
	Middle	% CORAL	20.5	13.2	12.4	19.3	32.0	37.9	35.5	23.9	45.9	26.3
		% P.I.	17.9	10	10.2	16.1	20.6	21.7	16.5	11.4	25.8	13.2
		% P.c.			0.1				0.6	0.3	1.1	
		% P.m.	2.4	1.9	0.6	2.6	7.0	11.8	13.7	9.1	13.1	8.5
		Sp. #	5	6	6	6	4	6	7	5	5	5
		Sp. Div.	0.43	0.85	0.72	0.56	0.98	1.03	1.16	1.13	1.11	1.20
	Deep	% CORAL	10.3	4.6	7.6	13.8	13.9	15.1	32.0	22.7	23.2	29.4
		% P.I.	9.8	1.4	4.9	4.2	7.7	7	19.7	10.4	10.4	13.5
		% P.c.	0.6	0.6	0.8		0.6	1.7	0.9	1.5	0.3	0.6
		% P.m.	0.1	2.5	1.9	9.3	5.3	4.5	10.8	8.9	10.8	11.5
		Sp. #	5	5	3	3	4	5	5	4	4	5
		Sp. Div.	0.26	1.08	0.86	0.7	0.91	1.25	0.85	1.11	0.96	1.15
18" PIPE	Shallow	% CORAL	24.7	19.7	21.6	22.9	35.2	54.5	49.8	36.8	46.4	45.9
		% P.I.	5.3	11.6	10.4	16.6	14.5	21.8	17.7	17.9	11.9	15.1
		% P.c.							0.8			
		% P.m.	13.1	5.5	10.7	3.9	15.7	20.08	26.2	13.8	27.4	27.4
		Sp. #	7	6	5	5	4	5	5	5	6	6
		Sp. Div.	1.28	1.1	0.81	0.85	1.03	1.26	1.05	1.11	1.13	0.96
	Middle	% CORAL	22.9	22.3	19.3	21.7	39.6	53.5	44.9	44.9	49.5	43.2
		% P.I.	5	7.5	7.6	6.9	12.2	15.5	20.0	19.2	8.2	8.4
		% P.c.	0.3	0.1								0.7
		% P.m.	16.2	13.7	10.5	13.1	23.5	25.8	18.9	20.9	38.8	30.7
		Sp. #	7	6	5	6	6	5	5	5	4	7
		Sp. Div.	0.87	0.86	0.92	0.94	1.03	1.22	1.10	1.03	0.67	0.89
	Deep	% CORAL	7.7	7.2	8.2	5.2	18.9	22.0	22.6	12.6	27.0	36.9
		% P.I.	2.5	3.5	2.8	3.3	8.0	7.7	10.6	3.5	2.5	4.6
		% P.c.	0.1	0.3				3.7	1.1	0.1	0.1	
		% P.m.	4.9	0.8	2.8	1.3	9.9	10.4	10.1	8.7	22.6	31.4
		Sp. #	7	5	3	4	3	4	7	5	7	4
		Sp. Div.	0.87	1.13	1.1	1	0.86	1.06	1.02	0.75	0.65	0.50

Appendix B. 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-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99	Dec-99	Jun-00
12" PIPE SOUTH	Shallow	% CORAL	14.1	24.9	25.1	21.1	31.8	15.0	21.6	13.2	21.5	29.6
		% P.l.	6.3	11.7	15.2	12.3	17.3	3.5	7.8	7.5	7.8	9.0
		% P.c.										
		% P.m.	6.6	10.8	9.2	7.5	12.2	7.7		4.7	13.5	19.6
		Sp. #	5	5	4	5	4	6	6	3	3	3
		Sp. Div.	1.01	0.99	0.78	0.9	0.92	1.27	0.93	0.88	0.70	0.75
	Middle	% CORAL	22.6	17	16.9	19.8	42.7	42.2	50.9	36.9	57.5	57.5
		% P.l.	8.6	9.2	6.5	6.8	12.9	15.0	32.9	18.8	30.0	20.4
		% P.c.			0.1			1.4				0.4
		% P.m.	12.8	7.5	9.8	11.7	26.2	20.7		13.1	17.0	26.5
		Sp. #	5	4	5	5	6	5	4	4	6	5
		Sp. Div.	0.9	0.79	0.82	0.91	0.95	1.12	0.77	1.05	1.14	1.18
	Deep	% CORAL	38.6	24	30.4	37.1	50.4	75.6	68.2	36.3	65	65.3
		% P.l.	19.8	9.5	8.9	12.3	15.5	28.9	23.1	15.9	26	20.08
		% P.c.	1.1	1	0.5	0.2	0.5	1	1.1	1.4	0.6	0.7
		% P.m.	14.8	12.6	19.6	22.3	27.3	35.3	35.7	5	30.3	34.5
		Sp. #	6	6	5	6	6	7	6	7	7	8
		Sp. Div.	1.09	1	0.88	0.91	1.17	1.16	1.12	1.41	1.16	1.20
12" PIPE NORTH	Shallow	% CORAL	14.3	10.7	7.8	12.5	35.9	32.0	36.2	27.2	37.1	34.1
		% P.l.	6.6	5.2	2.8	2	9.7	11.9	10.0	6.6	10.9	8.0
		% P.c.						0.2	0.2			
		% P.m.	6.5	3.8	4.3	9.5	22.1	18.7	22.9	20.2	24.1	22.8
		Sp. #	6	5	5	5	3	5	4	4	4	4
		Sp. Div.	1.02	1.19	0.99	0.79	0.90	0.85	0.88	0.64	0.81	0.90
	Middle	% CORAL	15.6	25.6	14.2	20	29.8	45.9	41.5	53.0	33.7	33.2
		% P.l.	9.9	17.5	8.9	13.2	14.8	23.9	22.5	15.7	16.3	20.6
		% P.c.	2.2	0.1		0.3	2.2			1.2	1.2	
		% P.m.	5.2	7.6	4.9	6.4	12.1	16.1	14.4	31.1	12.5	11.1
		Sp. #	4	6	5	6	4	4	4	7	7	5
		Sp. Div.	0.78	0.72	0.79	0.76	0.99	1.04	0.95	1.09	1.19	0.85
	Deep	% CORAL	10.8	17.5	22.6	17.1	40.6	63.6	47.3	58.1	59.8	63.7
		% P.l.	4.2	12.2	13.8	9.5	23.5	32.0	26.6	36.0	32.2	36.2
		% P.c.	0.1	0.5	0.7	0.4	2.3	1.4	1.7	0.9	1.8	2.3
		% P.m.	5.6	3.3	6.1	6.1	7.1	14.6	8.0	13.7	15.4	13.7
		Sp. #	6	5	5	5	6	6	5	5	7	5
		Sp. Div.	1.03	0.89	1.01	0.98	1.22	1.22	1.23	1.03	1.23	1.17

Appendix B. 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-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99	Dec-99	Jun-00
NPPE	Shallow	% CORAL	28.2	13.2	17.5	12.1	62.0	46.7	42.5	47.8	66.8	53.7
		% P.l.	16.3	8.5	10	5.1	33.8	20.5	15.4	19.1	31.9	25.3
		% P.c.	0.6				0.6	0.6				
		% P.m.	9.1	4.1	5.3	5.1	21.2	20.0	16.3	21.8	24.6	22.1
		Sp. #	5	4	6	6	6	7	6	5	6	4
		Sp. Div.	0.98	0.82	1.11	1.21	1.06	1.19	1.37	1.12	1.17	1.05
	Middle	% CORAL	46.4	9.6	20.9	43.8	61.6	75.3	64.8	75.3	85.4	71.3
		% P.l.	27.1	2.3	13.8	26.2	24.9	31.9	27.1	35.6	46.9	39.6
		% P.c.	2.7		0.4	0.3	2.8	1.2	1.3	1.6	1.9	4.5
		% P.m.	11.5	7	5.2	13.8	19.1	33.1	30.4	27.7	30.6	22.8
		Sp. #	8	5	6	5	7	7	6	7	6	5
		Sp. Div.	1.18	0.74	0.96	0.94	1.50	1.17	1.11	1.23	1.04	1.08
	Deep	% CORAL	60.7	22.4	49.3	63.3	83.8	83.9	77.2	79.8	74.7	89.8
		% P.l.	47.1	14.1	23.1	43.5	57.1	55.4	47.7	49.7	48.8	56.3
		% P.c.	3.9	0.8	5.1	2.4	11.1	6.3	14.3	20.5	11.7	14.5
		% P.m.	7	6.2	12.4	16.2	8.3	10.6	8.9	5.3	6.3	9.0
		Sp. #	6	5	6	6	7	7	4	7	7	6
		Sp. Div.	0.79	0.96	1.3	0.82	1.05	1.15	1.06	1.01	1.11	1.17
HO'ONA BAY	Shallow	% CORAL	8.7	14.2	14.4	18.5	17.6	24.0	27.7	15.3	32.2	35.2
		% P.l.	6.6	12.5	13.4	13.9	12.0	16.5	13.5	7.0	15.2	19.0
		% P.c.		0.5					0.2		0.2	
		% P.m.	0.4	0.9	0.8	4.2	4.3	6.8	10.1	8.3	12.7	14.9
		Sp. #	5	6	3	4	5	4	4	2	4	3
		Sp. Div.	0.78	0.53	0.29	0.64	0.86	0.74	1.03	0.69	1.02	0.82
	Middle	% CORAL	40.3	40.5	45.8	59.4	68.0	82.6	64.9	48.0	48.4	44.0
		% P.l.	21.6	23.9	26.9	28.8	46.4	51.0	28.7	28.1	24.2	29.3
		% P.c.	8.4	12	10.8	13.7	18.9	29.4	28.7	12.6	17.8	10.1
		% P.m.	6.2	3.5	4.4	7.6	0.6	1.1	6.7	3.2	5.2	3.6
		Sp. #	7	6	6	7	7	5	5	5	6	6
		Sp. Div.	1.27	1.00	1.16	1.44	0.80	0.79	1.02	1.10	1.06	0.92
	Deep	% CORAL	56.7	57.5	49.7	65.2	77.1	88.9	82.0	83.4	69.5	72.0
		% P.l.	18.2	21.6	17.2	16.9	27.9	30.4	28.3	28.8	27.0	24.6
		% P.c.	36.3	33.1	29.6	458	44.7	54.3	49.4	52.6	38.7	43.8
		% P.m.	1.1	0.7	0.9			0.3	0.2		0.5	
		Sp. #	6	6	6	6	4	6	6	6	6	4
		Sp. Div.	0.82	0.89	0.92	0.76	0.88	0.85	0.88	0.78	0.91	0.85

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

SITE	DEPTH	PARAMETER	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Jul-08	Oct-08
WAWALOLI	Shallow	% CORAL	34.1	32.4	23.5	42.3	25.3	17.7	20.9	28.3	41.2	29.1	21.0
		% P.l.	17.8	15.5	7.5	27.3	17.5	9.9	13.1	18.4	24.9	22.2	16.0
		% P.c.		0.1		0.8			0.2		0.2		
		% P.m.	14.1	14.3	14.3	11.6	6.1	5.0	5.4	5.7	11.0	1.6	3.0
		Sp. #	4	5	5	7	4	4	6	5	6	5	4
		Sp. Div.	0.92	0.94	0.93	0.93	0.82	0.92	1.02	0.85	0.97	0.80	0.77
	Middle	% CORAL	31.4	44.8	33.7	34.7	22	15.7	34.1	23.0	59.1	46.3	34.3
		% P.l.	14.4	14.4	14.3	16.3	13.4	11.2	24.2	11.7	38.9	39.7	29.4
		% P.c.		0.3	0.3	0.3					5.1	0.2	
		% P.m.	12.0	22.1	16.6	14.1	6.6	3.5	5.8	9.3	12.6	4.5	3.5
		Sp. #	4	6	5	6	4	3	4	4	5	4	5
		Sp. Div.	1.08	1.18	0.97	1.12	0.87	0.76	0.85	0.93	0.97	0.51	0.52
	Deep	% CORAL	29.5	28.3	8.5	14.6	22.2	18.6	32.5	19.0	67.4	47.9	13.4
		% P.l.	13.8	15.2	4.9	5.8	16.9	13.3	25.2	12.9	30.7	21.7	9.8
		% P.c.		1.2	0.6	2.6	0.3		0.5	2.1	36.1	26.2	0.3
		% P.m.	13.0	9.9	1.8	4.4	7.7	2.2	5.9	2.7	0.4		3.1
		Sp. #	4	5	5	4	5	4	4	5	4	2	6
		Sp. Div.	0.95	1.07	1.15	1.29	0.69	0.7	0.68	0.96	0.74	0.69	0.73
18" PIPE	Shallow	% CORAL	49.5	46.3	54.7	41.7	37.4	40.3	39.9	47.5	47.8	56.7	43.1
		% P.l.	20.1	16.3	22.9	14.2	18.8	23.7	22.7	29.3	24.7	33.4	29.9
		% P.c.	0.3										
		% P.m.	24.7	29.3	25.2	22.6	11.4	14	14.2	12.4	20.3	19.9	9.8
		Sp. #	7	4	7	4	5	6	3	5	4	5	4
		Sp. Div.	1.04	0.73	1.11	0.97	1.13	0.93	0.88	0.66	0.91	0.89	0.81
	Middle	% CORAL	53.1	59.0	40.1	52.9	23	35.2	28.7	29.8	32.3	57.1	40.9
		% P.l.	12.7	16.7	8.2	21.2	9.5	16.5	13.9	10.8	12.1	27.1	26.6
		% P.c.		0.2									
		% P.m.	32.0	32.6	24.2	23.5	11.5	15.4	12.9	16.5	18.8	18.7	9.9
		Sp. #	7	5	6	5	5	4	5	5	5	5	5
		Sp. Div.	1.11	1.11	1.15	1.12	1	0.96	0.97	0.85	0.86	1.2	0.94
	Deep	% CORAL	40.8	36.4	41.4	31.6	31.9	35.5	32.8	29.8	34.6	35.1	32.8
		% P.l.	5.3	9.6	15.7	16.4	9.7	14.5	11.1	9.1	15.7	15.0	18.1
		% P.c.	0.2		0.4	1.6		0.1	0.3	0.6	0.2	0.2	0.1
		% P.m.	31.2	26.6	22.1	10.9	20.1	18.1	17.4	16.2	14.9	18.5	13.0
		Sp. #	6	3	6	5	3	6	6	6	5	5	5
		Sp. Div.	0.80	0.61	0.99	1.12	0.84	1.0	1.07	1.1	1.07	0.88	0.9

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

SITE	DEPTH	PARAMETER	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Jul-08	Oct-08
12" PIPE SOUTH	Shallow	% CORAL	39.0	51.3	28.7	28.7	14.5	18.1	16.4	22.9	61.1	27.1	23.4
		% P.l.	19.9	23.1	10.8	9.2	8.3	7.9	4.6	10.5	31.7	9.8	15.2
		% P.c.											
		% P.m.	18.1	18.8	15.7	15.4	6.1	6.6	10.2	10.6	25.1	15.8	5.9
		Sp. #	5	6	4	5	3	6	4	4	4	5	5
		Sp. Div.	0.82	1.28	0.93	1.13	0.73	1.22	0.89	0.89	0.94	0.9	0.95
	Middle	% CORAL	56.9	60.9	56.7	52.0	36.4	29.4	33.9	35.5	32.6	60.1	33.1
		% P.l.	15.3	23.3	14.1	20.1	16.7	15.1	19.9	19.6	18.7	24.9	20.1
		% P.c.		0.2									
		% P.m.	37.7	27.1	28.4	24.2	15.3	11.8	11.9	15.0	12.2	20.8	10.1
		Sp. #	5	8	5	6	5	3	5	3	4	5	4
		Sp. Div.	0.86	1.23	1.28	1.19	1.08	0.92	0.91	0.79	0.87	1.25	0.87
	Deep	% CORAL	71.7	76.6	72.2	68	27.5	17.4	29.4	36.4	74.8	75.2	31.9
		% P.l.	30.6	28.6	45	28	9.2	5.8	13.6	11.9	41.4	37.0	12.9
		% P.c.	1.8	5.8	5.3	2.1			0.1		10.7	8.8	
		% P.m.	27	32.1	14.7	24.9	14.7	10.3	14.2	23.5	14.3	15.2	17.4
		Sp. #	7	6	6	7	6	4	5	5	5	6	4
		Sp. Div.	1.32	1.30	1.14	1.32	1.09	0.9	0.91	0.72	1.24	1.44	0.86
12" PIPE NORTH	Shallow	% CORAL	40.5	43.4	41.9	32.0	17.8	36.7	27.5	33.0	26.5	39.2	21.5
		% P.l.	14.9	11.8	16.1	9.2	10.9	17.2	15.3	20.0	12.0	20.3	13.6
		% P.c.				0.1		0.3				0.2	
		% P.m.	22.9	26.4	21.1	18.4	6.1	10.6	6.3	7.7	12.8	12.7	5.7
		Sp. #	5	4	5	7	4	6	6	5	3	5	4
		Sp. Div.	0.93	0.94	1.05	1.07	0.84	1.31	1.28	0.82	0.89	1.1	0.93
	Middle	% CORAL	50.9	40.5	51.0	49.2	26.7	19.1	33.3	35.1	50.8	55.3	35.9
		% P.l.	21.7	16.1	19.1	23.6	14	9.3	16.0	19.0	20.9	27.3	17.1
		% P.c.		0.8	2.2	0.3				0.1		0.3	
		% P.m.	21.5	18.9	21.6	16.2	10	8.4	11.3	9.8	15.1	18.6	13.9
		Sp. #	7	6	8	7	3	4	7	6	6	6	5
		Sp. Div.	1.20	1.17	1.35	1.28	0.94	0.95	1.22	0.90	1.37	1.15	1.07
	Deep	% CORAL	66.6	60.1	60.4	64.8	33.8	19.6	44.3	41.3	72.0	74.8	55.3
		% P.l.	35.4	29.0	27.7	38.1	18.6	11.8	20.4	23.7	46.6	41.5	37.8
		% P.c.	2.8	3.2	1.9	5.6			0.1		4.7	16.2	2.8
		% P.m.	17.8	21.0	14.4	10.8	9.9	6.3	14.8	13	16.2	12	11.2
		Sp. #	6	6	6	6	4	3	6	4	5	5	5
		Sp. Div.	1.19	1.22	1.35	1.24	1.07	0.87	1.28	0.91	0.99	1.17	0.95

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

SITE	DEPTH	PARAMETER	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Jul-08	Oct-08
NPPE	Shallow	% CORAL	37.7	48.1	52.9	45.3	34.5	37	20.5	51.7	41.1	50.6	53.8
		% P.l.	12.6	21.1	28.4	19.7	24	29.2	13.7	39.9	26.3	23.4	40.5
		% P.c.		0.8			0.2				12.7	2.8	0.3
		% P.m.	22.9	24.3	19.8	22.1	3.7	6.7	2.2	7.8		14.8	6.7
		Sp. #	5	5	4	7	6	4	5	6	3	8	5
		Sp. Div.	0.87	0.92	0.98	0.97	1.04	0.62	1.01	0.60	0.80	1.43	0.78
	Middle	% CORAL	77.2	71.7	70.2	59.2	56.8	40.5	43.8	53.6	77.3	75.8	53.0
		% P.l.	33.4	38.0	41.5	28.7	37.5	29.2	31.5	41.2	47.5	40.2	41.3
		% P.c.	2.8	2.4	6.4		1.8		0.1		10.1	4.8	
		% P.m.	35.2	22.6	17.2	22.4	11.5	8.3	9.7	7	11.1	15.9	7.0
		Sp. #	6	7	6	6	5	4	6	4	6	5	5
		Sp. Div.	1.10	1.20	1.13	1.11	1.02	0.8	0.79	0.57	1.19	1.29	0.71
	Deep	% CORAL	77.7	89.6	76.6	90.3	64.5	69	72.1	69.1	88.6	87.5	75.2
		% P.l.	45.5	62.0	41.9	61.1	40.2	54.3	49.9	46.1	65.9	55.5	46.2
		% P.c.	17.2	17.0	10.3	21.4	13.4	7.6	12.7	14.7	16.0	24.5	20.4
		% P.m.	8.2	6.3	15.2	5.1	7.6	6.1	7.0	6.6	5.6	4.7	6.1
		Sp. #	5	5	7	5	5	5	6	5	5	5	5
		Sp. Div.	1.15	0.93	1.29	0.89	1.04	0.72	0.93	0.88	0.77	0.93	0.99
HO'ONA BAY	Shallow	% CORAL	46.9	41.9	43.6	35.2	6.7	16.9	38.5	33.9	34.9	46.2	32.5
		% P.l.	24.2	15.9	22.7	4.4	4.2	12.7	29.2	28.6	26.6	28.1	27.9
		% P.c.											0.5
		% P.m.	17.6	21.2	19.1	30.8	2.5	3.2	8.4	4.2	8.3	15.4	3.6
		Sp. #	5	6	4	2	2	3	4	3	2	4	3
		Sp. Div.	1.03	1.08	0.85	0.38	0.61	0.69	0.64	0.52	0.55	0.86	0.43
	Middle	% CORAL	49.5	30.6	42.1	38.9	21.3	21.6	25.8	46.3	39.1	60.6	62.2
		% P.l.	29.9	16.1	30.3	26.3	16.8	16.4	17.7	35.6	32.6	33.2	33.0
		% P.c.	16.1		2.9	0.9	0.3		2.9	9.5	1.2	21.9	27.3
		% P.m.	2.9	12.0	7.2	11.6	4	4.5	4.2	1.0	4.3	3.6	1.4
		Sp. #	4	4	6	4	4	3	6	6	5	5	5
		Sp. Div.	0.89	0.95	0.88	0.73	0.66	0.65	0.97	0.62	0.61	0.99	0.83
	Deep	% CORAL	65.0	82.9	76.8	86.5	52.4	55.2	71.1	57.7	61.2	59.5	47.6
		% P.l.	38.2	32.9	33.0	39.3	13.8	19.9	15.6	13.6	36.0	35.6	28.3
		% P.c.	22.4	43.8	38.4	39.7	37.7	34.1	53.8	42.3	23.5	22.2	18.6
		% P.m.	1.1		1.6	0.4				0.1	0.2	0.2	0.6
		Sp. #	6	5	6	6	4	3	4	7	5	6	4
		Sp. Div.	0.95	0.97	0.98	1.04	0.65	0.75	0.64	0.59	0.80	0.81	0.75

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 January 2008. 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
Wawaloli	Boulder	*E. mathaei*	36	14	8	11	24	14	20	24	31	26	22	31	27
		H. mammilatus			1		1					2		1	1
		T. gratilla			1							1	1	2	3
		E. diadema													
	Bench	*E. mathaei*	9	40	30	17	34	29	25	31	35	41	35	39	42
		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
		H. mammilatus	1										1	1	1
		T. gratilla		2		1									
		E. diadema													
18" Pipe	Boulder	*E. mathaei*	19	2	4	3	8	4	6	3	2	4	3	5	4
	Bench	*E. mathaei*	8	5	3	11	13	6	14	21	28	24	27	32	35
		E. aciculatus				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
		E. diadema													
		T. gratilla													
12" Pipe S	Boulder	*E. mathaei*		2	3	2	1		1	2	1	2	3	4	2
		E. diadema													
		E. oblongata													
	Bench	*E. mathaei*		15	4	6	11	8	5	3	2	2	2	3	3
	Slope	*E. mathaei*		2	1	1	1	1	1	1	4	1	3	2	1
		E. diadema											1	2	2
		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 January 2008. 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
12" Pipe N	Boulder	*E. mathaei*		3	2	7	4	2	4	3	4	4	2	2	1
	Bench	*E. mathaei*		9	15	7	11	6	6	4	3	2	4	3	2
		E. calimaris													
	Slope	*E. mathaei*		2		1	1	1	4	2	2	3	3	5	3
		E. diadema													
NPPE	Boulder	*E. mathaei*		7	7	7	4	4	3	1	2	5	4	6	2
		E. diadema													
	Bench	*E. mathaei*		1	4	1	1	6	8	3	4	41	27	38	26
		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
		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
		H. mammilatus	7	3	4		1	1	1	1	2	2	2	4	5
		T. gratilla													
		E. aciculatus													
	Slope	*E. mathaei*	7			1	1			1	3	4	2	2	4
		H. mammilatus	4		1	2		1	1	1	1	1	1	3	3
		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 January 2008. Locations of transects are shown in Figure 3.

Location	Site	Species	May-99	Dec-99	May-00	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Oct-08
Wawaloli	Boulder	*E. mathaei*	34	38	29	41	29	32	21	39	38	63	24	29	30
		H. mammilatus	2		2										
		T. gratilla	3						1	14	2	2		2	2
		E. diadema		2	1				1		2		5	1	1
	Bench	*E. mathaei*	31	29	32	26	24	37	26	18	74	40	58	31	22
		H. mammilatus													
		E. calamaris								1					
		E. diadema					1	1	1					2	1
													2		1
	Slope	*E. mathaei*	3	4	2	5	4	4	2	2	8	6	14	6	6
		H. mammilatus	2		2									1	
		T. gratilla	1							13		2			1
		E. diadema			1									2	3
18" Pipe	Boulder	*E. mathaei*	2	5	6	8	11	12	14	9	28	17	26	8	17
	Bench	*E. mathaei*	39	19	32	31	29	19	21	4	13	25	17	22	14
		E. aciculatus	1							1		4			
		E. calimaris								1					
		E. diadema		1	2										2
		T. gratilla								1				1	
	Slope	*E. mathaei*	2	11	4	21	18	13	11	4	1	9	5	15	7
														2	
		T. gratilla								1			1		
12" Pipe S	Boulder	*E. mathaei*	6	5	11	16	21	19	12	8	9	18	7	16	11
														1	
		E. oblongata								1					
	Bench	*E. mathaei*	4	4	8	11	14	15	11	14	4	16	3	16	9
	Slope	*E. mathaei*	1	5	5	8	6	11	9	4	2	5	1	4	5
		E. diadema	3								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 January 2008. Locations of transects are shown in Figure 3.

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

APPENDIX D

MARINE FISH COMMUNITY SURVEY SUMMARY

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. 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	52	296	441	255	540	670	260	340	105	170	177	62	185	190	89	81		5	3918
Chromis agilis					4	15			500		8	34			208		40	138	947
Acanthurus nigroris	28	30	13	24	32	22	31	37	8	29	25	14	27	14	7	23			364
Zebrasoma flavescens	21	3	2		33	14	19	16	12	56	38	18	17	14	18	7	11	12	311
Ctenochaetus strigosus		7	2	4	23	13	15	15	11	13	21	14	18	2	9	31	42	23	263
Thalassoma duperrey	26	8	12	29	11	8	19	18	13	14	9	6	9	5	3	16	1		207
Paracirrhites arcatus	6	16	15	8	18	10		10	26	10	18	14	9	9	6	6	5	1	187
Chaetodon multicinctus	1	2	4	6	2	7	5	7	9	2	7	7	5	2	14	2	2		84
Halichoeres ornatissimus	5	5	5	7	5	2	3	4	4		2	3	3	7	3	3	2		63
Scarus sordidus			1	3	6	3	1	2	9	5	11	2	8		1	1		9	62
Decapterus macarellus								60											60
Forcipiger flavissimus				21	2	4	1		11		1	5		5	3	2		4	59
Scarus sp.juvenile	6					4	6	5		20	6		1	1		9			58
Acanthurus olivaceus	2	3	15		3	1		1	14	3	2	2		1		1			48
Acanthurus leucoparieus	13						2			5						26			46
Pseudocheilinus tetrataenia		1	5		7	5		4	1	2	1	4	1	8	1		2		42
Acanthurus nigrofuscus					15	1											14	7	37
Plectroglyphidodon johnstonianus	1	1	3		1	5	2	4	1		4	4	2		5	1	1	1	36
Gomphosus varius			1	6	1	4	5	4	1		3	3	3	1		1	1	1	35
Chaetodon quadrimaculatus	1	1		6	3	2	6	1		1	2	1	2	3		1			30
Sufflamen bursa	1	1	1	3	2	2	3		1	2	1	4	3		1			3	28
Canthigaster jactator		4	3	3	1	2		2	3			1	1	4		3	1		28
Naso lituratus				2	2	1	2	5	1		1	3	1	2	2		1	3	26
Chromis hanui					1				6		1	18							26
Zanclus cornutus	2			2	3	1	2	2			4	3	2	1				1	23
Abudefduf abdominalis					12		1										9		22
Naso hexacanthus								3				19							22
Pseudocheilinus octotaenia		1	4		1	4			3			1			7				21
Stegastes fasciolatus	1	2		5	4		1						1			6			20
Pseudocheilinus evanidus			13									5			2				20
Stenojulis balteata	1	1	2	4		1		2	2	3	1	1				1			19
Acanthurus blochii					14	3													17
Centropyge potteri									7		1	3					2	2	15
Chaetodon ornatissimus	1		2	1					2	2		1			2			3	14
Parupeneus multifasciatus			4	1	2				2			1			2	2			14
Acanthurus thompsoni						1		8	1									4	14
Melichthys niger	1		2	3			1						1			5			13
Plectroglyphidodon imparipenis	1	4		2			1						3			1			12
Cephalopholis argus			1		1	2			2			1			3			1	11
Labroides phthirophagus		1				1			5		1						3		11
Coris gaimard		1	1	1		2			1	2	1								9
Plagiotremus goslinei	2	2	1	2			1						1						9

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. 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	
Scarus psittacus	6	1	1							1									9
Chaetodon lunula					1		1		2	1		2				1			8
Pervagor aspricaudus								3			1	3							7
Naso brevirostris			1			6													7
Paracirrhites fosteri				1	1	1						1	2						6
Parupeneus bifasciatus	1					1	2				1	1							6
Cheilinus unifasciatus								1	1						1			2	5
Cantherhines dumerilii	2			1										2					5
Myripristis berndti											1							4	5
Alphareus furca			1			1			1						1				4
Melichthys vidua			1					1		1		1							4
Arothron meleagris	1	1					1	1											4
Aulostomus chinensis									1									3	4
Chaetodon auriga			2												2				4
Xanthichthys auromarginatus						3								1					4
Chaetodon miliaris						4													4
Scarus rubroviolaceus					1	1						1							3
Catherhines sanwichiensis	1							1	1										3
Ostracion memeagris					1					1			1						3
Fistularia petimba						1					1							1	3
Hemitaurichthys polylepis						2					1								3
Acanthurus nigricans										2	1								3
Acanthurus triostegus					2											1			3
Naso unicornis		2								1									3
Monotaxis grandoculis					3														3
Hemitaurichthys thompsoni												3							3
Acanthurus guttatus										3									3
Gymnothorax meleagris													1			1			2
Dascyllus albisella								1										1	2
Anampses chrysocephalus			1			1													2
Cirripectes vanderbilti		1			1														2
Mulloides vanicolensis											2								2
Chaetodon unimaculatus											2								2
Forcipiger longirostris									2										2
Ctenochaetus hawaiiensis							2												2
Zebrasoma veliferum				2															2
Gymnothorax flavimarginatus														1					1
Synodus variegatus		1																	1
Neoniphon sammara																		1	1
Scombroides lysan							1												1
Parupeneus chrysonemus									1										1
Kyphosus bigibbus				1															1

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on October 28-29, 2008. 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 ephippium						1													1
Chaetodon fremblii										1									1
Chaetodon kleini			1																1
Macropharyngodon geoffroy													1						1
Calotomus carolinus						1													1
Acanthurus achilles					1														1
Acanthurus xanthopterus			1																1
Sufflamen fraenatus			1																1
Parupeneus chyrserydros	1																		1
Thalassoma purpureum										1									1
Parupeneus porphyreus					1														1

Appendix D.2. Number of individuals counted along 25 m transects within three biotopes (boulders, *Porites lobata* , *Porites compressa*) at six locations off NELHA between 1989 and 2008.

Site	Biotope	Dec-97	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
Wawaloli	Boulder	371	223	248	315	198	673	375	350	514	202	112	197	291	228	464	265	184
	Bench	636	177	295	255	231	424	540	234	339	200	193	241	305	260	327	690	397
	Slope	510	143	176	316	174	246	299	389	298	159	231	353	315	528	655	1470	565
18-inch Pipe	Boulder	471	453	448	376	344	596	314	250	419	280	207	345	591	349	716	476	406
	Bench	598	400	485	321	484	312	336	289	299	172	298	314	521	231	620	274	761
	Slope	465	533	848	349	599	818	1019	671	493	678	416	576	698	397	878	500	835
12-inch Pipe South	Boulder	678	289	654	295	246	359	731	423	493	349	146	434	400	200	401	427	408
	Bench	535	302	937	396	294	549	371	343	324	227	327	493	506	302	341	565	559
	Slope	157	381	922	357	819	274	319	309	391	316	327	627	960	1105	728	707	770
12-inch Pipe North	Boulder	523	231	530	257	338	124	336	305	336	213	240	433	267	294	269	284	351
	Bench	364	260	468	321	301	107	315	415	347	219	302	291	506	179	231	273	356
	Slope	790	300	603	344	279	344	351	338	404	429	297	359	387	329	425	392	268
NPPE Site	Boulder	834	308	660	391	385	150	379	343	350	187	277	271	286	306	412	330	308
	Bench	467	305	425	375	250	93	313	410	186	294	210	478	413	304	249	313	273
	Slope	346	107	355	252	292	162	922	299	393	272	324	578	486	246	287	335	390
Ho'ona Bay	Boulder	252	237	314	258	332	140	385	431	332	277	193	270	385	314	293	280	232
	Bench	269	418	317	322	267	150	323	365	309	356	202	259	221	281	247	192	137
	Slope	261	364	506	270	509	124	508	307	330	323	190	253	833	361	310	375	230
Mean		474	302	511	321	352	314	452	360	364	286	250	376	465	345	436	453	413
Stdev		187	110	225	48	160	218	218	97	81	122	76	130	201	206	198	293	207

Appendix D.2. Number of individuals counted along 25 m transects within three biotopes (boulders, *Porites lobata* , *Porites compressa*) at six locations off NELHA between 1989 and 2008.

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

Appendix D.3. Number of species counted along 25 m transects within three biotopes (boulders, *Porites lobata*, *Porites compressa*) at six locations off NELHA between 1989 and 2007.

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
Wawaloli	Boulder	25	30	25	20	25	22	22	21	22	18	23	24	22	22	20
	Bench	37	33	26	21	19	22	18	17	26	16	23	22	24	18	17
	Slope		28	24	24	28	25	25	25	29	24	19	29	26	24	20
18-inch Pipe	Boulder		39	37	40	40	36	38	38	37	36	30	38	28	24	28
	Bench		32	31	30	28	25	26	36	38	28	27	30	36	30	27
	Slope		36	29	36	26	34	39	36	36	30	33	41	35	39	31
12-inch Pipe South	Boulder				30	30	28	39	34	27	29	32	32	28	31	26
	Bench				42	32	29	33	36	32	24	22	26	28	23	22
	Slope				36	40	32	37	29	39	35	27	36	27	30	28
12-inch Pipe North	Boulder				34	27	25	33	26	35	33	26	28	25	21	23
	Bench				28	30	34	36	33	34	35	24	36	28	30	26
	Slope				28	30	34	31	27	25	23	22	30	30	28	27
NPPE Site	Boulder				31	31	22	29	27	31	35	20	26	23	30	24
	Bench				20	27	27	26	28	23	30	25	30	27	23	20
	Slope				20	22	22	28	21	17	24	24	30	24	37	27
Ho'ona Bay	Boulder	26	24	32	36	25	22	26	33	30	20	27	26	27	25	21
	Bench	33	34	28	30	31	22	27	24	29	30	25	30	26	32	26
	Slope		35	32	31	25	26	26	28	27	29	22	24	23	27	23
Mean		30	32	29	30	29	27	30	29	30	28	25	30	27	27	24
Stdev		6	5	4	7	5	5	6	6	6	6	4	5	4	6	4

Appendix D.3. Number of species counted along 25 m transects within three biotopes (boulders, *Porites lobata*, *Porites compressa*) at six locations off NELHA between 1989 and 2007.

Site	Biotope	Jun-97	Dec-97	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
Wawaloli	Boulder	18	27	18	26	27	20	34	23	20	31	26	17	17	18	23	20	24	26
	Bench	18	29	23	22	18	19	27	24	20	24	24	25	17	20	22	23	26	27
	Slope	22	29	18	18	27	22	29	27	20	24	20	17	22	28	30	24	39	34
18-inch Pipe	Boulder	31	26	36	38	41	34	45	27	28	38	34	26	32	32	29	38	34	28
	Bench	29	32	36	32	31	25	36	31	28	24	24	26	25	33	28	33	27	37
	Slope	31	38	20	32	32	27	38	33	36	36	33	24	34	34	34	36	34	42
12-inch Pipe South	Boulder	29	33	29	36	35	26	30	42	34	33	37	32	25	29	22	27	32	28
	Bench	23	29	27	32	34	21	29	35	45	37	27	25	24	28	28	29	31	29
	Slope	30	20	33	38	38	33	37	33	42	39	34	29	28	22	29	38	32	35
12-inch Pipe North	Boulder	26	33	27	40	32	29	33	25	27	35	27	31	25	31	26	30	31	26
	Bench	26	21	29	32	34	34	38	34	34	34	33	27	26	32	25	32	34	33
	Slope	32	34	30	29	34	30	38	28	29	27	36	23	24	26	35	33	27	38
NPPE Site	Boulder	27	32	30	35	31	29	37	32	37	30	29	27	35	24	18	29	21	26
	Bench	26	30	23	35	39	25	31	30	35	32	30	23	27	20	25	27	26	20
	Slope	26	26	22	30	33	24	29	36	30	30	24	27	24	28	27	27	32	23
Ho'ona Bay	Boulder	23	22	26	25	28	29	27	32	32	32	34	17	23	20	22	28	24	25
	Bench	25	24	27	31	27	22	32	29	26	23	26	26	23	22	23	24	25	16
	Slope	28	26	25	28	29	35	28	25	35	30	25	21	24	27	21	27	28	23
Mean		26	28	27	31	32	27	33	30	31	31	29	25	25	26	26	29	29	29
Stdev		4	5	5	6	5	5	5	5	7	5	5	4	5	5	5	5	5	7

Appendix D.4. Estimated biomass (g/m^2) along 25 m transects within three biotopes (boulders, *Porites lobata*, *Porites compressa*) at six locations off NELHA between 1989 and 2007.

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

Appendix D.4. Estimated biomass (g/m^2) along 25 m transects within three biotopes (boulders, *Porites lobata*, *Porites compressa*) at six locations off NELHA between 1989 and 2007.

Site	Biotope	Dec-97	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
Wawaloli	Boulder	280	144	311	274	100	673	143	115	228	155	30	143	107	314	189	84	119
	Bench	891	76	76	61	91	424	115	148	128	82	48	92	139	114	111	84	84
	Slope	190	78	168	110	151	264	103	108	110	110	37	76	241	346	242	139	212
18-inch Pipe	Boulder	518	307	346	251	400	596	297	227	170	207	199	204	256	194	297	321	138
	Bench	319	308	297	103	239	312	414	185	120	86	139	153	230	163	212	213	288
	Slope	430	37	169	125	270	818	258	274	189	145	95	388	179	187	514	234	231
12-inch Pipe South	Boulder	385	177	1382	281	437	359	578	523	190	227	148	270	227	268	261	251	119
	Bench	211	312	1255	168	361	549	180	373	293	166	68	101	231	246	297	308	147
	Slope	77	331	1809	162	994	274	308	214	213	214	75	116	106	146	497	265	163
12-inch Pipe North	Boulder	1637	178	265	135	183	124	198	116	212	133	226	349	150	352	222	125	158
	Bench	123	114	219	149	238	107	204	93	86	118	96	94	270	149	79	100	101
	Slope	183	200	2152	328	340	344	293	127	89	259	94	298	120	502	120	96	128
NPPE Site	Boulder	912	195	1816	269	148	150	108	161	122	110	330	171	245	231	115	97	70
	Bench	143	93	121	219	122	93	836	81	153	134	89	180	100	83	135	109	94
	Slope	631	47	83	96	267	162	303	73	172	77	65	74	84	149	60	170	92
Ho'ona Bay	Boulder	201	129	201	150	131	140	169	127	111	163	224	143	87	492	296	151	109
	Bench	82	85	94	69	77	150	548	82	74	98	101	188	76	150	90	105	36
	Slope	132	79	398	126	152	124	67	161	100	109	82	90	367	114	106	81	60
Mean		408	161	620	171	261	315	285	177	153	144	119	174	179	233	214	163	131
Stdev		399	97	706	80	213	218	200	115	59	53	79	95	83	124	133	81	63

APPENDIX E

DIGITAL QUADRAT PHOTOS

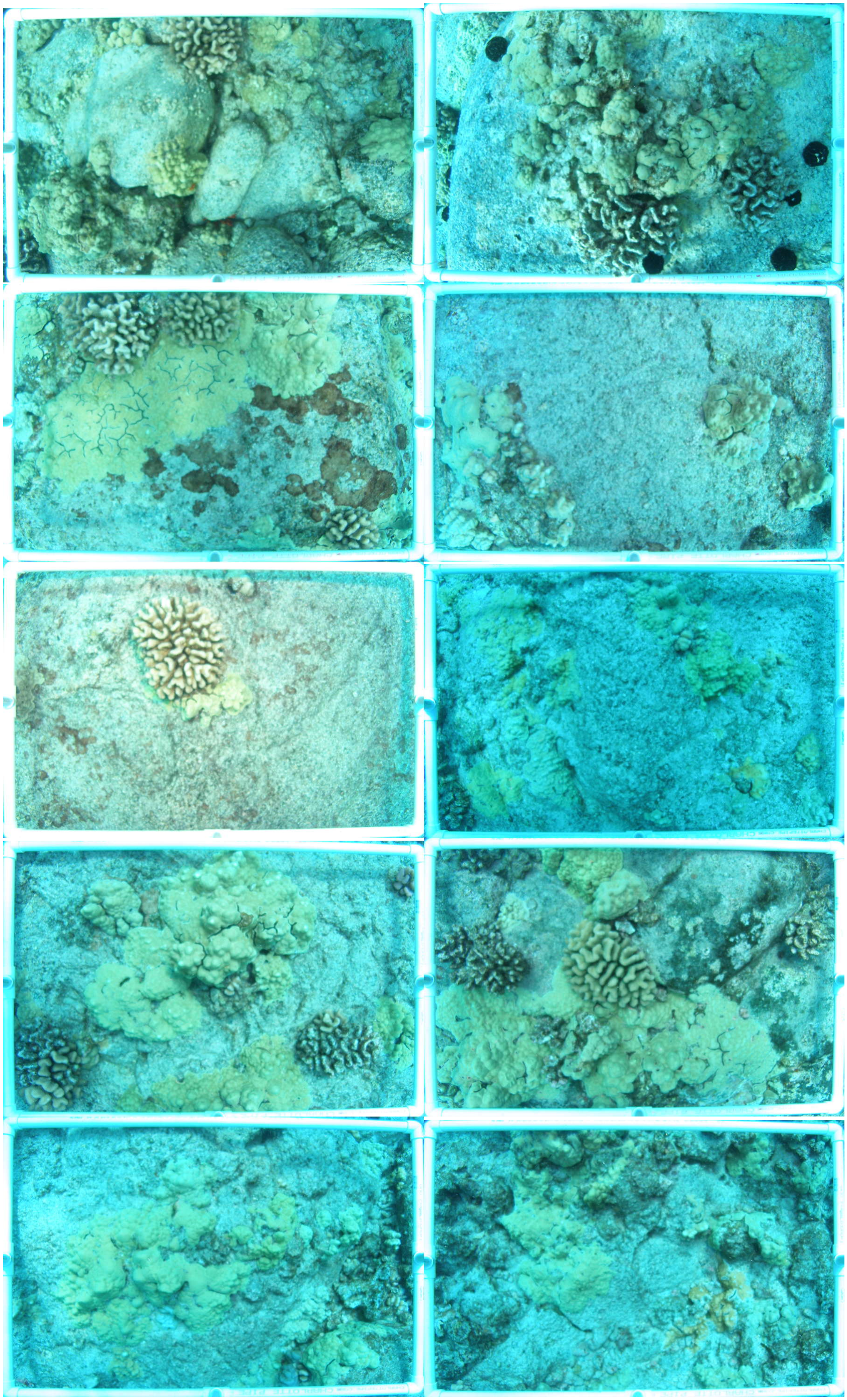

Plate 1. Quadrat photos for Hoona Bay Shallow transect.

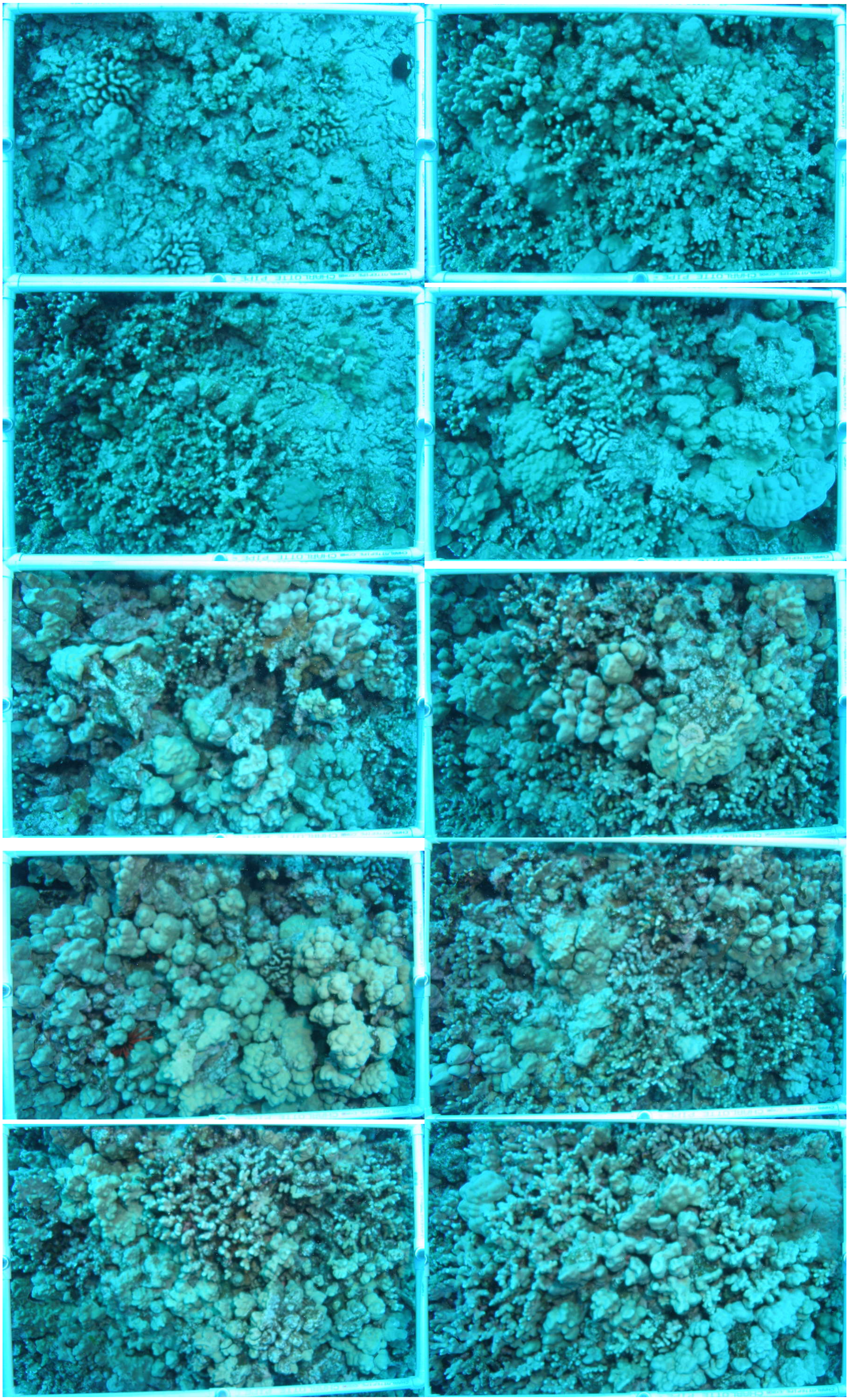

Plate 2. Quadrat photos for Hoona Bay Middle transect.

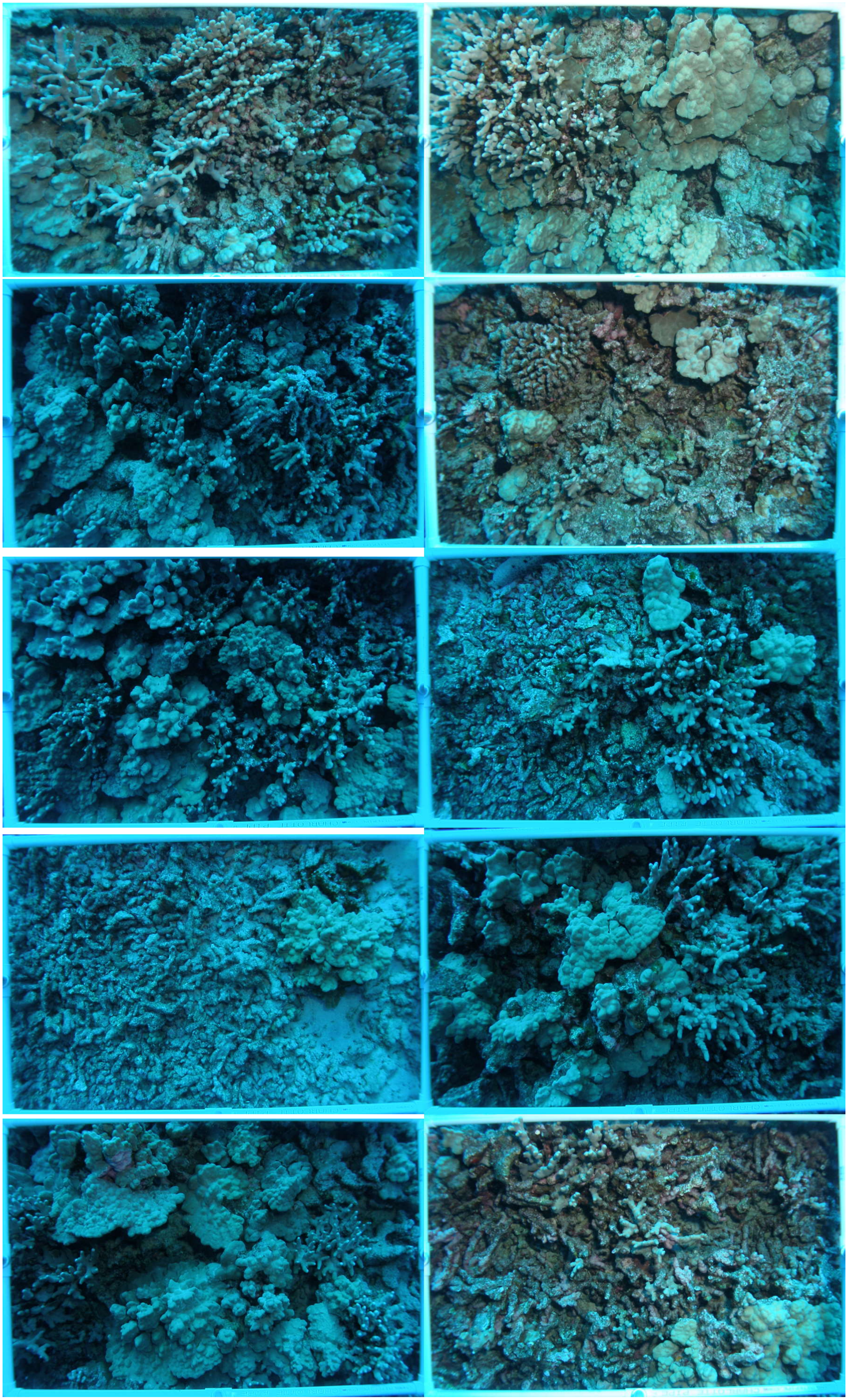

Plate 3. Quadrat photos for Hoona Bay Deep transect.

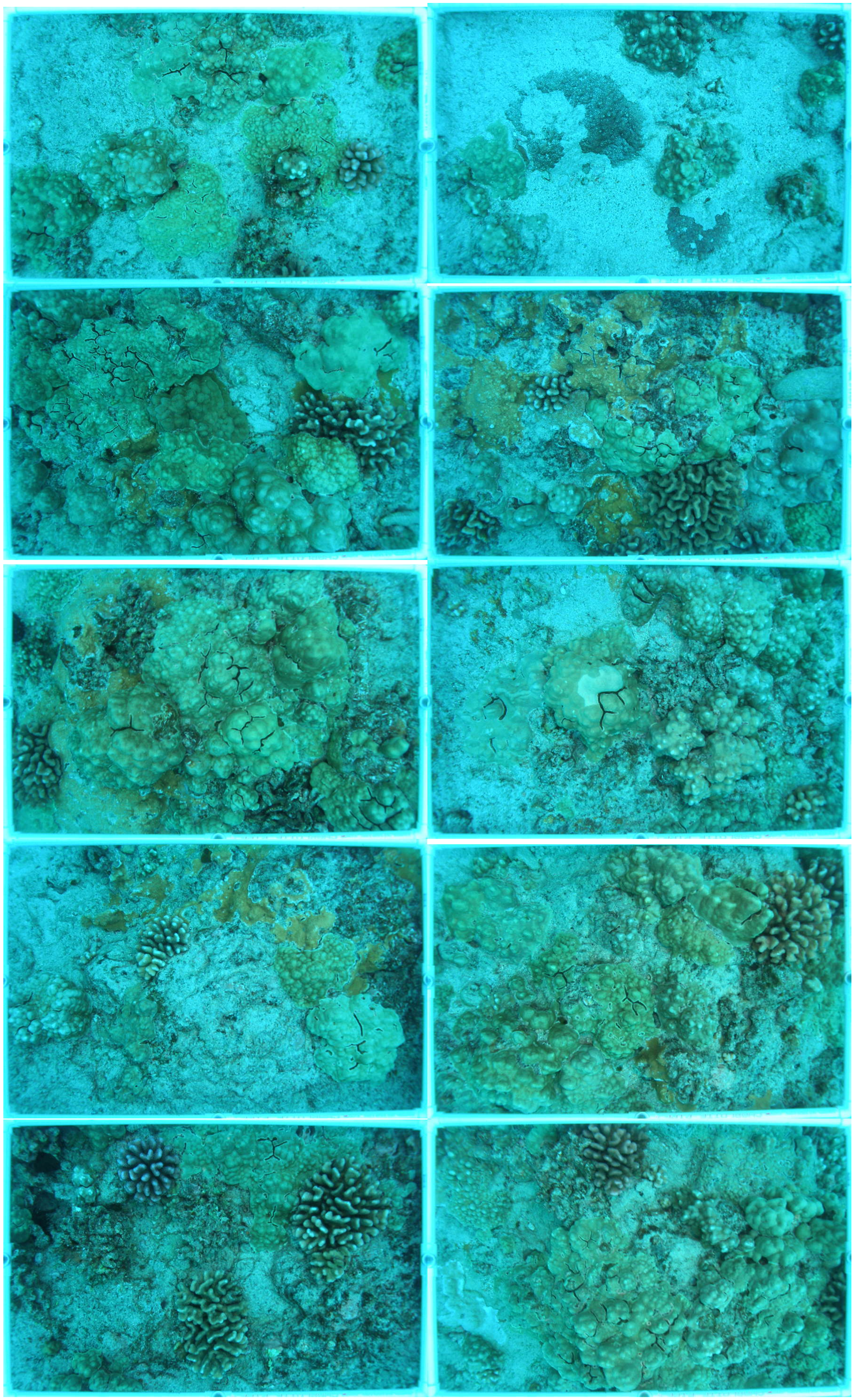

Plate 4. Quadrat photos for NPPE Shallow transect.

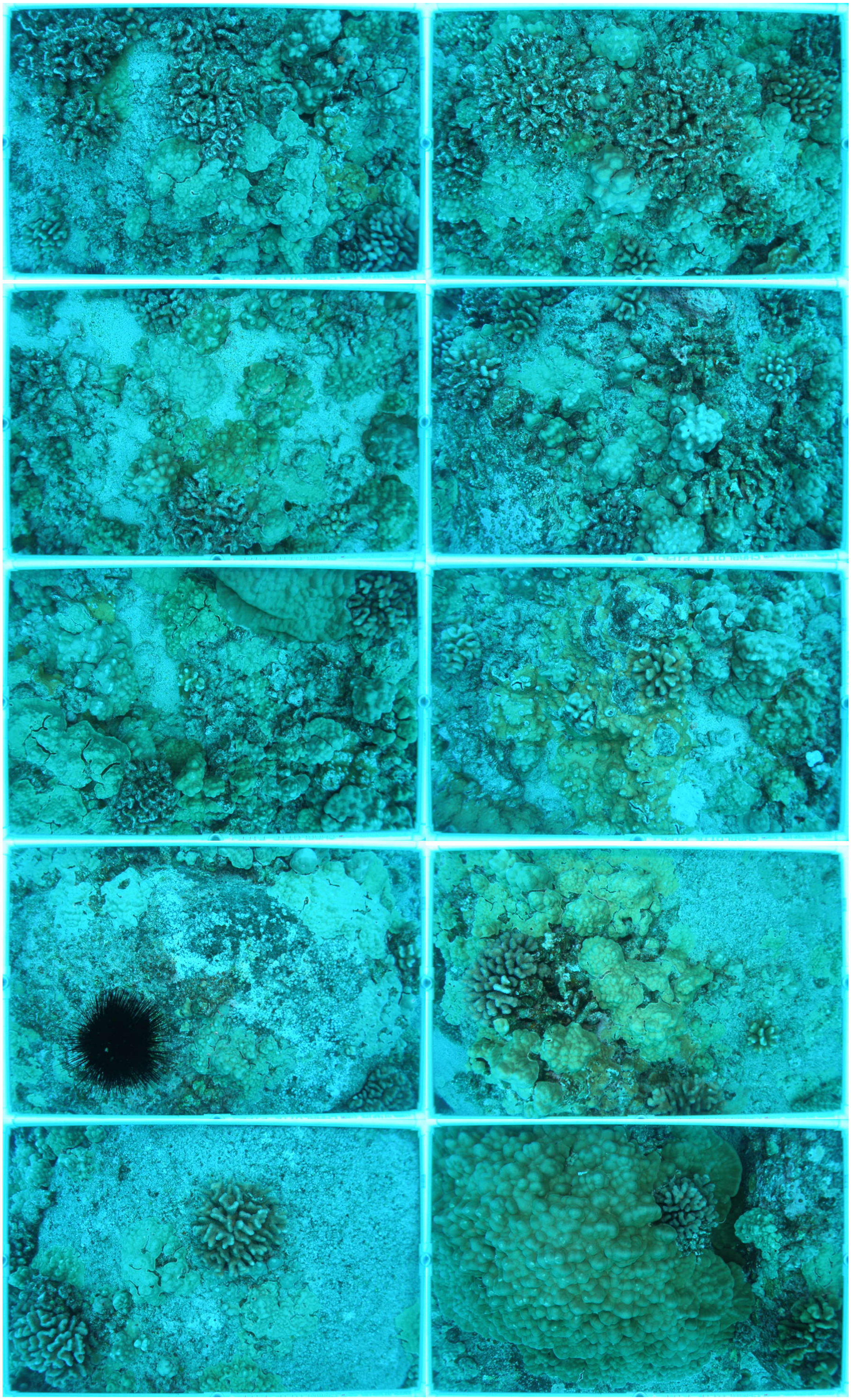

Plate 5. Quadrat photos for NPPE Middle transect.

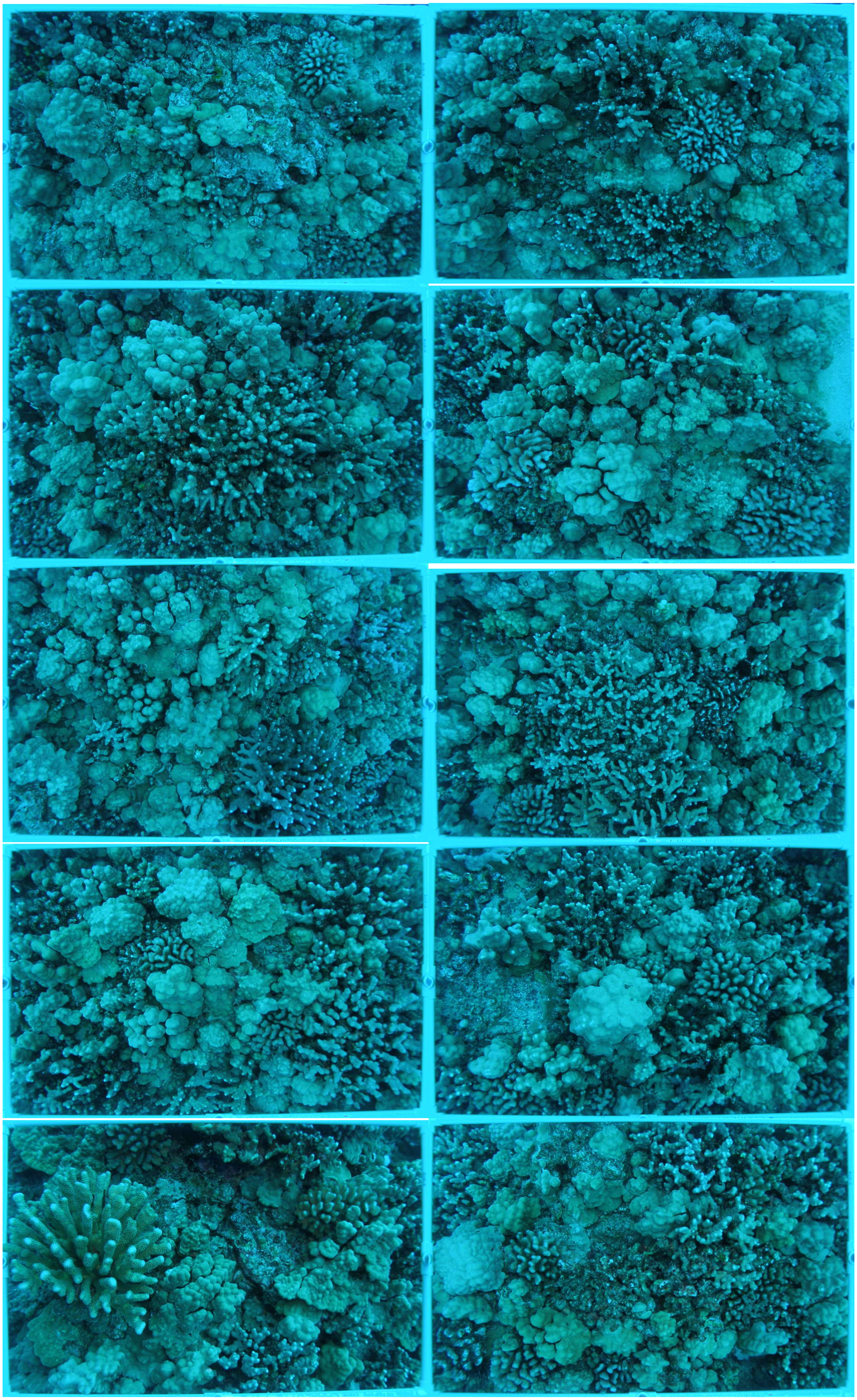

Plate 6. Quadrat photos for NPPE Deep transect.

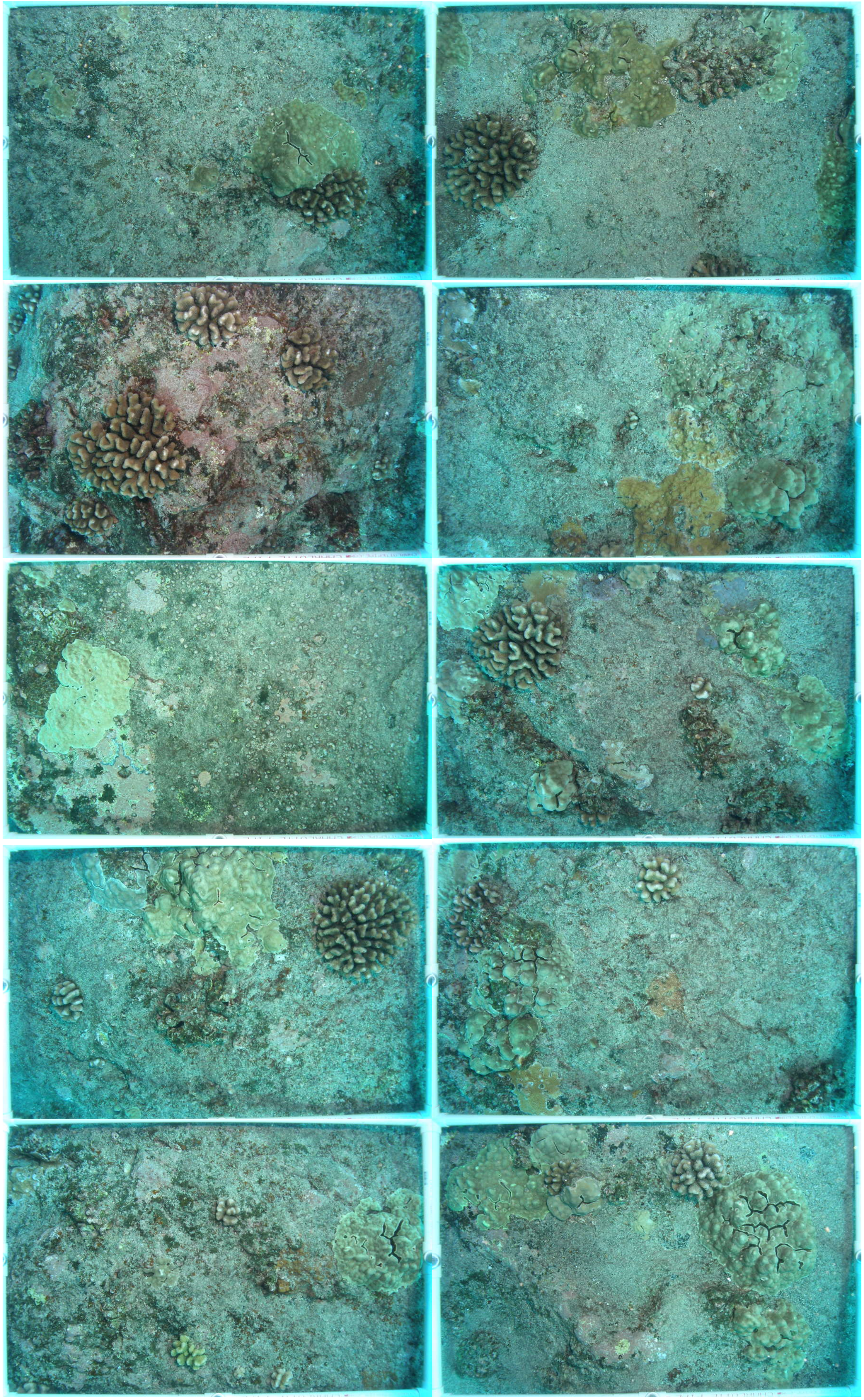

Plate 7. Quadrat photos for 12” Pipe North Shallow transect.

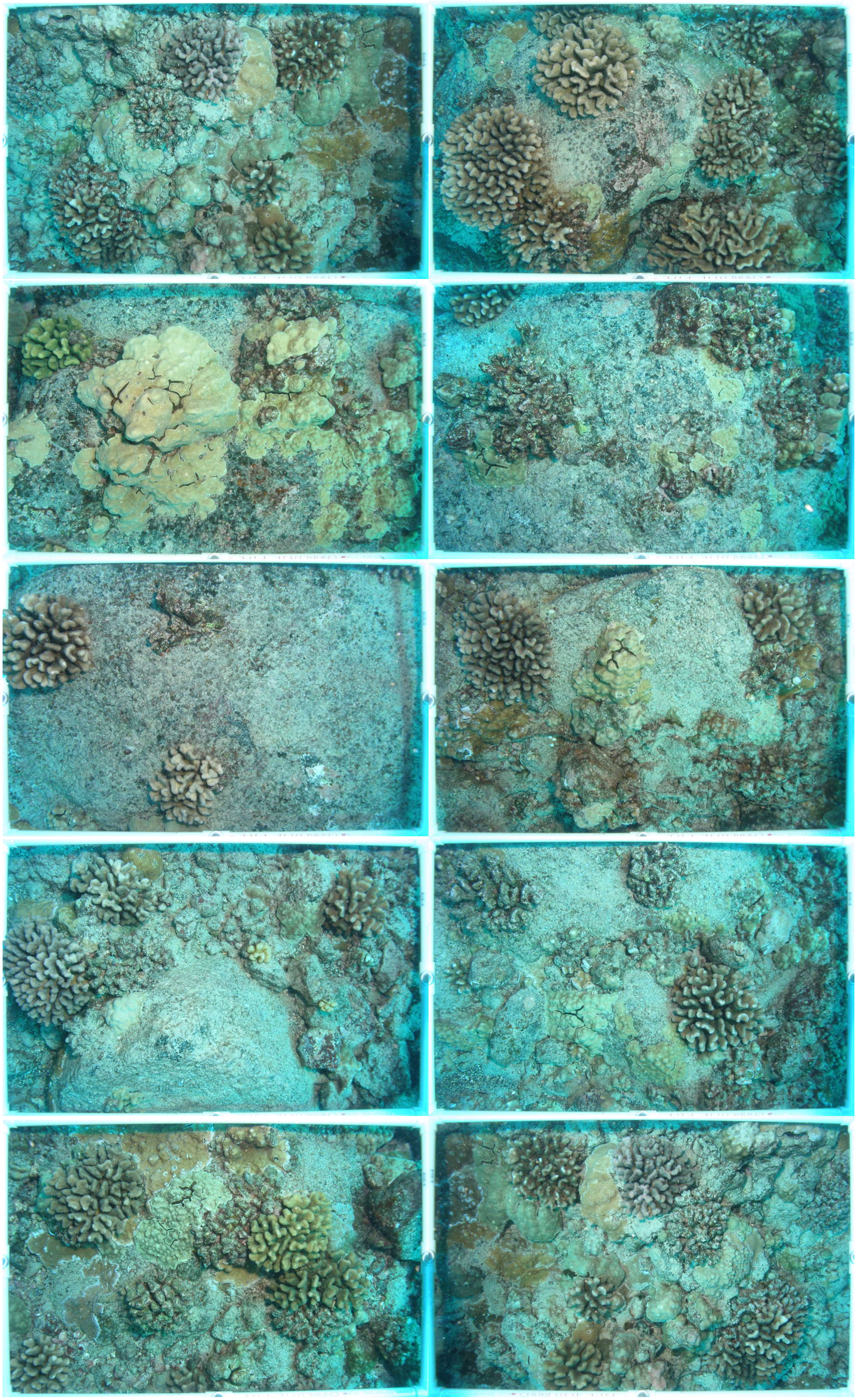

Plate 8. Quadrat photos for 12" Pipe North Middle transect.

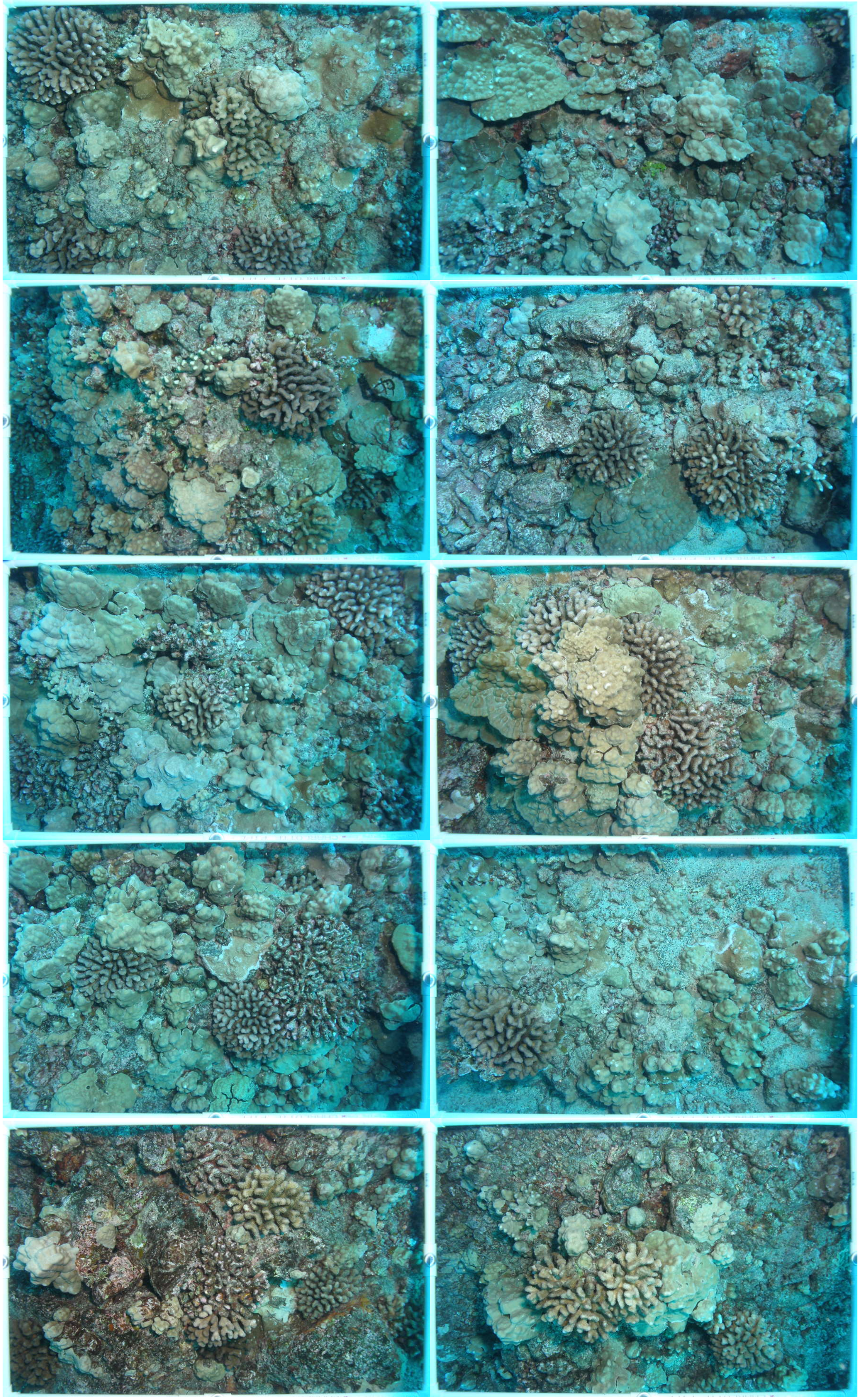

Plate 9. Quadrat photos for 12" Pipe North Deep transect.

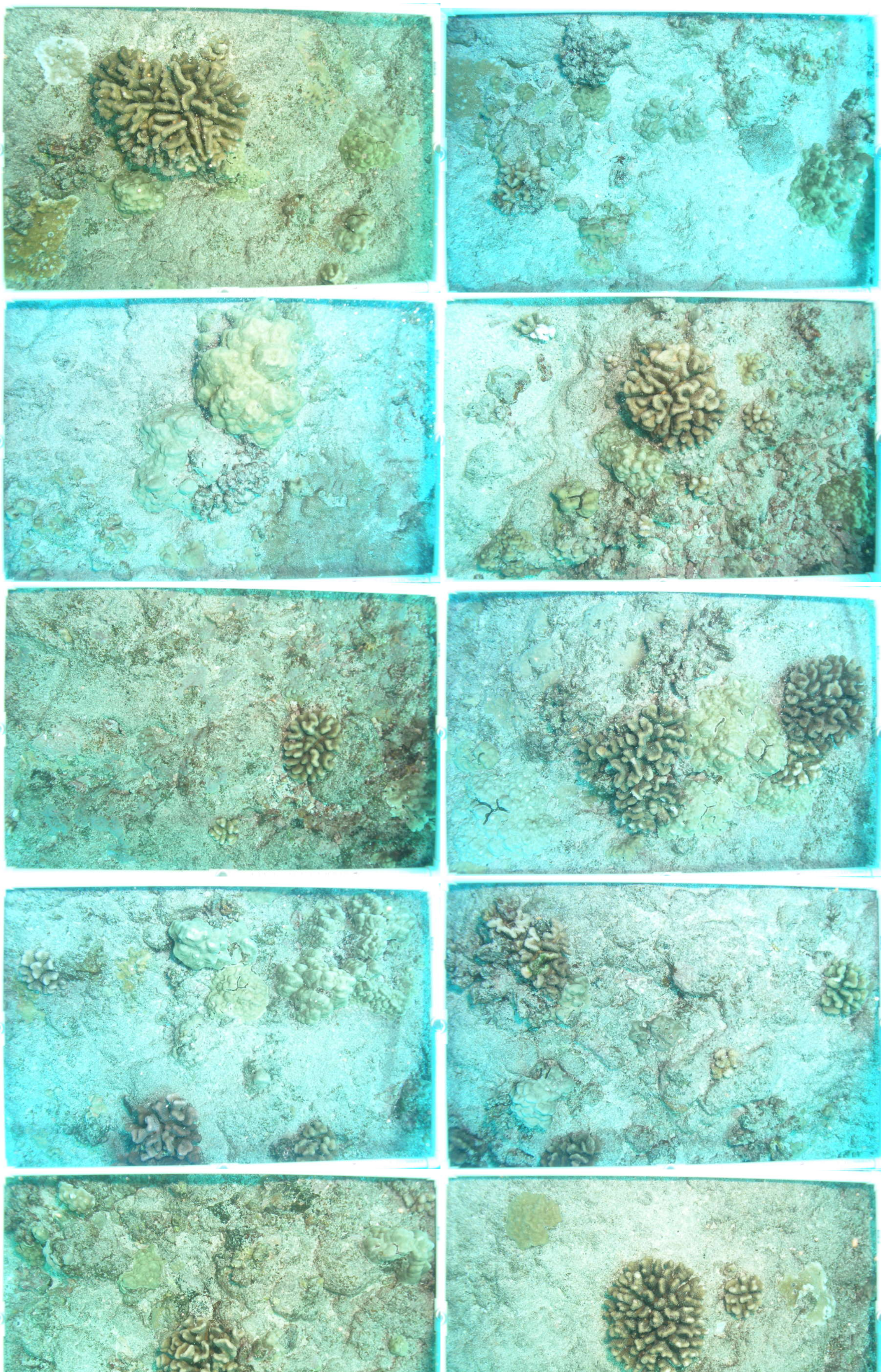

Plate 10. Quadrat photos for 12" Pipe South Shallow transect.

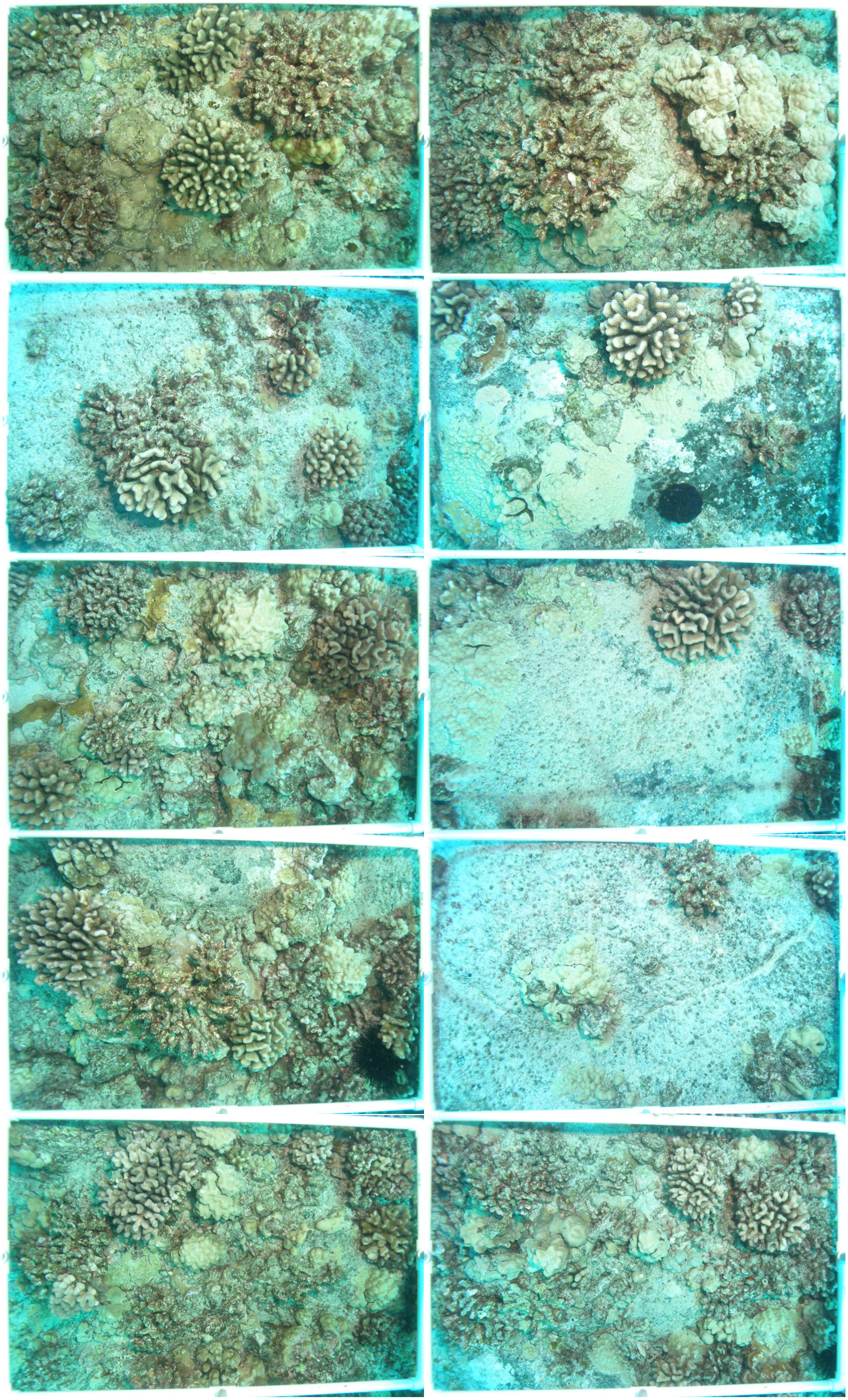

Plate 11. Quadrat photos for 12” Pipe South Middle transect.

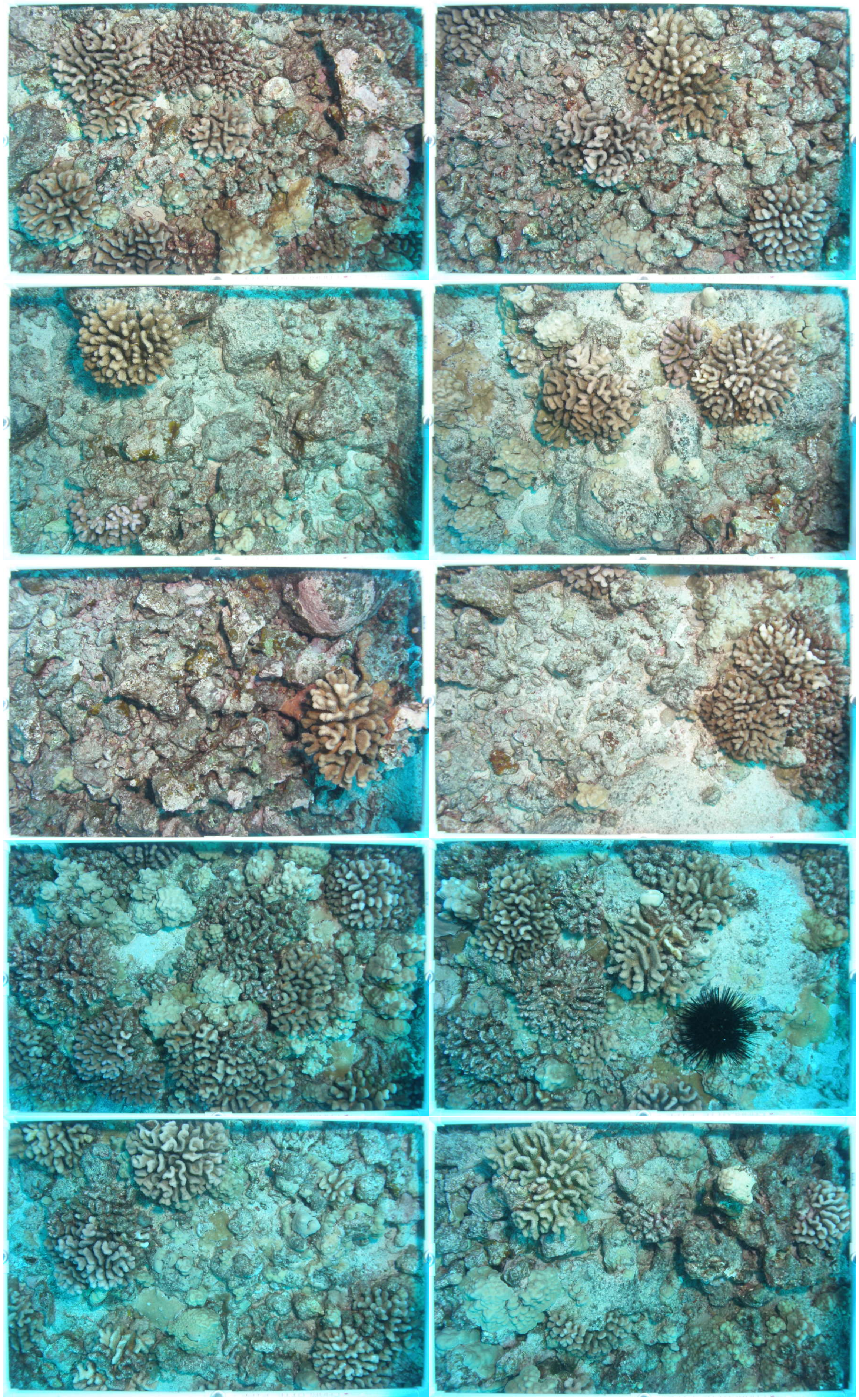

Plate 12. Quadrat photos for 12” Pipe South Deep transect.

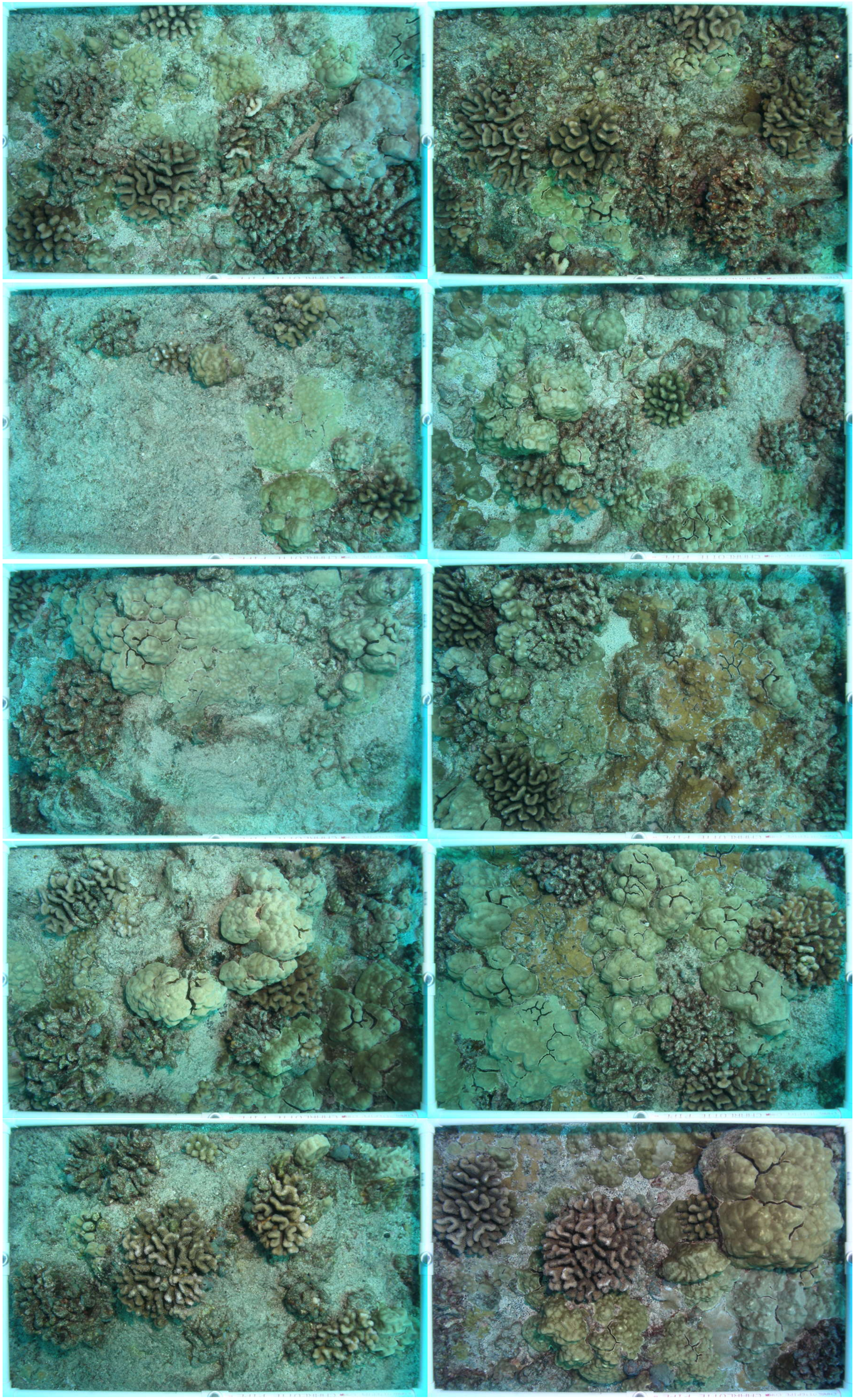

Plate 13. Quadrat photos for 18" Pipe Shallow transect.

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

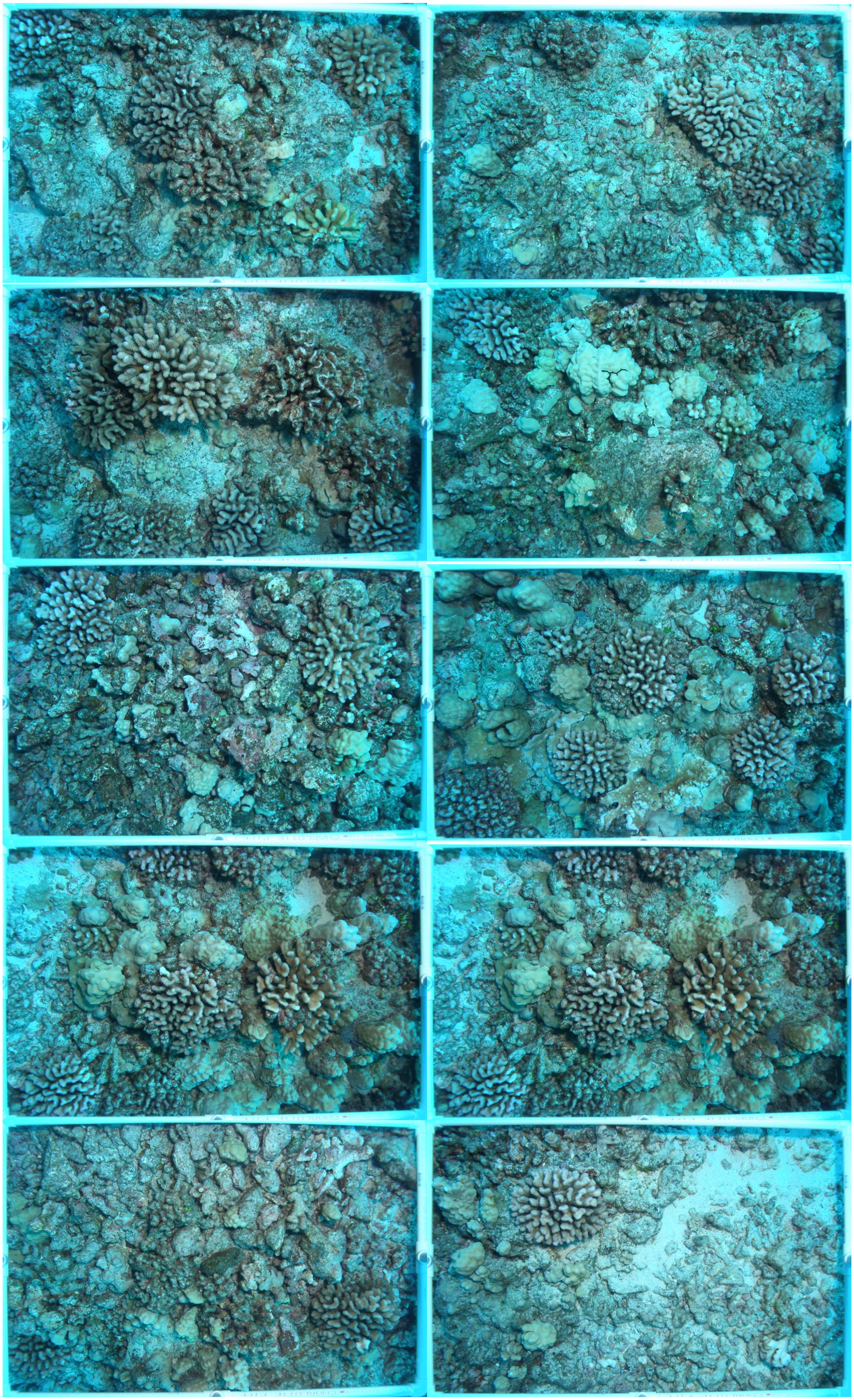

Plate 15. Quadrat photos for 18” Pipe Deep transect.

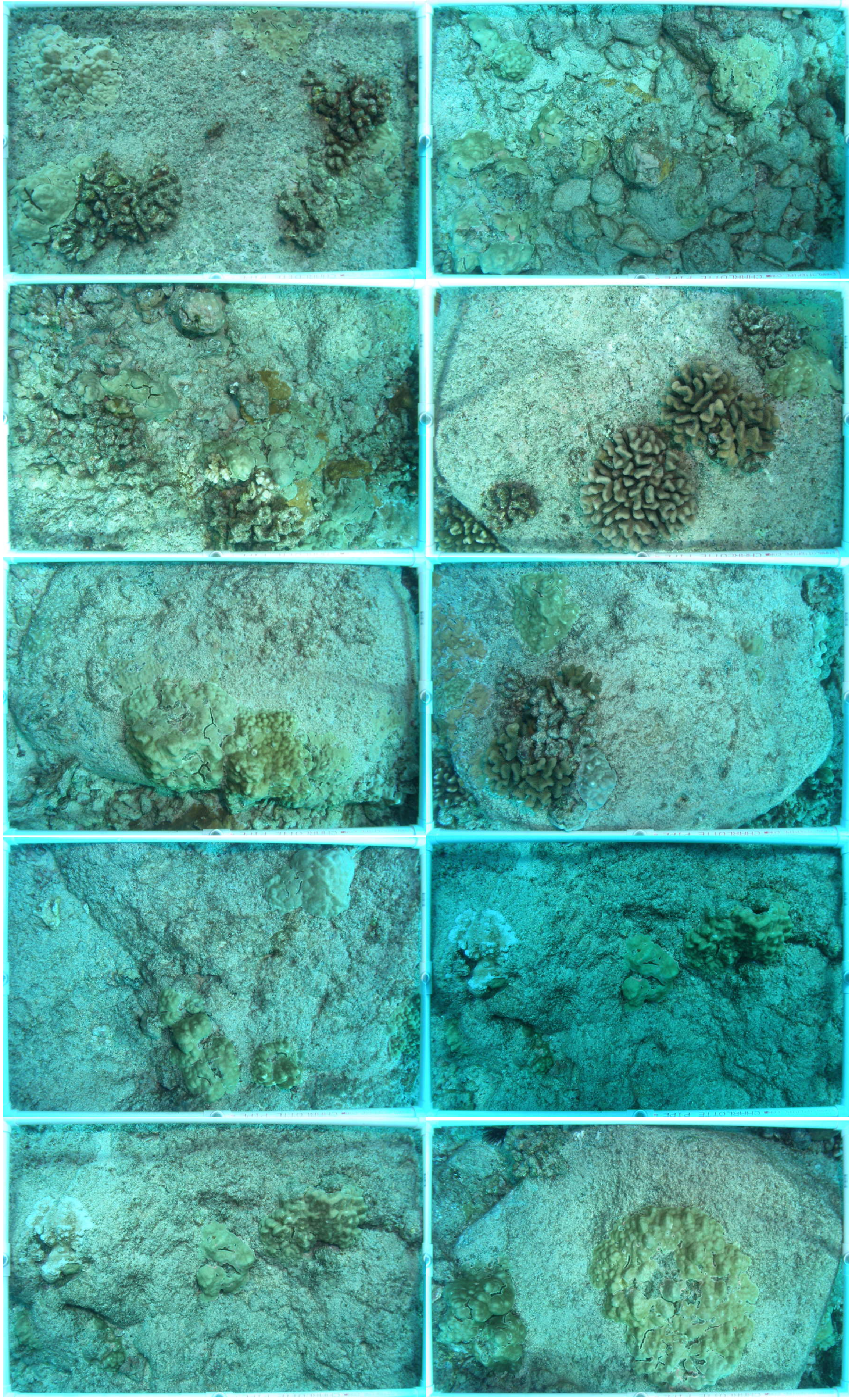

Plate 16. Quadrat photos for Wawaloli Shallow transect.

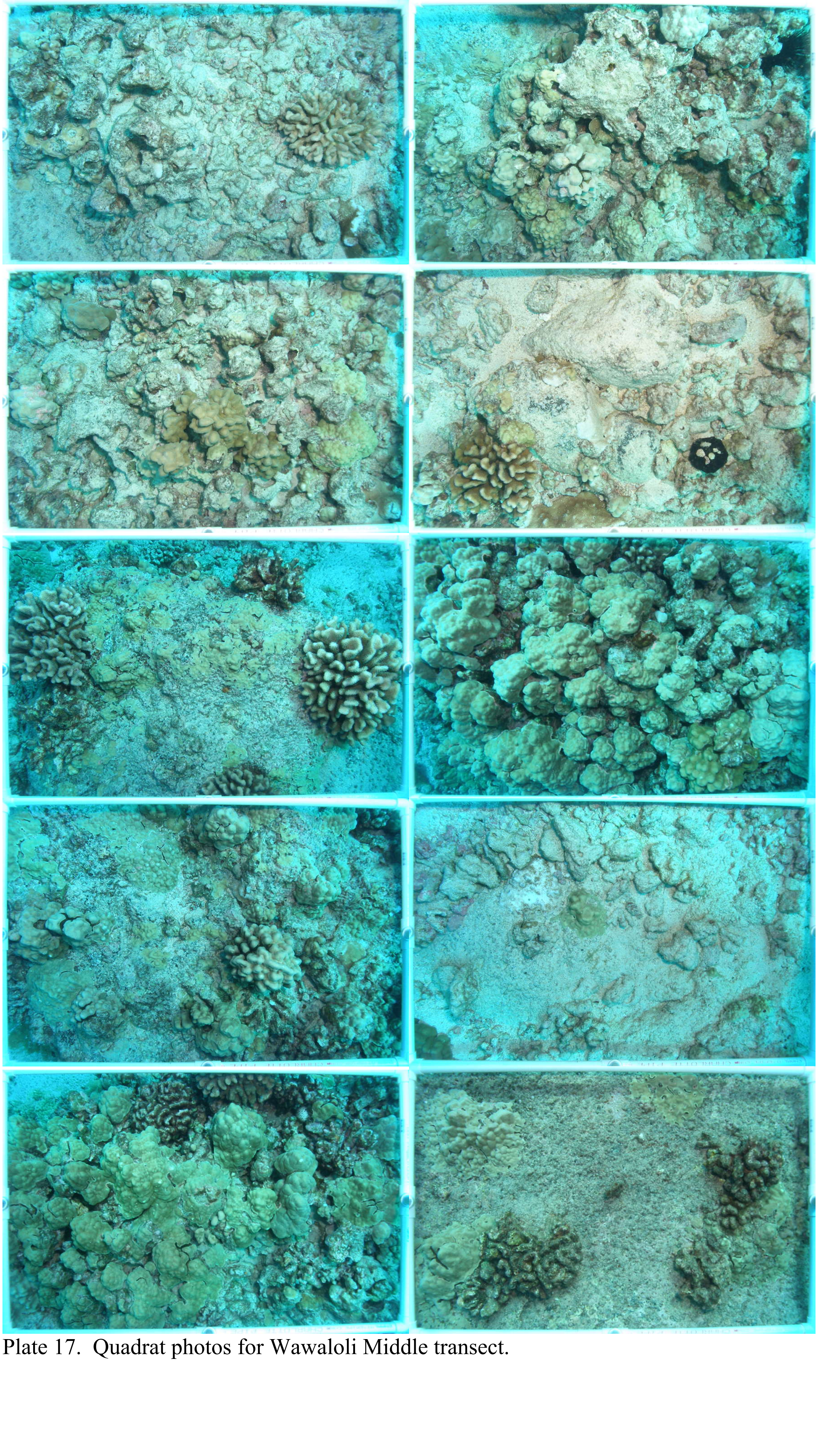

Plate 17. Quadrat photos for Wawaloli Middle transect.

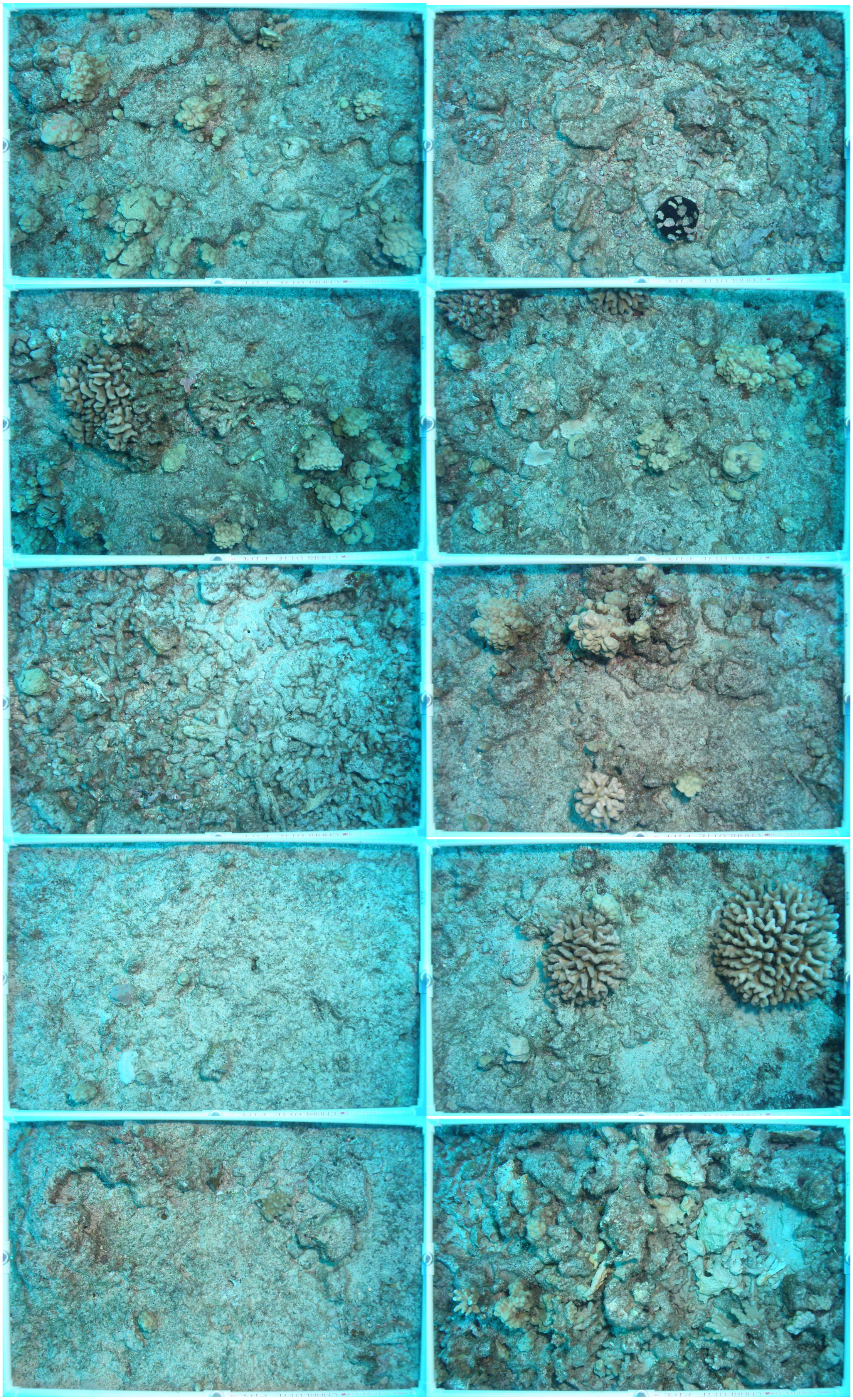

Plate 18. Quadrat photos for Wawaloli Deep transect.