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

SURVEY REPORT
November 2010

Prepared for

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NELHA MARINE BIOTA MONITORING PROGRAM
November 2010

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 November 2010.

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

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

Total coral cover, *Porites lobata* cover, *Pocillopora meandrina* cover and coral species diversity have been monitored over the period from May 1992 to November 2010. The data suggest that there may have been systematic differences in monitoring protocols between contractors. 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 November 2010. This increase is the result of the continued growth of existing corals, the settlement and growth of new corals, or a combination of the two processes. No other significant changes in benthic communities have been observed. There is no evidence that the operational activities at NELHA have had any impact on the benthic communities in the region.

The fish community in the NELHA region has remained relatively constant over a period of nineteen 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 November 2010 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.

TABLE OF CONTENTS

LIST OF APPENDICES

NELHA ANCHIALINE POND MONITORING PROGRAM
November 2010

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, 33 surveys of the ponds have been completed. The results of the first 12 surveys (through June 1995) are summarized in Brock, 1995; for November 1995 through May 1997 in Oceanic Institute, 1997; for December 1997 through May 2002 in Brock 2002; for July 2005 – January 2007 in Oceanic Institute 2007; for December 2007 and August 2008 in Brock 2008; for October 2008, May 2009 and March 2010 in Ziemann 2008, 2009, 2010. Results of the pond monitoring survey conducted in November 2010 are presented below.

METHODS

Anchialine ponds are located in two groups on the NELHA site (Figure 1): Prior to 2008, five ponds were located near the shoreline to the north of NELHA (Figure 2 upper). Sometime in 2008 an additional pond was dug in the sandy back-beach area adjacent to Pond N1; this pond has been labeled N6. Nine ponds are located to the south, inland of the NELHA access road (Figure 2 lower). A survey of the general conditions and biota within the ponds was conducted for this project on November 14, 2010 in morning hours on a high (1+ foot) tide. At each pond, water temperature was determined with a mercury thermometer and salinity was determined with a hand-held refractometer calibrated against distilled water. From one to four 0.1 m^2 quadrats were placed in each pond, in areas of different substrate, if possible. After five minutes, the number of organisms within each quadrat was counted and recorded. The presence of organisms not within the quadrats was noted and abundance estimated.

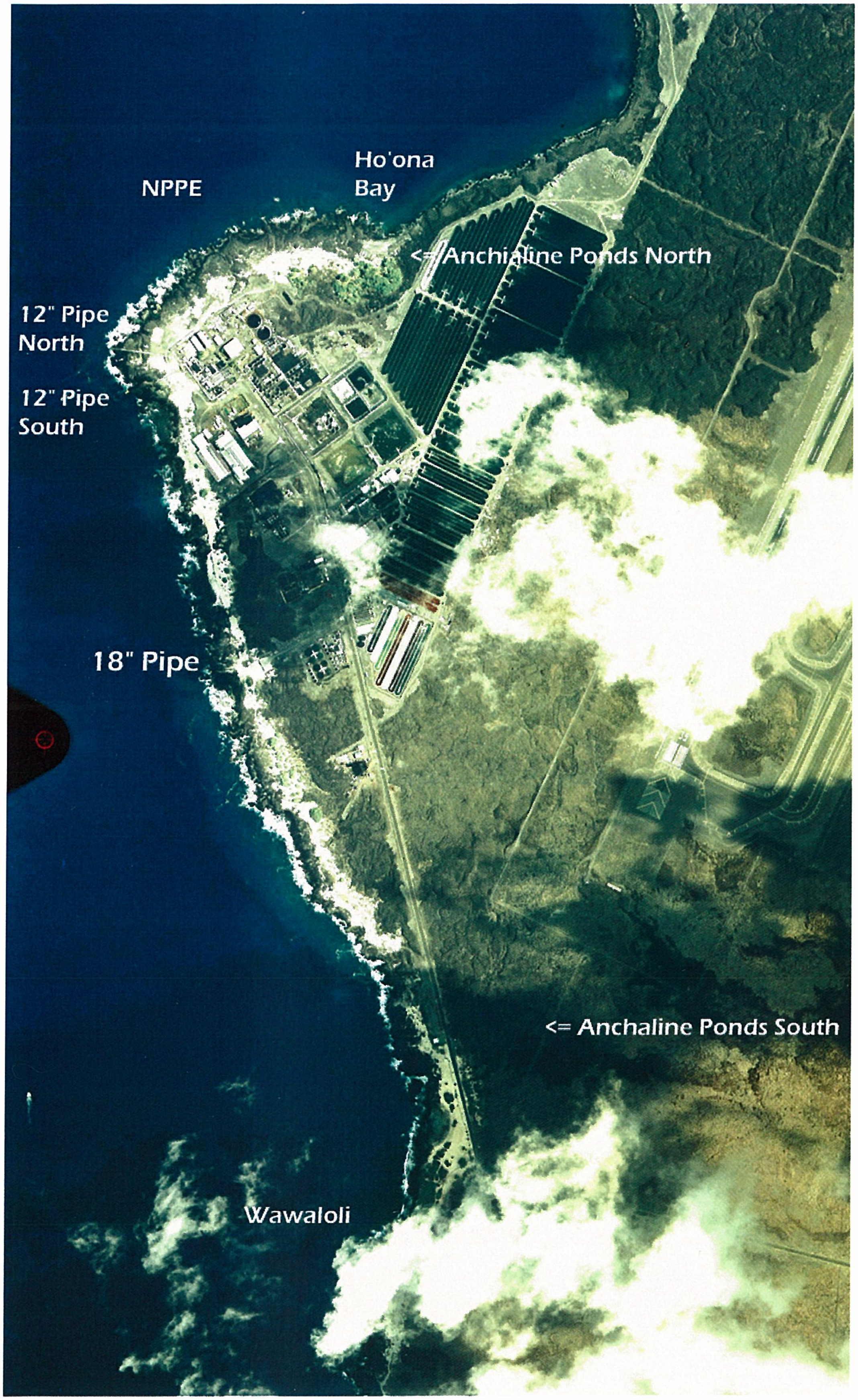

Figure 1. Locations of anchialine ponds and marine biota monitoring transects off NELHA.

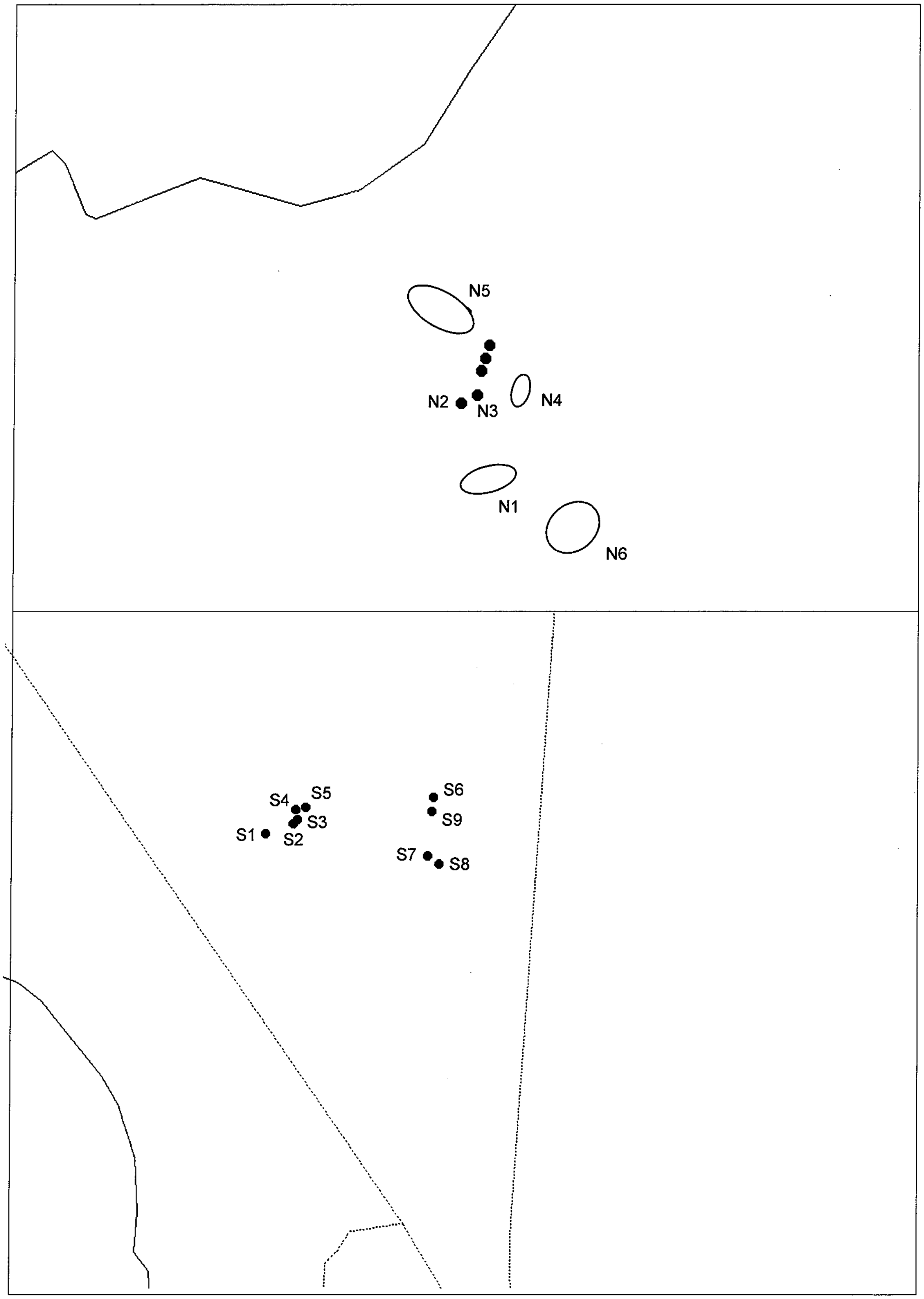

Figure 2. Locations of northern (upper) and southern (lower) anchialine pond groups at NELHA. Figures not to the same scale.

RESULTS

The results of the survey of the anchialine ponds at NELHA performed on November 14, 2010 are presented in Table 1. The distribution and abundance of organisms in the northern and southern pond complexes were very different, but generally similar to the conditions observed in previous surveys (Brock, 1995; Oceanic Institute, 1997; Brock, 2002; Oceanic Institute, 2007; Brock 2008; Ziemann 2008, 2009, 2010), with the exception of apparent changes to several ponds in the northern complex. The northern ponds are shallow and located near the shoreline (Figure 2 upper). Ponds N1 – N4 are formed in depressions in the low-lying lava; Pond N5 is at least partially man-made, consisting of a depression in the back-beach rubble formed by manual removal of rubble material. Pond N5 is closest to the shoreline and separated from the ocean by the rubble back-beach. Pond N6 was recently dug in the sandy back-beach area adjacent to Pond N1. Salinity during the May 2009 survey was uniform in the five northern ponds (10 ppt). Temperature was lowest (18.0 deg C) in pond N1 and elevated (22.0 deg C) in Pond N4.

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, May 2009 and March 2010 surveys (Ziemann 2008, 2009, 2010). The numbers and distributions of *H. rubra* in the northern ponds in the present survey were very similar to those observed in the previous three surveys. Notably, *H. rubra* were observed for the first time in low densities (10/quadrat) in the recently-dug Pond N6.

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 slightly warmer (19 - 20 deg C) than the southern group (S6 – S9), where temperatures were uniformly 18.5 – 19.0 deg C. Salinity in the southern ponds was slightly lower than in the northern ponds and ranged from 8 - 10 ppt.

Table 1. Physical and biological data collected in anchialine ponds within the NELHA facility in November 2010. 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	18.0	10	++					+++	-	-	*H. rubra* 100-150/quad over sand; 160/quad in gravel along pond edge; 50/quad in *Ruppia*.
N2	21.0	10						++	-	-	*H. rubra* 35/quad on rocks; 75/quad on rubble.
N3	20.5	10	+++					+++	-	-	*H. rubra* 200/quad on rock shelf; TNTC/quad on *Ruppia; Ruppia* covers 80% of central basin
N4	22.0	10			+			+	-	-	*H. rubra* 15/quad on rocks; 200/quad on sand.
N5	20.0	10	+					++	-	-	*H. rubra* 150/quad on rock shelf; 125/quad along edge; 50/quad on *Ruppia; Ruppia* covers 20% of central basin, evidence of recent removal of *Ruppia*.
N6	20.0	10									Man-made pond; H. rubra 10/quad on sand bottom.
S1	20.0	8						-	-	+	Poecilids present, no shrimp
S2	20.0	8						+	+	-	*H. rubra* 10/quad on rocks.
S3	19.0	9						-	-	+	Poecilids present, no shrimp
S4	19.0	10						+	-	-	*H. rubra* 15/quad on rocks.
S5	20.0	10						-	-	+	Poecilids present, no shrimp
S6	18.5	9						++	-	-	*H. rubra* 50/quad on rocks.
S7	18.5	9						-	-	++	Poecilids present, no shrimp.
S8	19.0	9						++	+	-	*H. rubra* 25/quad on rocks; 2 *M. lohena; 1 dead M.grandi* Beach heliotrope previously covering pond now cut back.
S9	18.5	8						++	+	-	*H. rubra* 30/quad on rocks; 1 *M. lohena.*

Qualitative abundance:

- \- none observed
- \+ few animals; scattered plants
- ++ animals common; plants abundant in patches
- +++ animals too numerous to count; plants covering substrate

The first exotic fishes in the southern ponds were recorded in the May 2002 survey (Brock, 2002) in Pond S7. Subsequently, exotic fishes expanded to all the southern ponds (except S6 and S9, which are dry at low tide) by January 2007. As a result, no anchialine pond crustaceans were observed in surveys conducted in December 2007 and August 2008 (Brock 2008). During the October 2008, May 2009 and March 2010 surveys (Ziemann 2008, 2009, 2010) and the present survey, however, exotic fishes were observed in four ponds (S1, S3, S5 and S7). *Halocaridina rubra* were present in the ponds which did not contain exotic fish. Another common pond crustacean, *Metabateaus lohena*, was seen in Pond S8, a deeper pond previously overgrown with beach heliotrope, but which had been cleared of overgrowth between October 2008 and May 2009, and in Pond S9, a thin fissure in the barren lava that is dry at low tide.

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 appear to have been successful, as they have not been observed in these ponds since 2007.

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

None of the anchialine ponds on the NELHA site exhibit any conditions which might be attributable to anthropogenic inputs of material to the ponds. Water clarity remains high, and macroalgal growth is minimal even in ponds containing exotic fish. A large pond dug in the sandy back-shore sometime in late 2008 or early 2009 now, two years after being dug, contains significant numbers of *Halocaridina rubra.* There is no evidence of any long term changes attributable to operational activities of NELHA on the anchialine ponds at NELHA.

NELHA BENTHIC MARINE BIOTA MONITORING PROGRAM
November 2010

INTRODUCTION

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

Between 1991 and the present, 33 surveys of the benthic communities have been completed. The results of surveys between 1991 and 1995 are summarized in Marine Research Consultants, 1995; for surveys between 1995 and 1997 in Oceanic Institute 1997; for surveys performed from 1997 to 2002 in Marine Research Consultants, 2002; for surveys from July 2005 to January 2007 in Oceanic Institute 2007; for October 2007 and July 2008 surveys in Marine Research Consultants 2008; and for the October 2008, May 2009 and March 2010 surveys in Ziemann 2008, 2009, 2010. Results of the survey conducted in November 2010 are reported here.

METHODS

A survey to examine the nearshore benthic marine biota was performed using SCUBA between November 10 - 13, 2010. Surveys were performed at six locations along the NELHA coastline (Figure 3): Ho'ona Bay, the NPPE site, 12" Pipe - North, 12" Pipe - South, 18" Pipe, and Wawaloli. At each location, a series of three transects was laid out. Transects were performed in the shallow (~5m) boulder zone, the intermediate depth (~8-10 m) reef bench, and the deeper (15-20 m) reef slope. These station locations and transect depths have been chosen as representative of major biotopes along the Kona coast (Dollar, 1975, 1982; Dollar and Tribble, 1993), and are the same locations visited in previous surveys (Marine Research Consultants, 2008; Brock, 2008; Ziemann, 2008). At each location, a 50 m transect line was laid out parallel to the depth contours. At ten randomly selected points along the transect line, photographs of a 0.6 x 1.0 m quadrat frame were taken using a digital camera with a wide angle lens in an underwater housing with a dome port. Lighting was provided by underwater strobes or natural light. Digital quadrat photos were analyzed using Coral Point Count with Excel extensions (CPCe v3.6; National Coral Reef Institute, Nova Southeastern University, 2006). On the computer screen, each digital photo was overlaid with a 20 (vertical) x 10 (horizontal) grid of equally spaced points, and the biotic components and substrate type under each point was recorded. Point count data were exported into Excel spreadsheets for compilation and analysis. For each transect, the mean abundance (as percent cover) of coral species and substrate type was tabulated, and the species diversity (Shannon-Weaver Index) of the coral community (Shannon and Weaver, 1949; Pielou, 1969) calculated.

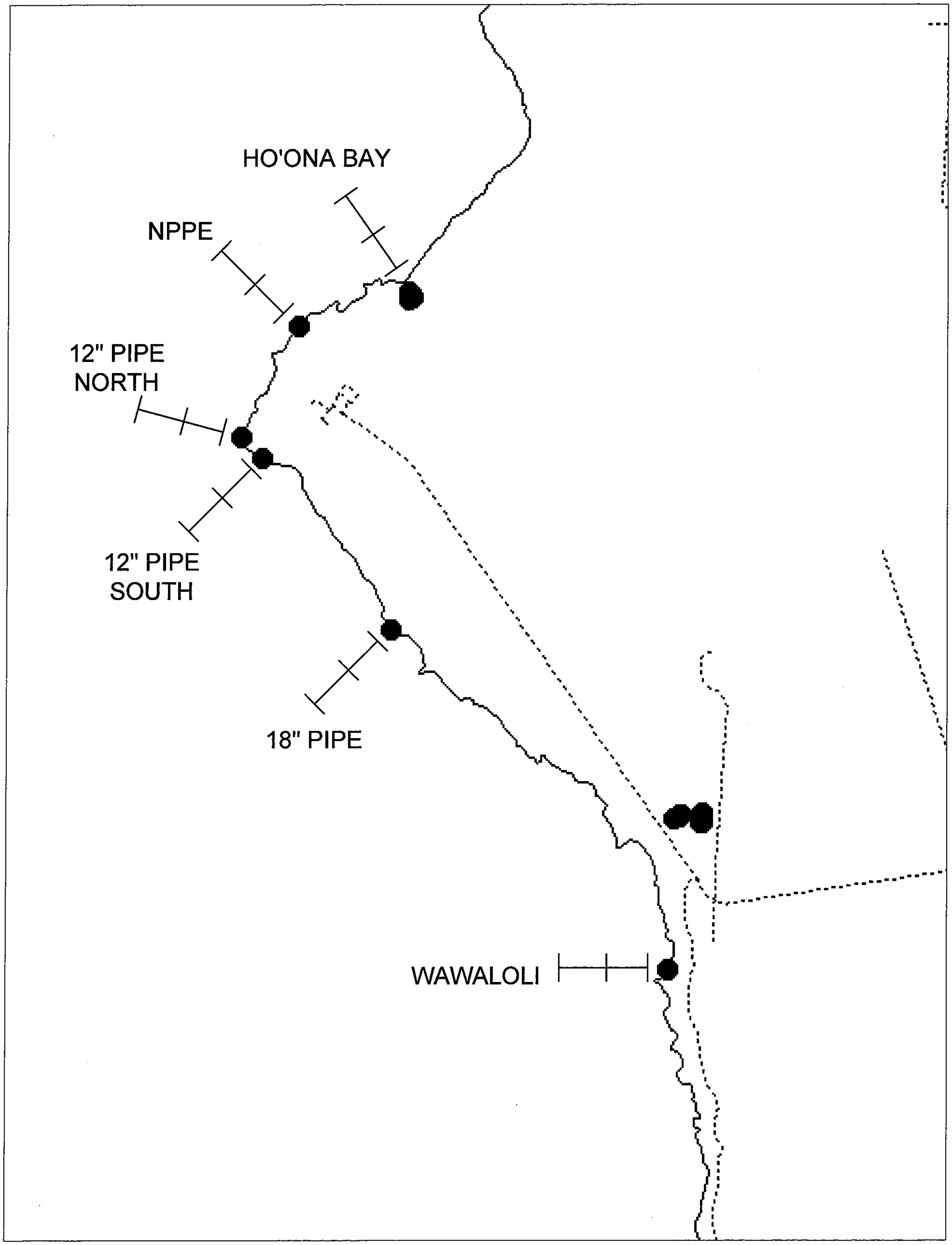

Figure 3. Locations of marine biota monitoring survey transects.

RESULTS

Coral species abundance and coral diversity for the November 2010 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. Overall, total coral cover was 46.4%. Two species, *Porites lobata* and *Pocillopora meandrina*, comprised the majority of the coral observed, constituting over 30.5% and 8.7%, respectively. *Porites lobata* and *Pocillopora meandrina* were found throughout all stations and habitat types. *Porites compressa* was abundant (16.8% - 20.0%) only at the deepest reef slope transects at stations NPPE and Ho'ona Bay, the two most northern stations. *Montipora capitata* [previously *verrucosa*], was found at all stations with coverage ranging from 0.6 - 9.3%. Other stony coral species (*Porites monticulosa, Pocillopora eydouxi, Montipora patula, M. incrassata, Pavona varians, Leptastrea purpurea*) made up generally less than 2% of the benthic cover.

The percent cover of all coral species (Total Coral) 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 differences in coral abundance both between habitat types and also between sites, but only the differences between sites for *P. compressa* were statistically significant ($p = 0.03$, two-way ANOVA; Holm-Sladek pair-wise comparison test). Total coral cover was highest at the NPPE site (60.2%) and ranged from 36.2% to 48.1% at the other sites. Total coral cover in the deep reef slope habitat was higher (51.1%) than the middle (47.1%) or shallow reef habitat (41.0%), but the differences were not statistically significant ($p = 0.34$, two-way ANOVA; Holm-Sladek pair-wise comparison test). Among the deep reef slope stations, total coral abundance was highest at NPPE (75.2%), 12" Pipe North (62.1%) and Ho'ona Bay (59.6%) sites. At Ho'ona Bay and NPPE, this was due to the high abundance of *Porites compressa* (16.8% - 20.0% cover). At the other four deep reef slope stations, *P. lobata* and *Pocillopora meandrina* accounted for the high coral abundance (combined average cover of 34.7% - 37.4%).

Between areas, the highest mean and also maximum coral was found in two most northern areas, the NPPE and 12" Pipe North sites. The most southern area, Wawaloli had the lowest overall coral coverage. The highest mean *Porites lobata* coverage was found at the NPPE site (51.7%), with similar but lower coverage at the Ho'ona Bay, 18" Pipe, 12" Pipe North and Wawaloli; lowest P. lobata cover was observed at the 12" Pipe South site. For *Pocillopora meandrina,* the 18" Pipe, 12" Pipe North and South stations had the highest mean abundance of all the stations. The differences between these sites were not statistically different ($p < 0.26$).

The number of coral species observed in photoquadrats was not significantly different between sites ($p = 0.68$) or between habitats ($p = 0.14$; two-way ANOVA; Holm-Sladek pair-wise comparison test). The mean number of species observed was highest at Ho'ona Bay (5.3) and lowest at NPPE (4.3). The mean number of species observed at the deep habitats (5.3) was not significantly greater than at the shallow (4.3) or middle (5.2) habitats ($p = 0.14$; two-way ANOVA; Holm-Sladek pair-wise comparison test).

Table 2. Summary of quantitative coral photoquadrat surveys conducted off Natural Energy Laboratory of Hawaii on November 10--13, 2010. Locations of transects are shown in Figure 3. Quantitative data are presented in Appendix B.

Station	Wawaloli Beach			18" Pipe			12" Pipe South		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
% Total coral	35.5	47.2	34.7	59.3	44.5	37.5	30.0	41.1	37.4
% *P. lobata*	21.0	38.2	24.9	41.1	27.0	21.7	17.8	23.9	22.0
% *P. compressa*		1.1	1.0		0.8	0.5		0.2	
% *Poc. meandrina*	9.4	3.1	3.2	8.5	12.1	12.9	9.5	14.2	10.2
Species	4	5	5	6	5	4	4	6	6
Diversity	1.02	1.00	0.90	1.01	1.01	0.92	0.92	0.91	1.12

Station	12" Pipe North			NPPE			Ho'ona Bay		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
% Total coral	35.3	45.8	62.1	41.1	64.2	75.2	44.8	39.9	59.6
% *P. lobata*	18.7	21.5	43.9	31.5	49.4	51.7	30.9	30.6	34.0
% *P. compressa*			2.3		0.5	16.8	0.2	3.2	20.0
% *Poc. meandrina*	12.7	12.0	11.1	9.0	9.3	3.9	11.5	4.0	0.2
Species	4	5	6	3	5	5	5	5	6
Diversity	1.00	1.26	0.91	0.61	0.73	0.88	0.82	0.82	1.02

Survey Means	Wawaloli Beach	18" Pipe	12" Pipe South	12" Pipe North	NPPE	Ho'ona Bay	p level	Shallow	Middle	Deep	p level
% Total coral	39.1	47.1	36.2	47.7	60.2	48.1	*0.24*	41.0	47.1	51.1	*0.34*
% *P. lobata*	28.0	29.9	21.2	28.0	44.2	31.8	*0.17*	26.8	31.8	33.0	*0.51*
% *P. compressa*	1.0	0.6	0.2	2.3	8.6	7.8	*0.03*	0.2	1.1	8.1	*0.09*
% *Poc. meandrina*	5.2	11.1	11.3	11.9	7.4	5.2	*0.08*	10.1	9.1	6.9	*0.26*
Species	4.7	5.0	5.3	5.0	4.3	5.3	*0.68*	4.3	5.2	5.3	*0.14*
Diversity	0.97	0.98	0.98	1.06	0.74	0.89	*0.12*	0.90	0.95	0.96	*0.64*

Other Benthic Invertebrates

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

Comparative Analysis - Benthic Marine Resources

Data for the NELHA benthic marine resources monitoring program has been collected since May 1989. However, the current arrangement of six stations with three transects at each station was not established until May 1992. Since that time, 33 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 November 2010, 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 33 surveys from May 1992 to November 2010 for total coral cover, *Porites lobata* abundance and *Pocillopora meandrina* abundance using SigmaStat for Windows, a PC-based statistical analysis program. However, all data sets failed the test of normality, in raw form or after transformations (log, exp, arc-sine). Therefore, one-way ANOVA tests utilizing ranked data (Kruskal-Wallis analysis of variance on ranks) were conducted on each factor independently; pair-wise comparison comparisons on ranked data using the Tukey test were performed to identify significant differences between all pairs. The level of significance for all tests was $p = 0.05$.

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

Summary of three-way analysis of variance on ranked data (Kruskal-Wallis test) for quantitative benthic community abundance for the period May 1992 – November 2010.

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 pair-wise comparisons (Tukey tests) from the one-way ANOVA on ranks are presented in Table 3. Total coral abundance showed a clear pattern over time. Mean total coral abundance did not change significantly from May 1992 through May 1997, although there was a generally increasing trend, with values ranging from 16.9 to 27.0%. Mean cover almost doubled, from 27% to 42.5%, between surveys conducted in May 1997 and November 1997. Mean total coral cover remained high (40.7% to 52.5%) through June 2002. In July and November 2005, after a nearly three-year hiatus in monitoring, the mean total coral cover was 30.8 and 30.2%, respectively, significantly higher than during the May 1992 to May 1997 period, but significantly lower than during the November 1997 – June 2002 period. Mean coral cover was reported as 52.4% and 54.7% for surveys in October 2007 and July 2008. Mean total coral cover was 39.5% in the survey conducted in October 2008, 39.5% in May 2009 and 43.2% in March 2010 and 46.4% in the present survey.

Mean total coral cover was significantly different between all sites except the 12" Pipe North, 12" Pipe South and 18" Pipe sites. Mean total coral cover was highest (52.3%) at the NPPE site, decreasing through the Ho'ona Bay, 12" Pipe S and N, and 18" Pipe sites to a minimum of 22.0% at the Wawaloli site. Mean total coral cover was significantly different between the deep reef slope (42.0%), the reef bench (37.0%), and the shallow boulder (26.7%) stations.

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

As for total coral cover, *P. lobata* cover was highest at the NPPE station (31.4%) and lowest at Wawaloli (13.8%) and the 18" Pipe (12.8%) sites, and increased from lowest values (13.5%) in the shallow boulder habitat to highest values (22.6%) in the deep reef slope habitat.

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

Mean *Poc. meandrina* cover was similar (12.0 – 13.5%) at the NPPE, 18" Pipe, and 12" Pipe South sites. The 12" Pipe North, Wawaloli and Ho'ona Bay sites showed significantly lower cover (3.8 – 5.4%). Mean *Poc. meandrina* cover was similar at the shallow boulder (10.1%) and middle reef shelf (11.3%) sites, and significantly lower 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.

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

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

Table 3. Summary of one-way analysis of variance (ANOVA) of total coral abundance (percent cover) for surveys conducted off NELHA from 1992 - 2010. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

		Mean	group						
Date									
	May-92	17.4						f	g
	Oct-92	16.9							g
	May-93	19.3					e	f	g
	Oct-93	21.0					e	f	g
	Mar-94	21.0					e	f	g
	May-94	19.4					e	f	g
	Sep-94	23.3			c	d	e	f	g
	Jan-95	23.5			c	d	e	f	g
	May-95	21.7				d	e	f	g
	Nov-95	25.1		b	c	d	e	f	g
	Jun-96	19.6					e	f	g
	Dec-96	21.6					e	f	g
	May-97	27.0		b	c	d	e	f	g
	Nov-97	42.5	a	b	c	d	e		
	May-98	49.4	a	b					
	Nov-98	46.1	a	b	c	d			
	May-99	40.7	a	b	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	a	b	c	d	e	f	g
	Nov-05	30.2	a	b	c	d	e	f	g
	Jul-06	35.8	a	b	c	d	e	f	g
	Jan-07	38.5	a	b	c	d	e	f	
	Oct-07	52.4	a						
	Jul-08	54.7	a						
	Oct-08	39.5	a	b	c	d	e	f	
	May-09	39.5	a	b	c	d	e		
	Mar-10	43.2	a	b	c	d	e		
	Nov-10	46.4	a	b	c	d			
Location									
	Wawaloli	22.0				d			
	18-inch Pipe	30.3			c				
	12-inch South	32.6			c				
	12-inch North	32.5			c				
	NPPE	52.3	a						
	Ho'ona Bay	41.7		b					
Biotope									
	Shallow	26.7			c				
	Middle	37.0		b					
	Deep	42.0	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 - 2010. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

		Mean			group		
Date							
	May-92	10.3					e
	Oct-92	10.0					e
	May-93	10.9					e
	Oct-93	11.4					e
	Mar-94	12.2				d	e
	May-94	10.4					e
	Sep-94	13.1				d	e
	Jan-95	14.6		b	c	d	e
	May-95	12.2					e
	Nov-95	13.3			c	d	e
	Jun-96	10.4					e
	Dec-96	11.0					e
	May-97	13.7			c	d	e
	Nov-97	20.6	a	b	c	d	e
	May-98	22.9	a	b	c	d	e
	Nov-98	20.9	a	b	c	d	e
	May-99	18.9	a	b	c	d	e
	Dec-99	21.5	a	b	c	d	e
	Jun-00	20.9	a	b	c	d	e
	Feb-01	22.5	a	b	c	d	e
	May-01	22.5	a	b	c	d	e
	Dec-01	22.5	a	b	c	d	e
	Jun-02	22.7	a	b	c	d	e
	Jul-05	16.7	a	b	c	d	e
	Nov-05	17.7	a	b	c	d	e
	Jul-06	19.8	a	b	c	d	e
	Jan-07	22.3	a	b	c	d	e
	Oct-07	30.7	a				
	Jul-08	29.8	a				
	Oct-08	25.8	a	b	c	d	
	May-09	25.9	a	b	c		
	Mar-10	27.5	a	b			
	Nov-10	30.5	a				
Location							
	Wawaloli	13.8				d	e
	18-inch Pipe	12.8					e
	12-inch South	14.9			c	d	
	12-inch North	16.8			c		
	NPPE	31.4	a				
	Ho'ona Bay	22.4		b			
Biotope							
	Shallow	13.5			c		
	Middle	19.9		b			
	Deep	22.6	a				

Table 5. Summary of three-way analysis of variance (ANOVA) of mean *Pocillopora meandrina* abundance (percent cover) for surveys conducted off NELHA from 1992 - 2010. For each ANOVA factor (date, location and biotope), data which are not significantly different (Tukey test) are grouped by letter.

		Mean	group				
Date							
	May-92	4.3					e
	Oct-92	3.7					e
	May-93	4.3					e
	Oct-93	5.0				d	e
	Mar-94	4.0					e
	May-94	4.5				d	e
	Sep-94	4.9				d	e
	Jan-95	4.5				d	e
	May-95	4.8				d	e
	Nov-95	7.0		b	c	d	e
	Jun-96	5.3				d	e
	Dec-96	6.3			c	d	e
	May-97	8.0	a	b	c	d	e
	Nov-97	13.0	a	b	c	d	e
	May-98	14.9	a	b	c	d	
	Nov-98	13.6	a	b	c	d	e
	May-99	12.3	a	b	c	d	e
	Dec-99	17.5	a	b	c		
	Jun-00	17.8	a	b	c		
	Feb-01	20.0	a	b			
	May-01	20.3	a				
	Dec-01	16.7	a	b	c		
	Jun-02	16.1	a	b	c		
	Jul-05	8.6	a	b	c	d	e
	Nov-05	8.0	a	b	c	d	e
	Jul-06	9.0	a	b	c	d	e
	Jan-07	9.4	a	b	c	d	e
	Oct-07	10.2	a	b	c	d	e
	Jul-08	11.8	a	b	c	d	e
	Oct-08	7.3	a	b	c	d	e
	May-09	8.1	a	b	c	d	e
	Mar-10	8.8	a	b	c	d	e
	Nov-10	8.7	a	b	c	d	e
Location							
	Wawaloli	5.4			c		
	18-inch Pipe	13.5	a				
	12-inch South	12.9	a				
	12-inch North	10.3		b			
	NPPE	12.0	a				
	Ho'ona Bay	3.8				d	
Biotope							
	Shallow	10.1		b			
	Middle	11.3	a				
	Deep	7.6			c		

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

Benthic monitoring surveys have been conducted by different parties over the course of the CEMP program: Marine Research Consultants (MRC, Dr. Steven Dollar) from August 1991 – May 1995; Oceanic Institute (OI, Dr. David Ziemann), four surveys from November 1995 – May 1997; Marine Research Consultants (MRC, Dr. Steven Dollar), ten surveys from November 1997 – June 2002; Oceanic Institute (OI, Dr. David Ziemann), four surveys between July 2005 and January 2007; Marine Research Consultants (MRC, Dr. Steven Dollar), two surveys in October 2007 and July 2008; and Dr. David Ziemann, the surveys in October 2008, May 2009 March 2010 and November 2010. 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 chose not to include the data from the OI surveys of November 1995 – May 1997 in their analysis, speculating "it appears that locations of the monitoring sites were not identical between the two investigators", but the present analysis shows the results of the four OI surveys between November 1995 and May 1997 were not significantly different from those conducted by MRC up to May 1995. Table 6 of the MRC report for the November 1997 survey (Marine Research Consultants, 1998) clearly shows highly significant differences between the coral abundances found in their prior surveys (through 1995) and their November 1997 survey. While the significant difference between surveys conducted up to May 1995 and after November 1997 is recognized (Marine Research Consultants, 1998), it is attributed to "increased coral cover at many of the survey sites directly off the NELHA facility."

The overall mean total coral cover, mean *Porites lobata* cover, and mean *Pocillopora meandrina* cover for six periods during which monitoring was conducted by different contractors are presented below. Figures in bold type represent mean values that are significantly different from the remaining means (see Tables 3 – 5 and accompanying text for details). Mean total coral cover and cover for *P. lobata* and *Poc. meandrina* was not significantly different between monitoring conducted by MRC in 1992 – 1995, by OI between 1995 – 1997, by OI in 2005 – 2007 and by Ziemann between 2008 - 2010. Mean values were significantly higher, however, for the monitoring conducted by MRC between 1997 - 2002 and 2007 - 2008.

Dates	Monitor	Mean Total Coral Cover	Mean *Porites lobata* cover	Mean *Pocillopora meandrina* cover
May 1992 – May 1995	Marine Research Consultants	20.4	11.7	4.5
Nov 1995 – May 1997	Oceanic Institute	23.4	12.1	6.7
Nov 1997 – Jun 2002	Marine Research Consultants	**47.4**	**21.6**	**11.2**
Jul 2005 - Jan 2007	Oceanic Institute	33.3	19.1	8.8
Oct 2007 – July 2008	Marine Research Consultants	**53.6**	**30.3**	**11.0**
Oct 2008 – November 2010	David A. Ziemann	42.2	27.4	8.2

Mean total coral cover, and cover for *P. lobata* and *Poc. meandrina* increased by 21.8%, 15.7% and 3.7%, respectively, over the approximately 24-year period 1992-1995 and 2010; these equate to rates of increase of 4.45%, 5.59% and 3.43% per year. 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.

NELHA NEARSHORE MARINE FISH RESOURCES MONITORING PROGRAM
November 2010

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, 33 surveys of the fish communities have been completed. The results of the first 12 surveys through May 1995 are summarized in Brock, 1995; for November 1995 through May 1997 surveys in Oceanic Institute 1997; for surveys conducted between November 1997 and June 2002 in Brock, 2002; for July 2005 – January 2007 in Oceanic Institute 2007; for December 2007 and August 2008 in Brock 2008; for October 2008, May 2009 and March 2010 in Ziemann 2008, 2009, 2010. Results from the current survey performed in November 2010 are presented below. The data from the 33 complete surveys (May 1992 – March 2010) are used in the subsequent analysis of long-term trends.

METHODS

Surveys to examine the nearshore fish populations were performed using SCUBA between November 10-13, 2010. Surveys were performed at six locations along the NELHA coastline (Figure 3, above): Ho'ona Bay, the NPPE site, 12" Pipe - North, 12" Pipe - South, 18" Pipe, and Wawaloli. At each location, a series of three transects were laid out, starting at permanently placed markers or facility features (NELHA supply pipes). Transects were performed in the shallow (~5m) boulder zone, the intermediate depth (~8-10 m) reef bench, and the deeper (15-20 m) reef slope. These station locations and transect depths have been chosen as representative of major biotopes along the Kona coast (Dollar, 1975, 1982; Dollar and Tribble, 1993), and are the same locations occupied in previous surveys (Marine Research Consultants, 1995, 2002, 2008; Brock, 1995, 2002, 2008; Oceanic Institute, 1997, 2007; Ziemann 2008, 2009, 2010). 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 March 2010 in terms of number of species, individual abundance, biomass, and species diversity are summarized in Table 6 and Figure 4 and presented in detail in Appendix D.1 – D.5.

Numerical Abundance and Habitat Distribution

The number of individuals per transect for the November 2010 fish survey off NELHA are summarized in Table 6. Numerical abundance varied widely between locations and habitats (Fig. 4A). A large (1,000+) school of 'opelu at the middle transect of the NPPE site caused a spike in both abundance and biomass at that station. Not considering that school, the highest mean number of individuals occurred at the 18" Pipe (384) and 12" Pipe South (315) sites. The number of individuals at the other four locations ranged from 226 to 260. The mean number of fish observed was not significantly different between locations ($p = 0.48$), or between biotope types ($p = 0.44$; two-way ANOVA on raw data, Tukey test on interactions).

Number of Species

The number of species per transect for the November 2010 survey off NELHA is summarized in Table 6 and Figure 4B. The mean number of species observed per transect ranged from 22.3 at NPPE to 32.3 at the 18" Pipe site. The number of species observed at the 18" Pipe, 12" Pipe South and 12" Pipe North locations were not significantly higher than the number observed at the other three locations. ($p = 0.15$; two-way ANOVA on raw data, Tukey test on interactions). The mean number of species per transect ranged from 28.3 in the shallow boulder habitats to 27.2 in the middle reef shelf habitat; the differences were not statistically significant ($p = 0.90$; two-way ANOVA on raw data, Tukey test on interactions).

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

Species Diversity

Shannon's Index for species diversity for the March 2010 survey off NELHA is summarized in Table 6. Mean species diversity ranged from 1.70 at the NPPE site to 2.30 at the 12" Pipe South station, but there were no significant differences between locations ($p = 0.19$). Mean species diversity was not significantly different between habitats ($p = 0.11$).

Table 6. Summary of quantitative fish transects conducted off Natural Energy Laboratory of Hawaii on November 10-13, 2010. 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	209	313	173	446	308	399	242	293	410
Number of species	31	29	28	37	25	35	32	26	29
Diversity	2.52	2.02	2.22	2.26	2.00	1.93	2.42	2.29	2.18
Biomass (g/m^2)	156	87	135	187	147	190	70	118	127

Station	12" Pipe North			NPPE			Ho'ona Bay		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total number	211	209	298	238	1274	267	210	247	220
Number of species	24	36	28	23	24	20	23	23	27
Diversity	2.13	2.34	2.16	2.43	0.95	1.71	2.38	2.17	2.38
Biomass (g/m^2)	100	61	63	198	465	44	137	61	96

Survey Means	Wawaloli Beach	18" Pipe	12" Pipe South	12" Pipe North	NPPE	Ho'ona Bay	p level	Shallow	Middle	Deep	p level
Total number	231.7	384.3	315.0	239.3	593.0	225.7	*0.48*	259.3	440.7	294.5	*0.44*
Number of species	29.3	32.3	29.0	29.3	22.3	24.3	*0.15*	28.3	27.2	27.8	*0.90*
Diversity	2.25	2.06	2.30	2.21	1.70	2.31	*0.19*	2.36	1.96	2.10	*0.11*
Biomass (g/m^2)	125.8	174.5	104.8	74.6	235.7	98.2	*0.40*	141.3	156.4	109.1	*0.70*

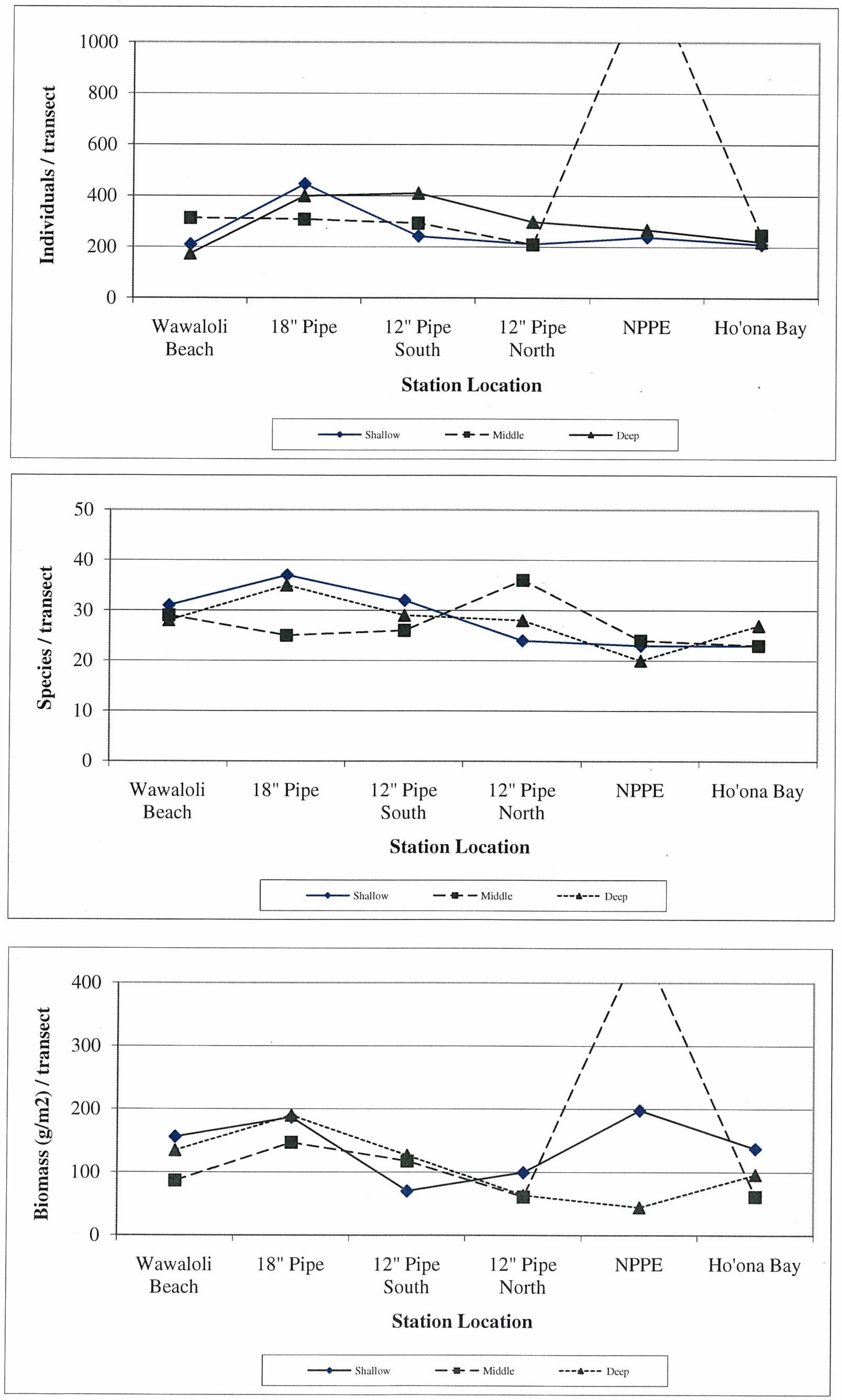

Figure 4. Plots of A: numerical abundance; B: number of species; and C: estimated biomass (g/m2) per transect for fish surveys conducted off NELHA in March 2010. Transect locations are shown in Figure 3.

Biomass

The distribution of fish biomass per transect for the November 2010 survey off NELHA is summarized in Table 6 and presented in Figure 4C. Not including the biomass of the large 'opelu school mentioned above, mean biomass was highest at the 18" Pipe site (174.5 g/m^2); differences between other locations were not significant ($p = 0.40$). Mean biomass was lowest in the deep reef habitat (109.1 g/m^2) and highest in the shallow boulder (141.3 g/m^2) habitat. Differences in biomass between habitats was not significant ($p = 0.70$).

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, 33 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 November 2010, 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 33 surveys from May 1992 to May 2009 are presented in Appendix D.3 – D.5, respectively. Three-way analyses of variance (ANOVA) tests were performed on data for each of the three fish population variables using SigmaStat for Windows, a PC-based statistical analysis program. Three-way ANOVA provides an estimate of the significance of the differences between levels for each source of variance, while post hoc pair-wise analyses provides details of which pairs of data are significantly different. If the data failed either the test that the data were normally distributed (normality test) or that the variances were equally distributed, the tests were performed using the rank-transformed data rather that the untransformed data. The ANOVA test utilizing ranked data is known as the Kruskal-Wallis analysis of variance on ranks (K-W test), while the multiple pair-wise comparison test on ranked data is known as the Student-Newman-Keuls Method (SNK test). The level of significance for all tests was $p = 0.05$.

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

Summary of three-way analysis of variance on ranked data (Kruskal-Wallis test) for date of survey, number of individuals, number of fish species and biomass per transect for survey conducted between November 1992 and November 2010.

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

A summary of the post-hoc S-N-K test for pair-wise comparisons on numbers of individuals per transect for date, location and habitat is presented in Table 7. While the ANOVA indicated significant differences between mean abundance by date, mean abundance showed no temporal pattern of differences that would suggest impacts due to anthropogenic influences (Figure 5). The fifteen 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 November 2010 fell within a group of data that were not significantly different, suggesting that no change in fish abundance has taken place over the 19-year monitoring period.

Mean abundance (Figure 6) was not significantly different at the 18" Pipe (466.6 individuals per transect) and 12" Pipe South (428.3 individuals per transect) sites. Mean abundance at the remaining four locations were not significantly different (303.6 – 324 individuals per transect). Abundance was significantly higher at the deep reef slope habitat (405.1 individuals per transect) than at the other two habitats (330.8 – 334.5 individuals per transect).

A summary of the post-hoc S-N-K test for pair-wise comparisons on numbers of species per transect for date, location and habitat is presented in Table 8. While the ANOVA indicated significant differences between mean number of species by date, mean species per transect showed no pattern of differences that would suggest impacts due to anthropogenic influences (Figure 7). Mean number of species per transect ranged from 24.2 to 33.2, and data for surveys conducted between May 1992 and November 2010 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 19-year monitoring period. Mean species per transect (Figure 8) were similar and significantly higher at the 18" Pipe site (32.2 species per transect) and 12" Pipe

South site (30.8 species per transect). The fewest species were seen at the Wawaloli site (23.3 species per transect). Significantly more species were seen in the reef slope habitat (28.9 species per transect) than in the reef bench habitat (27.5 species per transect) or the shallow boulder habitat (28.0 species per transect).

A summary of the post-hoc S-N-K test for pair-wise comparisons on mean biomass per transect for date, location and habitat is presented in Table 9. While the ANOVA indicated significant differences between mean biomass by date, mean biomass showed no pattern of differences that would suggest impacts due to anthropogenic influences (Figure 9). A single survey in November 1998 (Figure 10) had biomass levels higher than the remaining 26 surveys, but this high level is likely due to the presence of large schools of fish within the transect area. Biomass for surveys conducted between May 1992 and November 2010 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 18-year monitoring period. Mean biomass (Figure 10) was significantly highest at the 12" Pipe South site (287.9 g/m^2). Biomass at the 18" Pipe, 12" Pipe North and NPPE sites were lower and not significantly different (175.4 – 232.1 g/m^2). Biomass at Wawaloli and Ho'ona Bay were lowest (141.5 – 156.9 g.m^2). Biomass was significantly higher at the shallow boulder habitat (244.9 g/m^2) than at the other two habitats (166.6 – 202.1 g/m^2).

Table 7. Summary of three-way analysis of variance (ANOVA) of number of individuals per transect for surveys conducted off NELHA from 1992 - 2010. All pair-wise comparisons tested by Holm-Sidak method. For each ANOVA factor (date, location and biotope), data which are not significantly different are grouped by letter.

Date	Mean	group							
May-92	318.2				d	e	f	g	h
Oct-92	341.2		b	c	d	e	f	g	h
May-93	295.3						f	g	h
Dec-93	389.4	a	b	c	d	e	f	g	h
May-94	351.6		b	c	d	e	f	g	h
Jun-94	359.1	a	b	c	d	e	f	g	h
Oct-94	379.7	a	b	c	d	e	f	g	h
Mar-95	278.9							g	h
Jun-95	477.2	a	b						
Nov-95	241.2								h
Jun-96	297.2						f	g	h
Dec-96	284.6						f	g	h
May-97	302.4				d	e	f	g	h
Dec-97	473.7	a	b	c					
Jun-98	301.7					e	f	g	h
Nov-98	510.6	a							
May-99	320.6			c	d	e	f	g	h
Dec-99	352.3		b	c	d	e	f	g	h
Jun-00	313.6				d	e	f	g	h
Nov-00	452.0	a	b	c	d	e			
May-01	359.5	a	b	c	d	e	f	g	h
Nov-01	286.3						f	g	h
May-02	364.3	a	b	c	d	e	f	g	h
Jul-05	249.6								h
Nov-05	376.8	a	b	c	d	e	f	g	h
Jul-06	465.1	a	b	c	d				
Jan-07	345.2		b	c	d	e	f	g	h
Dec-07	436.3	a	b	c	d	e	f		
Aug-08	452.7	a	b	c	d	e			
Oct-08	412.8	a	b	c	d	e	f	g	
May-09	283.1						f	g	h
Mar-10	370.9	a	b	c	d	e	f	g	h
Nov-11	331.5		b	c	d	e	f	g	h

Location	Mean		
Wawaloli	303.6		b
18-inch Pipe	466.6	a	
12-inch South	428.3	a	
12-inch North	307.3		b
NPPE Site	324.0		b
Ho'ona Bay	311.0		b

Biotope	Mean		
Shallow	330.8		b
Middle	334.5		b
Deep	405.1	a	

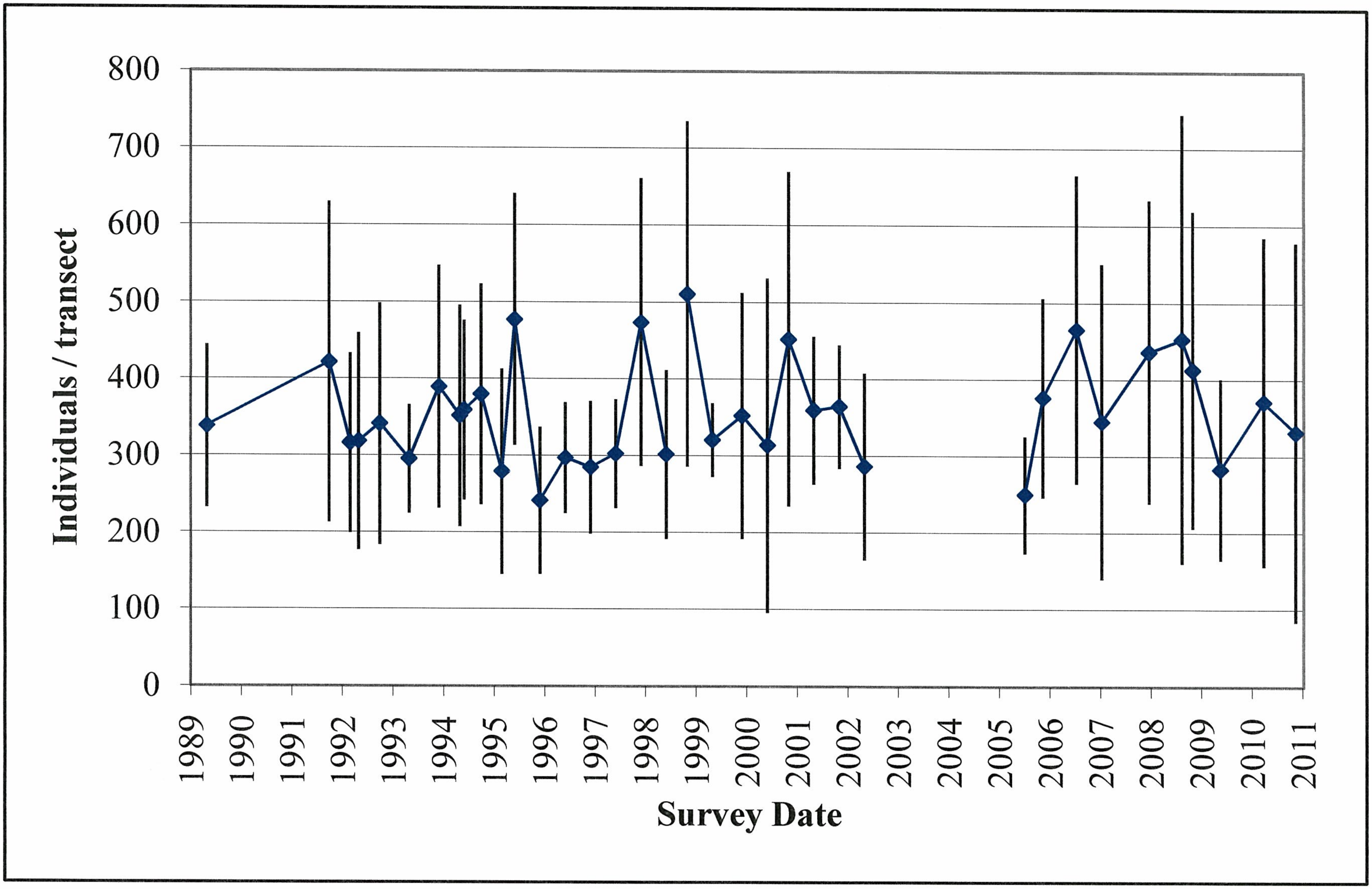

Figure 5. Plot of mean number of individuals (with standard deviation) per transect for each survey off NELHA from 1989 through 2010. Error bars +/- 1 standard deviation of the mean.

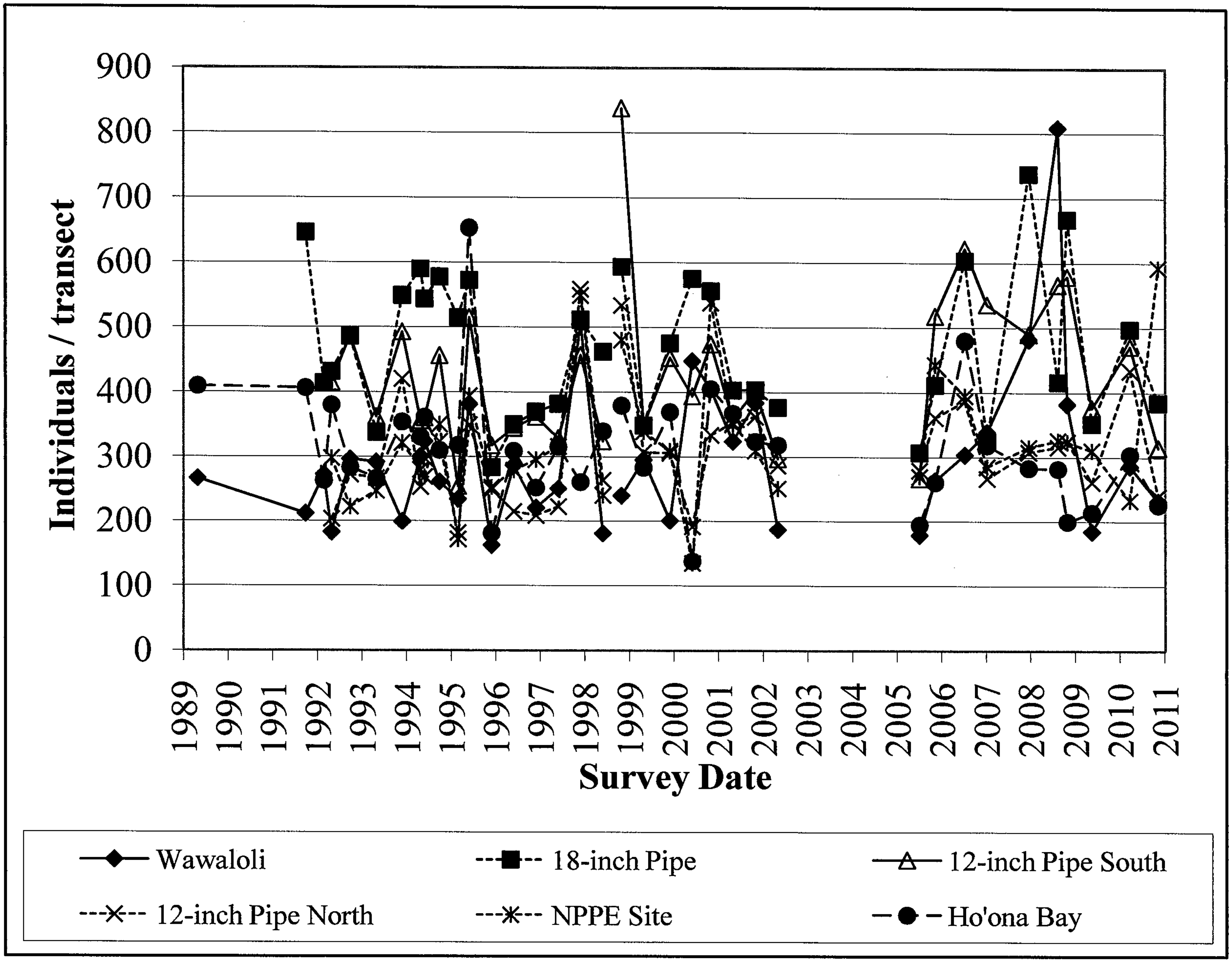

Figure 6. Plot of mean number of individuals per transect across the three biotopes at each of six survey locations off NELHA between 1989 and 2010.

Table 8. Summary of three-way analysis of variance (ANOVA) of number of species per transect for surveys conducted off NELHA from 1992 - 2010. 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	e		
Oct-92	28.7	a	b	c	d	e	f	g
May-93	27.1		b	c	d	e	f	g
Dec-93	29.9	a	b	c	d	e		
May-94	28.8	a	b	c	d	e	f	g
Jun-94	29.8	a	b	c	d	e		
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	e		
Nov-95	27.1		b	c	d	e	f	g
Jun-96	27.4		b	c	d	e	f	g
Dec-96	24.2							g
May-97	26.1			c	d	e	f	g
Dec-97	28.4	a	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		b	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	f	g
May-02	31.1	a	b	c				
Jul-05	24.6						f	g
Nov-05	25.3					e	f	g
Jul-06	26.3			c	d	e	f	g
Jan-07	25.9				d	e	f	g
Dec-07	29.2	a	b	c	d	e	f	g
Aug-08	29.3	a	b	c	d	e	f	
Oct-08	28.7	a	b	c	d	e	f	g
May-09	25.4				d	e	f	g
Mar-10	24.8					e	f	g
Nov-10	27.8		b	c	d	e	f	g

Location	Mean				
Wawaloli	23.3				d
18-inch Pipe	32.2	a			
12-inch South	30.8	a	b		
12-inch North	29.7		b		
NPPE Site	26.8			c	
Ho'ona Bay	26.1			c	

Biotope	Mean		
Shallow	28.0		b
Middle	27.5		b
Deep	28.9	a	

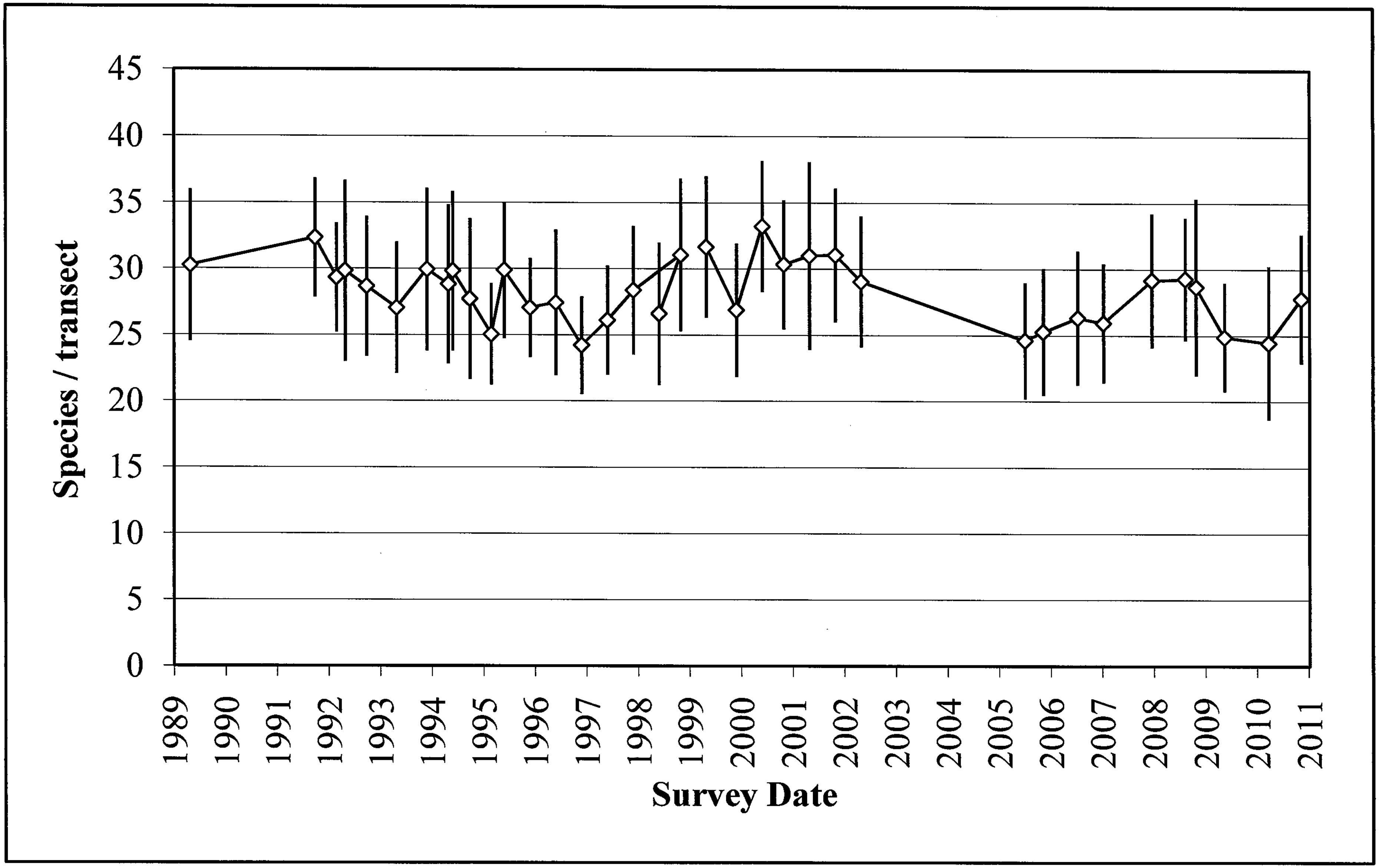

Figure 7. Plot of mean number of species (with standard deviation) per transect for each survey off the NELHA site from 1989 through 2010. Error bars +/- one standard deviation of the mean.

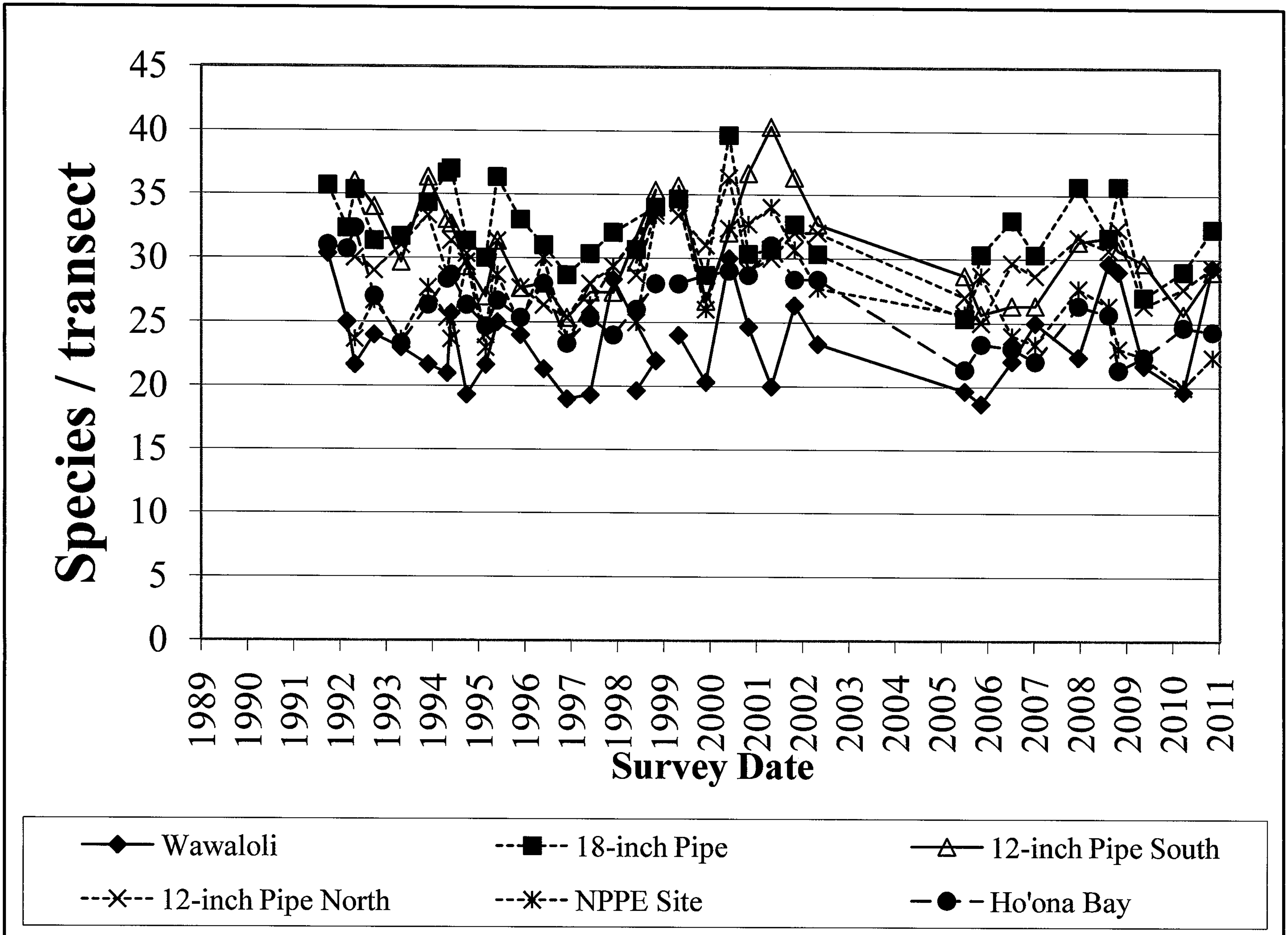

Figure 8. Plot of mean number of species per transect across the three biotopes at each of six survey locations off NELHA between 1989 and 2010.

Table 9. Summary of three-way analysis of variance (ANOVA) of biomass (g/m^2) per transect for surveys conducted off NELHA from 1992 - 2010. 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	f
Oct-92	177.7	a	b	c	d	e	f
May-93	154.1		b	c	d	e	f
Dec-93	289.8	a	b				
May-94	173.8	a	b	c	d	e	f
Jun-94	157.0	a	b	c	d	e	f
Oct-94	205.6	a	b	c	d	e	
Mar-95	193.4	a	b	c	d	e	f
Jun-95	185.7	a	b	c	d	e	f
Nov-95	148.3		b	c	d	e	f
Jun-96	137.5				d	e	f
Dec-96	187.6	a	b	c	d	e	f
May-97	183.7	a	b	c	d	e	f
Dec-97	408.1	a					
Jun-98	160.6	a	b	c	d	e	f
Nov-98	620.1	a					
May-99	170.9	a	b	c	d	e	f
Dec-99	261.2	a	b	c			
Jun-00	314.6	a					
Nov-00	284.6	a	b				
May-01	177.1	a	b	c	d	e	f
Nov-01	153.3		b	c	d	e	f
May-02	144.1		b	c	d	e	f
Jul-05	119.2					e	f
Nov-05	173.9	a	b	c	d	e	f
Jul-06	178.6	a	b	c	d	e	f
Jan-07	233.3	a	b	c			
Dec-07	213.5	a	b	c	d	e	
Aug-08	162.9	a	b	c	d	e	f
Oct-08	130.5				d	e	f
May-09	106.4						f
Mar-10	178.8	a	b	c	d	e	f
Nov-11	135.6				d	e	f

Location	Mean			
Wawaloli	156.9			c
18-inch Pipe	232.1	a	b	
12-inch South	287.9	a		
12-inch North	221.1		b	
NPPE Site	175.4		b	c
Ho'ona Bay	141.5			c

Biotope	Mean			
Shallow	244.9	a		
Middle	166.6			c
Deep	202.1		b	

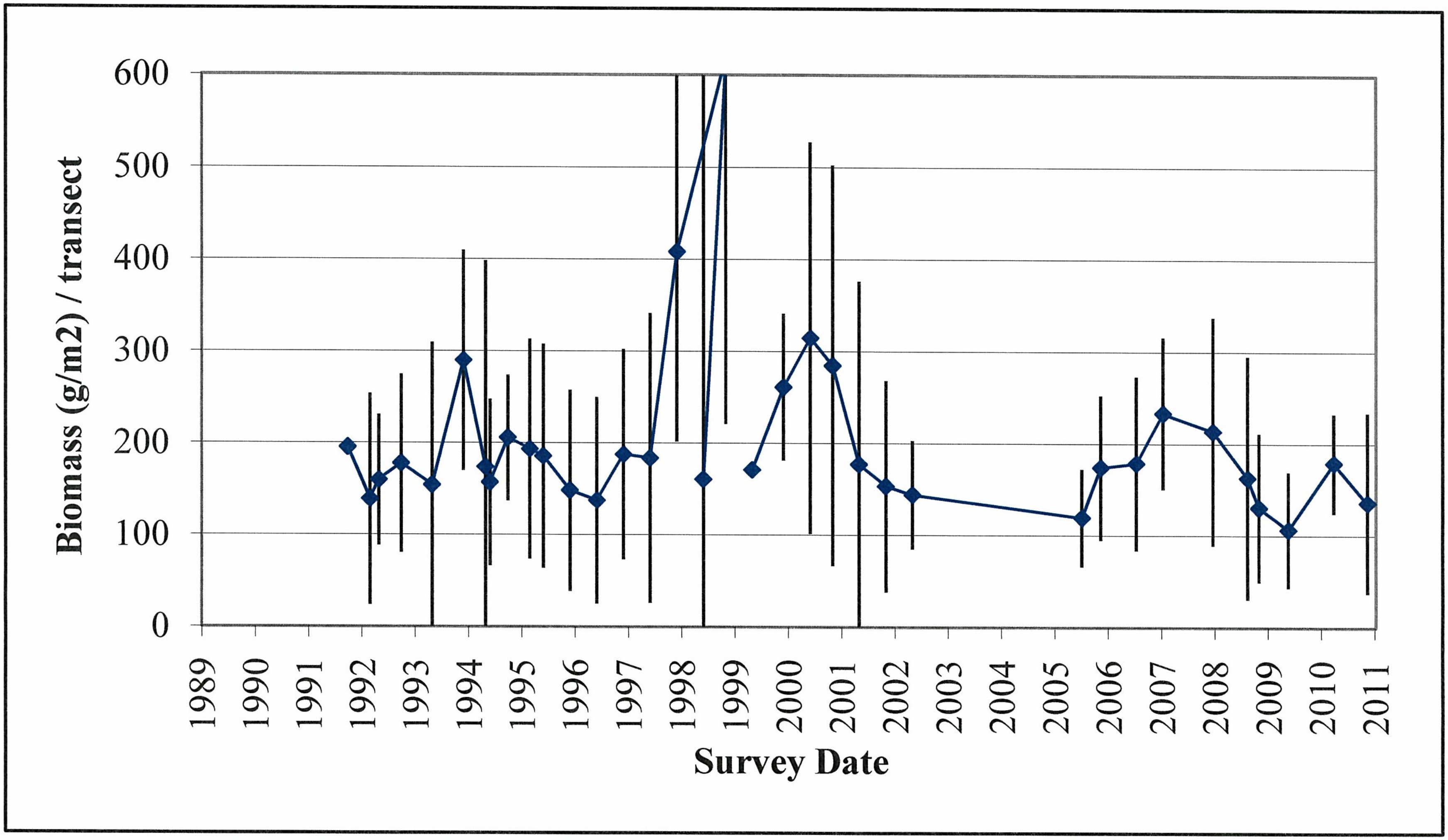

Figure 9. Plot of mean (standard deviation) biomass per transect for each survey off the NELHA site from 1992 through 2010. Error bars +/- one standard deviation of the mean.

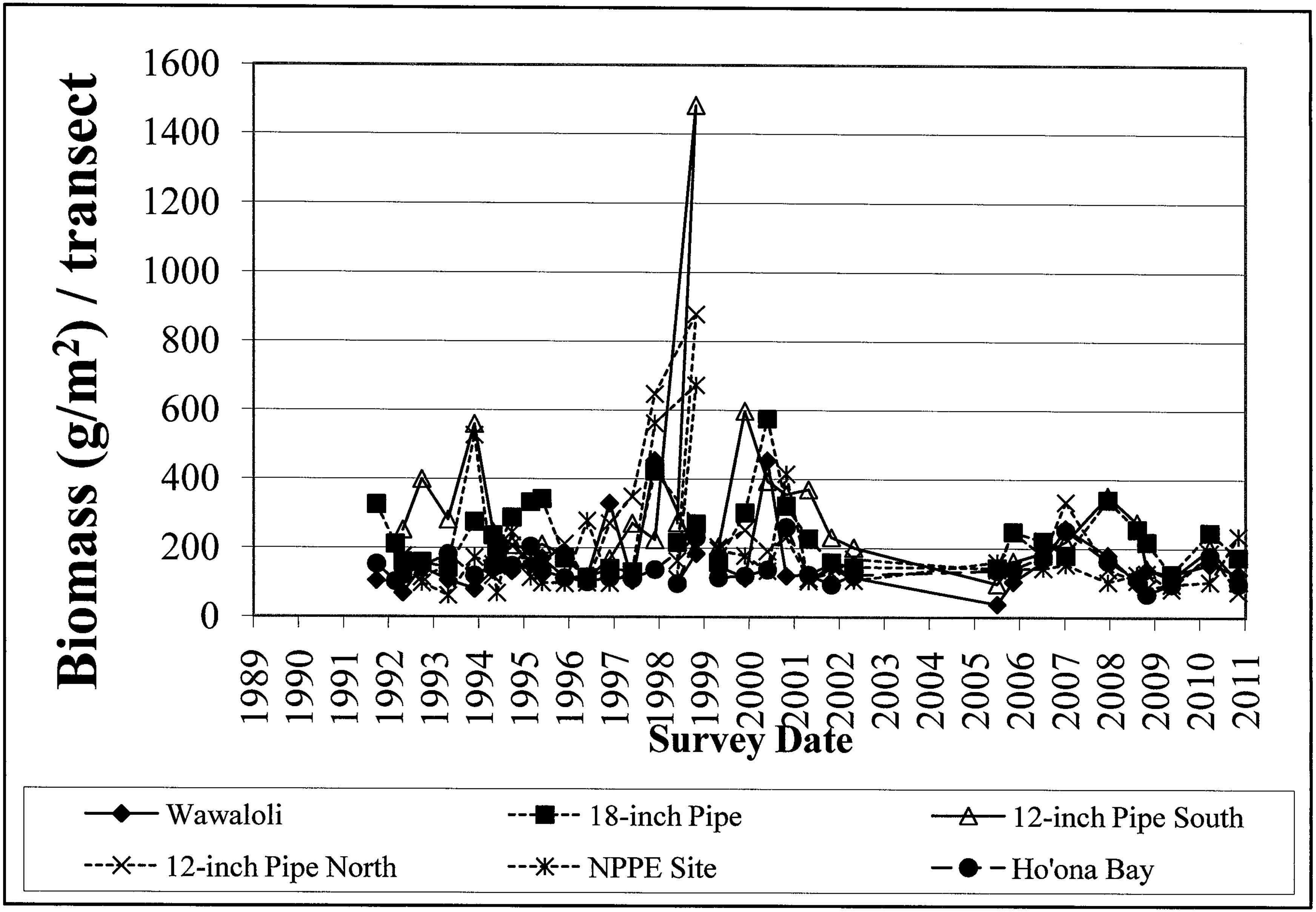

Figure 10. Plot of the estimated biomass (g/m2) on transects across the three biotopes at each of six survey locations off NELHA between 1989 and 2010.

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 this survey, a school of 'opelu numbering more than 1,000 passed through the transect area of the reef bench at the NPPE site . In addition, we observed that the fish communities in the opposite direction from the transect direction (e.g., to the south, where our transect ran to the north) were often visually 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 nineteen 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 2010.
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	Mar-95
N-1	*Melania* (mean)	75	44	40	43	43	43	51	52	56	82	46
	Theodoxus cariosa											
	Halocaridina rubra (mean)										0	0
	Macrobrachium grandimanus									2	0	0
	Palaemon debilis											
	Metopograpsus											
	Poecilia	x	x	x	x	x	x	x	x	x	x	x
N-2	*Melania*	36	42	72	85	41	22	27	31	28	19	31
	Halocaridina rubra (mean)	22	15	3	0	72	0	0	0	4	0	42
	Metabataeus lohena											
	Poecilia	-	-	-	x	-	x	x	x	x	x	-
N-3	*Melania* (mean)	42	7	30	23	15	15	19	24	30	41	24
	Theodoxus cariosa											
	Halocaridina rubra (mean)	8	14	0	0	26.5	0	0	1	0	0	0
	Metabataeus lohena											
	Palaemon debilis	0	0	0	1	1	2	1	2	1	1	2
	Macrobrachium lar									1	0	1
	Poecilia	-	-	x	x	-	x	x	x	x	x	x
N-4	*Melania* (mean)	77	2	5	9	48	26	23	33	38	22	23
	Halocaridina rubra (mean)	12	11.5	0	0	21.5	0	0	0	0	0	0
	Metabataeus lohena											
	Macrobrachium grandimanus											5
	Poecilia	-	-	x	x	-	x	x	x	x	x	x
N-5	*Melania* (mean)	3	3	22	5	5	7	20	23	17	40	20
	Theodoxus cariosa											
	Halocaridina rubra (mean)	0	0	0	0	41	0	0	0	0	0	0
	Metabataeus lohena											
	Macrobrachium grandimanus											3
	Metopograpsus											
	Poecilia	-	-	x	x	-	x	x	x	x	x	x
N-6	*Halocaridina rubra* (mean)											

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 2010. Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

Pond	Species	Jun-95	Dec-97	Jun-98	Nov-98	May-99	Dec-99	Jun-00	Nov-00	May-01	Nov-01	May-02
N-1	*Melania* (mean)	57	53	47	45	38	52	40	45	33	30	38
	Theodoxus cariosa			6	2	6	3	2	4	3	2	9
	Halocaridina rubra	0	0	0	0	0	0	0	0	0	0	0
	Macrobrachium grandimanus	1	0	0	0	0	0	0	0	0	0	0
	Palaemon debilis	2					0	0	0	0	0	0
	Metopograpsus		4	7	9	6	8	9	5	4	6	5
	Poecilia	x	x	x	x	x	x	x	x	x	x	x
N-2	*Melania*	28	33	44	56	47	47	39	51	79	66	72
	Halocaridina rubra	0	0	0	0	0	0	1	2	3	4	5
	Poecilia	x	x	x	x	x	x	x	x	x	x	x
N-3	*Melania* (mean)	29	33	38	22	28	27	34	24	22	25	17
	Theodoxus cariosa										0	0
	Halocaridina rubra (mean)	0	0	0	0	0	0	0	0	0	0	0
	Metabataeus lohena										0	0
	Palaemon debilis	3	0	0	0	0	0	0	0	0	0	0
	Macrobrachium lar	0	0	0	0	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	x	x	x	x	x
N-4	*Melania* (mean)	24	22	27	28	23	33	23	24		23	26
	Halocaridina rubra (mean)	0	0	0	0	0	0	0	0		0	0
											0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0		0	0
	Poecilia	x	x	x	x	x	x	x	x		x	x
N-5	*Melania* (mean)	23	23	35	21	18	18	19	19	17	15	20
	Theodoxus cariosa										0	0
	Halocaridina rubra	0	0	0	0	0	0	0	0	0	8	0
	Metabataeus lohena										0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	1	0	0
	Metopograpsus		3	5	5	4	5	5	5	7	5	6
	Poecilia	x	x	x	x	x	x	x	x	x	x	x
N-6	*Halocaridina rubra* (mean)											

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	Jul-05	Nov-05	Jul-06	Jan-07	Dec-07	Aug-08	Oct-08	May-09	Mar-10	Nov-10
N-1	*Melania* (mean)	53	43	0	0	0	4	0	0	0	0
	Theodoxus cariosa	1	3	0	1	0	0	0	0	0	0
	Halocaridina rubra	0	0	0	0	0	100	200+	200+	100	150
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0
	Palaemon debilis	0	0	0	0	0	0	0	0	0	0
	Metopograpsus	1	1	0	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	-	-	-	-	-	-
N-2	*Melania*	0	0	0	0	0	3	0	0	0	0
	Halocaridina rubra	0	0	0	0	0	10	40	35	35	50
	Metabataeus lohena								2		
	Poecilia	x	x	x	x	-	-	-	-	-	-
N-3	*Melania* (mean)	60	35	2	0	0	2	0	0	0	0
	Theodoxus cariosa	4	0	0	0	0	0	0	0	0	0
	Halocaridina rubra (mean)	0	0	0	0	0	22	200+	200+	200+	200+
	Metabataeus lohena	0	0	2	0	0	0	0	0	0	0
	Palaemon debilis	0	0	0	0	0	0	0	0	0	0
	Macrobrachium lar	0	0	0	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	-	-	-	-	-	-
N-4	*Melania* (mean)	100+	100+	100+	100+	dry	2	0	0	0	0
	Halocaridina rubra (mean)	0	0	40	0		20	100+	10	40	120
	Metabataeus lohena	0	0	10	0		0	0	0	0	0
	Macrobrachium grandimanus	0	0	0	0		0	0	0	0	0
	Poecilia	x	x	-	-		-	-	-	-	-
N-5	*Melania* (mean)	0	0	10	10	0	4	0	0	0	0
	Theodoxus cariosa	3	0	0	0	0	0	0	0	0	0
	Halocaridina rubra	0	0	0	0	0	80	170	150	50	125
	Metabataeus lohena	0	0	5	0	0	0	0	0	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0
	Metopograpsus	0	0	0	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	-	-	-	-	-	-
N-6	*Halocaridina rubra* (mean)								-	-	10

Appendix A.2. Summary of the census data of the anchialine pools of the southern complex (S-1 - S-9) sampled between 1998 and 2010.
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	Mar-95
S-1	*Halocaridina rubra*	56	29	31	61	29	49	37	47	52	84	61
	Metabataeus lohena											
	Macrobrachium grandimanus	0	0	1	1	0	0	1	2	0	0	0
	Amphipoda	0	0	0	6	19	12	15	21	18	26	23
	Poecilia											
S-2	*Halocaridina rubra* (mean)	71	31	40	14	34	54	Dry	Dry	Dry	42	Dry
	Metabataeus lohena											
	Amphipoda	185	32	6	2	9	2				9	
	Poecilia											
S-3	*Halocaridina rubra* (mean)	38	21	43	64	56	Dry	49	37	86	94	Dry
	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* (mean)	9	42	6	9	7	Dry	Dry	21	Dry	39	Dry
	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	0
	Macrobrachium grandimanus	0	0	0	0	0	1	0	1	4	1	2
	Amphipoda	94	65	48	27	34	7	0	0	0	0	0
	Poecilia											
S-6	*Halocaridina rubra*	3	3	1	1	7	5	4	7	4	23	Dry
	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	77
	Metabataeus lohena											
	Macrobrachium grandimanus	0.5	0.5	0.5	0.75	1	0.5	1	2	1	1	1
	Amphipoda	11	17	12	10	13	9	10	18	23	39	25
	Poecilia											
S-8	*Halocaridina rubra* (mean)				65	72	81	71	68	81	80	52
	Metabataeus lohena											
	Macrobrachium grandimanus				0.5	0.75	1	1	2	1	1	1
	Poecilia											
S-9	*Halocaridina rubra*					3	Dry	Dry	Dry	Dry	14	Dry
	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 2010.
Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

Pond	Species	Jun-95	Dec-97	Jun-98	Nov-98	May-99	Dec-99	Jun-00	Nov-00	May-01	Nov-01	May-02
S-1	*Halocaridina rubra*	57	73	49	81	63	65	35	35	55	40	35
											0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0	0
	Amphipoda	27	24	23	14	12	14	16	9	11	12	11
	Poecilia											
S-2	*Halocaridina rubra*	39	Dry	62	Dry	52	Dry	6	Dry	Dry	35	9
	Metabataeus lohena										0	0
	Amphipoda			12		14		0			4	3
S-3	*Halocaridina rubra*	78	Dry	14	Dry	29	8	17	Filled	Filled	45	55
	Metabataeus lohena	2		0		0	0	0			0	0
	Amphipoda	21		17		10	12	9			6	5
S-4	*Halocaridina rubra*	16	Dry	0	Dry	0	15	31	Dry	Dry	31	12
											0	0
	Amphipoda	3		2		3	4	8			4	7
	Poecilia											
S-5	*Halocaridina rubra*	0	0	0	0	0	0	0	0	35	0	0
	Macrobrachium grandimanus	1	0	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0	0
	Poecilia											
S-6	*Halocaridina rubra*	17	Dry	12	Dry	6	Dry	4	Dry	Dry	0	12
	Metabataeus lohena										0	0
	Amphipoda	0		2		3		0			0	2
	Amphipod (white)	0		0		0		0			0	0
S-7	*Halocaridina rubra*	121	86	79	87	59	43	41	56	47	60	0
	Metabataeus lohena										0	0
	Macrobrachium grandimanus	3	0	1	2	3	2	1	1	1	1	0
	Amphipoda	29	21	31	20	18	14	22	6	9	8	0
	Poecilia											X
S-8	*Halocaridina rubra*	61	55	57	63	72	30	38	48	80	81	45
	Metabataeus lohena										0	0
	Macrobrachium grandimanus	1	0	0	0	1	0	0	0	0	0	0
S-9	*Halocaridina rubra*	9	Dry	12	Dry	10	4	1	7	Dry	20	3
											0	0

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 2010. Non-native species (the introduced fish *Poecilia*) are denoted as present (x) or absent (-). (mean) denotes the average of multiple quadrat counts.

Pond	Species	Jul-05	Nov-05	Jul-06	Jan-07	Dec-07	Aug-08	Oct-08	May-09	Mar-10	Nov-10
S-1	*Halocaridina rubra*	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	2	0	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
	Poecilia	X	X	X	X	X	X	X	X	X	X
S-2	*Halocaridina rubra*	65	150	40	200	0	0	100	17	10	10
	Metabataeus lohena	2	5	6	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
						X	X	-	-	-	-
S-3	*Halocaridina rubra*	85	185	100	100	0	0	200	12	20	0
	Metabataeus lohena	6	8	2	0	0	0	1	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
						X	X	-	-	-	X
S-4	*Halocaridina rubra*	0	4	60	0	8	0	5	17	85	15
	Metabataeus lohena	0	0	3	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
	Poecilia	X	X	-	X	-	-	-	-	-	-
S-5	*Halocaridina rubra*	0	0	0	0	3	0	0	0	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
	Poecilia	X	X	X	X		X	X	X	X	X
S-6	*Halocaridina rubra*	4	0	1	50	dry	5	20	0	0	50
	Metabataeus lohena	1	0	0	0		0	1	0	0	0
	Amphipoda	0	0	0	0		0	0	0	0	0
	Amphipod (white)	0	0	0	0		0	0	0	0	0
S-7	*Halocaridina rubra*	0	0	0	0	0	0	0	0	0	0
	Metabataeus lohena	3	0	0	0	0	0	0	0	0	0
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0	0
	Poecilia	X		X	X	X	X	X	X	X	X
S-8	*Halocaridina rubra*	30	115	50	50	0	0	75	50	20	25
	Metabataeus lohena	3	30	6	1	0	0	15	5	2	2
	Macrobrachium grandimanus	0	0	0	0	0	0	0	0	0	1
						X	X	-	-	-	-
S-9	*Halocaridina rubra*	2	0	50	80	0	0	0	30	0	30
	Metabataeus lohena	0	0	3	0	0	0	0	2	0	1
						X	X	-	-	-	-

APPENDIX B

MARINE BENTHIC COMMUNITY SURVEY RESULTS

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in November 2010. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

Site	**Average**	Hoona Bay			NPPE			12" Pipe N		
Depth		Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep
Number of quadrats		10	10	10	10	10	10	10	10	10
Total points		2000	2000	2000	2000	2000	2000	2000	2000	2000
TOTAL CORAL (%)	46.4	44.8	39.9	59.6	41.1	64.2	75.2	35.3	45.8	62.1
Shannon-Weaver Index	0.9	0.82	0.82	1.02	0.61	0.73	0.88	1.00	1.26	0.91
Species	7.0	7	7	7	7	7	7	7	7	7
Porites lobata	30.5	30.9	30.6	34.0	31.5	49.4	51.7	18.7	21.5	43.9
Porites compressa	2.6	0.2	3.2	20.0	0.0	0.5	16.8	0.0	0.0	2.3
Porites monticulosa	0.2	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.3
Pocillopora meandrina	8.7	11.5	4.0	0.2	9.0	9.3	3.9	12.7	12.0	11.1
Pocillopora eydouxi	1.0									
Montipora capitata	3.2	1.7	2.0	2.8	0.6	4.9	2.7	3.4	9.3	4.3
Montipora patula	0.3	0.2	0.1	0.1	0.0	0.2	0.1	0.1	2.1	0.3
Montipora incrassata	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0
Pavona varians	0.3	0.4	0.2	1.0	0.1		0.1		0.1	
Leptastrea purpurea	0.2	0.1						0.5	0.0	0.1
Palythoa sp.	0.1									
Anthelia edmondsoni	0.7									
Urchins	0.3									
Macroalgae	0.6									0.7
TOTAL CORAL (%)		44.8	39.9	59.6	41.1	64.2	75.2	35.3	45.8	62.1
Porites lobata		30.9	30.6	34.0	31.5	49.4	51.7	18.7	21.5	43.9
Porites compressa		0.2	3.2	20.0		0.5	16.8			2.3
Pocillopora meandrina		11.5	4.0	0.2	9.0	9.3	3.9	12.7	12.0	11.1
Species		5	5	6	3	5	5	4	5	6
Shannon-Weaver Index		0.82	0.82	1.02	0.61	0.73	0.88	1.00	1.26	0.91

Appendix B.1. Percent coverage for photo-quadrats taken along biota monitoring transects off NELHA in November 2010. Transect locations are shown in Figure 3. Data are results of 200 point analyses of digital photos of 0.6 x 1.0 m quadrats.

Site		12" Pipe S			18" Pipe			Wawaloli	
Depth	Shallow	Middle	Deep	Shallow	Middle	Deep	Shallow	Middle	Deep
Number of quadrats	10	10	10	10	10	10	10	10	10
Total points	2000	2000	2000	2000	2000	2000	2000	2000	2000
TOTAL CORAL (%)	30.0	41.1	37.4	59.3	44.5	37.5	35.5	47.2	34.7
Shannon-Weaver Index	0.92	0.91	1.12	1.01	1.01	0.92	1.02	0.00	0.90
Species	7	7	7	7	7	7	7	7	7
Porites lobata	17.8	23.9	22.0	41.1	27.0	21.7	21.0	38.2	24.9
Porites compressa	0.0	0.2	0.0	0.0	0.8	0.5	0.0	1.1	1.0
Porites monticulosa									
Pocillopora meandrina	9.5	14.2	10.2	8.5	12.1	12.9	9.4	3.1	3.2
Pocillopora eydouxi	0.0	0.2	2.5	0.4	0.0	0.0	0.0	0.8	5.2
Montipora capitata	2.6	2.6	1.7	5.1	4.0	2.5	3.7	4.1	0.5
Montipora patula	0.0	0.0	0.4	0.5	0.2	0.0	1.4	0.0	0.0
Montipora incrassata	0.3	0.1	0.6	3.9	0.0	0.0	0.0	0.0	0.0
Pavona varians			0.2		0.5				
Leptastrea purpurea									
Palythoa sp.				0.1					
Anthelia edmondsoni				1.3	1.9	0.6	0.2	0.2	0.1
Urchins						0.2		0.6	0.2
Macroalgae						1.1			0.1
TOTAL CORAL (%)	30.0	41.1	37.4	59.3	44.5	37.5	35.5	47.2	34.7
Porites lobata	17.8	23.9	22.0	41.1	27.0	21.7	21.0	38.2	24.9
Porites compressa		0.2			0.8	0.5		1.1	1.0
Pocillopora meandrina	9.5	14.2	10.2	8.5	12.1	12.9	9.4	3.1	3.2
Species	4	6	6	6	5	4	4	5	5
Shannon-Weaver Index	0.92	0.91	1.12	1.01	1.01	0.92	1.02	0.00	0.90

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. 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
WAWALOLI	Shallow	% CORAL	12.5	5.5	5.1	4.7	7.6	2.5	5	6.9	5.8
		% P.l.	10.8	4.4	2.9	1.9	5.7	1.3	2.8	3.0	3.8
		% P.c.							0.1		
		% P.m.	1.7	1.0	2.2	2.5	1.7	0.4	0.7	1.8	1.6
		Sp. #	2	4	2	3	4	4	8	6	5
		Sp. Div.	0.39	0.57	0.68	0.87	0.67	1.19	1.41	1.32	0.89
	Middle	% CORAL	1.7	23.6	10.8	12.1	17.7	8.7	14.9	23.3	15.6
		% P.l.	1.4	22.2	9.8	11.4	16.5	4.1	13.3	21.7	13.8
		% 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
		Sp. #	4	6	3	3	5	5	3	5	4
		Sp. Div.	0.57	0.27	0.37	0.23	0.33	0.99	0.41	0.32	0.47
	Deep	% CORAL	23.9	2.9	2.5	2.2	5.3	8.5	8.4	8.9	9.9
		% P.l.	14.7	2.5	2.2	1.5	2.9	3.6	6.3	7.1	7.5
		% 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
		Sp. #	3	3	3	5	4	7	4	3	3
		Sp. Div.	0.68	0.42	0.44	1.05	1.15	1.32	0.74	0.62	0.72
18" PIPE	Shallow	% CORAL	12.5	15.6	19.2	15.8	18.6	10.0	15.5	15.1	15.2
		% P.l.	5.8	2.8	5.2	6.4	4.9	4.1	6.1	3.8	6.7
		% P.c.									
		% P.m.	6.2	10.0	11.2	5.7	11.8	3.9	8.4	6.2	6.8
		Sp. #	4	7	5	6	3	5	5	5	5
		Sp. Div.	0.84	1.01	1	1.24	0.87	1.21	0.95	1.34	1.06
	Middle	% CORAL	14.3	13	9.1	13.1	11.8	16.0	17.3	13.2	23.0
		% P.l.	5.2	4.4	3.9	2.6	3.4	4.8	3.7	3.3	12.6
		% P.c.						0.3		0.5	
		% P.m.	8.5	8.0	3.2	8.9	6.0	5.9	10.7	6.9	6.4
		Sp. #	6	6	4	5	6	8	5	6	4
		Sp. Div.	0.84	0.85	1.15	0.89	1.17	1.56	1.06	1.27	1.04
	Deep	% CORAL	12.4	7.4	5.5	16.2	10.7	12.9	12..9	8.4	12.5
		% P.l.	9.2	6.0	4.0	13.3	8.0	11.9	9.3	7.7	11.8
		% P.c.	2.5	1.3	1.3	1.3	2.4	0.6	2.7	0.4	0.2
		% P.m.	0.1	0.5	0.1		0.2	0.2		0.3	0.4
		Sp. #	6	4	4	3	4	5	3	3	4
		Sp. Div.	0.58	0.54	0.72	59	0.67	0.36	0.75	0.34	0.27

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. 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
12" PIPE SOUTH	Shallow	% CORAL		8.9	8.7	8.5	6.5	6.5	9.4	12	10.7
		% P.l.		1.4	1.4	2.0	2.4	1.9	2.5	4.1	2.2
		% P.c.		0.3				0.1			
		% P.m.		6.9	7.1	6.6	4.1	3.4	5.1	7.5	7.7
		Sp. #		5	4	2	2	4	4	3	4
		Sp. Div.		0.70	0.56	0.54	0.66	1.04	1.10	0.77	0.81
	Middle	% CORAL		20.2	13.7	21.2	16.8	20.5	18.8	19.2	23.4
		% P.l.		8.5	7.3	14.3	9.9	12.6	7.8	6.9	12.9
		% P.c.									
		% P.m.		7.2	3.6	4.6	2.8	5.1	5.2	8.5	6.1
		Sp. #		6	6	6	5	4	5	4	5
		Sp. Div.		1.28	1.28	0.95	1.21	1.01	1.36	1.14	1.17
	Deep	% CORAL		15.0	17.9	22.2	31.0	22.9	14.3	30.8	28.9
		% P.l.		11.5	14.1	16.8	19.1	17.9	10.1	18.9	18.3
		% P.c.		0.5	0.2	0.9	0.7	0.4	1	1.4	
		% P.m.		0.9	1.2	2.3	2.8	1.3	0.8	2.8	4.4
		Sp. #		6	6	6	9	7	7	6	4
		Sp. Div.		0.86	0.78	0.84	1.22	0.83	1.00	1.20	1.04
12" PIPE NORTH	Shallow	% CORAL		8.3	4.5	7.6	14.8	10.0	10.2	9.6	7.5
		% P.l.		3.2	2.2	2.5	5.0	3.0	3.3	3.4	4.6
		% P.c.									
		% P.m.		4.3	2.3	3.1	6.3	3.5	3.9	5.1	1.5
		Sp. #		7	3	6	6	6	5	4	5
		Sp. Div.		1.02	0.78	1.30	1.33	1.58	1.40	1.03	1.13
	Middle	% CORAL		13.8	12.5	14.1	17.8	20.8	23.7	22.7	19.1
		% P.l.		9.2	9.9	7.1	7.0	9.2	9.0	10.4	9.3
		% 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
		Sp. #		6	6	6	7	7	6	5	4
		Sp. Div.		0.95	0.79	1.26	1.48	1.47	1.39	1.18	1.10
	Deep	% CORAL		17.4	13.2	17.7	27.1	21.8	19.4	22.5	30.4
		% P.l.		14.1	10.5	13.9	15.3	16.4	14.0	14.4	24.8
		% P.c.		1.2	0.3	0.8	0.6	0.4	0.2	0.5	0.8
		% P.m.		0.1	0.5	0.5	3.6	0.8	1.0	2.0	0.8
		Sp. #		6	4	6	5	5	6	5	5
		Sp. Div.		0.70	0.67	0.77	1.13	0.75	0.87	1.07	0.67

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. 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
NPPE	Shallow	% CORAL		18.6	21.7	20.6	25.6	22.9	26.4	33.7	24.5
		% P.l.		6.9	6.1	5.9	9.4	7.4	8.7	11.0	8.2
		% P.c.									
		% P.m.		8.8	10.2	11.8	10.7	11.8	15.0	13.6	9.6
		Sp. #		6	7	6	5	7	5	6	6
		Sp. Div.		1.21	1.43	1.13	1.25	1.25	0.99	1.40	1.45
	Middle	% CORAL		29.5	33.9	36.6	51.3	44.1	45.3	47.2	51.7
		% P.l.		10.4	16.6	14.1	18.7	19.3	22.1	23	28.1
		% P.c.		0.3	0.3	1.6	0.8		2.8	1.6	1.7
		% P.m.		17.6	15.8	18.8	26.2	22.0	17.0	19.1	19.7
		Sp. #		6	7	6	7	5	5	6	6
		Sp. Div.		0.88	0.9	1.05	1.13	0.95	1.13	1.09	0.98
	Deep	% CORAL		28.0	38.3	45.5	40.5	47.7	40.5	60.3	58.4
		% P.l.		23.2	30.1	34.2	32.4	41.1	31.6	47.7	41.7
		% P.c.		1.9	1.4	3.5	1.4	1.7	3.8	2.1	5.4
		% P.m.		1.5	3.0	3.8	4.4	2.1	1.0	5.7	5.5
		Sp. #		6	7	6	6	5	5	6	6
		Sp. Div.		0.68	0.83	0.91	0.74	0.56	0.78	0.78	0.96
HO'ONA BAY	Shallow	% CORAL	15.1	15.1	24.8	12.0	7.5	9.0	6.8	10.9	10.8
		% P.l.	12.3	10.0	18.3	7.5	4.8	7.2	4.7	6.2	9.1
		% 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
		Sp. #	3	4	5	6	3	5	6	3	2
		Sp. Div.	0.55	0.79	0.85	0.87	0.90	0.73	1.02	0.98	0.44
	Middle	% CORAL	42.1	30.8	27.8	30.7	26.0	38.1	18.6	25.7	28.7
		% P.l.	37.4	25.4	22.1	22.8	21.3	35.2	13.1	23.0	24.9
		% P.c.	4.1	3.5	5.0	6.8	2.3	2.1	4.1	1.1	3.5
		% P.m.	0.6	1.7	0.6	1.0	2.3	0.3	1.2		0.1
		Sp. #	3	4	3	3	4	6	5	4	4
		Sp. Div.	0.39	0.58	0.57	0.66	0.61	0.35	0.81	0.44	0.43
	Deep	% CORAL	34.7	39.1	35.1	45.9	40.8	55.0	41.5	49.0	46.3
		% P.l.	12.5	20.0	12.7	18.8	18.7	18.9	19.2	20.8	23.3
		% P.c.	20.0	18.0	21.7	25.3	19.9	35.2	19.1	25.3	21.8
		% P.m.	0.5	0.3	0.1	0.3	1.1	0.1	0.7	0.4	0.3
		Sp. #	7	5	5	6	4	5	7	5	6
		Sp. Div.	0.93	0.83	0.76	0.86	0.90	0.74	1.02	0.92	0.82

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	May-95	Nov-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99
WAWALOLI	Shallow	% CORAL	5.7	9.4	9.5	5.9	12.7	24.3	30.2	19.4	16.9
		% P.l.	2.9	6.4	5.7	1.4	9.6	11.3	17.8	7.6	8.1
		% P.c.									0.6
		% P.m.	1.9	2.6	2.7	4.2	2.8	12.5	9.9	11.0	5.3
		Sp. #	4	5	6	5	6	4	4	4	6
		Sp. Div.	1.1	0.81	1.06	0.76	0.65	0.79	0.93	0.85	1.27
	Middle	% CORAL	15.9	20.5	13.2	12.4	19.3	32.0	37.9	35.5	23.9
		% P.l.	14.2	17.9	10	10.2	16.1	20.6	21.7	16.5	11.4
		% P.c.				0.1				0.6	0.3
		% P.m.	1.1	2.4	1.9	0.6	2.6	7.0	11.8	13.7	9.1
		Sp. #	3	5	6	6	6	4	6	7	5
		Sp. Div.	0.41	0.43	0.85	0.72	0.56	0.98	1.03	1.16	1.13
	Deep	% CORAL	14.2	10.3	4.6	7.6	13.8	13.9	15.1	32.0	22.7
		% P.l.	8.2	9.8	1.4	4.9	4.2	7.7	7	19.7	10.4
		% P.c.		0.6	0.6	0.8		0.6	1.7	0.9	1.5
		% P.m.	4.8	0.1	2.5	1.9	9.3	5.3	4.5	10.8	8.9
		Sp. #	5	5	5	3	3	4	5	5	4
		Sp. Div.	0.94	0.26	1.08	0.86	0.7	0.91	1.25	0.85	1.11
18" PIPE	Shallow	% CORAL	24.5	24.7	19.7	21.6	22.9	35.2	54.5	49.8	36.8
		% P.l.	7	5.3	11.6	10.4	16.6	14.5	21.8	17.7	17.9
		% P.c.								0.8	
		% P.m.	9.3	13.1	5.5	10.7	3.9	15.7	20.08	26.2	13.8
		Sp. #	6	7	6	5	5	4	5	5	5
		Sp. Div.	1.44	1.28	1.1	0.81	0.85	1.03	1.26	1.05	1.11
	Middle	% CORAL	20.4	22.9	22.3	19.3	21.7	39.6	53.5	44.9	44.9
		% P.l.	8.6	5	7.5	7.6	6.9	12.2	15.5	20.0	19.2
		% P.c.	0.4	0.3	0.1						
		% P.m.	9.0	16.2	13.7	10.5	13.1	23.5	25.8	18.9	20.9
		Sp. #	5	7	6	5	6	6	5	5	5
		Sp. Div.	1.13	0.87	0.86	0.92	0.94	1.03	1.22	1.10	1.03
	Deep	% CORAL	4.3	7.7	7.2	8.2	5.2	18.9	22.0	22.6	12.6
		% P.l.	2.4	2.5	3.5	2.8	3.3	8.0	7.7	10.6	3.5
		% P.c.	0.7	0.1	0.3				3.7	1.1	0.1
		% P.m.	0.9	4.9	0.8	2.8	1.3	9.9	10.4	10.1	8.7
		Sp. #	4	7	5	3	4	3	4	7	5
		Sp. Div.	1.13	0.87	1.13	1.1	1	0.86	1.06	1.02	0.75

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	May-95	Nov-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99
12" PIPE SOUTH	Shallow	% CORAL	5.9	14.1	24.9	25.1	21.1	31.8	15.0	21.6	13.2
		% P.l.	1.3	6.3	11.7	15.2	12.3	17.3	3.5	7.8	7.5
		% P.c.									
		% P.m.	4.6	6.6	10.8	9.2	7.5	12.2	7.7		4.7
		Sp. #	2	5	5	4	5	4	6	6	3
		Sp. Div.	0.53	1.01	0.99	0.78	0.9	0.92	1.27	0.93	0.88
	Middle	% CORAL	17.6	22.6	17	16.9	19.8	42.7	42.2	50.9	36.9
		% P.l.	5.1	8.6	9.2	6.5	6.8	12.9	15.0	32.9	18.8
		% P.c.				0.1			1.4		
		% P.m.	7.5	12.8	7.5	9.8	11.7	26.2	20.7		13.1
		Sp. #	5	5	4	5	5	6	5	4	4
		Sp. Div.	1.27	0.9	0.79	0.82	0.91	0.95	1.12	0.77	1.05
	Deep	% CORAL	26.1	38.6	24	30.4	37.1	50.4	75.6	68.2	36.3
		% P.l.	16.7	19.8	9.5	8.9	12.3	15.5	28.9	23.1	15.9
		% P.c.	0.4	1.1	1	0.5	0.2	0.5	1	1.1	1.4
		% P.m.	4.6	14.8	12.6	19.6	22.3	27.3	35.3	35.7	5
		Sp. #	6	6	6	5	6	6	7	6	7
		Sp. Div.	1.08	1.09	1	0.88	0.91	1.17	1.16	1.12	1.41
12" PIPE NORTH	Shallow	% CORAL	15.1	14.3	10.7	7.8	12.5	35.9	32.0	36.2	27.2
		% P.l.	3.5	6.6	5.2	2.8	2	9.7	11.9	10.0	6.6
		% P.c.							0.2	0.2	
		% P.m.	8.1	6.5	3.8	4.3	9.5	22.1	18.7	22.9	20.2
		Sp. #	7	6	5	5	5	3	5	4	4
		Sp. Div.	1.35	1.02	1.19	0.99	0.79	0.90	0.85	0.88	0.64
	Middle	% CORAL	16.2	15.6	25.6	14.2	20	29.8	45.9	41.5	53.0
		% P.l.	10.1	9.9	17.5	8.9	13.2	14.8	23.9	22.5	15.7
		% P.c.		2.2	0.1		0.3	2.2			1.2
		% P.m.	4.3	5.2	7.6	4.9	6.4	12.1	16.1	14.4	31.1
		Sp. #	6	4	6	5	6	4	4	4	7
		Sp. Div.	1.01	0.78	0.72	0.79	0.76	0.99	1.04	0.95	1.09
	Deep	% CORAL	29.9	10.8	17.5	22.6	17.1	40.6	63.6	47.3	58.1
		% P.l.	23.9	4.2	12.2	13.8	9.5	23.5	32.0	26.6	36.0
		% P.c.	0.5	0.1	0.5	0.7	0.4	2.3	1.4	1.7	0.9
		% P.m.	1.8	5.6	3.3	6.1	6.1	7.1	14.6	8.0	13.7
		Sp. #	5	6	5	5	5	6	6	5	5
		Sp. Div.	0.74	1.03	0.89	1.01	0.98	1.22	1.22	1.23	1.03

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	May-95	Nov-95	Jun-96	Dec-96	May-97	Nov-97	May-98	Nov-98	May-99
NPPE	Shallow	% CORAL	19.6	28.2	13.2	17.5	12.1	62.0	46.7	42.5	47.8
		% P.l.	6.6	16.3	8.5	10	5.1	33.8	20.5	15.4	19.1
		% P.c.		0.6				0.6	0.6		
		% P.m.	8.6	9.1	4.1	5.3	5.1	21.2	20.0	16.3	21.8
		Sp. #	5	5	4	6	6	6	7	6	5
		Sp. Div.	1.28	0.98	0.82	1.11	1.21	1.06	1.19	1.37	1.12
	Middle	% CORAL	42.1	46.4	9.6	20.9	43.8	61.6	75.3	64.8	75.3
		% P.l.	26.5	27.1	2.3	13.8	26.2	24.9	31.9	27.1	35.6
		% P.c.	0.2	2.7		0.4	0.3	2.8	1.2	1.3	1.6
		% P.m.	13.2	11.5	7	5.2	13.8	19.1	33.1	30.4	27.7
		Sp. #	6	8	5	6	5	7	7	6	7
		Sp. Div.	0.89	1.18	0.74	0.96	0.94	1.50	1.17	1.11	1.23
	Deep	% CORAL	55.1	60.7	22.4	49.3	63.3	83.8	83.9	77.2	79.8
		% P.l.	37.8	47.1	14.1	23.1	43.5	57.1	55.4	47.7	49.7
		% P.c.	7.6	3.9	0.8	5.1	2.4	11.1	6.3	14.3	20.5
		% P.m.	3.8	7	6.2	12.4	16.2	8.3	10.6	8.9	5.3
		Sp. #	7	6	5	6	6	7	7	4	7
		Sp. Div.	1.04	0.79	0.96	1.3	0.82	1.05	1.15	1.06	1.01
HO'ONA BAY	Shallow	% CORAL	11.0	8.7	14.2	14.4	18.5	17.6	24.0	27.7	15.3
		% P.l.	6.3	6.6	12.5	13.4	13.9	12.0	16.5	13.5	7.0
		% P.c.			0.5					0.2	
		% P.m.	2.4	0.4	0.9	0.8	4.2	4.3	6.8	10.1	8.3
		Sp. #	3	5	6	3	4	5	4	4	2
		Sp. Div.	0.98	0.78	0.53	0.29	0.64	0.86	0.74	1.03	0.69
	Middle	% CORAL	23.4	40.3	40.5	45.8	59.4	68.0	82.6	64.9	48.0
		% P.l.	20.3	21.6	23.9	26.9	28.8	46.4	51.0	28.7	28.1
		% P.c.	3.0	8.4	12	10.8	13.7	18.9	29.4	28.7	12.6
		% P.m.	0.1	6.2	3.5	4.4	7.6	0.6	1.1	6.7	3.2
		Sp. #	3	7	6	6	7	7	5	5	5
		Sp. Div.	0.41	1.27	1.00	1.16	1.44	0.80	0.79	1.02	1.10
	Deep	% CORAL	43.4	56.7	57.5	49.7	65.2	77.1	88.9	82.0	83.4
		% P.l.	17.4	18.2	21.6	17.2	16.9	27.9	30.4	28.3	28.8
		% P.c.	23.3	36.3	33.1	29.6	458	44.7	54.3	49.4	52.6
		% P.m.	0.5	1.1	0.7	0.9			0.3	0.2	
		Sp. #	6	6	6	6	6	4	6	6	6
		Sp. Div.	0.95	0.82	0.89	0.92	0.76	0.88	0.85	0.88	0.78

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Dec-99	Jun-00	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06
WAWALOLI	Shallow	% CORAL	21.2	24.1	34.1	32.4	23.5	42.3	25.3	17.7	20.9
		% P.l.	10.9	12.3	17.8	15.5	7.5	27.3	17.5	9.9	13.1
		% P.c.				0.1		0.8			0.2
		% P.m.	9.4	9.5	14.1	14.3	14.3	11.6	6.1	5.0	5.4
		Sp. #	3	5	4	5	5	7	4	4	6
		Sp. Div.	0.84	1.01	0.92	0.94	0.93	0.93	0.82	0.92	1.02
	Middle	% CORAL	45.9	26.3	31.4	44.8	33.7	34.7	22	15.7	34.1
		% P.l.	25.8	13.2	14.4	14.4	14.3	16.3	13.4	11.2	24.2
		% P.c.	1.1			0.3	0.3	0.3			
		% P.m.	13.1	8.5	12.0	22.1	16.6	14.1	6.6	3.5	5.8
		Sp. #	5	5	4	6	5	6	4	3	4
		Sp. Div.	1.11	1.20	1.08	1.18	0.97	1.12	0.87	0.76	0.85
	Deep	% CORAL	23.2	29.4	29.5	28.3	8.5	14.6	22.2	18.6	32.5
		% P.l.	10.4	13.5	13.8	15.2	4.9	5.8	16.9	13.3	25.2
		% P.c.	0.3	0.6		1.2	0.6	2.6	0.3		0.5
		% P.m.	10.8	11.5	13.0	9.9	1.8	4.4	7.7	2.2	5.9
		Sp. #	4	5	4	5	5	4	5	4	4
		Sp. Div.	0.96	1.15	0.95	1.07	1.15	1.29	0.69	0.7	0.68
18" PIPE	Shallow	% CORAL	46.4	45.9	49.5	46.3	54.7	41.7	37.4	40.3	39.9
		% P.l.	11.9	15.1	20.1	16.3	22.9	14.2	18.8	23.7	22.7
		% P.c.			0.3						
		% P.m.	27.4	27.4	24.7	29.3	25.2	22.6	11.4	14	14.2
		Sp. #	6	6	7	4	7	4	5	6	3
		Sp. Div.	1.13	0.96	1.04	0.73	1.11	0.97	1.13	0.93	0.88
	Middle	% CORAL	49.5	43.2	53.1	59.0	40.1	52.9	23	35.2	28.7
		% P.l.	8.2	8.4	12.7	16.7	8.2	21.2	9.5	16.5	13.9
		% P.c.		0.7		0.2					
		% P.m.	38.8	30.7	32.0	32.6	24.2	23.5	11.5	15.4	12.9
		Sp. #	4	7	7	5	6	5	5	4	5
		Sp. Div.	0.67	0.89	1.11	1.11	1.15	1.12	1	0.96	0.97
	Deep	% CORAL	27.0	36.9	40.8	36.4	41.4	31.6	31.9	35.5	32.8
		% P.l.	2.5	4.6	5.3	9.6	15.7	16.4	9.7	14.5	11.1
		% P.c.	0.1		0.2		0.4	1.6		0.1	0.3
		% P.m.	22.6	31.4	31.2	26.6	22.1	10.9	20.1	18.1	17.4
		Sp. #	7	4	6	3	6	5	3	6	6
		Sp. Div.	0.65	0.50	0.80	0.61	0.99	1.12	0.84	1.0	1.07

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Dec-99	Jun-00	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06
12" PIPE SOUTH	Shallow	% CORAL	21.5	29.6	39.0	51.3	28.7	28.7	14.5	18.1	16.4
		% P.l.	7.8	9.0	19.9	23.1	10.8	9.2	8.3	7.9	4.6
		% P.c.									
		% P.m.	13.5	19.6	18.1	18.8	15.7	15.4	6.1	6.6	10.2
		Sp. #	3	3	5	6	4	5	3	6	4
		Sp. Div.	0.70	0.75	0.82	1.28	0.93	1.13	0.73	1.22	0.89
	Middle	% CORAL	57.5	57.5	56.9	60.9	56.7	52.0	36.4	29.4	33.9
		% P.l.	30.0	20.4	15.3	23.3	14.1	20.1	16.7	15.1	19.9
		% P.c.		0.4		0.2					
		% P.m.	17.0	26.5	37.7	27.1	28.4	24.2	15.3	11.8	11.9
		Sp. #	6	5	5	8	5	6	5	3	5
		Sp. Div.	1.14	1.18	0.86	1.23	1.28	1.19	1.08	0.92	0.91
	Deep	% CORAL	65	65.3	71.7	76.6	72.2	68	27.5	17.4	29.4
		% P.l.	26	20.08	30.6	28.6	45	28	9.2	5.8	13.6
		% P.c.	0.6	0.7	1.8	5.8	5.3	2.1			0.1
		% P.m.	30.3	34.5	27	32.1	14.7	24.9	14.7	10.3	14.2
		Sp. #	7	8	7	6	6	7	6	4	5
		Sp. Div.	1.16	1.20	1.32	1.30	1.14	1.32	1.09	0.9	0.91
12" PIPE NORTH	Shallow	% CORAL	37.1	34.1	40.5	43.4	41.9	32.0	17.8	36.7	27.5
		% P.l.	10.9	8.0	14.9	11.8	16.1	9.2	10.9	17.2	15.3
		% P.c.						0.1		0.3	
		% P.m.	24.1	22.8	22.9	26.4	21.1	18.4	6.1	10.6	6.3
		Sp. #	4	4	5	4	5	7	4	6	6
		Sp. Div.	0.81	0.90	0.93	0.94	1.05	1.07	0.84	1.31	1.28
	Middle	% CORAL	33.7	33.2	50.9	40.5	51.0	49.2	26.7	19.1	33.3
		% P.l.	16.3	20.6	21.7	16.1	19.1	23.6	14	9.3	16.0
		% P.c.	1.2			0.8	2.2	0.3			
		% P.m.	12.5	11.1	21.5	18.9	21.6	16.2	10	8.4	11.3
		Sp. #	7	5	7	6	8	7	3	4	7
		Sp. Div.	1.19	0.85	1.20	1.17	1.35	1.28	0.94	0.95	1.22
	Deep	% CORAL	59.8	63.7	66.6	60.1	60.4	64.8	33.8	19.6	44.3
		% P.l.	32.2	36.2	35.4	29.0	27.7	38.1	18.6	11.8	20.4
		% P.c.	1.8	2.3	2.8	3.2	1.9	5.6			0.1
		% P.m.	15.4	13.7	17.8	21.0	14.4	10.8	9.9	6.3	14.8
		Sp. #	7	5	6	6	6	6	4	3	6
		Sp. Div.	1.23	1.17	1.19	1.22	1.35	1.24	1.07	0.87	1.28

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Dec-99	Jun-00	Feb-01	May-01	Dec-01	Jun-02	Jul-05	Nov-05	Jul-06
NPPE	Shallow	% CORAL	66.8	53.7	37.7	48.1	52.9	45.3	34.5	37	20.5
		% P.I.	31.9	25.3	12.6	21.1	28.4	19.7	24	29.2	13.7
		% P.c.				0.8			0.2		
		% P.m.	24.6	22.1	22.9	24.3	19.8	22.1	3.7	6.7	2.2
		Sp. #	6	4	5	5	4	7	6	4	5
		Sp. Div.	1.17	1.05	0.87	0.92	0.98	0.97	1.04	0.62	1.01
	Middle	% CORAL	85.4	71.3	77.2	71.7	70.2	59.2	56.8	40.5	43.8
		% P.I.	46.9	39.6	33.4	38.0	41.5	28.7	37.5	29.2	31.5
		% P.c.	1.9	4.5	2.8	2.4	6.4		1.8		0.1
		% P.m.	30.6	22.8	35.2	22.6	17.2	22.4	11.5	8.3	9.7
		Sp. #	6	5	6	7	6	6	5	4	6
		Sp. Div.	1.04	1.08	1.10	1.20	1.13	1.11	1.02	0.8	0.79
	Deep	% CORAL	74.7	89.8	77.7	89.6	76.6	90.3	64.5	69	72.1
		% P.I.	48.8	56.3	45.5	62.0	41.9	61.1	40.2	54.3	49.9
		% P.c.	11.7	14.5	17.2	17.0	10.3	21.4	13.4	7.6	12.7
		% P.m.	6.3	9.0	8.2	6.3	15.2	5.1	7.6	6.1	7.0
		Sp. #	7	6	5	5	7	5	5	5	6
		Sp. Div.	1.11	1.17	1.15	0.93	1.29	0.89	1.04	0.72	0.93
HO'ONA BAY	Shallow	% CORAL	32.2	35.2	46.9	41.9	43.6	35.2	6.7	16.9	38.5
		% P.I.	15.2	19.0	24.2	15.9	22.7	4.4	4.2	12.7	29.2
		% P.c.	0.2								
		% P.m.	12.7	14.9	17.6	21.2	19.1	30.8	2.5	3.2	8.4
		Sp. #	4	3	5	6	4	2	2	3	4
		Sp. Div.	1.02	0.82	1.03	1.08	0.85	0.38	0.61	0.69	0.64
	Middle	% CORAL	48.4	44.0	49.5	30.6	42.1	38.9	21.3	21.6	25.8
		% P.I.	24.2	29.3	29.9	16.1	30.3	26.3	16.8	16.4	17.7
		% P.c.	17.8	10.1	16.1		2.9	0.9	0.3		2.9
		% P.m.	5.2	3.6	2.9	12.0	7.2	11.6	4	4.5	4.2
		Sp. #	6	6	4	4	6	4	4	3	6
		Sp. Div.	1.06	0.92	0.89	0.95	0.88	0.73	0.66	0.65	0.97
	Deep	% CORAL	69.5	72.0	65.0	82.9	76.8	86.5	52.4	55.2	71.1
		% P.I.	27.0	24.6	38.2	32.9	33.0	39.3	13.8	19.9	15.6
		% P.c.	38.7	43.8	22.4	43.8	38.4	39.7	37.7	34.1	53.8
		% P.m.	0.5		1.1		1.6	0.4			
		Sp. #	6	4	6	5	6	6	4	3	4
		Sp. Div.	0.91	0.85	0.95	0.97	0.98	1.04	0.65	0.75	0.64

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Jan-07	Oct-07	Jul-08	Oct-08	May-09	May-10	Nov-10
WAWALOLI	Shallow	% CORAL	28.3	41.2	29.1	21.0	27.4	28.4	35.5
		% P.l.	18.4	24.9	22.2	16.0	18.5	21.0	21.0
		% P.c.		0.2					
		% P.m.	5.7	11.0	1.6	3.0	6.5	2.0	9.4
		Sp. #	5	6	5	4	5	3	4
		Sp. Div.	0.85	0.97	0.80	0.77	0.88	0.73	1.02
	Middle	% CORAL	23.0	59.1	46.3	34.3	38.6	44.3	47.2
		% P.l.	11.7	38.9	39.7	29.4	30.3	36.2	38.2
		% P.c.		5.1	0.2			0.2	1.1
		% P.m.	9.3	12.6	4.5	3.5	3.9	4	3.1
		Sp. #	4	5	4	5	5	5	5
		Sp. Div.	0.93	0.97	0.51	0.52	0.77	0.63	0.00
	Deep	% CORAL	19.0	67.4	47.9	13.4	29.8	24.3	34.7
		% P.l.	12.9	30.7	21.7	9.8	21.6	18.3	24.9
		% P.c.	2.1	36.1	26.2	0.3	0.6	0.8	1.0
		% P.m.	2.7	0.4		3.1	2.9	3.5	3.2
		Sp. #	5	4	2	6	5	4	5
		Sp. Div.	0.96	0.74	0.69	0.73	0.88	0.79	0.90
18" PIPE	Shallow	% CORAL	47.5	47.8	56.7	43.1	39.5	45.5	59.3
		% P.l.	29.3	24.7	33.4	29.9	25.8	26.3	41.1
		% P.c.							
		% P.m.	12.4	20.3	19.9	9.8	11.1	14.9	8.5
		Sp. #	5	4	5	4	4	3	6
		Sp. Div.	0.66	0.91	0.89	0.81	0.85	0.91	1.01
	Middle	% CORAL	29.8	32.3	57.1	40.9	31.8	44.9	44.5
		% P.l.	10.8	12.1	27.1	26.6	16.3	26.3	27.0
		% P.c.					0.1	0.5	0.8
		% P.m.	16.5	18.8	18.7	9.9	9.0	11.9	12.1
		Sp. #	5	5	5	5	8	6	5
		Sp. Div.	0.85	0.86	1.2	0.94	1.27	1.03	1.01
	Deep	% CORAL	29.8	34.6	35.1	32.8	41.4	46.9	37.5
		% P.l.	9.1	15.7	15.0	18.1	24.5	24.8	21.7
		% P.c.	0.6	0.2	0.2	0.1	0.4	0.4	0.5
		% P.m.	16.2	14.9	18.5	13.0	13.5	14.9	12.9
		Sp. #	6	5	5	5	7	5	4
		Sp. Div.	1.1	1.07	0.88	0.9	1.0	1.11	0.92

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Jan-07	Oct-07	Jul-08	Oct-08	May-09	May-10	Nov-10
12" PIPE SOUTH	Shallow	% CORAL	22.9	61.1	27.1	23.4	21.8	27.25	30.0
		% P.l.	10.5	31.7	9.8	15.2	11.7	14.1	17.8
		% P.c.							
		% P.m.	10.6	25.1	15.8	5.9	10.2	12.3	9.5
		Sp. #	4	4	5	5	2	4	4
		Sp. Div.	0.89	0.94	0.9	0.95	0.69	0.83	0.92
	Middle	% CORAL	35.5	32.6	60.1	33.1	32.8	40.1	41.1
		% P.l.	19.6	18.7	24.9	20.1	20.9	17.8	23.9
		% P.c.						0.1	0.2
		% P.m.	15.0	12.2	20.8	10.1	10.4	12.9	14.2
		Sp. #	3	4	5	4	4	7	6
		Sp. Div.	0.79	0.87	1.25	0.87	0.82	1.26	0.91
	Deep	% CORAL	36.4	74.8	75.2	31.9	31.2	36.9	37.4
		% P.l.	11.9	41.4	37.0	12.9	16.1	19.3	22.0
		% P.c.		10.7	8.8		0.1	0	
		% P.m.	23.5	14.3	15.2	17.4	12.0	13.5	10.2
		Sp. #	5	5	6	4	6	5	6
		Sp. Div.	0.72	1.24	1.44	0.86	1.04	1.01	1.12
12" PIPE NORTH	Shallow	% CORAL	33.0	26.5	39.2	21.5	29.5	32.4	35.3
		% P.l.	20.0	12.0	20.3	13.6	18.4	17.6	18.7
		% P.c.			0.2				
		% P.m.	7.7	12.8	12.7	5.7	6.0	10.5	12.7
		Sp. #	5	3	5	4	4	4	4
		Sp. Div.	0.82	0.89	1.1	0.93	1.03	1.05	1.00
	Middle	% CORAL	35.1	50.8	55.3	35.9	41.8	41	45.8
		% P.l.	19.0	20.9	27.3	17.1	18.6	19.6	21.5
		% P.c.	0.1		0.3		0.1		
		% P.m.	9.8	15.1	18.6	13.9	14.1	14.9	12.0
		Sp. #	6	6	6	5	5	5	5
		Sp. Div.	0.90	1.37	1.15	1.07	1.22	1.14	1.26
	Deep	% CORAL	41.3	72.0	74.8	55.3	57.2	65.4	62.1
		% P.l.	23.7	46.6	41.5	37.8	48.8	40.6	43.9
		% P.c.		4.7	16.2	2.8	5.4	5.2	2.3
		% P.m.	13	16.2	12	11.2	7.8	10.4	11.1
		Sp. #	4	5	5	5	5	6	6
		Sp. Div.	0.91	0.99	1.17	0.95	0.92	1.09	0.91

Appendix B2. Summary of the quantitative photo-quadrat analysis of dominant coral species abundance, total coral species and species diversity for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

SITE	DEPTH	PARAMETER	Jan-07	Oct-07	Jul-08	Oct-08	May-09	May-10	Nov-10
NPPE	Shallow	% CORAL	51.7	41.1	50.6	53.8	42.5	31.05	41.1
		% P.I.	39.9	26.3	23.4	40.5	29.7	21.3	31.5
		% P.c.		12.7	2.8	0.3			
		% P.m.	7.8		14.8	6.7	7.6	5.3	9.0
		Sp. #	6	3	8	5	6	5	3
		Sp. Div.	0.60	0.80	1.43	0.78	0.98	0.9	0.61
	Middle	% CORAL	53.6	77.3	75.8	53.0	52.1	76	64.2
		% P.I.	41.2	47.5	40.2	41.3	37.1	59.8	49.4
		% P.c.		10.1	4.8		0.6	4.1	0.5
		% P.m.	7	11.1	15.9	7.0	7.8	7.1	9.3
		Sp. #	4	6	5	5	7	5	5
		Sp. Div.	0.57	1.19	1.29	0.71	0.88	0.75	0.73
	Deep	% CORAL	69.1	88.6	87.5	75.2	65.1	79.1	75.2
		% P.I.	46.1	65.9	55.5	46.2	36.7	56.5	51.7
		% P.c.	14.7	16.0	24.5	20.4	14.2	8.6	16.8
		% P.m.	6.6	5.6	4.7	6.1	7.1	7.7	3.9
		Sp. #	5	5	5	5	7	5	5
		Sp. Div.	0.88	0.77	0.93	0.99	1.23	0.92	0.88
HO'ONA BAY	Shallow	% CORAL	33.9	34.9	46.2	32.5	39.0	39.4	44.8
		% P.I.	28.6	26.6	28.1	27.9	31.1	31	30.9
		% P.c.				0.5			0.2
		% P.m.	4.2	8.3	15.4	3.6	6.9	6.3	11.5
		Sp. #	3	2	4	3	4	5	5
		Sp. Div.	0.52	0.55	0.86	0.43	0.58	0.69	0.82
	Middle	% CORAL	46.3	39.1	60.6	62.2	41.0	27.2	39.9
		% P.I.	35.6	32.6	33.2	33.0	29.2	17.1	30.6
		% P.c.	9.5	1.2	21.9	27.3	0.5	3.7	3.2
		% P.m.	1.0	4.3	3.6	1.4	8.1	4.9	4.0
		Sp. #	6	5	5	5	4	6	5
		Sp. Div.	0.62	0.61	0.99	0.83	0.81	1.07	0.82
	Deep	% CORAL	57.7	61.2	59.5	47.6	49.1	47.7	59.6
		% P.I.	13.6	36.0	35.6	28.3	31.4	28.1	34.0
		% P.c.	42.3	23.5	22.2	18.6	15.9	16.7	20.0
		% P.m.	0.1	0.2	0.2	0.6		1.1	0.2
		Sp. #	7	5	6	4	5	6	6
		Sp. Div.	0.59	0.80	0.81	0.75	0.79	0.92	1.02

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 November 2010. 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
Wawaloli	Boulder	*E. mathaei*	36	14	8	11	24	14	20	24	31	26
		H. mammilatus			1		1					2
		T. gratilla			1							1
		E. diadema										
		E. aciculatus										
	Bench	*E. mathaei*	9	40	30	17	34	29	25	31	35	41
		H. mammilatus				1	1					
		E. calamaris										
		E. diadema										
		T. gratilla										
		E. aciculatus										
	Slope	*E. mathaei*	5		3	1	1	6	3	4	5	3
		H. mammilatus	1									
		T. gratilla		2		1						
		E. diadema										
		E. calamaris										
		E. aciculatus										
18" Pipe	Boulder	*E. mathaei*	19	2	4	3	8	4	6	3	2	4
		E. aciculatus										
	Bench	*E. mathaei*	8	5	3	11	13	6	14	21	28	24
		E. aciculatus				1		1	1			
		E. calimaris										
		E. diadema										
		T. gratilla										
	Slope	*E. mathaei*	4	9	8	7	6	2	11	7	5	4
		E. diadema										
		T. gratilla										
12" Pipe S	Boulder	*E. mathaei*		2	3	2	1		1	2	1	2
		E. diadema										
		E. oblongata										
	Bench	*E. mathaei*		15	4	6	11	8	5	3	2	2
		E. calimaris										
		E. aciculatus										
	Slope	*E. mathaei*		2	1	1	1	1	1	1	4	1
		E. diadema										
		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 November 2010. 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
12" Pipe N	Boulder	*E. mathaei*		3	2	7	4	2	4	3	4	4
		E. aciculatus										
	Bench	*E. mathaei*		9	15	7	11	6	6	4	3	2
		E. calimaris										
	Slope	*E. mathaei*		2		1	1	1	4	2	2	3
		E. diadema										
NPPE	Boulder	*E. mathaei*		7	7	7	4	4	3	1	2	5
		E. calamaris										
		E. aciculatus										
	Bench	*E. mathaei*		1	4	1	1	6	8	3	4	41
		E. aciculatus										
		H. mammilatus										
	Slope	*E. mathaei*		1	4			2	4	1	3	
		E. calamaris										
		E. aciculatus										
		T. gratilla										
		E. metularia										
Ho'ona Bay	Boulder	*E. mathaei*	4	23	9	4	12	6	11	16	19	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
		H. mammilatus	7	3	4		1	1	1	1	2	2
		T. gratilla										
		E. aciculatus										
		E. diadema										
		E. metularia										
	Slope	*E. mathaei*	7			1	1			1	3	4
		H. mammilatus	4		1	2		1	1	1	1	1
		T. gratilla				3	1					
		E. aciculatus										
		E. diadema										
		E. metularia										

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 November 2010. Locations of transects are shown in Figure 3.

Location	Site	Species	Nov-97	May-98	Nov-98	May-99	Dec-99	May-00	Feb-01	May-01	Dec-01	Jun-02
Wawaloli	Boulder	*E. mathaei*	22	31	27	34	38	29	41	29	32	21
		H. mammilatus		1	1	2		2				
		T. gratilla	1	2	3	3						1
		E. diadema					2	1				1
		E. aciculatus										
	Bench	*E. mathaei*	35	39	42	31	29	32	26	24	37	26
		H. mammilatus										
		E. calamaris										
		E. diadema								1	1	1
		T. gratilla										
		E. aciculatus										
	Slope	*E. mathaei*	2	1	2	3	4	2	5	4	4	2
		H. mammilatus	1	1	1	2		2				
		T. gratilla				1						
		E. diadema						1				
		E. calamaris										
		E. aciculatus										
18" Pipe	Boulder	*E. mathaei*	3	5	4	2	5	6	8	11	12	14
		E. calimaris										
	Bench	*E. mathaei*	27	32	35	39	19	32	31	29	19	21
		E. aciculatus				1						
		E. calimaris										
		E. diadema					1	2				
		T. gratilla										
	Slope	*E. mathaei*	4	2	2	2	11	4	21	18	13	11
		E. calimaris										
		T. gratilla										
12" Pipe S	Boulder	*E. mathaei*	3	4	2	6	5	11	16	21	19	12
		E. diadema										
		E. oblongata										
	Bench	*E. mathaei*	2	3	3	4	4	8	11	14	15	11
		E. calimaris										
		E. aciculatus										
	Slope	*E. mathaei*	3	2	1	1	5	5	8	6	11	9
		E. diadema	1	2	2	3						
		T. gratilla										

Appendix C. Summary of the quantitative counts of sea urchins within 0.6 x 1.0 m photo-quadrats for surveys conducted between December 1991 and November 2010. Locations of transects are shown in Figure 3.

Location	Site	Species	Nov-97	May-98	Nov-98	May-99	Dec-99	May-00	Feb-01	May-01	Dec-01	Jun-02
12" Pipe N	Boulder	*E. mathaei*	2	2	1	2	5	6	11	13	12	21
		E. aciculatus										
	Bench	*E. mathaei*	4	3	2	3	5	7	12	16	15	18
		E. calimaris										
	Slope	*E. mathaei*	3	5	3	4	4	7	14	21	13	15
		E. diadema										
NPPE	Boulder	*E. mathaei*	4	6	2	6	8	11	21	25	18	11
		E. calamaris										
		E. aciculatus										
	Bench	*E. mathaei*	27	38	26	28	18	31	43	32	21	16
		E. calimaris								1		
		H. mammilatus										
	Slope	*E. mathaei*					5	2	9	11	13	7
		E. calimaris										
		E. aciculatus										
		T. gratilla										
		E. metularia										
Ho'ona Bay	Boulder	*E. mathaei*	11	14	12	16	7	5	9	13	11	11
		H. mammilatus										
		E. diadema								1		
		E. aciculatus										
		T. gratilla										
	Bench	*E. mathaei*	2	3	2	3	5	5	11	21	15	14
		H. mammilatus	2	4	5	2						
		T. gratilla						1				
		E. aciculatus										
		E. calimaris										
		E. metularia										
	Slope	*E. mathaei*	2	2	4	4	3	6	12	19	12	9
		H. mammilatus	1	3	3	2						
		T. gratilla										1
		E. aciculatus										
		E. diadema										
		E. metularia										

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 November 2010. Locations of transects are shown in Figure 3.

Location	Site	Species	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Oct-08	May-09	Mar-10	Nov-10
Wawaloli	Boulder	*E. mathaei*	39	38	63	24	29	30	12	58	37
		H. mammilatus									
		T. gratilla	14	2	2		2	2			
		E. diadema		2		5	1	1	1		
		E. aciculatus								1	2
	Bench	*E. mathaei*	18	74	40	58	31	22	12	111	56
		H. mammilatus								2	1
		E. calamaris	1							1	3
		E. diadema					2	1	3		
		T. gratilla				2		1	1		
		E. aciculatus								1	2
	Slope	*E. mathaei*	2	8	6	14	6	6		44	37
		H. mammilatus					1		1		
		T. gratilla	13		2			1			1
		E. diadema					2	3			
		E. calamaris								3	1
		E. aciculatus								5	
18" Pipe	Boulder	*E. mathaei*	9	28	17	26	8	17	8	12	13
		E. calimaris							1	1	2
	Bench	*E. mathaei*	4	13	25	17	22	14	8	16	13
		E. aciculatus	1		4				2	1	
		E. calimaris	1							1	
		E. diadema						2	4		
		T. gratilla	1				1				1
	Slope	*E. mathaei*	4	1	9	5	15	7	10	12	8
		E. calimaris					2			1	
		T. gratilla	1			1					1
12" Pipe S	Boulder	*E. mathaei*	8	9	18	7	16	11	7	8	10
		E. diadema					1				
		E. oblongata	1								
	Bench	*E. mathaei*	14	4	16	3	16	9	1		2
		E. calimaris								1	
		E. aciculatus								1	1
	Slope	*E. mathaei*	4	2	5	1	4	5	3	1	4
		E. diadema		1			1	3		2	
		T. gratilla	1					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 November 2010. Locations of transects are shown in Figure 3.

Location	Site	Species	Jul-05	Nov-05	Jul-06	Jan-07	Oct-07	Oct-08	May-09	Mar-10	Nov-10
12" Pipe N	Boulder	*E. mathaei*	11	8	15	5	8	12	7	42	34
		E. aciculatus							2		
	Bench	*E. mathaei*	6	3	23	9	13	10	5	20	14
		E. calimaris	2							2	1
	Slope	*E. mathaei*	5	3	6	7	11	9	8		6
		E. diadema					2				
NPPE	Boulder	*E. mathaei*	14	14	27	21	12	16	3	71	23
		E. calamaris					3				1
		E. aciculatus							1	1	1
	Bench	*E. mathaei*	15	16	13	5	28	15	2	27	33
		E. calimaris	1					2	1	1	1
		H. mammilatus					1			2	
	Slope	*E. mathaei*	2	2	13	15		8		46	48
		E. calimaris	1							1	
		E. aciculatus	3					2	2	2	
		T. gratilla									4
		E. metularia									19
Ho'ona Bay	Boulder	*E. mathaei*	56	2	53	25	14	21	14	54	73
		H. mammilatus									
		E. diadema			1						
		E. aciculatus	1			1					4
		T. gratilla						5		18	
	Bench	*E. mathaei*	59	46	33	51	13	37	28	67	30
		H. mammilatus			1	1				5	9
		T. gratilla			1	2		1	1	2	
		E. aciculatus	7		2					1	
		E. calimaris							5	1	
		E. metularia									7
	Slope	*E. mathaei*	10	60	6	7	15	20	2	9	12
		H. mammilatus			2	2				3	
		T. gratilla	1		11	16		4		11	3
		E. aciculatus	13						4		
		E. diadema					2		6		2
		E. metularia									6

APPENDIX D

MARINE FISH COMMUNITY SURVEY SUMMARY

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. 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 meleagris*											1						1		2
Holocentridae	*Myripristis berndti*				6							7								13
	Myripristis kuntee																		63	63
	Sargocentron ensiferum											1								1
Aulostomidae	*Aulostomus chinensis*								3			1							2	6
Fistularidae	*Fistularia commersonii*													1						1
	Fistularia petimba		1							1										2
Serranidae	*Cephalopholis argus*															1				1
Cirrhitidae	*Cirrhitops fasciatus*				1							1								2
	Paracirrhites arcatus	16	17	16	13	25	17	13	21	23	13	19	16	7	11	6	10	14	2	259
	Paracirrhites fosteri	2	1		2					2		1	1							9
Scombridae	*Euthyunnus affinis*								1											1
Carangidae	*Decapterus macarellus*						45					1								46
Lutjanidae	*Alphareus furca*			1			5						1		1					8
	Lutjanus kasmira						1					1								2
Lethirinidae	*Monotaxis grandoculis*				2		1		2	1		1			3					10
Mullidae	*Mulloidichthys vanicolensis*											2		6						8
	Parupeneus bifasciatus						1				2						1			4
	Parupeneus chyrserydros													2						2
	Parupeneus multifasciatus	1	4	1		1	2	1	1	1	2	1			1			1	1	18
Kyphosidae	*Kyphosus bigibbus*				2															2
Chaetodontidae	*Chaetodon auriga*	5				2														7
	Chaetodon ephippium					1														1
	Chaetodon kleini									1										1
	Chaetodon lineolatus	2																		2
	Chaetodon lunula		2		5			1	2								2			12
	Chaetodon lunulatus				2															2
	Chaetodon multicinctus	8	7		4	5	6	4	4	7	4	5	7	2	6	7		2	3	81
	Chaetodon ornatissimus	1			2	2	1		1					1			2	2		12
	Chaetodon quadrimaculatus	1	6		3		2	1		1			1	1	3		1			20
	Chaetodon reticulatus																		1	1

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. 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	
Chaetodontidae	*Chaetodon unimaculatus*										2									2
	Forcipiger flavissimus				3	3				3	1	1	4		1			3	4	23
	Hemitaurichthys polylepis				6			15	45										4	70
	Hemitaurichthys thompsoni								3			1								4
Pomacanthidae	*Centropyge loriculus*															1				1
	Centropyge potteri									3		1							5	9
Pomacentridae	*Abudefduf abdominalis*				17			21	6					30	25					99
	Chromis agilis									153			60			68		23	46	350
	Chromis hanui									12			11					4		27
	Chromis vanderbilti	36	165	83	212	143	225	83	106	83	76	95	120	47	131	128	30	99		1862
	Chromis verater							3												3
	Dascyllus albisella																	6	8	14
	Plectroglyphidodon imparipenis		5		5			6												16
	Plectroglyphidodon johnstonianus		1	3			1	1	1	6	1	6	3			2			1	26
	Stegastes fasciolatus		6		4	2		1				2		2			6			23
Labridae	*Bodianus bilunulatus*															1				1
	Coris gaimard	1	2	3	2		1	1										1		11
	Gomphosus varius	2	1	1	2	1	3		3	3	1		1		1		2			21
	Halichoeres ornatissimus	7	5	6	4	4	4	4	2	1	1	2	2		2	2		4		50
	Labroides phthirophagus		3		1			1		1		2	1		2	1		3	1	16
	Oxycheilinus bimaculatus																		1	1
	Oxycheilinus unifasciatus																		1	1
	Pseudocheilinus evanidus			1												3			1	5
	Pseudocheilinus octotaenia			5			9			3		1	3		2	1				24
	Pseudocheilinus tetrataenia	1	1	2	5	4	7	1	5	8		3	3	1	1	2		2		46
	Stethojulis balteata		2	2	4	1		2			2	1					1	2		17
	Thalassoma duperrey	26	13	8	43	16	10	27	21	26	14	6	9	23	10	3	8	11	3	277
Scaridae	*Calotomus carolinus*																	1		1
	Scarus psittacus	1		2													3			6
	Scarus rubroviolaceus	2		1			4											2		9
	Scarus sordidus	1	1		5	2	3		4	2	7	6	6	8	8	3		3	4	63
	Scarus sp.juvenile		9				3			2	5									19

Appendix D.1. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. 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	
Blennidae	*Cirripectes vanderbilti*											2	1							3
	Plagiotremus ewanensis							1												1
Zanclidae	*Zanclus cornutus*	2	1	2	1	3	2	1	1		1	1		1					3	19
Acanthuridae	*Acanthurus achilles*											2								2
	Acanthurus dussumieri			3			1													4
	Acanthurus guttatus							1			1									2
	Acanthurus leucoparieus	50			9			3			2			35			28			127
	Acanthurus nigricans										1	1								2
	Acanthurus nigrofuscus	23	32	9	34	37	16	23	18	31	13	8	13	13	24	9	14	24	5	346
	Acanthurus olivaceus	1	1	4	2		1				1		1						1	12
	Acanthurus thompsoni																		27	27
	Acanthurus triostegus																9			9
	Ctenochaetus hawaiiensis				4			2						3			3			12
	Ctenochaetus strigosus	1	3		10	22	2	4	15	14	7	11	6	26	17	16	19	31	15	219
Acanthuridae	*Naso brevirostris*						1													1
	Naso hexacanthus			2		2	4													8
	Naso lituratus	1	4	1	1	1	3	1	1		1	1	2	1	3	2			5	28
	Naso unicornis									1										1
	Zebrasoma flavescens	6	11	6	22	23	8	15	18	16	50	12	18	24	18	10	60	7	11	335
Balistidae	*Melichthys niger*	4	2	1	2												2			11
	Melichthys vidua			2	1			1					1		1		3			9
	Rhinecanthus rectangulus	1																		1
	Sufflamen bursa	1	2	3	2	3	2	1	6	1	3	1	2	2	1	1	1		1	33
	Sufflamen fraenatus			1																1
	Xanthichthys auromarginatus			1			3													4
Monacanthidae	*Cantherhines dumerilii*					1	1						2				1			5
	Catherhines sanwichiensis	1																		1
	Pervagor aspricaudus								2	2			2							6
Ostraciidae	*Ostracion memeagris*	1												1			1			3
Tetraodontidae	*Canthigaster jactator*	3	5	3	3	3	1			2		1	1	1	2		3	1		29
Diodontidae	*Diodon histrix*					1													1	2
Cheloniidae	*Chelonia midas*	1																		1

Appendix D.2. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. Transect locations are shown in Figure 3. Species listed in order of numeric abundance.

		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	
Pomacentridae	*Chromis vanderbilti*	36	165	83	212	143	225	83	106	83	76	95	120	47	131	128	30	99		1862
Carangidae	*Decapterus macarellus*						45					1			1000					1046
Pomacentridae	*Chromis agilis*									153			60			68		23	46	350
Acanthuridae	*Acanthurus nigrofuscus*	23	32	9	34	37	16	23	18	31	13	8	13	13	24	9	14	24	5	346
Acanthuridae	*Zebrasoma flavescens*	6	11	6	22	23	8	15	18	16	50	12	18	24	18	10	60	7	11	335
Labridae	*Thalassoma duperrey*	26	13	8	43	16	10	27	21	26	14	6	9	23	10	3	8	11	3	277
Cirrhitidae	*Paracirrhites arcatus*	16	17	16	13	25	17	13	21	23	13	19	16	7	11	6	10	14	2	259
Acanthuridae	*Ctenochaetus strigosus*	1	3		10	22	2	4	15	14	7	11	6	26	17	16	19	31	15	219
Acanthuridae	*Acanthurus leucoparieus*	50			9			3			2			35			28			127
Pomacentridae	*Abudefduf abdominalis*				17			21	6					30	25					99
Chaetodontidae	*Chaetodon multicinctus*	8	7		4	5	6	4	4	7	4	5	7	2	6	7		2	3	81
Chaetodontidae	*Hemitaurichthys polylepis*				6			15	45										4	70
Holocentridae	*Myripristis kuntee*																		63	63
Scaridae	*Scarus sordidus*	1	1		5	2	3		4	2	7	6	6	8	8	3		3	4	63
Labridae	*Halichoeres ornatissimus*	7	5	6	4	4	4	4	2	1	1	2	2		2	2		4		50
Labridae	*Pseudocheilinus tetrataenia*	1	1	2	5	4	7	1	5	8		3	3	1	1	2		2		46
Balistidae	*Sufflamen bursa*	1	2	3	2	3	2	1	6	1	3	1	2	2	1	1	1		1	33
Tetraodontidae	*Canthigaster jactator*	3	5	3	3	3	1			2		1	1	1	2		3	1		29
Acanthuridae	*Naso lituratus*	1	4	1	1	1	3	1	1		1	1	2	1	3	2			5	28
Pomacentridae	*Chromis hanui*									12			11					4		27
Acanthuridae	*Acanthurus thompsoni*																		27	27
Pomacentridae	*Plectroglyphidodon johnstonianus*		1	3			1	1	1	6	1	6	3			2			1	26
Labridae	*Pseudocheilinus octotaenia*			5			9			3		1	3		2	1				24
Chaetodontidae	*Forcipiger flavissimus*				3	3				3	1	1	4		1			3	4	23
Pomacentridae	*Stegastes fasciolatus*		6		4	2		1				2		2			6			23
Labridae	*Gomphosus varius*	2	1	1	2	1	3		3	3	1		1		1		2			21
Chaetodontidae	*Chaetodon quadrimaculatus*	1	6		3		2	1		1			1	1	3		1			20
Scaridae	*Scarus sp.juvenile*		9				3			2	5									19
Zanclidae	*Zanclus cornutus*	2	1	2	1	3	2	1	1		1	1		1					3	19
Mullidae	*Parupeneus multifasciatus*	1	4	1		1	2	1	1	1	2	1			1			1	1	18
Labridae	*Stethojulis balteata*		2	2	4	1		2			2	1					1	2		17
Pomacentridae	*Plectroglyphidodon imparipenis*		5		5			6												16

Appendix D.2. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. Transect locations are shown in Figure 3. Species listed in order of numeric abundance.

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	
Labridae	*Labroides phthirophagus*		3		1			1		1		2	1		2	1		3	1	16
Pomacentridae	*Dascyllus albisella*																	6	8	14
Holocentridae	*Myripristis berndti*				6							7								13
Chaetodontidae	*Chaetodon lunula*		2		5			1	2								2			12
Chaetodontidae	*Chaetodon ornatissimus*	1			2	2	1		1					1			2	2		12
Acanthuridae	*Acanthurus olivaceus*	1	1	4	2		1				1		1						1	12
Acanthuridae	*Ctenochaetus hawaiiensis*				4			2						3			3			12
Labridae	*Coris gaimard*	1	2	3	2		1	1										1		11
Balistidae	*Melichthys niger*	4	2	1	2												2			11
Lethirinidae	*Monotaxis grandoculis*				2		1		2	1		1			3					10
Cirrhitidae	*Paracirrhites fosteri*	2	1		2					2		1	1							9
Pomacanthidae	*Centropyge potteri*									3		1							5	9
Scaridae	*Scarus rubroviolaceus*	2		1			4											2		9
Acanthuridae	*Acanthurus triostegus*																9			9
Balistidae	*Melichthys vidua*			2	1			1					1		1		3			9
Lutjanidae	*Alphareus furca*			1			5						1		1					8
Mullidae	*Mulloidichthys vanicolensis*											2		6						8
Acanthuridae	*Naso hexacanthus*			2		2	4													8
Chaetodontidae	*Chaetodon auriga*	5				2														7
Aulostomidae	*Aulostomus chinensis*								3			1							2	6
Scaridae	*Scarus psittacus*	1		2													3			6
Monacanthidae	*Pervagor aspricaudus*								2	2			2							6
Labridae	*Pseudocheilinus evanidus*			1												3			1	5
Monacanthidae	*Cantherhines dumerilii*					1	1						2				1			5
Mullidae	*Parupeneus bifasciatus*						1				2						1			4
Chaetodontidae	*Hemitaurichthys thompsoni*								3			1								4
Acanthuridae	*Acanthurus dussumieri*			3			1													4
Balistidae	*Xanthichthys auromarginatus*			1			3													4
Pomacentridae	*Chromis verater*							3												3
Blennidae	*Cirripectes vanderbilti*											2	1							3
Ostraciidae	*Ostracion memeagris*	1												1			1			3
Muraenidae	*Gymnothorax meleagris*											1						1		2

Appendix D.2. Abundance of fish observed along 25 m transects off NELHA on November 10-13, 2010. Transect locations are shown in Figure 3. Species listed in order of numeric abundance.

		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	
Fistularidae	*Fistularia petimba*		1							1										2
Cirrhitidae	*Cirrhitops fasciatus*				1							1								2
Lutjanidae	*Lutjanus kasmira*						1					1								2
Mullidae	*Parupeneus chyrserydros*													2						2
Kyphosidae	*Kyphosus bigibbus*				2															2
Chaetodontidae	*Chaetodon lineolatus*	2																		2
Chaetodontidae	*Chaetodon lunulatus*				2															2
Chaetodontidae	*Chaetodon unimaculatus*										2									2
Acanthuridae	*Acanthurus achilles*											2								2
Acanthuridae	*Acanthurus guttatus*							1			1									2
Acanthuridae	*Acanthurus nigricans*										1	1								2
Diodontidae	*Diodon histrix*					1													1	2
Holocentridae	*Sargocentron ensiferum*											1								1
Fistularidae	*Fistularia commersonii*													1						1
Serranidae	*Cephalopholis argus*															1				1
Scombridae	*Euthyunnus affinis*								1											1
Chaetodontidae	*Chaetodon ephippium*					1														1
Chaetodontidae	*Chaetodon kleini*									1										1
Chaetodontidae	*Chaetodon reticulatus*																		1	1
Pomacanthidae	*Centropyge loriculus*															1				1
Labridae	*Bodianus bilunulatus*															1				1
Labridae	*Oxycheilinus bimaculatus*																		1	1
Labridae	*Oxycheilinus unifasciatus*																		1	1
Scaridae	*Calotomus carolinus*																	1		1
Blennidae	*Plagiotremus ewanensis*							1												1
Acanthuridae	*Naso brevirostris*						1													1
Acanthuridae	*Naso unicornis*									1										1
Balistidae	*Rhinecanthus rectangulus*	1																		1
Balistidae	*Sufflamen fraenatus*			1																1
Monacanthidae	*Catherhines sanwichiensis*	1																		1
Cheloniidae	*Chelonia midas*	1																		1

Appendix D.3. Number of individuals counted along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2010.

Site	Biotope	May-89	Oct-91	Mar-92	May-92	Oct-92	May-93	Dec-93	May-94	Jun-94	Oct-94	Mar-95	Jun-95	Dec-95	Jun-96	Dec-96	Jun-97	Dec-97	Jun-98
Wawaloli	Boulder	187	209	204	154	434	336	175	230	242	221	256	454	106	279	224	269	371	223
	Bench	346	237	341	227	80	339	227	413	351	218	214	281	157	326	231	250	636	177
	Slope		188	272	166	375	200	196	258	378	345	232	407	224	255	206	233	510	143
18-inch Pipe	Boulder		510	274	357	420	398	434	455	480	526	417	493	196	276	315	369	471	453
	Bench		604	467	447	355	310	350	499	423	505	430	387	310	259	320	323	598	400
	Slope		824	499	491	682	305	862	816	728	701	698	836	346	514	473	453	465	533
12-inch Pipe South	Boulder				350	709	317	524	421	363	650	309	406	213	378	353	302	678	289
	Bench				541	392	446	565	386	384	446	226	521	439	296	347	308	535	302
	Slope				353	361	322	388	260	333	272	227	616	300	359	384	376	157	381
12-inch Pipe North	Boulder				204	243	268	441	255	287	339	168	258	243	199	213	227	523	231
	Bench				248	267	214	424	327	383	421	189	487	229	203	182	188	364	260
	Slope				157	306	320	396	178	222	210	188	302	275	243	232	252	790	300
NPPE Site	Boulder				443	297	308	330	271	326	454	195	342	148	290	283	246	834	308
	Bench				357	229	290	400	345	289	329	177	417	436	265	195	272	467	305
	Slope				93	140	143	235	223	191	266	142	424	175	282	408	429	346	107
Ho'ona Bay	Boulder	389	339	263	319	307	315	383	329	354	272	376	473	159	293	217	300	252	237
	Bench	430	399	144	248	282	257	292	343	311	307	281	706	249	278	193	295	269	418
	Slope		481	382	573	263	228	387	320	418	352	296	780	136	355	347	351	261	364
Mean		338	421	316	318	341	295	389	352	359	380	279	477	241	297	285	302	474	302
Stdev		106	208	117	141	157	71	158	144	118	144	134	164	96	72	87	71	187	110

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

Site	Biotope	Nov-98	May-99	Dec-99	Jun-00	Nov-00	May-01	Nov-01	May-02	Jul-05	Nov-05	Jul-06	Jan-07	Dec-07	Aug-08	Oct-08	May-09	Mar-10	Nov-10
Wawaloli	Boulder	248	315	198	673	375	350	514	202	112	197	291	228	464	265	184	240	186	209
	Bench	295	255	231	424	540	234	339	200	193	241	305	260	327	690	397	139	164	313
	Slope	176	316	174	246	299	389	298	159	231	353	315	528	655	1470	565	174	509	173
18-inch Pipe	Boulder	448	376	344	596	314	250	419	280	207	345	591	349	716	476	406	343	416	446
	Bench	485	321	484	312	336	289	299	172	298	314	521	231	620	274	761	366	400	308
	Slope	848	349	599	818	1019	671	493	678	416	576	698	397	878	500	835	347	678	399
12-inch Pipe South	Boulder	654	295	246	359	731	423	493	349	146	434	400	200	401	427	408	207	244	242
	Bench	937	396	294	549	371	343	324	227	327	493	506	302	341	565	559	386	311	293
	Slope	922	357	819	274	319	309	391	316	327	627	960	1105	728	707	770	535	858	410
12-inch Pipe North	Boulder	530	257	338	124	336	305	336	213	240	433	267	294	269	284	351	326	198	211
	Bench	468	321	301	107	315	415	347	219	302	291	506	179	231	273	356	260	270	209
	Slope	603	344	279	344	351	338	404	429	297	359	387	329	425	392	268	199	833	298
NPPE Site	Boulder	660	391	385	150	379	343	350	187	277	271	286	306	412	330	308	203	192	238
	Bench	425	375	250	93	313	410	186	294	210	478	413	304	249	313	273	186	269	1274
	Slope	355	252	292	162	922	299	393	272	324	578	486	246	287	335	390	543	238	267
Ho'ona Bay	Boulder	314	258	332	140	385	431	332	277	193	270	385	314	293	280	232	229	341	210
	Bench	317	322	267	150	323	365	309	356	202	259	221	281	247	192	137	177	244	247
	Slope	506	270	509	124	508	307	330	323	190	253	833	361	310	375	230	235	326	220
Mean		511	321	352	314	452	360	364	286	250	376	465	345	436	453	413	283	371	332
Stdev		225	48	160	218	218	97	81	122	76	130	201	206	198	293	207	118	215	247

Appendix D.4. Number of species counted along 25 m transects within three biotopes (Shallow, Middle, Deep) at six locations off NELHA between 1989 and 2010.

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

Appendix D.4. Number of species counted along 25 m transects within three biotopes (Shallow, Middle, Deep) at six locations off NELHA between 1989 and 2010.

Site	Biotope	May-99	Dec-99	Jun-00	Nov-00	May-01	Nov-01	May-02	Jul-05	Nov-05	Jul-06	Jan-07	Dec-07	Aug-08	Oct-08	May-09	Mar-10	Nov-10
Wawaloli	Boulder	27	20	34	23	20	31	26	17	17	18	23	20	24	26	21	12	31
	Bench	18	19	27	24	20	24	24	25	17	20	22	23	26	27	20	27	29
	Slope	27	22	29	27	20	24	20	17	22	28	30	24	39	34	24	20	28
18-inch Pipe	Boulder	41	34	45	27	28	38	34	26	32	32	29	38	34	28	25	24	37
	Bench	31	25	36	31	28	24	24	26	25	33	28	33	27	37	26	32	25
	Slope	32	27	38	33	36	36	33	24	34	34	34	36	34	42	30	31	35
12-inch Pipe South	Boulder	35	26	30	42	34	33	37	32	25	29	22	27	32	28	25	26	32
	Bench	34	21	29	35	45	37	27	25	24	28	28	29	31	29	31	23	26
	Slope	38	33	37	33	42	39	34	29	28	22	29	38	32	35	33	28	29
12-inch Pipe North	Boulder	32	29	33	25	27	35	27	31	25	31	26	30	31	26	22	22	24
	Bench	34	34	38	34	34	34	33	27	26	32	25	32	34	33	29	28	36
	Slope	34	30	38	28	29	27	36	23	24	26	35	33	27	38	28	33	28
NPPE Site	Boulder	31	29	37	32	37	30	29	27	35	24	18	29	21	26	19	15	23
	Bench	39	25	31	30	35	32	30	23	27	20	25	27	26	20	22	19	24
	Slope	33	24	29	36	30	30	24	27	24	28	27	27	32	23	26	26	20
Ho'ona Bay	Boulder	28	29	27	32	32	32	34	17	23	20	22	28	24	25	19	19	23
	Bench	27	22	32	29	26	23	26	26	23	22	23	24	25	16	25	25	23
	Slope	29	35	28	25	35	30	25	21	24	27	21	27	28	23	23	30	27
Mean		32	27	33	30	31	31	29	25	25	26	26	29	29	29	25	24	28
Stdev		5	5	5	5	7	5	5	4	5	5	5	5	5	7	4	6	5

Appendix D.5. Estimated biomass (g/m^2) along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2010.

Site	Biotope	May-89	Oct-91	Mar-92	May-92	Oct-92	May-93	Dec-93	May-94	Jun-94	Oct-94	Mar-95	Jun-95	Dec-95	Jun-96	Dec-96	Jun-97	Dec-97	Nov-98
Wawaloli	Boulder		210	113	91	251	171	85	151	276	188	154	184	121	174	482	211	280	311
	Bench		51	138	83	67	105	58	104	87	62	112	142	103	103	445	44	891	76
	Slope		57	54	37	117	46	102	151	100	150	191	187	121	74	62	64	190	168
18-inch Pipe	Boulder		379	230	223	285	193	362	342	208	394	555	303	205	94	196	180	518	346
	Bench		327	158	175	85	106	255	169	153	380	288	173	210	122	146	124	319	297
	Slope		271	248	86	110	128	213	200	217	91	156	551	97	129	83	92	430	169
12-inch Pipe South	Boulder				258	727	483	700	318	286	314	244	214	116	109	240	538	385	1382
	Bench				364	259	222	626	288	170	191	130	268	348	101	141	84	211	1255
	Slope				136	210	142	351	136	229	121	207	148	74	125	126	193	77	1809
12-inch Pipe North	Boulder				122	137	153	610	160	162	311	154	131	98	64	140	104	1637	265
	Bench				108	125	103	246	124	149	204	119	222	50	120	76	58	123	219
	Slope				298	85	187	726	74	132	105	212	116	490	116	599	886	183	2152
NPPE Site	Boulder				316	149	66	217	95	89	478	146	125	58	179	121	146	912	1816
	Bench				171	78	68	118	316	74	113	116	74	163	80	60	150	143	121
	Slope				45	71	55	186	48	47	150	85	99	73	579	115	96	631	83
Ho'ona Bay	Boulder		105	108	131	251	88	151	241	181	209	413	198	141	119	170	112	201	201
	Bench		187	36	54	67	44	68	77	93	125	143	101	165	125	53	89	82	94
	Slope		170	166	178	124	414	143	134	173	115	57	106	36	62	122	135	132	398
Mean			195	139	160	178	154	290	174	157	206	193	186	148	138	188	184	408	620
Stdev			115	71	97	156	120	225	91	69	120	122	110	113	115	158	206	399	706

Jun-98
144
76
78
307
308
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177
312
331
178
114
200
195
93
47
129
85
79
161
97

Appendix D.5. Estimated biomass (g/m^2) along 25 m transects within three biotopes (Shallow, Middle Deep) at six locations off NELHA between 1989 and 2010.

Site	Biotope	May-99	Dec-99	Jun-00	Nov-00	May-01	Nov-01	May-02	Jul-05	Nov-05	Jul-06	Jan-07	Dec-07	Aug-08	Oct-08	May-09	Mar-10	Nov-10
Wawaloli	Boulder	274	100	673	143	115	228	155	30	143	107	314	189	84	119	268	352	156
	Bench	61	91	424	115	148	128	82	48	92	139	114	111	84	84	34	56	87
	Slope	110	151	264	103	108	110	110	37	76	241	346	242	139	212	70	57	135
18-inch Pipe	Boulder	251	400	596	297	227	170	207	199	204	256	194	297	321	138	88	227	187
	Bench	103	239	312	414	185	120	86	139	153	230	163	212	213	288	198	213	147
	Slope	125	270	818	258	274	189	145	95	388	179	187	514	234	231	94	299	190
12-inch Pipe South	Boulder	281	437	359	578	523	190	227	148	270	227	268	261	251	119	110	189	70
	Bench	168	361	549	180	373	293	166	68	101	231	246	297	308	147	146	88	118
	Slope	162	994	274	308	214	213	214	75	116	106	146	497	265	163	82	323	127
12-inch Pipe North	Boulder	135	183	124	198	116	212	133	226	349	150	352	222	125	158	114	92	100
	Bench	149	238	107	204	93	86	118	96	94	270	149	79	100	101	74	141	61
	Slope	328	340	344	293	127	89	259	94	298	120	502	120	96	128	60	332	63
NPPE Site	Boulder	269	148	150	108	161	122	110	330	171	245	231	115	97	70	122	143	198
	Bench	219	122	93	836	81	153	134	89	180	100	83	135	109	94	100	96	465
	Slope	96	267	162	303	73	172	77	65	74	84	149	60	170	92	66	72	44
Ho'ona Bay	Boulder	150	131	140	169	127	111	163	224	143	87	492	296	151	109	119	179	137
	Bench	69	77	150	548	82	74	98	101	188	76	150	90	105	36	95	123	61
	Slope	126	152	124	67	161	100	109	82	90	367	114	106	81	60	75	237	96
Mean		171	261	315	285	177	153	144	119	174	179	233	214	163	131	106	179	136
Stdev		80	213	218	200	115	59	53	79	95	83	124	133	81	63	54	99	95

APPENDIX E

DIGITAL QUADRAT PHOTOS

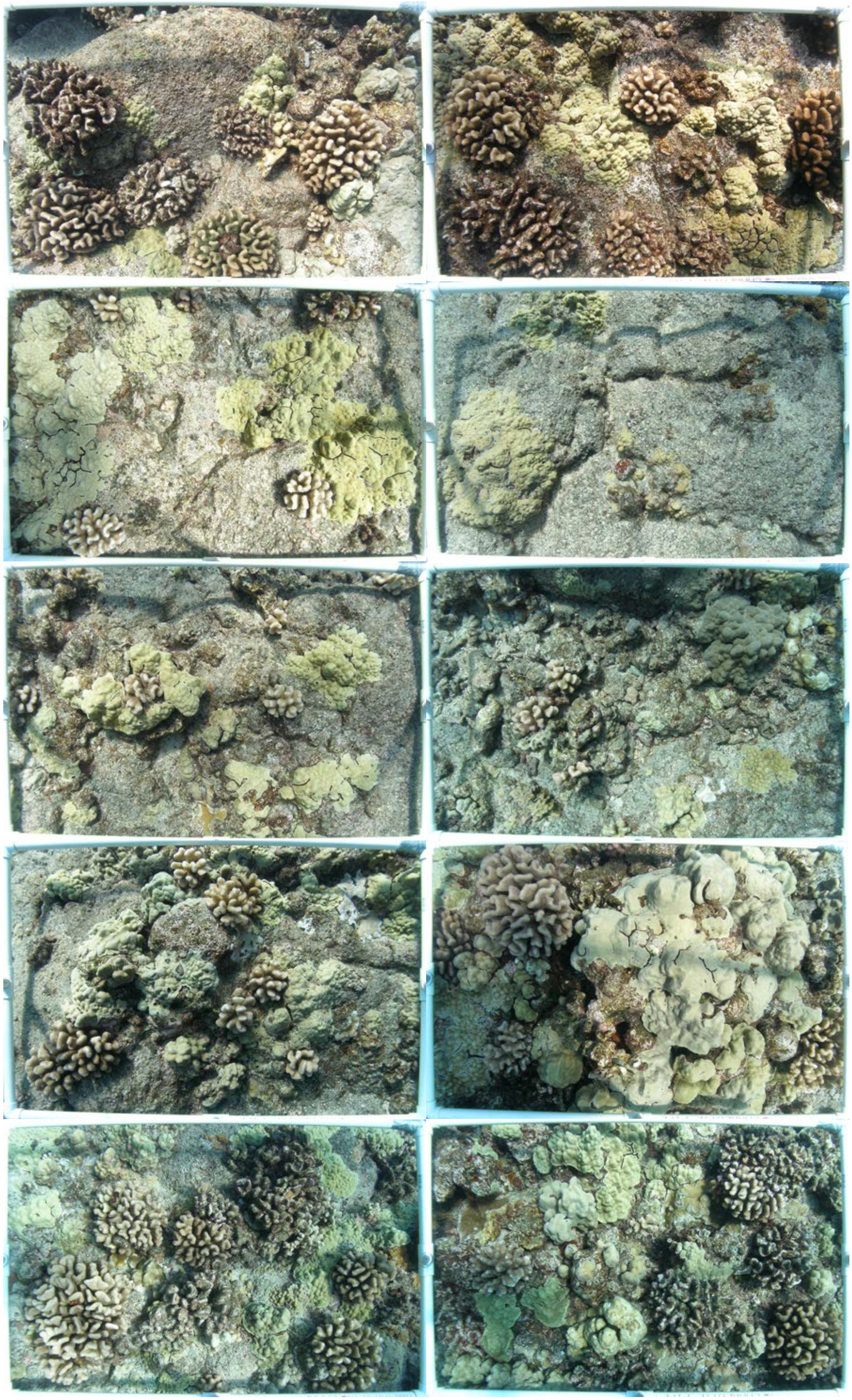

Plate A1. Quadrat photos taken at 10 random locations along a 50 m transect line at Ho’ona Bay - Shallow.

Plate A2. Quadrat photos taken at 10 random locations along a 50 m transect line at Ho’ona Bay - Middle.

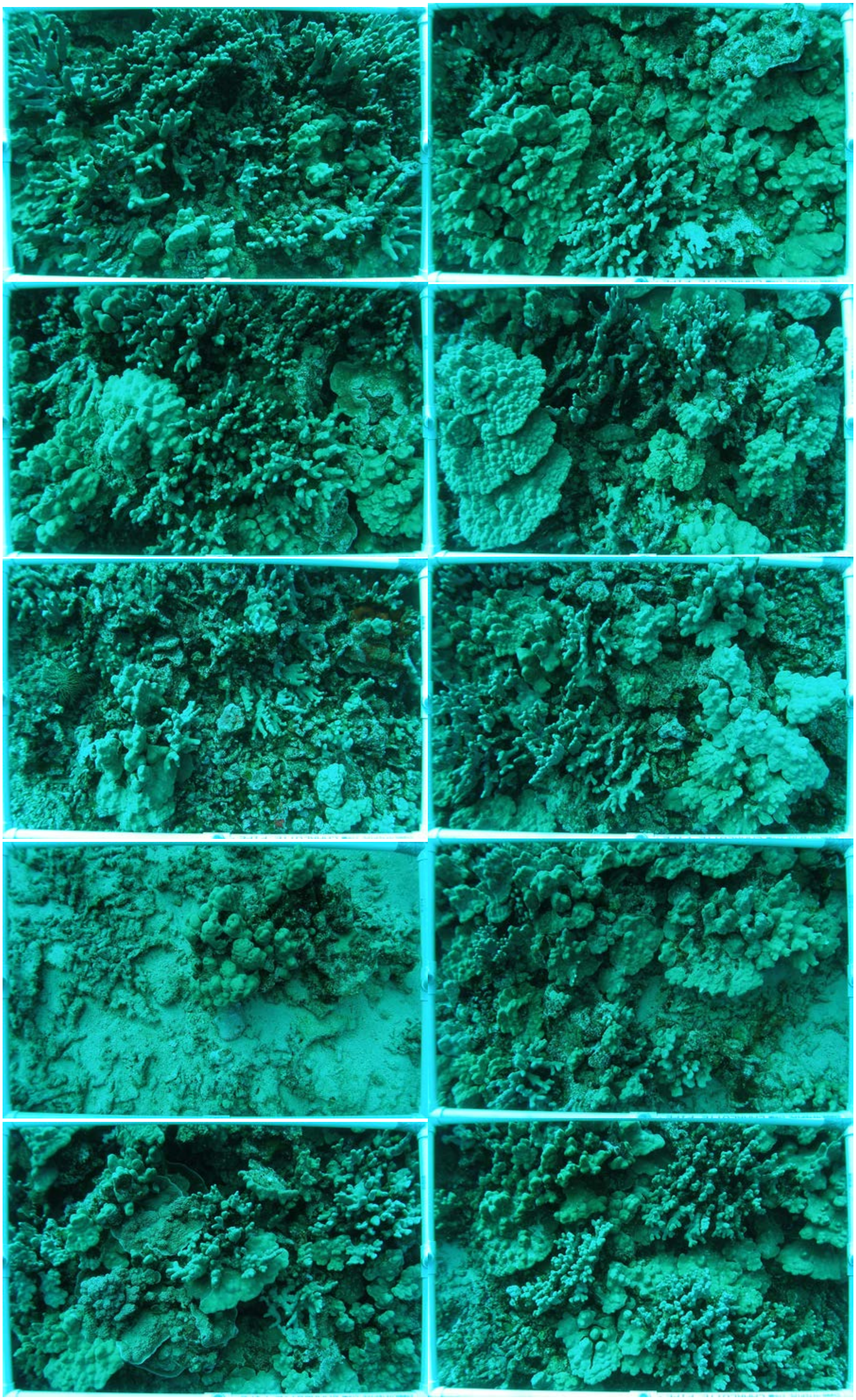

Plate A3. Quadrat photos taken at 10 random locations along a 50 m transect line at Ho'ona Bay - Deep.

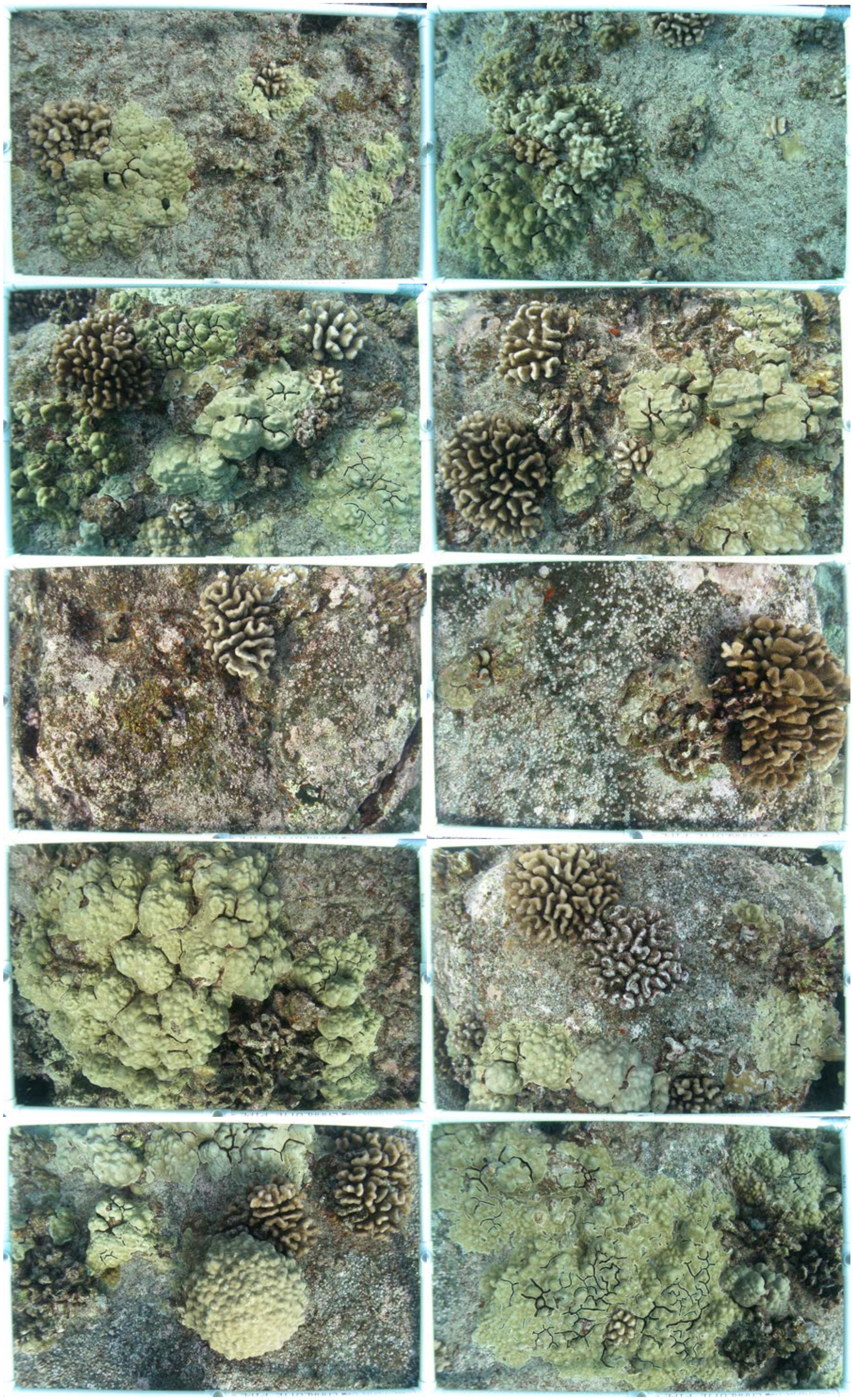

Plate B1. Quadrat photos taken at 10 random locations along a 50 m transect line at NTTP - Shallow.

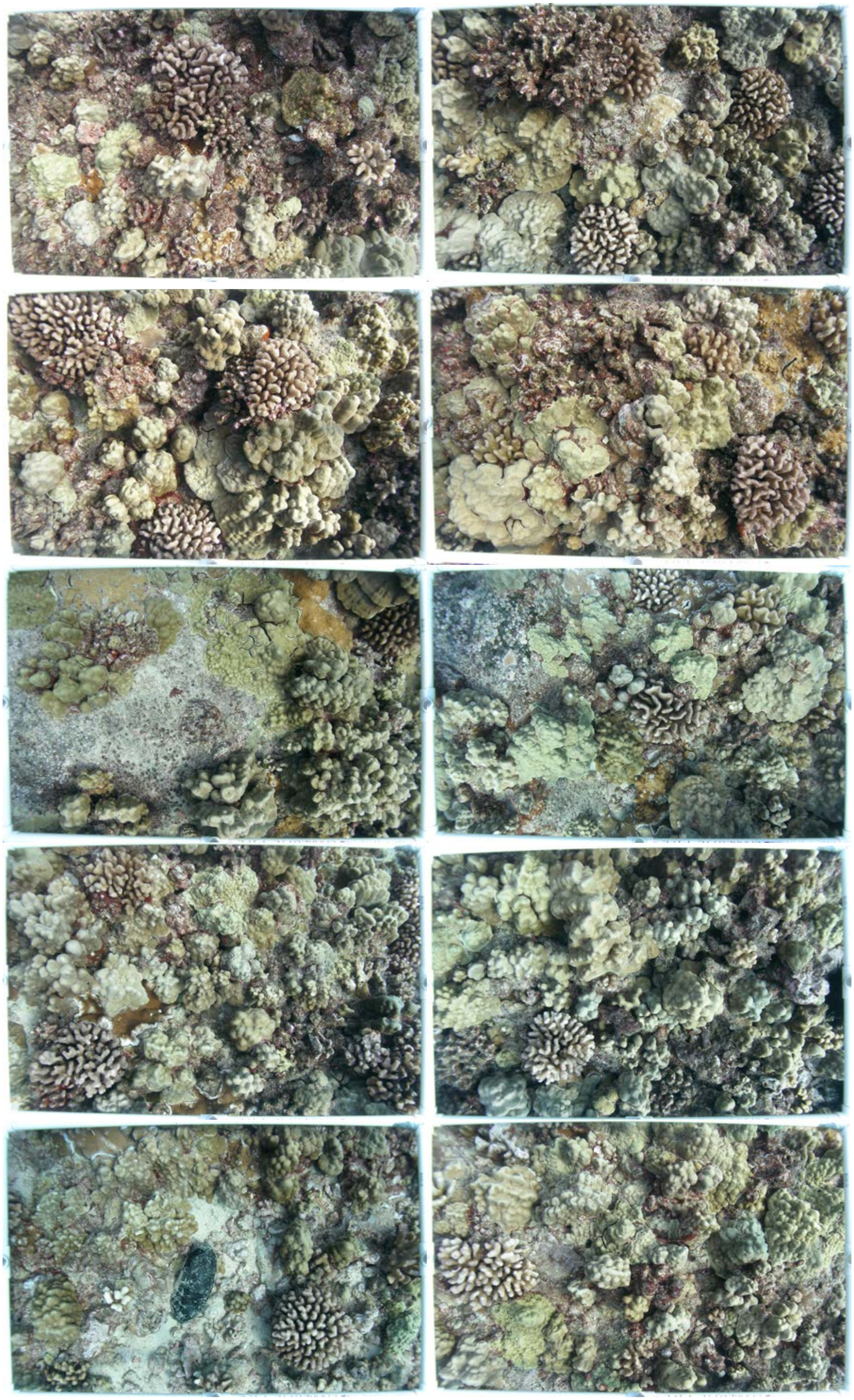

Plate B2. Quadrat photos taken at 10 random locations along a 50 m transect line at NTTP - Middle.

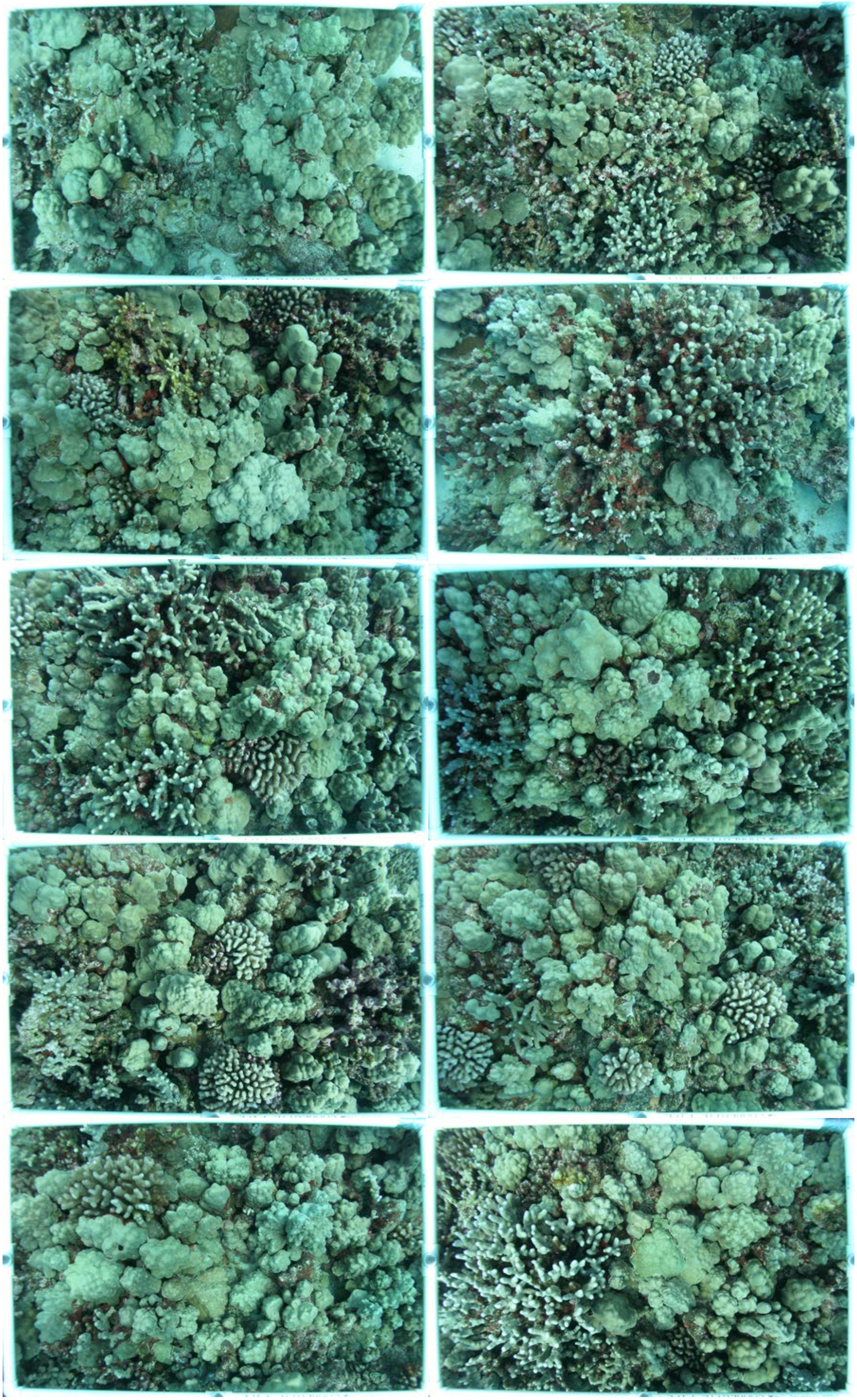

Plate B3. Quadrat photos taken at 10 random locations along a 50 m transect line at NPPT - Deep.

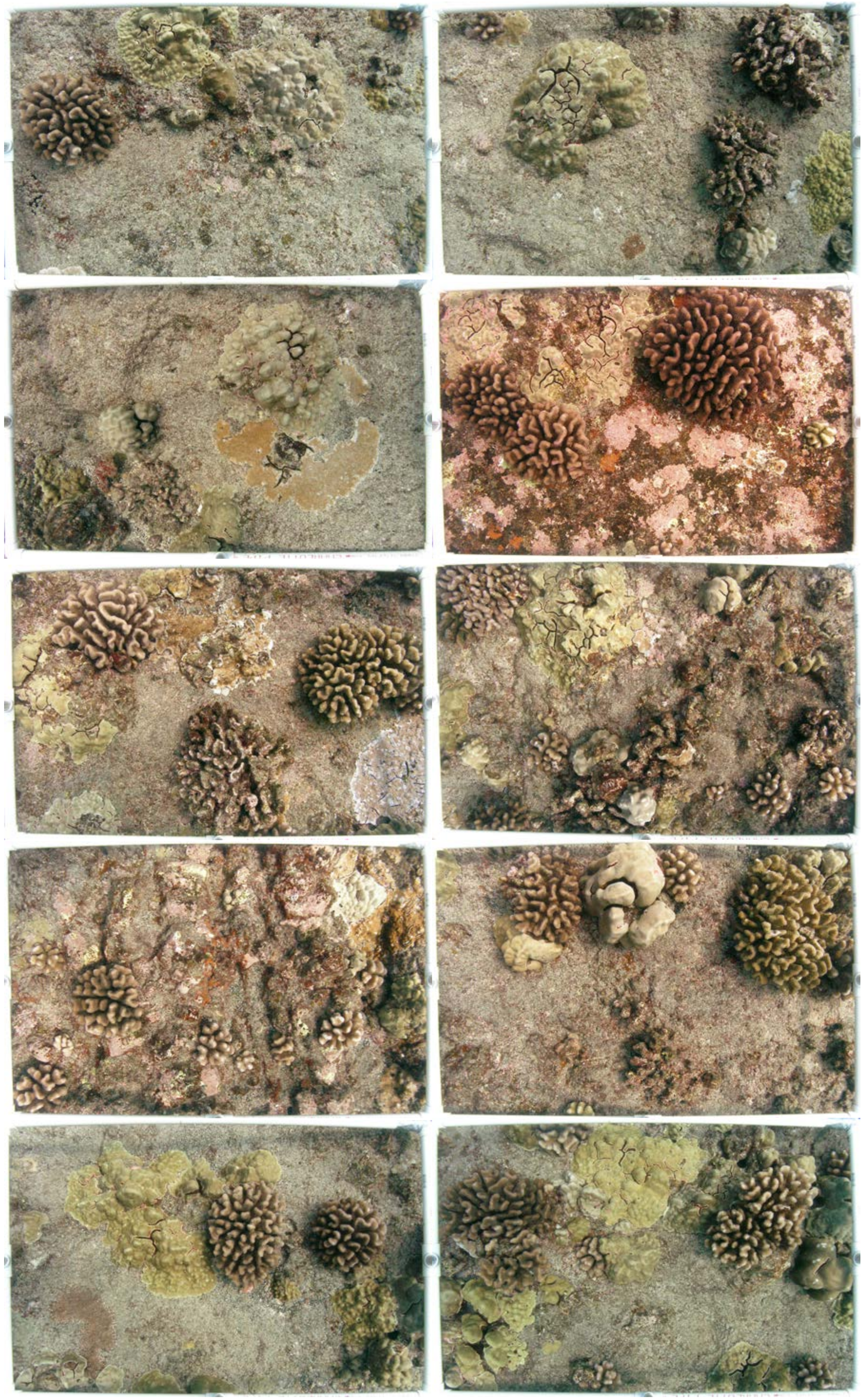

Plate C1. Quadrat photos taken at 10 random locations along a 50 m transect line at 12” Pipe North - Shallow.

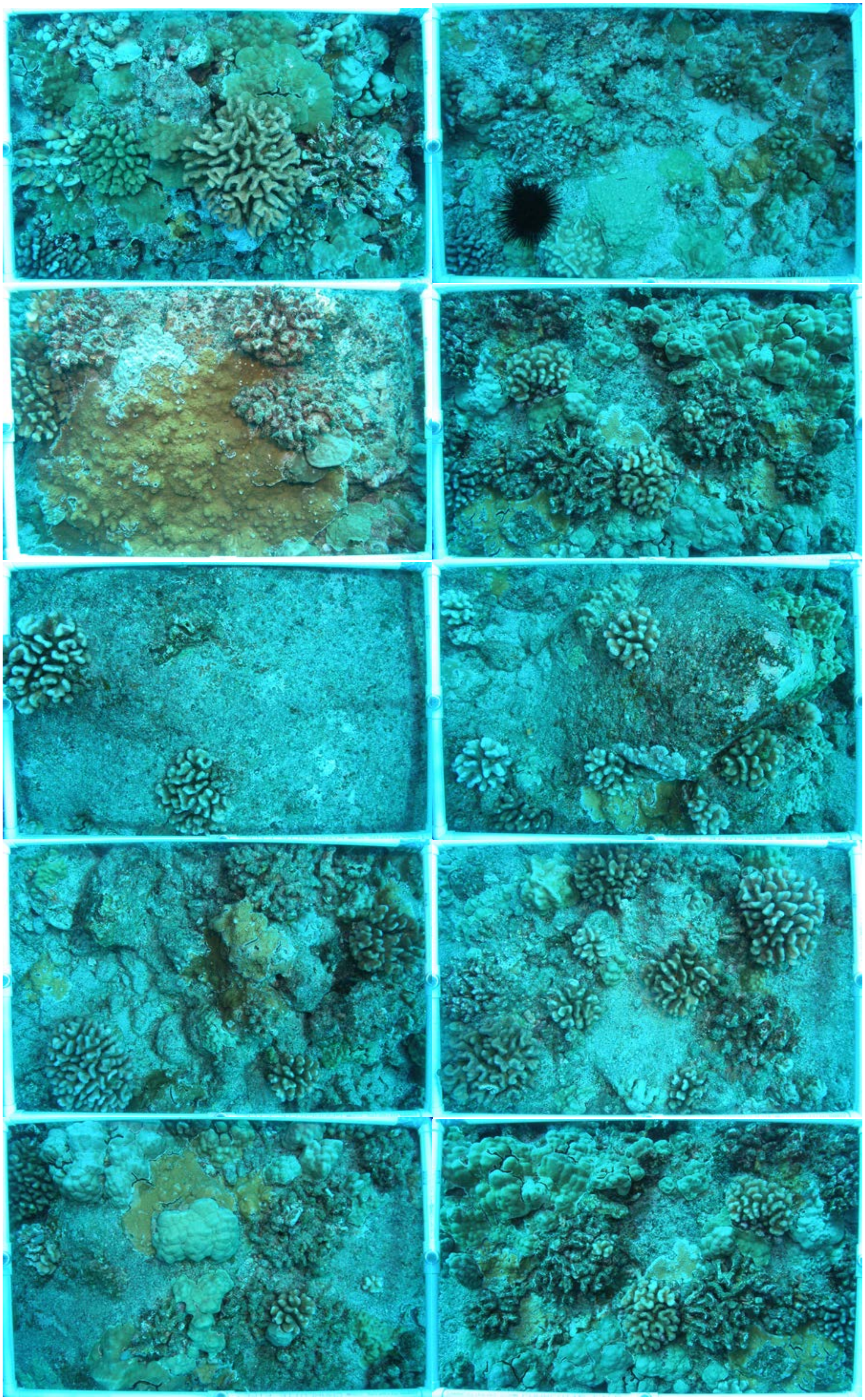

Plate C2. Quadrat photos taken at 10 random locations along a 50 m transect line at 12” Pipe North - Middle.

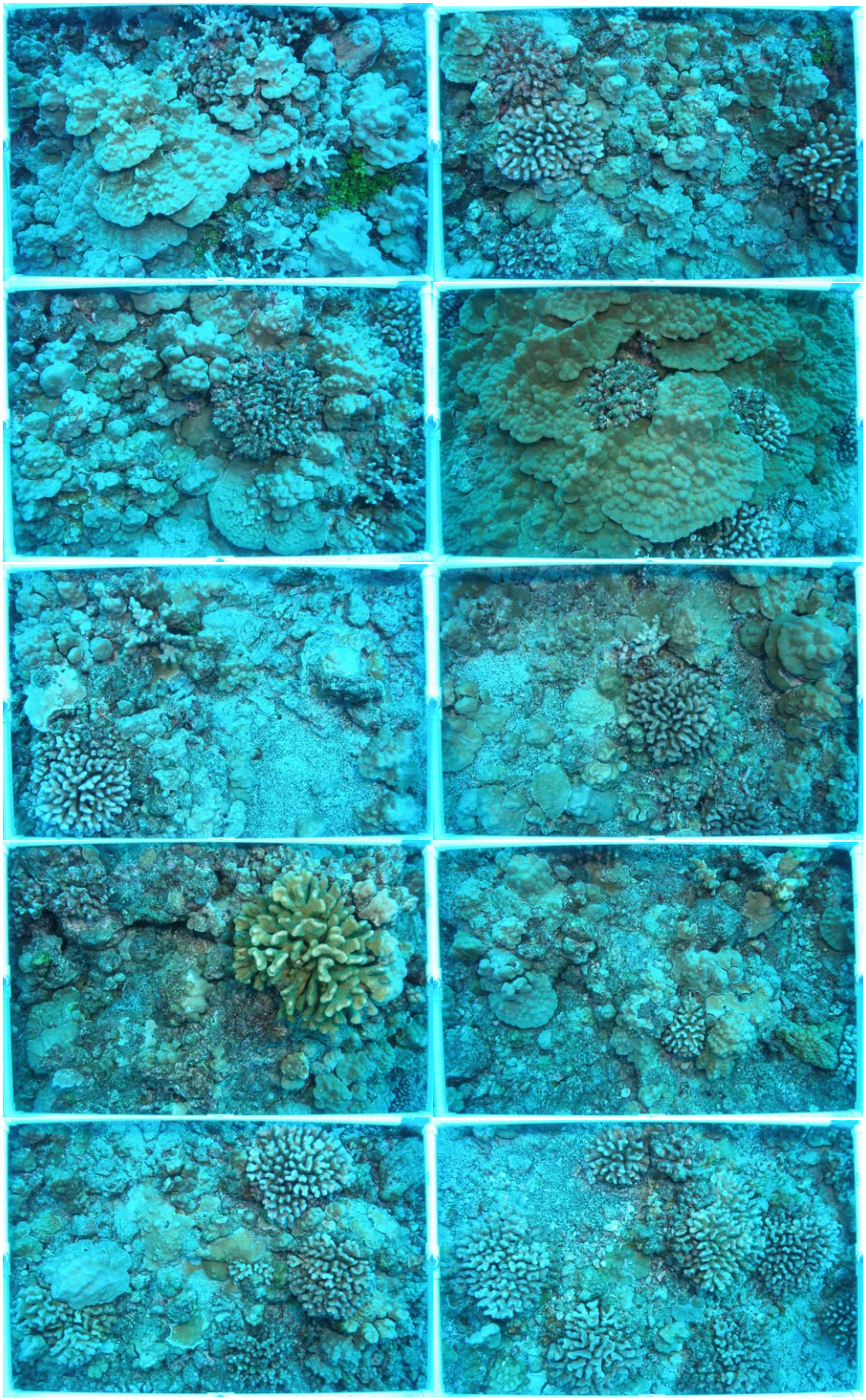

Plate C3. Quadrat photos taken at 10 random locations along a 50 m transect line at 12" Pipe North - Deep.

Plate D1. Quadrat photos taken at 10 random locations along a 50 m transect line at 12” Pipe South - Shallow.

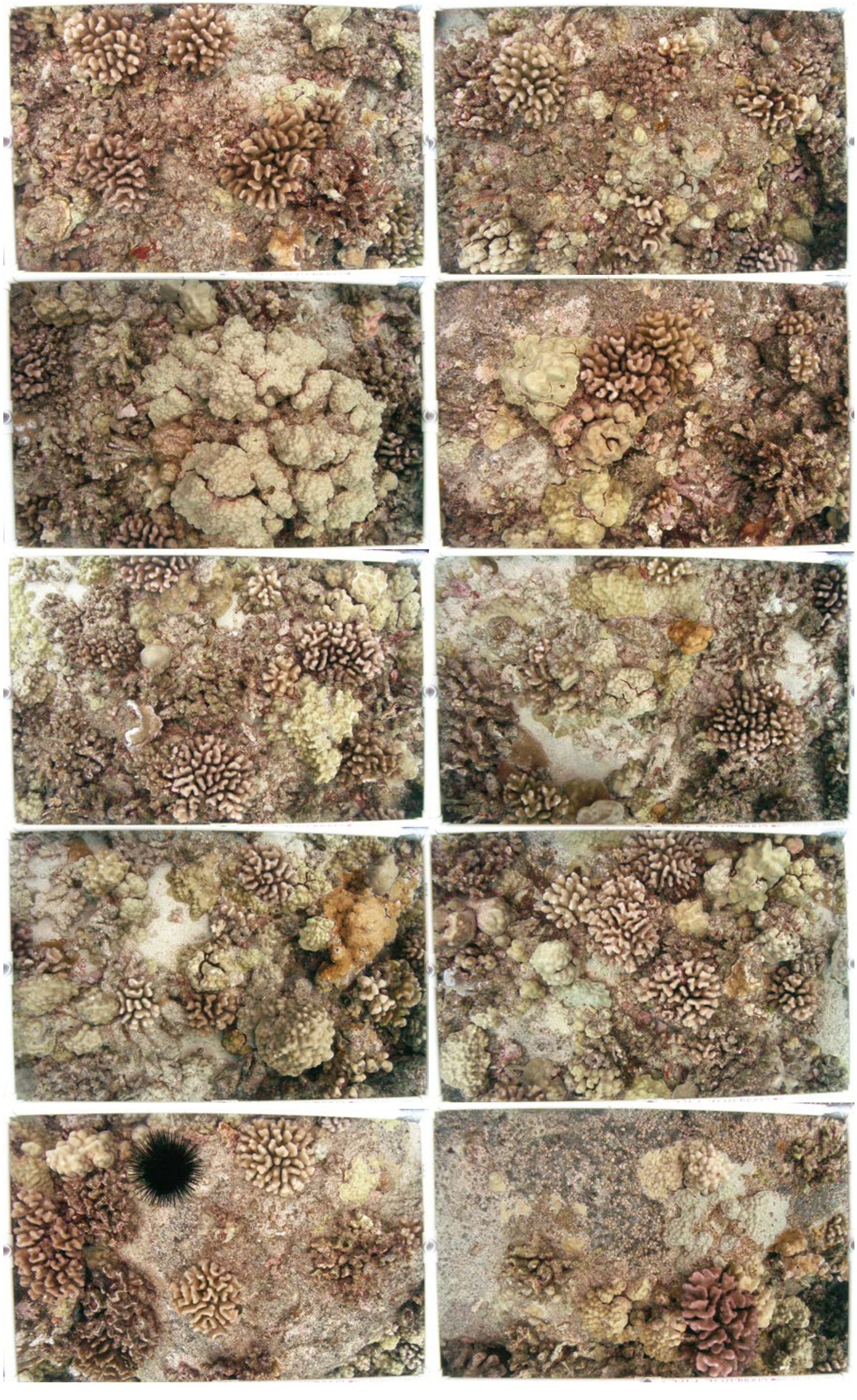

Plate D2. Quadrat photos taken at 10 random locations along a 50 m transect line at 12” Pipe South - Middle.

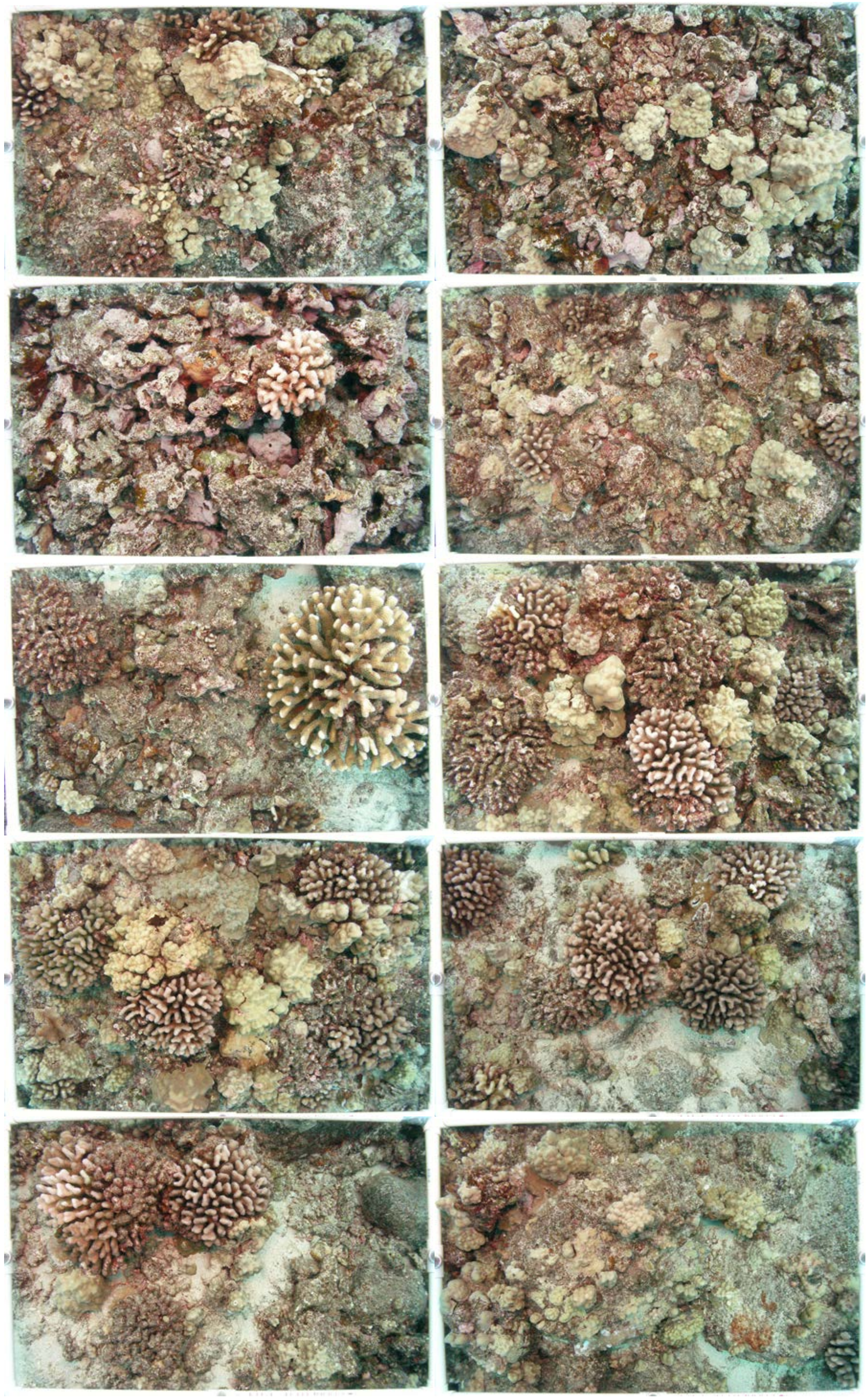

Plate D3. Quadrat photos taken at 10 random locations along a 50 m transect line at 12” Pipe South - Deep.

Plate E1. Quadrat photos taken at 10 random locations along a 50 m transect line at 18” Pipe - Shallow.

Plate E2. Quadrat photos taken at 10 random locations along a 50 m transect line at 18” Pipe - Middle.

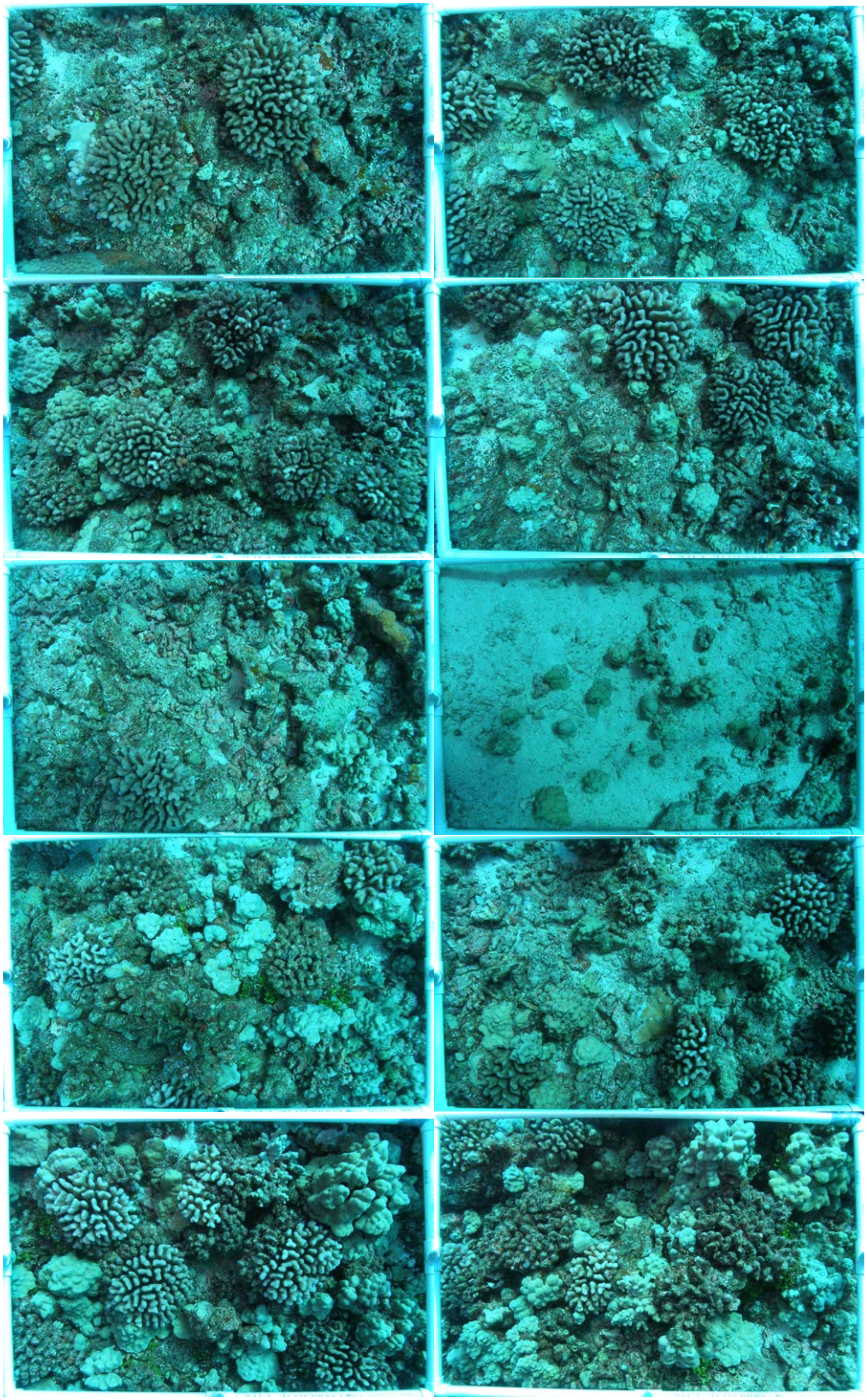

Plate E3. Quadrat photos taken at 10 random locations along a 50 m transect line at 18” Pipe - Deep.

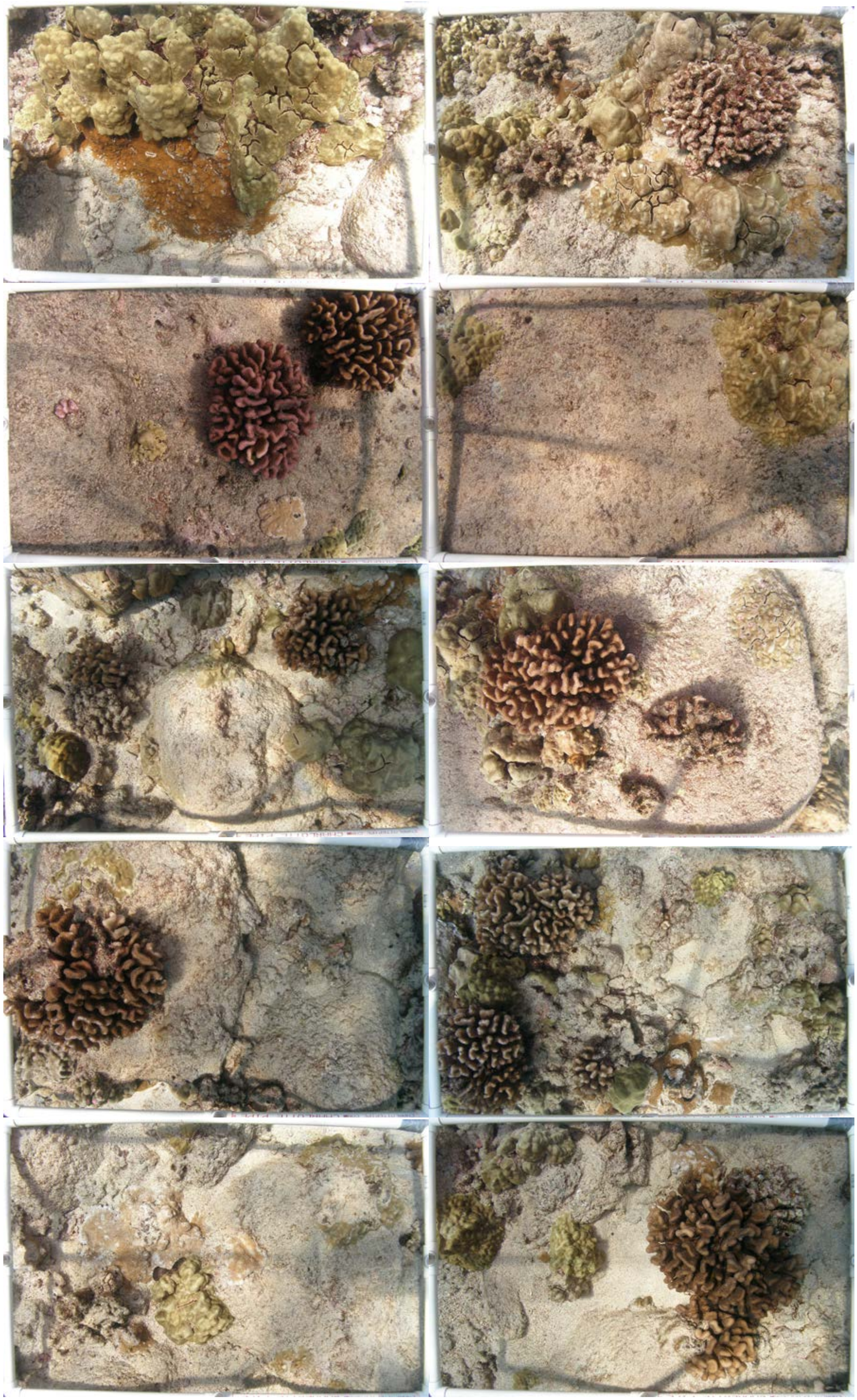

Plate F1. Quadrat photos taken at 10 random locations along a 50 m transect line at Wawaloli - Shallow.

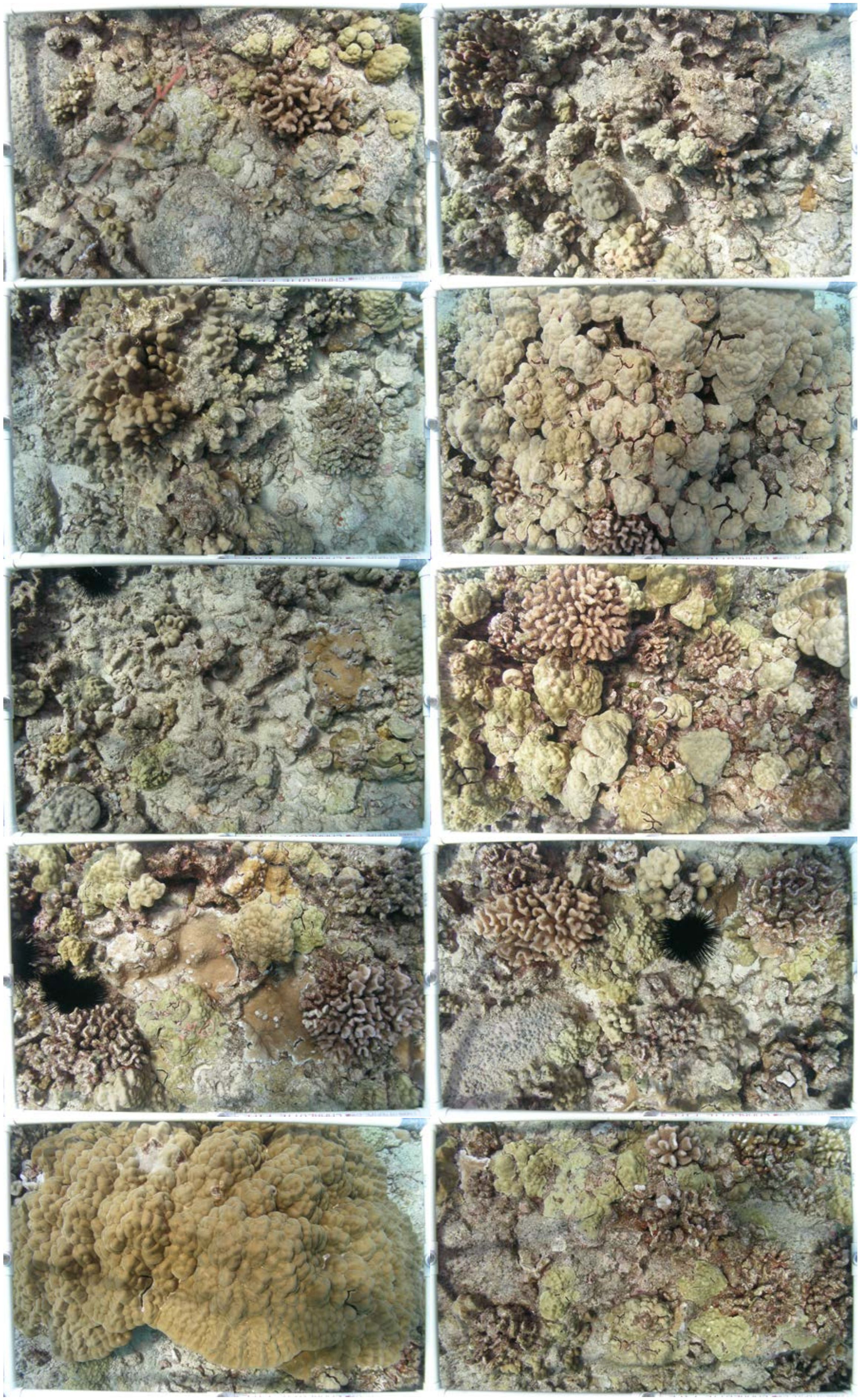

Plate F2. Quadrat photos taken at 10 random locations along a 50 m transect line at Wawaloli - Middle.

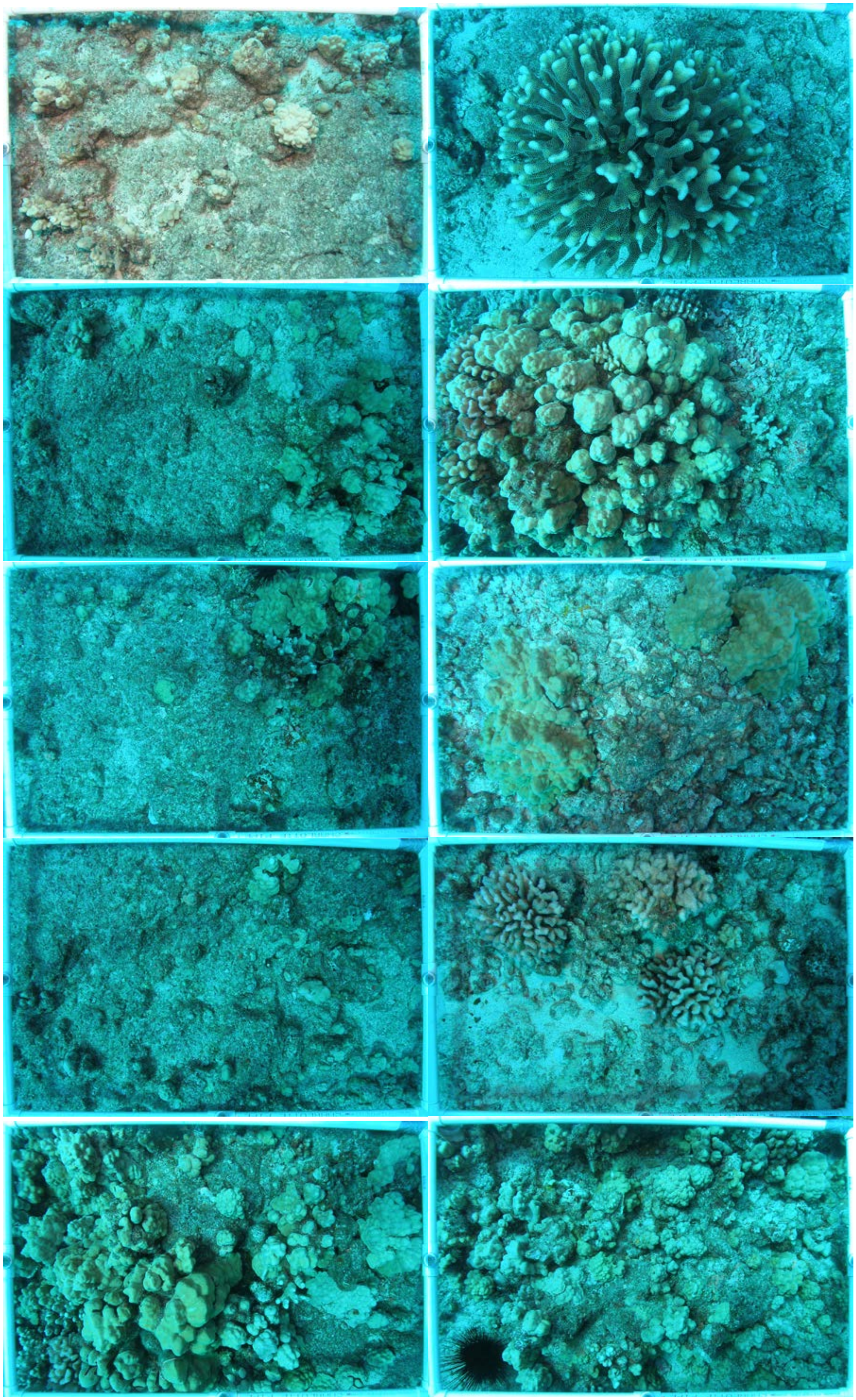

Plate F3. Quadrat photos taken at 10 random locations along a 50 m transect line at Wawaloli - Deep.