COOPERATIVE ENVIRONMENTAL MONITORING

PROGRAM FOR THE

NATURAL ENERGY LABORATORY OF HAWAII AUTHORITY

SURVEY FOR ANCHIALINE AND MARINE FISH RESOURCES

SYNOPSIS OF 2007-2008 SURVEYS

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EXECUTIVE SUMMARY

The Cooperative Environmental Monitoring program for the NELHA facility has monitored anchialine and marine fish resources since October 1991. Our monitoring efforts continued from 1991 through mid-1995 at which time another firm assumed the monitoring program that continued until late-1997 when we again commenced monitoring through January 2003 at which time the other firm again assumed the program through mid- 2007. In late 2007 we again commenced monitoring at the NELHA facility completing field work in December 2007 and again in August 2008. Over the 202 months since this monitoring program commenced, we have carried out field surveys on 24 occasions (October 1991, March, May and October 1992, May and December 1993, May, June and October 1994, March and June 1995 and again in December 1997, June and November 1998, May and December 1999, June 2000, March 2001 (for the December 2000 survey), May and November 2001, May and December 2002, 19 December 2007 and 12 August 2008. This report covers the results of the two most recent field surveys and compares these to the results from earlier surveys.

In total there are fourteen identified anchialine pools on the project site: five of these are located north of the NELHA compound and nine in the southern part of the project site. One of these nine pools was first recorded in the October 1992 survey and is the result of the extreme high tide at that time. The southern complex of anchialine pools were inhabited by native species up through the November 2001 survey. In the May 2002 survey one pool was found to contain alien mosquito fish and native crustaceans were absent. Sometime after December 2002 but before December 2007 survey, the mosquito fish were in all but two of the south complex of pools resulting in a significant decrease in the abundance of native aquatic biota in the affected pools. The northern complex of five pools was colonized by exotic fishes (topminnows) which spread since October 1991 and had colonized all pools by May 1992. The exotic fishes effectively preclude many of the important native aquatic species. On 4 May 1992 the exotic fishes were removed from these pools using an ichthyocide. Native species (shrimp) returned to four of the five pools; one pool remained with exotic fishes through the October 1992 survey. By May 1993, these exotic fishes had once again recolonized all of the pools in the northern complex, thus effectively driving the native shrimp from the lighted portion of the system up through the December 2007 survey at which time all aquatic biota in the north complex of pools had been recently killed due to unknown factors. However, with the most recent survey (August 2008) native shrimp have again colonized the north complex of pools. Thus today, the five pools in the northern cluster are biologically intact while seven of the nine pools in the southern group are infested with mosquito fish reducing the presence of native aquatic biota.

The Cooperative Environmental Monitoring program has routinely surveyed the status of the marine fish resources at three locations offshore of NELHA project area since October 1991. These sites are offshore of Wawaloli Beach, the 18-inch pipeline and Ho'ona Bay. In the May 1992 survey we added transects to three additional permanently marked sites for routine sampling to bring the total number of sites up to six. The sites now routinely sampled are (from south to north): Wawaloli Beach, the 18-inch pipeline, the 12-inch warmwater pipe, the 12-inch coldwater pipe, the Net Power Production Experiment site (or NPPE) and Ho'ona Bay. Three ecological zones or biotopes are sampled at each of the six sites resulting in the routine sampling of 18 transects. The sampled zones are depth related with the biotope of boulders and *Pocillopora meandrina* being the shallowest and located adjacent to shore, the mid-depth zone or biotope of *Porites lobata* and the deeper more offshore biotope of *Porites compressa.*

The data on marine fish communities from October 1991 to present (August 2008) are directly comparable, thus the question, "Are there any significant differences among the means for the number of species, individuals or biomass over this 202-month period of study?" is first addressed using the nonparametric Kruskal-Wallis ANOVA which found significant differences among the means by survey data for the number of species, number of individuals and standing crop. However, the Student-Newman-Keuls (SNK) Test which is used to distinguish which survey means differ significantly from others, noted significant overlap among the survey dates for the number of species and biomass suggesting that any significant differences may only exist with the extremes in the data and there is no chronology to any increases or decreases among these data. A second Krsukal-Wallis ANOVA carried out on the means of the three parameters (number of species, number of individuals and biomass) examined by ecological zone found no statistically significant differences among these means in the three ecological zones examined in this study. Applying the SNK Test to these data found a significant difference in the number of individual fish censused in the boulder zone only. Again these data showed considerable overlap suggesting any significant difference would only possibly lie with the two extremes in the data and again, there was no chronological order to these data (i.e., showing increases or decreases through time). These data and analyses show no evidence of a decrease or decline in any of the measured parameters that could suggest an increasing perturbation which would be the hallmark of an impact coming from the operation of the NELHA facility. Rather the variation seen in the data over the 202-month period of this study are related to the movement of fishes relative to the presence of food resources, recruitment of newly settled juveniles into the adult habitat or to aggregations of adult fish for the purpose of reproduction. Thus in summary, the analysis of the fish communities in the waters fronting Keahole Point over this 202-month period of study show that the development at NELHA has had no significant impact to these communities.

COOPERATIVE ENVIRONMENTAL MONITORING PROGRAM

FOR

HAWAII OCEAN SCIENCE AND TECHNOLOGY PARK

AND THE

NATURAL ENERGY LABORATORY OF HAWAII AUTHORITY

SYNOPSIS OF THE 2007-2008 SURVEYS

INTRODUCTION

Both the Hawaii Ocean Science and Technology Park (HOST Park) and the Natural Energy Laboratory of Hawaii Authority (NELHA) are situated at Keahole Point, North Kona, Hawaii. These two State of Hawaii facilities are linked in a number of ways: they share critical infrastructure for the delivery and disposal of seawater; the impact of their operations on the environment will be similar and affect the same ecosystems and they share certain environmental permits. These common elements has allowed the development of a combined program to monitor the environmental effects of operations at the two facilities.

The Cooperative Environmental Monitoring Program has two broad objectives: (1) to protect the unique environmental resources of the Keahole Point area and their diverse uses, and (2) to provide the information necessary to comply with the permit requirements of the various County, State and Federal agencies.

Both HOST Park and NELHA use and dispose of large quantities of warm and cold seawater brought on-site and distributed through a network of pipes. At the present time, disposal of water from these facilities has been into trenches dug into the lava at some distance inland from the shore. The potential impacts of this and other disposal options (i.e., injection wells, deep ocean outfall, direct discharge) were described and compared in the Environmental Impact Statements for the respective facility (HTDC 1985; NELH 1987). The latter document suggested a monitoring program and GK and Associates (1989) presented the details for such a program. The first phase of the biological monitoring program establishing a preliminary baseline was carried out by Brock (1989).

In the Cooperative Environmental Monitoring Program are four steps to meeting the objective of protecting the environmental resources of Keahole Point. These steps are:

1. To collect field data in the monitoring program utilizing methods identical and complementary to those used in the baseline and subsequent surveys to allow comparative analysis;

2. To undertake comparative analysis of data from the monitoring program with those of the baseline and previous surveys to detect change;

3. To work with NELHA personnel and the water quality monitoring program to trace the cause of any unacceptable change to its source;

4. To provide facilities management with suggested options for corrective measures.

Since the completion of the preliminary baseline in December 1989 (Brock 1989), several changes were instituted in the monitoring program. The first change was to divide the sampling effort between two parties and to redefine some of the stations. Secondly, in late 1995, the monitoring program was assigned to OI Consultants, Inc. with whom it remained until late 1997 and again from January 2003 through mid-2007. Under the OI Consultants, Inc. program, some of the sampling methodologies were different making much of the data collected in this period difficult to analyze with respect to earlier and our subsequent recent surveys. This document comparatively analyses data collected from the surveys conducted prior to the OI Consultants 1995-97 and 2003-2007 work to the data collected between and subsequent to these two periods. In summary, sampling under the present program has occurred at the following times: October 1991, March, May and October 1992, May and December 1993, May June and October 1994, March and June 1995, (followed by a break from late 1995 through mid-1997), December 1997, June and November 1998, May and December 1999, June 2000, March 2001 (representing the December 2000 survey), May and November 2001, May and December 2002 (followed by a break from January 2003 through mid-2007), 19 December 2007 and 12 August 2008. The sampling covers in this study covers the status of (1) the marine fish communities at a series of eighteen permanently marked stations and (2) the aquatic fauna of the anchialine pools present on the NELHA project site. Marine benthic communities are covered by Dollar in separate reports filed with NELHA. Data on the status of the anchialine resources is presented first followed by information on the near shore fish communities resident to the waters fronting the NELHA project site.

ANCHIALINE POOL BIOTA

A. Introduction

Anchialine pools are land-locked bodies of water that may be characterized as not having any surface connections to the sea, yet have measurable salinities and display damped tidal fluctuations. Naturally occurring anchialine pools are restricted to highly porous substrates such as recent lavas or limestone adjacent to the sea. These unique habitats have been described from a number of widely dispersed tropical localities; anchialine pools are most numerous at sites in Fiji, the Ryukyus and Hawaii. Most of the known Hawaiian anchialine resources occur along the West Hawaii (Kona) shoreline and have in recent years been the focus of attention with respect to coastal development.

Anchialine pools harbor a distinctive assemblage of organisms, some of which are found nowhere else. Anchialine pond organisms fall into two classes, i.e., epigeal and hypogeal species. The epigeal fauna is comprised of species that require the well-illuminated (sunlit) part of the anchialine system. Most of these species are found in other Hawaiian habitats albeit individuals from anchialine systems frequently show ecotype (morphological) variations. The hypogeal organisms occur not in the illuminated part of the system but also in the interconnected watertable below. These species are primarily decapod crustaceans, some of which are known only from the anchialine biotope.

Species characteristic of Hawaiian anchialine pools include crustaceans (shrimps and amphipods), fishes, mollusks, a hydroid, sponges, polychaetes, tunicates, aquatic insects, algae and aquatic macrophytes. Most striking are a number of red-pigmented caridean shrimp species and the most abundant of these is the opae'ula or *Halocaridina rubra.*

In the NELHA/HOST Park area, two clusters of anchialine ponds have been identified: the northern complex of approximately five pools is situated north of the NELHA facility and the second more southerly group is comprised of nine small permanent ponds adjacent to the most southerly bend in the NELHA access road. These latter ponds are located on Department of Transportation (Keahole Airport) lands. These pools are collectively known as the Keahole Point anchialine ponds.

The Keahole Point pools were first inventoried by Maciolek and Brock (1974); these authors noted nine anchialine ponds in the boundaries of the combined NELHA/HOST Park project area. Three of these ponds were situated north of the NELHA facility inland of Hoona Bay and six were located to the south, along Wawaloli Beach. In their study, Maciolek and Brock (1974) found one of the 3 northern pools to be less than 10 square meters in surface area while the two adjacent pools were between 10 to 100 square meters. Depths were shallow (0.5 m), pond bottoms rocky with some sand and sediment, and salinities ranged between 7 and 8 ppt. Algae and plants present included the encrusting carbonate producing cyano-bacteria mat *Schizothrix calcicola*; the alga, *Rhizoclonium* sp. and the aquatic flowering plant, *Ruppia maritima.* In the vicinity of the ponds were kiawe (*Prosopis pallida*), naupaka (*Scaevola taccada*), fountain grass (*Pennisetum setaceum*), pohuehue (*Ipomoea pre-caprae*) and pickleweed (*Bacopa* sp.). Fauna inventoried in these ponds included an unidentified oligochaete, the snails *Assiminea* sp. and *Melania* sp., the limpet *Theodoxus cariosa* in one pond, opae'ula (*Halocaridina rubra*) in one pond, and opae'o'haa (*Macrobrachium grandimanus*) present in two of the three ponds.

Ziemann (1985) examined ponds in the vicinity of NELHA and noted five bodies of water. It was hypothesized by Brock (1989) that coralline and basalt rubble washed ashore by storm surf and carried into these ponds subdividing them and temporarily creating additional pools. These rubble barriers subsequently broke down leaving the three pool complex at high tide as sampled by GK & Associates (1986). When he sampled these pools in 1985, Ziemann (1985) found higher salinities (10 to 11 ppt); shoreline vegetation included the sedge (*Cladium* sp.), fountain grass, pickleweed, pohuehue, pluchea, naupaka, akulikuli and kiawe. In the ponds Ziemann (1985) noted the alga, *Enteromorpha* sp., the snail, *Melania* sp., opae'ula in two ponds and only opae'o'haa in one pond. All aquatic species were noted as being abundant.

In September 1986 GK & Associates (1986) examined the northern or NELHA series of ponds. Three ponds were located, suggesting that rubble seen by Ziemann in 1985 had broken down. Further evidence for this was seen at high tide on 27 September 1986, when a very shallow surface interconnection between two of the ponds was observed. The more northerly situated pool of the pair had a surface area of about 20 square meters and was 38 m inland of the ocean. The basin was rocky attaining a maximum depth of about 46 cm. Salinity of this pool was 8 ppt. In the deeper parts of this pool was the alga, *Cladophora* sp. and numerous snails (*Melania* sp.) were present. Neither fish nor shrimp were observed in this pond. The more southerly adjoining pool was slightly deeper (about 75 cm) and a single aholehole (*Kuhlia sandvicensis*) and rock crab (*Metopograpsus messor*) were observed. This pond had a surface area of about 11 square meters at high tide. Opae'ula (*Halocaridina rubra*) were seen in this pool. The flora of this pond was dominated by the cyanophyte mat (*Schizothrix* and *Lygnbya*). The third pool sampled by GK & Associates (1986) located about 30 m south of the above pools had a surface area of 11 square meters at high tide and a maximum depth of 1 m. This pool was situated beneath a fringing canopy of kiawe and around it were naupaka and pickleweed. The salinity of this pond was 10 ppt. No fish or shrimp were observed in this pool.

In his baseline survey, Brock (1989) noted 12 anchialine pools in the project area; five of these were located in the northern complex north of the NELHA facility and the seven pools in the southern complex are on lands controlled by the Department of Transportation. These same pools were resurveyed in October 1991 (Brock 1991), again in March, May and October 1992 (Brock 1992a, 1992b, 1992c) as well as in May 1993 (Brock 1993). The May 1992 survey noted another pond (S-8) located about 4 m inland and south of pond S-7 and the October 1992 survey we located an additional anchialine pool in the southern pool complex not previously seen; this pond (S-9) is located about 6 m south of pool no. S-6. This pond is situated in rough a'a lava and is a low point in the lava that never previously contained water; the exceptionally high tide on 31 October 1992 was probably responsible for the presence of water at this site at that time. In November 1995 OI Consultants, Inc. (1996) sampled the same twelve anchialine pools and found the biota to be in a similar condition as reported earlier by Brock.

B. Methods

GK and Associates (1989) suggested that the biota of all these anchialine pools be sampled on a quarterly basis; 3 to 15 permanent 0.1 m^2 quadrats should be placed in each pool and the biota in each assessed by counts or percent cover (as appropriate). If present, counts of larger motile forms (prawns, crabs and fish) were to be made for the entire pool.

Previous experience with leaving permanent quadrats in anchialine ponds in the Waikoloa Anchialine Pond Preservation Area and elsewhere has demonstrated that people remove them, thus negating the idea of using "permanent" quadrats in pools that are visited by the public. Accordingly, this study has utilized temporarily placed 0.1 m^2 quadrats in the sampled pools. Only native species were censused however the presence or absence of exotic species was noted.

Sampling of the biota comprised using quadrats to assess benthic forms; a minimum of four quadrats were placed in each sampled pool where sufficient substratum was present as not to have quadrats overlap. Fishes were assessed using visual methods. No emphasis was placed on quantifying non-native species such as the poecilids. Approximate pool dimensions and relative locations were roughly mapped in the field; notes were taken on the species composition of surrounding vegetation, etc. Salinities were field measured using a refractometer. These methods duplicate those used previously (see earlier reports Brock 1989, 1991, 1992a,b,c, 1993a,b, 1994a,b,c, 1995a,b, 1998).

C. Results

In total fourteen anchialine pools were sampled in this study; five of these are located in the northern complex north of the NELHA facility and the nine pools in the southern complex are on lands controlled by the Department of Transportation. The relative locations and sizes of the five northern pools are shown in Figure 1; Figure 2 provides the same information for the nine southern pools. The NELHA anchialine pools were sampled on 19 December 2007 and 12 August 2008 in the afternoon. The tide state in the December 2007 survey was about +0.4 feet and in the August 2008 survey, it was at +2.0 feet.

The northern complex of pools is situated primarily in a pahoehoe flow; on the seaward edge of the complex, the substratum is basalt and coral cobble which is part of a berm serving as part of the beach. The pools are from 30 to 40 m mauka of the shoreline. As noted in the preliminary baseline, the number of pools in this complex obviously fluctuates with the movement of rubble caused by high surf as well as the state of the tide (see above discussion). Vegetation surrounding the northern pools was comprised of a mix of naupaka (*Scaevola taccada*), kiawe (*Prosopis pallida*), akulikuli (*Sesuvium portulacastrum*), pluchea (*Pluchea odorata*) and fountain grass (*Pennisetum setaceum*). These plants were situated primarily along the landward (mauka) border of the system. In 1995 a caretaker begin to clear much of the understory and unwanted non-native vegetation away on the lands surrounding the northern complex of pools. This clearing had not proceeded very far by the June 1995 survey but on our return in December 1997 it was near complete such that only a few kiawe trees and akulikuli remain in the vicinity of these pools. This situation remains largely unchanged up to the present time. However, with the most recent (August 2008) survey, someone has commenced clearing loose sand and rock from some of the pools in the north cluster.

FIGURE 1. Map of the northern complex of the five anchialine pools mauka of the beach berm of basalt cobble and coral rubble at Ho'ona Bay, Keahole Point. The apparent number of anchialine pools varies with the tide. Tide height at the time of sampling on 7 November 2001 was ~+0.8 feet thus all basins contained water. Not to scale.

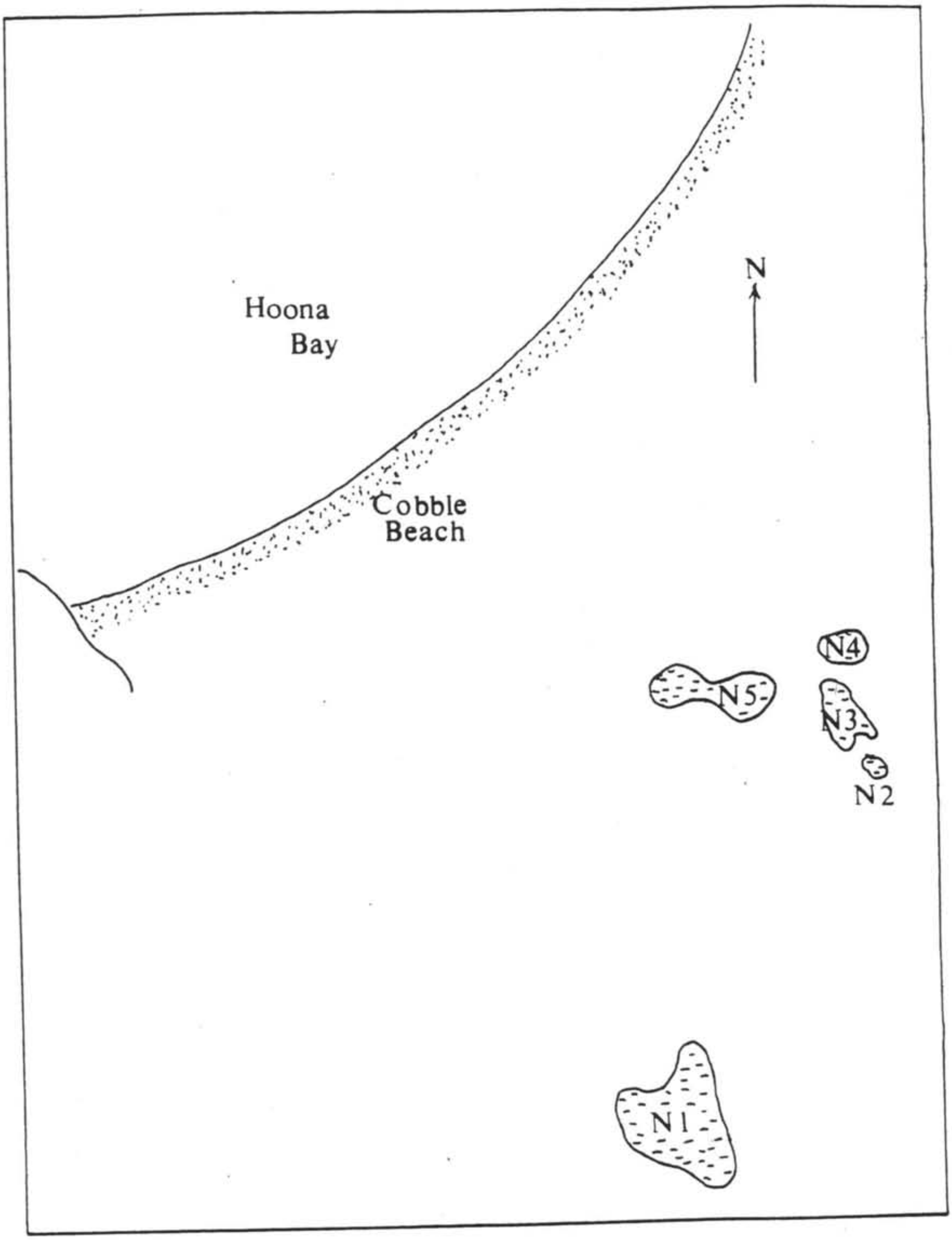
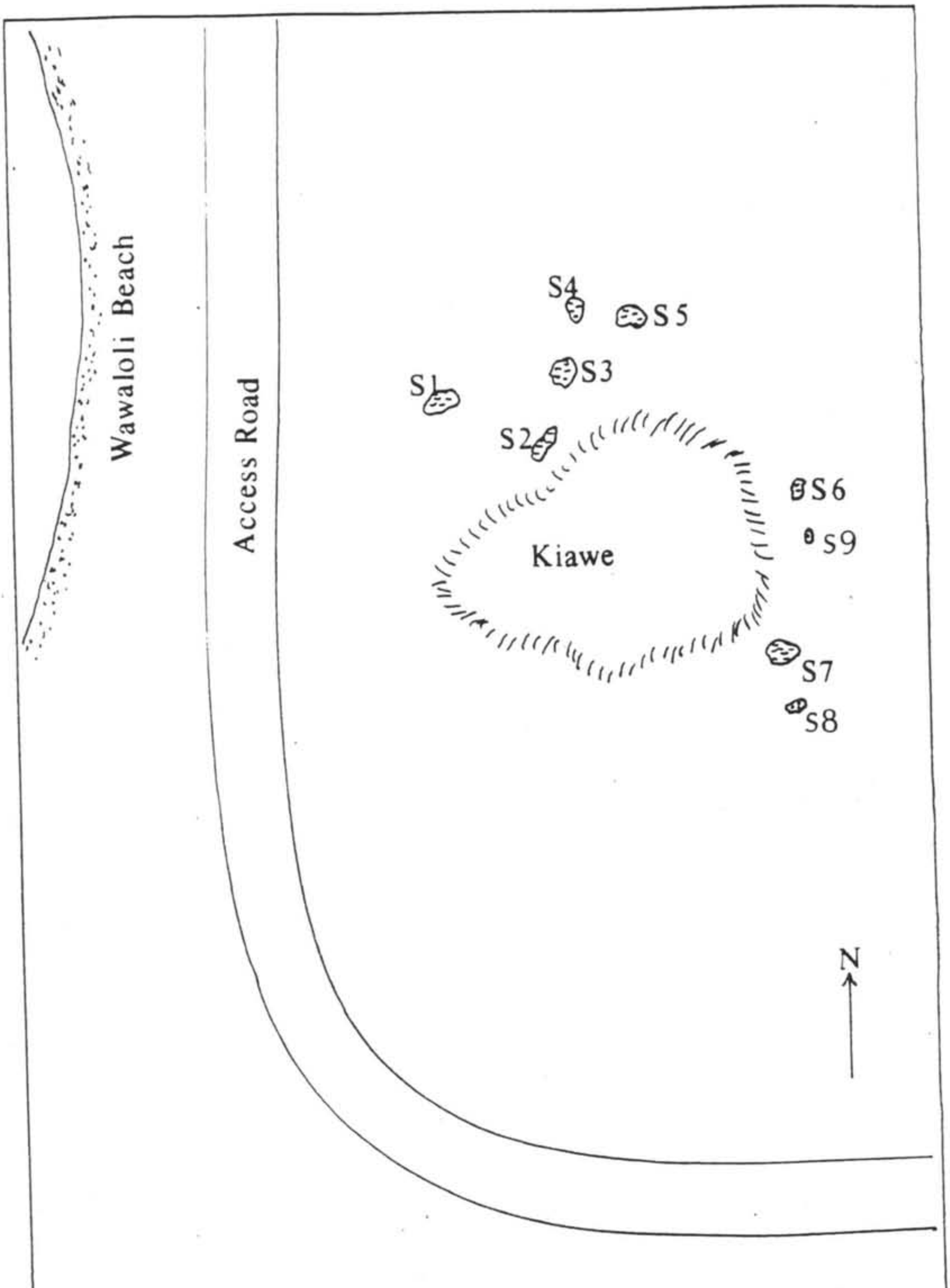

Hoona
Bay
Cobble
Beach
N
N4
N5
N3
N2
N1

FIGURE 2. Map of the southern complex of nine anchialine pools mauka of Wawaloli Beach and the NELHA access road at Keahole Point. Note that Pond no. S-9 was first located and sampled on 31 October 1992 due to the extreme high tide. All pools contained water at the time of sampling on the most recent August 2008 survey. Not to scale.


Wawaloli Beach
Access Road
S4
S5
S3
S1
S2
S6
S9
Kiawe
S7
S8
N

In the southern complex, ponds are situated in a pahoehoe flow; these pools are well inland of the beach, being mauka of the access road more than 70 m from the shoreline. Some pools are surrounded by vegetation. Plant species present include kiawe, fountain grass, pluchea, pohuehue or morning glory (*Ipomoea pes-caprae*), naupaka, christmas berry (*Schinus terebinthifolius*) and noni (*Morinda citrifolia*).

All pools containing water at the time of sampling were sampled; organism abundance and basin morphology are given in Tables 1 - 4 for both complexes. Unlike many anchialine pools on the West Hawaii coast, the anchialine ponds in the southern complex had not been subjected to the introduction of exotic fishes up through the November 2001 survey. In the May 2002 survey, pond S-7 was found to contain mosquito fish (family Poecillidae) and the native opae'ula were absent but all of the other pools remained clear of this alien fish species. The December 2002 survey found the conditions to be unchanged with mosquito fish only in S-7. However, sometime between the December 2002 and the December 2007 surveys, the mosquito fish had spread probably by someone releasing them into pond numbers S-1, S-2, S-3, S-7, S-8 and S-9. In the most recent (August 2008) survey, only pond numbers S-4 and S-6 remain clear of alien fish but in S-4 someone had released a single blackspot sergeant or kupipi (*Abdufduf sordidus*) which is a native marine (but euryhaline) species that has displaced the shrimp in the pool. In the northern series of pools, poecilids had been present in all of the pools in the December 2002 survey but the December 2007 survey found all of the pools in the north complex devoid of aquatic life. Several dead native prawns or 'opae o'ha'a (*Macrobrachium grandimanus*), limpets or hihiwai (*Theodoxus cariosa*) and clear glass shrimp or 'opae (*Palaemon debilis*) were found spread through the pools. These specimens appeared to have succumbed at least two to three days previously (see Table 4). By the August 2008 survey of the north complex of pools were recolonized by native shrimp, opae'ula (*Halocardina rubra*).

Pool N-1 is the largest in the northern complex (Figure 1, Table 1). This pond has a fine mud substratum and is the southernmost pool sampled by GK & Associates (1986) and Brock (1989, 1991). Besides the snail, *Melania* sp., alien mosquito fish were the dominant species up to the December 2007 survey. The August 2008 survey found only *Halocaridina rubra* and a few melanid snails present in all of the pools of the complex (Table 4). In the past, other aquatic species found in this pool include the waterboatman (*Trichocorixa reticulata*) algae, (*Cladophora* sp. and an unidentified chlorophyte similar to *Ulva reticulata*), the black rock crab, *Metopograpsus messor* and the hihiwai (*Theodoxus cariosa*).

The 3 May 1992 survey found exotic fishes (poecilids) in all ponds of the northern complex. Poecilids spread through these ponds over a relatively short period of time; in October 1991 guppies were restricted to just Pond N-1 and by March 1992 they were present in all but pond N-2. Concurrent with the spread of the exotic fish was a decline in the abundance of the shrimp or opae'ula (*Halocaridina rubra*). The poecilids apparently prey on the native shrimp and amphipods. Poecilids were present in all of the pools of the northern complex in 1988; these were removed from all but pool N-1 sometime prior to October 1991 probably by chemical means. Because of their impact to the native shrimp, an effort was again made to rid the northern complex of pools of the exotic fishes on 4 May 1992 during an extremely low tide. Within 45 minutes, shrimp were noted

TABLE 1. Summary of the physical characteristics of the anchialine pools of the northern complex (N-1 - N-5) sampled on 25 occasions since May 1989. Basins N-2 through N-5 were coalesced into one pond on 26 October 1991, 3 May 1992, 31 October 1992, 3 October 1994, 7 June 1998, 26 May 1999, 1 June 2000 and 12 August 2008 due to exceptionally high tides. On other dates with lower and medium tides pools were separate. Note that on 17 December 2007 tide height was +0.4 feet and no live shrimp or fish were seen in the ponds. In N-3 and N-5 were seen several dead *M. grandimanus* and *P. debilis* but snails were still alive. Tide height on 12 August 2008 survey was +2.0 feet and native shrimp were present. Also given are the salinities as measured in the latest sample effort (August 2008).

Pond No.	Dimensions (m)	Basin Characteristics	Latest Salinity (°/oo)
N-1	15.5 x 6	deep mud bottom; in pahoehoe/basalt cobble	13.5
N-2	1 x 1	rubble basin; in pahoehoe	13.5
N-3	7.5 x 3	cobble basin; in pahoehoe	13.5
N-4	2 x 2	rubble & mud bottom; in pahoehoe	13.5
N-5	7.5 x 3	2 interconnected basins in cobble	13.5

TABLE 2. Summary of the census data of the anchialine pools of the northern complex (N-1 - N-5) sampled on 25 occasions since May 1989. Tide heights at the time of the December 2007 survey was +0.4 feet and August 2008, +2.0 feet. Note that non-native species such as topminnows (*Poecilia*) are simply denoted as present (x) or absent (0). Table continued on next two pages.

		Census Data (no/0.1m^2)						
Pond No.	Species	May89	Oct91	Mar92	May92	Oct92	May93	Dec93
N-1	*Melania*	78	35	49	56	24	31	42
		71	52	31	29	62	54	59
	Poecilia	x	x	x	x	x	x	x
N-2	*Melania*	36	42	72	85	41	22	27
	H. rubra	22	15	3	0	72	0	0
	Poecilia	0	0	0	x	0	x	x
N-3	*Melania*	62	12	67	29	24	19	31
		21	9	23	41	15	26	17
			0	0	0	6	0	8
	H. rubra	1	0	0	0	15	0	0
		15	28	0	0	38	0	0
	Palaemon	0	0	0	1	1	2	1
	Poecilia	0	0	x	x	0	x	x
N-4	*Melania*	39	0	0	14	10	9	14
		115	4	9	3	85	42	31
	H. rubra	3	0	0	0	12	0	0
		21	23	0	0	31	0	0
	Poecilia	0	0	x	x	0	x	x
N-5	*Melania*	2	2	42	9	8	12	23
		4	4	2	1	1	1	17
	H. rubra	0	0	0	0	41	0	0
	Poecilia	0	0	x	x	0	x	x

TABLE 2. Continued.

Pond No.	Species	Census Data ($no/0.1m^2$) May94	Jun94	Oct94	Mar95	Jun95	Dec97	Jun98	Nov98	May99
N-1	*Melania*	31	43	29	40	63	39	41	38	27
		72	68	72	52	50	67	53	52	49
	Poecilia	x	x	x	x	x	x	x	x	x
	M. grandimanus		2	0	0	1	0	0	0	0
	Palaemon					2				
	Metopograpsus						4	7	9	6
	T. cariosa							6	2	6
N-2	*Melania*	31	28	19	31	28	33	44	56	47
	H. rubra	0	4	0	42	0	0	0	0	0
	Poecilia	x	x	x	0	x	x	x	x	x
N-3	*Melania*	42	51	72	40	53	49	57	27	39
		24	33	41	23	19	31	22	26	24
		5	6	9	9	14	18	34	14	22
	H. rubra	2	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0
	Palaemon	2	1	1	2	3	0	0	0	0
	M. lar		1	0	1	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	x	x	x
N-4	*Melania*	12	26	25	26	25	27	33	29	27
		53	49	19	19	23	17	21	26	19
	H. rubra	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0
	M. grandimanus				5	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	x	x	x
N-5	*Melania*	19	27	51	21	29	33	42	23	24
		27	6	29	19	16	13	27	19	12
	H. rubra	0	0	0	0	0	0	0	0	0
	M. grandimanus				3	0	0	0	0	0
	Metopograpsus						3	5	5	4
	Poecilia	x	x	x	x	x	x	x	x	x

TABLE 2. Continued.

Pond No.	Species	Dec99	Jun00	Nov00	May01	Nov01	May02	Dec02	Dec07	Aug08
		Census Data (no/0.1m^2)								
N-1	*Melania*	36	42	34	39	37	29	21	0	4
		68	37	55	27	23	47	17	0	0
	Poecilia	x	x	x	x	x	x	x	0	0
	M. grandimanus	0	0	0	0	0	0	0	0	0
	Palaemon	0	0	0	0	0	0	0	0	0
	Metopograpsus	8	9	5	4	6	5	7	0	0
	T. cariosa	3	2	4	3	2	9	5	0	0
	H. rubra	0	0	0	0	0	0	0	0	100
N-2	*Melania*	47	39	51	79	66	72	37	0	3
	H. rubra	0	0	0	0	0	0	0	0	10
	Poecilia	x	x	x	x	x	x	x	0	0
N-3	*Melania*	37	44	34	41	39	27	41	0	2
		31	51	29	22	33	19	38	0	0
		12	6	9	3	3	5	5	0	0
	H. rubra	0	0	0	0	0	0	0	0	25
		0	0	0	0	0	0	0	0	21
	Palaemon	0	0	0	0	0	0	0	0	0
	M. lar	0	0	0	0	0	0	0	0	0
	Poecilia	x	x	x	x	x	x	x	0	0
N-4	*Melania*	36	29	27	Dry	29	31	27	Dry	2
		29	17	21		17	20	18		1
	H. rubra	0	0	0		0	0	0		23
		0	0	0		0	0	0		17
	M. grandimanus	0	0	0		0	0	0		0
	Poecilia	x	x	x		x	x	x		0
N-5	*Melania*	16	12	21	19	17	23	17	0	4
		19	26	17	14	12	16	21	0	5
	H. rubra	0	0	0	0	8	0	0	0	80
	M. grandimanus	0	0	0	1	0	0	0	0	0
	Metopograpsus	5	5	5	7	5	6	3	0	0
	Poecilia	x	x	x	x	x	x	x	0	0

TABLE 3. Summary of the physical characteristics of the nine anchialine pools of the southern complex (S-1 - S-9) sampled on 25 occasions since May 1989. Note that pool no. S-8 was first seen and sampled on 3 May 1992 and S-9 on 31 October 1992. Salinities as measured on the most recent (12 August 2008) survey are also given.

Pond No.	Dimensions (m)	Basin Characteristics	Latest Salinity (°/oo)
S-1	1.4 x 1.2	Pahoehoe and rubble	11.5
S-2	1 x 1	Pahoehoe and rubble	11.5
S-3	1 x 1	Pahoehoe and rubble	11.5
S-4	0.75 x 0.75	Pahoehoe and rubble	11.5
S-5	2 x 2.5	Pahoehoe and rubble	11.5
S-6	0.2 x 0.5	Pahoehoe and rubble	11.5
S-7	2 x 2.4	Pahoehoe and rubble	10.5
S-8	1 x 1	Pahoehoe and rubble	11.5
S-9	0.2 x 0.5	In small a'a crack	11.5

TABLE 4. Summary of the census data of the anchialine pools of the southern complex (S-1 - S-9) sampled on 25 occasions since May 1989. Tide height +0.4 feet on the 19 December 2007 and +2.0 feet on 12 August 2008 survey. Table continued on the next two pages.

Pond No.	Species	Census Data (no/0.1m^2) May89	Oct91	Mar92	May92	Oct92	May93	Dec93
S-1	*H. rubra*	56	29	31	61	29	49	37
	M. grandimanus	0	0	1	1	0	0	1
	Amphipoda	0	0	0	6	19	12	15
S-2	*H. rubra*	71	31	40	14	34	54	Dry
	Amphipoda	185	32	6	2	9	2	
S-3	*H. rubra*	38	21	43	64	56	Dry	49
	Amphipoda	54	14	9	12	9		12
S-4	*H. rubra*	9	42	6	9	7	Dry	Dry
	Amphipoda	0	0	0	2	12		
S-5	*H. rubra*	43	121	131	92	107	113	0
	Amphipoda	94	65	48	27	34	7	0
	M. grandimanus						1	0
S-6	*H. rubra*	3	3	1	1	7	5	4
	Amphipoda	0	9	2	3	3	2	3
	White "	0	2	0	0	2	1	1
S-7	*H. rubra*	97	95	87	96	49	72	68
	Amphipoda	11	17	12	10	13	9	10
	M. grandimanus	0.5	0.5	0.5	0.75	1	0.5	1
S-8	*H. rubra*				65	72	81	71
	M. grandimanus				0.5	0.75	1	1
S-9	*H. rubra*					3	Dry	Dry

TABLE 4. Continued.

Pond No.	Species	Census Data (no/0.1m^2) May94	Jun94	Oct94	Mar95	Jun95	Dec97	Jun98	Nov98	May99
S-1	*H. rubra*	47	52	84	61	57	73	49	81	63
	M. grandimanus	2	0	0	0	0	0	0	0	0
	Amphipoda	21	18	26	23	27	24	23	14	12
S-2	*H. rubra*	Dry	Dry	42	Dry	39	Dry	62	Dry	52
	Amphipoda			9				12		14
S-3	*H. rubra*	37	86	94	Dry	78	Dry	14	Dry	29
	M. lohena		1	0		2		0		0
	Amphipoda	14	3	16		21		17		10
S-4	*H. rubra*	21	Dry	39	Dry	16	Dry	0	Dry	0
	Amphipoda	6		12		3		2		3
S-5	*H. rubra*	0	0	0	0	0	0	0	0	0
	Amphipoda	0	0	0	0	0	0	0	0	0
	M. grandimanus	1	4	1	2	1	0	0	0	0
S-6	*H. rubra*	7	4	23	Dry	17	Dry	12	Dry	6
	Amphipoda	3	3	0		0		2		3
	White "	3	1	2		0		0		0
S-7	*H. rubra*	82	94	113	77	121	86	79	87	59
	Amphipoda	18	23	39	25	29	21	31	20	18
	M. grandimanus	2	1	1	1	3	0	1	2	3
S-8	*H. rubra*	68	81	80	52	61	55	57	63	72
	M. grandimanus	2	1	1	1	1	0	0	0	1
S-9	*H. rubra*	Dry	Dry	14	Dry	9	Dry	12	Dry	10

TABLE 4. Continued.

Pond No.	Species	Dec99	Jun00	Nov00	May01	Nov01	May02	Dec02	Dec07	Aug08
		Census Data (no/0.1m^2)								
S-1	*H. rubra*	65	35	35	55	40	35	58	0	0
	M. grandimanus	0	0	0	0	0	1	0	0	0
	Amphipoda	14	16	9	11	12	11	9	0	0
	Poecilids								x	x
S-2	*H. rubra*	Dry	6	Dry	Dry	35	9	48	0	0
	Amphipoda		0			4	3	1	0	0
	Poecilids								x	x
S-3	*H. rubra*	8	17	(Filled w/sand)		45	55	0	0	0
	M. lohena	0	0			0	0	0	0	0
	Amphipoda	12	9			6	5	3	0	0
	Poecilids								x	x
S-4	*H. rubra*	15	31	Dry	Dry	31	12	38	8	0
	Amphipoda	4	8			4	7	1	0	0
	Abudefduf sordidus									1
S-5	*H. rubra*	0	0	0	35	0	0	49	3	0
	Amphipoda	0	0	0	0	0	0	4	0	0
	M. grandimanus	0	0	0	0	0	0	0	0	0
	Poecilids									x
S-6	*H. rubra*	Dry	4	Dry	Dry	0	15	7	Dry	5
	Amphipoda		0		0	0	2	0		0
	White "		0			0	0	0		0
S-7	*H. rubra*	43	41	56	47	60	0	0	0	0
	Amphipoda	14	22	6	9	8	0	0	0	0
	M. grandimanus	2	1	1	1	1	0	1	0	0
	Poecilids						x	x	x	x
S-8	*H. rubra*	30	38	48	80	81	45	81	0	0
	M. grandimanus	0	0	0	0	0	0	0	0	0
	Poecilids								x	x
S-9	*H. rubra*	4	1	7	Dry	20	3	27	0	0
	Poecilids								x	x

as having returned to pool N-2 despite the continuing cloudy water due to the ichthyocide used (10% rotenone). The eradication of fish from the northern pools was successful in Ponds N-2 through N-5 but mosquito fish were present in Pond N-1 during the 31 October 1992 sample period. By 23 May 1993 all ponds in the northern complex had been reinvaded by these exotic fish driving out the native red shrimp (*Halocaridina rubra*). The situation remained unchanged up to the December 2007 survey when all aquatic life appeared to be dead and as noted above but by the August 2008 survey the native shrimp (opae'ula) had returned.

The ubiquitous brackish water snail, *Melania* sp. was seen in all the pools of the northern complex up to the December 2007 survey. The abundances of these and other native species encountered in the northern pools are given in Table 2. The glass shrimp or 'opae (*Palaemon debilis*), 'opae o'ha'a (*Macrobrachium grandimanus*), and introduced prawn (*M. lar*) have been encountered in some of these pools during some of the surveys (Table 2). Other than the June 1994, 11 March 1995 and the November 2001 surveys, the native opae'ula (*Halocaridina rubra*) were absent from all pools of the northern complex due to the successful recolonization by topminnows in these ponds from Pond N-1 as noted above.

Mean densities of *Halocaridina rubra* in the northern complex of pools has changed over time. The grand mean for May 1989 was 12 shrimp/0.1 m^2 and in October 1991 the mean density was 13 shrimp/0.1 m^2 for those pools containing shrimp. The change between these two surveys is insignificant (Wilcoxon matched-pairs signed-ranks test, $t=37$, $n=14$, N.S.). However in March 1992 the grand mean fell to 0.6 shrimp/0.1 m^2; this decrease is highly significant (Wilcoxon matched-pairs signed rank test, $t=10$, $n=9$, $P>0.01$). Obviously, with the decline of *H. rubra* to zero in the northern pools in May 1992 created another decline. However, as noted above, within an hour of the time of fish eradication on 4 May, *Halocaridina rubra* re-emerged from the watertable below, into Pond N-2. The successful eradication of poecilids from Ponds N-2 through N-5 allowed the recolonization of these pools by *H. rubra* such that the mean density in October 1992 was 35 individuals/0.1 m^2. No *H. rubra* were encountered in the northern pools in the May 1993 survey because of the recolonization by poecilids; this decline is significant relative to the previous survey (Wilcoxon two-sample test, $P>0.003$). Since the disappearance of poecilids in the December 2007 survey and the reappearance of *H. rubra* in all of the north complex of pools in the August 2008 survey, the abundance of this species has significantly increased.

Prior to the December 2007 survey, the populations of the snail *Melania* sp. have fluctuated through time from a low of 18 snails/0.1 m^2 in the October 1991 survey to 48 snails/0.1 m^2 in the May 1989 survey. The grand mean is 30.5 snails/0.1 m^2 across all surveys up through the December 2002 survey. In the December 2007 no live snails were seen but with the August 2008 survey the density was estimated at it was 2.1 snails/0.1 m^2. One difficulty in censusing melanid snails is the fact that separating live from dead shells on the substratum is difficult without removing and disturbing the population. Also, the "apparent" abundance of *Melania* sp. in anchialine habitats appears to vary according to tide state and salinity. Often with higher tides (and salinities) the snails will frequently be under rocks rather than on dorsal aspects of the rocks where they may be censused. Mean salinity of the northern pools in May 1989 was 8.4°/oo; since that time it has varied from 8 to

15°/oo according to tide state.

The pools in the southern complex are scattered around the perimeter of a large mixed stand of christmas berry and kiawe. The 3 May 1992 survey found an eighth pool in the complex (number S-8 - Figure 2). Pool S-8 is located about 4 m south of pond S-7 and is situated in a pahoehoe flow surrounded by fountain grass. The basin dimensions are approximately 1 x 1 m and the maximum water depth was 75 cm at the time of sampling (extreme high tide). There is no explanation for having missed this pool in previous sample periods other than it was not obvious due to the large amount of fountain grass around it. The 31 October 1992 survey found yet another small pool, number S-9. Pool S-9 is situated in the topographically complex rough a'a flow about 6 m south of Pool S-6. Pond S-9 had a surface exposure of about 0.25 x 0.5 m and was up to 15 cm in maximum depth during the extreme high tide (about 62 cm). This pool is situated down in the a'a and is easily missed; indeed, it is absent unless the tide is sufficiently high. The 19 December 2007 survey was carried out when the tide was at +0.4 feet and the 12 August 2008 survey was conducted when the tide was at +2.0 feet. In the December 2007 survey pool S-6 was dry, otherwise all other basins had water present and in the August 2008 survey all pools contained water.

The pools of the southern complex all have a mixed assemblage of opae'ula (*Halocaridina rubra*) and small unidentified red amphipods (Table 4) up until the time of the May 2002 survey when mosquito fish were discovered in pond no. S-7. The only logical explanation for the appearance of mosquito fish is that someone intentionally released them into pond S-7. The situation remained unchanged with the December 2007 survey with only pond no. S-7 being affected. The December 2007 survey found mosquito fish in pond numbers S-1, S-2, S-3, S-7, S-8 and S-9. With the August 2008 survey only pool numbers S-4, and S-6 remain free of these alien fishes. The spread of these fish from S-7 to the other pools was probably done as intentional releases into the ponds containing them due to the distances between the affected ponds and the presence of pools between the affected ponds that lack mosquito fish. Prior to the introduction of alien fish, there appeared to be at least one species of amphipod in the southern complex of pools and there may have been others. Many of the anchialine amphipods have received little scientific attention and undoubtably, there are species that have yet to be described. Pond number S-7 has been physically modified to serve as a bathing pool; a second pool (number S-8) is walled and appears to have been used as a well. Discounting the now present mosquito fish, pool S-7 appears to have changed little from the first time I surveyed it in 1972. Besides opae'ula, this pond as well as numbers S-5, S-7 and S-8 also sometimes have opae'o'haa (*Macrobrachium grandimanus*).

The range in abundance of opae'ula in the southern complex of pools between the 25 surveys (May 1989 through December 2002) is from 19 to 62 shrimp/0.1 m^2 across all ponds in a survey grand mean is 41 shrimp/0.1 m^2. The mean number of opae'ula counted in the December 2007 survey of the southern pools is 1.4 shrimp/0.1 m^2 and in the August 2008 survey it had decreases to 0.6 shrimp/0.1 m^2. There is a statistically significant decrease (Kruskal-Wallis ANOVA $P>0.003$, significant) in the mean number of shrimp counted between the earlier (May 1989 through December 2002) period (grand mean = 41 shrimp/0.1 m^2) to those counted in the two subsequent periods (December 2007 mean = 1.4 shrimp/0.1 m^2 and August 2008 mean = 0.6 shrimp/0.1 m^2).

Abundance estimates of the unidentified red amphipods in the southern pools has been more variable between surveys ranging from 0 to 89 individuals/0.1 m^2 on a survey. The per survey grand mean is 14 amphipods counted/0.1 m^2 and with the arrival of predatory alien fish, amphipods have disappeared from the lighted portions of the pools. Because of their small size and cryptic habits, accurate counts of these organisms is very difficult and the census results are of limited value. At this point, we assign little value to the amphipod data, other than they have disappeared with the arrival of the mosquito fish.

In the May 1989 survey, many of the anchialine ponds in both groups were being used by beach goers as receptacles for rubbish and human wastes. It appears that these practices have decreased probably because of more restricted access by keeping the public out of the area after hours as well as the construction of restroom facilities almost directly across the access road from the southern ponds. This management is important to the maintenance of the system. However in the December 1993 survey we again noted that pond S-1 has been used as a toilet facility; there is no excuse for this deplorable situation with a restroom no more than 100 m away. The ponds in the northern complex are located in an area that was through early 2001 being managed by native Hawaiians. This served to reduce the misuse of these resources. More recently, access to the north cluster of pools at Ho'ona Bay area has opened up and as noted above, the alien fish have disappeared probably due to chemical means sometime just prior to the December 2007 survey. This action has served to restore the habitat which is now, once again, occupied by native anchialine species.

The NELHA/HOST CEMP water quality monitoring program monitors water quality at the NELHA and HOST Park. Inspection of the results from groundwater and anchialine pool sampling at NELHA in the past (through June 2000) show water quality parameters in the range usually encountered at other locations on the West Hawaii coast, irrespective of surrounding development. However one NELHA site (Well No. W4A) in the past had a number of parameters well above the usual range seen elsewhere in Kona. This situation occurred off-and-on in the April 1994 - March 2000 but has since declined in the 1 April-30 June 2000 data set (the latest data available to us). In the October-December 1994 quarterly water quality report, NELHA identified the source of this high nitrate from a leaking holding pond liner at Cyanotech, a site well removed from the anchialine resources at NELHA/HOST Park. The leak was repaired and the nitrate levels subsided but subsequently increased. More recently, a second well site (W-8B) located north of the NELHA compound has shown similar increases in nitrate. In the 1 October - 31 December 1999 period the mean nitrate concentration for this well was ~ 95 uM; in the January-March 2000 period the mean increased to 117 uM but appears to be decreasing in the April - June 2000 period (mean = 103 uM). In all cases these increases in nitrate are apparently contained and have occurred in individual wells; there is no evidence of increased concentrations for any of these materials in the anchialine pools or marine water sample sites and no indication of impact to anchialine resources.

These two well sites not withstanding, studies elsewhere on the coast (e.g., at Waikoloa, Brock *et al.* 1988, Brock and Kam 1994) have shown that anchialine biota is little affected by changes in inorganic nutrient concentrations in ground- and anchialine pool water. Thus increases in nutrients from anthropogenic sources (treated sewage effluent or fertilizers) has no impact to the biota. The data support the hypothesis that these nutrient species under completely natural situations (i.e., from measurements taken in undeveloped areas) are frequently in excess and thus are not limiting and further loading has no observable impact. The native anchialine species have evolved under a situation of highly variable nutrient concentrations and thus are not impacted by changes in the ranges measured on the Kona coast (Brock *et al.* 1988, Brock and Kam 1994).

D. Discussion

Up to the December 2007 survey, there had been no statistically significant quantitative change in the abundance of red shrimp (*Halocaridina rubra*) in the southern complex of pools. However, with the introduction and spread of mosquitofish in these pools, the native shrimp populations have disappeared in all but two pools. In contrast, after many years of alien mosquito fish overrunning the pond habitat in the north complex of anchialine pools at Ho'ona Bay, an unknown agent (probably chemical) cleared the pools of unwanted fish and all other aquatic species just prior to the December 2007 survey which led the way for a recolonization of the north pools by the native anchialine shrimp *Halocaridina rubra*. The earlier disappearance of these shrimp in the northern pools is directly related to the spread of exotic fish through that system. Removal of fish using an ichthyocide on 4 May 1992 allowed *Halocaridina rubra* to return to four of the five pools. However, the recolonization of these pools by poecilids between October 1992 and May 1993 once again resulted in the disappearance of shrimp. Our previous studies carried out at Waikoloa and elsewhere on the West Hawaii coast suggest that recolonization of anchialine pools by *Halocaridina rubra* following fish eradication occurs in a period from hours to weeks; the rapidity at which this happens is probably related to the distance to the closest propagule source (i.e., pool with shrimp) and the porosity of the rock through which they must travel.

As part of the expansion of experimental work at NELHA, a large disposal trench (about 7 x 10 m in dimensions and extending about 1.7 m down into the watertable) was dug north of the main NELHA facility. This trench is designed to receive about 16,000 gpm of waste seawater from the nearby demonstration OTEC plant. The open trench was rapidly colonized by *Halocaridina rubra* occurring in densities exceeding 200 individual/0.1 m^2. Prior to the discharge of cold seawater in this trench, regular surface (warm) seawater was flushed through the trench to drive the *H. rubra* from the site. The higher mean density of *H. rubra* seen in the northern complex of pools (situated about 300 m away from the trench) in the October 1992 survey may be related to (1) the absence of exotic fish in four of the five pools and (2) the movement of shrimp away from the disposal trench to other nearby pools which serve as sources of food. The infrequently used disposal trench was examined in December 1997 survey and found to be serving as habitat for numerous *H. rubra* and this situation probably has continued up to the present time.

Our estimates on the abundance of red amphipods show decreases from 1989 to later surveys and has fluctuated since that time in the southern complex of pools. The small size and cryptic habits of these amphipods makes quantitative delineation very difficult and of dubious value. Other than their complete demise in December 2007, the fluctuations in abundance noted for *Melania* sp. in the northern pools is probably related to sampling error rather than a real changes in the snail population. The numerous melanid shells on the bottom of most anchialine pools makes it a near impossibility of separating live from dead shells (this is a problem in the northern complex of pools). Also, these snails often appear to move from under cover and out into the open (where they can be counted) with different tide states. These problems among others has lead the West Hawaii Coastal Monitoring Task Force (1992) to recommend the use of *Halocaridina rubra* in quantitative monitoring programs because it can be counted; other species are not recommended. We have included the abundance estimates for these other species because they are among the few diurnally-active anchialine species present in the two NELHA pond complexes.

There are seven hypogeal shrimp species found in Hawaiian anchialine pools. The surveys of the Keahole anchialine pools have noted two: the opae'ula or *Halocaridina rubra* and its predator, the alpheid, *Metabetaeus lohena*. More life history information is available for *Halocaridina rubra* than for any of the other species. Opae'ula feed on detritus, benthic diatoms, phytoplankton, filamentous algae, vascular plant tissue (Wong 1975), and when available, animal tissue. *Halocaridina rubra* feed by plucking the substratum with bristled chelae; midwater and surface film feeding is accomplished by using the chelae and bristles as plankton filters (Bailey-Brock and Brock 1993). Opae'ula have been maintained in small sealed containers for years. Presumably under these conditions, they are capable of utilizing bacterial films.

The embryogensis and larval development of *H. rubra* has been documented (Couret and Wong 1978). Opae'ula have a low fecundity with the female carrying 10 to 16 eggs for at least 38 days. Earlier studies suggested that darkness was necessary to induce oviposition and females remained in dark seclusion until after eclosion and the offspring emerged into the open water as juveniles (Maciolek 1983). This author noted that ovigerous females (those carrying eggs on the abdomen) have not been seen in nature among the thousands of individuals observed or hundreds collected. However, Maciolek (1983) notes that 12 to 42 percent of the females may have eggs visible within the carapace, which suggests that reproduction is not rare. Our recent observations on *H. rubra* maintained in aquaria is that reproduction is very common and does not require darkness but rather is dependent upon a steady source of food; apparently, females must be at least four years of age prior to reproduction. Laboratory observations indicate that opae'ula may have lifespans of at least 10 years.

Halocaridina rubra is the most abundant of the Hawaiian hypogeal shrimps. It frequently occurs in concentrations exceeding hundreds of individuals per square meter in a given pond on a rising tide; at other nearby pools it may be scarce. The apparent abundance of opae'ula in a given pond or pond system can be very misleading for nothing is known of the population size of these hypogeal shrimp in subterranean interstitial waters. The co-occurring alpheid, *Metabetaeus lohena* is known to prey on *H. rubra* as well as other aquatic species (amphipods, etc.) and insects. *Metabetaeus lohena* is usually quite cryptic and is often overlooked. The appearance of one *M. lohena* in Pond N-5 (seen in the October 1992 survey) confirms that the species is present at Keahole Point.

The remaining anchialine fauna found in the Keahole system has either marine or freshwater origins. This group includes the snail, *Melania* sp. and the limpet or hihiwai (*Theodoxus cariosa*). Both the snail and limpet are known from stream and brackish habitats. The native prawn, *Macrobrachium grandimanus* also is found as adults in streams. Individuals of this shrimp encountered in the anchialine habitat usually show morphological or ecotypic variation; the individuals seen in Ponds S-5, S-7, S-8 in some of the surveys are morphologically similar to those encountered in the Kukio anchialine system along the Kona coast.

Fishes are a part of the fauna of the Hawaiian anchialine habitat; usually, their presence in a pond signals the lack of hypogeal shrimp. Fishes in anchialine systems fall into two broad categories -- native or exotic species. Fishes are usually predators on the red shrimp species. Native fishes will have less of an impact than exotic species because the latter are able to complete their lifecycles in these systems whereas the native species require marine conditions to do so.

Guppies or topminnows (Family Poeciliidae probably *Gambusia affinis* and/or *Poecilia mexicana*) appeared in the north Keahole pools sometime after the survey conducted in September 1986 by GK & Associates (1986). The most obvious impact resulting from the colonization of anchialine pond systems by fishes is their predation on resident crustaceans particularly the shrimps. The impact of native fish in anchialine systems continues only for the duration of the individual fish's lifespan. Exotic fishes, unlike their native counterparts are able to complete their lifecycle in the anchialine habitat, thus they present a continuing threat to the resident biota.

The introduction of exotic fishes to Kona coast anchialine systems has probably had the greatest negative impact to the biota of any perturbation to date. Brock (1985) and Bailey-Brock and Brock (1993) document the decline in native fauna following the introduction of exotic fishes to Kona coast anchialine pools. In the period from 1972 to 1985, exotic fish spread from 15% of the pools examined to 46% of the ponds. Recent estimates by Brock (unpublished) suggest that more than 95% of the Kona coast anchialine ponds are infested. With the spread of exotic fish has come a decline in the apparent distribution of *Halocaridina rubra* from a presence in 67% of the sampled pools in 1972 to less than 39% in 1985; it is considerably lower today. The removal of the exotic fishes on 4 May 1992 from the northern complex allowed the native fauna and flora the opportunity to re-establish in four of the five pools of the northern complex; however, the re-invasion of the pools by these unwanted exotics quickly drove the native shrimp from the system. The situation reversed when in December 2007, all aquatic life appeared to have died in the north complex of pools which removed the threat of alien fish preying on the native shrimp, allowing them to return to the north pools. However, the introduction and spread of alien fish in the southern complex of pools has had a large and continuing impact to the native species that formerly occupied the habitat.

MARINE BIOTA

A. Introduction

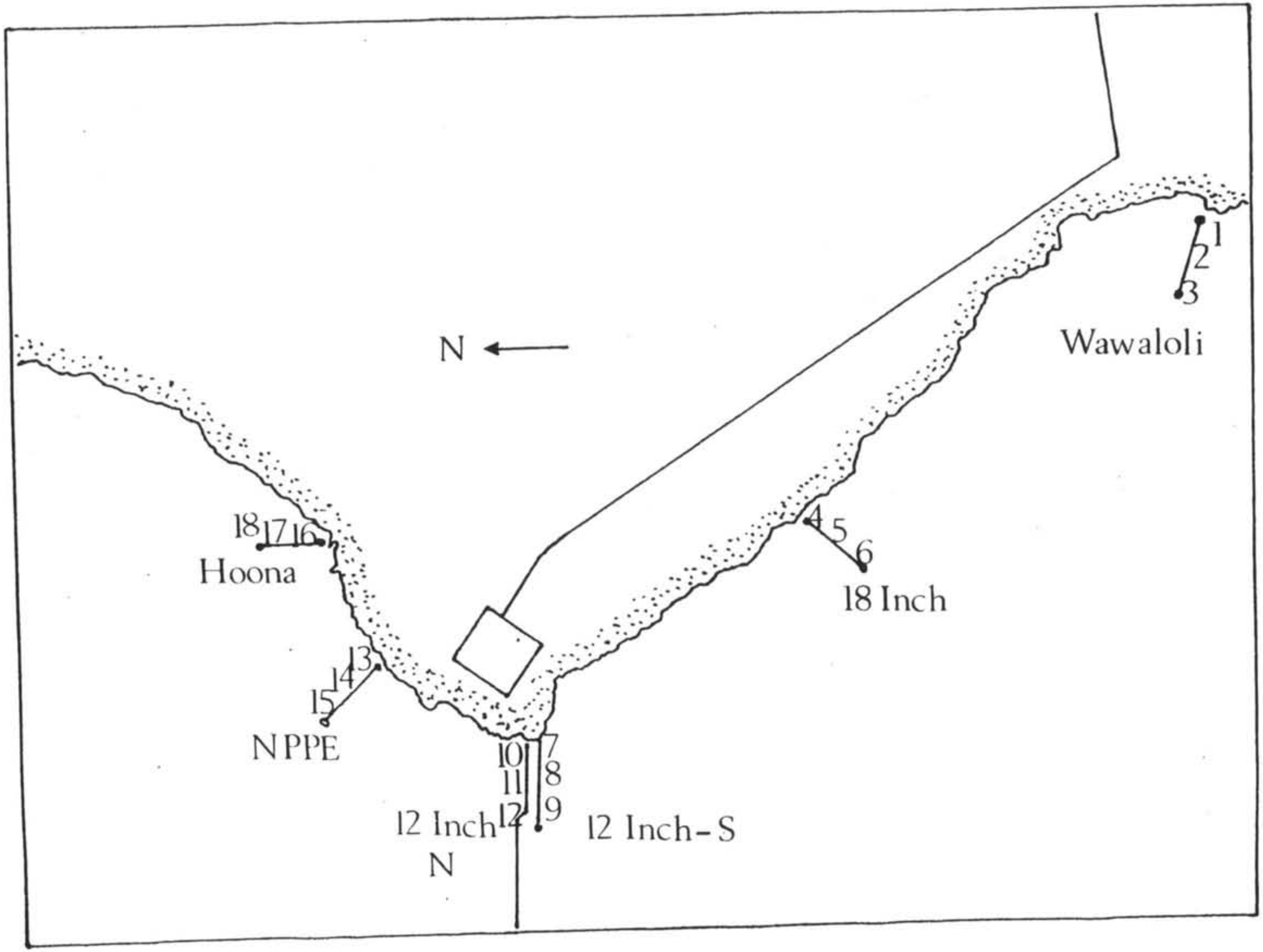
The near shore marine communities in the vicinity of Keahole Point have, for years been recognized as some of the most biologically diverse in Hawaiian waters. In his pioneering survey work of Hawaiian fish communities, Brock (1954) noted that the fish communities of the Keahole Point area were amongst the most specious and had the greatest standing crops of any in the islands; more recent workers (Brock and Norris 1987a, 1987b, 1988; Brock and Kam 1989) have found similar results. Because of this diversity and the need to preserve the quality of near shore waters, a comprehensive program of monitoring both water quality and the "health" of near shore marine communities was identified as a central component of the cooperative environmental program at NELHA.

Important objectives of the marine study are to determine the baseline conditions of the near shore communities and to quantitatively ascertain any impacts that might occur due to the discharge of cold/aquacultural water effluents into the watertable beneath adjacent on-land lava fields. Thus the ability to repeatedly sample the same communities through time is a prerequisite. Presumably impacts from this discharge to near shore communities will come in the form of alterations in the quality of the groundwater entering the sea. If this is correct, one might expect to measure a gradient of impacts from greatest at the point of discharge dissipating with increasing distance from the source. Stations to monitor water quality, benthos and fish communities have been situated so as to capitalize on any existing gradients.

B. Methods

GK and Associates (1989) identified two areas fronting the NELHA project site that showed depressions in salinity, i.e., having groundwater input. These areas are directly fronting the northern complex of anchialine pools at Ho'ona Bay as well as to the south fronting Wawaloli Beach next to the southern boundary of the project site (Figure 3). These two locations served to pinpoint the locations of stations for preliminary baseline studies. An initial control site was selected in the vicinity of Honokohau Harbor and was sampled in 1989 and the first quarterly survey (Brock 1989, 1991) but has been subsequently dropped. A fourth site, the 18-inch pipe station was added to the program and first sampled in October 1991; it has been resampled in all subsequent surveys. The 18-inch pipe is located about midway along the coast of the project area between Wawaloli Beach and Keahole Point. In the May 1992 three more areas were identified, permanently marked and sampled. These sites are the 12-inch warmwater pipe (here the "12-Inch South" site) and 12-inch coldwater pipe (here the "12-Inch North" site) at Keahole Point fronting the main NELHA facility.

FIGURE 3. Outline map depicting the approximate locations of the six study sites for marine fish community monitoring. These sites from south to north are: Wawaloli Beach, 18-inch pipeline, 12-inch warmwater pipe, 12-inch coldwater pipe, Net Power Production Experiment site (or NPPE) and Ho'ona Bay. Three transects sampling the three zones or biotopes (biotope of boulders and *Pocillopora meandrina,* biotope of *Porites lobata* and the biotope of *Porites compressa*) have been established at each of the six sites, thus 18 transects comprise the monitoring effort. Map redrawn from NELHA.


N
Wawaloli
1
2
3
4
5
6
18 Inch
18
17
16
Hoona
13
14
15
NPPE
10
11
12
12 Inch
N
7
8
9
12 Inch-S

The final routine sampling site first survey in May 1992 is directly offshore of the NPPE (Net Power Producing Experiment) located just north of the NELHA compound (see Figure 3).

Quantitative studies were carried out in the communities adjacent to the shore; the rationale was that it will be those communities in closest proximity to any nonpoint discharge of effluents that would be first impacted and thus the first in which change could be measured. In the initial baseline, fish and benthic communities were sampled; four stations were established offshore of Ho'ona Bay, four stations fronting Wawaloli Beach and four stations offshore of Honokohau Harbor to serve as the control site. The October 1991 study established three transects at each location (Ho'ona Bay, 18-inch pipe, Wawaloli Beach and Honokohau) that sampled the boulder/*Pocillopora meandrina* zone (shallowest depths), the *Porites lobata* zone (in intermediate depths) and the *Porites compressa* zone (deepest depths) that are common major biotopes on the West Hawaii coast. The March 1992 survey sampled transects offshore of Wawaloli Beach, the 18-inch pipe and Ho'ona Bay and focused only on the fish communities at these locations. Additional studies were done along the 40-inch pipe path during the March 1992 survey and are summarized in a companion report. Since May 1992 the surveys reported on here have focused on fish community structure in the three zones at all six sites (Wawaloli Beach, the 18-Inch Pipe, the 12-Inch South Pipe, the 12-Inch North Pipe, the NPPE site and Ho'ona Bay).

Permanent stations have been established in each biotope or zone at each location. These stations are marked by small subsurface floats that pinpoint the transect line. Fish communities were sampled using visual assessment techniques modified from Brock (1954). Immediately following station location, the visual fish census was undertaken to estimate the abundance and biomass of fishes. Data collected included species and numbers of individuals. The fish censuses were conducted over the entire length of the 25 m transect line which was paid out as the census progressed as not to frighten wary fishes. All fishes within the 4 x 25 m transect area to the water's surface were counted. A single diver equipped with SCUBA, transect line, slate and pencil would enter the water, count and note all fishes in the prescribed area. All quantitative studies were carried out using SCUBA.

Besides frightening wary fishes, other problems with the visual census technique include the underestimation of cryptic species such as moray eels (Family Muraenidae) and nocturnal species, e.g., squirrelfishes (Family Holocentridae), aweoweos (Family Priancanthidae), etc. This problem is compounded in areas of high relief and coral coverage affording numerous shelter sites. Species lists and abundance estimates are more accurate for areas of low relief, although some fishes with cryptic habits or protective coloration (e.g., the nohus, Family Scorpaenidae; the flatfishes, Family Bothidae) might still be missed. Obviously, the effectiveness of the visual census technique is reduced in turbid water and species of fishes which move quickly and/or are very numerous (e.g., opelu, Family Carangidae) may be difficult to count. Problems may arise with the bias related to the experience of the diver conducting counts when attempting to make comparisons between surveys. In spite of the above drawbacks, the visual census technique probably provides the most accurate non-destructive assessment of diurnally active fishes presently available (Brock 1982).

Data were subjected to simple nonparametric statistical procedures provided in the SAS Institute statistical package (SAS Institute Inc. 1985). Nonparametric methods were used to avoid meeting requirements of normal distribution and homogeneity of variance in the data. Data were analyzed using the Kruskal-Wallis one-way analysis of variance (ANOVA) to discern significant differences among ranked means for each measured parameter in the fish community, sample date and habitat type; this procedure is outlined by Siegel (1956) and Sokal and Rohlf (1981). The *a posteriori* Student-Newman-Keuls multiple range test (or SNK Test; SAS Institute Inc. 1985) was also used to eludicate between which dates significant differences occurred.

C. Results

Communities in closest proximity to any nonpoint source of pollution entering the sea via the groundwater would be the first to manifest problems thus we established quantitative stations to sample the fish and benthos in the boulder/*Pocillopora meandrina* zone, the *Porites lobata* zone and the *Porites compressa* zone. All of these biotopes or zones are in very close proximity of the shoreline in the Keahole Point area. The results are discussed by transect commencing with the south end of the NELHA project area.

In the earlier studies, two shoreline areas appeared to have lower salinities; these were at Wawaloli Beach on the south and Ho'ona Bay on the north. Lower salinity water was not as evident elsewhere. These low salinity sites are candidate locations where wastewater from aquaculture or OTEC studies discharged back inland in the watertable may enter the ocean. If the discharged water is to have an impact on the benthic and fish communities, the impacts would probably first become evident at locations in close proximity to the discharge.

The shallow subtidal bench at Wawaloli Beach extends 60 to 80 m seaward before the water depth appreciably increases. At this distance offshore, the depth increases from 1.2 to about 6 m and the biotope of boulders and *Pocillopora meandrina* is encountered. Three transects were established offshore of Wawaloli Beach; one of these (T-1) was situated in the biotope of boulders and *Pocillopora meandrina*, a second (Transect T-2) was placed in the biotope of *Porites lobata* and the third transect (T-3) was setup in the biotope of *Porites compressa*. The approximate locations of these transects are given in Figure 3.

Transect T-1 was established in 5 m of water in the biotope of boulders and *Pocillopora meandrina*. The substratum at this transect location is dominated by large basalt boulders (mean size about 1.4 m) with a small amount of coral present. The fish census for the December 2007 survey (Appendix A) noted 20 species of fish having a total of 465 individuals present. The most abundant fishes were the damselfish (*Chromis vanderbilti*), the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), and the yellow tang or lau'ipala (*Zebrasoma flavescens*). The August 2008 survey (Appendix B) found 24 species of fishes and 265 individuals present. Again the most common species included *Chromis vanderbilti* and *Acanthurus nigrofuscus* as well as the saddleback wrasse or hinalea aluwili (*Thalassoma duperrey*). The standing crop of fishes at Transect

T-1 was estimated to be 189 g/m^2 in December 2007 The ringtail surgeonfish or pualo contributed 37% of the total weight of fishes present and the orangespine surgeonfish or umaumalei (*Naso lituratus*) contributed 13% to the standing crop at this station in December 2007. In the August 2008 survey the standing crop was estimated to be 84 g/m 2 at this station and the redlip parrotfish or palukaluka (*Scarus rubroviolaceus*) comprised 24% of the estimated biomass present and the orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*) made up 17% of the total at this station.

Transect T-2 sampled the biotope of *Porites lobata* in 6.7 m of water. The substratum at this location is a mix of scattered basalt boulders (0.5 to 2 m in diameter), and corals with *Porites lobata* being the dominant species. In the December 2007 survey, 23 species of fishes were censused and 327 individuals counted in the 100 m^2 census area. The most abundant species present at Transect T-2 in December 2007 was the damselfish or (*Chromis vanderbilti*) and the ma'i'i'i (*Acanthurus nigrofuscus*). In the August 2008 survey 26 species of fishes were noted and 690 individual fishes were censused. The same two species (i.e., the ma'i'i'i and the damselfish) were the two most abundnat species in the transect area in August 2008. The biomass of fishes was estimated to be 111 g/m^2 in the December 2007 survey with the na'ena'e (*Acanthurus nigrofuscus*) making up 53% of the estimated biomass and the lau'ipala (*Zebrasoma flavescens*) adding another 10% to the estimated total at this station. In the August 2008 survey, the standing crop was estimated to be 84 g/m^2 with the na'ena'e (*Acanthurus olivaceus*) making up 22% of the total and the black triggerfish or humu ele'ele (*Melichthys niger*) adding 12% to the estiamted total at this station.

Transect T-3 was situated near the shelf break in 11 m of water in the ecotone (zone of transition) between the biotope of *Porites lobata* and the *Porites compressa* zone. The substratum is dominated by open basalt and some limestone; coral cover is limited at this site. The December 2007 fish census yielded 24 species, 655 individuals and an estimated biomass of 243 g/m^2. The most abundant fish species present at Transect T-3 in December 2007 include the damselfish (*Chromis vanderbilti*) and the na'ena'e (*Acanthurus olivaceus*) and species contributing heavily to the biomass of fishes at Transect T-3 include a single blue spotted grouper or roi (*Cephalopholis argus*) contributing 7% of the total and the na'ena'e (*Acanthurus olivaceus*) adding 52% of the standing crop present. In the August 2008 survey of this staiton 30 species of fishes were present having a total abundance of 1,470 individuals and an estimated standing crop of 139 g/m^2. The most common species present in the August 2008 survey include two damselfish species, *Chromis vanderbilti* and *Chromis agilis*. Again the na'ena'e (*Acanthurus olivaceus*) made up 29% of the biomass encountered and the umaumalei (*Naso lituratus*) contributed 14% to the estimated standing crop present at this station.

Three transects were established offshore of the 18-inch pipe south of the NELHA facility (Figure 3). These transects again sampled the boulder/*Pocillopora meandrina* zone, the biotope of *Porites lobata* and the biotope of *Porites compressa* which lies in deeper water. All transects offshore of the 18-inch pipe site commenced just to the south of the pipe, and parallel the shore. Transect T-4 was situated in the boulder/*Pocillopora meandrina* zone in approximately 6 m of water. The substratum at this transect was boulders affording cover for fishes. These boulders ranged in size from 0.5 to well over 3 m and covered much of the basalt substratum. The census at this transect site in December 2007 recorded 38 species and 716 individuals (Appendix A). The most abundant fishes at Transect T-4 in the December 2007 survey were the damselfish (*Chromis vanderbilti*), the yellow tang or lau'ipala (*Zebrasoma flavescens*), ma'i'i'i (*Acanthurus nigrofuscus*) and the goldring surgeonfish or kole (*Ctenochaetus strigosus*). The December 2007 standing crop at Transect T-4 was estimated to be 297 g/m^2 and species that contributed heavily to this biomass include the brick soldierfish or menpachi (*Myripristes amaenus* - 14%) and the whitebar surgeonfish or maiko (*Acanthurus leucoparieus*) adding 12% to the total at this station. In the August 2008 survey of this station, there were 34 species of fishes seen and 476 individuals counted (Appendix B). The most common species were the damselfish (*Chromis vanderbilti*), the maiko (*Acanthurus leucoparieus*) and the ma'i'i'i (*Acanthurus nigrofuscus*). The August 2008 standing crop was estimated to be 321 g/m^2 with the maiko (*Acanthurus leucoparieus*) contributing 20% to the total and the kole (*Ctenochaetus strigosus*) adding 15% to the estimated biomass.

Transect T-5 was established in 8-9 m of water in the biotope of *Porites lobata* at the 18-inch pipe site. The substratum at this transect location was comprised of boulders and coral (dominant species *Porites lobata*). In the December 2007 survey, 33 species and 620 individuals were recorded at this location. The most abundant fishes were the damselfish (*Chromis vanderbilti*) and the ma'i'i'i (*Acanthurus nigrofuscus*). The December 2007 standing crop of fishes at Station T-5 was estimated to be 212 g/m^2 and the bullethead parrotfish or uhu (*Scarus sordidus*) made up 17% of the biomass while the ringtail surgeonfish or pualo contributed 21% to the estimated total at this station. The August 2008 survey noted 27 species and 274 individuals present (Appendix B). Again, the damselfish (*Chromis vanderbilti*) and the ma'i'i'i (*Acanthurus nigrofuscus*) were the most common species while the estimated standing crop was estimated to be 213 g/m^2. The two most important contributors to this standing crop include the na'ena'e (*Acanthurus olivaceus*) contributing 37% to the total and the pualo (*Acanthurus blochii*) adding 19% to the total at this station.

Transect T-6 was established to sample the *Porites compressa* zone at the 18-inch pipe site. This transect is situated in 13 to 14 m of water at the shelf break. The substratum at this location is dominated by *Porites compressa* coral. The December 2007 fish census noted 36 species and 878 individual fishes at this site. The most abundant species were the damselfish (*Chromis vanderbilti*), and the ringtail surgeonfish or pualo (*Acanthurus blochii*). The December 2007 fish biomass estimate at Transect T-6 was 513 g/m^2. The species of fishes that comprised the largest proportion of this standing crop include the pualo (*Acanthurus blochii*) making up 37% of the total and the na'ena'e (*Acanthurus olivaceus*) adding 11% to the total biomass at this station. In the August 2008 survey of Transect T-6, 34 species of fishes and 500 individuals were censused. The most common fishes in the August 2008 survey were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*). The August 2008 standing crop was estimated to be 234 g/m^2 and species contributing most heavily to this estimate included the redlip parrotfish or palukaluka (*Scarus rubroviolaceus*) making up 33% of the total and a single male spectacled parrotfish or uhu'uli'uli (*Scarus perspicillatus*) contributing 9% to the biomass at this station.

The May 1992 survey marked the commencement of study of three transects located along the old 12-inch warmwater intake pipe as well as also along the adjacent 12-inch coldwater intake pipe both offshore of Keahole Point (Figure 3). The 12-inch warmwater intake pipe is just south of the coldwater intake. The warmwater intake is called the 12-Inch South Pipe. The three transects located along the 12-Inch South pipe sampled the biotope of boulders (Transect T-7), the biotope of *Porites lobata* (Transect T-8) and the biotope of *Porites compressa* (Transect T-9). These three transects commenced on the pipe, parallel the shoreline and have an orientation to the south. The three transects located on the 12-Inch South warmwater intake pipe were sampled on 19 December 2007 and again on 12 August 2008. In the August 2008 survey most of the warmwater intake pipe had been removed but the path of the pipeline alignment was clearly evident on the bottom so establishing the three transects did not present a problem because many familiar nearby "landmarks" were still present.

Transect T-7 was established in the biotope of boulders about 20 m offshore of the point in about 5.5 m of water. The substratum at this location is a pahoehoe bench with large basalt boulders. The boulders range in size from 0.5 to well over 3.5 m in greatest dimension; the mean size approaches 2 m. These boulders have a spacing from contact with one another to about 5 m apart and their presence provides considerable vertical relief and shelter for fishes. The results of the December 2007 fish census are presented in Appendix A; in total, 27 species (401 individuals) were censused on this transect. The most abundant fishes were the goldring surgeonfish or kole (*Ctenochaetus strigosus*), the yellow tang or lau'ipala (*Zebrasoma flavescens*), the damselfish (*Chromis vanderbilti*) and the ma'i'i'i (*Acanthurus nigrofuscus*). The standing crop of fishes at this site (T-7) in the December 2007 survey was estimated to be 261 g/m^2. Species contributing heavily to this biomass include the pualo (*Acanthurus blochii*) which made up 36% of the biomass, the kole (*Ctenochaetus strigosus*) and the black surgeonfish (*Ctenochaetus hawaiiensis*) each comprising 12% of the total standing crop. In the August 2008 survey of Transect T-7 noted 32 species and 427 individual fishes censused (Appendix B). The most abundant species in the August 2008 survey were Thompson's butterflyfish (*Hemitaurichthys thompsoni*), the damselfish (*Chromis vanderbilti*) and Thompson's surgeonfish (*Acanthurus thompsoni*). The standing crop was estimated to be 251 g/m^2 and two species contributing the most to this estimated biomass were Thompson's butterflyfish (*Hemitaurichthys thompsoni*) comprising 17% of the total and the black surgeonfish (*Ctenochaetus hawaiiensis*) adding 14% to the total biomass at this station.

Transect T-8 sampled the biotope of *Porites lobata* along the 12-Inch South (warmwater intake) pipe. The water depth at this location ranges from 6.7 to 9.1 m; the substratum is pahoehoe with some basalt boulders continuing from the shallows into this area. The dominant coral of the zone is *Porites lobata*. The December 2007 fish census noted 29 species and 341 individuals Appendix A). The most abundant fishes were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*), and the kole (*Ctenochaetus strigosus*). The biomass of fishes at this location (T-8) in the December 2007 survey was estimated to be 297 g/m^2. The species of fishes that contributed most heavily to this of the biomass include the pualo (*Acanthurus blochii*) making up 47% of the total and the uhu (*Scarus sordidus*) as well as the emperor or mu (*Monotaxis grandoculis*) each contributing 7% of the total estimated standing crop at this station. The August 2007 survey noted 31 species and 565 individuals in the transect area (Appendix B). The most abundant fishes included Thompson's butterflyfish (*Hemitaurichthys thompsoni*), the damselfish (*Chromis vanderbilti*) and Thompson's surgeonfish (*Acanthurus thompsoni*). The August 2008 standing crop was estimated to be 308 g/m^2 and two eagle rays or hihimanu (*Aetobatus narinari*) made up 35% of the total and the uhu (*Scarus sordidus*) comprised 16% of the total at this station.

Located at a depth of 13.7 m along the top of the shelf break is Transect T-9. This transect samples the fishes in the biotope of *Porites compressa*. The substratum at this station is pahoehoe with some basalt boulders; the dominant coral is *Porites compressa* but also present is *P. lobata*. The December 2007 fish census at this site noted 38 species and 728 individual fishes. The most common fishes on this transect were the damselfishes (*Chromis vanderbilti* and *C. agilis*) and the kole (*Ctenochaetus strigosus*). The biomass of fishes at this location in the December 2007 survey was estimated to be 497 g/m^2 and a single grey snapper or uku (*Aprion virescens*) comprised 14% of the biomass at this station and the pualo (*Acanthurus blochii*) contributed 51% to the standing crop at this station. The August 2008 survey of Transect T-9 found 32 species and 707 individual fishes. The most abundant speiceis included the damselfishes (*Chromis vanderbilti* and *C. agilis*) a small school of mackerel scad or opelu (*Decapterus macarellus*) and Thompson's surgeonfish (*Acanthurus thompsoni*). The August 2008 standing crop was estimated to be 265 g/m 2 and the species contribution the greatest to this estimated weight included the opelu (*Decapterus macarellus*) adding 30% to the total and the uhu (*Scarus sordidus*) adding 17% to the total at this station.

A few meters to the north of the 12-inch warmwater intake pipe is the 12-inch coldwater intake (the "12-Inch North pipe in Figure 3). Again, three transects (T-10, T-11 and T-12) were established to sample the three biotopes present in the area. All of the 12-inch coldwater intake pipe transects commenced on the pipe, paralleled the shore along a given bathymetric contour and have an orientation to the north. The biotopes are similar in description to that given for the 12-inch warmwater intake pipe and will not be repeated here. The 12-Inch North cold water pipe was still in place at the time of the 12 August 2008 survey.

Transect T-10 is situated in 5.2 to 6.4 m of water in the biotope of boulders and *Pocillopora meandrina*. The 19 December 2007 fish census noted 30 species and 269 individuals. The most abundant fishes at Transect T-10 include the lau'ipala (*Zebrasoma flavescens*), ma'i'i'i (*Acanthurus nigrofuscus*), the damselfish (*Chromis vanderbilti*) and the kole (*Ctyenochaetus strigosus*). The standing crop of fishes at this site was estimated to be 222 g/m^2 in the December 2007 survey and the species contributing the most to this biomass were the palukluka (*Scarus rubroviolaceus*) and kole (*Ctenochaetus strigosus*) each making up 8% of the total and the lau'ipala (*Zebrasoma flavescens*) as well as the pualo (*Acanthurus blochii*) each of which contributed 18% to the total standing crop at this station. In the August 2008 survey of Transect T-10, 31 species and 284 individual fish were censused. The most abundant species were the damselfish (*Chomis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the lau'ipala (*Zebrasoma flavescens*). Two species were the important contributors to the estimated biomass (here 125 g/m^2) present at this site; these were the orangespine unicornfish or umaumalei (*Naso lituratus*) making up 21% of the total and the lau'ipala (*Zebrasoma flavescens*) adding 20% to the estimated total at this station.

Transect T-11 sampled the biotope of *Porites lobata* along the 12-inch coldwater intake pipe. The substratum characteristics and water depth were similar to that found in the same biotope at the 12-inch warmwater intake pipe (Transect T-8). In the December 2007 survey 32 species of fishes were censused at this site (231 individuals); the most abundant species were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The biomass of fishes at Transect T-11 was estimated to be 79 g/m^2 and the kole (*Ctenochaetus strigosus*) contributed 16% and the umaumalei (*Naso lituratus*) contributed 16% of the standing crop at this station. In the August 2008 survey of Transect T-11, 34 species (273 individuals) were censused on the transect; the most common were the damselfish (*Chromis vanderbilti*), the kole (*Ctenochaetus strigosus*) and the lau'ipala (*Zebrasoma flavescens*). The August 2008 estimated standing crop of fishes was 100 g/m^2 and the species contributing the most to this biomass were the umaumalei (*Naso lituratus*) providing 16% to the total and the lau'ipala (*Zebrasoma flavescens*) adding 15%.

Transect T-12 sampled the biotope of *Porites compressa* along the top of the shelf break at the 12-inch coldwater intake pipe in 13 to 14 m of water (Figure 3). The 19 December 2007 survey noted 33 species and 425 individual fish in the transect area (Appendix A). The most abundant fishes were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The standing crop was estimated to be 120 g/m^2 and the two most important contributors to this estimate were the uhu (*Scarus sordidus*) making up 23% and the lau'ipala (*Zebrasoma flavescens*) adding another 10% to the total at this station. In the August 2008 survey (Appendix B), 27 species were seen (392 individuals). The most common species present were the damselfishes (*Chromis vanderbilti* and *Chromis agilis*) and the lau'ipala (*Zebrasoma flavescens*). The standing crop of fishes at this site in August 2008 was estimated to be 96 g/m^2. The species contributing most to this standing crop were the uhu (*Scarus sordidus*) comprising 16% of the total weight, the lau'ipala (*Zebrasoma flavescens* - 17%), and the umaumalei (*Naso lituratus*) making up 23% of the biomass at this station.

The Net Power Producing Experiment or NPPE site is located just north of the NELHA facility. The NPPE experiment discharges up to 16,000 gpm of cold seawater into a trench located 150 m inland of the shoreline. A station (the NPPE station) was established directly fronting and offshore of the NPPE disposal trench. Transect T-13 sampled the biotope of boulders and *Pocillopora meandrina,* T-14 sampled the biotope of *Porites lobata* and T-15 sampled the biotope of *Porites compressa* at this station.

Transect T-13 was established in the biotope of boulders and *Pocillopora meandrina* at a depth of 5.5 to 7.5 m. The substratum at this station is again pahoehoe overlain with large basalt boulders. The boulders range in size from about 1 to 4 m and range from being in contact to one another to being spaced over 5 m apart. Over the basalt substratum are colonies of the coral, *Pocillopora meandrina*. The December 2007 fish census noted 29 species and 412 individual fishes (Appendix A); the most common fishes were the damselfish (*Chromis vanderbilti*), ma'i'i'i (*Acanthurus nigrofuscus*), and the kole (*Ctenochaetus strigosus*). The December 2007 standing crop of fishes on this transect was estimated to be 115 g/m^2; the kole (*Ctenochaetus strigosus*) contributed 22%

of the biomass and the palukaluka (*Scarus rubroviolaceus*) made up 29% of the weight present at this station. In the August 2008 survey of Transect T-13, 21 species and 330 individual fishes were censused (Appendix B). The most abundant species present included the damselfish (*Chromis vanderbilti*), ma'i'i'i (*Acanthurus nigrofuscus*) and the lau'ipala (*Zebrasoma flavescens*). The August 2008 standing crop was estimated to be 97 g/m^2 and the two heaviest contributions included the palukaluka (*Scarus rubroviolaceus*) and the lau'ipala (*Zebrasoma flavescens*) each providing 15% to the estimated biomass at this station.

Transect T-14 sampled the biotope of *Porites lobata* at a depth from 8.5 to 9.8 m. The substratum at this station is basalt boulders and exposed pahoehoe; over this are scattered *Porites lobata* corals. The December 2007 survey fish census noted 27 species and 249 individuals present at Transect T-14 (Appendix A). Common species at this location include the damselfish (*Chromis vanderbilti*), ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The December 2007 standing crop of fishes was estimated to be 135 g/m^2; the yellowstripe goatfish or weke (*Mulloides flavolineatus*) made up 22% and the palukaluka (*Scarus rubroviolaceus*) added 20% to the total at this station. The August 2008 survey (Appendix B) encountered 26 species and 313 individuals in the census area. The most abundant species were the damselfish (*Chromis vanderbilti*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The standing crop was estimated to be 109 g/m^2 and the uhu (*Scarus sordidus*) added 16% to the total and the umaumalei (*Naso lituratus*) contributed 18% to the estimated biomass present in this survey.

The biotope of *Porites compressa* was sampled at Transect T-15 offshore of the NPPE disposal trench. Water depth at this location ranges from 12 to 13.5 m; the substratum is a mix of basalt boulders, pahoehoe and coral. The dominant coral species are *Porites compressa* and *P. lobata*. The results of the December 2007 fish census are presented in Appendix A; 27 species (287 individuals) were counted on this transect. The most abundant fishes were the damselfishes (*Chromis vanderbilti, Chormis agilis*). The biomass of fishes at this site was estimated to be 60 g/m^2 and the uhu (*Scarus sordidus*) comprised 12% of the total weight while the umaumalei (*Naso lituratus*) contributed 18% to the biomass at this station. The August 2008 survey of this site noted 32 species and 335 individuals present with Thompson's butterflyfish (*Hemitaurichthys thompsoni*) and the damselfishes (*Chromis vanderbilti* and *C. agilis*) being the most common species in the census area. The August 2008 standing crop was estiamted to be 170 g/m^2 and the palukaluka (*Scarus rubroviolaceus*) making up 13% of the total and the sleek unicornfish or kalaholo (*Naso hexacanthus*) adding 14% to the total at this station.

The salinity depression indicating groundwater input along the shoreline at Ho'ona Bay made this location an appropriate site for quantitative marine studies. Three transects were established; T-16 sampled the fish community in the boulder/*Pocillopora meandrina* zone, T-17 the community present in the *Porites lobata* zone and T-18 which sampled the fishes in the deeper *Porites compressa* zone. Figure 3 shows the approximate locations of these three transects relative to the shoreline and to each other.

Transect T-16 was established about 10 m offshore of the pahoehoe bench in water from 2.5 to

3 m in depth in the biotope of boulders and *Pocillopora meandrina*. The substratum at this station is comprised of pahoehoe overlain by basalt boulders ranging in size from 0.5 to 3 m; much of the bottom is strewn with boulders providing considerable local cover. A complete listing of all fishes censused at this station in the December 2007 survey is given in Appendix A. In total, 28 species of fishes (293 individuals) were censused. The most abundant species on T-16 were the damselfish (*Chromis vanderbilti*), the whitebar surgeonfish or maiko'iko (*Acanthurus leucoparieus*) and the ma'i'i'i (*Acanthurus nigrofuscus*). The estimated biomass of fishes at Station T-16 was 296 g/m^2; the species contributing most heavily to this biomass include the maiko'iko (*Acanthurus leucoparieus*) making up 37% of the total, the uhu (*Scarus sordidus*) adding 10% and the na'ena'e (*Acanthurus olivaceus*) contributing 6% of the biomass at this station. In the August 2008 survey, 24 species of fishes (280 individuals) were censused (Appendix B). The two most common species were the damselfish (*Chromis vanderbilti*) and the ma'i'i'i (*Acanthurus nigrofuscus*). The August 2008 standing crop was estimated to be 151 g/m^2 and species contributing heavily to this biomass included the uhu uliuli (*Scarus perspicillatus*) and the palukaluka (*Scarus rubroviolaceus*) as well as the umaumalei (*Naso lituratus*) each contributing 15% to the total weight at this station.

Station T-17 is situated about 45 m from the shoreline at Ho'ona Bay in 7.9 m of water. This station sampled the biotope of *Porites lobata*. The substratum at this station is comprised of boulders and *Porites lobata* as the dominant coral. Boulders at this site range in size from 0.5 to about 2 m. Again, the December 2007 census results are presented in Appendix A; 24 species (247 individuals) were censused. The most abundant fish species at Station T-17 were the damselfish (*Chromis vanderbilti*), ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The standing crop of fish at this station was estimated to be 90 g/m^2 and the uhu (*Scarus sordidus*) made up 25% of the total while the palukaluka (*Scarus rubroviolaceus*) added 20% to the total at this station. The August 2008 survey of Transect T-17 found 25 species and 192 individual fishes in the transect area. The most common species were the damselfish (*Chromis agilis*), the ma'i'i'i (*Acanthurus nigrofuscus*) and the kole (*Ctenochaetus strigosus*). The August 2008 standing crop was estimated at 105 g/m^2 and a small group of mackerel scad or opelu (*Decapterus macarellus*) made up 8% of this standing crop while the kala holo (*Naso hexacanthus*) added 23% to the total at this station.

Transect T-18 sampled the fish community of the *Porites compressa* zone about 20 m seaward of Transect T-17. The substratum at this site is comprised of boulders, coral rubble and coral (*Porites compressa*) on a steep seaward facing slope. The December 2007 survey found 27 fish species (310 individuals) in the census of T-18; biomass was estimated to be 106 g/m^2. The most abundant fishes at this station were the damselfish (*Chromis agilis*), the 'alo'ilo'i (*Dascyllus albisella*) and the shoulderbar soldierfish or menpachi (*Myripristes kuntee*). The most important species contributing to the biomass of fishes at this site were the menpachi (*Myripristes kuntee* - 30%) and the blue-spotted grouper or roi (*Cephalopholis argus*) comprising 25% of the total estimated weight at this station. In the August 2008 survey of Transect T-18 (Appendix B), 28 species of fishes were recorded and 375 individual fish. The most abundant were the damselfish (*Chromis agilis*), the kole (*Ctenochaetus strigosus*) and the menpachi (*Myripristes kuntee*). The August 2008 biomass was estimated to be81 g/m^2 and the menpachi (*Myripristes kuntee*) contributed

20% to this total and the umaumalei (*Naso lituratus*) added 19% at this station.

The results of the December 2007 fish censuses at the six sites are graphically summarized in Figures 4-6 and for the August 2008 survey these data are given in Figures 7-9. One general trend apparent in these graphs which is the greatest number of species, individuals and biomass are encountered at the 18-inch and 12-inch south pipe stations but the high abundance at Wawaloli Beach in the *Porites compressa* zone in August 2008 was simply due to an extremely high abundance of newly-recruited damselfishes *Chromis vanderbilti*). Stations to the north tend to have lower counts. In general these high number of individual fishes counted on a transect are due to the presence of a large number of small planktivorous damselfishes (*Chromis vanderbilti, C. hanui* and *C. agilis*). Considering all transects, these three species account for about 50% of all fishes counted in these two most recent surveys.

Appendix 3 presents a summary of the major parameters measured in the fish communities at each station for the 25 surveys completed by us at NELHA (October 1991 - August 2008). The means of each parameter (number of species, number of individuals and estimated biomass) calculated by combining all data from each survey are given in Figures 10-12. Inspection of these means suggests that there is high variability among surveys for the measured parameters. Some peaks in the mean number of individuals or biomass per transect are related to spawning aggregations encountered in 1998-99 and 2003 surveys which includes species such as the ringtail surgeonfish or pualo (*Acanthurus blochii*) and the smalltooth snapper or wahanui (*Alphareus furcatus*). Many coral reef fish form large temporary aggregations for the purposes of reproduction. Encounters with these spawning groups will result in fluctuations in the data. These same data are presented as means for each of the six stations combining each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) over the period of this study in Figures 13-15. Again these data reflect the encounters with spawning aggregations in 1998-99 and 2003.

A Kruskal-Wallis ANOVA is presented in Table 5 and points out a statistically significant difference among the various sample dates for the mean number of species encountered in a census ($n=24$, $P>0.0015$, significant). However, the SNK Test showed considerable overlap among the means which suggests that possibly only the upper and lower extremes in the range may be significantly different (June 2000 = 33 species from the lower extreme which was March 1995 = 25 species). Thus insofar as the mean number of species per transect is concerned, all other sample dates were not statistically separable from one another. The Kruskal-Wallis ANOVA also noted that there were statistically significant differences among the sample dates for the mean number of individual fish censused on a transect ($n=24$, $P>0.0001$, significant) but the SNK Test did not discern any significant differences among the means from the various sample dates, suggesting that there no real differences among the mean number of individual fishes counted during 24 surveys. As with the other two measures, mean estimated biomass per transect differed significantly among the sample dates (Kruskal-Wallis ANOVA, $n=24$, $P>0.0092$, significant) but like the mean number of species per survey, the SNK Test found considerable overlap among the means suggesting again that only the extremes may be significantly different where the November 1998 mean biomass (620 g/m^2) was significantly greater than the March 1992 mean biomass (139 g/m^2).

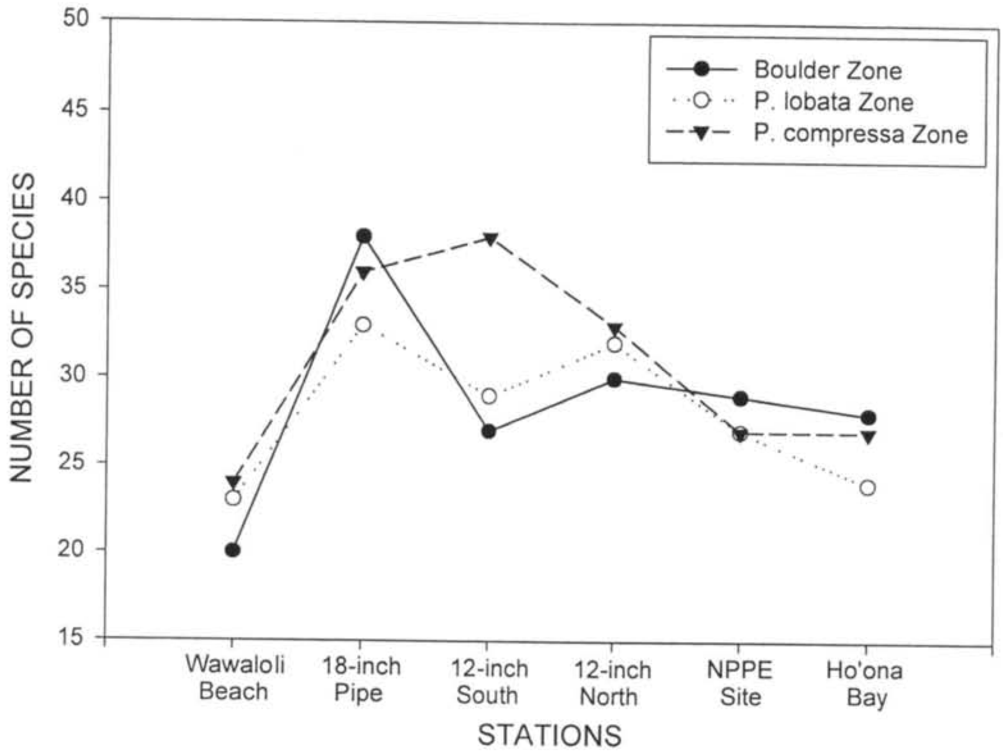


FIGURE 4. Plot of the number of fish species censused in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 19 December 2007.

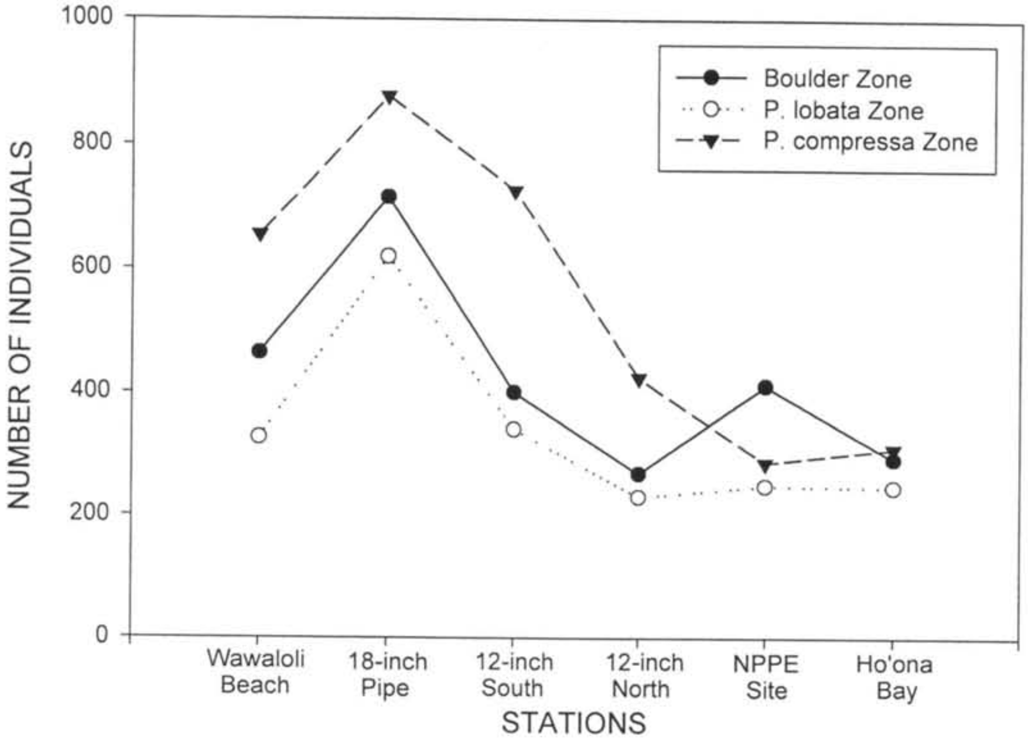


FIGURE 5. Plot of the number of individual fishes censused in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 19 December 2007.

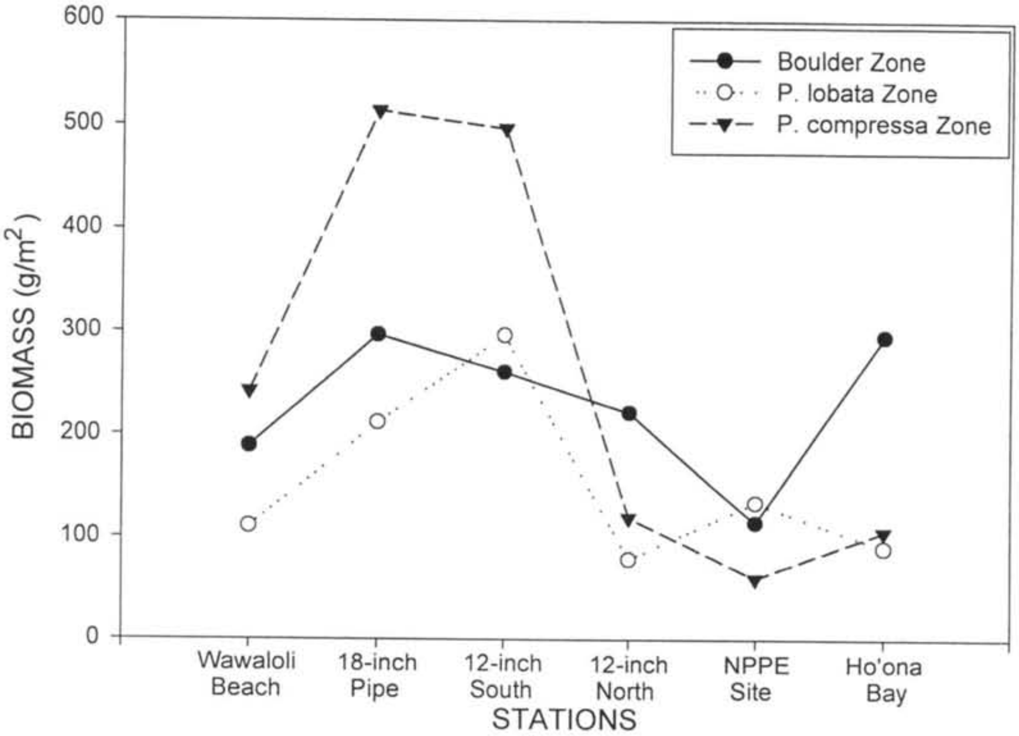


FIGURE 6. Plot of the estimated fish biomass (g/m^2) from censuses in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 19 December 2007.

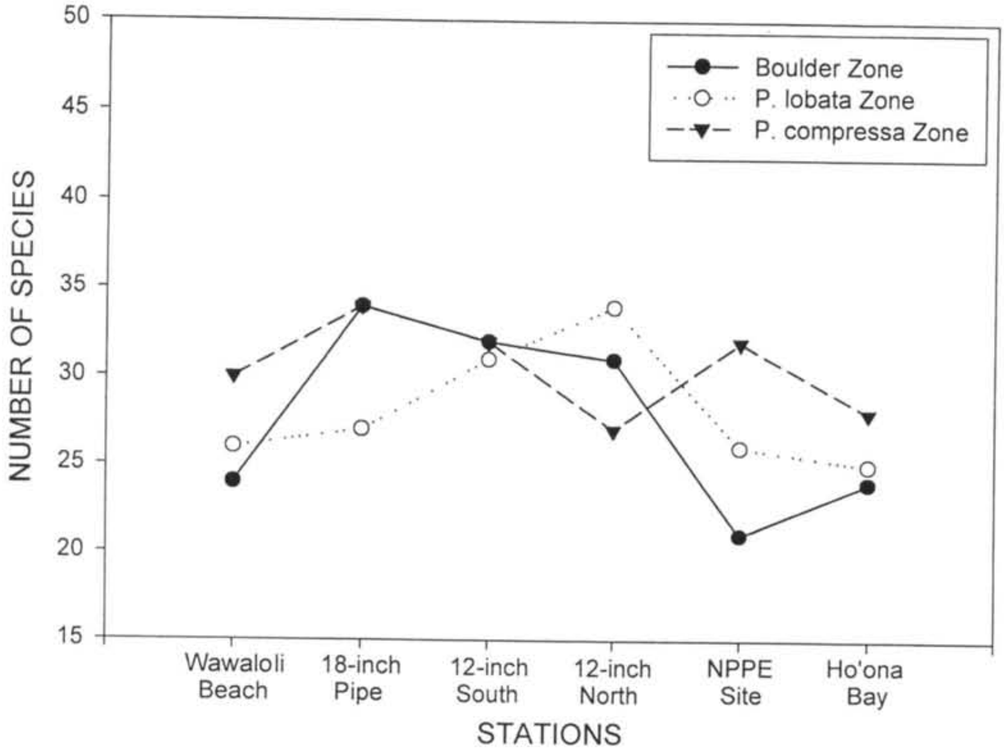


FIGURE 7. Plot of the number of fish species censused in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 12 August 2008.

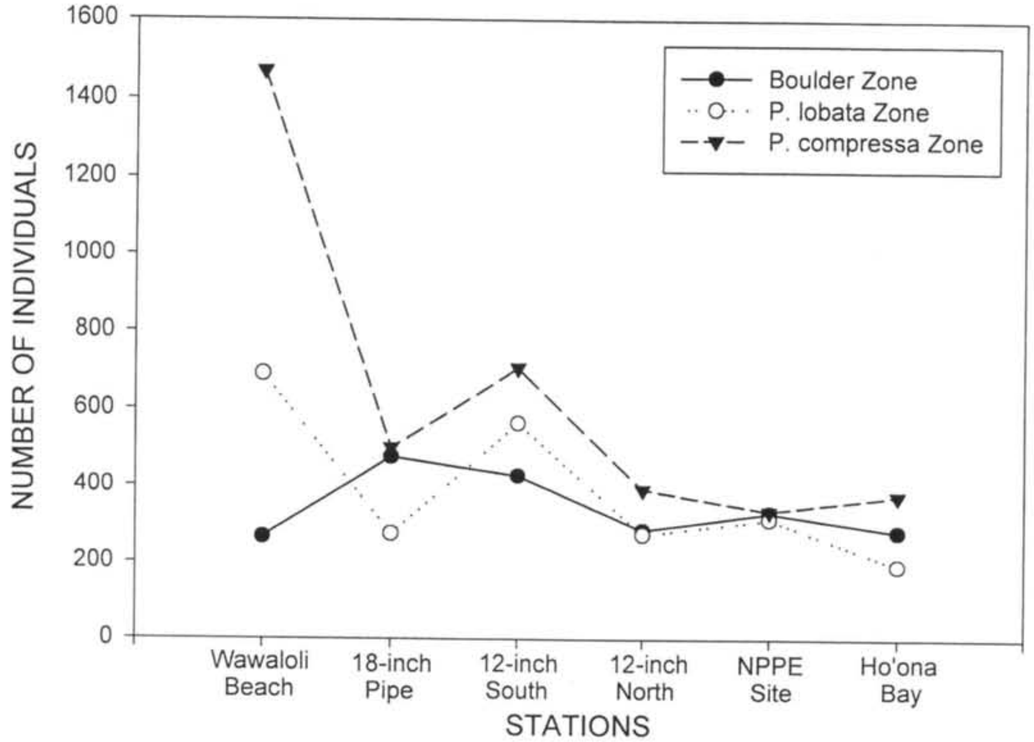


FIGURE 8. Plot of the number of individual fishes censused in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 12 August 2008.

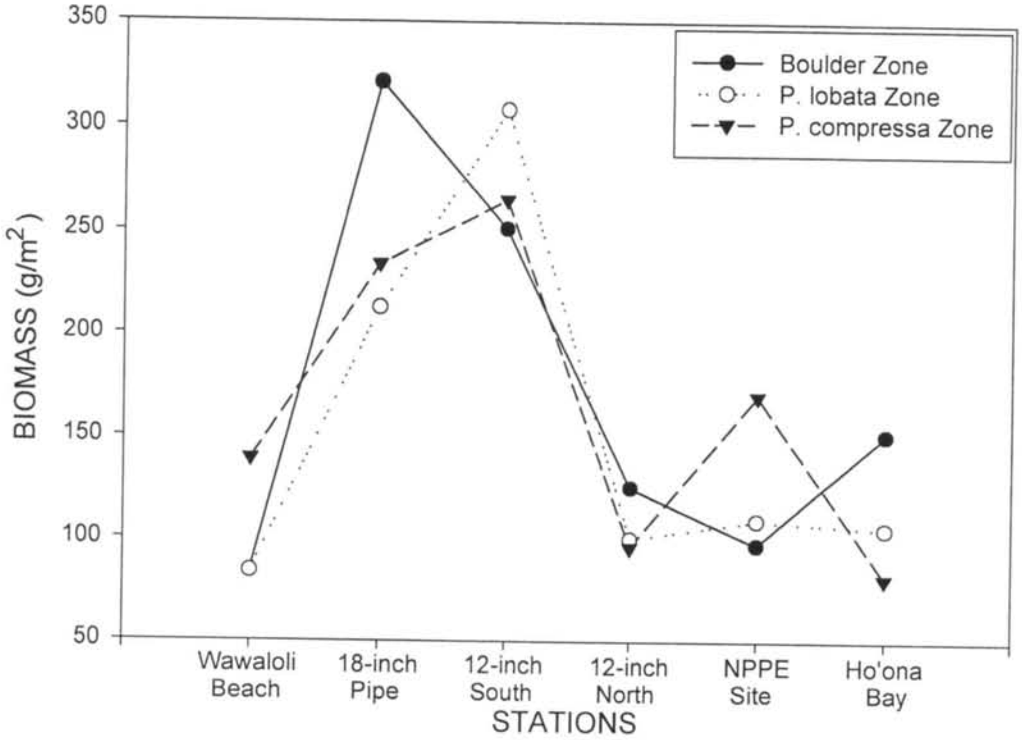


FIGURE 9. Plot of the estimated fish biomass (g/m^2) from censuses in each of the three zones (i.e., boulder, *Porites lobata* and *Porites compressa*) carried out at each of six locations fronting NELHA on 12 August 2008.

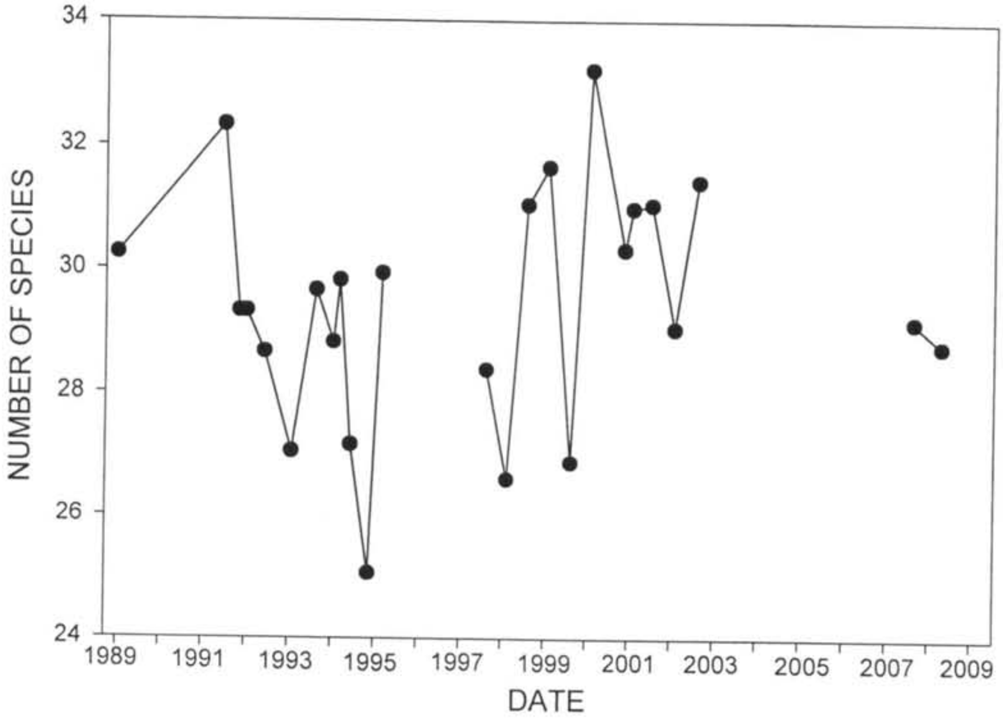


FIGURE 10. Plot of the mean number of fish species per transect for all 18 transects (i.e., 3 zones x 6 locations) sampled on each of 24 surveys at NELHA. Note the breaks in the line represents the periods when sampling was carried out by others.

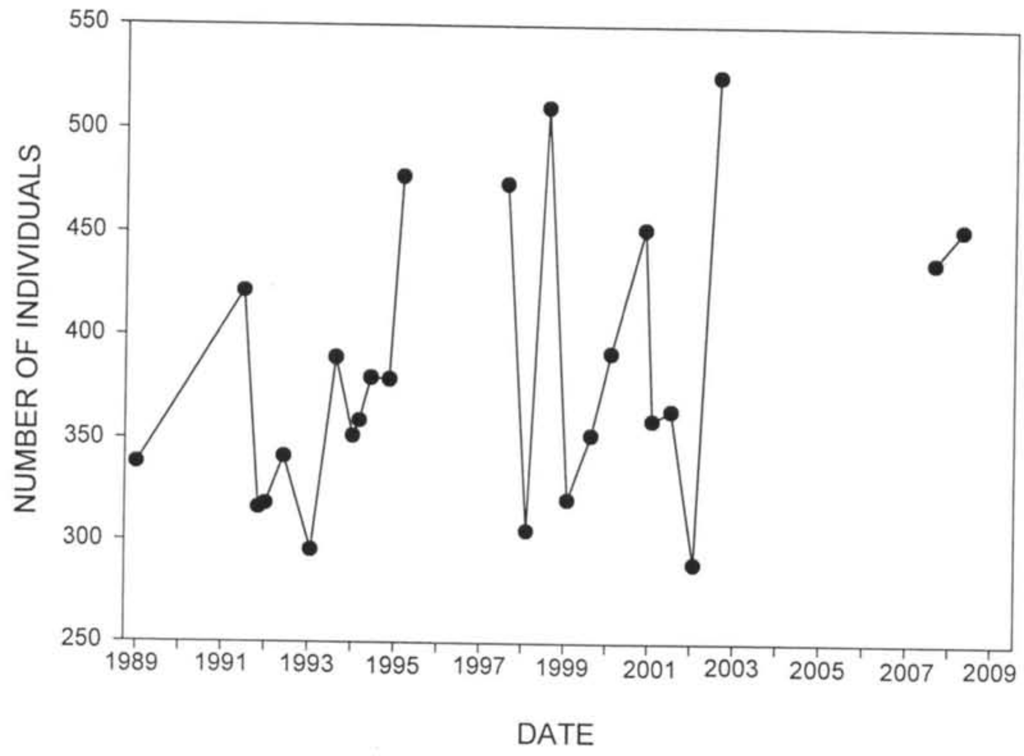


FIGURE 11. Plot of the mean number of individual fish per transect for all 18 transects (i.e., 3 zones x 6 locations) sampled on each of 24 surveys at NELHA. Note the breaks in the line represents the periods when sampling was carried out by others.

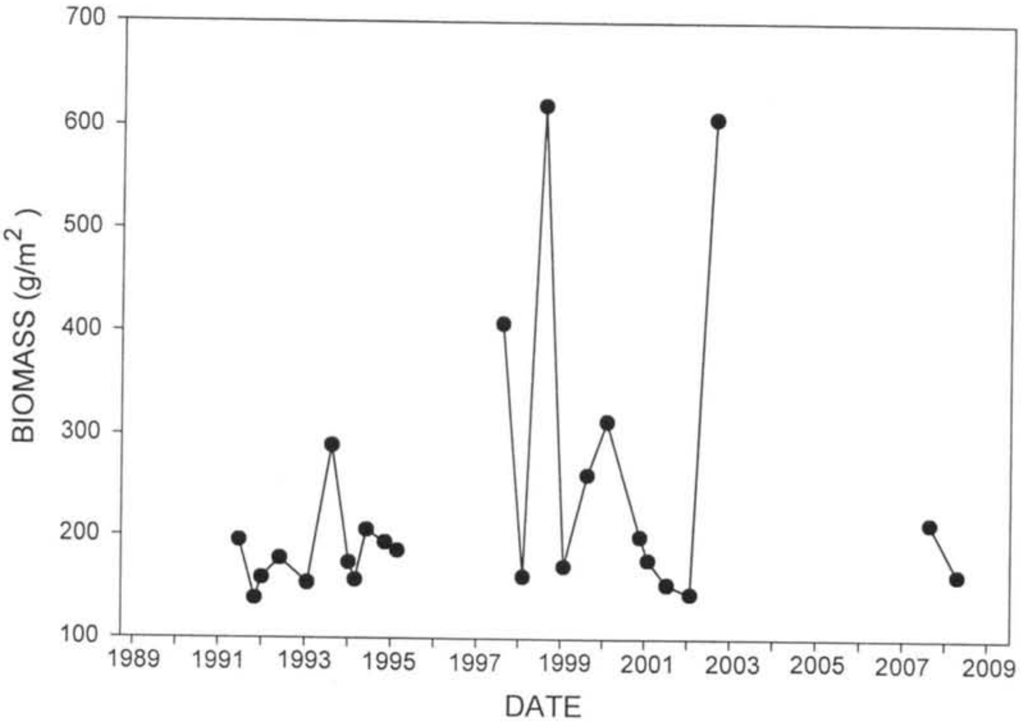


FIGURE 12. Plot of the mean estimated biomass of fishes per transect for all 18 transects (i.e., 3 zones x 6 locations) sampled on each of 24 surveys at NELHA. Note the breaks in the line represents the periods when sampling was carried out by others.

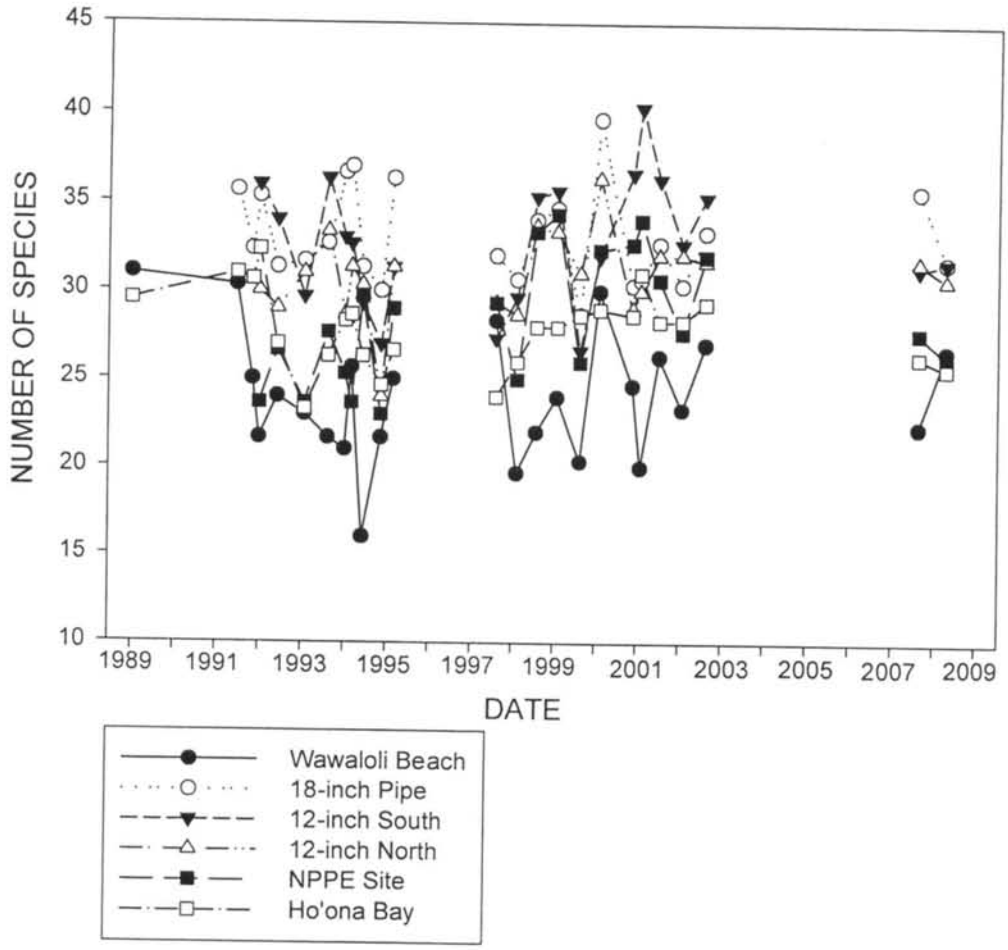


FIGURE 13. Mean number of fish species across the three zones (boulder, *Porites lobata* and *Porites compressa*) at each of six locations sampled on 24 occasions fronting NELHA. Note the breaks in the lines represent the periods when sampling was carried out by others.

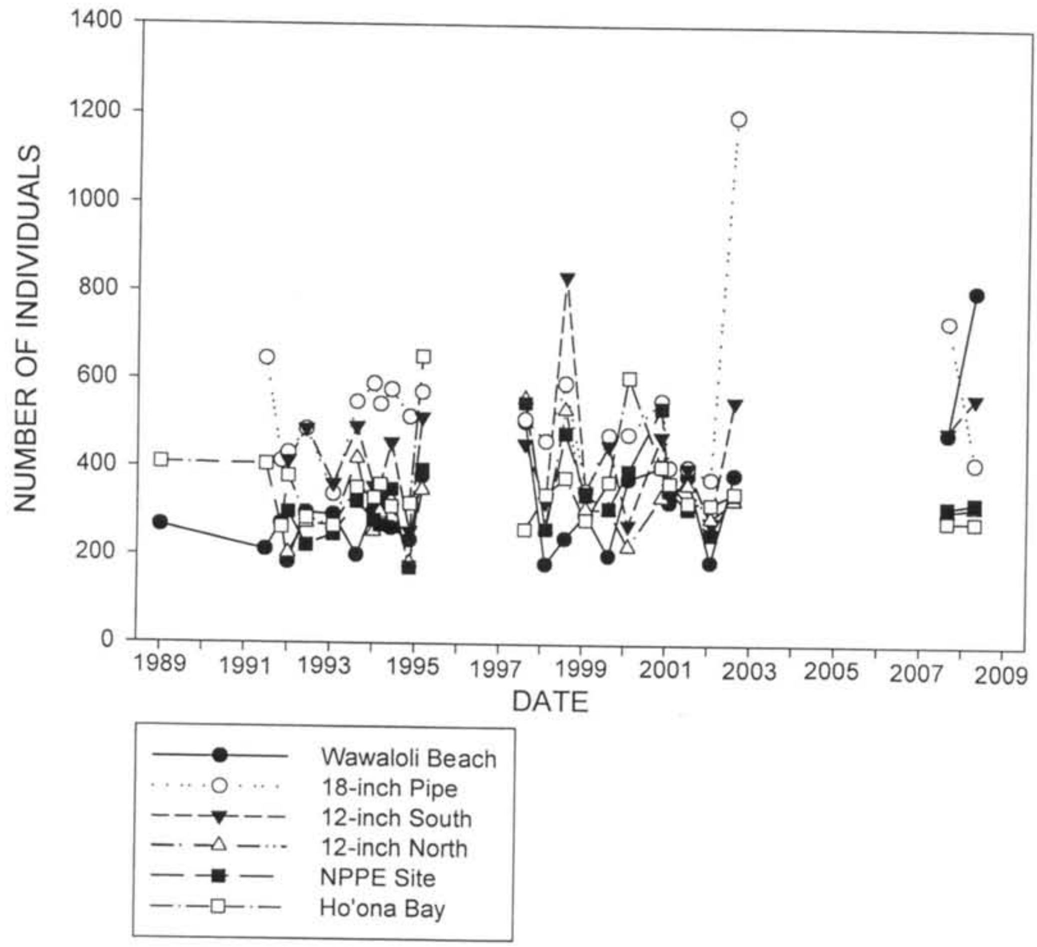


FIGURE 14. Mean number of individual fish across the three zones (boulder, *Porites lobata* and *Porites compressa*) at each of six locations sampled on 24 occasions fronting NELHA. Note the breaks in the lines represent the periods when sampling was carried out by others.

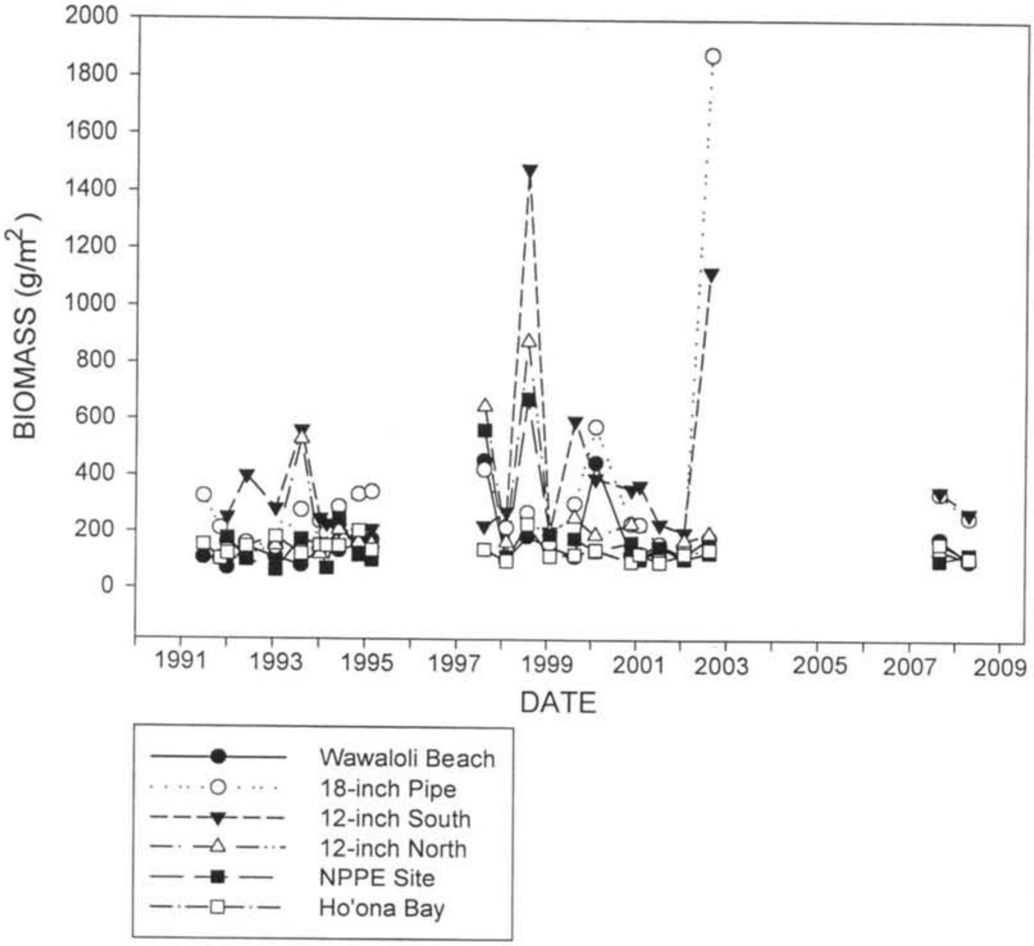


FIGURE 15. Mean estimated biomass of fish across the three zones (boulder, *Porites lobata* and *Porites compressa*) at each of six locations sampled on 24 occasions fronting NELHA. Note the breaks in the lines represent the periods when sampling was carried out by others.

TABLE 5. Summary of the significant changes that have occurred in the fish communities at NELHA as measured by the mean number of species, number of individuals and biomass by date (n=24; from October 1991 through August 2008). Data were analyzed by use of non-parametric methods: the Kruskal-Wallis ANOVA was used to discern statistically significant differences among ranked means for each variable and date and the Student-Newman-Keuls Test separated the significant dates from one another. Where significant differences exist, means are given.

DATE

	Kruskal-Wallis Test		SNK Test	
Variable	P-Value	Significant?	Significant?	If so, What?
No. Species	P>0.0015	YES	YES	Overlap so possibly only two extremes Jun00 (33 spp) from Mar 95 (25 spp) (range 25 to 33 spp)
No. Individuals	P>0.0001	YES	NO	SNK - no significant differences (range279 to 526 individuals)
Biomass	P>0.0092	YES	YES	Overlap so possibly only two extremes Nov 98 (620 g/m^2) from Mar 92 (139 g/m^2) (range 139 to 620 g/m^2)

Table 6 presents a summary of the statistical analysis of the variables (mean number of species, individuals and biomass) by sampling date and habitat type (boulder/*Pocillopora* zone, mid-depth *Porites lobata* zone and the deeper *Porites compressa* zone). In no cases did both the Kruskal-Wallis ANOVA and the SNK Tests find concurrence in significance among any of the parameters and dates for any of the three habitat types (boulder zone, *Porites lobata* zone and the *Porites compressa* zone). Without this concurrence, any statistically significant difference for a parameter using one test is probably not truly significantly different if the second test does not find a similar significance. One significant difference using SNK Test did appear in the analysis of parameters and dates by habitat zone as given in Table 6. The SNK Test did point out a significant difference in the boulder zone for the number of individual fishes censused over the different sample dates but the data showed considerable overlap suggesting that if these differences are real, they would probably only hold for the two extremes (March 1992 mean = 247 individuals/transect and December 1997 mean = 522 individuals/transect) but the Kruskal-Wallis ANOVA did not support this significant difference. Other than this, the statistical tests found no significant differences among the parameters measured here (i.e., mean number of species, individuals or biomass by zone) for either the *Porites lobata* zone or for the *Porites compressa* zone (Table 6).

Impacts to aquatic communities due to coastal development are frequently mediated through changes in water quality. These impacts are usually cumulative and most apparent in communities in closer proximity to the source(s) of the perturbation than in similar communities located further away. Because of their cumulative nature, evidence of impacts in aquatic communities becomes more obvious with the passage of time and are usually equated with decreases in the number of species, abundance of individuals, standing crop or changes in trophic structure (the latter parameter not measured in this study). In summary, the statistical analyses suggest no cumulative or progressive impacts to marine fish communities which would be manifested by change through time, rather, the analysis has shown a large variation in the numbers through time for all variables. These data do not suggest a declining trend but rather support the contention that the operations at NELHA are not having a negative impact on the adjacent marine fish communities.

Thus despite the imposition of Hurricane Iniki on benthic communities in September 1992 and continuing development at NELHA, the fish communities at Keahole Point appear not to have been significantly impacted by either the storm or ongoing coastal development based on data collected over the 202-month duration of this study.

D. Discussion

On September 11, 1992 the Hawaiian Islands were struck by Hurricane Iniki. The hurricane passed directly over Kauai and considerable damage occurred to improvements and forests of that island and the west (leeward) coast of Oahu. To a lesser extent, high surf caused damage in Kailua-Kona. Marine communities along south, east and west shores were also impacted around Oahu, Kauai, Maui, Lanai and Hawaii; this damage was primarily to coral communities. In many areas a large amount of sand and other loose material was avected out of shallow areas (depths less

TABLE 6. Summary of the significant changes that have occurred in the fish communities at NELHA as measured by the number of species, number of individuals and biomass in each of three habitat types: the shallow boulder/*Pocillopora* zone, the mid-depth *Porites lobata* zone, and the deeper *Porites compressa* zone (n=24; from October 1991 through August 2008). Data were analyzed by use of non-parametric methods: the Kruskal-Wallis ANOVA was used to discern statistically significant differences among ranked means for each variable and date and the Student-Newman-Keuls Test separated the significant dates from one another. Where significant differences exist, means are given.

Boulder Zone

Variable	Kruskal-Wallis Test P-Value	Kruskal-Wallis Test Significant?	SNK Test Significant?	SNK Test If so, What?
No. Species	P>0.65	NO	NO	
No. Individuals	P>0.09	NO	YES	Overlap so possibly 2 extremes only Dec97 (522ind) from Mar92 (247ind)
Biomass	P>0.16	NO	NO	

Porites lobata Zone

Variable	Kruskal-Wallis Test P-Value	Kruskal-Wallis Test Significant?	SNK Test Significant?	SNK Test If so, What?
No. Species	P>0.37	NO	NO	
No. Individuals	P>0.07	NO	NO	
Biomass	P>0.91	NO	NO	

Porites compressa Zone

Variable	Kruskal-Wallis Test P-Value	Kruskal-Wallis Test Significant?	SNK Test Significant?	SNK Test If so, What?
No. Species	P>0.61	NO	NO	
No. Individuals	P>0.17	NO	NO	
Biomass	P>0.25	NO	NO	

than 27 m) into deeper water. On Oahu, storm waves emanating from the southeast were estimated to exceed 6 to 7 m in height and were breaking in water of depths of at least 20 m (personal observations). Damage to corals was evident during the October 1992 survey particularly in those communities south of Keahole Point but was not as severe as seen around Oahu.

Despite changes in the coral communities due to the hurricane, the measures of fish communities used in this study showed little change. This may be due to the period of time that elapsed since the storm to the October 1992 survey (50 days). Walsh (1983) did note changes in fish communities directly after a major storm event; these changes included the movement of fishes away from shallow areas, obvious abrasions and wounds on the bodies of some fishes and a general disorientation of the fishes to the substratum. Besides the obvious damage to corals, we only observed a small number of fishes with wounds that for the most part appeared to be healed. As noted above, the measures used in this study of the fish communities offshore of the NELHA did not detect any significant change to these communities suggesting that the damage that Hurricane Iniki may have inflicted to Keahole Point fish communities was transitory.

As noted above, there are several biological zones or biotopes characteristic of the Kona coast (Dollar 1975, Hobson 1974) whose presence in the Keahole area has been well documented (see Brock and Norris 1987a, 1987b, 1988; Brock and Kam 1989). The geologically young age of the Keahole Point region and its exposure to periodic high energy conditions dictates that the development of benthic communities (here primarily coral) are in an early stage of succession. Thus in mature coral reefs, the reef corals grow on a limestone or calcareous base developed over a considerable period of time; in the case of the reefs at Keahole Point and much of West Hawaii, they are young and the corals are growing on a basalt substratum. Typically, three zones are found in West Hawaii benthic communities that are defined by depth, physical conditions and dominant coral species. In the shallowest water (usually to about 30 m offshore) is the boulder/*Pocillopora meandrina* zone; seaward is the *Porites lobata* reef bench zone that grades into the *Porites compressa* slope zone usually commencing at a depth of about 10 m. The *P. compressa* slope zone continues deeper to depths of 30 m or more.

The fish communities quantitatively assessed in this study at the six station sites (i.e., Wawaloli Beach, the 18-inch pipe, the 12-inch south pipe, the 12-inch north pipe, the area fronting NPPE and offshore of Ho'ona Bay) are quite similar. At each location one station each sampled the biotope of boulders and *Pocillopora meandrina,* the biotope of *Porites lobata* and the *Porites compressa* zone further offshore. These biotopes are near continuous features along much of the West Hawaii coast and are the zones usually closest to shore hence would be most susceptible to impact from human generated effluents discharged with groundwater.

Studies conducted on coral reefs in Hawaii and elsewhere have estimated fish standing crops to range from 20 to 200 g/m^2 (Brock 1954, Brock *et al.* 1979). Eliminating the direct impact of man due to fishing pressure and/or pollution, the variation in standing crop appears to be usually related to the variation in local topographical complexity of the substratum. Thus habitats with high structural complexity affording considerable shelter space usually harbor a greater estimated standing crop of coral reef fish; conversely, transects conducted in structurally simple habitats (e.g., sand flats) usually result in a lower estimated standing crop of fish (5 to 20 g/m^2). Goldman and Talbot (1975) noted that the upper limit to fish biomass on coral reefs is about 200 g/m^2. Ongoing studies (Brock and Norris 1989) suggest that with the manipulation (increasing) of habitat space or food resources (Brock 1987), local fish standing crops may approach 2000 g/m^2. Thus under certain circumstances, coral reefs may be able to support much larger standing crops of fishes than previously realized.

The high standing crops encountered in this study are probably related to the steep and rugged topographical relief found at most of the transect sites for most of the sampling periods (however, see below). The presence of adequate shelter coupled with strong tidal currents which transport particulate food materials may serve to sustain unusually high standing crops of fishes at specific sites.

The December 1997 and November 1998 surveys provided some unusual results. In the December 1997 survey, one species, the ringtail surgeonfish or pualo (*Acanthurus blochii*) was abundant at 11 of the 18 stations occurring in schools of primarily adults. These schools were present at all shallow and mid-depth stations except for Wawaloli Beach (southern extreme of the study area) and absent at the mid and deep stations fronting Ho'ona Bay as well as at most other deep stations. These aggregated pualo contributed an average of 10% to the numbers of fish counted and 45% of the biomass. The extreme was encountered in the shallow boulder/*Pocillopora meandrina* zone at the 18-Inch Pipe (T-4 in Appendix A) where 171 pualo contributed an estimated 1,431 g/m^2 to the census. The widespread aggregation of *A. blochii* had not, up to that time, been previously encountered at Keahole Point in this study (although seen elsewhere in the Hawaiian Islands) and these fish were probably aggregated for reproductive purposes.

In the November 1998 survey large aggregations of pualo (*Acanthurus blochii*) along with lesser numbers of the smalltooth jobfish or wahanui (*Alphareus furcatus*) were encountered in the vicinity of Keahole Point. These schools of fish appear to be aggregated again, for the purpose of reproduction. Currents were relatively strong at the time of sampling on 24 November, running towards the north approximately following the coastline. At Keahole Point along the steep offshore slope (stations T-9 and T-12) wahanui were aggregated in the water column above the substratum. At these stations wahanui contributed more than 9% of the mean estimated standing crop and 11% of the numbers of fishes censused. In most transects in the waters fronting NELHA, wahanui usually comprise no more than 1% of the biomass and 0.5% of the numbers censused, if they are present at all.

The pualo (*Acanthurus blochii*) was similarly aggregated but over a greater area in the vicinity of Keahole Point. *Acanthurus blochii* aggregations were encountered at station T-4 (18-inch pipe, shallow), at all three stations along the 12-inch south pipe (T-7, T-8, T-9), as well as at the mid-depth (T-11) and deep (T-12) stations on the 12-inch north pipe. Like the wahanui, these pualo were adults and in terms of means, contributed more than 52% of the estimated standing crop and 18% of the numbers censused at these stations. In terms of estimated biomass, the extreme was at station T-7 (12-inch south pipe, shallow transect) where the estimated mean standing crop for this station was

1,382 g/m^2 and pualo contributed more than 81% (or 1,123 g/m^2) of this biomass. These spawning aggregations resulted in many of the November 1998 counts being among the highest recorded during any of the surveys to date. Spawning aggregations have been present up through the May 2001 survey although to a lesser extent than previously and continuing up through the December 2007 survey. In the December 2007 survey, *Acanthurus blochii* comprised 14% of the overall total estimated standing crop present across all eighteen transects; by the August 2008 survey, this species made up only 1% of the overall estimated biomass. Besides *A. blochii* in the December 2007 survey, important contributors included the na'ena'e (*Acanthurus olivaceus*) which overall comprised 6% of the total biomass and remaining unchanged in the August 2008 survey as well as the uhu (*Scarus sordidus*) making up 5% of the overall standing crop but the latter species decreasing in importance to 4% in the August 2008 survey. In general, there is a greater diversity of species contributing heavily to the estimated standing crop at the survey sites in the August 2008 (~15 species) survey relative to the December 2007 survey (~12 species) but the overall mean standing crop in December was 213 g/m^2 while in the August survey it had decreased to 163 g/m^2.

In conclusion, this study spans a period from May 1989 to August 2008. The data from October 1991 to present were collected from the same locations and are directly comparable. Utilizing these data, and asking the question, "Are there any significant differences among the means for the number of species, individuals or biomass over this 202-month period of study?" is first addressed using the Kruskal-Wallis ANOVA which found significant differences among the survey means by date for the number of fish species, the number of fish individuals and the standing crop. However, the SNK Test which is used to distinguish which survey means are significantly different from others, noted significant overlap among the data by survey dates for the number of species and with biomass. This finding suggests that any significant difference may only exist with the extremes in the data. Thus for the mean number of species only the June 2000 mean (here 33 species) may be significantly greater than the March 1995 mean (25 species). Similarly for the analysis of standing crop, only the November 1998 mean (620 g/m^2) may be significantly greater than the March 1992 mean (139 g/m^2). Finally, the SNK Test failed to find any statistically significant differences among the mean number of individuals encountered on a given survey date.

A second Kruskal-Wallis ANOVA carried out on the means of three parameters (number of species, number of individuals and standing crop) examined by biotope (here boulder zone, the biotope of *Porites lobata* and the biotope of *Porites compressa*) found no statistically significant differences among these means in the three biotopes. Applying the SNK Test to these data found a significant difference in the number of individual fishes censused in the boulder zone biotope only. Because these data again showed considerable overlap, any statistically significant difference would possibly only lie with the two extremes in the data which was with December 1997 (mean = 522 fishes seen) relative to the March 1992 data (mean = 247 fishes). Nowhere in the data is there any evidence of a decrease or decline in any of the measured parameters that could suggest an increasing perturbation which would be the hallmark of an impact from this perturbation that could be coming from the operation of the NELHA facility. Rather the variation seen in the data from this 202-month period of this study are from the movement of fishes related to the presence of food or aggregations of adult fishes for purposes of reproduction. Thus, the analysis of the fish community structure in the waters fronting Keahole Point over the period of this 202-month study do not support the contention that the development at NELHA has had a significant negative impact on the fish communities.

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APPENDIX A. Results of the quantitative visual censuses for fishes conducted at eighteen stations, three established at Wawaloli Beach (T-1 - T-3), the 18-inch pipe (T-4 - T-6), the 12-inch warmwater pipe (T-7 - T-9), the 12-inch coldwater pipe (T-10 - T-12), the NPPE site (T-13 - T-15), and Ho'ona Bay (T-16 - T-18) at NELHA, Keahole Point, Hawaii on 19 December 2007. Each entry in the body of the table represents the total number of individuals of each species observed during each census. Census totals and biomass estimates are given at the foot of the table.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MURAENIDAE																		
Gymnothorax meleagris	1								1							1		
HOLOCENTRIDAE																		
Adioryx spinifer									1									
Adioryx xantherythrus						2												
Myripristis amaenus				38							6							1
Myripristis kuntee																		81
AULOSTOMIDAE																		
Aulostomus chinensis					1	1		1	1	1			2				1	1
FISTULARIIDAE																		
Fistularia commersoni			1					1										
SERRANIDAE																		
Cephalopholis argus			1			1						1						3
CARANGIDAE																		
Seriola dumerili														1		1		
Decapterus macarellus								6				1						
Caranx melampygus								2										
LUTJANIDAE																		
Lutjanus kasmira						6			1		1	2			1			
Aphareus furcatus					1	2			1			1		1	1	2		
Aprion virescens									1									
SPARIDAE																		
Monotaxis grandoculis	1			1	1		1	1										
MULLIDAE																		
Mulloides flavolineatus														11				
Mulloides vanicolensis				4			7			4								
Parupeneus cyclostomus								2										
Parupeneus multifasciatus	2				1	1	1		3			2		1	1		2	2
Parupeneus bifasciatus				1	1		1	2		2	1	1		1		1		
KYPHOSIDAE																		
Kyphosus bigibbus										1								
CHAETODONTIDAE																		
Forcipiger flavissimus				4	2				2	1	5		4	2	3	2	1	
Forcipiger longirostris				2	2					2	2		5	2				
Heniochus diphreutes						1		4										
Hemitaurichthys thompsoni											1	9	3		6			
Hemitaurichthys polylepis													23		32			
Chaetodon auriga				2												1		
Chaetodon lunula				3												8		
Chaetodon lineolatus				2														
Chaetodon ornatissimus				2	2	2		2	4	2	2	2	2	4			1	2
Chaetodon quadrimaculatus	1			3	1		1		2		5		2	1		1		
Chaetodon multicinctus	4	4	2	6	12	6	8	6	7	2	2	6	6	4	4	2	2	2
Chaetodon ephippium												2						
POMACANTHIDAE																		
Centropyge potteri												2						1
POMACENTRIDAE																		
Dascyllus albisella												4						38
Abudefduf abdominalis				48									41					
Plectroglyphidodon johnstonianus		1	1	3	4		2	1	2			4		2	1		1	3
Plectroglyphidodon imparipennis	1									1						1		
Chromis vanderbilti	328	224	551	291	381	671	160	163	380	52	57	225	158	94	56	31	78	
Chromis hanui									13		3	9			9			
Chromis agilis									120			12			80		21	82
Stegastes fasciolatus				17			4			4			2			1		
CIRRHITIDAE																		
Paracirrhites arcatus	6	5	6	3	14	8	2	4	5	3	6	6	3	4	7	3	3	4
Paracirrhites forsteri				1		2					1		1		1			

APPENDIX A. Continued.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LABRIDAE																		
Labroides phthirophagus				1					1		3		1					2
Cheilinus rhodochrous				2	1			1	1				1	1				
Pseudocheilinus octotaenia		1	3			3			2		1	2			2			2
Pseudocheilinus tetrataenia				1								1						
Novaculichthys taeniourus								1					1					
Thalassoma duperrey	15	8	14	38	18	12	7	8	13	26	8	10	8	6	6	3	9	8
Gomphosus varius		1	2		1	4		4	2		1				1	2	3	
Coris gaimard	3	1	2			1			1		1						1	
Pseudojuloides cerasinus						2												1
Stethojulis balteata	1								1		1		2					
Macropharyngodon geoffroy		1																1
Halichoeres ornatissimus	1	1	2	1	2	1	2	1	1		1		1			1	1	
SCARIDAE																		
Calotomus carolinus						1	1					1						
Scarus dubius					1	1												
Scarus sordidus		2		4	24	2	7	13	18	4	5	9	1	8	7	8	7	7
Scarus psittacus	2		3		4	15	5		4	5					1	6	3	
Scarus rubroviolaceus		1			1					1			2	1		1	1	
BLENNIIDAE																		
Plagiotremus ewaensis		1			1													
ACANTHURIDAE																		
Acanthurus guttatus										1								
Acanthurus achilles											1							
Acanthurus glaucopareius				3			3				1	1		1				
Acanthurus leucopareius				33			1			2						114		
Acanthurus nigrofuscus	50	33	13	55	67	22	58	28	14	25	35	28	52	42	13	44	59	17
Acanthurus nigroris		2	4	1	4	6		4	4		2			3	6			5
Acanthurus blochi	9	1	10		10	32	12	17	32	5		1						
Acanthurus thompsoni														1	17			
Acanthurus olivaceus		10	20		3	11		1	5	1	1					5		
Acanthurus dussumieri	1		1			3						1						
Ctenochaetus strigosus		3		78	15	9	59	31	45	37	45	46	65	36	18	24	41	14
Ctenochaetus hawaiiensis				2			14	4		5	1	1	1			4		
Zebrasoma flavescens	27	16	5	51	37	19	36	27	30	73	23	25	18	14	7	19	5	26
Zebrasoma veliferum		2			1								1					
Naso hexacanthus						13												1
Naso lituratus	5	2	4	4	2	8	1	2	5	4	4	3	3	3	3	1	2	3
ZANCLIDAE																		
Zanclus cornutus			2	1	1	2	2	1	1	1	3		2	2			1	1
BALISTIDAE																		
Melichthys niger				1												5		
Melichthys vidua	2		2	1					1	1		1			1	1		1
Sufflamen bursa	4	3	2	3	2	1	3	3		1	2	2	1	2	1		3	
Xanthicthy auromarginatus			1															
Xanthicthy mento						2						4			2			
MONACANTHIDAE																		
Pervagor melanocephalus									1									
Cantherhines sandwichiensis				1			1		1	1							1	
OSTRACIIDAE																		
Ostracion meleagris										1								
TETRAODONTIDAE																		
Canthigaster jactator		4	3	4	2	3	2		1					1				1
DIODONTIDAE																		
Diodon hystrix						2												
Number of Species	20	23	24	38	33	36	27	29	38	30	32	33	29	27	27	28	24	27
Number of Individuals	465	329	658	720	625	884	469	349	737	279	242	437	425	263	302	309	264	328
Biomass (g/m2)	189	111	243	297	212	513	261	297	497	222	79	120	115	135	60	296	90	106

APPENDIX B. Results of the quantitative visual censuses for fishes conducted at eighteen stations, three established at Wawaloli Beach (T-1 - T-3), the 18-inch pipe (T-4 - T-6), the 12-inch warmwater pipe (T-7 - T-9), the 12-inch coldwater pipe (T-10 - T-12), the NPPE site (T-13 - T-15), and Ho'ona Bay (T-16 - T-18) at NELHA, Keahole Point, Hawaii on 12 August 2008. Each entry in the body of the table represents the total number of individuals of each species observed during each census. Census totals and biomass estimates are given at the foot of the table.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MYLIOBATIDAE																		
Aetobatis narinari								2										
MURAENIDAE																		
Gymnothorax meleagris								1		1								
HOLOCENTRIDAE																		
Adioryx tiere				1	1						1							
Adioryx xantherythrus								2										
Myripristis amaenus											3							
Myripristis kuntee																		29
AULOSTOMIDAE																		
Aulostomus chinensis				1				2		1	1	2						
SERRANIDAE																		
Cephalopholis argus	1		2			2			1						2		1	
CARANGIDAE																		
Scomberoides laysan							7			1								
Decapterus macarellus							6		30		2						6	
Caranx melampygus			1						1						1			
LUTJANIDAE																		
Lutjanus kasmira														1				
Lutjanus fulvus														1				
Aphareus furcatus			2	1	1			2	1		2	4						
SPARIDAE																		
Monotaxis grandoculis		1					1							1	1			
MULLIDAE																		
Mulloides flavolineatus														6				
Mulloides vanicolensis										1					2			
Parupeneus pleurostigma																	1	
Parupeneus cyclostomus							1											
Parupeneus multifasciatus		1	1			1				1		1		1	2	1	1	4
Parupeneus bifasciatus	1			1		1	1	1	1		1		1		2			
KYPHOSIDAE																		
Kyphosus bigibbus							1											
CHAETODONTIDAE																		
Forcipiger flavissimus	1	4		1	2		2	3	3	4	2	6	3	2	4	2		2
Forcipiger longirostris																	2	1
Heniochus diphreutes						1	26	12										
Hemitaurichthys thompsoni							87	89	25		1							
Hemitaurichthys polylepis							30	19	20			4		2	27			
Chaetodon fremblii										2								
Chaetodon auriga				4							1							
Chaetodon unimaculatus									2			2						
Chaetodon lunula			2	4			4				1							
Chaetodon lineolatus				1														
Chaetodon trifasciatus																1		
Chaetodon ornatissimus	2	2	2	4	2	2		2	2		2	2	2	2			2	2
Chaetodon quadrimaculatus	1	4			9		4	5		1	1	1	2					
Chaetodon multicinctus		2	4	6	4	10		6	2	2	6	6		4	8	6	4	4
Chaetodon miliaris					2													
POMACANTHIDAE																		
Centropyge potteri											2							1
POMACENTRIDAE																		
Dascyllus albisella									10				1					22
Abudefduf abdominalis				16										2	6			
Plectroglyphidodon johnstonianus		2	1	2		1					2	2		1			1	1
Plectroglyphidodon imparipennis	1												1			1		
Chromis vanderbilti	177	601	950	162	64	335	40	204	400	122	126	250	175	177	128	130		
Chromis ovalis																		15
Chromis verater														1	7			
Chromis hanui											4	5						
Chromis agilis			420			8			58		6	33			65		37	195
Stegastes fasciolatus	1			6	2		4	2	1	1								

APPENDIX B. Continued.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CIRRHITIDAE																		
Paracirrhites arcatus	1	3	5	2	9	4	1	6	9	3	7	7	6	2	5	3	6	1
Paracirrhites forsteri		1			1						1				1			
Cirrhitus pinnulatus								1										
Cirrhitops fasciatus			2															
LABRIDAE																		
Labroides phthirophagus	2	2				1		1			1			1				1
Cheilinus rhodochrous							1			1						1	1	2
Pseudocheilinus octotaenia		1	6			5											1	1
Pseudocheilinus tetrataenia												1		1	1			
Novaculichthys taeniourus	1				1				1									
Thalassoma duperrey	17	7	9	17	15	22	7	24	20	13	9	1	30	8	6	16	8	3
Gomphosus varius			1	3		4			2	1	2		1		1	2	2	1
Coris gaimard	2		1			2	1	1								2		
Pseudojuloides cerasinus			1			5												
Stethojulis balteata	2		3							1			1					
Halichoeres ornatissimus	2	4	3	1	1	5		2	1		1	1				1	1	
SCARIDAE																		
Calotomus carolinus		1				1												
Scarus dubius		1	1			1		1										
Scarus perspicillatus						1										1		
Scarus sordidus					7	12	13	19	10	19	5	3	8	12	5	16	7	10
Scarus psittacus	4	5	6	2	3	6	9		4	6			1			21		2
Scarus rubroviolaceus	2		1	2	1	4	6					1	1		1	2		
BLENNIIDAE																		
Plagiotremus ewaensis				1														
ACANTHURIDAE																		
Acanthurus guttatus							2											
Acanthurus triostegus				1			1											
Acanthurus glaucopareius							13			3	2			1				
Acanthurus leucopareius				64	9		8			3			19					
Acanthurus nigrofuscus	26	16	12	54	52	22	24	14	28	22	10	19	41	32	13	32	47	12
Acanthurus nigroris						7									3		4	
Acanthurus blochi		2		3	22													
Acanthurus thompsoni							45	55	30	3								19
Acanthurus olivaceus	3	6	10	1	17	2			4	2	2	1		1		2	1	
Ctenochaetus strigosus				50	22	12	22	35	9	8	26			38	22	10	40	30
Ctenochaetus hawaiiensis				13			14		1	1	6		3		1	2		
Zebrasoma flavescens	8	12	6	41	14	11	43	45	22	47	31	31	28	9	7	20		9
Zebrasoma veliferum										3							2	
Naso hexacanthus						3			4						6		11	1
Naso lituratus	4	2	4	4	4	2	2	2	1	7	3	3	3	4	2	6	3	3
Naso unicornis						1												
Naso brevirostris			9															
ZANCLIDAE																		
Zanclus cornutus		2	1	2	3	1		2		1		1						
BALISTIDAE																		
Melichthys niger		6		1												1		
Melichthys vidua		1										2	1		2		1	
Sufflamen bursa	2	1	1	2		2		1		2	2	1	2	2		1		2
Xanthicthy mento					1				3						1			
ALUTERIDAE																		
Alutera scripta															1			
MONACANTHIDAE																		
Pervagor melanocephalus									1					1				
Cantherhines sandwichiensis	1										1							
OSTRACIIDAE																		
Ostracion meleagris							1			1								
TETRAODONTIDAE																		
Arothron meleagris															1			1
Canthigaster jactator	3		3	2	5			4				2			1		2	1
Canthigaster rivulata						3												
Number of Species	24	26	30	34	27	34	32	31	32	31	34	27	21	26	32	24	25	28
Number of Individuals	266	692	1473	480	279	506	434	573	716	294	284	404	343	327	350	296	209	393
Biomass (g/m2)	83.6	84.3	138.9	320.7	212.7	234.0	250.6	308.1	264.8	124.7	100.1	95.6	96.7	108.6	169.9	150.7	105.4	80.9

APPENDIX 3. Summary of the fish censuses from the May 1989,to present on surveys carried out by the author in the study area offshore of NELHA. Note that fish standing crop was not estimated in the May 1989 survey and that mean numbers of species and individuals are given where more than one station sampled a biotope at a given location. Earlier data are from previous reports. Table continued on the next 8 pages.

	May 1989		October 1991			March 1992		
	No.	No.	No.	No.	Biomass	No.	No.	Biomass
Location	Spp.	Ind.	Spp.	Ind.	(g/m^2)	Spp.	Ind.	(g/m^2)
Wawaloli Beach								
Boulder	25	187	30	209	210	25	204	113
P. lobata	37	346	33	237	51	26	341	138
P. compressa			28	188	57	24	272	54
18-Inch Pipe								
Boulder			39	510	379	37	274	230
P. lobata			32	604	327	31	467	158
P. compressa			36	824	271	29	499	248
Ho'ona Bay								
Boulder	26	389	24	339	105	32	263	108
P. lobata	33	430	34	399	187	28	144	36
P. compressa			35	481	170	32	382	166
Honokohau								
Boulder	30	265	28	180	72			
P. lobata	30	260	26	273	66			

APPENDIX 3. Continued.

Location	May 1992 No. Spp.	May 1992 No. Ind.	May 1992 Biomass (g/m^2)	October 1992 No. Spp.	October 1992 No. Ind.	October 1992 Biomass (g/m^2)	May 1993 No. Spp.	May 1993 No. Ind.	May 1993 Biomass (g/m^2)
Wawaloli Beach									
Boulder	20	154	91	25	434	251	22	336	171
P. lobata	21	227	83	19	80	67	22	339	105
P. compressa	24	166	37	28	375	117	25	200	46
18-Inch Pipe									
Boulder	40	357	223	40	420	285	36	398	193
P. lobata	30	447	175	28	355	85	25	310	106
P. compressa	36	491	86	26	682	110	34	305	128
12-Inch South									
Boulder	30	350	258	30	709	727	28	317	483
P. lobata	42	541	364	32	392	259	29	446	222
P. compressa	36	353	136	40	361	210	32	322	142
12-Inch North									
Boulder	34	204	122	27	243	137	25	268	153
P. lobata	28	248	108	30	267	125	34	214	103
P. compressa	28	157	298	30	306	85	34	320	187
NPPE Site									
Boulder	31	443	316	31	297	149	22	308	66
P. lobata	20	357	171	27	229	78	27	290	68
P. compressa	20	93	45	22	140	71	22	143	55
Ho'ona Bay									
Boulder	36	319	131	25	307	251	22	315	88
P. lobata	30	248	54	31	282	67	22	257	44
P. compressa	31	573	178	25	263	124	26	228	414

APPENDIX 3. Continued.

Location	December 93 No. Spp.	December 93 No. Ind.	December 93 Biomass (g/m^2)	May 94 No. Spp.	May 94 No. Ind.	May 94 Biomass (g/m^2)	June 94 No. Spp.	June 94 No. Ind.	June 94 Biomass (g/m^2)
Wawaloli Beach									
Boulder	22	175	85	21	230	151	22	242	276
P. lobata	18	227	58	17	413	104	26	351	87
P. compressa	25	196	102	25	258	151	29	378	100
18-Inch Pipe									
Boulder	38	434	362	38	455	342	37	480	208
P. lobata	26	350	255	36	499	169	38	423	153
P. compressa	39	862	213	36	816	200	36	728	217
12-Inch South									
Boulder	39	524	700	34	421	318	27	363	286
P. lobata	33	565	626	36	386	288	32	384	170
P. compressa	37	388	351	29	260	136	39	333	229
12-Inch North									
Boulder	33	441	610	26	255	160	35	287	162
P. lobata	36	424	246	33	327	124	34	383	149
P. compressa	31	393	726	27	178	74	25	222	132
NPPE Site									
Boulder	29	330	217	27	271	95	31	326	89
P. lobata	26	400	118	28	345	316	23	289	74
P. compressa	28	235	186	21	223	48	17	191	47
Ho'ona Bay									
Boulder	26	383	151	33	329	241	30	354	181
P. lobata	27	292	68	24	343	77	29	311	93
P. compressa	26	387	143	28	320	134	27	418	173

APPENDIX 3. Continued.

Location	October 94 No. Spp.	October 94 No. Ind.	October 94 Biomass (g/m^2)	March 95 No. Spp.	March 95 No. Ind.	March 95 Biomass (g/m^2)	June 95 No. Spp.	June 95 No. Ind.	June 95 Biomass (g/m^2)
Wawaloli Beach									
Boulder	18	221	188	23	256	154	24	454	184
P. lobata	16	218	62	23	214	112	22	281	142
P. compressa	24	345	150	19	232	191	29	407	187
18-Inch Pipe									
Boulder	36	526	394	30	417	555	38	493	303
P. lobata	28	505	380	27	430	288	30	387	173
P. compressa	30	701	91	33	698	156	41	836	551
12-Inch South									
Boulder	29	650	314	32	309	244	32	406	214
P. lobata	24	446	191	22	226	130	26	521	268
P. compressa	35	272	121	27	227	207	36	616	148
12-Inch North									
Boulder	33	339	311	26	168	154	28	258	131
P. lobata	35	421	204	24	189	119	36	487	222
P. compressa	23	210	105	22	188	212	30	302	116
NPPE Site									
Boulder	35	454	478	20	195	146	26	342	125
P. lobata	30	329	113	25	177	116	30	417	74
P. compressa	24	266	150	24	142	85	31	424	99
Ho'ona Bay									
Boulder	20	272	209	27	376	413	26	473	198
P. lobata	30	307	125	25	281	143	30	706	101
P. compressa	29	352	115	22	296	57	24	780	106

APPENDIX 3. Continued.

Location	December 97 No. Spp.	December 97 No. Ind.	December 97 Biomass (g/m^2)	June 98 No. Spp.	June 98 No. Ind.	June 98 Biomass (g/m^2)	November 98 No. Spp.	November 98 No. Ind.	November 98 Biomass (g/m^2)
Wawaloli Beach									
Boulder	27	371	280	18	223	144	26	248	311
P. lobata	29	636	891	23	177	76	22	295	76
P. compressa	29	510	190	18	143	78	18	176	168
18-Inch Pipe									
Boulder	26	471	518	36	453	307	38	448	346
P. lobata	32	598	319	36	400	308	32	485	297
P. compressa	38	465	430	20	533	37	32	848	169
12-Inch South									
Boulder	33	678	385	29	289	177	36	654	1382
P. lobata	29	535	211	27	302	312	32	937	1255
P. compressa	20	157	77	33	381	331	38	922	1809
12-Inch North									
Boulder	33	523	1637	27	231	178	40	530	265
P. lobata	21	364	123	29	260	114	32	468	219
P. compressa	34	790	183	30	300	200	29	603	2152
NPPE Site									
Boulder	32	834	912	30	308	195	35	660	1816
P. lobata	30	467	143	23	305	93	35	425	121
P. compressa	26	346	631	22	170	47	30	355	83
Ho'ona Bay									
Boulder	22	252	201	26	237	129	25	314	201
P. lobata	24	269	82	27	418	85	31	317	94
P. compressa	26	261	132	25	364	79	28	506	398

APPENDIX 3. Continued.

Location	May 99 No. Spp.	May 99 No. Ind.	May 99 Biomass (g/m^2)	Dec 99 No. Spp.	Dec 99 No. Ind.	Dec 99 Biomass (g/m^2)	Jun 00 No. Spp.	Jun 00 No. Ind.	Jun 00 Biomass (g/m^2)
Wawaloli Beach									
Boulder	27	315	274	20	198	100	34	504	673
P. lobata	18	255	61	19	231	91	27	316	424
P. compressa	27	316	110	22	174	151	29	307	246
18-Inch Pipe									
Boulder	41	376	251	34	344	400	45	319	596
P. lobata	31	321	103	25	484	239	36	437	312
P. compressa	32	349	125	27	599	270	38	679	818
12-Inch South									
Boulder	35	295	281	26	246	437	30	279	359
P. lobata	34	396	168	21	294	361	29	273	549
P. compressa	38	357	162	33	819	994	37	267	274
12-Inch North									
Boulder	32	257	135	29	338	183	33	192	124
P. lobata	34	321	149	34	301	238	38	216	107
P. compressa	34	344	328	30	279	340	38	257	344
NPPE Site									
Boulder	31	391	269	29	385	148	37	350	150
P. lobata	39	375	219	25	250	122	31	280	93
P. compressa	33	252	96	24	292	267	29	554	162
Ho'ona Bay									
Boulder	28	258	150	29	332	131	27	392	140
P. lobata	27	322	69	22	267	77	32	626	150
P. compressa	29	270	126	35	509	152	28	806	124

APPENDIX 3. Continued.

Location	Nov 00 No. Spp.	Nov 00 No. Ind.	Nov 00 Biomass (g/m²)	May 01 No. Spp.	May 01 No. Ind.	May 01 Biomass (g/m²)	Nov 01 No. Spp.	Nov 01 No. Ind.	Nov 01 Biomass (g/m²)
Wawaloli Beach									
Boulder	23	375	143	20	350	115	31	514	228
P. lobata	24	540	115	20	234	148	24	339	128
P. compressa	27	299	103	20	389	108	24	298	110
18-Inch Pipe									
Boulder	27	314	297	28	250	227	38	419	170
P. lobata	31	336	141	28	289	185	24	299	120
P. compressa	33	1019	258	36	671	274	36	493	189
12-Inch South									
Boulder	42	731	578	34	423	523	33	493	190
P. lobata	35	371	180	45	343	373	37	324	293
P. compressa	33	319	308	42	309	214	39	391	213
12-Inch North									
Boulder	25	336	198	27	305	116	35	336	212
P. lobata	34	315	204	34	415	93	34	347	86
P. compressa	28	351	293	29	338	127	27	404	89
NPPE Site									
Boulder	32	379	108	37	343	161	30	350	122
P. lobata	30	313	836	35	410	81	32	186	153
P. compressa	36	922	303	30	299	73	30	393	172
Ho'ona Bay									
Boulder	32	385	169	32	431	127	32	332	111
P. lobata	29	323	548	26	365	82	23	309	74
P. compressa	25	508	67	35	307	161	30	330	100

APPENDIX 3. Continued.

Location	May 02 No. Spp.	May 02 No. Ind.	May 02 Biomass (g/m^2)	Dec 02 No. Spp.	Dec 02 No. Ind.	Dec 02 Biomass (g/m^2)	Dec 07 No. Spp.	Dec 07 No. Ind.	Dec 07 Biomass (g/m^2)
Wawaloli Beach									
Boulder	26	202	155	27	215	148	20	464	189
P. lobata	24	200	82	27	521	153	23	327	111
P. compressa	20	159	110	27	421	238	24	655	242
18-Inch Pipe									
Boulder	34	280	207	38	542	445	38	716	297
P. lobata	24	172	86	27	292	74	33	620	212
P. compressa	33	678	145	35	2763	5122	36	878	514
12-Inch South									
Boulder	37	349	227	28	616	1645	27	401	261
P. lobata	27	277	166	43	718	1144	29	341	297
P. compressa	34	316	214	35	330	582	38	728	497
12-Inch North									
Boulder	27	213	133	32	336	129	30	269	222
P. lobata	33	219	118	35	377	230	32	231	79
P. compressa	36	429	259	28	271	227	33	425	120
NPPE Site									
Boulder	29	187	110	32	285	180	29	412	115
P. lobata	30	294	134	32	292	148	27	249	135
P. compressa	24	272	77	32	451	54	27	287	60
Ho'ona Bay									
Boulder	34	277	163	33	316	157	28	293	296
P. lobata	26	356	98	30	265	101	24	247	90
P. compressa	25	323	109	25	452	159	27	310	106

APPENDIX 3. Continued.

Location	Aug 08 No. Spp.	No. Ind.	Biomass (g/m^2)
Wawaloli Beach			
Boulder	24	265	84
P. lobata	26	690	84
P. compressa	30	1470	139
18-Inch Pipe			
Boulder	34	476	321
P. lobata	27	274	213
P. compressa	34	500	234
12-Inch South			
Boulder	32	427	251
P. lobata	31	565	308
P. compressa	32	707	265
12-Inch North			
Boulder	31	284	125
P. lobata	34	273	100
P. compressa	27	392	96
NPPE Site			
Boulder	21	330	97
P. lobata	26	313	109
P. compressa	32	335	170
Ho'ona Bay			
Boulder	24	280	151
P. lobata	25	192	105
P. compressa	28	375	81

BENTHIC MARINE BIOTA

MONITORING PROGRAM

AT THE NATURAL ENERGY LABORATORY OF HAWAII

KEAHOLE POINT, HAWAII

October 2007

Prepared for

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I. INTRODUCTION AND PURPOSE

Facilities at the Natural Energy Laboratory of Hawaii Authority (NELHA), and the Hawaii Ocean Science and Technology (HOST) Park employ cold, nutrient rich waters from below the thermocline, as well as surface water above the thermocline, for various aquaculture activities at Keahole Point, on the west coast of the Island of Hawaii. A concern regarding discharge of these waters at the shoreline and into the groundwater aquifer is the potential for environmental alteration of community structure in the adjacent marine environment and anchialine pools.

In the interest of addressing this concern and assuring maintenance of environmental quality, it has been deemed necessary to carry out a comprehensive marine environmental monitoring program (CEMP) off Keahole Point. One component of the monitoring deals with the benthic (bottom-dwelling) biological communities. The intent of the benthic component of the monitoring program is to quantitatively describe existing community structure, and to identify changes from natural and man-induced factors. This report described results of the twenty-first increment of benthic monitoring conducted by Marine Research Consultants, Inc. (MRCI) during October 2007.

This phase of monitoring was conducted approximately fifteen years after Hurricane Iniki struck the Hawaiian Islands in September 1992, and fourteen years after an unusually strong northwest swell impacted the west Hawaii coastline in January 1993. Waves generated by these two storms generated surf with heights estimated at 10-15 feet in the vicinity of Keahole Point. Thus, in addition to evaluating the effects of NELHA discharge, a key interest in the monitoring survey is to assess the impact of, and recovery from, severe wave stress on coral community structure in the vicinity of NELHA. The monitoring surveys can provide an indication of the cumulative impact of storm effects, as well as short-term recovery of coral communities.

II. MONITORING RATIONALE

Benthic marine community structure can be defined as the abundance, diversity, and distribution of stony and soft corals, motile benthos such as echinoderms, and macroalgae. In the context of time-series surveys, benthic assemblages are often the most useful biological assemblages for direct evaluation of environmental impacts to the marine environment. Because benthos are generally long-lived, immobile, and unable to avoid extreme environmental conditions or input of potential pollutants, these organisms must either tolerate the surrounding conditions within the limits of adaptability or die.

As members of the benthos, stony corals are of particular importance in nearshore Hawaiian environments. Corals compose a large portion of the reef biomass and their skeletal structures are vital in providing a complex of habitat space, shelter, and food for other species. Because corals serve in such a keystone function, coral community structure is often considered the most "relevant" parameter for evaluating impacts to the marine environment associated with activities on land. For this reason, and because alterations in coral communities are easy to identify, observable change in coral populations is a practical and direct method for obtaining the information that is required to meet existing environmental regulations.

The overall intent of the benthic monitoring program is to identify changes to biotic assemblages as a result of input to the nearshore ocean of dissolved materials in waters used for aquaculture. These changes may potentially take the form of alteration in settlement and growth, as well as mortality, of the living components of the community. Such effects are likely to be difficult to decipher when superimposed over the combined effects of natural phenomena (e.g., dislodgement, predations, sediment flow) that routinely cause alteration in the arrangement of the living, as well as nonliving components of the reef. Studies of windward reef areas have shown that while overall coral cover may remain fairly constant, there can be a high degree of spatial change as resources are continually covered and uncovered in a "temporally varying mosaic." As the study area at Keahole is known to be a high energy environment, natural factors of environmental change are likely to be substantial, and could mask changes related to the NELHA facilities.

Thus, it is essential that the sampling methodologies employed for benthic monitoring extend beyond repetitive surveys employing randomly placed quadrats on line transects. Instead, a series of semi-permanent quadrats have been established, where intensive, rather than extensive, repetitive quantitative analyses are being routinely performed.

III. METHODS

All phases of the benthic monitoring program employ diver/scientists using SCUBA equipment operating from a small boat. All field surveys were conducted on October 13, 2007. Three quantitative survey sites that were established in the preliminary NELHA surveys by R. Brock were utilized as monitoring sites in the initial monitoring survey in August 1991. In response to anticipated additional construction and operational activities at NELHA in the near future, three additional monitoring stations were selected and have been evaluated during all subsequent surveys. The locations of the six monitoring sites are shown in Figure 1.

For ease of identification, each survey site is labeled with a name as well as a number. Moving from south to north, Site 1 is immediately to the south of Wawaloli Beach; Site 2 is located at the 18" Pipe to the south of Keahole Point; Site 3 is on the southern side of the 12" pipe off Keahole Point; Site 4 is off the northern side of the 12" pipe; Site 5 is off the NPPE site; and Site 6 is in Ho'ona Bay. Locations of the survey sites were fixed by triangulation with conspicuous landmarks, and are easily relocated during replicate surveys.

At each of the monitoring sites, three semi-permanent transect stations have been established. Each station is placed in one of the three major physiographic/biotic structural zones described for the Kona Coast (Dollar 1975, 1982, Dollar and Tribble 1993). These zones are characterized as the "nearshore boulder zone" (depth ≈ 0-15 ft.), the "reef-building platform zone" (depth ≈15-30 ft.), and the "reef slope zone" (depth ≈ 30-60 ft.). During the initial survey, permanent transects at each site were established by placing markers into solid substratum of the ocean floor (either basalt or limestone). Marker placement was carried out by Ocean Innovators, utilizing methods and equipment developed for the purpose of permanently attaching artificial reef structures to the sea floor. The attachment procedure involved drilling a hole for anchoring an expandable eye-bolt. Small marker buoys on wire rope that float above the bottom were attached to the eye-bolts for ease in locating transect stations on subsequent surveys. During the years since placement of the markers, buoys have been periodically lost and replaced with large cable ties. As a result, locations of the transects have been relatively constant over the course of the monitoring program.

The permanent markers defined the ends of 50 meter (~160 ft.) long transects, oriented parallel to depth contours. At ten random locations along the transect line, composition of the benthos is evaluated within rectangular quadrats one m x 0.66 m (3 ft. x 2 ft.) in dimension. Each quadrat is photographed with a digital Canon Eos camera with a super wide angle lens (15 mm, 94° field of view) in an underwater housing. The camera is mounted on a tripod frame to ensure exact repeatability of quadrat area. The photographic technique provides excellent resolution of the detail of the benthic structure, to the degree that individual calices of certain corals are distinguishable. Color photographs of all quadrats are attached as an appendix to this report, and are on file at NELHA.

In addition to the quadrat photographs, visual estimates of species abundance of attached and motile benthos is recorded on writing slates. Bared substratum (bare rock, sand, dead coral and coral rubble) are also evaluated in terms of 2-dimensional area coverage.

In the laboratory, evaluation of benthic cover of biota and substrata is performed. Area coverage of each component in the quadrat photos is determined using an overlay grid divided into 200 equally sized segments. The number of segments of each coral species and non-coral substratum type within each grid are summed to calculate area coverage. Thus, for each transect, there are the equivalent of 2,000 data points. Verification of species identification is performed using the information collected in the field. In addition, field data provides input on small organisms that are not visible in photographs. This method provides for accurate estimates of cover of organisms that cover a large percentage of the reef surface through photographic coverage, as well as occurrence of very small and/or rare organisms. Few, is any other methods provide for such accurate characterization of both extremes of benthic community structure.

The Shannon-Weaver index of diversity is also calculated for percent coral cover on each transect using estimates from area cover. The formula for calculating diversity (H') is:

$$H' = -\sum_{i=1}^{s} pi \ln pi,$$

where pi is the proportion of the ith species in the population, and s is the number of species.

IV. RESULTS

A. Physical Structure

The shoreline and intertidal area of the subject property consist predominantly of basaltic boulder outcrops interspersed between narrow, steeply sloping beaches. The beaches are composed of rounded cobbles and coarse calcium carbonate sands which extend into the intertidal area. The area directly off of Keahole Point consists of a basaltic extension of the island mass that meets the ocean in steep vertical cliff faces that extend approximately 5-7 m (15-20 feet) below the ocean surface.

The structure of the offshore environment in the vicinity of Keahole Point generally conforms to the pattern that has been documented as characterizing much of the west coast of the Island of Hawaii (Dollar 1982, Dollar and Tribble 1993). The zonation scheme consists of three predominant regions, each with a characteristic coral assemblage that is adapted to the prevalent physical regime (i.e. wave stress) of the region.

Beginning at the shoreline and moving seaward, the shallowest zone at the land-sea interface is comprised of a flat basaltic terrace that is the underwater continuation of the island landmass. In areas offshore of basaltic shorelines the intertidal zone is often covered with large boulders that have entered the ocean after breaking off from the shoreline. The seaward edge of the nearshore reef terrace terminates in a vertical cliff face approximately 3-5 m (10-15 feet) in height. The face of the cliff is irregular in that it is scalloped and cut with caves and arches. In areas fronting shoreline beaches, boulder cover is not as prominent, and the intertidal area consists primarily of flat basaltic shelf. The nearshore zone receives most of the force of breaking waves and surge, and as a result is inhabited predominantly by organisms capable of withstanding these stresses on a regular basis. The predominant coral species occupying the nearshore area is *Pocillopora meandrina*, which is recognized as a "pioneering" species that is the first coral to settle on newly cleared substratum, or to occupy areas that are too harsh for other species. The shallow transects conducted at each of the six survey sites traverse the "nearshore boulder" zone.

Seaward of the nearshore boulder zone, bottom structure is composed predominantly of a gently sloping reef bench. In some areas, the bench is characterized by high relief in the form of undercut ledges and basaltic blocks and pinnacles. Fine-grained calcareous sand also occurs in pockets on the reef bench. Water depth in this mid-reef zone ranges from about 7-15 m (20 to 40 feet). As wave stress in this region is substantially less than in the shallower areas, and suitable hard substrata abounds, the area provides an ideal locale for colonization by attached benthos, particularly reef corals. The intermediate depth transects at each survey site are located on the "reef bench" zone.

The seaward edge of the reef platform (at a depth of about 15 m (45-50 feet) is marked by a sharp increase in slope to an angle of approximately 20-30 degrees. In the deep slope zone, substratum type changes from the solid continuation of the island mass to an aggregate of generally unconsolidated sand and rubble. Moving down the reef slope, coral settlement and growth ceases at a depth of approximately 35 m (100 feet); beyond this depth the bottom consists mostly of sand, with occasionally basaltic outcrops. The deep transects at each survey site are located on the upper portions of the "reef slope" zone.

While each of the survey sites has similarities to the typical scenario described above, each station also has distinctive characteristics, resulting in four relatively unique habitats. At Ho'ona Bay (Site 6) the "typical" zonation scheme is best developed in that all three zones are clearly apparent. The entire zonation scheme is compressed into a relatively narrow band (about 100-150 m wide) between the shoreline and the sand slope that extends to abyssal depths. At the 18" and 12" pipe sites (2, 3, and 4) and the NPPE site (5), the entire region from the shoreline to the reef slope is representative of the typical nearshore boulder zone, and biotic assemblages that occur in areas that are consistently subjected to intense wave scour. At the Wawaloli Beach site (1), the typical zonal structure appears to have been well established. However, even before the impacts of Hurricane Iniki, there was substantial evidence of recent destruction of a major portion of living corals as a result of storm wave damage.

B. Biotic Community Structure

1. Reef Coral Communities

The overwhelming majority of benthic biota on the monitoring transects consisted of stony, reef-building (Scleractinian) corals. Benthic frondose macroalgae (e.g., not coralline algae) was extremely rare on all survey transects, as has been the case during all surveys since the inception of the monitoring program. Motile invertebrates were primarily limited to occasionally occurring echinoderms (sea urchins and sea cucumbers).

Inspection of the reef following Hurricane Iniki and the severe 1993 winter storm revealed what the investigators classified as "intermediate" impacts. Many colonies, especially *Pocillopora meandrina* sustained some branch breakage. Areas of *Porites compressa* were noticeably affected by wave energy in terms of breakage and redistribution of finger coral fragment beds on the reef slope. It must be noted, however, that most of the *P. compressa* beds in the deeper areas of the monitoring sites were already documented in previous surveys to consist largely of rubble fragments that were likely the result of previous extreme storm impacts. In addition, breakage of corals appeared to be patchy with respect to spatial distribution. Patches of extensively damaged colonies occurred between areas that sustained no damage. This phenomenon has been observed repeatedly, not only in Hawaii, elsewhere in the Atlantic and Pacific where coral reefs are subject to intense storms of hurricane or cyclone intensity. It is theorized that such localized damage is a result of what has been termed "bowling." Fragments of coral skeletons or boulders dislodged by wave action causes damage to surrounding corals by impacts when the loosened material is hurled by wave forces. As a result, the concussive force of wave impact *per se* may not be the only physical factor responsible for damaging corals.

Observations of the survey region also suggested that the impacts from the storms were more intense on the southward facing reefs. Such an observation is consistent with the direction of wave propagation from Hurricane Iniki, which passed to the south of the Island. Site 6 (Ho'ona Bay), which lies to the north of Keahole Point appeared to be almost totally protected from destructive wave forces as a result of orientation to incoming swells. In summary, while the Hurricane and severe winter storm did produce observable effects to the reef environment, the effects do not appear to be "catastrophic" as the entire survey area appears to have been recently (or continually) subject to wave forces of similar magnitude from large winter surf that occurs periodically. Between the seven most recent surveys, no substantial wave events occurred. Thus, differences in coral community structure may indicate if short term recovery of corals has occurred.

Inspection of the reef in 1995 at all of the survey sites (except Site 1) revealed very noticeable continued recolonization of basalt surfaces at the intermediate and deep transects. Most of the recolonization was in the form of numerous small colonies of *Porites lobata* growing as knobby projections and flat encrustations. This recolonization appeared to be an initial recovery phase from the storm events that occurred in 1992-1993. Further inspection of the reef during the most recent surveys progressing from 1997 to 2002 to 2007 revealed substantial increases in coral cover, presumably as a result of uninterrupted recovery from the severe storm events.

Table 1 shows the quantitative summary of coral community structure collected during the October 2007 survey, while Appendix A shows the composition of individual quadrats that comprises transect results. Tables 2a and 2b show comparative data from the twenty-two surveys conducted from 1991 to 2007. Over the course of the surveys to date, seven to fourteen species of corals have been encountered on all transects during a single survey, while the number of coral species on a single transect has ranged from two to eight. In the most recent survey in October 2007, eight species were encountered on transects, with the number on a single transect ranging from two to six.

Over the sixteen-year course of the monitoring program, coral community structure in terms of species occurrence (e.g., number of species) has not shifted substantially. There is, however, an overall upward trend in coral cover. Mean total coral cover on all transects during each of the surveys has gradually increased from lows of 16-17% in 1991-92 to 48% in June 2002 and 52% in the most recent survey in October 2007. These results suggest that there has not been a decrease in overall coral cover during the course of the monitoring program to date. Rather, there has been a substantial overall increase of about 3-fold (300%) in coral cover over the entire monitoring period. The largest single between-survey increase (21%) occurred between May 1995 (22%) and November 2007 (43%). During the ten years between November 1997 and October 2007, total coral cover increased about 9%.

Figures 2-4 are histograms that show coral community structure (percent coral cover, species diversity, and number of species) from December 1991 to October 2007 at each transect site. Several dominant points are evident in examining Figures 2-4. As discussed above, with several exceptions, coral cover is highest on each transect during surveys since 1998. On many transects, a sequential increase in cover over time is also evident (Figure 2). There is, however, no similar pattern of peaks for number of coral species number (Figure 3) or species diversity (Figure 4).
There also appears to be no completely consistent difference in relative coral coverage between zones at each site. At sites 1 and 2, overall cover is highest on the shallow or mid-depth transect and lowest on the deep transect. The single exception is the large increase in cover at the deep transect of Site 1 in October 2007. On the remaining four transects, cover is consistently highest on the deep transect.

With respect to difference in coral coverage on each transect, the greatest difference that occurred was 51% at Site 6 (Ho'ona Bay). During most previous surveys, Site 6 has consistently shown the greatest difference in cover between the shallow, mid-depth and deep transects. However, during the October 2007 survey, the greatest within site difference occurred at Sites 5 (47.5%) and 4 (45.5%), while Site 6 exhibited a difference between the shallow and deep station of only 26.3%.

As stated above, in addition to determining the effects of the NELHA discharge, a consideration of the monitoring program is to assess the impacts of severe storms on coral community structure. It can be seen in Figure 2 that for total coral cover, many of the transect sites showed substantial decreases in cover following both Hurricane Iniki in 1992 and the 1993 winter storm. Between May and October 1992, when Hurricane Iniki occurred, coral cover decreased on 12 of the 18 transects. Between October 1992 and May 1993, when the winter storm occurred, coral cover decreased on 5 of the 18 transects. Between May 1993 and October 2007, when no major storm events occurred, coral cover increased on all 18 transects. These comparisons suggest that the communities are recovering (or have recovered and are now in an equilibrium condition) from damage that occurred as a result of the major storms that took place during the course of the monitoring program.

Figure 4 shows plots of diversity on each transect during each survey. Diversity is an index of the equitability of distribution of cover of each coral species within the total coral coverage. Thus, diversity can be low when there is either a low number of species of equal distribution, or a high number of species but with an extremely uneven distribution of cover (most species occur as very small percentages of cover). It can be seen in Figures 2 and 4 that while many of the shallow transect had lower cover than the deeper counterparts, there is not a corresponding increase in diversity on the deeper transects. Rather, the patterns of diversity were mirror images of the estimates of coral cover. When total coral cover is high, it tends to be the result of dominance by one species, resulting in relatively low diversity.

The dominant species on all transects was *Porites lobata*, which accounted for between 42% and 72% of total coral cover in the previous surveys. During the present survey, *P. lobata* comprised 58% of coral cover, while in the previous survey this species accounted for 47% of coral cover. The second most abundant species, *Pocillopora meandrina* accounted for between 12% - 36% of coral cover in previous surveys. During the October 2007 survey, cover of *P. meandrina* comprised about 19% of coral cover. *Porites compressa*, accounted for between 8% and 14% of coral cover in previous surveys, while in June 2002 and October 2007 cover of *P. compressa* accounted for approximately 14% and 15% of coral cover, respectively. *P. compressa*, commonly known as "finger coral" consists of a delicate branching growth form that is highly susceptible to breakage from wave forces. Hence, while percentage cover of other species of coral that are more resistant to wave forces were within the middle of the ranges of the entire span of monitoring, cover of *P. compressa* was at the peak of percentage cover during the most recent surveys. The increasing cover of *P. compressa* is likely a response to the long interlude since an episode of destructive wave impacts.

The remaining "rare" species encountered on transects totaled between about 0.4% and 15% of coral cover between August 1991 and June 2002. In the most recent study, rare species accounted for about 8% of coral cover.

Figures 5-10 shows percent cover of the five most dominant coral species (*Porites lobata, P. compressa*, *Pocillopora meandrina*, *Montipora capitata* and *M. patula*) at each transect station during each of the monitoring surveys. At most of the sites, community structure is similar: *P. lobata* and *P. compressa* increase in percent cover as water depth increases, while *P. meandrina* decreases in percent cover with depth.

Site 1 has been impacted by events associated with installation of a new seawater pipeline. At the deep transect station, live coral cover was about 28% of bottom cover during the May 2001 survey. During the December 2001 survey, cover dropped to 8.5% of bottom cover, while cover was about 15% in June 2002. In the most recent survey in 2007, total coral cover on the deep transect was 67%. None of the other stations showed similar precipitous drops in coral cover between two successive surveys, followed by a substantial increase in cover. Inspection of the bottom in 2001-1002 revealed that coral cover was affected by some activity such as anchor drag or cable scour.

As mentioned above, owing to the fragile growth form with respect to wave energy, *Porites compressa* is rare in the shallow zones, but is often the most abundant coral on the deep reef slope in west Hawaii (Dollar 1982). On many of the NELHA survey transects conducted in the early years of monitoring, however, *P. compressa* was essentially absent. Bottom cover at Sites 1-4 consisted of only very small percentages of living *P. compressa* (<6%), even on the deep slope transects. All of these sites are located either directly off of Keahole Point, or to the south of the point, in the regions that are directly impacted by large waves impinging from both northerly and southerly swells. Examination of the bottom revealed that coral cover has been steadily increasing on the deep slope zones since 1993, but the primary species that are recruiting to the slopes are *Porites lobata* and *Pocillopora meandrina*, rather than *Porites compressa*. At Sites 6, which is the most sheltered site from the major force of storm waves, *P. compressa* cover is relatively high at the deep transect site (36% of bottom cover), and is the only Site where cover of this species has been consistently high (>17%) throughout the surveys to date (see Table 2, Figure 10).

Conversely, *Pocillopora meandrina* is adapted to areas of high wave stress, and is most abundant in the nearshore boulder zones. At Sites 1-5, the entire reef area from the shoreline to the slope is subjected to substantial wave stress. As a result, the entire reef shelf exhibits characteristics of the nearshore boulder zone with *P. meandrina* one of the dominant corals. At Sites 1-5, *Pocillopora meandrina* is also the greatest contributor to increased coral cover over the last several years, as is readily evident in Figures 5-9.

One-way analysis of variance (ANOVA) statistics were performed for total coral cover (Table 3), *Porites lobata* cover (Table 4), and *Pocillopora meandrina* cover (Table 5) at each transect site. The null hypothesis for these analyses is that over the time span of the monitoring surveys, within a site each sample area (i.e., transect) contains a population with equal mean coral cover. It can be seen in Table 3 that the null hypothesis is rejected ($P<0.05$) at all 18 transects.

For the most abundant species, *Porites lobata*, ANOVAs also show significant differences ($P \leq 0.05$) on 17 of the 18 transects (Table 4). ANOVAs performed on transect cover of *Pocillopora meandrina* also revealed significant differences ($P \leq 0.05$) on 16 transects (Table 5). These results indicate that over the course of the monitoring program, coral cover has changed significantly on most of the transects.

In order to evaluate if significant differences in mean coral cover could be attributed to specific variations between surveys, *post hoc* Tukey multiple comparison probability tests were performed on the ANOVA statistics. Results of the Tukey multiple comparisons provide a matrix of pairwise probabilities for all samplings. Table 6 shows results of the combined matrices for all sampling sites. The Tukey comparison assigns an association to each transect on each survey date depending on the mean coral cover. Mean coral cover on survey dates with the same association are not significantly different at the 0.05 level.

It can be seen in Table 6 that coral cover falls into two major groupings over time. With two exceptions (Transects 3-30 and 6-25) mean cover from the inception of monitoring from the mid to late 1990's was significantly different than from that time to the present. These early phases of monitoring are depicted as Association A in Figure 6. For the most recent survey, coral cover on 15 of the 18 transects ranked in the most distant Association from Association A, indicating the greatest change in cover over time. As total coral cover on all but one transect was higher in 2007 compared to 1991, it can be interpreted that there has been significant increase in coral cover from the initial survey to the present.

When the last two surveys (June 2002-October 2007) are compared, only three transects showed significant differences in mean coral cover (1-20, 1-35 and 3-20). At all three of these transect stations there was substantial increases in cover between the successive surveys (24.4%, 53.8% and 32.4%, respectively). Hence the only significant differences in coral over the last five years have been significant increases in coral cover. The overall lack of significant differences over the last five years between surveys suggests that the community may be near an equilibrium climax state where coral cover is no either changing at a rapid rate, and has attained the maximum equilibrium coverage under the prevailing physical conditions.

2. Other Benthic Macroinvertebrates

The other dominant group of macroinvertebrates on survey transects are the sea urchins (Class Echinoidea) (see Table 7). The most common urchins are *Echinometra matheai*, *Heterocentrotus mammillatus*, and *Tripneustes gratilla*. *E. matheai* are small urchins that are generally found within interstitial spaces bored into basaltic and limestone substrata. In the October 2007 survey, *E. matheai* occurred on all 18 transects in numbers from 4 to 29 individuals. This species was generally least abundant on the reef slope transects where solid substrata was not common.

Three species of sea cucumbers (Holothurians) were observed sporadically on the reef, but did not occur on transects. Individuals of these species (*Holothuria atra*, *H. nobilis*, and *Actinopyga obesa)* were distributed sporadically across the mid-reef and deep reef zones. The most common large starfish (Asteroidea) observed on the reef surface in past surveys has been the crown-of-thorns starfish (*Acanthaster planci*). However, no *A. planci* were observed during the last four surveys at any of the transect sites.

The design of the reef survey was such that no cryptic organisms or species living within interstitial spaces of the reef surface were enumerated. Since this is the habitat of the majority of mollusks and Crustacea, detailed species counts were not included in the transecting scheme. No dominant communities of these classes of biota were observed during the reef surveys at any of the study stations.

V. SUMMARY

In summary, based on the results of the time-course surveys, composition of coral communities off of the NELHA facility are largely controlled by the degree of physical energy that impacts the area from storm waves. Results of the twenty-two sequential surveys dating from 1991-2007 reveal no statistically significant decreases in coral cover that could be attributable to activities at NELHA.

Rather, results of the survey set indicates substantially more coral cover at present than in past years as a result of regrowth during a period when no storm waves have impacted the area. Recover of reef corals at Site 1 from damage caused by scouring of the reef surface from anchors and cables associated with installation of a pipeline has been raised the level of coral in this area to an equivalent level as other survey sites.

Examination of water chemistry monitoring data collected as part of the CEMP also indicates that there does not appear to be changes in marine environmental conditions from discharge that could affect mortality of benthos.

Comparisons of the mean coral cover over the course of monitoring indicate two discrete groupings; surveys prior to 1999 generally had significantly lower coral cover than the surveys in the last five years (2002-2007). These results indicate that coral cover has increased substantially over the last five years. Comparisons of cover over the last year (June 2002-October 2007) indicate statistically significant changes on only three of the eighteen transects, all of which are increases in cover. This result may indicate that the community has recovered from storm damage, and may be in a phase that can be considered an "equilibrium climax state." Observations of the coral communities indicate that substantial recolonization by newly settled corals has progressed on areas that were probably bared as a result of intense wave action in 1992. Based on these results, it appears that the activities of the NELHA facilities do not appear to be exerting any negative effects to the benthic communities in the vicinity of Keahole Point.

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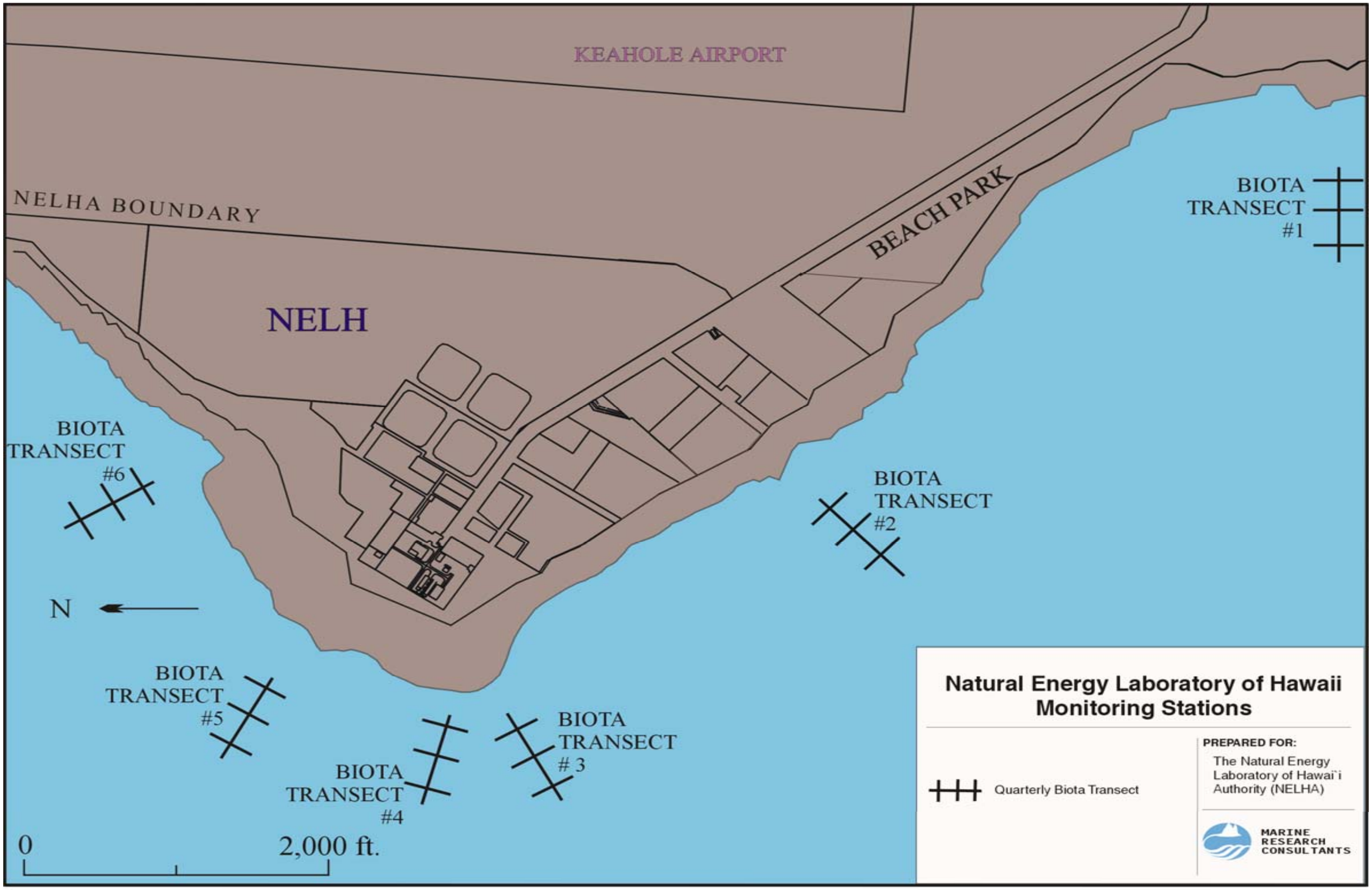


Figure 1. Map showing locations of six biological monitoring transects off of NELHA.

TABLE 1. Percent coral and non-coral substratum cover, total number of species and coral diversity on transects surveyed in the vicinity of NELHA on October 13, 2007. For survey sites, see Figure 1.

SITE 1 - WAWALOLI CORAL SPECIES	15'	20'	35'
Porites lobata	24.9	38.9	30.7
Porites compressa	0.2	5.1	36.1
Pocillopora meandrina	11.0	12.6	0.4
Montipora capitata	4.8	2.1	0.2
Montipora patula	0.1	0.4	
Pavona varians	0.2		
TOTAL CORAL COVER	41.2	59.1	67.4
NUMBER OF SPECIES	6	5	4
CORAL COVER DIVERSITY	0.97	0.97	0.74
NON-CORAL SUBSTRATA			
Basalt	52.2	28.0	0.0
Limestone	6.6	12.9	32.6
Sand	0.0	0.0	0.0
Rubble	0.0	0.0	0.0

SITE 2 - 18" PIPE CORAL SPECIES	20'	25'	45'
Porites lobata	24.7	12.1	15.7
Porites compressa	20.3		0.2
Pocillopora meandrina		18.8	14.9
Pocillopora eydouxi			2.0
Montipora capitata	1.0	0.6	1.8
Montipora patula	1.8	0.6	
Pavona varians		0.2	
TOTAL CORAL COVER	47.8	32.3	34.6
NUMBER OF SPECIES	4	5	5
CORAL COVER DIVERSITY	0.91	0.86	1.07
NON-CORAL SUBSTRATA			
Basalt	38.4	38.9	14.3
Limestone	13.8	23.8	51.1
Sand	0.0	1.0	0.0
Rubble	0.0	4.0	0.0

SITE 3 - 12" PIPE SOUTH CORAL SPECIES	20'	30'	45'
Porites lobata	31.7	18.7	41.4
Porites compressa			10.7
Pocillopora meandrina	25.1	12.2	14.3
Montipora capitata	2.2	0.6	4.8
Montipora patula	2.1	1.1	3.6
TOTAL CORAL COVER	61.1	32.6	74.8
NUMBER OF SPECIES	4	4	5
CORAL COVER DIVERSITY	0.94	0.87	1.24
NON-CORAL SUBSTRATA			
Basalt	19.5	58.9	13.8
Limestone	18.9	8.5	11.4
Sand	0.0	0.0	0.0
Rubble	0.5	0.0	0.0

SITE 4 - 12" PIPE NORTH CORAL SPECIES	20'	25'	50'
Porites lobata	12.0	20.9	46.6
Porites compressa			4.7
Pocillopora meandrina	12.8	15.1	16.2
Montipora capitata		1.7	4.0
Montipora patula	1.7	8.0	0.5
Pavona varians			
TOTAL CORAL COVER	26.5	50.8	72.0
NUMBER OF SPECIES	3	6	5
CORAL COVER DIVERSITY	0.89	1.37	0.99
NON-CORAL SUBSTRATA			
Basalt	70.0	30.5	18.8
Limestone	3.5	18.7	9.2
Sand	0.0	0.0	0.0
Rubble	0.0	0.0	0.0

SITE 5 - NPPE CORAL SPECIES	20'	30'	50'
Porites lobata	26.3	47.5	65.9
Porites compressa	12.7	10.1	16.0
Pocillopora meandrina		11.1	5.6
Pocillopora eydouxi		5.5	
Montipora capitata		1.9	0.6
Montipora patula	2.1	1.2	0.5
Pavona varians			
TOTAL CORAL COVER	41.1	77.3	88.6
NUMBER OF SPECIES	3	6	5
CORAL COVER DIVERSITY	0.80	1.19	0.77
NON-CORAL SUBSTRATA			
Basalt	34.1	15.7	0.0
Limestone	24.8	7.0	11.4
Sand	0.0	0.0	0.0
Rubble	0.0	0.0	0.0

SITE 6 - HO`ONA BAY CORAL SPECIES	10'	25'	60'
Porites lobata	26.6	32.6	36.0
Porites compressa		1.2	23.5
Pocillopora meandrina	8.3	4.3	0.2
Montipora capitata		0.3	1.0
Montipora patula		0.7	0.5
TOTAL CORAL COVER	34.9	39.1	61.2
NUMBER OF SPECIES	2	5	5
CORAL COVER DIVERSITY	0.55	0.61	0.80
NON-CORAL SUBSTRATA			
Basalt	62.7	17.3	1.0
Limestone	2.4	43.6	9.0
Sand	0.0	0.0	2.0
Rubble	0.0	0.0	26.8

TABLE 2a. Coral community data for each survey of the NELHA benthic monitoring program at Sites 1-3. % Coral represents percentage of bottom covered by all species of coral. % Pl, Pc and Pm are percentage cover of bottom by each of the three most common corals (*Porites lobata, Porites compressa and Pocillopora meandrina). S* p.# represents total number of coral species encountered on transects; Sp. div. represents Shannon-Weaver Species diversity. For locations of transect sites, see Figure 1.

SITE	DEPTH	PARAMETER	SURVEY NUMBER/DATE																				
			2 12/91	3 5/92	4 10/92	5 5/93	6 10/93	7 3/94	8 5/94	9 9/94	10 1/95	11 5/95	12 11/97	13 5/98	14 11/98	15 5/99	16 12/99	17 6/00	18 2/01	19 5/01	20 12/01	21 6/02	22 10/07
1 - WAWALOLI	15'	% CORAL	12.5	5.5	5.1	4.7	7.6	2.5	5.0	6.9	5.8	5.7	24.3	30.2	19.4	16.9	21.2	24.1	34.1	32.4	23.5	42.3	41.2
		% P. l.	10.8	4.4	2.9	1.9	5.7	1.3	2.8	3.0	3.8	2.9	11.3	17.8	7.6	8.1	10.9	12.3	17.8	15.5	7.5	27.3	24.9
		% P. c.							0.1							0.6				0.1		0.8	0.2
		% P. m.	1.7	1.0	2.2	2.5	1.7	0.4	0.7	1.8	1.6	1.9	12.5	9.9	11.0	5.3	9.4	9.5	14.1	14.3	14.3	11.6	11.0
		Sp. #	2	4	2	3	4	4	8	6	5	4	4	4	4	6	3	5	4	5	5	7	6
		Sp. div.	0.39	0.57	0.68	0.87	0.67	1.19	1.41	1.32	0.89	1.10	0.79	0.93	0.85	1.27	0.84	1.01	0.92	0.94	0.93	0.93	0.97
	20'	% CORAL	1.7	23.6	10.8	12.1	17.7	8.7	14.9	23.3	15.6	15.9	32.0	37.9	35.5	23.9	45.9	26.3	31.4	44.8	33.7	34.7	59.1
		% P. l.	1.4	22.2	9.8	11.4	16.5	4.1	13.3	21.7	13.8	14.2	20.6	21.7	16.5	11.4	25.8	13.2	14.4	14.4	14.3	16.3	38.9
		% P. c.	0.2				0.1	0.1							0.6	0.3	1.1			0.3	0.3	0.3	5.1
		% P. m.	0.1	1.1	0.5	0.2	0.5	3.9	0.6	0.2	0.3	1.1	7.0	11.8	13.7	9.1	13.1	8.5	12.0	22.1	16.6	14.1	12.6
		Sp. #	4	6	3	3	5	5	3	5	4	3	4	6	7	5	5	5	4	6	5	6	5
		Sp. div.	0.57	0.27	0.37	0.23	0.33	0.99	0.41	0.32	0.47	0.41	0.98	1.03	1.16	1.13	1.11	1.20	1.08	1.18	0.97	1.12	0.97
	35'	% CORAL	23.9	2.9	2.5	2.2	5.3	8.5	8.4	8.9	9.9	14.2	13.9	15.1	32.0	22.7	23.2	29.4	29.5	28.3	8.5	14.6	67.4
		% P. l.	14.7	2.5	2.2	1.5	2.9	3.6	6.3	7.1	7.5	8.2	7.7	7.0	19.7	10.4	10.4	13.5	13.8	15.2	4.9	5.8	30.7
		% P. c.	9.2	0.3		0.3	1.0	0.5					0.6	1.7	0.9	1.5	0.3	0.6		1.2	0.6	2.6	36.1
		% P. m.	0.1	0.1	0.1	0.1	1.0	3.3	1.6	1.3	1.2	4.8	5.3	4.5	10.8	8.9	10.8	11.5	13.0	9.9	1.8	4.4	0.4
		Sp. #	3	3	3	5	4	7	4	3	3	5	4	5	5	4	4	5	4	5	5	4	4
		Sp. div.	0.68	0.42	0.44	1.05	1.15	1.32	0.74	0.62	0.72	0.94	0.91	1.25	0.85	1.11	0.96	1.15	0.95	1.07	1.15	1.29	0.74
2-18" PIPE	20'	% CORAL	12.5	15.6	19.2	15.8	18.6	10.0	15.5	15.1	15.2	24.5	35.2	54.5	49.8	36.8	46.4	45.9	49.5	46.3	54.7	41.7	47.8
		% P. l.	5.8	2.8	5.2	6.4	4.9	4.1	6.1	3.8	6.7	7.0	14.5	21.8	17.7	17.9	11.9	15.1	20.1	16.3	22.9	14.2	24.7
		% P. c.													0.8				0.3				
		% P. m.	6.2	10.0	11.2	5.7	11.8	3.9	8.4	6.2	6.8	9.3	15.7	20.8	26.2	13.8	27.4	27.4	24.7	29.3	25.2	22.6	20.3
		Sp. #	4	7	5	6	3	5	5	5	5	6	4	5	5	5	6	6	7	4	7	4	4
		Sp. div.	0.84	1.01	1.00	1.24	0.87	1.21	0.95	1.34	1.06	1.44	1.03	1.26	1.05	1.11	1.13	0.96	1.04	0.73	1.11	0.97	0.91
	25'	% CORAL	14.3	13.0	9.1	13.1	11.8	16.0	17.3	13.2	23.0	20.4	39.6	53.5	44.9	44.9	49.5	43.2	53.1	59.0	40.1	52.9	32.3
		% P. l.	5.2	4.4	3.9	2.6	3.4	4.8	3.7	3.3	12.8	8.6	12.2	15.5	20.0	19.2	8.2	8.4	12.7	16.7	8.2	21.2	12.1
		% P. c.						0.3		0.5		0.4						0.7		0.2			
		% P. m.	8.5	8.0	3.2	8.9	6.0	5.9	10.7	6.9	6.4	9.0	23.5	25.8	18.9	20.9	38.8	30.7	32.0	32.6	24.2	23.5	18.8
		Sp. #	6	6	4	5	6	8	5	6	4	5	6	5	5	5	4	7	7	5	6	5	5
		Sp. div.	0.84	0.85	1.15	0.89	1.17	1.56	1.06	1.27	1.04	1.13	1.03	1.22	1.10	1.03	0.67	0.89	1.11	1.11	1.15	1.12	0.86
	45'	% CORAL	12.4	7.4	5.5	16.2	10.7	12.9	12.9	8.4	12.5	4.3	18.9	22.0	22.6	12.6	27.0	36.9	40.8	36.4	41.4	31.6	34.6
		% P. l.	9.2	6.0	4.0	13.3	8.0	11.9	9.3	7.7	11.8	2.4	8.0	7.7	10.6	3.5	2.5	4.6	5.3	9.6	15.7	16.4	15.7
		% P. c.	2.5	1.3	1.3	1.3	2.4	0.6	2.7	0.4	0.2	0.7		3.7	1.1	0.1	0.1		0.2		0.4	1.6	0.2
		% P. m.	0.1	0.5	0.1		0.2	0.2		0.3	0.4	0.9	9.9	10.4	10.1	8.7	22.6	31.4	31.2	26.6	22.1	10.9	14.9
		Sp. #	6	4	4	3	4	5	3	3	4	4	3	4	7	5	7	4	6	3	6	5	5
		Sp. div.	0.58	0.54	0.72	0.59	0.67	0.36	0.75	0.34	0.27	1.13	0.86	1.06	1.02	0.75	0.65	0.50	0.80	0.61	0.99	1.12	1.07
3 -12" PIPE SOUTH	20'	% CORAL		8.9	8.7	8.5	6.5	6.5	9.4	12.0	10.7	5.9	31.8	15.0	21.6	13.2	21.5	29.6	39.0	51.3	28.7	28.7	61.1
		% P. l.		1.4	1.4	2.0	2.4	1.9	2.5	4.1	2.2	1.3	17.3	3.5	7.8	7.5	7.8	9.0	19.9	23.1	10.8	9.2	31.7
		% P. c.		0.3				0.1															
		% P. m.		6.9	7.1	6.6	4.1	3.4	5.1	7.5	7.7	4.6	12.2	7.7		4.7	13.5	19.6	18.1	18.8	15.7	15.4	25.1
		Sp. #		5	4	2	2	4	4	3	4	2	4	6	6	3	3	3	5	6	4	5	4
		Sp. div.		0.70	0.56	0.54	0.66	1.04	1.10	0.77	0.81	0.53	0.92	1.27	0.93	0.88	0.70	0.75	0.82	1.28	0.93	1.13	0.94
	30'	% CORAL		20.2	13.7	21.2	16.8	20.5	18.8	19.2	23.4	17.6	42.7	42.2	50.9	36.9	57.5	57.5	56.9	60.9	56.7	52.0	32.6
		% P. l.		8.5	7.3	14.3	9.9	12.6	7.8	6.9	12.9	5.1	12.9	15.0	32.9	18.8	30.0	20.4	15.3	23.3	14.1	20.1	18.7
		% P. c.												1.4				0.4		0.2			
		% P. m.		7.2	3.6	4.6	2.8	5.1	5.2	8.5	6.1	7.5	26.2	20.7		13.1	17.0	26.5	37.7	27.1	28.4	24.2	12.2
		Sp. #		6	6	6	5	4	5	4	5	5	6	5	4	4	6	5	5	8	5	6	4
		Sp. div.		1.28	1.28	0.95	1.21	1.01	1.36	1.14	1.17	1.27	0.95	1.12	0.77	1.05	1.14	1.18	0.86	1.23	1.28	1.19	0.87
	45'	% CORAL		15.0	17.9	22.2	31.0	22.9	14.3	30.8	28.9	26.1	50.4	75.6	68.2	36.3	65.0	65.3	71.7	76.6	72.2	68.0	74.8
		% P. l.		11.5	14.1	16.8	19.1	17.9	10.1	18.9	18.3	16.7	15.5	28.9	23.1	15.9	26.0	20.8	30.6	28.6	45.0	28.0	41.4
		% P. c.		0.5	0.2	0.9	0.7	0.4	1.0	1.4		0.4	0.5	1.0	1.1	1.4	0.6	0.7	1.8	5.8	5.3	2.1	10.7
		% P. m.		0.9	1.2	2.3	2.8	1.3	0.8	2.8	4.4	4.6	27.3	35.3	35.7	5.0	30.3	34.5	27.0	32.1	14.7	24.9	14.3
		Sp. #		6	6	6	9	7	7	6	4	6	6	7	6	7	7	8	7	6	6	7	5
		Sp. div.		0.86	0.78	0.84	1.22	0.83	1.00	1.20	1.04	1.08	1.17	1.16	1.12	1.41	1.16	1.20	1.32	1.30	1.14	1.32	1.24

TABLE 2b. Coral community data for each survey of the NELHA benthic monitoring program at Sites 4-6. % Coral represents percentage of bottom covered by all species of coral. % Pl, Pc and Pm are percentage cover of bottom by each of the three most common corals (*Porites lobata, Porites compressa and Pocillopora meandrina*). *S* p.# represents total number of coral species encountered on transects; Sp. div. represents Shannon-Weaver Species diversity. For locations of transect sites, see Figure 1.

SITE	DEPTH	PARAMETER	SURVEY NUMBER/DATE																				
			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			12/91	5/92	10/92	5/93	10/93	3/94	5/94	9/94	1/95	5/95	11/97	5/98	11/98	5/99	12/99	6/00	2/01	5/01	12/01	6/02	10/07
4- 12" PIPE NORTH	20'	% CORAL		8.3	4.5	7.6	14.8	10.0	10.2	9.6	7.5	15.1	35.9	32.0	36.2	27.2	37.1	34.1	40.5	43.4	41.9	32.0	26.5
		% P. l.		3.2	2.2	2.5	5.0	3.0	3.3	3.4	4.6	3.5	9.7	11.9	10.0	6.6	10.9	8.0	14.9	11.8	16.1	9.2	12.0
		% P. c.												0.2	0.2							0.1	
		% P. m.		4.3	2.3	3.1	6.3	3.5	3.9	5.1	1.5	8.1	22.1	18.7	22.9	20.2	24.1	22.8	22.9	26.4	21.1	18.4	12.8
		Sp. #		7	3	6	6	6	5	4	5	7	3	5	4	4	4	4	5	4	5	7	3
		Sp. div.		1.02	0.78	1.30	1.33	1.58	1.40	1.03	1.13	1.35	0.90	0.85	0.88	0.64	0.81	0.90	0.93	0.94	1.05	1.07	0.89
	25'	% CORAL		13.8	12.5	14.1	17.6	20.8	23.7	22.7	19.1	16.2	29.8	45.9	41.5	53.0	33.7	33.2	50.9	40.5	51.0	49.2	50.8
		% P. l.		9.2	9.9	7.1	7.0	9.2	9.0	10.4	9.3	10.1	14.8	23.9	22.5	15.7	16.3	20.6	21.7	16.1	19.1	23.6	20.9
		% P. c.		0.4	0.1		0.1						2.2			1.2	1.2			0.8	2.2	0.3	
		% P. m.		3.4	1.3	4.0	3.0	3.5	7.7	5.5	6.8	4.3	12.1	16.1	14.4	31.1	12.5	11.1	21.5	18.9	21.6	16.2	15.1
		Sp. #		6	6	6	7	7	6	5	4	6	4	4	4	7	7	5	7	6	8	7	6
		Sp. div.		0.95	0.79	1.26	1.48	1.47	1.39	1.18	1.10	1.01	0.99	1.04	0.95	1.09	1.19	0.85	1.20	1.17	1.35	1.28	1.37
	50'	% CORAL		17.4	13.2	17.7	27.1	21.8	19.4	22.5	30.4	29.9	40.6	63.6	47.3	58.1	59.8	63.7	66.6	60.1	60.4	64.8	72.0
		% P. l.		14.1	10.5	13.9	15.3	16.4	14.0	14.4	24.8	23.9	23.5	32.0	26.6	36.0	32.2	36.2	35.4	29.0	27.7	38.1	46.6
		% P. c.		1.2	0.3	0.8	0.6	0.4	0.2	0.5	0.8	0.5	2.3	1.4	1.7	0.9	1.8	2.3	2.8	3.2	1.9	5.6	4.7
		% P. m.		0.1	0.5	0.5	3.6	0.8	1.0	2.0	0.8	1.8	7.1	14.6	8.0	13.7	15.4	13.7	17.8	21.0	14.4	10.8	16.2
		Sp. #		6	4	6	5	5	6	5	5	5	6	6	5	5	7	5	6	6	6	6	5
		Sp. div.		0.70	0.67	0.77	1.13	0.75	0.87	1.07	0.67	0.74	1.22	1.22	1.23	1.03	1.23	1.17	1.19	1.22	1.35	1.24	0.99
NPPE TRENCH	20'	% CORAL		18.6	21.7	20.6	25.6	22.9	26.4	33.7	24.5	19.6	62.0	46.7	42.5	47.8	66.8	53.7	37.7	48.1	52.9	45.3	41.1
		% P. l.		6.9	6.1	5.9	9.4	7.4	8.7	11.0	8.2	6.6	33.8	20.5	15.4	19.1	31.9	25.3	12.6	21.1	28.4	19.7	26.3
		% P. c.											0.6	0.6						0.8			12.7
		% P. m.		8.8	10.2	11.8	10.7	11.8	15.0	13.6	9.6	8.6	21.2	20.0	16.3	21.8	24.6	22.1	22.9	24.3	19.8	22.1	
		Sp. #		6	7	6	5	7	5	6	6	5	6	7	6	5	6	4	5	5	4	7	3
		Sp. div.		1.21	1.43	1.13	1.25	1.25	0.99	1.40	1.45	1.28	1.06	1.19	1.37	1.12	1.17	1.05	0.87	0.92	0.98	0.97	0.80
	30'	% CORAL		29.5	33.9	36.6	51.3	44.1	45.3	47.2	51.7	42.1	61.6	75.3	64.8	75.3	85.4	71.3	77.2	71.7	70.2	59.2	77.3
		% P. l.		10.4	16.6	14.1	18.7	19.3	22.1	23.0	28.1	26.5	24.9	31.9	27.1	35.6	46.9	39.6	33.4	38.0	41.5	28.7	47.5
		% P. c.		0.3	0.3	1.6	0.8		2.8	1.6	1.7	0.2	2.8	1.2	1.3	1.6	1.9	4.5	2.8	2.4	6.4		10.1
		% P. m.		17.6	15.8	18.8	26.2	22.0	17.0	19.1	19.7	13.2	19.1	33.1	30.4	27.7	30.6	22.8	35.2	22.6	17.2	22.4	11.1
		Sp. #		6	7	6	7	5	5	6	6	6	7	7	6	7	6	5	6	7	6	6	6
		Sp. div.		0.88	0.90	1.05	1.13	0.95	1.13	1.09	0.98	0.89	1.50	1.17	1.11	1.23	1.04	1.08	1.10	1.20	1.13	1.11	1.19
	50'	% CORAL		28.0	38.3	45.5	40.5	47.7	40.5	60.3	58.4	55.1	83.8	83.9	77.2	79.8	74.7	89.8	77.7	89.6	76.6	90.3	88.6
		% P. l.		23.2	30.1	34.2	32.4	41.1	31.6	47.7	41.7	37.8	57.1	55.4	47.7	49.7	48.8	56.3	45.5	62.0	41.9	61.1	65.9
		% P. c.		1.9	1.4	3.5	1.4	1.7	3.8	2.1	5.4	7.6	11.1	6.3	14.3	20.5	11.7	14.5	17.2	17.0	10.3	21.4	16.0
		% P. m.		1.5	3.0	3.8	4.4	2.1	1.0	5.7	5.5	3.8	8.3	10.6	8.9	5.3	6.3	9.0	8.2	6.3	15.2	5.1	5.6
		Sp. #		6	7	6	6	5	5	6	6	7	7	7	4	7	7	6	5	5	7	5	5
		Sp. div.		0.68	0.83	0.91	0.74	0.56	0.78	0.78	0.96	1.04	1.05	1.15	1.06	1.01	1.11	1.17	1.15	0.93	1.29	0.89	0.77
HO'ONA BAY	10'	% CORAL	15.1	15.1	24.8	12.0	7.5	9.0	6.8	10.9	10.8	11.0	17.6	24.0	27.7	15.3	32.2	35.2	46.9	41.9	43.6	35.2	34.9
		% P. l.	12.3	10.0	18.3	7.5	4.8	7.2	4.7	6.2	9.1	6.3	12.0	16.5	13.5	7.0	15.2	19.0	24.2	15.9	22.7	4.4	26.6
		% P. c.		0.2		0.3									0.2		0.2						
		% P. m.	2.4	4.4	3.9	3.9	1.5	1.1	0.9	2.1	1.7	2.4	4.3	6.8	10.1	8.3	12.7	14.9	17.6	21.2	19.1	30.8	8.3
		Sp. #	3	4	5	6	3	5	6	3	2	3	5	4	4	2	4	3	5	6	4	2	2
		Sp. div.	0.55	0.79	0.85	0.87	0.90	0.73	1.02	0.98	0.44	0.98	0.86	0.74	1.03	0.69	1.02	0.82	1.03	1.08	0.85	0.38	0.55
	25'	% CORAL	42.1	30.8	27.8	30.7	26.0	38.1	18.6	25.7	28.7	23.4	68.0	82.6	64.9	48.0	48.4	44.0	49.5	30.6	42.1	38.9	39.1
		% P. l.	37.4	25.4	22.1	22.8	21.3	35.2	13.1	23.0	24.9	20.3	46.4	51.0	28.7	28.1	24.2	29.3	29.9	16.1	30.3	26.3	32.6
		% P. c.	4.1	3.5	5.0	6.8	2.3	2.1	4.1	1.1	3.5	3.0	18.9	29.4	28.7	12.6	17.8	10.1	16.1		2.9	0.9	1.2
		% P. m.	0.6	1.7	0.6	1.0	2.3	0.3	1.2		0.1	0.1	0.6	1.1	6.7	3.2	5.2	3.6	2.9	12.0	7.2	11.6	4.3
		Sp. #	3	4	3	3	4	6	5	4	4	3	7	5	5	5	6	6	4	4	6	4	5
		Sp. div.	0.39	0.58	0.57	0.66	0.61	0.35	0.81	0.44	0.43	0.41	0.80	0.79	1.02	1.10	1.06	0.92	0.89	0.95	0.88	0.73	0.61
	60'	% CORAL	34.7	39.1	35.1	45.9	40.8	55.0	41.5	49.0	46.3	43.4	77.1	88.9	82.0	83.4	69.5	72.0	65.0	82.9	76.8	86.5	61.2
		% P. l.	12.5	20.0	12.7	18.8	18.7	18.9	19.2	20.8	23.3	17.4	27.9	30.4	28.3	28.8	27.0	24.6	38.2	32.9	33.0	39.3	36.0
		% P. c.	20.0	18.0	21.7	25.3	19.9	35.2	19.1	25.3	21.8	23.3	44.7	54.3	49.4	52.6	38.7	43.8	22.4	43.8	38.4	39.7	23.5
		% P. m.	0.5	0.3	0.1	0.3	1.1	0.1	0.7	0.4	0.3	0.5		0.3	0.2		0.5		1.1		1.6	0.4	0.2
		Sp. #	7	5	5	6	4	5	7	5	6	6	4	6	6	6	6	4	6	5	6	6	5
		Sp. div.	0.93	0.83	0.76	0.86	0.90	0.74	1.02	0.92	0.82	0.95	0.88	0.85	0.88	0.78	0.91	0.85	0.95	0.97	0.98	1.04	0.80

TABLE 3. ANOVA summary table for total cover at sites off of NELHA, West Hawaii. Sites 1, 2 and 6 were surveyed on twenty-one dates (N=210); sites 3, 4 and 5 were surveyed on twenty dates (N=200). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	SS	df	MS	F	P-value
1 - WAWAOLI	15'	Between Groups	33339.03	20	1666.95	15.819	0.000
		Within Groups	19916.50	189	105.38		
	20'	Between Groups	40264.14	20	2013.21	11.929	0.000
		Within Groups	28352.85	168	168.77		
	35'	Between Groups	40483.42	20	2024.17	17.264	0.000
		Within Groups	19698.17	168	117.25		
2 - 18" PIPE	20'	Between Groups	48549.09	20	2427.45	17.948	0.000
		Within Groups	22721.42	168	135.25		
	25'	Between Groups	55438.80	20	2771.94	15.206	0.000
		Within Groups	30625.48	168	182.29		
	45'	Between Groups	26566.76	20	1328.34	6.427	0.000
		Within Groups	34724.56	168	206.69		
3 - 12" PIPE S.	20'	Between Groups	40514.88	19	2132.36	12.945	0.000
		Within Groups	26355.56	160	164.72		
	30'	Between Groups	54239.58	19	2854.71	14.834	0.000
		Within Groups	30790.17	160	192.44		
	45'	Between Groups	102724.58	19	5406.56	36.558	0.000
		Within Groups	23662.36	160	147.89		
4 - 12" PIPE N.	20'	Between Groups	31989.64	19	1683.67	13.567	0.000
		Within Groups	19855.56	160	124.10		
	25'	Between Groups	38549.20	19	2028.91	8.028	0.000
		Within Groups	40434.78	160	252.72		
	50'	Between Groups	73890.86	19	3888.99	18.319	0.000
		Within Groups	33967.72	160	212.30		
5 - NPPE	20'	Between Groups	41926.69	19	2206.67	10.723	0.000
		Within Groups	32927.00	160	205.79		
	30'	Between Groups	46199.35	19	2431.54	9.223	0.000
		Within Groups	42180.17	160	263.63		
	50'	Between Groups	73884.89	19	3888.68	21.219	0.000
		Within Groups	29321.67	160	183.26		
6 - HO'ONA BAY	10'	Between Groups	31954.49	20	1597.72	10.332	0.000
		Within Groups	25980.28	168	154.64		
	25'	Between Groups	50628.70	20	2531.44	5.301	0.000
		Within Groups	80220.50	168	477.50		
	60'	Between Groups	69657.91	20	3482.90	10.247	0.000
		Within Groups	57103.06	168	339.90		

TABLE 4. ANOVA summary table for *Porites lobata* cover at sites off of NELHA. Sites 1, 2 and 6 were surveyed on twenty-one dates (N=210); sites 3, 4 and 5 were surveyed on twenty dates (N=200). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	*SS*	*df*	*MS*	*F*	*P-value*
1 - WAWAOLI	15'	Between Groups	11252.58	20	562.63	7.006	0.000
		Within Groups	15178.03	189	80.31		
	20'	Between Groups	12995.79	20	649.79	4.181	0.000
		Within Groups	26108.66	168	155.41		
	35'	Between Groups	8566.30	20	428.32	5.706	0.000
		Within Groups	12610.82	168	75.06		
2 - 18" PIPE	20'	Between Groups	10403.80	20	520.19	5.780	0.000
		Within Groups	15119.83	168	90.00		
	25'	Between Groups	6911.45	20	345.57	5.355	0.000
		Within Groups	10841.33	168	64.53		
	45'	Between Groups	3595.53	20	179.78	1.351	0.154
		Within Groups	22355.28	168	133.07		
3 - 12" PIPE S.	20'	Between Groups	12156.47	19	639.81	6.251	0.000
		Within Groups	16376.28	160	102.35		
	30'	Between Groups	10371.69	19	545.88	3.651	0.000
		Within Groups	23920.22	160	149.50		
	45'	Between Groups	18049.64	19	949.98	10.817	0.000
		Within Groups	14051.17	160	87.82		
4 - 12" PIPE N.	20'	Between Groups	3432.59	19	180.66	3.349	0.000
		Within Groups	8631.39	160	53.95		
	25'	Between Groups	5693.42	19	299.65	1.665	0.047
		Within Groups	28787.56	160	179.92		
	50'	Between Groups	19321.37	19	1016.91	7.097	0.000
		Within Groups	22926.83	160	143.29		
5 - NPPE	20'	Between Groups	16500.64	19	868.45	8.938	0.000
		Within Groups	15545.44	160	97.16		
	30'	Between Groups	20101.30	19	1057.96	7.877	0.000
		Within Groups	21490.00	160	134.31		
	50'	Between Groups	25081.29	19	1320.07	9.242	0.000
		Within Groups	22853.94	160	142.84		
6 - HO'ONA BAY	10'	Between Groups	8969.52	20	448.48	5.000	0.000
		Within Groups	15068.22	168	89.69		
	25'	Between Groups	15011.38	20	750.57	1.741	0.031
		Within Groups	72428.83	168	431.12		
	60'	Between Groups	10648.70	20	532.43	2.283	0.002
		Within Groups	39179.94	168	233.21		

TABLE 5. ANOVA summary table for *Pocillopora meandrina* cover at sites off NELHA . Sites 1, 2 and 6 were surveyed on twenty-one dates (N=210); sites 3, 4 and 5 were surveyed on twenty dates (N=200). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	*SS*	*df*	*MS*	*F*	*P-value*
1 - WAWAOLI	15'	Between Groups	5608.94	20	280.447	9.274	0.000
		Within Groups	5715.61	189	30.241		
	20'	Between Groups	8674.42	20	433.72	11.969	0.000
		Within Groups	6087.78	168	36.23677		
	35'	Between Groups	4389.02	20	219.45	6.166	0.000
		Within Groups	5979.38	168	35.59		
			SS	*df*	*MS*	*F*	*P-value*
2 - 18" PIPE	20'	Between Groups	14608.19	20	730.41	8.980	0.000
		Within Groups	13665.33	168	81.34		
	25'	Between Groups	21596.91	20	1079.85	11.365	0.000
		Within Groups	15963.01	168	95.02		
	45'	Between Groups	22568.29	20	1128.41	15.132	0.000
		Within Groups	12528.00	168	74.57		
			SS	*df*	*MS*	*F*	*P-value*
3 - 12" PIPE S.	20'	Between Groups	7370.64	19	387.93	9.166	0.000
		Within Groups	6771.61	160	42.32		
	30'	Between Groups	20686.13	19	1088.74	15.117	0.000
		Within Groups	11523.22	160	72.02		
	45'	Between Groups	30308.81	19	1595.20	21.967	0.000
		Within Groups	11618.75	160	72.62		
			SS	*df*	*MS*	*F*	*P-value*
4 - 12" PIPE N.	20'	Between Groups	13283.77	19	699.15	9.553	0.000
		Within Groups	11709.67	160	73.19		
	25'	Between Groups	12262.63	19	645.40	8.690	0.000
		Within Groups	11882.56	160	74.27		
	50'	Between Groups	16584.75	19	872.88	23.491	0.000
		Within Groups	5945.33	160	37.16		
			SS	*df*	*MS*	*F*	*P-value*
5 - NPPE	20'	Between Groups	13831.75	19	727.99	1.350	0.160
		Within Groups	86274.67	160	539.22		
	30'	Between Groups	10454.77	19	550.25	3.512	0.000
		Within Groups	25066.22	160	156.66		
	50'	Between Groups	24575.72	19	1293.46	22.619	0.000
		Within Groups	9149.44	160	57.18		
			SS	*df*	*MS*	*F*	*P-value*
6 - HO'ONA BAY	10'	Between Groups	12799.49	20	639.97	13.434	0.000
		Within Groups	8003.00	168	47.64		
	25'	Between Groups	2274.20	20	113.71	5.233	0.000
		Within Groups	3650.89	168	21.73		
	60'	Between Groups	23.75	20	1.19	0.978	0.492
		Within Groups	204.06	168	1.21		

TABLE 6. Matrix of Tukey HSD multiple comparison probablilities showing significant (P<0.05) differences between mean coral cover on transects in the vicinity of NELHA. Survey Dates followed by the same Association letter are not significantly different.

TRANSECT	1-15	TRANSECT	1-20	TRANSECT	1-35	TRANSECT	2-20	TRANSECT	2-25	TRANSECT	2-45
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
Mar-94	A	Dec-91	A	May-93	A	Mar-94	A	Oct-92	A	May-95	A
May-93	AB	Mar-94	AB	Oct-92	A	Dec-91	A	Oct-93	AB	Oct-92	A
May-94	AB	Oct-92	ABC	May-92	A	Sep-94	A	May-92	AB	May-92	A
Oct-92	AB	May-93	ABCD	Oct-93	AB	Jan-95	A	May-93	AB	Sep-94	AB
May-92	AB	May-94	ABCDE	May-94	ABC	May-94	A	Sep-94	AB	Oct-93	AB
May-95	AB	Jan-95	ABCDEF	Mar-94	ABC	May-92	A	Dec-91	AB	Dec-91	ABC
Jan-95	AB	May-95	ABCDEF	Dec-01	ABC	May-93	A	Mar-94	AB	Jan-95	ABC
Sep-94	ABC	Oct-93	ABCDEF	Sep-94	ABC	Oct-93	AB	May-94	AB	May-99	ABC
Oct-93	ABCD	Sep-94	ABCDEFG	Jan-95	ABC	Oct-92	AB	May-95	ABC	May-94	ABC
Dec-91	ABCD	May-92	ABCDEFG	Nov-97	ABCD	May-95	ABC	Jan-95	ABCD	Mar-94	ABC
May-99	ABCDE	May-99	ABCDEFG	May-95	ABCD	Nov-97	BCD	Oct-07	BCDE	May-93	ABCD
Nov-98	ABCDEF	Jun-00	BCDEFG	Jun-02	ABCDE	May-99	BCDE	Nov-97	CDEF	Nov-97	ABCDE
Dec-99	BCDEF	Feb-01	BCDEFG	May-98	ABCDE	Jun-02	CDE	Dec-01	CDEF	May-98	ABCDE
Dec-01	CDEF	Nov-97	CDEFG	May-99	BCDE	Jun-00	DE	Jun-00	DEF	Nov-98	ABCDE
Jun-00	DEF	Dec-01	DEFG	Dec-99	CDE	May-01	DE	Nov-98	DEF	Dec-99	ABCDE
Nov-97	DEFG	Jun-02	DEFG	Dec-91	CDE	Dec-99	DE	May-99	DEF	Jun-02	BCDE
May-98	EFGH	Nov-98	EFG	May-01	DE	Oct-07	DE	Dec-99	EF	Oct-07	CDE
May-01	EFGH	May-98	FGH	Jun-00	DE	Feb-01	DE	Jun-02	EF	May-01	DE
Feb-01	FGH	May-01	GH	Feb-01	DE	Nov-98	DE	Feb-01	EF	Jun-00	DE
Oct-07	GH	Dec-99	GH	Nov-98	EF	May-98	E	May-98	EF	Feb-01	E
Jun-02	H	Oct-07	H	Oct-07	G	Dec-01	E	May-01	F	Dec-01	E

TRANSECT	3-20	TRANSECT	3-30	TRANSECT	3-45	TRANSECT	4-20	TRANSECT	4-25	TRANSECT	4-50
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
May-95	A	Oct-92	A	May-94	A	Oct-92	A	Oct-92	A	Oct-92	A
Mar-94	A	Oct-93	AB	May-92	A	Jan-95	A	May-92	A	May-92	A
Oct-93	A	May-95	AB	Oct-92	AB	May-93	A	May-93	A	May-93	AB
May-93	AB	May-94	AB	May-93	AB	May-92	AB	May-95	AB	May-94	AB
Oct-92	AB	Sep-94	ABC	Mar-94	AB	Sep-94	ABC	Oct-93	AB	Mar-94	AB
May-92	AB	May-92	ABCD	May-95	AB	Mar-94	ABC	Jan-95	AB	Sep-94	AB
May-94	ABC	Mar-94	ABCD	Jan-95	AB	May-94	ABC	Mar-94	ABC	Oct-93	ABC
Jan-95	ABC	May-93	ABCD	Sep-94	ABC	Oct-93	ABCD	Sep-94	ABC	May-95	ABC
Sep-94	ABCD	Jan-95	ABCD	Oct-93	ABC	May-95	ABCD	May-94	ABCD	Jan-95	ABC
May-99	ABCD	Oct-07	ABCDE	May-99	BC	Oct-07	BCDE	Nov-97	ABCDE	Nov-97	BCD
May-98	ABCD	May-99	BCDEF	Nov-97	CD	May-99	CDE	Jun-00	ABCDE	Nov-98	CDE
Dec-99	ABCDE	May-98	CDEFG	Dec-99	DE	Jun-02	DE	Dec-99	ABCDE	May-99	DEF
Nov-98	ABCDE	Nov-97	DEFG	Jun-00	DE	May-98	DE	May-01	BCDE	Dec-99	DEF
Jun-02	BCDE	Nov-98	EFG	Jun-02	DE	Jun-00	E	Nov-98	BCDE	May-01	DEF
Dec-01	BCDE	Jun-02	EFG	Nov-98	DE	Nov-97	E	May-98	CDE	Dec-01	DEF
Jun-00	CDE	Dec-01	FG	Feb-01	E	Nov-98	E	Jun-02	DE	May-98	DEF
Nov-97	DEF	Feb-01	FG	Dec-01	E	Dec-99	E	Oct-07	E	Jun-00	EF
Feb-01	EF	Jun-00	FG	Oct-07	E	Feb-01	E	Feb-01	E	Jun-02	EF
May-01	FG	Dec-99	FG	May-98	E	Dec-01	E	Dec-01	E	Feb-01	EF
Oct-07	G	May-01	G	May-01	E	May-01	E	May-99	E	Oct-07	F

TRANSECT	5-20	TRANSECT	5-30	TRANSECT	5-50	TRANSECT	6-10	TRANSECT	6-25	TRANSECT	6-60
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
May-92	A	May-92	A	May-92	A	May-94	A	May-94	A	Dec-91	A
May-95	A	Oct-92	AB	Oct-92	AB	Oct-93	A	May-95	A	Oct-92	A
May-93	A	May-93	ABC	May-94	AB	Mar-94	AB	Sep-94	A	May-92	AB
Oct-92	AB	May-95	ABCD	Oct-93	AB	Jan-95	AB	Oct-93	A	Oct-93	ABC
Mar-94	ABC	Mar-94	ABCDE	May-93	AB	Sep-94	AB	Oct-92	A	May-94	ABC
Jan-95	ABCD	May-94	ABCDEF	Mar-94	AB	May-95	AB	Jan-95	AB	May-95	ABCD
Oct-93	ABCD	Sep-94	ABCDEFG	May-95	BC	May-93	AB	May-01	AB	May-93	ABCD
May-94	ABCD	Oct-93	ABCDEFGH	Jan-95	BCD	Dec-91	ABC	May-93	AB	Jan-95	ABCD
Sep-94	ABCDE	Jan-95	ABCDEFGH	Sep-94	BCDE	May-92	ABC	May-92	AB	Sep-94	ABCDE
Feb-01	ABCDE	Jun-02	BCDEFGHI	Dec-99	CDEF	May-99	ABC	Mar-94	ABC	Mar-94	ABCDEF
Oct-07	ABCDEF	Nov-97	CDEFGHI	Dec-01	CDEF	Nov-97	ABC	Jun-02	ABC	Oct-07	ABCDEFG
Nov-98	ABCDEF	Nov-98	DEFGHI	Nov-98	CDEF	May-98	ABCD	Oct-07	ABC	Feb-01	BCDEFG
Jun-02	BCDEFG	Dec-01	EFGHI	Feb-01	CDEF	Oct-92	ABCD	Dec-01	ABC	Dec-99	CDEFG
May-98	CDEFG	Jun-00	FGHI	May-99	DEF	Nov-98	BCDE	Dec-91	ABC	Jun-00	DEFG
May-99	DEFG	May-01	GHI	Nov-97	EF	Dec-99	CDE	Jun-00	ABC	Dec-01	EFG
May-01	DEFG	May-99	HI	May-98	EF	Oct-07	CDE	May-99	ABCD	Nov-97	EFG
Dec-01	EFG	May-98	HI	Oct-07	F	Jun-02	CDE	Dec-99	ABCD	Nov-98	FG
Jun-00	EFG	Feb-01	HI	May-01	F	Jun-00	CDE	Feb-01	ABCD	May-01	FG
Nov-97	FG	Oct-07	HI	Jun-00	F	May-01	DE	Nov-98	BCD	May-99	FG
Dec-99	G	Dec-99	I	Jun-02	F	Dec-01	DE	Nov-97	CD	Jun-02	G
						Feb-01	E	May-98	D	May-98	G

TABLE 7. Cumulative sea urchin data for NELHA benthic monitoring program. For site and transect locations, see Figure 1.

SITE	TRANSECT	SPECIES	SURVEY NUMBER/DATE																				
			2 12/91	3 5/92	4 10/92	5 5/93	6 10/93	7 3/94	8 5/94	9 9/94	10 1/95	11 5/95	12 11/97	13 5/98	14 11/98	15 5/99	16 12/99	17 6/00	18 2/01	19 5/01	20 12/01	21 6/02	22 10/07
1	15'	E. matheai	36	14	8	11	24	14	20	24	31	26	22	31	27	34	38	29	41	29	32	21	29
		H. mammillatus			1		1					2		1	1	2		2					
		T. gratilla			1							1	1	2	3	3						1	2
		E. diadema															2	1				1	1
	20'	E. matheai	9	40	30	17	34	29	25	31	35	41	35	39	42	31	29	32	26	24	37	26	31
		H. mammillatus				1	1																
		E. diadema																		1	1	1	2
	35'	E. matheai	5		3	1	1	6	3	4	5	3	2	1	2	3	4	2	5	4	4	2	6
		H. mammillatus	1										1	1	1	2		2					1
		E. diadema																1					
		T. gratilla		2		1										1							2
2	20'	E. matheai	19	2	4	3	8	4	6	3	2	4	3	5	4	2	5	6	8	11	12	14	8
	25'	E. matheai	8	5	3	11	13	6	14	21	28	24	27	32	35	39	19	32	31	29	19	21	22
		E. aciculatus				1		1	1							1							
		E. diadema															1	2					
		T. gratilla																					1
	45'	E. matheai	4	9	8	7	6	2	11	7	5	4	4	2	2	2	11	4	21	18	13	11	15
		E. diadema																					2
3	20'	E. matheai		2	3	2	1		1	2	1	2	3	4	2	6	5	11	16	21	19	12	16
		E. diadema																					1
	30'	E. matheai		15	4	6	11	8	5	3	2	2	2	3	3	4	4	8	11	14	15	11	16
	45'	E. diadema											1	2	2	3							1
		E. matheai		2	1	1	1	1	1	1	4	1	3	2	1	1	5	5	8	6	11	9	4
4	20'	E. matheai		3	2	7	4	2	4	3	4	4	2	2	1	2	5	6	11	13	12	21	8
	25'	E. matheai		9	15	7	11	6	6	4	3	2	4	3	2	3	5	7	12	16	15	18	13
	50'	E. matheai		2	0	1	1	1	4	2	2	3	3	5	3	4	4	7	14	21	13	15	11
		E. diadema																					2
5	20'	E. matheai		7	7	7	4	4	3	1	2	5	4	6	2	6	8	11	21	25	18	11	12
		E. diadema																					3
	30'	E. matheai		1	4	1	1	6	8	3	4	41	27	38	26	28	18	31	43	32	21	16	28
		H. mammillatus																		1			1
	50'	E. matheai		1	4			2	4	1	3						5	2	9	11	13	7	
6	10'	E. matheai	4	23	9	4	12	6	11	16	19	12	11	14	12	16	7	5	9	13	11	11	14
		H. mammillatus	2	2		2	1	2															
		E. diadema				1														1			
	25'	E. matheai	39	20	4	1	9	7	6	3	4	3	2	3	2	3	5	5	11	21	15	14	13
		H. mammillatus	7	3	4		1	1	1	1	2	2	2	4	5	2							
		T. gratilla																1					
	60'	E. matheai	7			1	1			1	3	4	2	2	4	4	3	6	12	19	12	9	15
		H. mammillatus	4		1	2		1	1	1	1	1	1	3	3	2							
		T. gratilla				3	1															1	
		E. diadema																					2
		TOTAL	145	162	116	99	147	109	135	132	160	187	162	205	185	204	183	218	309	330	293	253	282

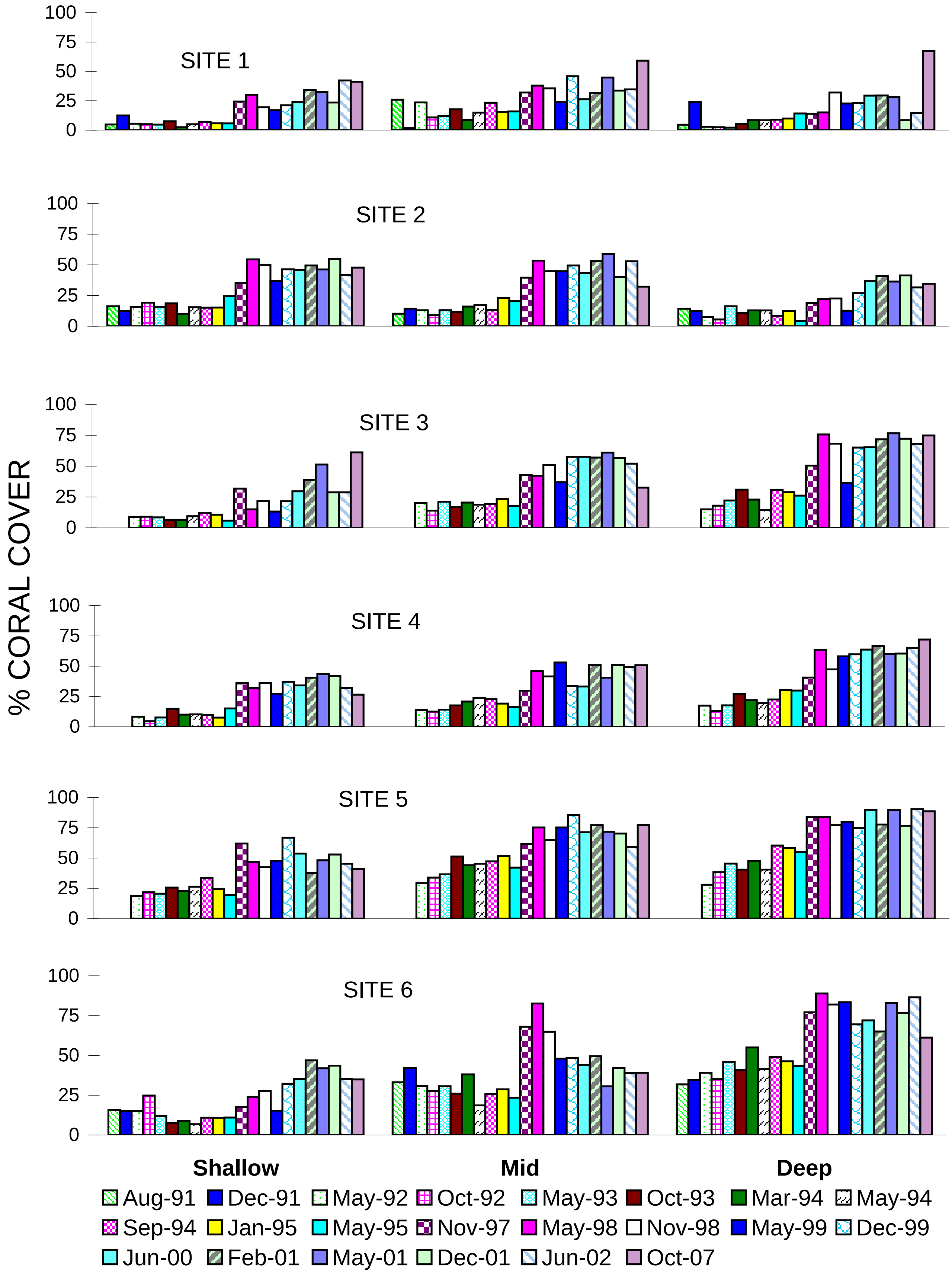


FIGURE 2. Bar graphs of percentage of total coral cover from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

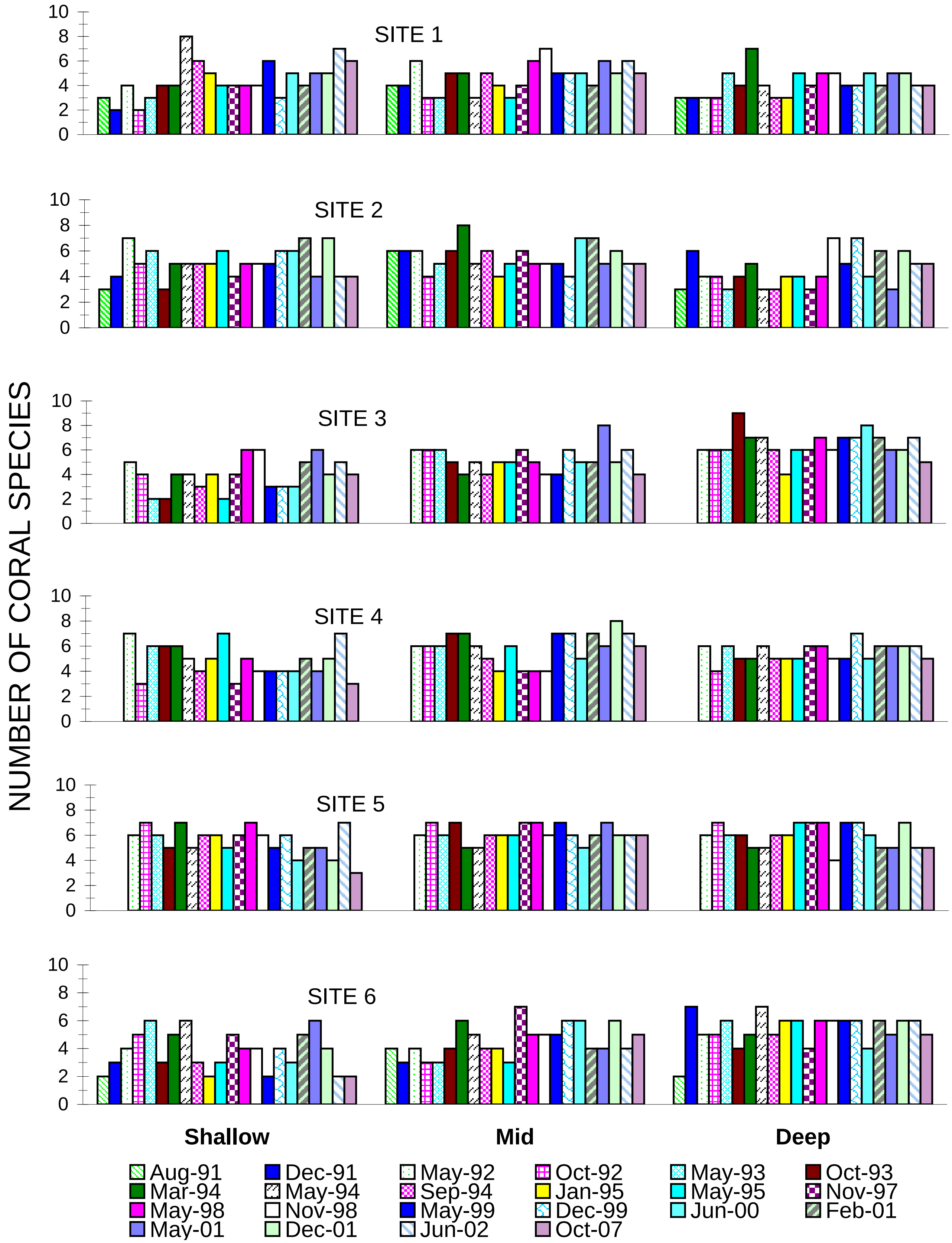


FIGURE 3. Bar graph of total number of coral species from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

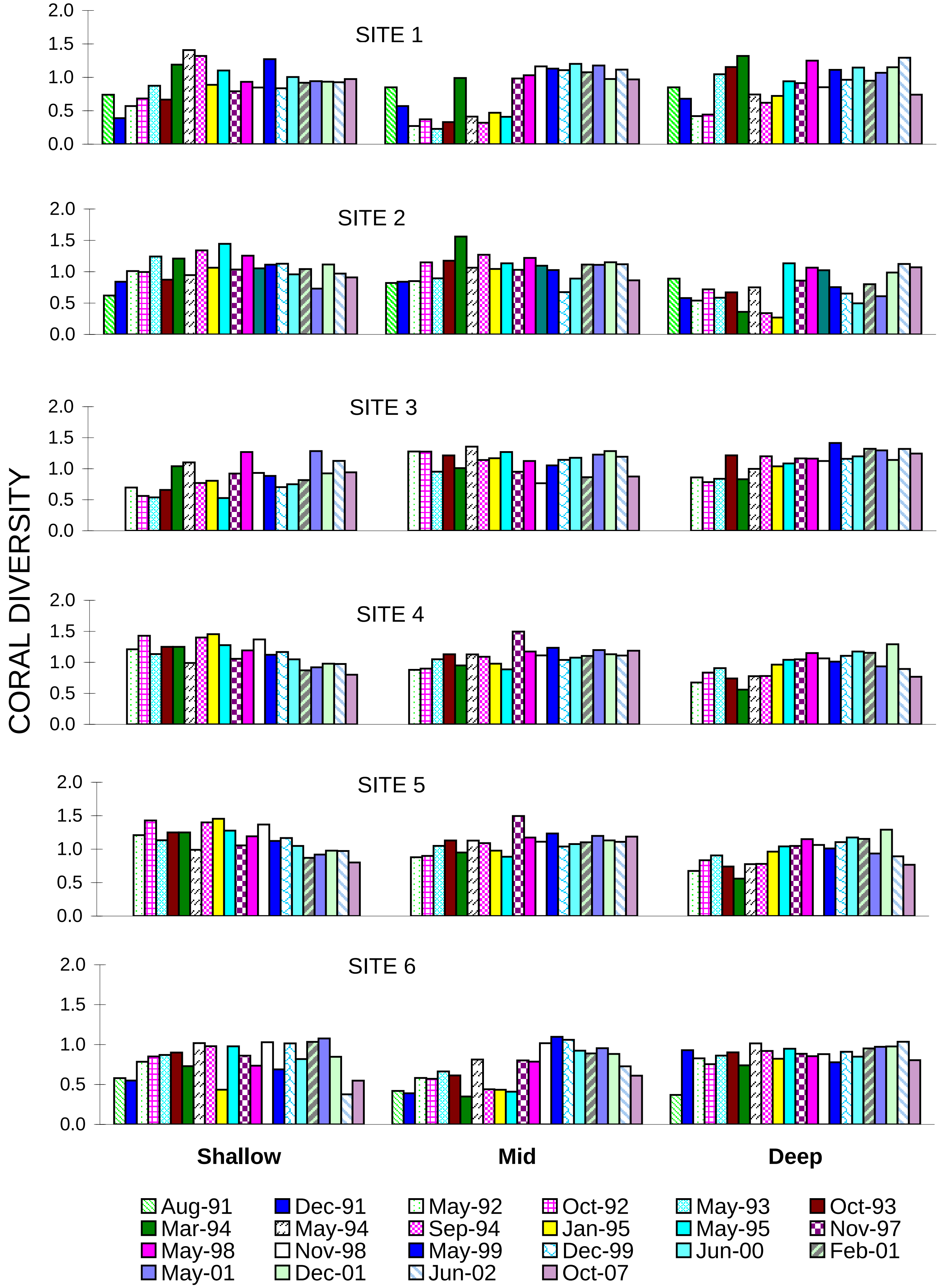


FIGURE 4. Bar graph of coral species diversity from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

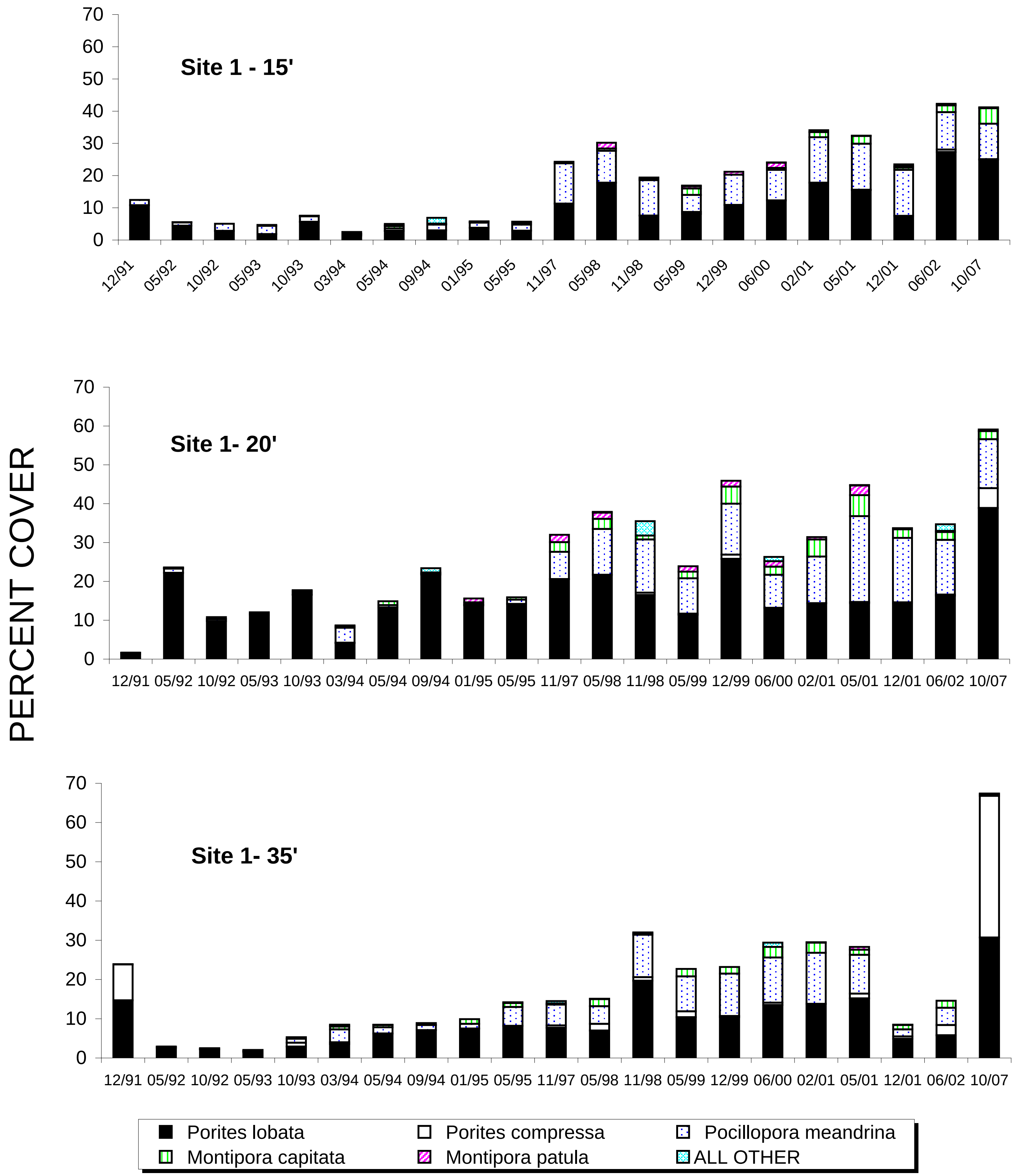


FIGURE 5. Bar graph showing percent cover of major coral species at three depths along the transect at Site 1. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. For location of Site 1, see Figure 1.

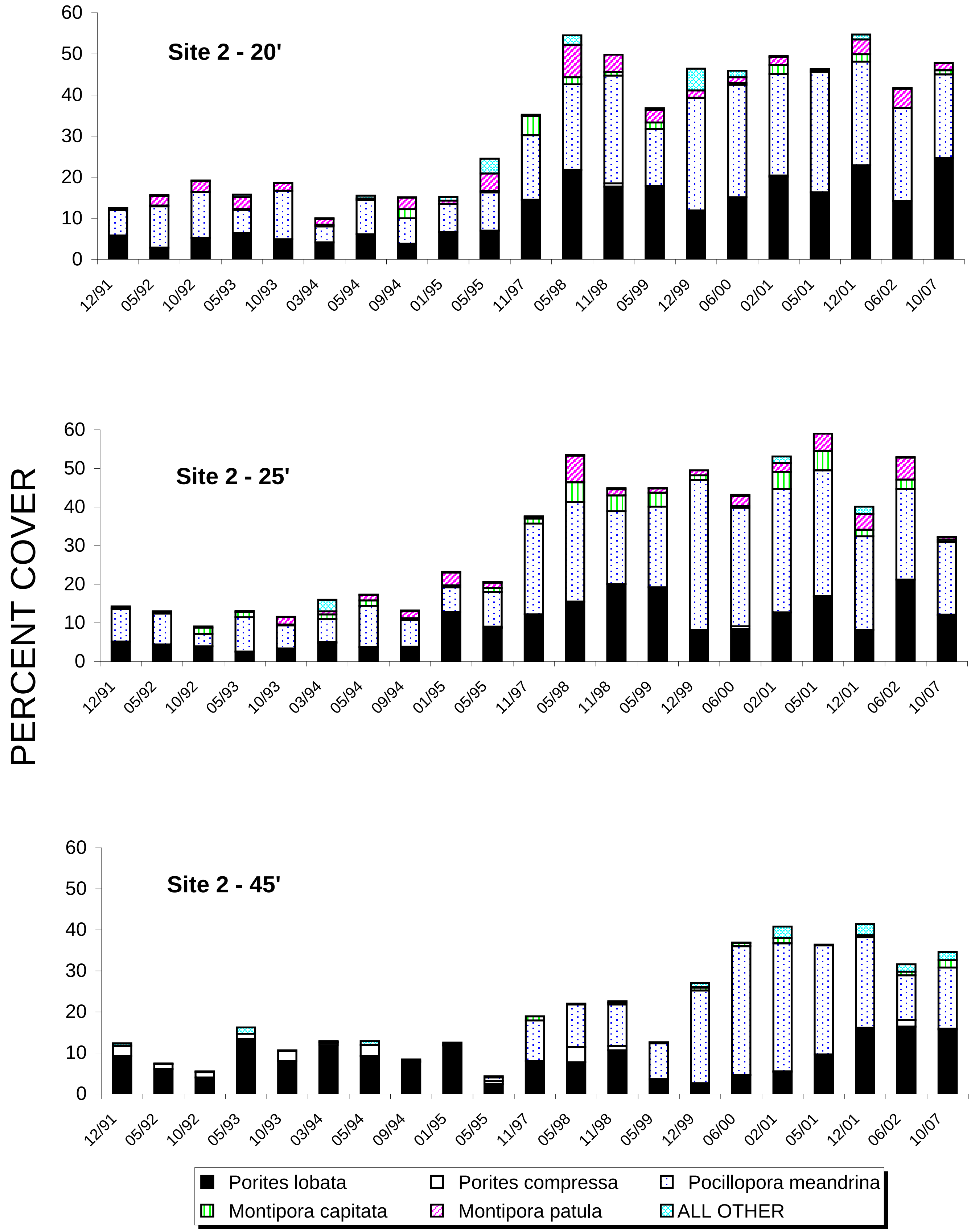


FIGURE 6. Bar graph showing percent cover of major coral species at three depths along the transect at Site 2. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. For location of Site 2, see Figure 1.

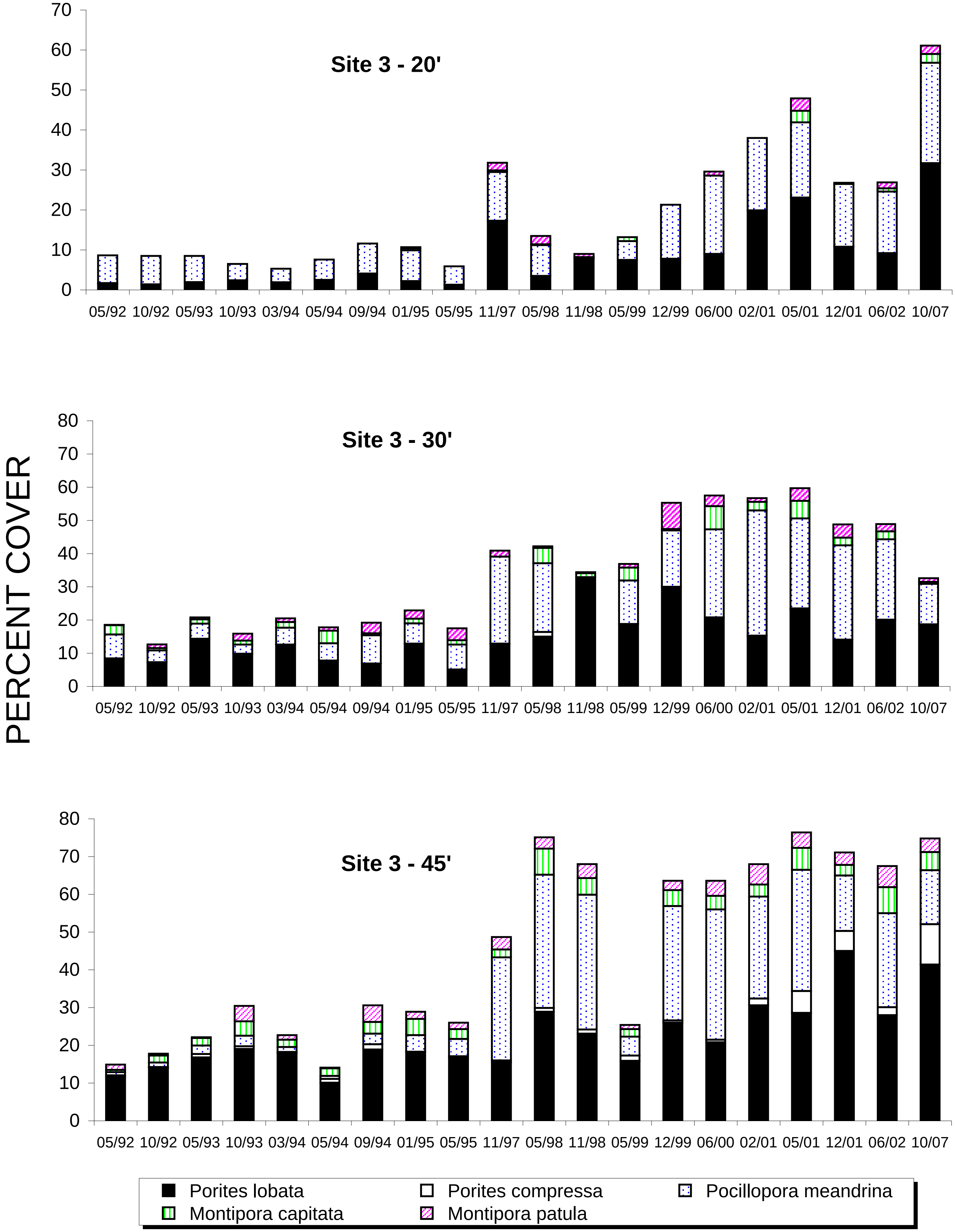


FIGURE 7. Bar graph showing percent cover of major coral species at three depths along the transect at Site 3. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axix scale change for deep transect. For location of Site 3, see Figure 1.

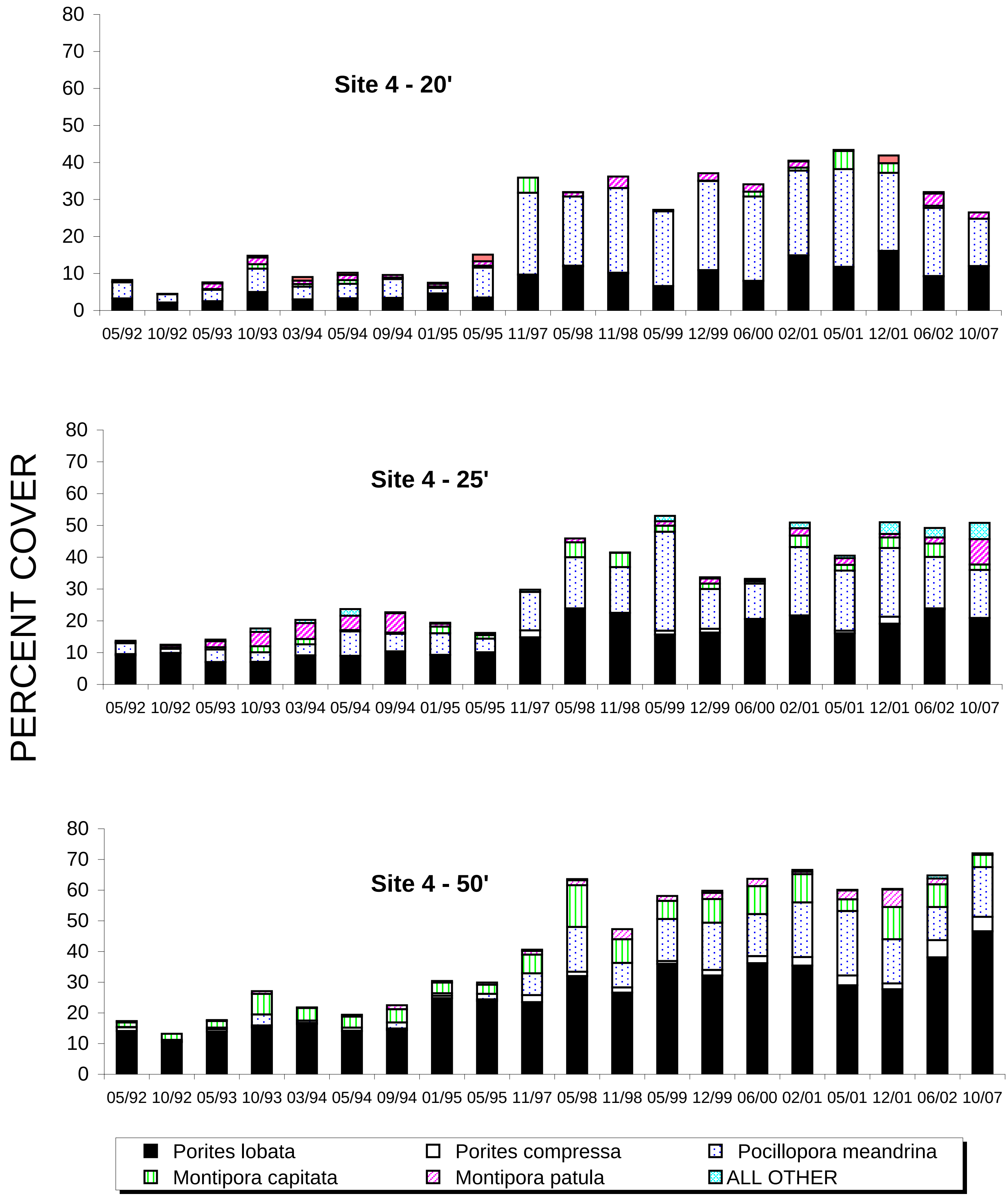


FIGURE 8. Bar graph showing percent cover of major coral species at three depths along the transect at Site 4. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for deep transect. For location of Site 4, see Figure 1.

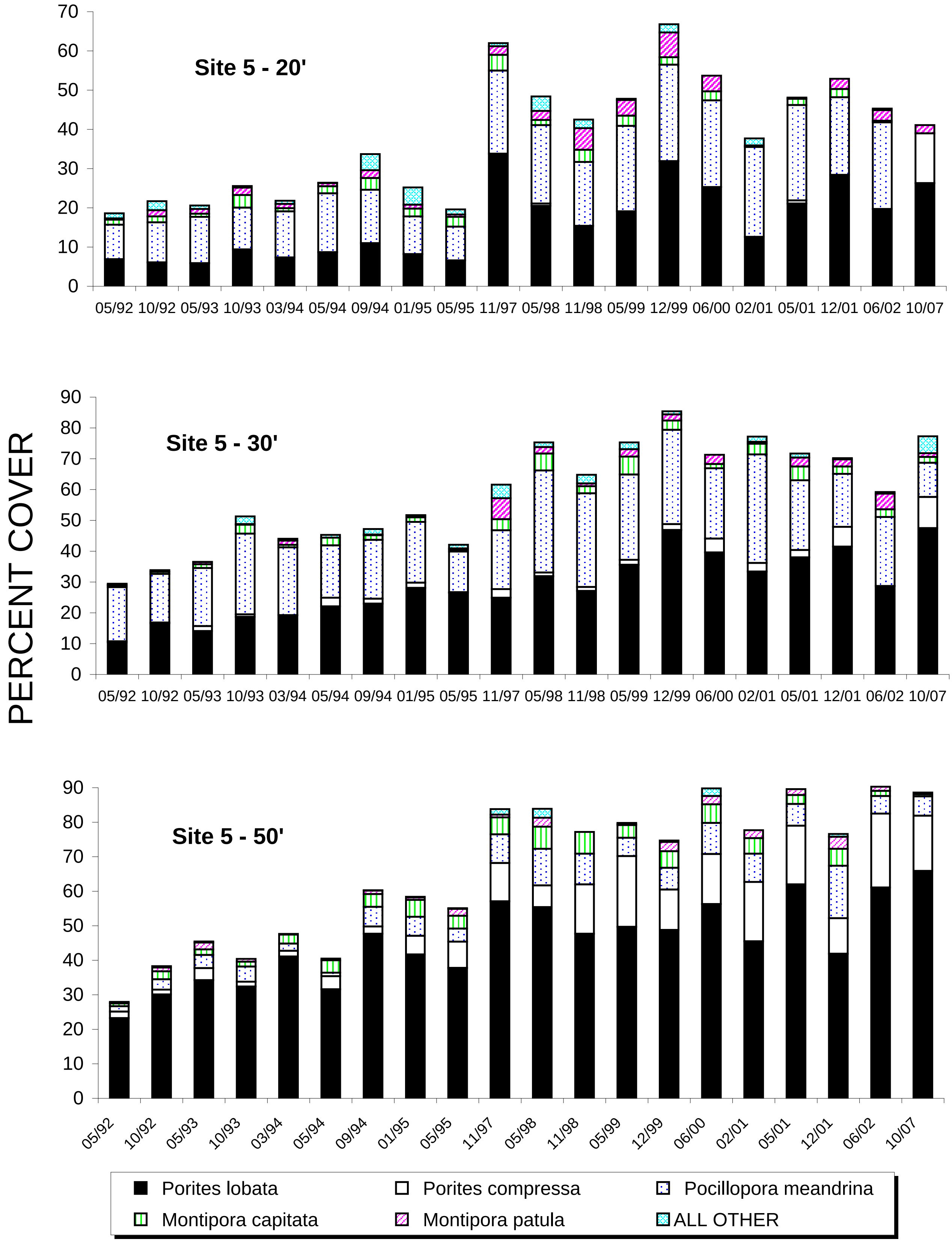


FIGURE 9. Bar graph showing percent cover of major coral species at three depths along the transect at Site 5. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for shallow transect. For location of Site 5, see Figure 1.

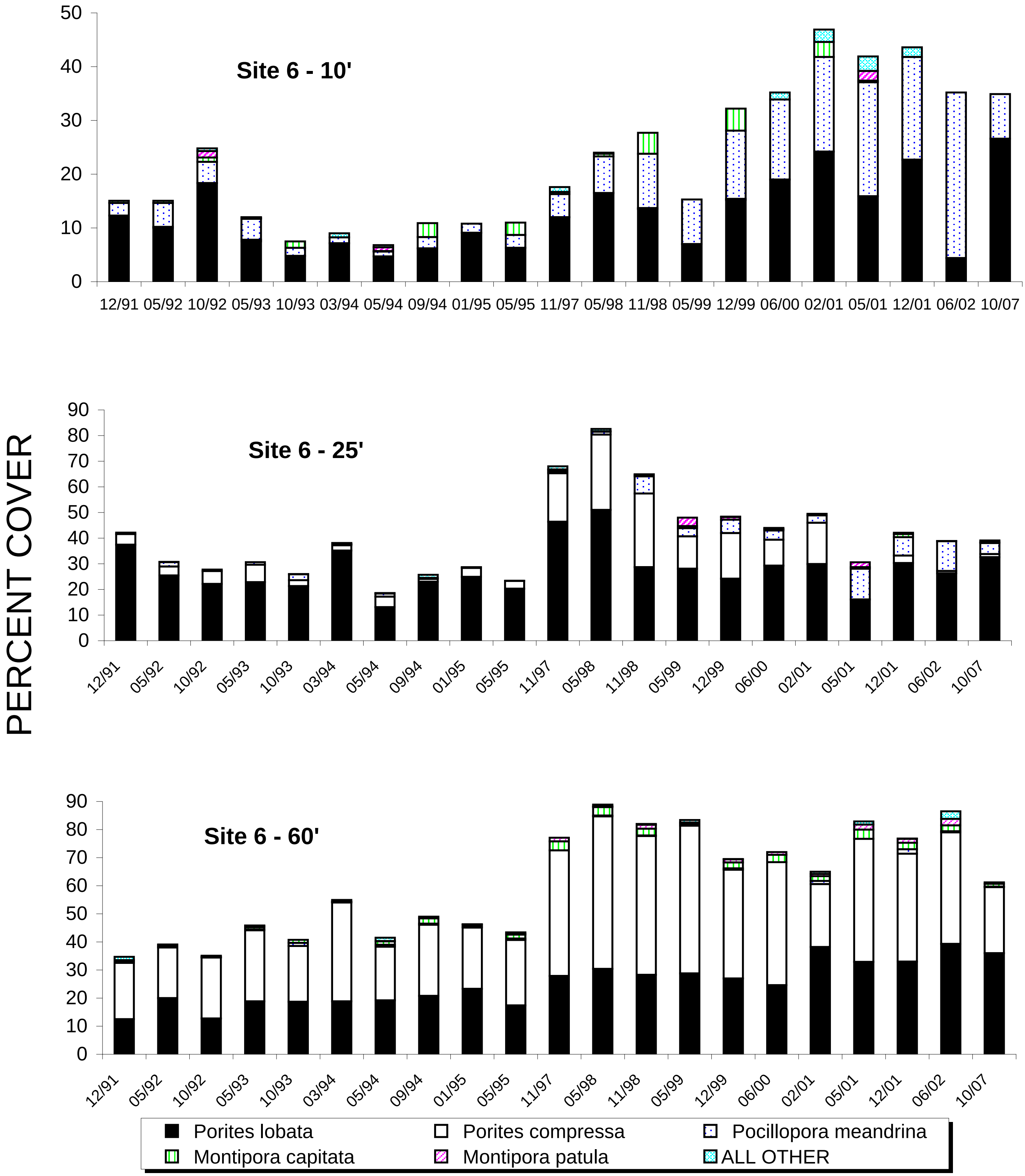


FIGURE 10. Bar graph showing percent cover of major coral species at three depths along the transect at Site 6. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for shallow transect. For location of Site 6, see Figure 1.

APPENDIX A

NELHA BENTHIC MONITORING
OCTOBER 2007

PHOTO-QUADRAT DATA

APPENDIX A-1. Percent cover of coral and non-coral substrata on transects surveyed at Site 1 (WAWALOLI) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	**WAWALOLI SITE 1**	**MEAN CORAL COVER**	**41.2 %**
TRANSECT ID #:	**1-1-15**	**STD. DEV.**	**18.2**
DATE:	**10/13/07**	**SPECIES COUNT**	**6**
		SPECIES DIVERSITY	**0.97**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	8.0	1.0	3.0	16.0	25.0	12.0	52.0	62.0	12.0	58.0	249.0
Porites compressa						2.0					2.0
Pocillopora meandrina	3.0	11.0	18.0	12.0	15.0	18.0	5.0		21.0	7.0	110.0
Montipora capitata	2.0	3.0	20.0	3.0	18.0				2.0		48.0
Montipora patula						1.0					1.0
Pavona varians										2.0	2.0
QUAD CORAL TOTAL	13.0	15.0	41.0	31.0	58.0	33.0	57.0	62.0	35.0	67.0	412.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	67.0	85.0	54.0	69.0	42.0	61.0	39.0	34.0	59.0	12.0	522.0
Limestone	20.0		5.0			6.0	4.0	4.0	6.0	21.0	66.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	**WAWALOLI SITE 1**	**MEAN CORAL COVER**	**59.1 %**
TRANSECT ID #:	**1-2-20**	**STD. DEV.**	**15.0**
DATE:	**10/13/07**	**SPECIES COUNT**	**5**
		SPECIES DIVERSITY	**0.97**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	35.0	44.0	46.0	22.0	58.0	12.0	35.0	24.0	45.0	68.0	389.0
Porites compressa	5.0	10.0	15.0	15.0	4.0			2.0			51.0
Pocillopora meandrina			15.0	16.0	8.0	16.0	29.0	21.0	21.0		126.0
Montipora capitata	2.0	5.0	3.0	3.0					4.0	4.0	21.0
Montipora patula	2.0		2.0								4.0
QUAD CORAL TOTAL	44.0	59.0	81.0	56.0	70.0	28.0	64.0	47.0	70.0	72.0	591.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	51.0	41.0	11.0	40.0	15.0	51.0	15.0	32.0		24.0	280.0
Limestone	5.0		8.0	4.0	15.0	21.0	21.0	21.0	30.0	4.0	129.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	**WAWALOLI SITE 1**	**MEAN CORAL COVER**	**67.4 %**
TRANSECT ID #:	**1-3-35**	**STD. DEV.**	**15.2**
DATE:	**10/13/07**	**SPECIES COUNT**	**4**
		SPECIES DIVERSITY	**0.74**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	28.0	2.0	35.0	75.0	55.0	10.0	22.0	15.0	10.0	55.0	307.0
Porites compressa	45.0	35.0	25.0	2.0	35.0	55.0	25.0	54.0	60.0	25.0	361.0
Pocillopora meandrina	1.0			3.0							4.0
Montipora capitata	1.0			1.0							2.0
QUAD CORAL TOTAL	75.0	37.0	60.0	81.0	90.0	65.0	47.0	69.0	70.0	80.0	674.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt											0.0
Limestone	25.0	63.0	40.0	19.0	10.0	35.0	53.0	31.0	30.0	20.0	326.0
Sand											0.0
Rubble											0.0

APPENDIX A-2. Percent cover of coral and non-coral substrata on transects surveyed at Site 2 (18" PIPE) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	**18" PIPE SITE 2**	**MEAN CORAL COVER**	**47.8 %**
TRANSECT ID #:	**2-1-20**	**STD. DEV.**	**4.8**
DATE:	**10/13/07**	**SPECIES COUNT**	**4**
		SPECIES DIVERSITY	**0.91**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	18.0	30.0	16.0	21.0	14.0	20.0	36.0	38.0	28.0	26.0	247.0
Porites meandrina	33.0	12.0	29.0	24.0	26.0	15.0	14.0	18.0	18.0	14.0	203.0
Montipora capitata	2.0					8.0					10.0
Montipora patula		2.0	2.0		4.0	10.0					18.0
QUAD CORAL TOTAL	53.0	44.0	47.0	45.0	44.0	53.0	50.0	56.0	46.0	40.0	478.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	42.0	41.0	53.0	24.0	56.0	29.0	35.0	26.0	42.0	36.0	384.0
Limestone	5.0	15.0		31.0		18.0	15.0	18.0	12.0	24.0	138.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	**18" PIPE SITE 2**	**MEAN CORAL COVER**	**32.3 %**
TRANSECT ID #:	**2-2-25**	**STD. DEV.**	**6.8**
DATE:	**10/13/07**	**SPECIES COUNT**	**5**
		SPECIES DIVERSITY	**0.86**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	15.0	16.0	3.0	10.0	14.0	5.0	12.0	20.0	15.0	11.0	121.0
Pocillopora meandrina	20.0	15.0	30.0	26.0	26.0	10.0	14.0	12.0	20.0	15.0	188.0
Montipora capitata			2.0	4.0							6.0
Montipora patula	1.0							4.0		1.0	6.0
Pavona varians						2.0					2.0
QUAD CORAL TOTAL	36.0	31.0	35.0	40.0	40.0	17.0	26.0	36.0	35.0	27.0	323.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	49.0	49.0	45.0	32.0	30.0	8.0	59.0	29.0	45.0	43.0	389.0
Limestone	15.0	20.0	20.0	28.0	30.0	25.0	15.0	35.0	20.0	30.0	238.0
Sand						10.0					10.0
Rubble						40.0					40.0

TRANSECT SITE:	**18" PIPE SITE 2**	**MEAN CORAL COVER**	**34.6 %**
TRANSECT ID #:	**2-3-45**	**STD. DEV.**	**14.4**
DATE:	**10/13/07**	**SPECIES COUNT**	**5**
		SPECIES DIVERSITY	**1.07**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	18.0	19.0	11.0	3.0	3.0	27.0	21.0	5.0	35.0	15.0	157.0
Porites compressa									2.0		2.0
Pocillopora meandrina	28.0	40.0	37.0	20.0	11.0	2.0		8.0	3.0		149.0
Pocillopora eydoux								20.0			20.0
Montipora capitata			3.0	2.0	2.0	4.0		5.0	2.0		18.0
QUAD CORAL TOTAL	46.0	59.0	51.0	25.0	16.0	33.0	21.0	38.0	42.0	15.0	346.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt								35.0	38.0	70.0	143.0
Limestone	54.0	41.0	49.0	75.0	84.0	67.0	79.0	27.0	20.0	15.0	511.0
Sand											0.0
Rubble											0.0

APPENDIX A-3. Percent cover of coral and non-coral substrata on transects surveyed at Site 3 (12" PIPE SOUTH) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	12" PIPE SOUTH SITE 3	MEAN CORAL COVER	61.1 %
TRANSECT ID #:	3-1-20	STD. DEV.	13.9
DATE:	10/13/07	SPECIES COUNT	4
		SPECIES DIVERSITY	0.94

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	35.0	55.0	35.0	30.0	34.0	35.0	34.0	26.0	1.0	32.0	317.0
Pocillopora meandrina	26.0	23.0	12.0	30.0	24.0	28.0	27.0	36.0	25.0	20.0	251.0
Montipora capitata	2.0	2.0								18.0	22.0
Montipora patula	4.0		5.0		3.0	3.0		1.0		5.0	21.0
QUAD CORAL TOTAL	67.0	80.0	52.0	60.0	61.0	66.0	61.0	63.0	26.0	75.0	611.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	23.0	15.0	39.0	25.0	19.0			21.0	39.0	14.0	195.0
Limestone	10.0	5.0	9.0	15.0	15.0	34.0	39.0	16.0	35.0	11.0	189.0
Sand											0.0
Rubble					5.0						5.0

TRANSECT SITE:	12" PIPE SOUTH SITE 3	MEAN CORAL COVER	32.6 %
TRANSECT ID #:	3-2-30	STD. DEV.	14.0
DATE:	10/13/07	SPECIES COUNT	4
		SPECIES DIVERSITY	0.87

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	45.0	26.0	18.0	10.0	20.0	2.0	6.0	28.0	4.0	28.0	187.0
Pocillopora meandrina	15.0	24.0	14.0	12.0	1.0	22.0	24.0		2.0	8.0	122.0
Montipora capitata								4.0	2.0		6.0
Montipora patula						5.0		6.0			11.0
QUAD CORAL TOTAL	60.0	50.0	32.0	22.0	21.0	29.0	30.0	38.0	8.0	36.0	326.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	40.0	35.0	48.0	78.0	74.0	51.0	52.0	62.0	90.0	59.0	589.0
Limestone		15.0	20.0		5.0	20.0	18.0		2.0	5.0	85.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE SOUTH SITE 3	MEAN CORAL COVER	74.8 %
TRANSECT ID #:	3-3-45	STD. DEV.	12.4
DATE:	10/13/07	SPECIES COUNT	5
		SPECIES DIVERSITY	1.24

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	20.0	66.0	55.0	40.0	35.0	44.0	45.0	35.0	34.0	40.0	414.0
Porites compressa	8.0	3.0	6.0	30.0	18.0		20.0	10.0		12.0	107.0
Pocillopora meandrina	16.0	12.0	15.0	20.0	21.0	9.0		10.0	26.0	14.0	143.0
Montipora capitata	20.0	4.0			18.0		4.0	2.0			48.0
Montipora patula	12.0	4.0					3.0	2.0	15.0		36.0
QUAD CORAL TOTAL	76.0	89.0	76.0	90.0	92.0	53.0	72.0	59.0	75.0	66.0	748.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt			19.0			47.0	7.0	41.0	10.0	14.0	138.0
Limestone	24.0	11.0	5.0	10.0	8.0		21.0		15.0	20.0	114.0
Sand											0.0
Rubble											0.0

APPENDIX A-4. Percent cover of coral and non-coral substrata on transects surveyed at Site 4 (12" PIPE NORTH) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	12" PIPE NORTH SITE 4	MEAN CORAL COVER	26.5 %
TRANSECT ID #:	4-1-20	STD. DEV.	11.5
DATE:	10/13/07	SPECIES COUNT	3
		SPECIES DIVERSITY	0.89

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	21.0	11.0	27.0	5.0	6.0	11.0	27.0	8.0		4.0	120.0
Pocillopora meandrina	20.0	10.0	5.0	4.0	10.0	21.0	20.0	5.0	15.0	18.0	128.0
Montipora patula	2.0				1.0			12.0		2.0	17.0
QUAD CORAL TOTAL	43.0	21.0	32.0	9.0	17.0	32.0	47.0	25.0	15.0	24.0	265.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	49.0	79.0	65.0	88.0	79.0	60.0	53.0	73.0	83.0	71.0	700.0
Limestone	8.0		3.0	3.0	4.0	8.0		2.0	2.0	5.0	35.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE NORTH SITE 4	MEAN CORAL COVER	50.8 %
TRANSECT ID #:	4-2-25	STD. DEV.	21.1
DATE:	10/13/07	SPECIES COUNT	6
		SPECIES DIVERSITY	1.37

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	19.0	3.0	15.0	38.0	16.0	10.0	35.0	60.0	5.0	8.0	209.0
Pocillopora meandrina	26.0	20.0	18.0	5.0	10.0	25.0	20.0	22.0		5.0	151.0
Pocillopora eydoux		25.0		25.0							50.0
Montipora capitata					8.0				6.0	3.0	17.0
Montipora patula			30.0	10.0	5.0	5.0	15.0			15.0	80.0
Pavona duerdeni										1.0	1.0
QUAD CORAL TOTAL	45.0	48.0	63.0	78.0	39.0	40.0	70.0	82.0	11.0	32.0	508.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	49.0	47.0	25.0	14.0	44.0	30.0	25.0	13.0		58.0	305.0
Limestone	6.0	5.0	12.0	8.0	17.0	30.0	5.0	5.0	89.0	10.0	187.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE NORTH SITE 4	MEAN CORAL COVER	72 %
TRANSECT ID #:	4-3-50	STD. DEV.	15.4
DATE:	10/13/07	SPECIES COUNT	5
		SPECIES DIVERSITY	0.99

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	50.0	29.0	33.0	26.0	80.0	60.0	50.0	60.0	35.0	43.0	466.0
Porites compressa			3.0	6.0	15.0	4.0	8.0	5.0		6.0	47.0
Pocillopora meandrina	16.0	20.0	21.0	6.0	3.0	28.0	17.0	22.0	14.0	15.0	162.0
Montipora capitata	2.0	15.0		12.0				3.0	8.0		40.0
Montipora patula			5.0								5.0
QUAD CORAL TOTAL	68.0	64.0	62.0	50.0	98.0	92.0	75.0	90.0	57.0	64.0	720.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	27.0	33.0	17.0	20.0			20.0	10.0	37.0	24.0	188.0
Limestone	5.0	3.0	21.0	30.0	2.0	8.0	5.0		6.0	12.0	92.0
Sand											0.0
Rubble											0.0

APPENDIX A-5. Percent cover of coral and non-coral substrata on transects surveyed at Site 5 (NPPE) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	NPPE SITE 5	MEAN CORAL COVER	41.1 %
TRANSECT ID #:	5-1-20	STD. DEV.	20.7
DATE:	10/13/07	SPECIES COUNT	3
		SPECIES DIVERSITY	0.80

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	12.0	3.0	6.0	14.0	46.0	46.0	19.0	22.0	56.0	39.0	263.0
Porites compressa	8.0	1.0	8.0	15.0	20.0	15.0	23.0	12.0	14.0	11.0	127.0
Montipora patula	20.0				1.0						21.0
QUAD CORAL TOTAL	40.0	4.0	14.0	29.0	67.0	61.0	42.0	34.0	70.0	50.0	411.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt	30.0	66.0	58.0	21.0	8.0	5.0	50.0	44.0	20.0	39.0	341.0
Limestone	30.0	30.0	28.0	50.0	25.0	34.0	8.0	22.0	10.0	11.0	248.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	NPPE SITE 5	MEAN CORAL COVER	77.3 %
TRANSECT ID #:	5-2-30	STD. DEV.	14.4
DATE:	10/13/07	SPECIES COUNT	6
		SPECIES DIVERSITY	1.19

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	44.0	35.0	26.0	40.0	76.0	22.0	40.0	60.0	52.0	80.0	475.0
Porites compressa					14.0	20.0	35.0	15.0	17.0		101.0
Pocillopora meandrina	21.0		18.0	30.0	6.0	8.0	18.0	5.0	5.0		111.0
Pocillopora eydoux		55.0									55.0
Montipora capitata	4.0					15.0					19.0
Montipora patula	8.0								4.0		12.0
QUAD CORAL TOTAL	77.0	90.0	44.0	70.0	96.0	65.0	93.0	80.0	78.0	80.0	773.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt			56.0	30.0	4.0	35.0			22.0	10.0	157.0
Limestone	23.0	10.0					7.0	20.0		10.0	70.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	NPPE SITE 5	MEAN CORAL COVER	88.6 %
TRANSECT ID #:	5-3-50	STD. DEV.	6.1
DATE:	10/13/07	SPECIES COUNT	5
		SPECIES DIVERSITY	0.77

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	65.0	60.0	75.0	68.0	65.0	59.0	54.0	63.0	66.0	84.0	659.0
Porites compressa	15.0	13.0	5.0	10.0	29.0	10.0	20.0	26.0	28.0	4.0	160.0
Pocillopora meandrina	5.0	15.0	11.0	2.0		10.0	8.0	4.0		1.0	56.0
Montipora capitata		2.0						2.0	2.0		6.0
Montipora patula	2.0		3.0								5.0
QUAD CORAL TOTAL	87.0	90.0	94.0	80.0	94.0	79.0	82.0	95.0	96.0	89.0	886.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt											0.0
Limestone	13.0	10.0	6.0	20.0	6.0	21.0	18.0	5.0	4.0	11.0	114.0
Sand											0.0
Rubble											0.0

APPENDIX A-6. Percent cover of coral and non-coral substrata on transects surveyed at Site 6 (HO'ONA BAY) in the vicinity of NELHA in October 2007. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	**HOONA BAY SITE 6**	**MEAN CORAL COVER**	**34.9 %**
TRANSECT ID #:	**6-1-10**	**STD. DEV.**	**19.5**
DATE:	**10/13/07**	**SPECIES COUNT**	**2**
		SPECIES DIVERSITY	**0.55**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	12.0	19.0	33.0	10.0	35.0	48.0	20.0	18.0	15.0	56.0	266.0
Pocillopora meandrina	1.0	26.0	27.0	8.0	5.0	1.0			1.0	14.0	83.0
QUAD CORAL TOTAL	13.0	45.0	60.0	18.0	40.0	49.0	20.0	18.0	16.0	70.0	349.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	87.0	55.0	26.0	82.0	60.0	51.0	80.0	82.0	84.0	20.0	627.0
Limestone			14.0							10.0	24.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	**HOONA BAY SITE 6**	**MEAN CORAL COVER**	**39.1 %**
TRANSECT ID #:	**6-2-25**	**STD. DEV.**	**20.3**
DATE:	**10/13/07**	**SPECIES COUNT**	**5**
		SPECIES DIVERSITY	**0.61**

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	68.0	26.0	21.0	21.0	21.0	14.0	34.0	80.0	15.0	26.0	326.0
Porites compressa									2.0	10.0	12.0
Pocillopora meandrina				18.0			7.0		4.0	14.0	43.0
Montipora capitata			3.0								3.0
Montipora patula		2.0			1.0	2.0			1.0	1.0	7.0
QUAD CORAL TOTAL	68.0	28.0	24.0	39.0	22.0	16.0	41.0	80.0	22.0	51.0	391.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt						84.0			53.0	36.0	173.0
Limestone	32.0	72.0	76.0	61.0	78.0		59.0	20.0	25.0	13.0	436.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	**HOONA BAY SITE 6**	**MEAN CORAL COVER**	**61.2 %**
TRANSECT ID #:	**6-3-50**	**STD. DEV.**	**35.2**
DATE:	**10/13/07**	**SPECIES COUNT**	**5**
		SPECIES DIVERSITY	**0.80**

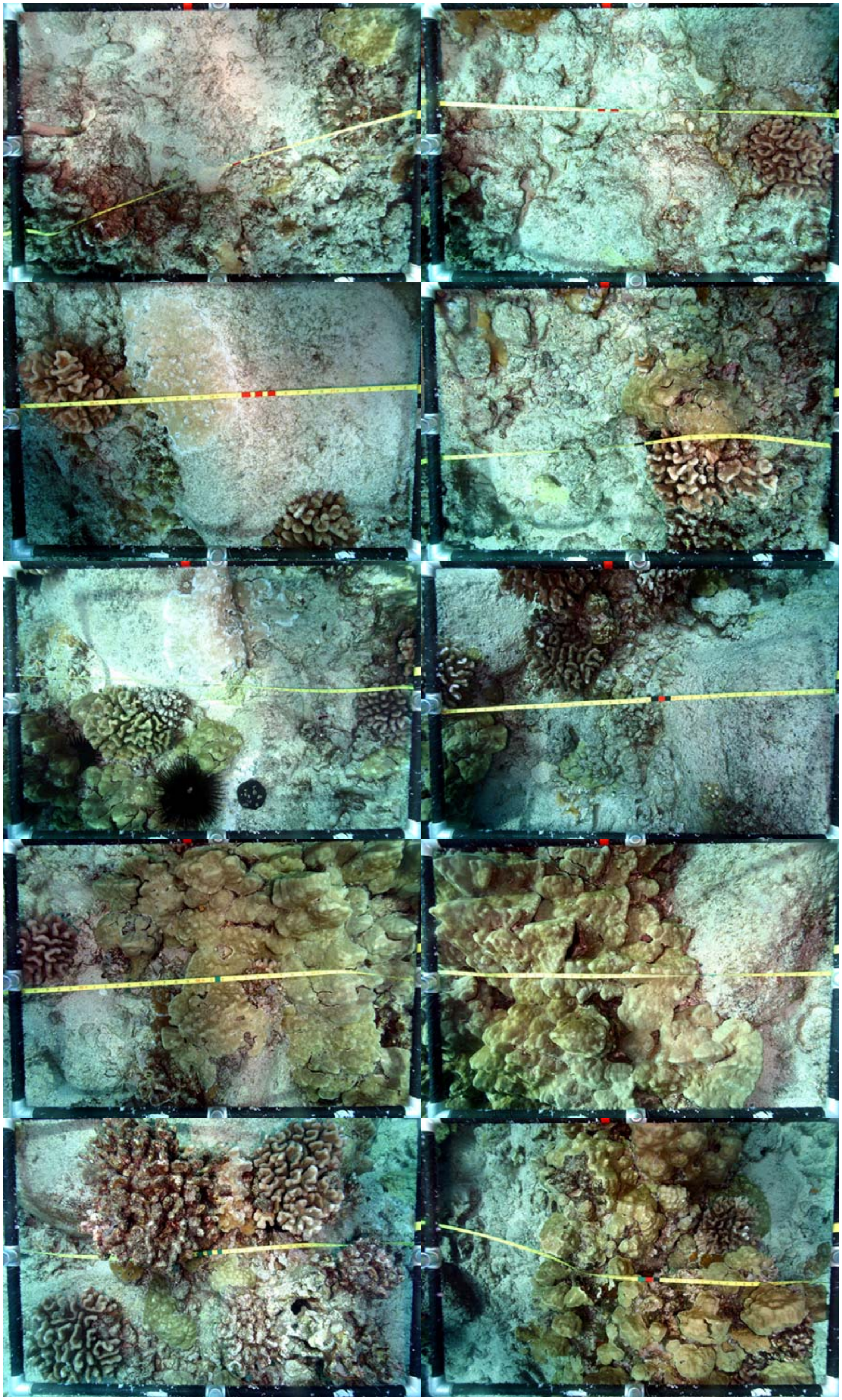
SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	56.0	76.0	40.0	35.0	22.0	46.0	35.0	10.0	30.0	10.0	360.0
Porites compressa	20.0	16.0	55.0	60.0		50.0	24.0	10.0			235.0
Pocillopora meandrina		2.0									2.0
Montipora capitata	9.0			1.0							10.0
Montipora patula		3.0	1.0	1.0							5.0
QUAD CORAL TOTAL	85.0	97.0	96.0	97.0	22.0	96.0	59.0	20.0	30.0	10.0	612.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt									10.0		10.0
Limestone	15.0	3.0	4.0	3.0		4.0	41.0	20.0			90.0
Sand									20.0		20.0
Rubble					78.0			60.0	40.0	90.0	268.0

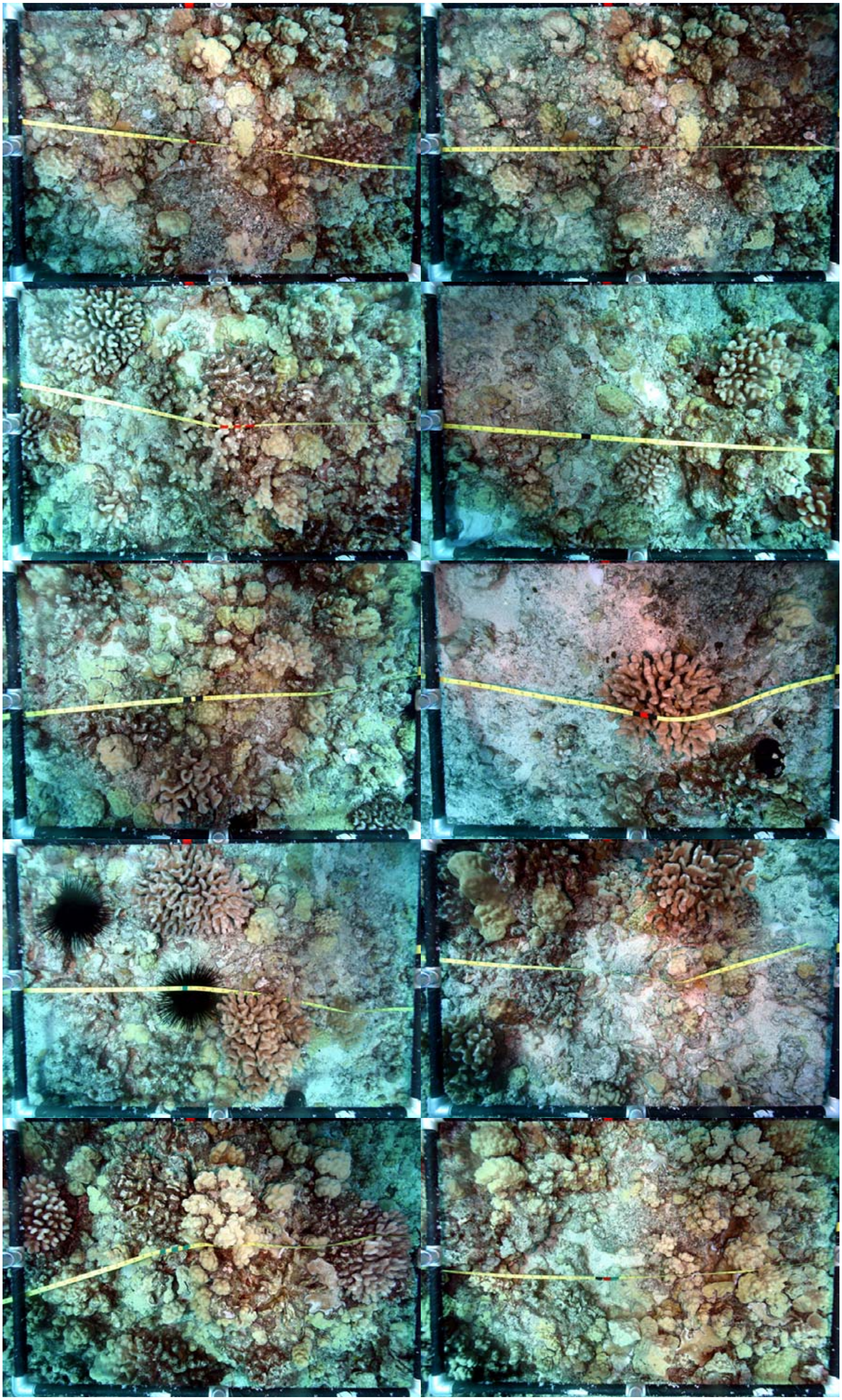
APPENDIX B

NELHA BENTHIC MONITORING
OCTOBER 2007

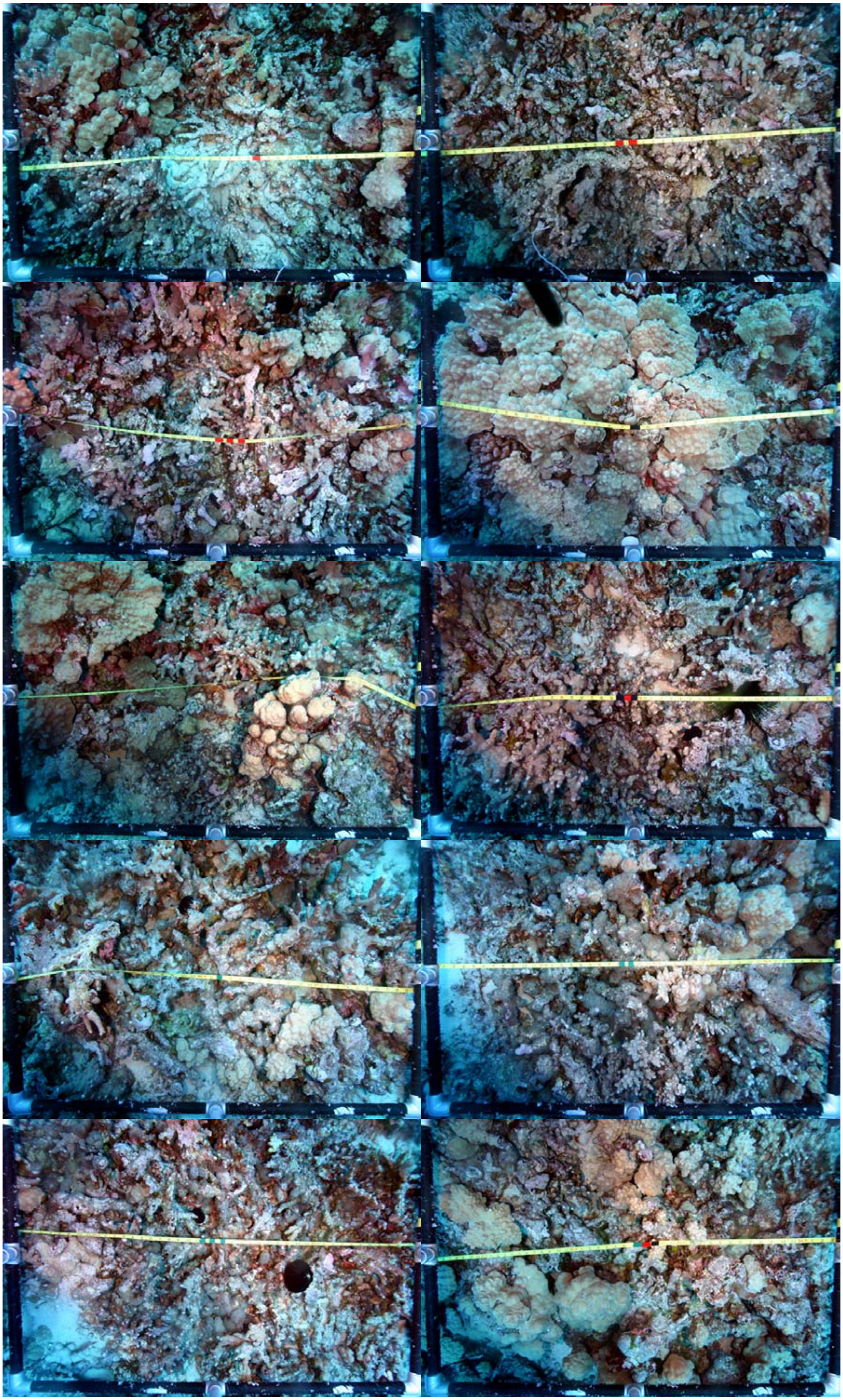
PHOTO-QUADRATS



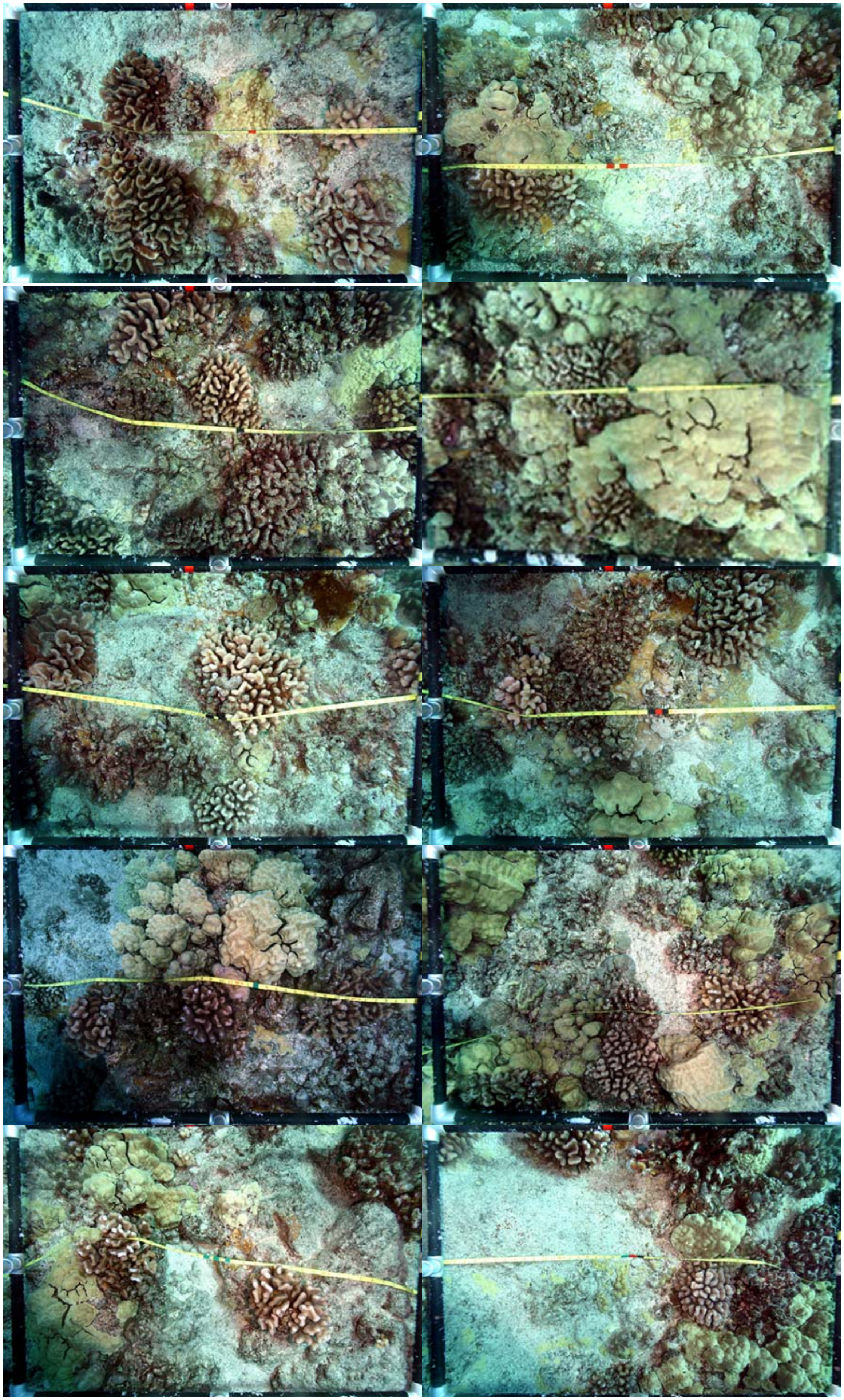
NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-15; QUADRATS 1-10
OCTOBER 2007



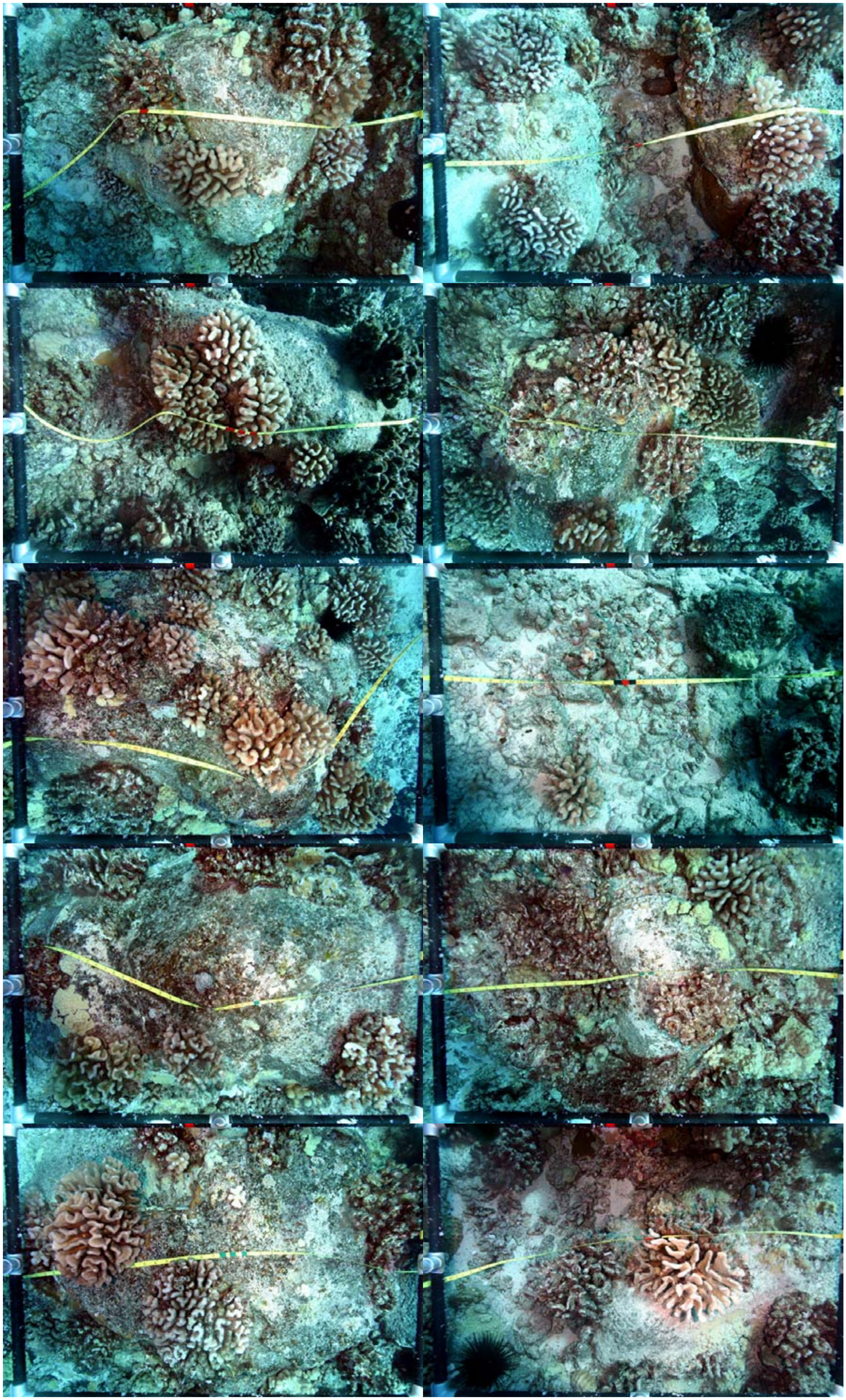
NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-20; QUADRATS 1-10
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-35; QUADRATS 1- 10.
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-20; QUADRATS 1-10
OCTOBER 2007



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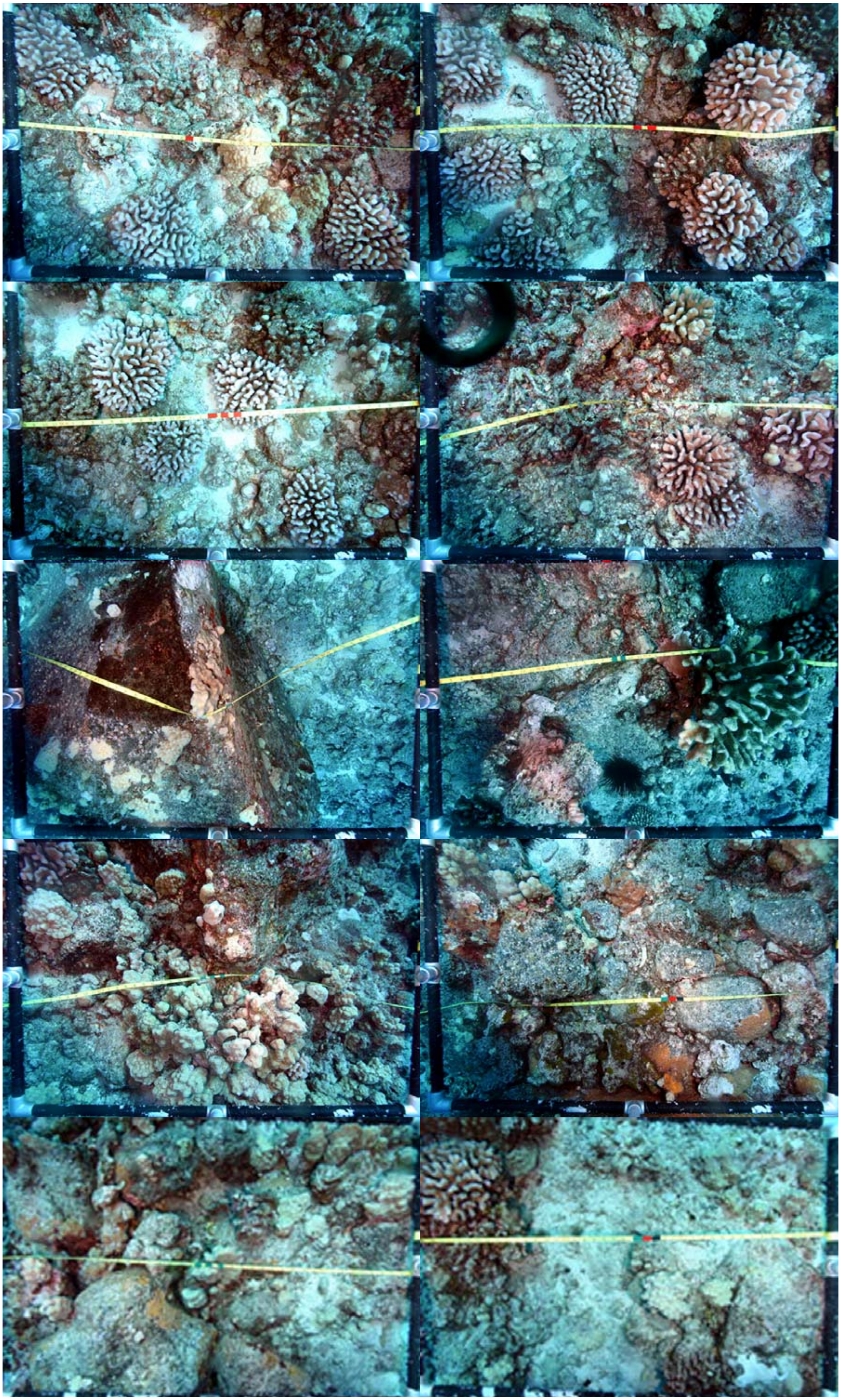
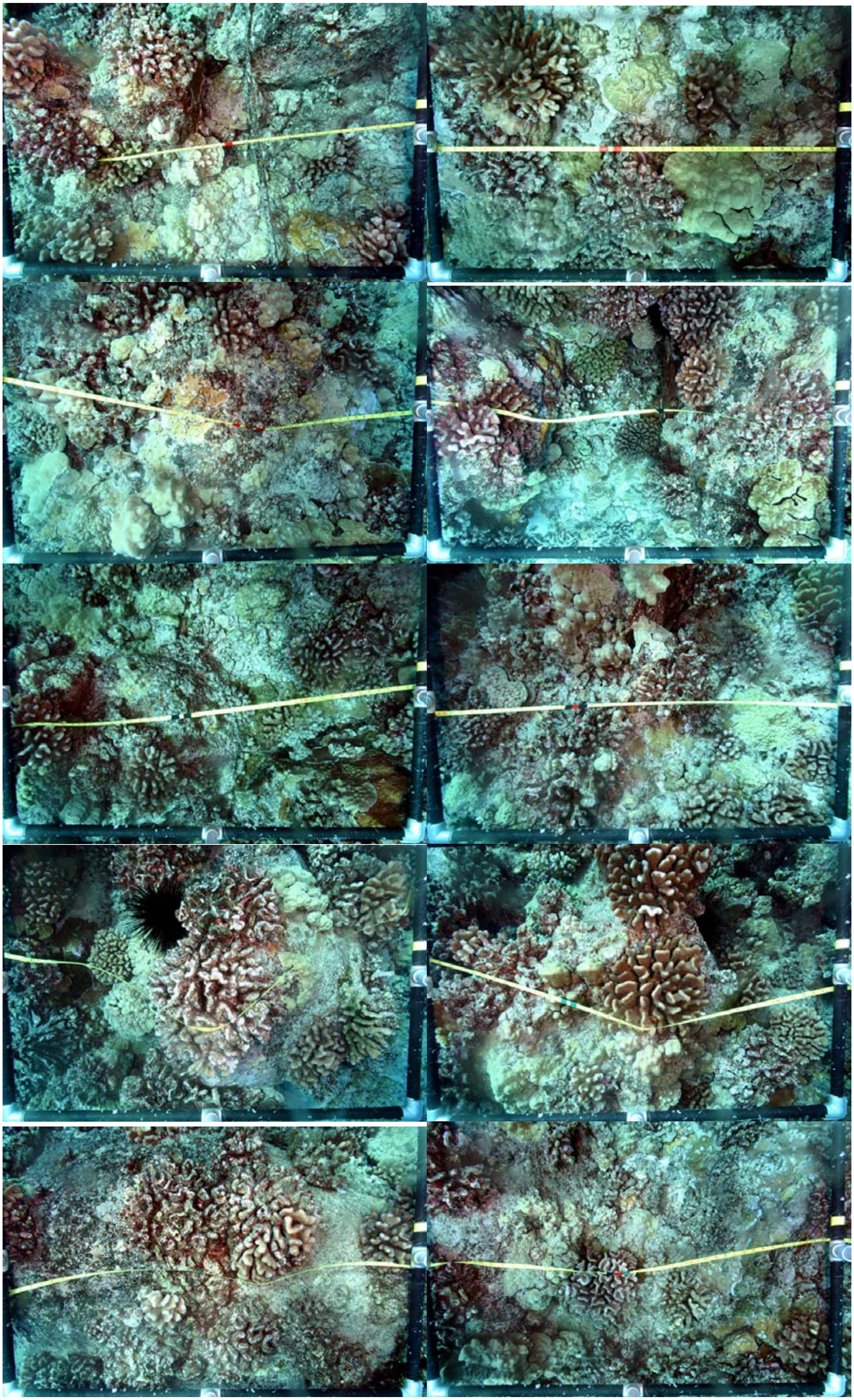
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-45; QUADRATS 1-10
OCTOBER 2008



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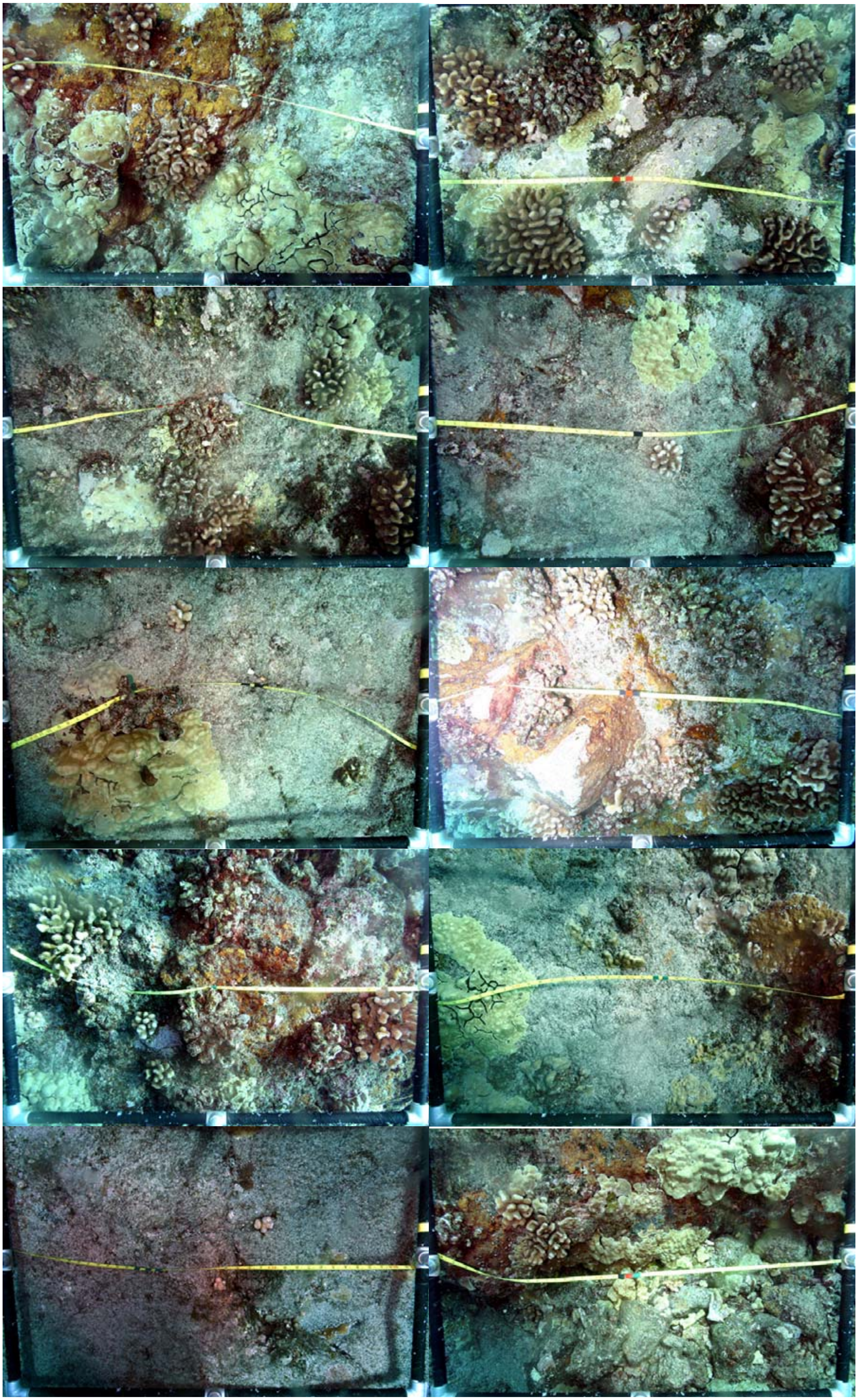
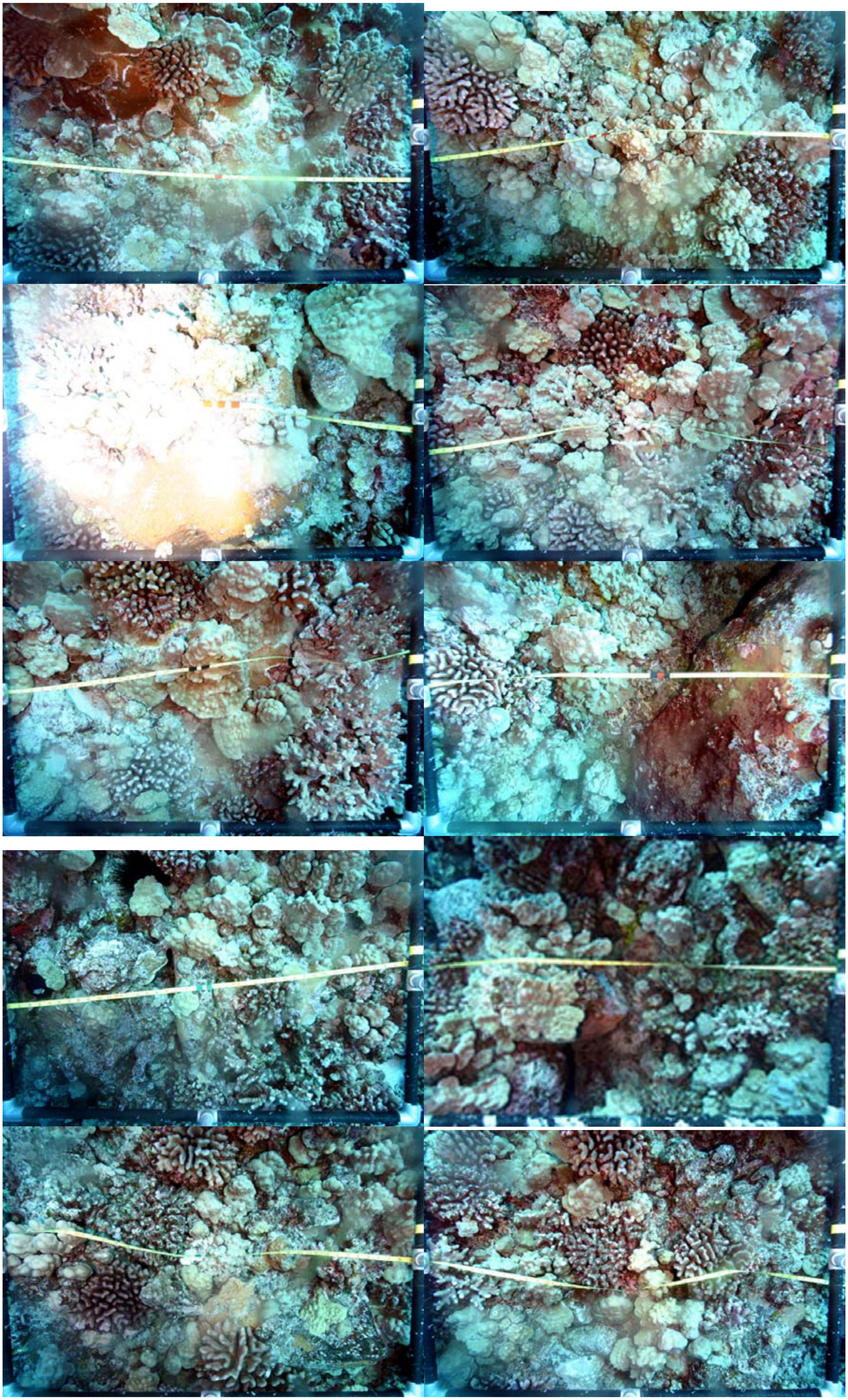
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 3-30; QUADRATS 1-10
OCTOBER 2007



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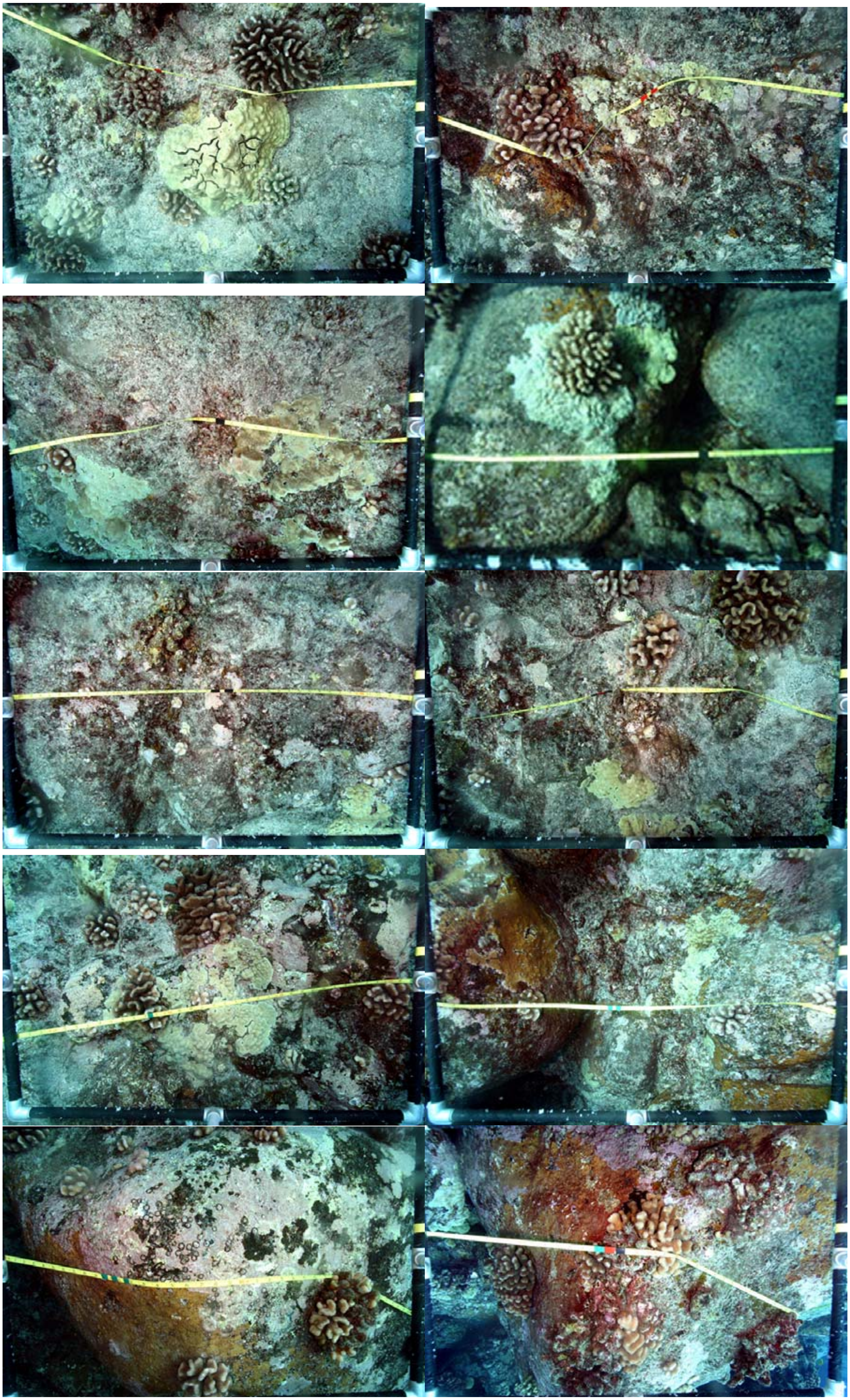
OCTOBER 2007



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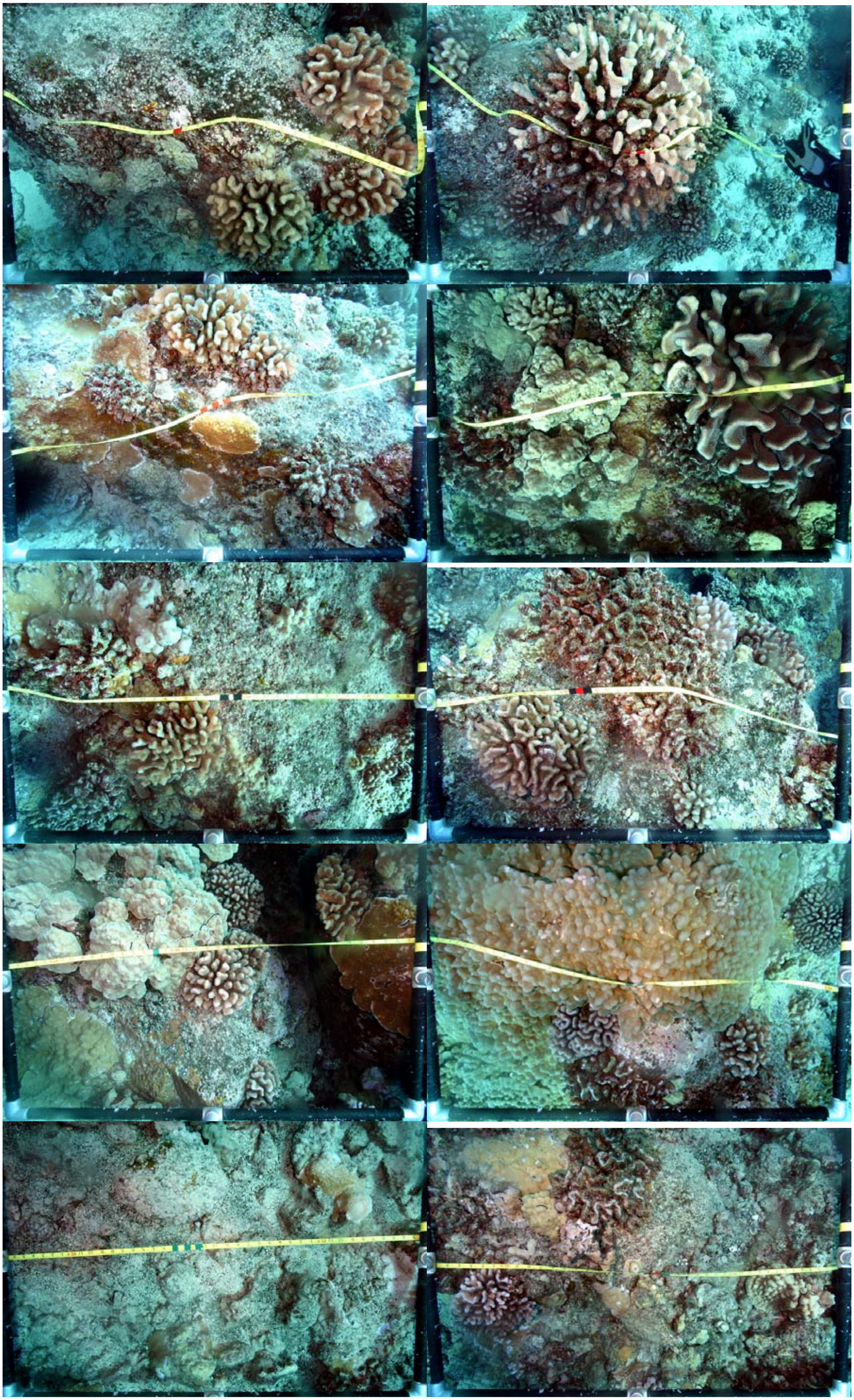
OCTOBER 2007



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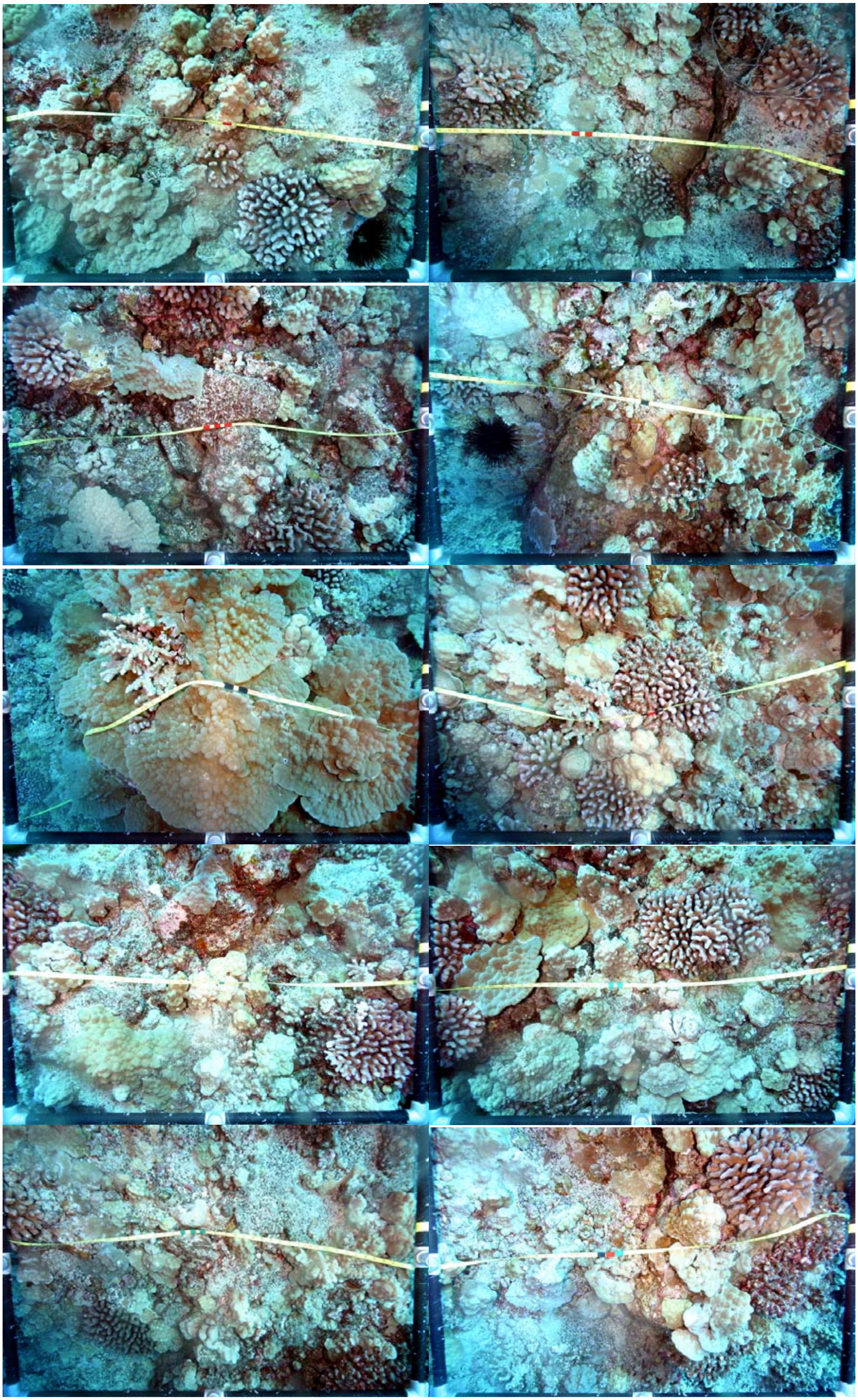
OCTOBER 2007



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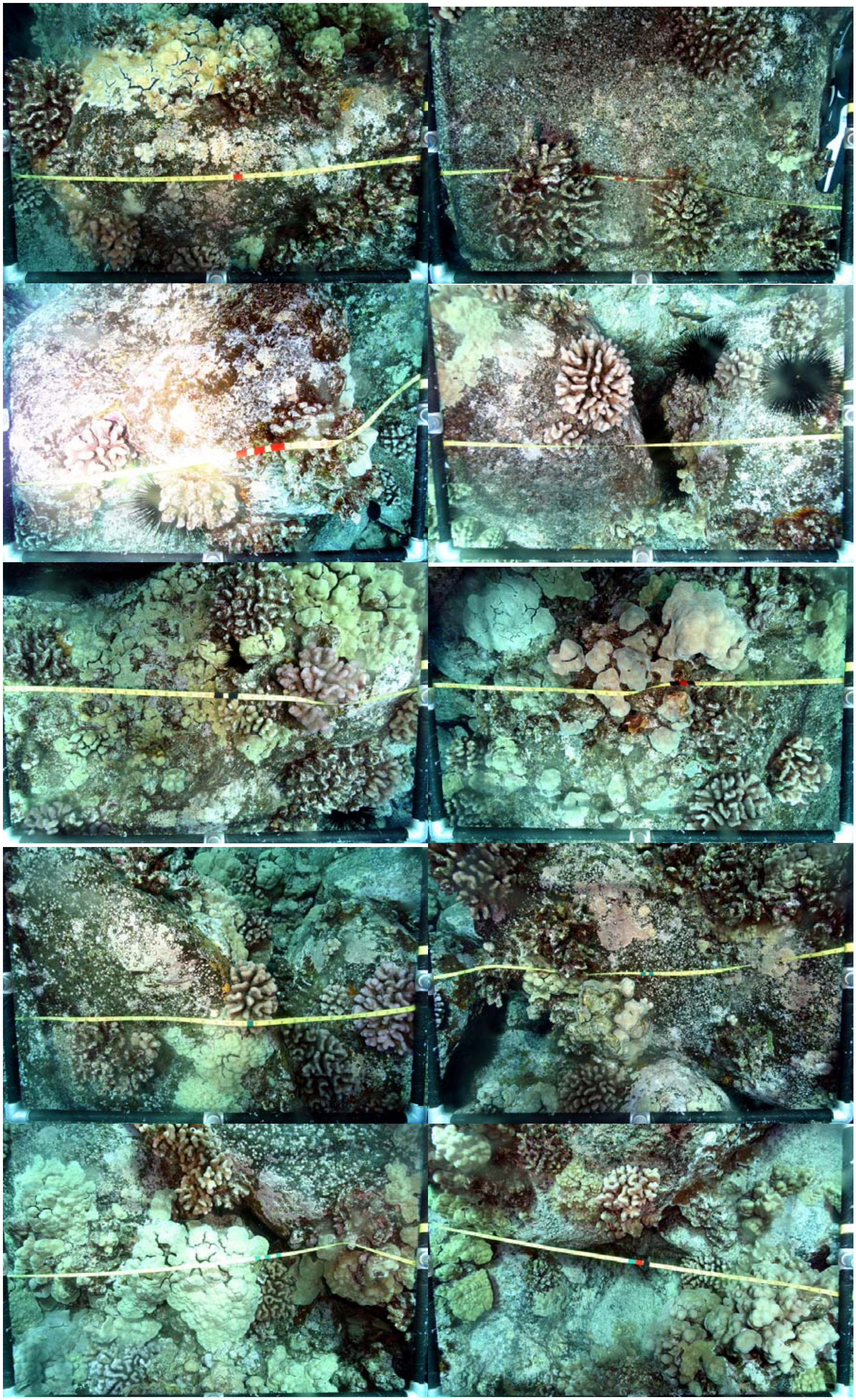
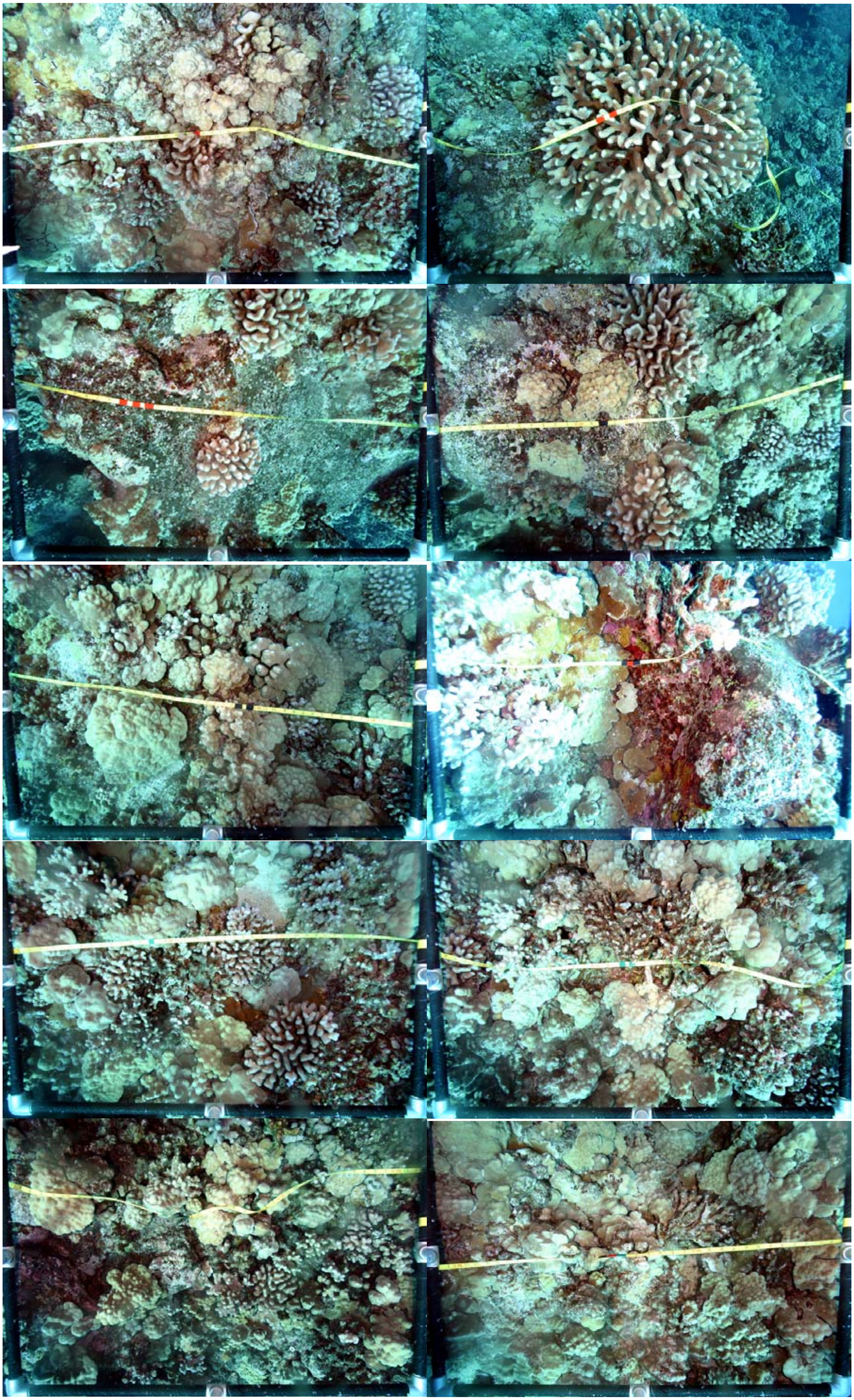
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 5-20; QUADRATS 1-10 - OCTOBER 2007



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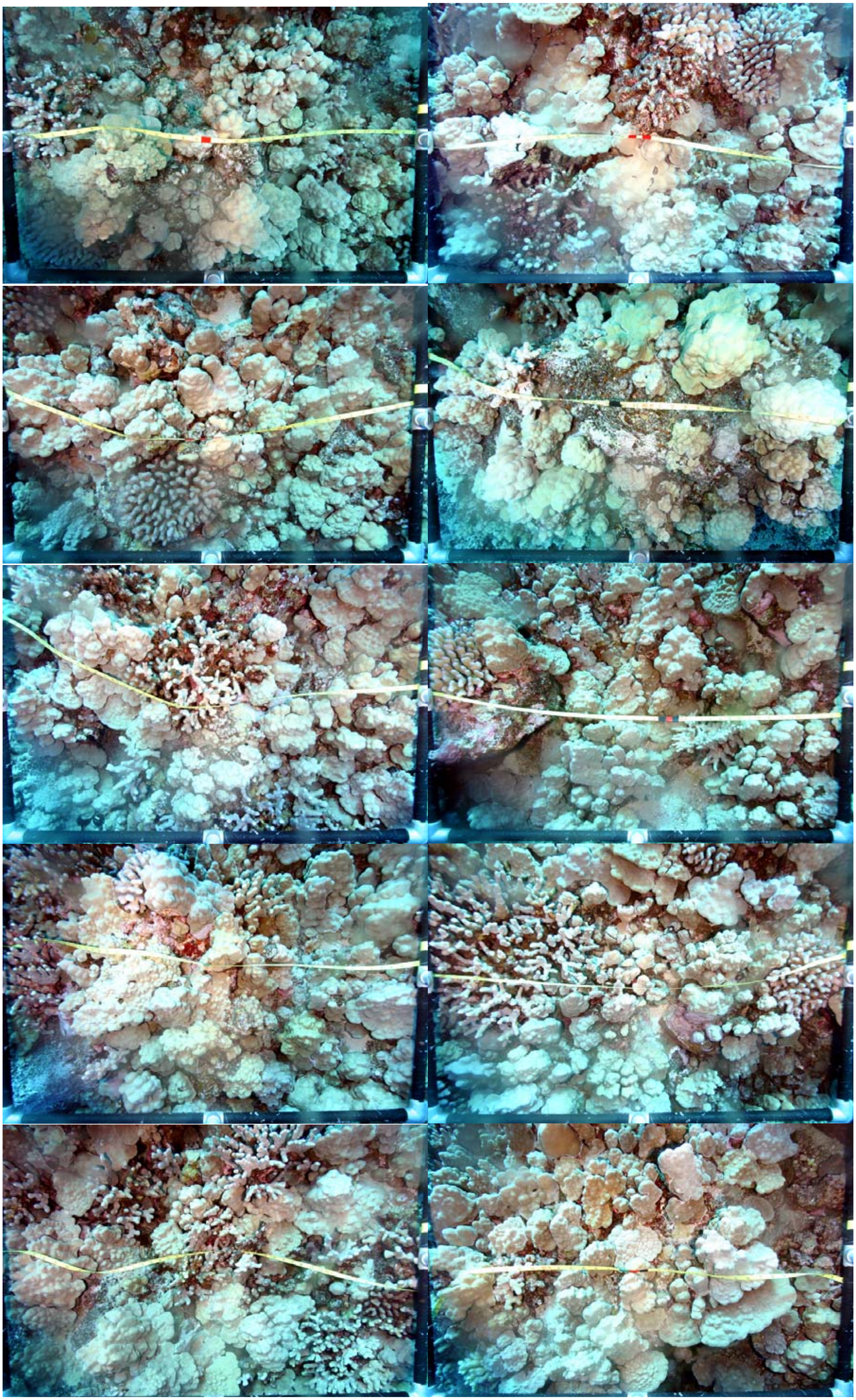

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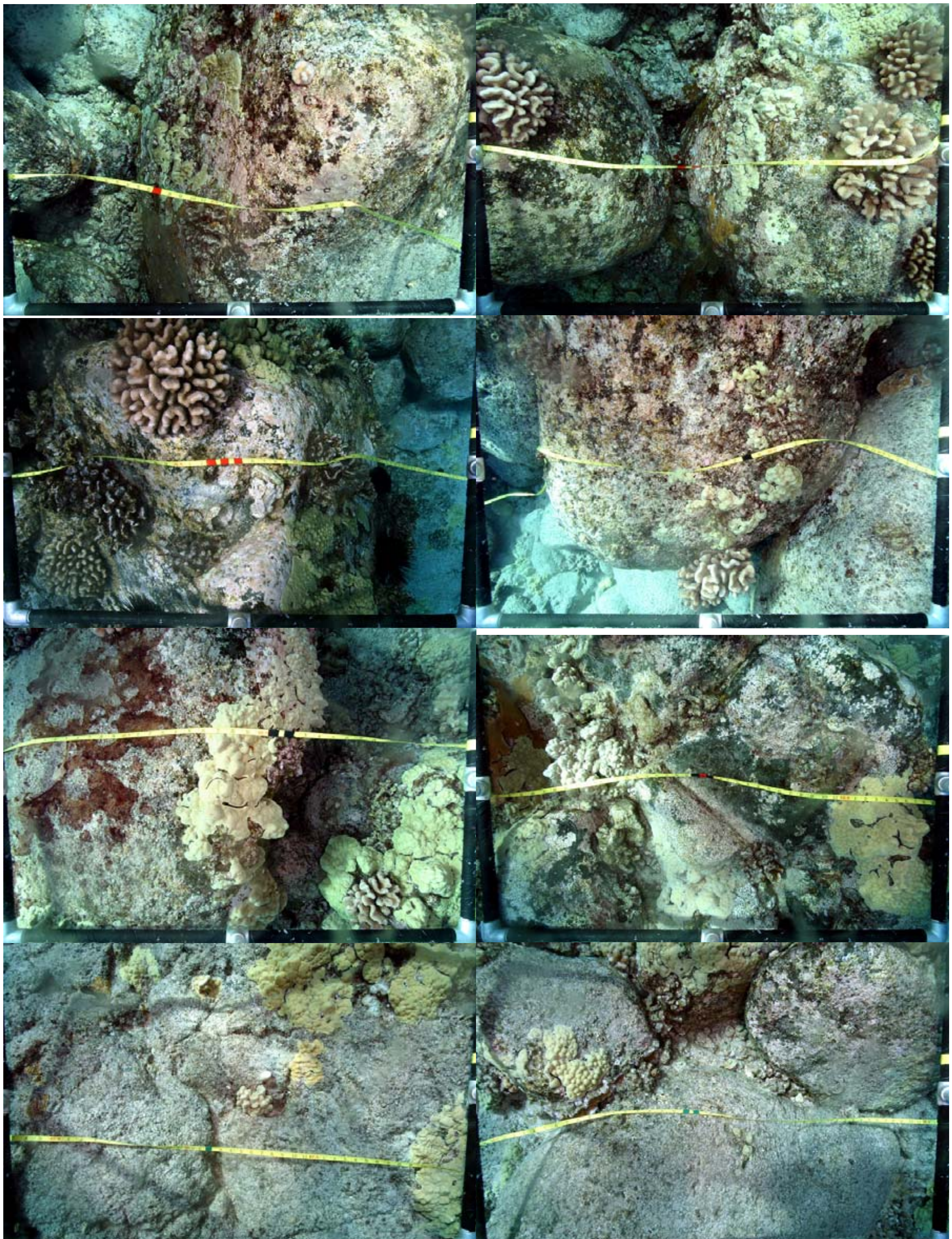
OCTOBER 2007



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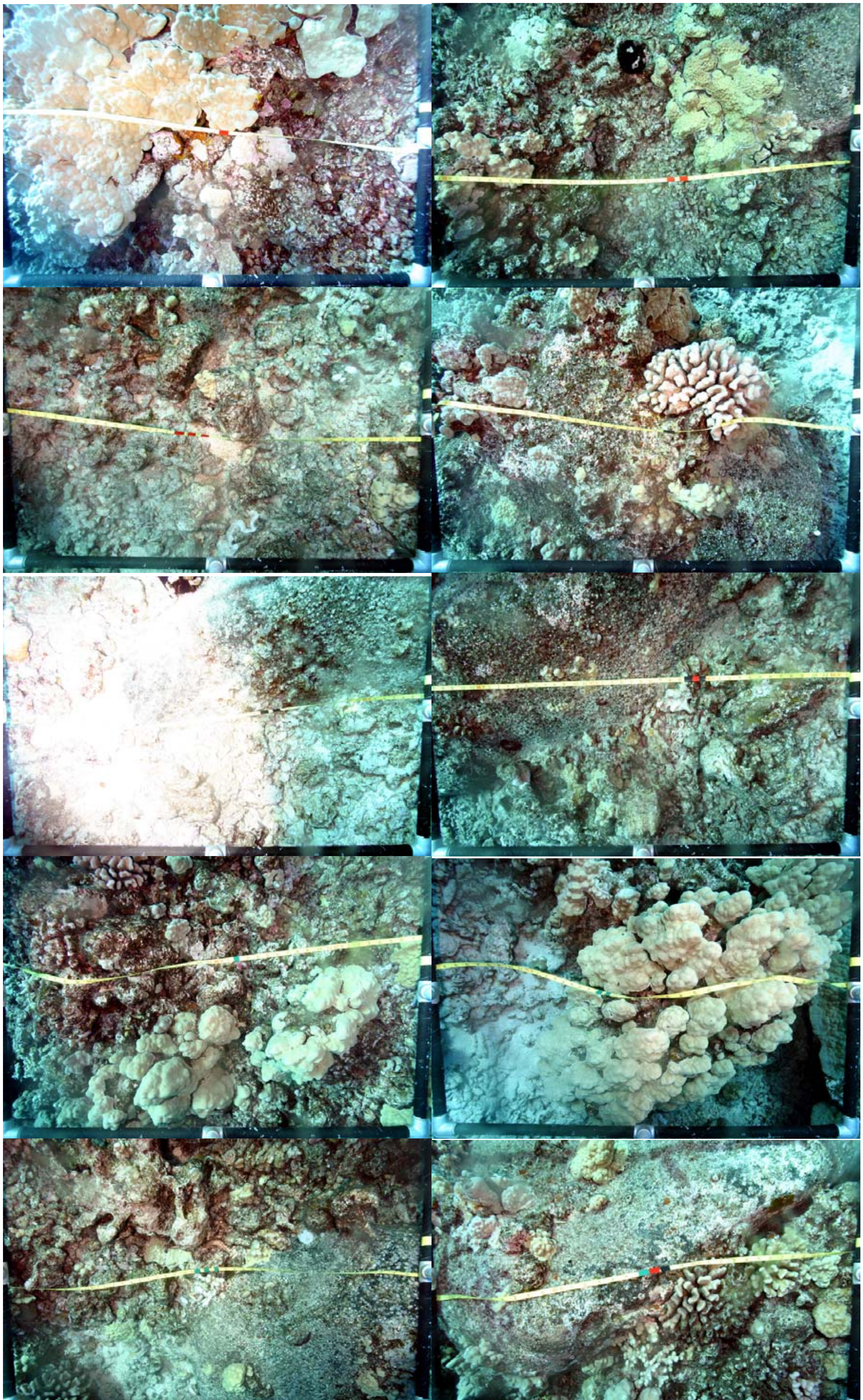

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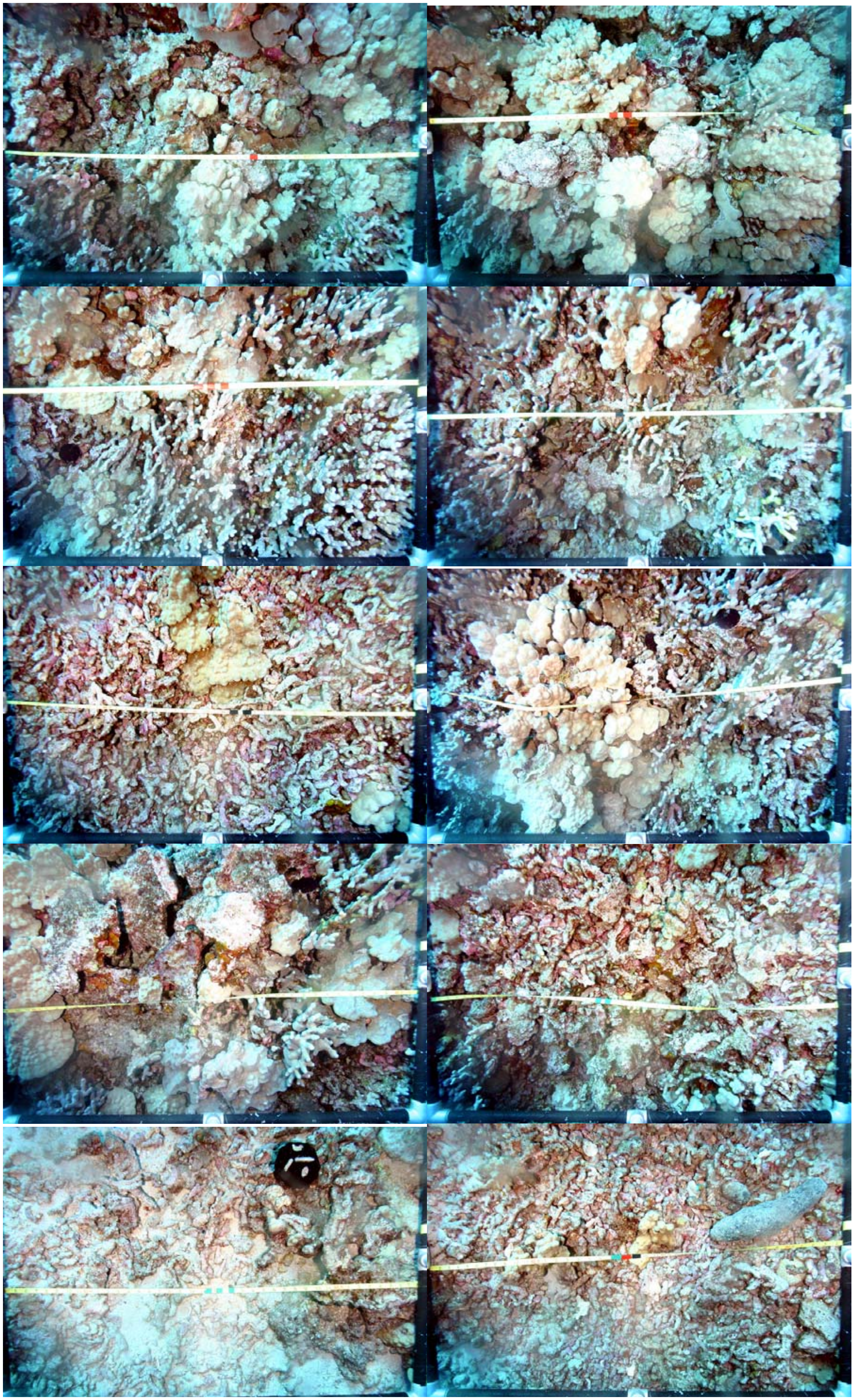
OCTOBER 2007

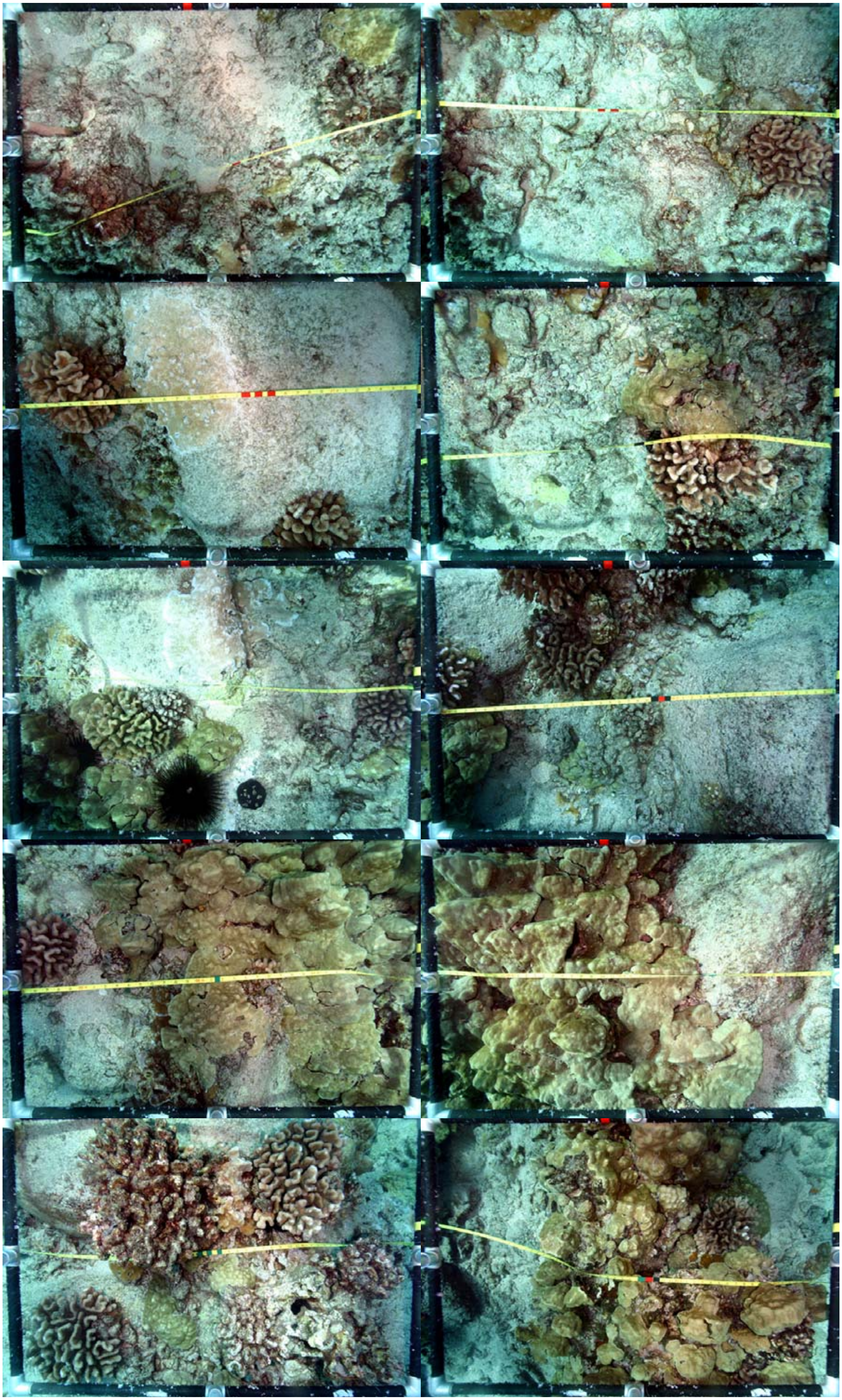


NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-60; QUADRATS 1-10
OCTOBER 2007

APPENDIX B

NELHA BENTHIC MONITORING
OCTOBER 2007

PHOTO-QUADRATS



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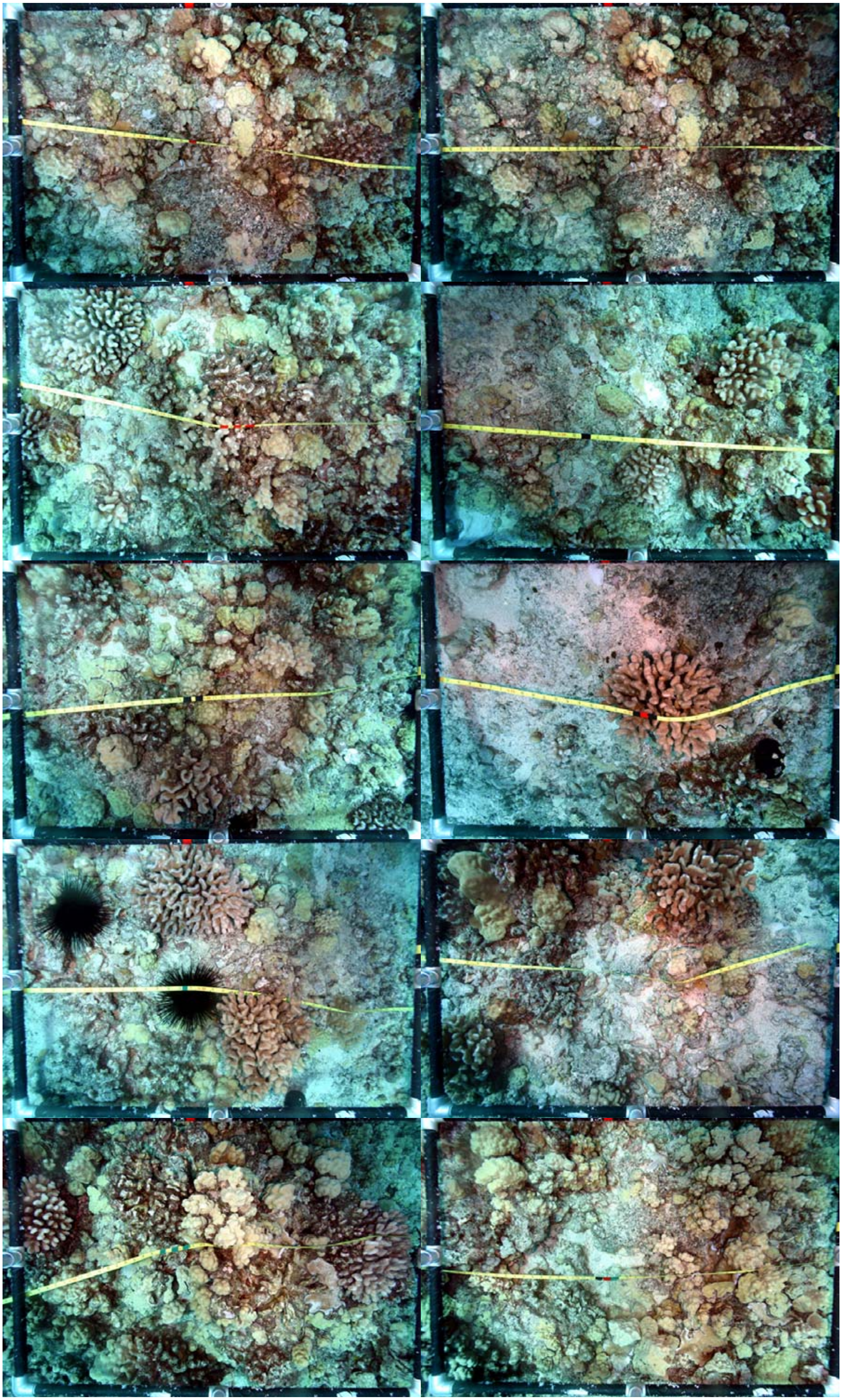
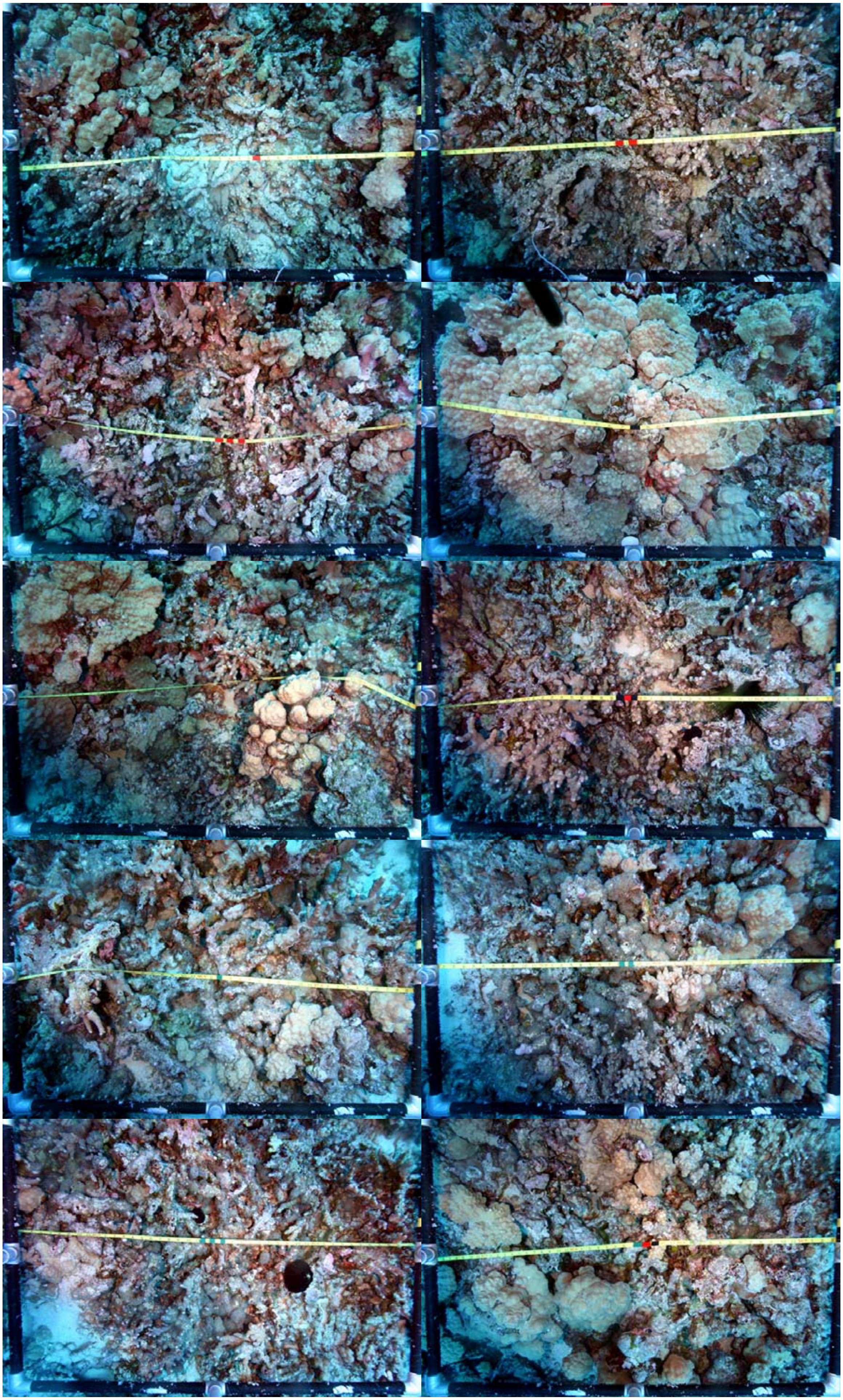
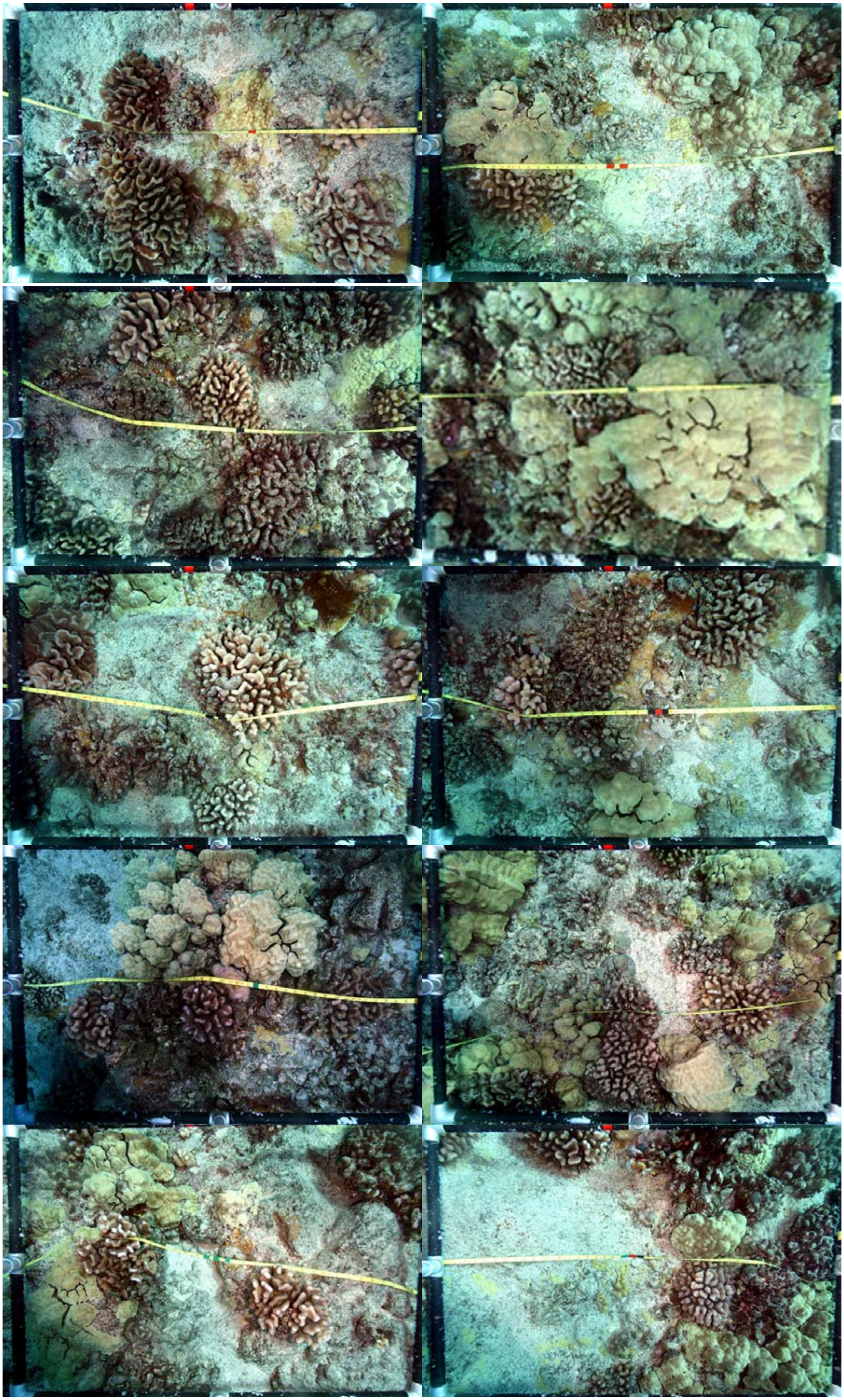
OCTOBER 2007



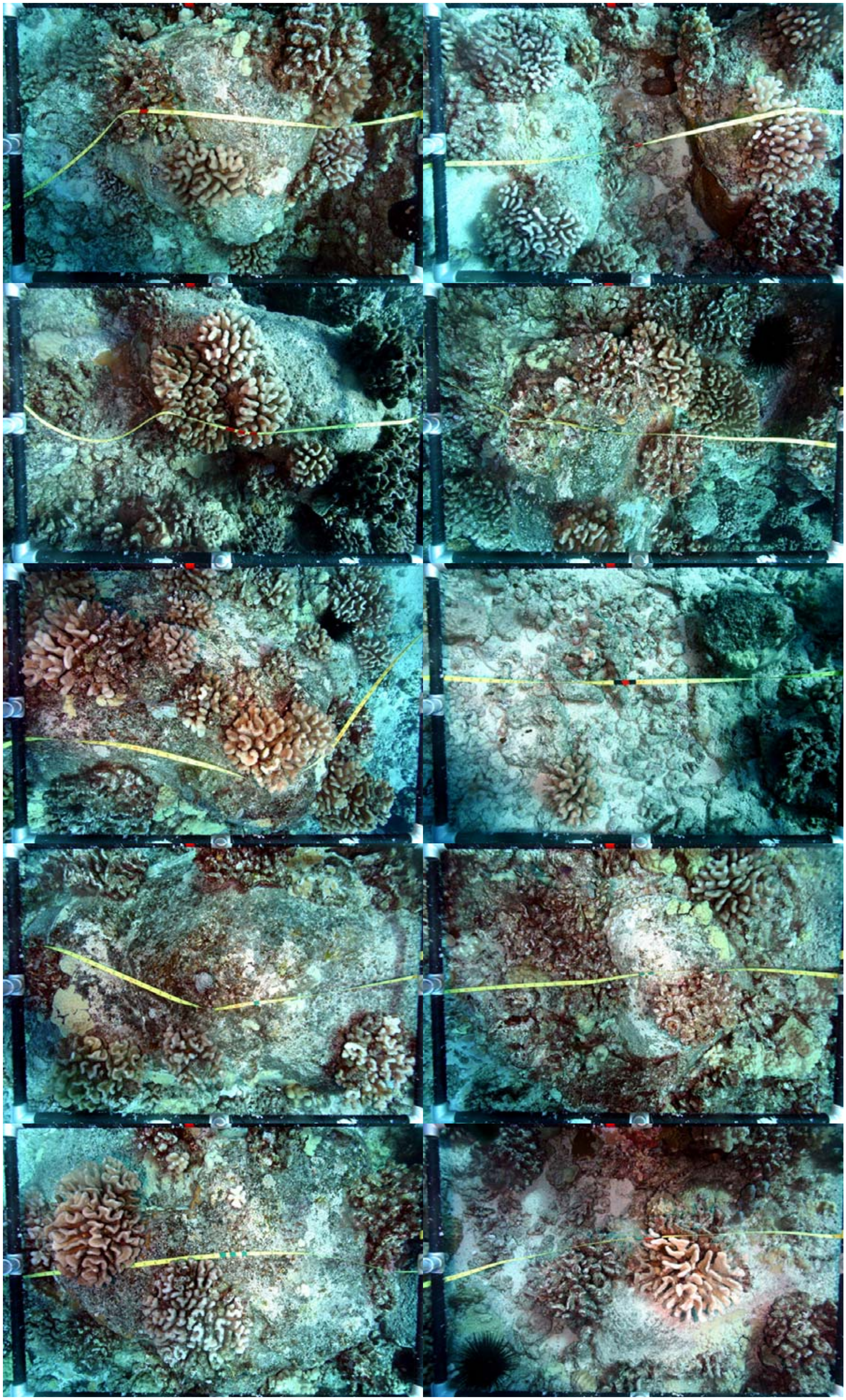
NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-20; QUADRATS 1-10
OCTOBER 2007



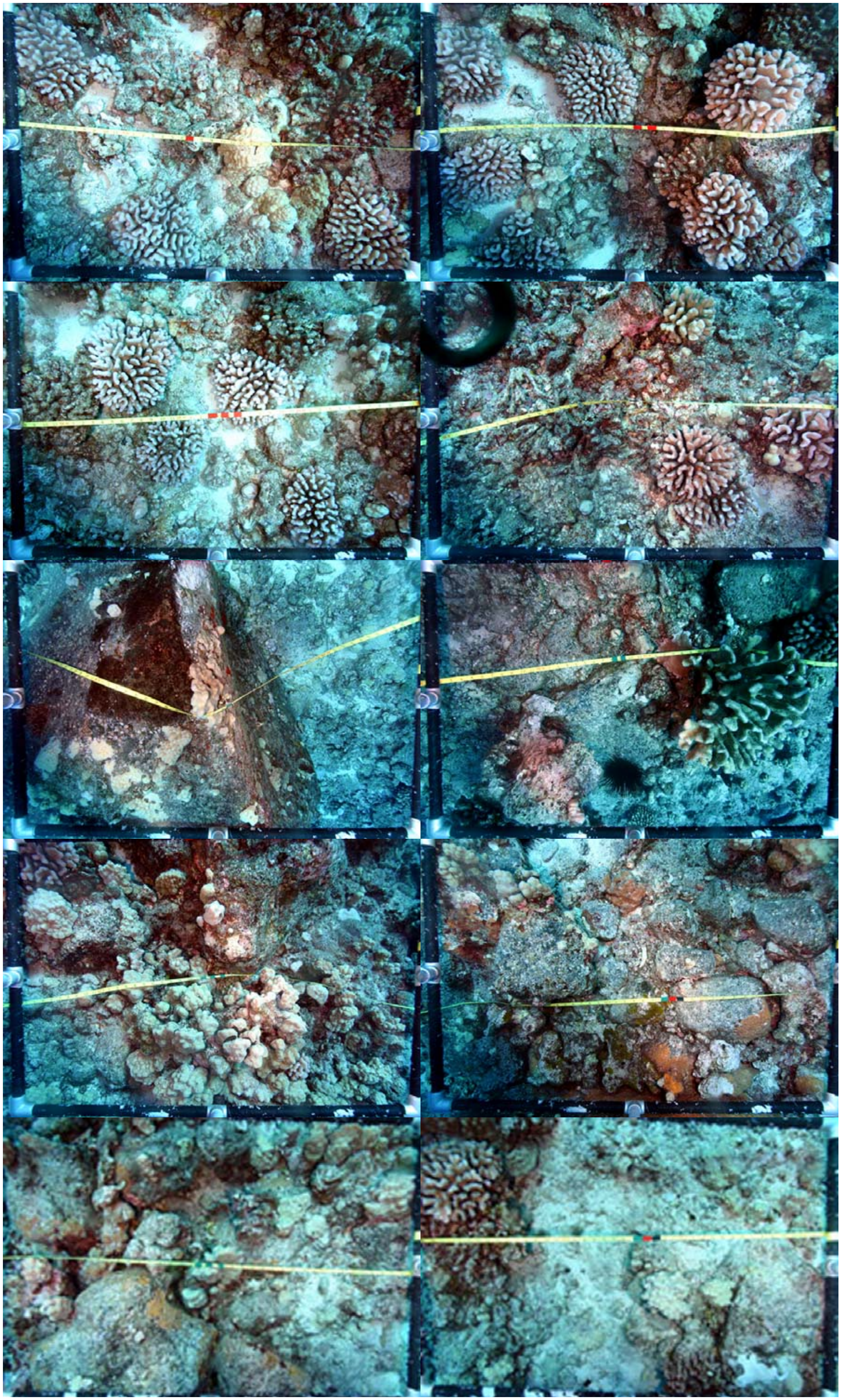
NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-35; QUADRATS 1- 10.
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-20; QUADRATS 1-10
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-25; QUADRATS 1-10
OCTOBER 2007



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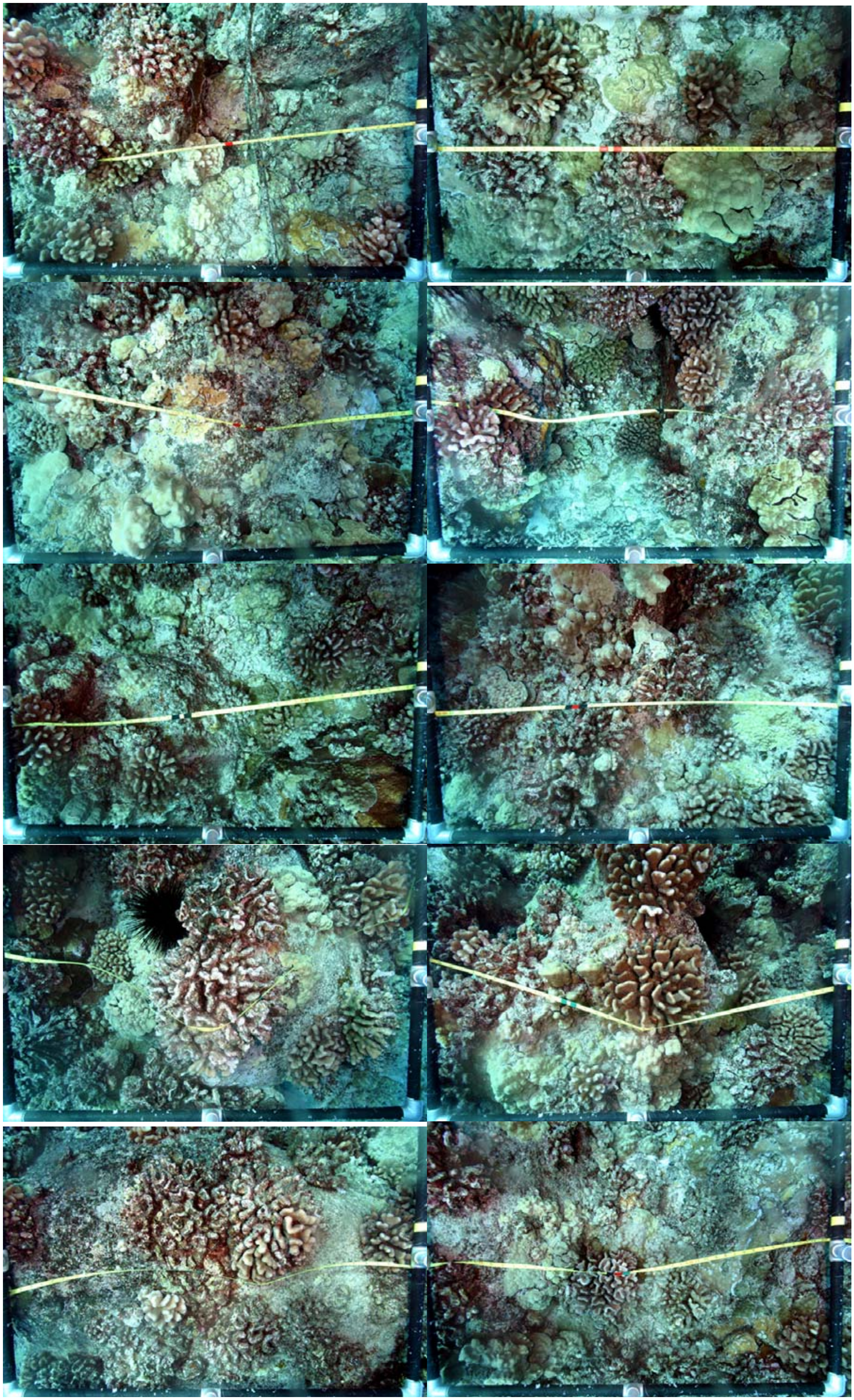
OCTOBER 2008



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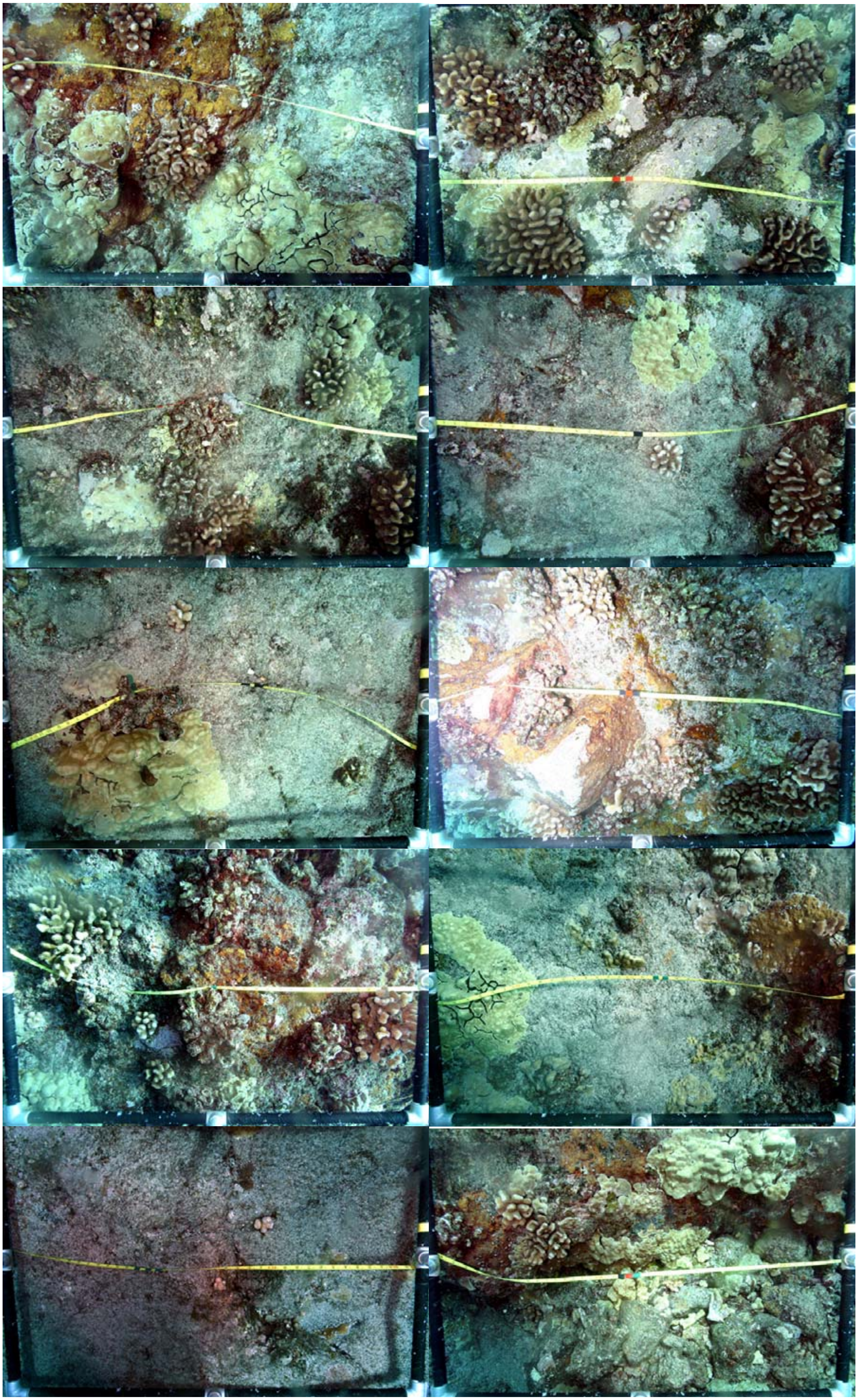

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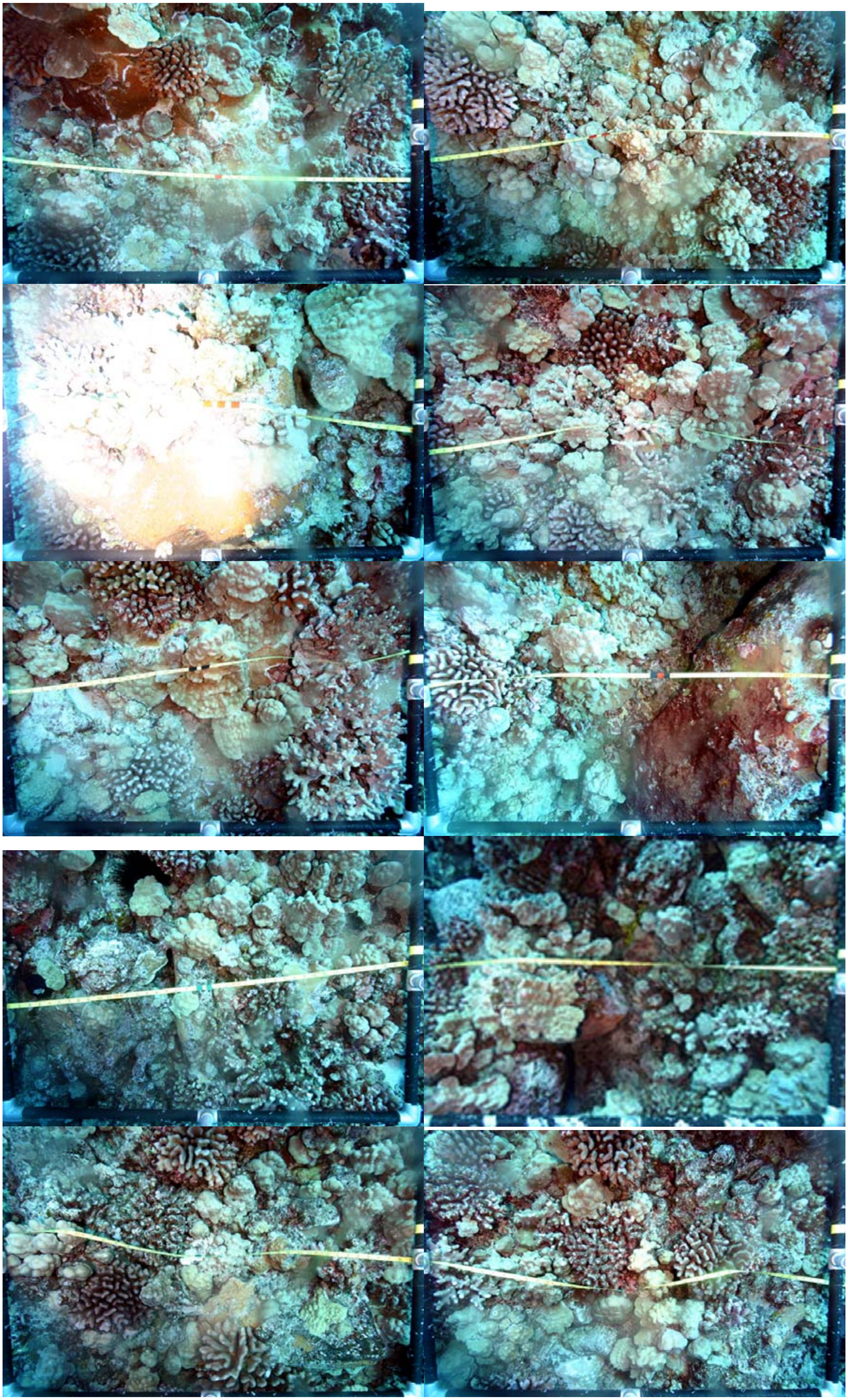
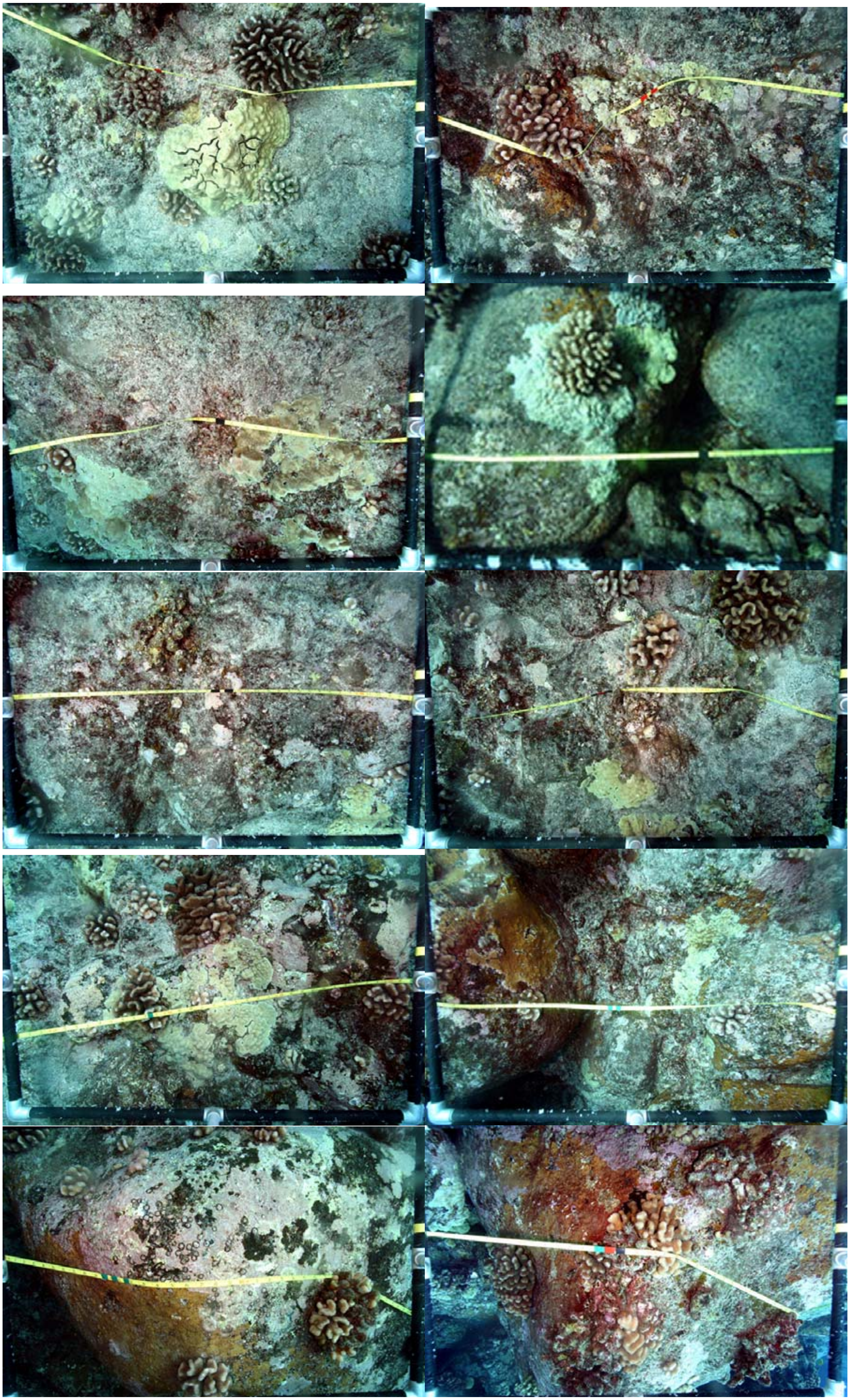
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 3-45; QUADRATS 1-10
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 4-20; QUADRATS 1-10
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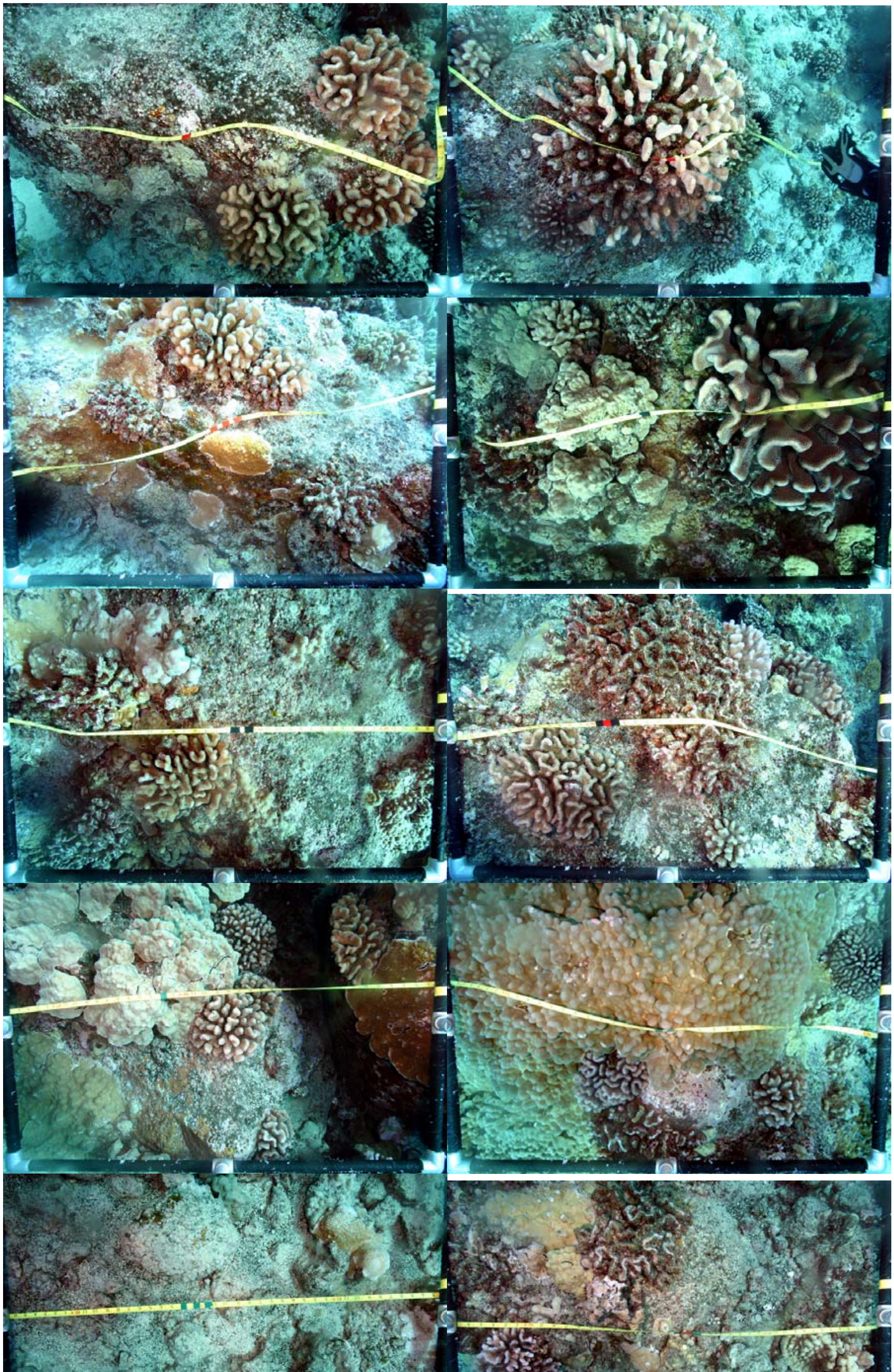

NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 4-25; QUADRATS 1-10
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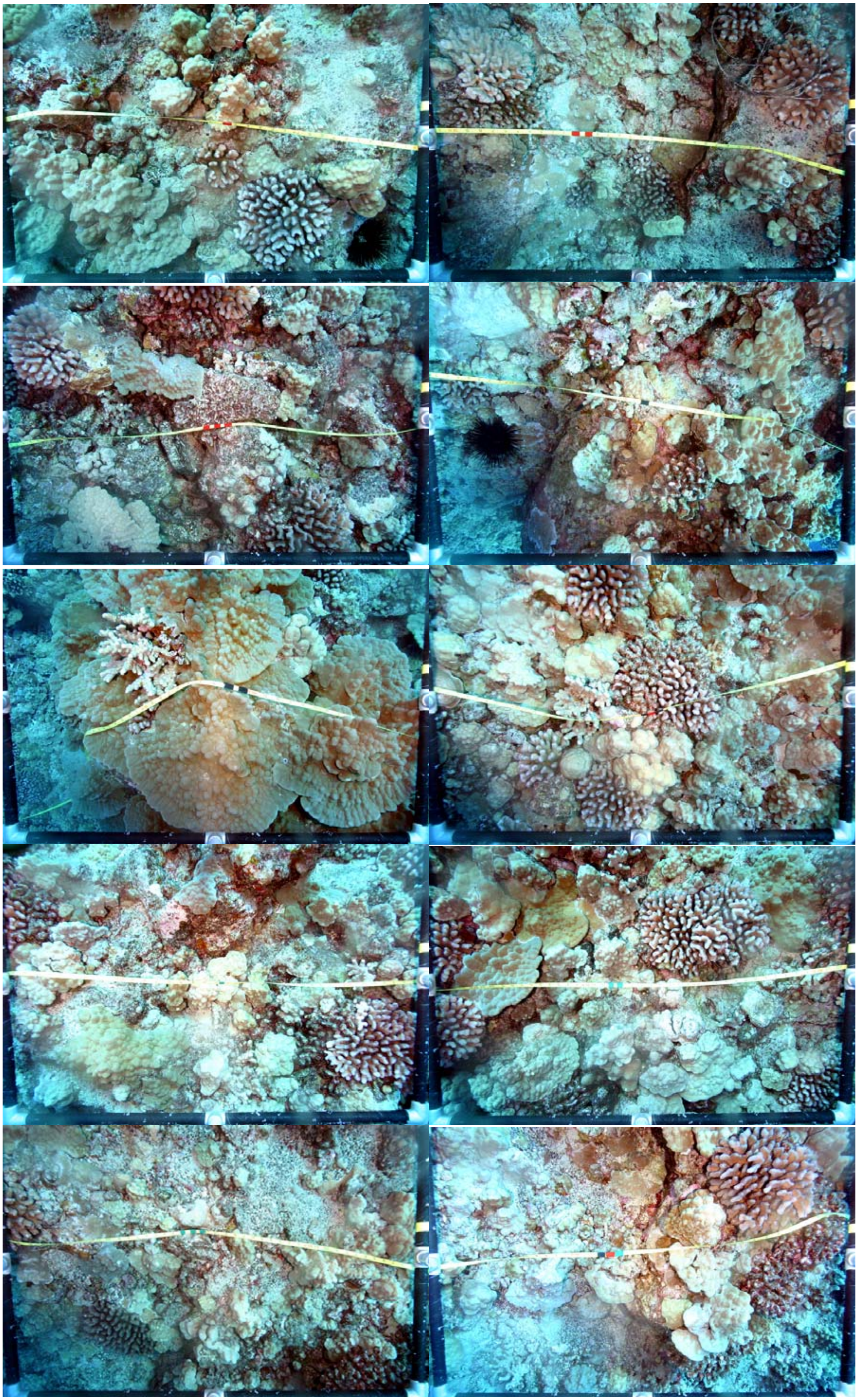
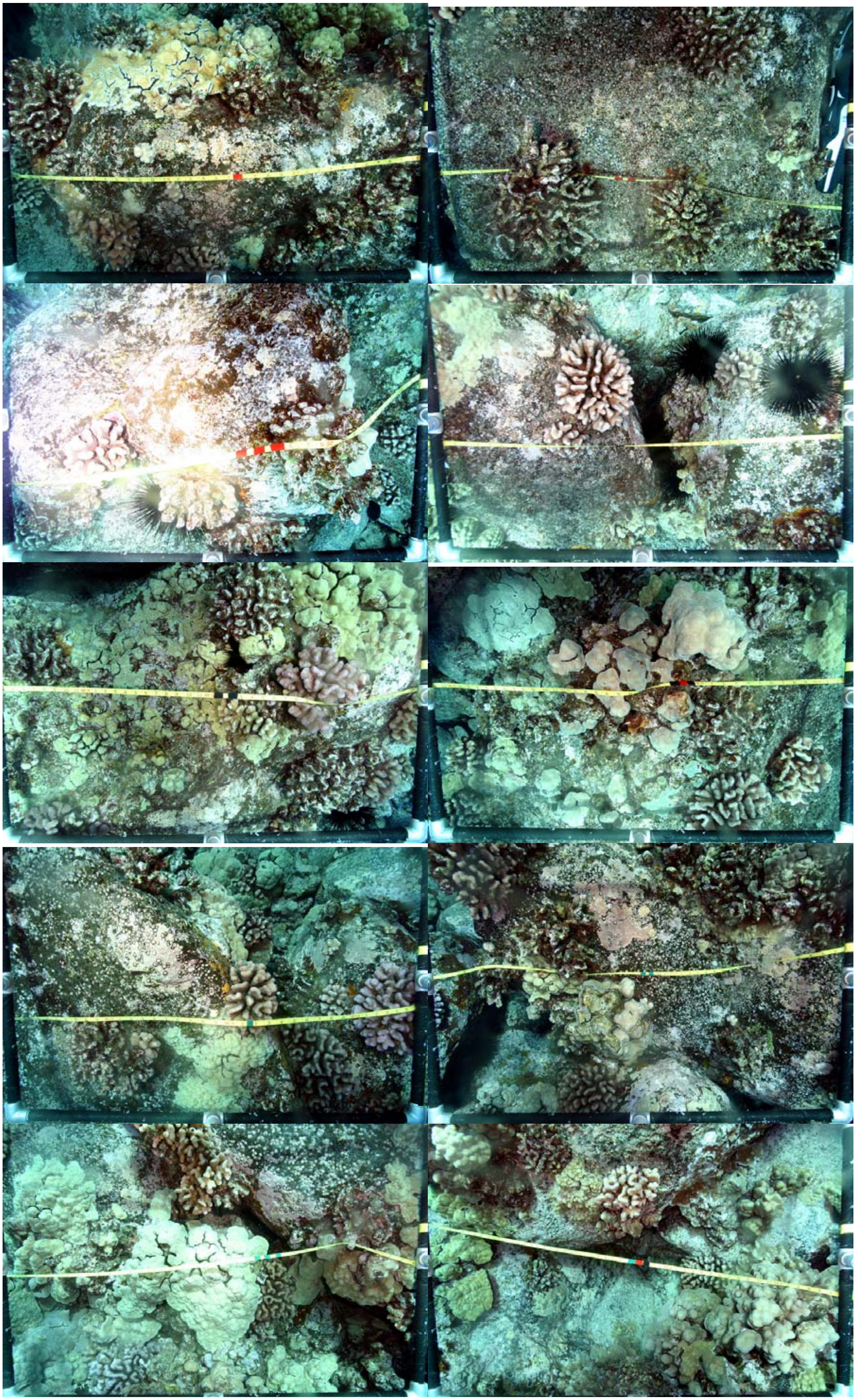
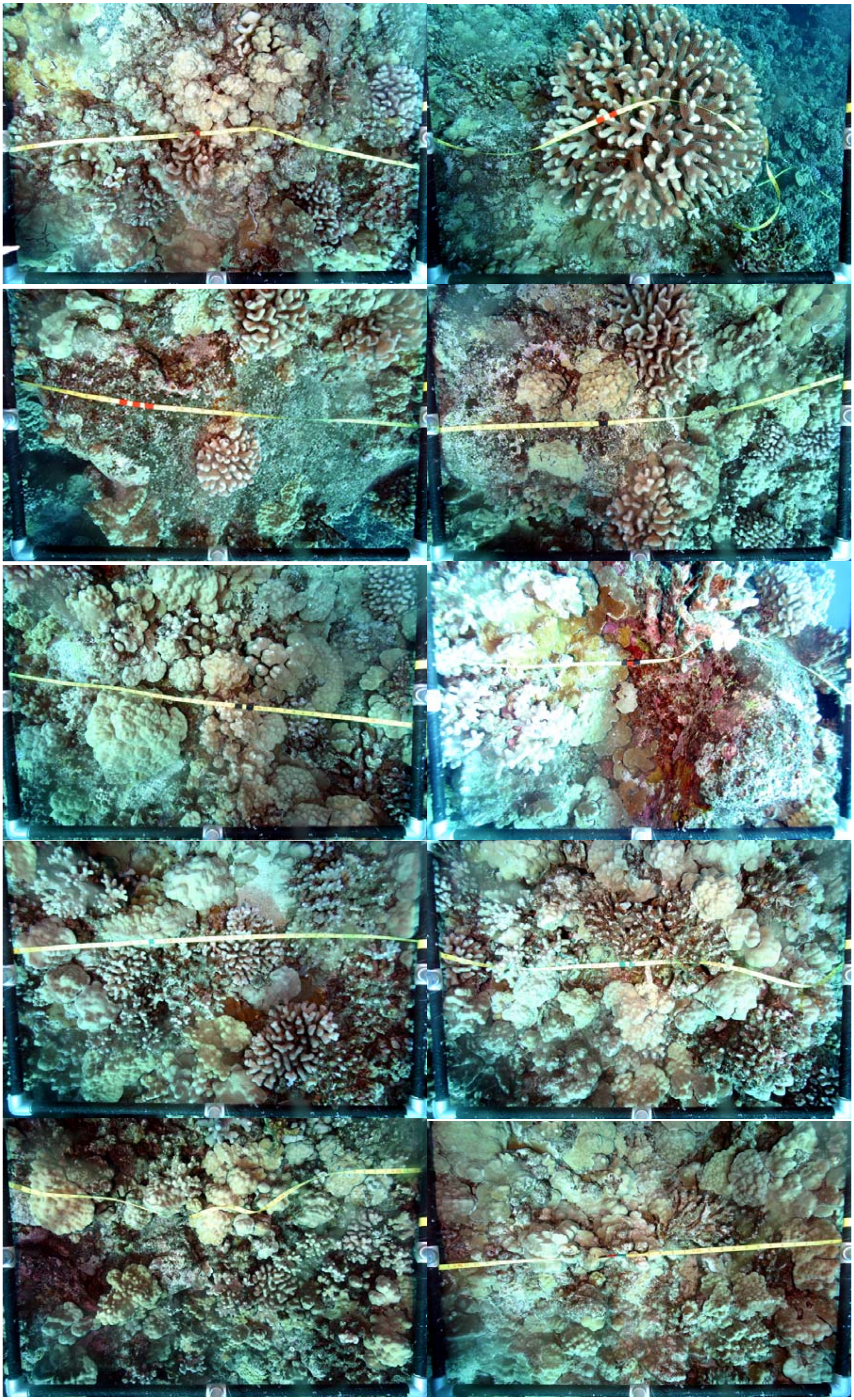


NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 4-50; QUADRATS 1-10
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 5-20; QUADRATS 1-10 - OCTOBER 2007



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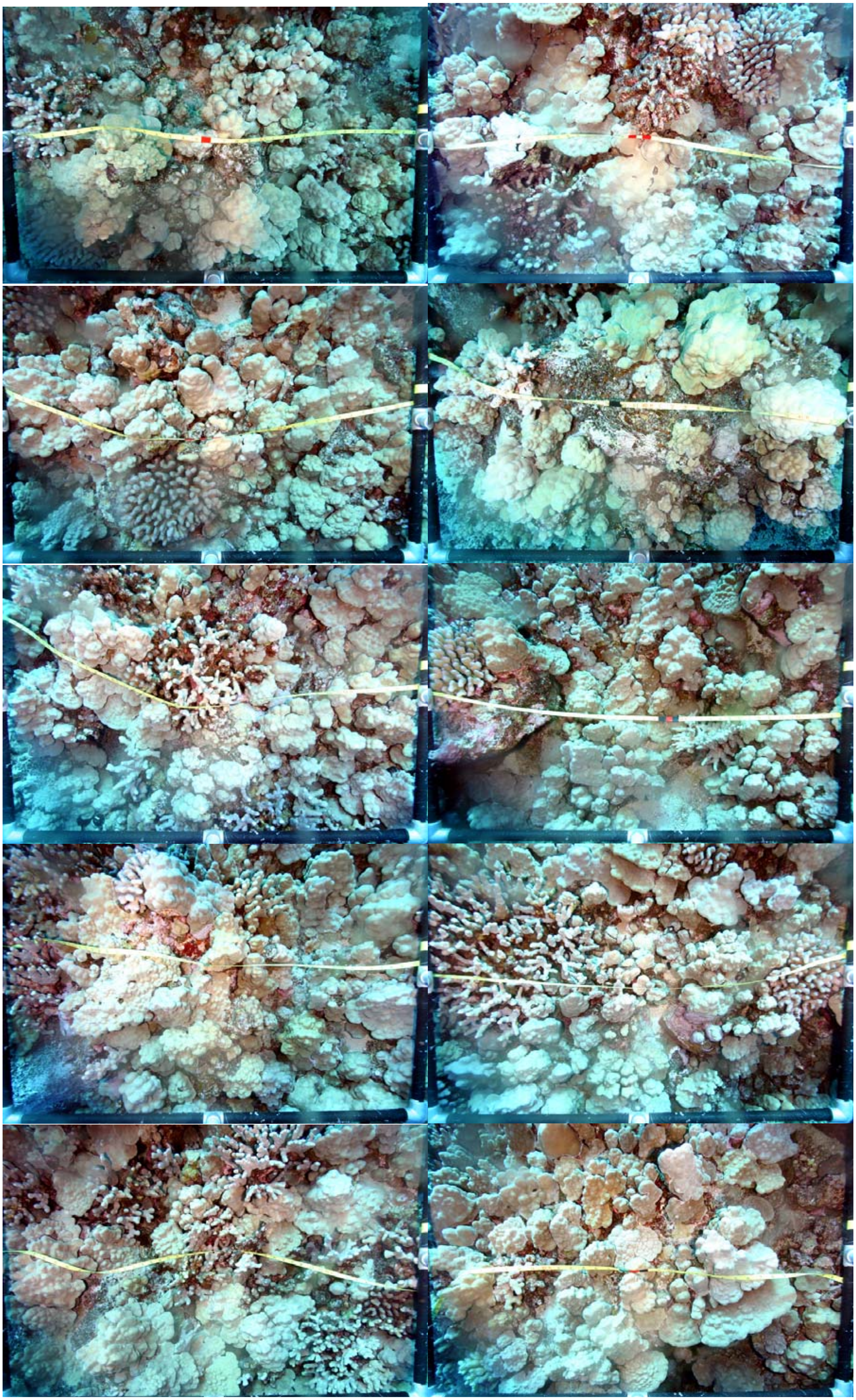

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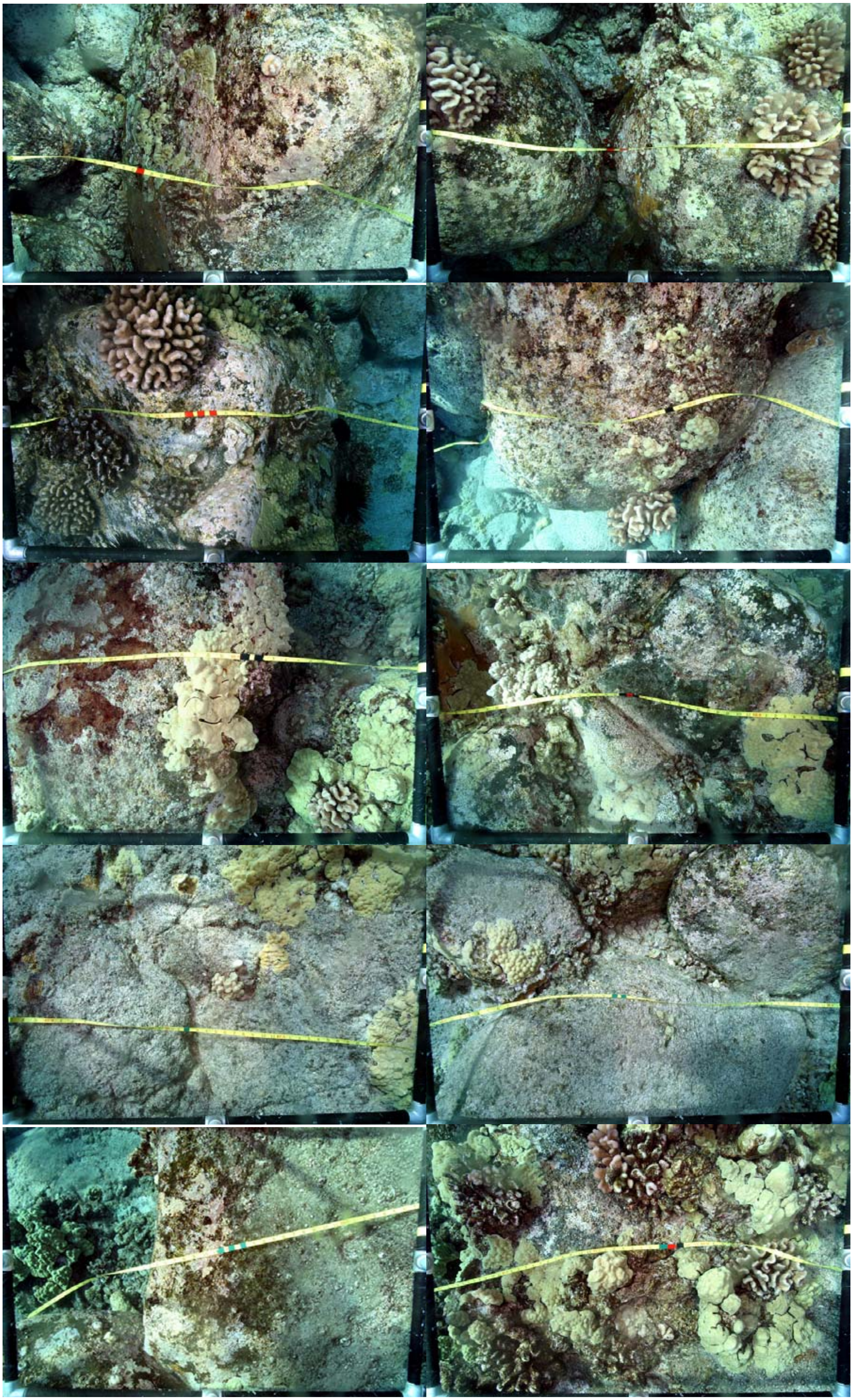
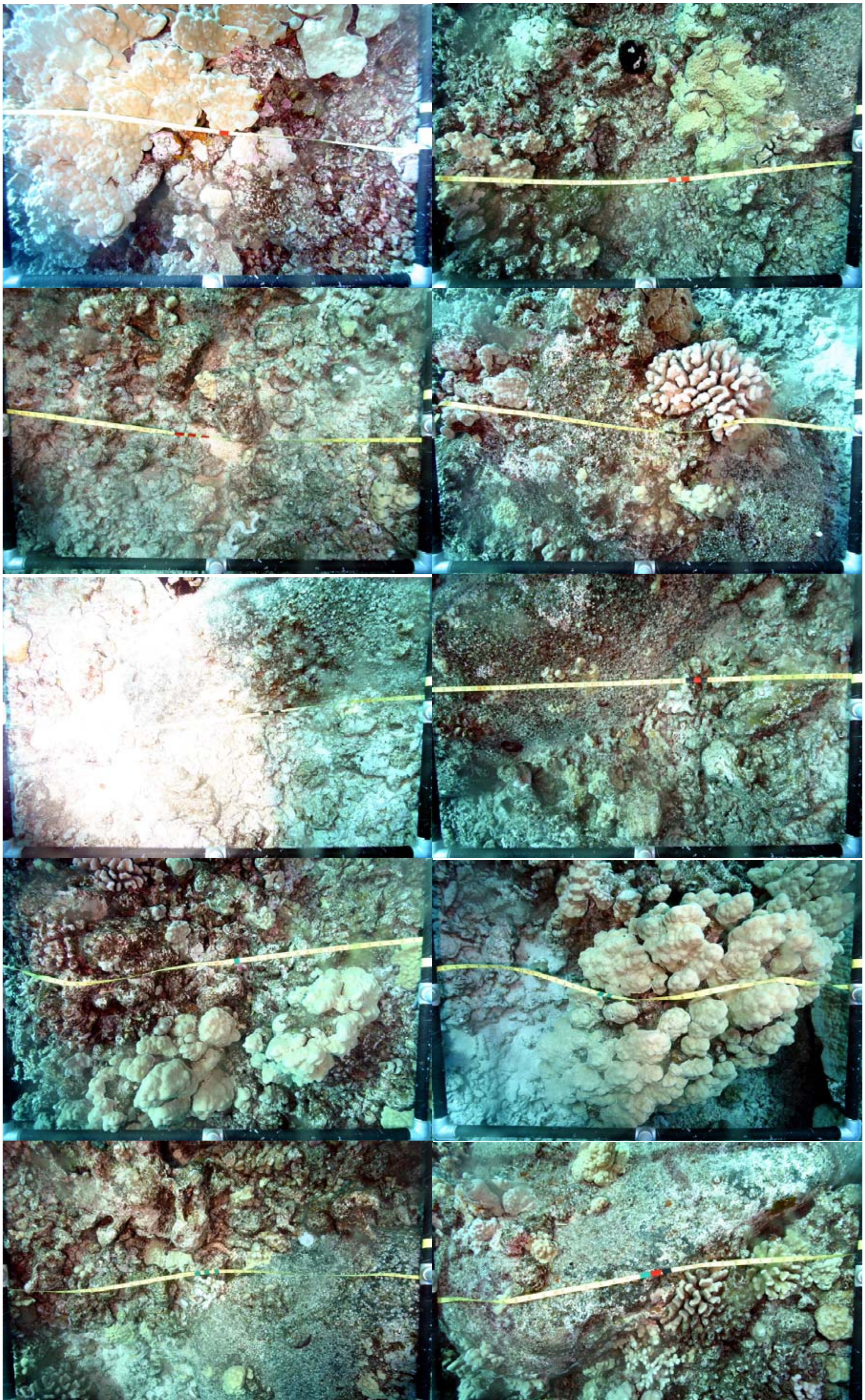
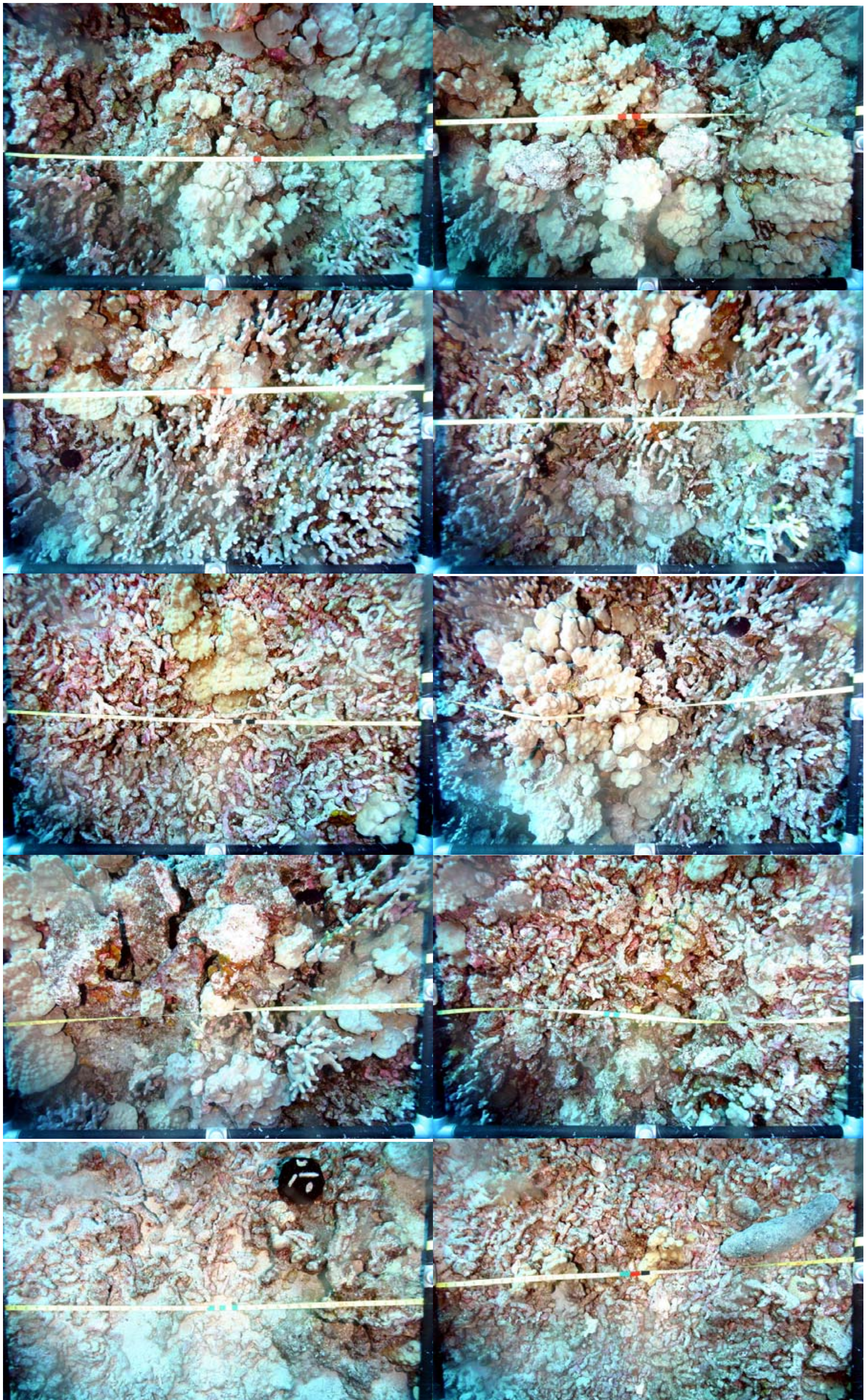
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-10; QUADRATS 1-10 - OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-25; QUADRATS 1-10
OCTOBER 2007



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-60; QUADRATS 1-10
OCTOBER 2007

BENTHIC MARINE BIOTA

MONITORING PROGRAM

AT THE NATURAL ENERGY LABORATORY OF HAWAII

KEAHOLE POINT, HAWAII

July 2008

Prepared for

The Natural Energy Laboratory of Hawaii Authority
P. O. Box 1749
Kailua-Kona, Hawaii 96745

by

Steven Dollar, Ph.D.
Marine Research Consultants, Inc.
1039 Waakaua Pl.
Honolulu, HI 96822

August 2008

I. INTRODUCTION AND PURPOSE

Facilities at the Natural Energy Laboratory of Hawaii Authority (NELHA), and the Hawaii Ocean Science and Technology (HOST) Park employ cold, nutrient rich waters from below the thermocline, as well as surface water above the thermocline, for various aquaculture activities at Keahole Point, on the west coast of the Island of Hawaii. A concern regarding discharge of these waters at the shoreline and into the groundwater aquifer is the potential for environmental alteration of community structure in the adjacent marine environment and anchialine pools.

In the interest of addressing this concern and assuring maintenance of environmental quality, it has been deemed necessary to carry out a comprehensive marine environmental monitoring program (CEMP) off Keahole Point. One component of the monitoring deals with the benthic (bottom-dwelling) biological communities. The intent of the benthic component of the monitoring program is to quantitatively describe existing community structure, and to identify changes from natural and man-induced factors. This report described results of the twenty-first increment of benthic monitoring conducted by Marine Research Consultants, Inc. (MRCI) in July 2008.

This phase of monitoring was conducted approximately sixteen years after Hurricane Iniki struck the Hawaiian Islands in September 1992, and fifteen years after an unusually strong northwest swell impacted the west Hawaii coastline in January 1993. Waves generated by these two storms generated surf with heights estimated at 10-15 feet in the vicinity of Keahole Point. Thus, in addition to evaluating the effects of NELHA discharge, a key interest in the monitoring survey is to assess the impact of, and recovery from, severe wave stress on coral community structure in the vicinity of NELHA. The monitoring surveys can provide an indication of the cumulative impact of storm effects, as well as short-term recovery of coral communities.

II. MONITORING RATIONALE

Benthic marine community structure can be defined as the abundance, diversity, and distribution of stony and soft corals, motile benthos such as echinoderms, and macroalgae. In the context of time-series surveys, benthic assemblages are often the most useful biological assemblages for direct evaluation of environmental impacts to the marine environment. Because benthos are generally long-lived, immobile, and unable to avoid extreme environmental conditions or input of potential pollutants, these organisms must either tolerate the surrounding conditions within the limits of adaptability or die.

As members of the benthos, stony corals are of particular importance in nearshore Hawaiian environments. Corals compose a large portion of the reef biomass and their skeletal structures are vital in providing a complex of habitat space, shelter, and food for other species. Because corals serve in such a keystone function, coral community structure is often considered the most "relevant" parameter for evaluating impacts to the marine environment associated with activities on land. For this reason, and because alterations in coral communities are easy to identify, observable change in coral populations is a practical and direct method for obtaining the information that is required to meet existing environmental regulations.

The overall intent of the benthic monitoring program is to identify changes to biotic assemblages as a result of input to the nearshore ocean of dissolved materials in waters used for aquaculture. These changes may potentially take the form of alteration in settlement and growth, as well as mortality, of the living components of the community. Such effects are likely to be difficult to decipher when superimposed over the combined effects of natural phenomena (e.g., dislodgement, predations, sediment flow) that routinely cause alteration in the arrangement of the living, as well as nonliving components of the reef. Studies of windward reef areas have shown that while overall coral cover may remain fairly constant, there can be a high degree of spatial change as resources are continually covered and uncovered in a "temporally varying mosaic." As the study area at Keahole is known to be a high energy environment, natural factors of environmental change are likely to be substantial, and could mask changes related to the NELHA facilities.

Thus, it is essential that the sampling methodologies employed for benthic monitoring extend beyond repetitive surveys employing randomly placed quadrats on line transects. Instead, a series of semi-permanent quadrats have been established, where intensive, rather than extensive, repetitive quantitative analyses are being routinely performed.

III. METHODS

All phases of the benthic monitoring program employ diver/scientists using SCUBA equipment operating from a small boat. All field surveys were conducted on July 7, 2008. Three quantitative survey sites that were established in the preliminary NELHA surveys by R. Brock were utilized as monitoring sites in the initial monitoring survey in August 1991. In response to anticipated additional construction and operational activities at NELHA in the near future, three additional monitoring stations were selected and have been evaluated during all subsequent surveys. The locations of the six monitoring sites are shown in Figure 1.

For ease of identification, each survey site is labeled with a name as well as a number. Moving from south to north, Site 1 is immediately to the south of Wawaloli Beach; Site 2 is located at the 18" Pipe to the south of Keahole Point; Site 3 is on the southern side of the 12" pipe off Keahole Point; Site 4 is off the northern side of the 12" pipe; Site 5 is off the NPPE site; and Site 6 is in Ho'ona Bay. Locations of the survey sites were fixed by triangulation with conspicuous landmarks, and are easily relocated during replicate surveys.

At each of the monitoring sites, three semi-permanent transect stations have been established. Each station is placed in one of the three major physiographic/biotic structural zones described for the Kona Coast (Dollar 1975, 1982, Dollar and Tribble 1993). These zones are characterized as the "nearshore boulder zone" (depth ≈ 0-15 ft.), the "reef-building platform zone" (depth ≈15-30 ft.), and the "reef slope zone" (depth ≈ 30-60 ft.). During the initial survey, permanent transects at each site were established by placing markers into solid substratum of the ocean floor (either basalt or limestone). Marker placement was carried out by Ocean Innovators, utilizing methods and equipment developed for the purpose of permanently attaching artificial reef structures to the sea floor. The attachment procedure involved drilling a hole for anchoring an expandable eye-bolt. Small marker buoys on wire rope that float above the bottom were attached to the eye-bolts for ease in locating transect stations on subsequent surveys. During the years since placement of the markers, buoys have been periodically lost and replaced with large cable ties. As a result, locations of the transects have been relatively constant over the course of the monitoring program.

The permanent markers defined the ends of 50 meter (~160 ft.) long transects, oriented parallel to depth contours. At ten random locations along the transect line, composition of the benthos is evaluated within rectangular quadrats one m x 0.66 m (3 ft. x 2 ft.) in dimension. Each quadrat is photographed with a digital Canon Eos camera with a super wide angle lens (15 mm, 94° field of view) in an underwater housing. The camera is mounted on a tripod frame to ensure exact repeatability of quadrat area. The photographic technique provides excellent resolution of the detail of the benthic structure, to the degree that individual calices of certain corals are distinguishable. Color photographs of all quadrats are attached as Appendix B to this report, and are on file at NELHA.

In addition to the quadrat photographs, visual estimates of species abundance of attached and motile benthos is recorded on writing slates. Bared substratum (bare rock, sand, dead coral and coral rubble) are also evaluated in terms of 2-dimensional area coverage.

In the laboratory, evaluation of benthic cover of biota and substrata is performed. Area coverage of each component in the quadrat photos is determined using an overlay grid divided into 200 equally sized segments. The number of segments of each coral species and non-coral substratum type within each grid are summed to calculate area coverage. Thus, for each transect, there are the equivalent of 2,000 data points. Verification of species identification is performed using the information collected in the field. In addition, field data provides input on small organisms that are not visible in photographs. This method provides for accurate estimates of cover of organisms that cover a large percentage of the reef surface through photographic coverage, as well as occurrence of very small and/or rare organisms. Few, is any other methods provide for such accurate characterization of both extremes of benthic community structure.

The Shannon-Weaver index of diversity is also calculated for percent coral cover on each transect using estimates from area cover. The formula for calculating diversity (H') is:

$$H' = -\sum_{i=1}^{s} pi\ \ln pi,$$

where pi is the proportion of the ith species in the population, and s is the number of species.

IV. RESULTS

A. Physical Structure

The shoreline and intertidal area of the subject property consist predominantly of basaltic boulder outcrops interspersed between narrow, steeply sloping beaches. The beaches are composed of rounded cobbles and coarse calcium carbonate sands which extend into the intertidal area. The area directly off of Keahole Point consists of a basaltic extension of the island mass that meets the ocean in steep vertical cliff faces that extend approximately 5-7 m (15-20 feet) below the ocean surface.

The structure of the offshore environment in the vicinity of Keahole Point generally conforms to the pattern that has been documented as characterizing much of the west coast of the Island of Hawaii (Dollar 1982, Dollar and Tribble 1993). The zonation scheme consists of three predominant regions, each with a characteristic coral assemblage that is adapted to the prevalent physical regime (i.e. wave stress) of the region.

Beginning at the shoreline and moving seaward, the shallowest zone at the land-sea interface is comprised of a flat basaltic terrace that is the underwater continuation of the island landmass. In areas offshore of basaltic shorelines the intertidal zone is often covered with large boulders that have entered the ocean after breaking off from the shoreline. The seaward edge of the nearshore reef terrace terminates in a vertical cliff face approximately 3-5 m (10-15 feet) in height. The face of the cliff is irregular in that it is scalloped and cut with caves and arches. In areas fronting shoreline beaches, boulder cover is not as prominent, and the intertidal area consists primarily of flat basaltic shelf. The nearshore zone receives most of the force of breaking waves and surge, and as a result is inhabited predominantly by organisms capable of withstanding these stresses on a regular basis. The predominant coral species occupying the nearshore area is *Pocillopora meandrina*, which is recognized as a "pioneering" species that is the first coral to settle on newly cleared substratum, or to occupy areas that are too harsh for other species. The shallow transects conducted at each of the six survey sites traverse the "nearshore boulder" zone.

Seaward of the nearshore boulder zone, bottom structure is composed predominantly of a gently sloping reef bench. In some areas, the bench is characterized by high relief in the form of undercut ledges and basaltic blocks and pinnacles. Fine-grained calcareous sand also occurs in pockets on the reef bench. Water depth in this mid-reef zone ranges from about 7-15 m (20 to 40 feet). As wave stress in this region is substantially less than in the shallower areas, and suitable hard substrata abounds, the area provides an ideal locale for colonization by attached benthos, particularly reef corals. The intermediate depth transects at each survey site are located on the "reef bench" zone.

The seaward edge of the reef platform (at a depth of about 15 m (45-50 feet) is marked by a sharp increase in slope to an angle of approximately 20-30 degrees. In the deep slope zone, substratum type changes from the solid continuation of the island mass to an aggregate of generally unconsolidated sand and rubble. Moving down the reef slope, coral settlement and growth ceases at a depth of approximately 35 m (100 feet); beyond this depth the bottom consists mostly of sand, with occasionally basaltic outcrops. The deep transects at each survey site are located on the upper portions of the "reef slope" zone.

While each of the survey sites has similarities to the typical scenario described above, each station also has distinctive characteristics, resulting in four relatively unique habitats. At Ho'ona Bay (Site 6) the "typical" zonation scheme is best developed in that all three zones are clearly apparent. The entire zonation scheme is compressed into a relatively narrow band (about 100-150 m wide) between the shoreline and the sand slope that extends to abyssal depths. At the 18" and 12" pipe sites (2, 3, and 4) and the NPPE site (5), the entire region from the shoreline to the reef slope is representative of the typical nearshore boulder zone, and biotic assemblages that occur in areas that are consistently subjected to intense wave scour. At the Wawaloli Beach site (1), the typical zonal structure appears to have been well established. However, even before the impacts of Hurricane Iniki, there was substantial evidence of recent destruction of a major portion of living corals as a result of storm wave damage.

B. Biotic Community Structure

1. Reef Coral Communities

The overwhelming majority of benthic biota on the monitoring transects consisted of stony, reef-building (Scleractinian) corals. Benthic frondose macroalgae (e.g., not coralline algae) was extremely rare on all survey transects, as has been the case during all surveys since the inception of the monitoring program. Motile invertebrates were primarily limited to occasionally occurring echinoderms (sea urchins and sea cucumbers).

Inspection of the reef following Hurricane Iniki and the severe 1993 winter storm revealed what the investigators classified as "intermediate" impacts. Many colonies, especially *Pocillopora meandrina* sustained some branch breakage. Areas of *Porites compressa* were noticeably affected by wave energy in terms of breakage and redistribution of finger coral fragment beds on the reef slope. It must be noted, however, that most of the *P. compressa* beds in the deeper areas of the monitoring sites were already documented in previous surveys to consist largely of rubble fragments that were likely the result of previous extreme storm impacts. In addition, breakage of corals appeared to be patchy with respect to spatial distribution. Patches of extensively damaged colonies occurred between areas that sustained no damage. This phenomenon has been observed repeatedly, not only in Hawaii, elsewhere in the Atlantic and Pacific where coral reefs are subject to intense storms of hurricane or cyclone intensity. It is theorized that such localized damage is a result of what has been termed "bowling." Fragments of coral skeletons or boulders dislodged by wave action causes damage to surrounding corals by impacts when the loosened material is hurled by wave forces. As a result, the concussive force of wave impact *per se* may not be the only physical factor responsible for damaging corals.

Observations of the survey region also suggested that the impacts from the storms were more intense on the southward facing reefs. Such an observation is consistent with the direction of wave propagation from Hurricane Iniki, which passed to the south of the Island. Site 6 (Ho'ona Bay), which lies to the north of Keahole Point appeared to be almost totally protected from destructive wave forces as a result of orientation to incoming swells. In summary, while the Hurricane and severe winter storm did produce observable effects to the reef environment, the effects do not appear to be "catastrophic" as the entire survey area appears to have been recently (or continually) subject to wave forces of similar magnitude from large winter surf that occurs periodically. Between the seven most recent surveys, no substantial wave events occurred. Thus, differences in coral community structure may indicate if short term recovery of corals has occurred.

Inspection of the reef in 1995 at all of the survey sites (except Site 1) revealed very noticeable continued recolonization of basalt surfaces at the intermediate and deep transects. Most of the recolonization was in the form of numerous small colonies of *Porites lobata* growing as knobby projections and flat encrustations. This recolonization can be considered to be an initial recovery phase from the storm events that occurred in 1992-1993. Further inspection of the reef during the most recent surveys progressing from 1997-2002-2007-2008 revealed substantial increases in coral cover, presumably as a result of uninterrupted recovery from the severe storm events.

Table 1 shows the quantitative summary of coral community structure collected during the July 2008, while Appendix A shows the composition of individual quadrats that comprises transect results. Tables 2a and 2b show comparative data from the twenty-three surveys conducted from 1991 to 2008. Over the course of the surveys to date, seven to fourteen species of corals have been encountered on all transects during a single survey, while the number of coral species on a single transect has ranged from two to eight. In the most recent survey in July 2008, ten species were encountered on transects, with the number on a single transect ranging from two to six.

Over the seventeen-year course of the monitoring program, coral community structure in terms of species occurrence (e.g., number of species) has not shifted substantially. There is, however, an overall upward trend in coral cover. Mean total coral cover on all transects during each of the surveys has gradually increased from lows of 16-17% in 1991-92 to 48% in June 2002 and 52% in October 2007 and 55% in the most recent survey in July 2008. These results suggest that there has not been a decrease in overall coral cover during the course of the monitoring program to date. Rather, there has been a substantial overall increase of about 3-fold (300%) in coral cover over the entire monitoring period. The largest single between-survey increase (21%) occurred between May 1995 (22%) and November 2007 (43%). During the eleven years between November 1997 and July 2008, total coral cover increased about 11%.

Figures 2-4 are histograms that show coral community structure (percent coral cover, species diversity, and number of species) from December 1991 to July 2008 at each transect site. Several dominant points are evident in examining Figures 2-4. As discussed above, with several exceptions, coral cover is highest on each transect during surveys since 1998. On many transects, a sequential increase in cover over time is also evident (Figure 2). There is, however, no similar pattern of peaks for number of coral species number (Figure 3) or species diversity (Figure 4).

In the most recent survey, there is a relatively consistent pattern of cover between depth zones. With the exception of Site 2, coral cover is lowest in the shallow boulder zone, and highest in the deep slope zone. With respect to difference in coral coverage on each transect, the greatest difference that occurred in July 2008 was 48% at Site 3 (12" Pipe South). During most previous surveys, Site 6 has consistently shown the greatest difference in cover between the shallow, mid-depth and deep transects. However, during the July 2008 survey, Site 6 exhibited a difference between the shallow and deep station of only 13%.

As stated above, in addition to determining the effects of the NELHA discharge, a consideration of the monitoring program is to assess the impacts of severe storms on coral community structure. It can be seen in Figure 2 that total coral cover on all transect sites was relatively low compared to present levels of cover, and showed further decreases in cover following both Hurricane Iniki in 1992 and the 1993 winter storm. Between May 1992 and October 1992, when Hurricane Iniki occurred, coral cover decreased on 12 of the 18 transects. Between October 1992 and May 1993, when the winter storm occurred, coral cover decreased on 5 of the 18 transects. Between May 1993 and July 2008, when no major storm events occurred, coral cover increased on all 18 transects. These comparisons suggest that the communities are recovering (or have recovered and are now in an equilibrium condition) from damage that occurred as a result of the major storms that took place during the course of the monitoring program.

Figure 4 shows plots of diversity on each transect during each survey. Diversity is an index of the equitability of distribution of cover of each coral species within the total coral coverage. Thus, diversity can be low when there is either a low number of species of equal distribution, or a high number of species but with an extremely uneven distribution of cover (most species occur as very small percentages of cover). It can be seen in Figures 2 and 4 that while many of the shallow transect had lower cover than the deeper counterparts, there is not a corresponding increase in diversity on the deeper transects. Rather, the patterns of diversity were mirror images of the estimates of coral cover. When total coral cover is high, it tends to be the result of dominance by one species, resulting in relatively low diversity.

The dominant species on all transects was *Porites lobata*, which accounted for between 42% and 72% of total coral cover in the previous surveys. During the present survey, *P. lobata* comprised 55% of coral cover, while in the previous survey this species accounted for 58% of coral cover. The second most abundant species, *Pocillopora meandrina* accounted for between 12% - 36% of coral cover in previous surveys. During the July 2008 survey, cover of *P. meandrina* comprised about 22% of coral cover, up from 19% in October 2007. *Porites compressa*, accounted for between 8% and 14% of coral cover in previous surveys, while in July 2008 and October 2007 cover of *P. compressa* accounted for approximately 13% and 15% of coral cover, respectively. *P. compressa*, commonly known as "finger coral" consists of a delicate branching growth form that is highly susceptible to breakage from wave forces. Hence, while percentage cover of other species of coral that are more resistant to wave forces were within the middle of the ranges of the entire span of monitoring, cover of *P. compressa* was at the peak of percentage cover during the most recent surveys. The increasing cover of *P. compressa* is likely a response to the long interlude since an episode of destructive wave impacts.

The remaining "rare" species encountered on transects totaled between about 0.4% and 15% of coral cover between August 1991 and June 2002. In the most recent study, rare species accounted for about 10% of coral cover.

Figures 5-10 shows percent cover of the five most dominant coral species (*Porites lobata, P. compressa*, *Pocillopora meandrina*, *Montipora capitata* and *M. patula*) at each transect station during each of the monitoring surveys. At most of the sites, community structure is similar: *P. lobata* and *P. compressa* increase in percent cover as water depth increases, while *P. meandrina* decreases in percent cover with depth.

Site 1 was impacted by events associated with installation of a new seawater pipeline in 2001. At the deep transect station, live coral cover was about 28% of bottom cover during the May 2001 survey. During the December 2001 survey, cover dropped to 8.5% of bottom cover, while cover was about 15% in June 2002. In the most recent survey in 2008, total coral cover on the deep transect was 48%, showing an increase of about 40% in seven years. None of the other stations showed similar precipitous drops in coral cover between two successive surveys, followed by a substantial increase in cover (Figures 5-10). Inspection of the bottom in 2001 also revealed that coral cover was affected by some activity such as anchor drag or cable scour.

As mentioned above, owing to the fragile growth form with respect to wave energy, *Porites compressa* is rare in the shallow zones, but is often the most abundant coral on the deep reef slope in west Hawaii (Dollar 1982). On many of the NELHA survey transects conducted in the early years of monitoring, however, *P. compressa* was essentially absent. Bottom cover at Sites 1-4 consisted of only very small percentages of living *P. compressa* (<6%), even on the deep slope transects. All of these sites are located either directly off of Keahole Point, or to the south of the point, in the regions that are directly impacted by large waves impinging from both northerly and southerly swells. Examination of the bottom revealed that coral cover has been steadily increasing on the deep slope zones since 1993, but the primary species that were recruiting to the slopes are *Porites lobata* and *Pocillopora meandrina*, rather than *Porites compressa*. At Sites 6, which is the most sheltered site from the major force of storm waves, *P. compressa* cover is relatively high at the deep transect site (36% of bottom cover), and is the only Site where cover of this species has been consistently high (>17%) throughout the surveys to date (see Table 2, Figure 10).

Conversely, *Pocillopora meandrina* is adapted to areas of high wave stress, and is most abundant in the nearshore boulder zones. At Sites 2-5, the entire reef area from the shoreline to the slope is subjected to substantial wave stress. As a result, the entire reef shelf exhibits characteristics of the nearshore boulder zone with *P. meandrina* one of the dominant corals. At Sites 2-5, *Pocillopora meandrina* is also the greatest contributor to increased coral cover over the last several years, as is readily evident in Figures 6-9.

One-way analysis of variance (ANOVA) statistics were performed for total coral cover (Table 3), *Porites lobata* cover (Table 4), and *Pocillopora meandrina* cover (Table 5) at each transect site. The null hypothesis for these analyses is that over the time span of the monitoring surveys, within a site each sample area (i.e., transect) contains a population with equal mean coral cover. It can be seen in Table 3 that the null hypothesis is rejected ($P<0.05$) at all 18 transects.

For the most abundant species, *Porites lobata* and *Pocillopora meandrina*, ANOVAs also show significant differences ($P\leq0.05$) on all 18 transects (Tables 4 and 5). These results indicate that over the course of the monitoring program, coral cover has changed significantly on all transects.

In order to evaluate if significant differences in mean coral cover could be attributed to specific variations between surveys, *post hoc* Tukey multiple comparison probability tests were performed on the ANOVA statistics. Results of the Tukey multiple comparisons provide a matrix of pairwise probabilities for all samplings. Table 6 shows results of the combined matrices for all sampling sites. The Tukey comparison assigns an association to each transect on each survey date depending on the mean coral cover. Mean coral cover on survey dates with the same association are not significantly different at the 0.05 level.

It can be seen in Table 6 that coral cover falls into two major groupings over time. With three exceptions (Transects 3-30, 6-25 and 6-60) mean cover from the inception of monitoring until the mid 1990's was significantly different than from that point to the present (Association A). For the most recent survey, coral cover on 14 of the 18 transects ranked in the most distant Association from Association A, indicating the greatest change in cover over time. As total coral cover on all but one transect was higher in 2008 compared to 1991, it can be interpreted that there has been significant increase in coral cover from the initial survey to the present. ****

When surveys over the last five years (June 2002-July 2008) are compared, only three transects showed significant differences in mean coral cover (1-20, 1-35 and 3-20). At the first two of these transect stations there was substantial increases in cover between surveys (11.6%, 33.3%, respectively). Between the two most recent surveys (October 2007 and July 2008) there are no significant differences between cover (Table 6). Hence the only significant differences in coral over the last five years have been significant increases in coral cover. The overall lack of significant differences over the last five years between surveys suggests that the community may be near an equilibrium climax state where coral cover is no either changing at a rapid rate, and has attained the maximum equilibrium coverage under the prevailing physical conditions.

2. Other Benthic Macroinvertebrates

The other dominant group of macroinvertebrates on survey transects are the sea urchins (Class Echinoidea) (see Table 7). The most common urchins are *Echinometra matheai*, *Heterocentrotus mammillatus*, and *Tripneustes gratilla*. *E. matheai* are small urchins that are generally found within interstitial spaces bored into basaltic and limestone substrata. In the July 2008 survey, *E. matheai* occurred on all 18 transects in numbers from 4 to 31 individuals. This species was generally least abundant on the reef slope transects where solid substrata was not common.

Three species of sea cucumbers (Holothurians) were observed sporadically on the reef, but did not occur on transects. Individuals of these species (*Holothuria atra*, *H. nobilis*, and *Actinopyga obesa)* were distributed sporadically across the mid-reef and deep reef zones. The most common large starfish (Asteroidea) observed on the reef surface in past surveys has been the crown-of-thorns starfish (*Acanthaster planci*). However, no *A. planci* were observed during the last four surveys at any of the transect sites.

The design of the reef survey was such that no cryptic organisms or species living within interstitial spaces of the reef surface were enumerated. Since this is the habitat of the majority of mollusks and Crustacea, detailed species counts were not included in the transecting scheme. No dominant communities of these classes of biota were observed during the reef surveys at any of the study stations.

V. SUMMARY

In summary, based on the results of the time-course surveys, composition of coral communities off of the NELHA facility are largely controlled by the degree of physical energy that impacts the area from storm waves. Results of the twenty-three sequential surveys dating from 1991-2008 reveal no statistically significant decreases in coral cover that could be attributable to activities at NELHA.

Rather, results of the survey set indicates substantially more coral cover at present than in past years as a result of regrowth during a period when no storm waves have impacted the area. Recover of reef corals at Site 1 from damage caused by scouring of the reef surface from anchors and cables associated with installation of a pipeline has been raised the level of coral in this area to an equivalent level as other survey sites.

Examination of water chemistry monitoring data collected as part of the CEMP also indicates that there does not appear to be changes in marine environmental conditions from discharge that could affect mortality of benthos.

Comparisons of the mean coral cover over the course of monitoring indicate two discrete groupings; surveys up to the mid 1990's generally had significantly lower coral cover than the surveys in the last six years (2002-2008). These results indicate that coral cover has increased substantially over the last decade. Comparisons of cover over the last five years (June 2002-July 2008) indicate statistically significant changes on only three of the eighteen transects, two of which are increases in cover. Over the last two successive surveys in 2007-2008 there were no significant differences in coral cover. This result may indicate that the community has recovered from storm damage, and may be in a phase that can be considered an "equilibrium climax state." Observations of the coral communities indicate that substantial recolonization by newly settled corals has progressed on areas that were probably bared as a result of intense wave action from two storm events in the early 1990's. Based on these results, it appears that the activities of the NELHA facilities are not exerting any detectable negative effects to the benthic communities in the vicinity of Keahole Point.

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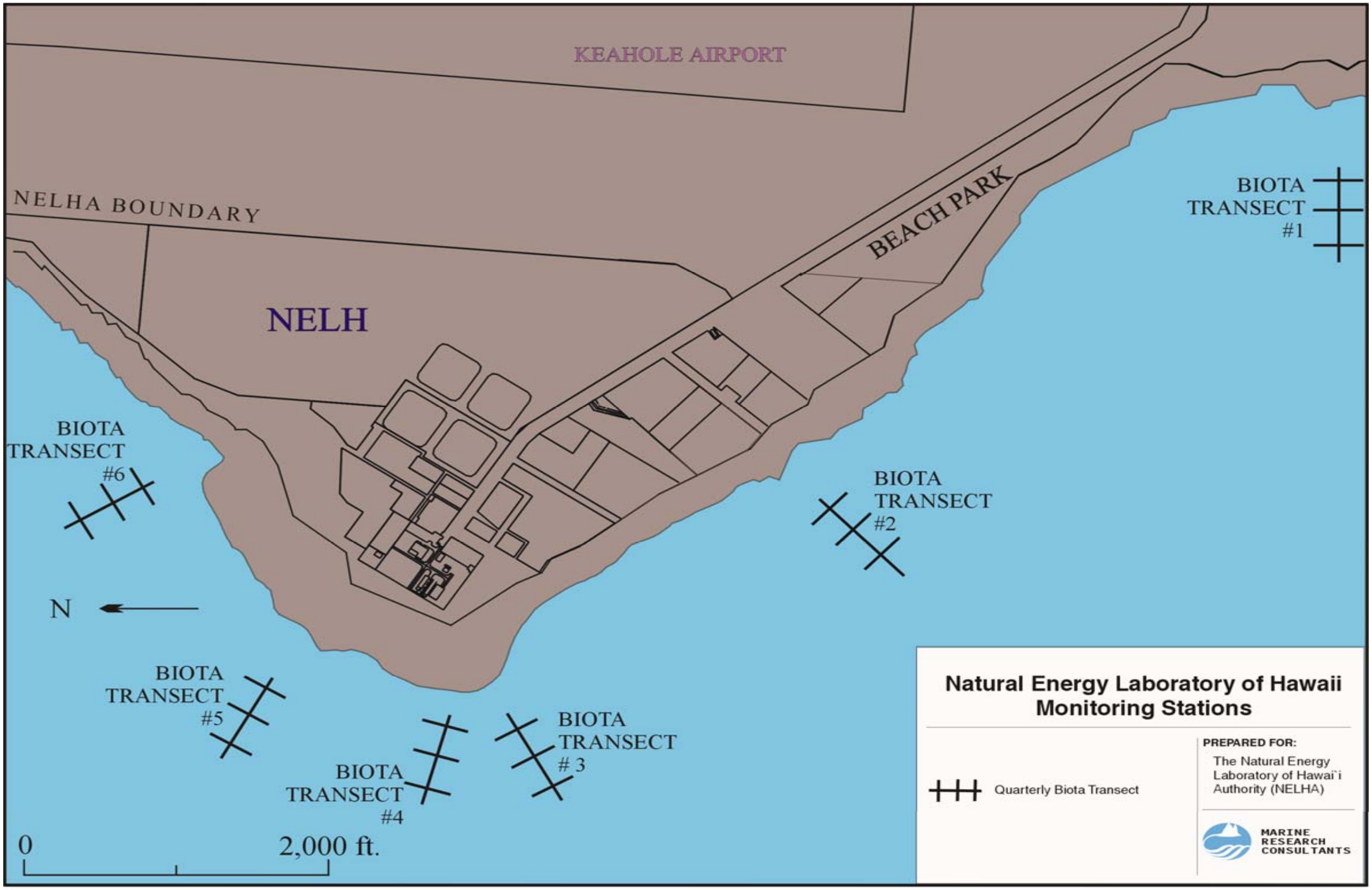


Figure 1. Map showing locations of six biological monitoring transects off of NELHA.

TABLE 1. Percent coral and non-coral substratum cover, total number of species and coral diversity on transects surveyed in the vicinity of NELHA on July 7, 2008. For survey sites, see Figure 1.

SITE 1 - WAWALOLI CORAL SPECIES	15'	20'	35'
Porites lobata	22.2	39.7	21.7
Porites compressa		0.2	26.2
Porites brighami			
Pocillopora meandrina	1.6	4.5	
Montipora capitata	3.8	1.9	
Montipora patula	1.3		
Pavona varians	0.2		
TOTAL CORAL COVER	29.1	46.3	47.9
NUMBER OF SPECIES	5	4	2
CORAL COVER DIVERSITY	0.80	0.51	0.69
NON-CORAL SUBSTRATA			
Basalt	55.1	38.3	0.0
Limestone	15.8	14.9	21.3
Sand	0.0	0.5	9.0
Rubble	0.0	0.0	21.8

SITE 4 - 12" PIPE NORTH CORAL SPECIES	20'	25'	50'
Porites lobata	20.3	27.3	41.5
Porites compressa	0.2	0.3	16.2
Porites brighami		0.4	
Pocillopora meandrina	12.7	18.6	12.0
Montipora capitata	4.8	6.8	4.1
Montipora patula	1.2	1.9	1.0
Pavona varians			
TOTAL CORAL COVER	39.2	55.3	74.8
NUMBER OF SPECIES	5	6	5
CORAL COVER DIVERSITY	1.10	1.15	1.17
NON-CORAL SUBSTRATA			
Basalt	55.3	32.9	10.1
Limestone	5.5	11.8	13.6
Sand	0.0	0.0	1.5
Rubble	0.0	0.0	0.0

SITE 2 - 18" PIPE CORAL SPECIES	20'	25'	45'
Porites lobata	33.4	27.1	15.0
Porites compressa			0.2
Pocillopora meandrina	19.9	18.7	18.5
Montipora capitata	2.6	3.8	1.1
Montipora patula	0.6	7.0	0.3
Pavona varians	0.2		
Leptastrea purpurea		0.5	
Porites rus			
TOTAL CORAL COVER	56.7	57.1	35.1
NUMBER OF SPECIES	5	5	5
CORAL COVER DIVERSITY	0.89	1.20	0.88
NON-CORAL SUBSTRATA			
Basalt	25.7	26.8	55.8
Limestone	17.6	16.1	9.1
Sand	0.0	0.0	0.0
Rubble	0.0	0.0	0.0

SITE 5 - NPPE CORAL SPECIES	20'	30'	50'
Porites lobata	23.4	40.2	55.5
Porites compressa	2.8	4.8	24.5
Pocillopora meandrina	14.8	15.9	4.7
Montipora capitata	2.4	6.2	2.4
Montipora patula	4.8	8.7	0.4
Pavona varians	0.5		
Leptastrea purpurea	0.4		
Porites rus	1.5		
TOTAL CORAL COVER	50.6	75.8	87.5
NUMBER OF SPECIES	8	5	5
CORAL COVER DIVERSITY	1.43	1.29	0.93
NON-CORAL SUBSTRATA			
Basalt	42.6	18.1	3.7
Limestone	4.8	6.1	8.8
Sand	0.0	0.0	0.0
Rubble	2.0	0.0	0.0

SITE 3 - 12" PIPE SOUTH CORAL SPECIES	20'	30'	45'
Porites lobata	9.8	24.9	37.0
Porites compressa			8.8
Pocillopora meandrina	15.8	20.8	15.2
Pocillopora eydouxi			4.5
Montipora capitata	0.8	5.7	5.5
Montipora patula		8.5	4.2
Pavona varians	0.4	0.2	
Porites rus	0.3		
TOTAL CORAL COVER	27.1	60.1	75.2
NUMBER OF SPECIES	5	5	6
CORAL COVER DIVERSITY	0.90	1.25	1.44
NON-CORAL SUBSTRATA			
Basalt	67.6	23.8	14.2
Limestone	5.3	15.3	10.6
Sand	0.0	0.8	0.0
Rubble	0.0	0.0	0.0

SITE 6 - HO`ONA BAY CORAL SPECIES	10'	25'	60'
Porites lobata	28.1	33.2	35.6
Porites compressa		21.9	22.2
Pocillopora meandrina	15.4	3.6	0.2
Pocillopora eydouxi			
Montipora capitata	2.3	0.6	0.5
Montipora patula	0.4		0.4
Pavona varians		1.3	0.6
Porites rus			
TOTAL CORAL COVER	46.2	60.6	59.5
NUMBER OF SPECIES	4	5	6
CORAL COVER DIVERSITY	0.86	0.99	0.81
NON-CORAL SUBSTRATA			
Basalt	46.7	19.0	0.0
Limestone	7.1	9.5	8.8
Sand	0.0	2.3	0.0
Rubble	0.0	8.6	31.7

TABLE 2A. Coral community data for each survey of the NELHA benthic monitoring program at Sites 1-3. % Coral represents percentage of bottom covered by all species of coral. % Pl, Pc and Pm are percentage cover of bottom by each of the three most common corals (*Porites lobata, Porites compressa and Pocillopora meandrina*). *S* p.# represents total number of coral species encountered on transects; Sp. div. represents Shannon-Weaver Species diversity. For locations of transect sites, see Figure 1.

SITE	DEPTH	PARAMETER	SURVEY NUMBER/DATE																					
			2 12/91	3 5/92	4 10/92	5 5/93	6 10/93	7 3/94	8 5/94	9 9/94	10 1/95	11 5/95	12 11/97	13 5/98	14 11/98	15 5/99	16 12/99	17 6/00	18 2/01	19 5/01	20 12/01	21 6/02	22 10/07	23 7/08
1- WAWALOLI	15'	% CORAL	12.5	5.5	5.1	4.7	7.6	2.5	5.0	6.9	5.8	5.7	24.3	30.2	19.4	16.9	21.2	24.1	34.1	32.4	23.5	42.3	41.2	29.1
		% P. l.	10.8	4.4	2.9	1.9	5.7	1.3	2.8	3.0	3.8	2.9	11.3	17.8	7.6	8.1	10.9	12.3	17.8	15.5	7.5	27.3	24.9	22.2
		% P. c.							0.1							0.6				0.1		0.8	0.2	
		% P. m.	1.7	1.0	2.2	2.5	1.7	0.4	0.7	1.8	1.6	1.9	12.5	9.9	11.0	5.3	9.4	9.5	14.1	14.3	14.3	11.6	11.0	1.6
		Sp. #	2	4	2	3	4	4	8	6	5	4	4	4	4	6	3	5	4	5	5	7	6	5
		Sp. div.	0.39	0.57	0.68	0.87	0.67	1.19	1.41	1.32	0.89	1.10	0.79	0.93	0.85	1.27	0.84	1.01	0.92	0.94	0.93	0.93	0.97	0.80
	20'	% CORAL	1.7	23.6	10.8	12.1	17.7	8.7	14.9	23.3	15.6	15.9	32.0	37.9	35.5	23.9	45.9	26.3	31.4	44.8	33.7	34.7	59.1	46.3
		% P. l.	1.4	22.2	9.8	11.4	16.5	4.1	13.3	21.7	13.8	14.2	20.6	21.7	16.5	11.4	25.8	13.2	14.4	14.4	14.3	16.3	38.9	39.7
		% P. c.	0.2				0.1	0.1							0.6	0.3	1.1			0.3	0.3	0.3	5.1	0.2
		% P. m.	0.1	1.1	0.5	0.2	0.5	3.9	0.6	0.2	0.3	1.1	7.0	11.8	13.7	9.1	13.1	8.5	12.0	22.1	16.6	14.1	12.6	4.5
		Sp. #	4	6	3	3	5	5	3	5	4	3	4	6	7	5	5	5	4	6	5	6	5	4
		Sp. div.	0.57	0.27	0.37	0.23	0.33	0.99	0.41	0.32	0.47	0.41	0.98	1.03	1.16	1.13	1.11	1.20	1.08	1.18	0.97	1.12	0.97	0.51
	35'	% CORAL	23.9	2.9	2.5	2.2	5.3	8.5	8.4	8.9	9.9	14.2	13.9	15.1	32.0	22.7	23.2	29.4	29.5	28.3	8.5	14.6	67.4	47.9
		% P. l.	14.7	2.5	2.2	1.5	2.9	3.6	6.3	7.1	7.5	8.2	7.7	7.0	19.7	10.4	10.4	13.5	13.8	15.2	4.9	5.8	30.7	21.7
		% P. c.	9.2	0.3		0.3	1.0	0.5					0.6	1.7	0.9	1.5	0.3	0.6		1.2	0.6	2.6	36.1	26.2
		% P. m.	0.1	0.1	0.1	0.1	1.0	3.3	1.6	1.3	1.2	4.8	5.3	4.5	10.8	8.9	10.8	11.5	13.0	9.9	1.8	4.4	0.4	
		Sp. #	3	3	3	5	4	7	4	3	3	5	4	5	5	4	4	5	4	5	5	4	4	2
		Sp. div.	0.68	0.42	0.44	1.05	1.15	1.32	0.74	0.62	0.72	0.94	0.91	1.25	0.85	1.11	0.96	1.15	0.95	1.07	1.15	1.29	0.74	0.69
2 - 18" PIPE	20'	% CORAL	12.5	15.6	19.2	15.8	18.6	10.0	15.5	15.1	15.2	24.5	35.2	54.5	49.8	36.8	46.4	45.9	49.5	46.3	54.7	41.7	47.8	56.7
		% P. l.	5.8	2.8	5.2	6.4	4.9	4.1	6.1	3.8	6.7	7.0	14.5	21.8	17.7	17.9	11.9	15.1	20.1	16.3	22.9	14.2	24.7	33.4
		% P. c.													0.8				0.3					
		% P. m.	6.2	10.0	11.2	5.7	11.8	3.9	8.4	6.2	6.8	9.3	15.7	20.8	26.2	13.8	27.4	27.4	24.7	29.3	25.2	22.6	20.3	19.9
		Sp. #	4	7	5	6	3	5	5	5	5	6	4	5	5	5	6	6	7	4	7	4	4	5
		Sp. div.	0.84	1.01	1.00	1.24	0.87	1.21	0.95	1.34	1.06	1.44	1.03	1.26	1.05	1.11	1.13	0.96	1.04	0.73	1.11	0.97	0.91	0.89
	25'	% CORAL	14.3	13.0	9.1	13.1	11.8	16.0	17.3	13.2	23.0	20.4	39.6	53.5	44.9	44.9	49.5	43.2	53.1	59.0	40.1	52.9	32.3	57.1
		% P. l.	5.2	4.4	3.9	2.6	3.4	4.8	3.7	3.3	12.8	8.6	12.2	15.5	20.0	19.2	8.2	8.4	12.7	16.7	8.2	21.2	12.1	27.1
		% P. c.						0.3		0.5		0.4						0.7		0.2				
		% P. m.	8.5	8.0	3.2	8.9	6.0	5.9	10.7	6.9	6.4	9.0	23.5	25.8	18.9	20.9	38.8	30.7	32.0	32.6	24.2	23.5	18.8	18.7
		Sp. #	6	6	4	5	6	8	5	6	4	5	6	5	5	5	4	7	7	5	6	5	5	5
		Sp. div.	0.84	0.85	1.15	0.89	1.17	1.56	1.06	1.27	1.04	1.13	1.03	1.22	1.10	1.03	0.67	0.89	1.11	1.11	1.15	1.12	0.86	1.20
	45'	% CORAL	12.4	7.4	5.5	16.2	10.7	12.9	12.9	8.4	12.5	4.3	18.9	22.0	22.6	12.6	27.0	36.9	40.8	36.4	41.4	31.6	34.6	35.1
		% P. l.	9.2	6.0	4.0	13.3	8.0	11.9	9.3	7.7	11.8	2.4	8.0	7.7	10.6	3.5	2.5	4.6	5.3	9.6	15.7	16.4	15.7	15.0
		% P. c.	2.5	1.3	1.3	1.3	2.4	0.6	2.7	0.4	0.2	0.7		3.7	1.1	0.1	0.1		0.2		0.4	1.6	0.2	0.2
		% P. m.	0.1	0.5	0.1		0.2	0.2		0.3	0.4	0.9	9.9	10.4	10.1	8.7	22.6	31.4	31.2	26.6	22.1	10.9	14.9	18.5
		Sp. #	6	4	4	3	4	5	3	3	4	4	3	4	7	5	7	4	6	3	6	5	5	5
		Sp. div.	0.58	0.54	0.72	0.59	0.67	0.36	0.75	0.34	0.27	1.13	0.86	1.06	1.02	0.75	0.65	0.50	0.80	0.61	0.99	1.12	1.07	0.88
3 - 12" PIPE SOUTH	20'	% CORAL		8.9	8.7	8.5	6.5	6.5	9.4	12.0	10.7	5.9	31.8	15.0	21.6	13.2	21.5	29.6	39.0	51.3	28.7	28.7	61.1	27.1
		% P. l.		1.4	1.4	2.0	2.4	1.9	2.5	4.1	2.2	1.3	17.3	3.5	7.8	7.5	7.8	9.0	19.9	23.1	10.8	9.2	31.7	9.8
		% P. c.		0.3				0.1																
		% P. m.		6.9	7.1	6.6	4.1	3.4	5.1	7.5	7.7	4.6	12.2	7.7		4.7	13.5	19.6	18.1	18.8	15.7	15.4	25.1	15.8
		Sp. #		5	4	2	2	4	4	3	4	2	4	6	6	3	3	3	5	6	4	5	4	5
		Sp. div.		0.70	0.56	0.54	0.66	1.04	1.10	0.77	0.81	0.53	0.92	1.27	0.93	0.88	0.70	0.75	0.82	1.28	0.93	1.13	0.94	0.90
	30'	% CORAL		20.2	13.7	21.2	16.8	20.5	18.8	19.2	23.4	17.6	42.7	42.2	50.9	36.9	57.5	57.5	56.9	60.9	56.7	52.0	32.6	60.1
		% P. l.		8.5	7.3	14.3	9.9	12.6	7.8	6.9	12.9	5.1	12.9	15.0	32.9	18.8	30.0	20.4	15.3	23.3	14.1	20.1	18.7	24.9
		% P. c.												1.4				0.4		0.2				
		% P. m.		7.2	3.6	4.6	2.8	5.1	5.2	8.5	6.1	7.5	26.2	20.7		13.1	17.0	26.5	37.7	27.1	28.4	24.2	12.2	20.8
		Sp. #		6	6	6	5	4	5	4	5	5	6	5	4	4	6	5	5	8	5	6	4	5
		Sp. div.		1.28	1.28	0.95	1.21	1.01	1.36	1.14	1.17	1.27	0.95	1.12	0.77	1.05	1.14	1.18	0.86	1.23	1.28	1.19	0.87	1.25
	45'	% CORAL		15.0	17.9	22.2	31.0	22.9	14.3	30.8	28.9	26.1	50.4	75.6	68.2	36.3	65.0	65.3	71.7	76.6	72.2	68.0	74.8	75.2
		% P. l.		11.5	14.1	16.8	19.1	17.9	10.1	18.9	18.3	16.7	15.5	28.9	23.1	15.9	26.0	20.8	30.6	28.6	45.0	28.0	41.4	37.0
		% P. c.		0.5	0.2	0.9	0.7	0.4	1.0	1.4		0.4	0.5	1.0	1.1	1.4	0.6	0.7	1.8	5.8	5.3	2.1	10.7	8.8
		% P. m.		0.9	1.2	2.3	2.8	1.3	0.8	2.8	4.4	4.6	27.3	35.3	35.7	5.0	30.3	34.5	27.0	32.1	14.7	24.9	14.3	15.2
		Sp. #		6	6	6	9	7	7	6	4	6	6	7	6	7	7	8	7	6	6	7	5	6
		Sp. div.		0.86	0.78	0.84	1.22	0.83	1.00	1.20	1.04	1.08	1.17	1.16	1.12	1.41	1.16	1.20	1.32	1.30	1.14	1.32	1.24	1.44

TABLE 2B. Coral community data for each survey of the NELHA benthic monitoring program at Sites 4-6. % Coral represents percentage of bottom covered by all species of coral. % Pl, Pc and Pm are percentage cover of bottom by each of the three most common corals (*Porites lobata, Porites compressa and Pocillopora meandrina). S* p.# represents total number of coral species encountered on transects; Sp. div. represents Shannon-Weaver Species diversity. For locations of transect sites, see Figure 1.

SITE	DEPTH	PARAMETER	SURVEY NUMBER/DATE																					
			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
			12/91	5/92	10/92	5/93	10/93	3/94	5/94	9/94	1/95	5/95	11/97	5/98	11/98	5/99	12/99	6/00	2/01	5/01	12/01	6/02	10/07	7/08
4 - 12" PIPE NORTH	20'	% CORAL		8.3	4.5	7.6	14.8	10.0	10.2	9.6	7.5	15.1	35.9	32.0	36.2	27.2	37.1	34.1	40.5	43.4	41.9	32.0	26.5	39.2
		% P. l.		3.2	2.2	2.5	5.0	3.0	3.3	3.4	4.6	3.5	9.7	11.9	10.0	6.6	10.9	8.0	14.9	11.8	16.1	9.2	12.0	20.3
		% P. c.												0.2	0.2							0.1		0.2
		% P. m.		4.3	2.3	3.1	6.3	3.5	3.9	5.1	1.5	8.1	22.1	18.7	22.9	20.2	24.1	22.8	22.9	26.4	21.1	18.4	12.8	12.7
		Sp. #		7	3	6	6	6	5	4	5	7	3	5	4	4	4	4	5	4	5	7	3	5
		Sp. div.		1.02	0.78	1.30	1.33	1.58	1.40	1.03	1.13	1.35	0.90	0.85	0.88	0.64	0.81	0.90	0.93	0.94	1.05	1.07	0.89	1.10
	25'	% CORAL		13.8	12.5	14.1	17.6	20.8	23.7	22.7	19.1	16.2	29.8	45.9	41.5	53.0	33.7	33.2	50.9	40.5	51.0	49.2	50.8	55.3
		% P. l.		9.2	9.9	7.1	7.0	9.2	9.0	10.4	9.3	10.1	14.8	23.9	22.5	15.7	16.3	20.6	21.7	16.1	19.1	23.6	20.9	27.3
		% P. c.		0.4	0.1		0.1						2.2			1.2	1.2			0.8	2.2	0.3		0.3
		% P. m.		3.4	1.3	4.0	3.0	3.5	7.7	5.5	6.8	4.3	12.1	16.1	14.4	31.1	12.5	11.1	21.5	18.9	21.6	16.2	15.1	18.6
		Sp. #		6	6	6	7	7	6	5	4	6	4	4	4	7	7	5	7	6	8	7	6	6
		Sp. div.		0.95	0.79	1.26	1.48	1.47	1.39	1.18	1.10	1.01	0.99	1.04	0.95	1.09	1.19	0.85	1.20	1.17	1.35	1.28	1.37	1.15
	50'	% CORAL		17.4	13.2	17.7	27.1	21.8	19.4	22.5	30.4	29.9	40.6	63.6	47.3	58.1	59.8	63.7	66.6	60.1	60.4	64.8	72.0	74.8
		% P. l.		14.1	10.5	13.9	15.3	16.4	14.0	14.4	24.8	23.9	23.5	32.0	26.6	36.0	32.2	36.2	35.4	29.0	27.7	38.1	46.6	41.5
		% P. c.		1.2	0.3	0.8	0.6	0.4	0.2	0.5	0.8	0.5	2.3	1.4	1.7	0.9	1.8	2.3	2.8	3.2	1.9	5.6	4.7	16.2
		% P. m.		0.1	0.5	0.5	3.6	0.8	1.0	2.0	0.8	1.8	7.1	14.6	8.0	13.7	15.4	13.7	17.8	21.0	14.4	10.8	16.2	12.0
		Sp. #		6	4	6	5	5	6	5	5	5	6	6	5	5	7	5	6	6	6	6	5	5
		Sp. div.		0.70	0.67	0.77	1.13	0.75	0.87	1.07	0.67	0.74	1.22	1.22	1.23	1.03	1.23	1.17	1.19	1.22	1.35	1.24	0.99	1.17
5 - NPPE	20'	% CORAL		18.6	21.7	20.6	25.6	22.9	26.4	33.7	24.5	19.6	62.0	46.7	42.5	47.8	66.8	53.7	37.7	48.1	52.9	45.3	41.1	50.6
		% P. l.		6.9	6.1	5.9	9.4	7.4	8.7	11.0	8.2	6.6	33.8	20.5	15.4	19.1	31.9	25.3	12.6	21.1	28.4	19.7	26.3	23.4
		% P. c.											0.6	0.6						0.8			12.7	2.8
		% P. m.		8.8	10.2	11.8	10.7	11.8	15.0	13.6	9.6	8.6	21.2	20.0	16.3	21.8	24.6	22.1	22.9	24.3	19.8	22.1		14.8
		Sp. #		6	7	6	5	7	5	6	6	5	6	7	6	5	6	4	5	5	4	7	3	8
		Sp. div.		1.21	1.43	1.13	1.25	1.25	0.99	1.40	1.45	1.28	1.06	1.19	1.37	1.12	1.17	1.05	0.87	0.92	0.98	0.97	0.80	1.43
	30'	% CORAL		29.5	33.9	36.6	51.3	44.1	45.3	47.2	51.7	42.1	61.6	75.3	64.8	75.3	85.4	71.3	77.2	71.7	70.2	59.2	77.3	75.8
		% P. l.		10.4	16.6	14.1	18.7	19.3	22.1	23.0	28.1	26.5	24.9	31.9	27.1	35.6	46.9	39.6	33.4	38.0	41.5	28.7	47.5	40.2
		% P. c.		0.3	0.3	1.6	0.8		2.8	1.6	1.7	0.2	2.8	1.2	1.3	1.6	1.9	4.5	2.8	2.4	6.4		10.1	4.8
		% P. m.		17.6	15.8	18.8	26.2	22.0	17.0	19.1	19.7	13.2	19.1	33.1	30.4	27.7	30.6	22.8	35.2	22.6	17.2	22.4	11.1	15.9
		Sp. #		6	7	6	7	5	5	6	6	6	7	7	6	7	6	5	6	7	6	6	6	5
		Sp. div.		0.88	0.90	1.05	1.13	0.95	1.13	1.09	0.98	0.89	1.50	1.17	1.11	1.23	1.04	1.08	1.10	1.20	1.13	1.11	1.19	1.29
	50'	% CORAL		28.0	38.3	45.5	40.5	47.7	40.5	60.3	58.4	55.1	83.8	83.9	77.2	79.8	74.7	89.8	77.7	89.6	76.6	90.3	88.6	87.5
		% P. l.		23.2	30.1	34.2	32.4	41.1	31.6	47.7	41.7	37.8	57.1	55.4	47.7	49.7	48.8	56.3	45.5	62.0	41.9	61.1	65.9	55.5
		% P. c.		1.9	1.4	3.5	1.4	1.7	3.8	2.1	5.4	7.6	11.1	6.3	14.3	20.5	11.7	14.5	17.2	17.0	10.3	21.4	16.0	24.5
		% P. m.		1.5	3.0	3.8	4.4	2.1	1.0	5.7	5.5	3.8	8.3	10.6	8.9	5.3	6.3	9.0	8.2	6.3	15.2	5.1	5.6	4.7
		Sp. #		6	7	6	6	5	5	6	6	7	7	7	4	7	7	6	5	5	7	5	5	5
		Sp. div.		0.68	0.83	0.91	0.74	0.56	0.78	0.78	0.96	1.04	1.05	1.15	1.06	1.01	1.11	1.17	1.15	0.93	1.29	0.89	0.77	0.93
6 - HO'ONA BAY	10'	% CORAL	15.1	15.1	24.8	12.0	7.5	9.0	6.8	10.9	10.8	11.0	17.6	24.0	27.7	15.3	32.2	35.2	46.9	41.9	43.6	35.2	34.9	46.2
		% P. l.	12.3	10.0	18.3	7.5	4.8	7.2	4.7	6.2	9.1	6.3	12.0	16.5	13.5	7.0	15.2	19.0	24.2	15.9	22.7	4.4	26.6	28.1
		% P. c.		0.2		0.3									0.2		0.2							
		% P. m.	2.4	4.4	3.9	3.9	1.5	1.1	0.9	2.1	1.7	2.4	4.3	6.8	10.1	8.3	12.7	14.9	17.6	21.2	19.1	30.8	8.3	15.4
		Sp. #	3	4	5	6	3	5	6	3	2	3	5	4	4	2	4	3	5	6	4	2	2	4
		Sp. div.	0.55	0.79	0.85	0.87	0.90	0.73	1.02	0.98	0.44	0.98	0.86	0.74	1.03	0.69	1.02	0.82	1.03	1.08	0.85	0.38	0.55	0.86
	25'	% CORAL	42.1	30.8	27.8	30.7	26.0	38.1	18.6	25.7	28.7	23.4	68.0	82.6	64.9	48.0	48.4	44.0	49.5	30.6	42.1	38.9	39.1	60.6
		% P. l.	37.4	25.4	22.1	22.8	21.3	35.2	13.1	23.0	24.9	20.3	46.4	51.0	28.7	28.1	24.2	29.3	29.9	16.1	30.3	26.3	32.6	33.2
		% P. c.	4.1	3.5	5.0	6.8	2.3	2.1	4.1	1.1	3.5	3.0	18.9	29.4	28.7	12.6	17.8	10.1	16.1		2.9	0.9	1.2	21.9
		% P. m.	0.6	1.7	0.6	1.0	2.3	0.3	1.2		0.1	0.1	0.6	1.1	6.7	3.2	5.2	3.6	2.9	12.0	7.2	11.6	4.3	3.6
		Sp. #	3	4	3	3	4	6	5	4	4	3	7	5	5	5	6	6	4	4	6	4	5	5
		Sp. div.	0.39	0.58	0.57	0.66	0.61	0.35	0.81	0.44	0.43	0.41	0.80	0.79	1.02	1.10	1.06	0.92	0.89	0.95	0.88	0.73	0.61	0.99
	60'	% CORAL	34.7	39.1	35.1	45.9	40.8	55.0	41.5	49.0	46.3	43.4	77.1	88.9	82.0	83.4	69.5	72.0	65.0	82.9	76.8	86.5	61.2	59.5
		% P. l.	12.5	20.0	12.7	18.8	18.7	18.9	19.2	20.8	23.3	17.4	27.9	30.4	28.3	28.8	27.0	24.6	38.2	32.9	33.0	39.3	36.0	35.6
		% P. c.	20.0	18.0	21.7	25.3	19.9	35.2	19.1	25.3	21.8	23.3	44.7	54.3	49.4	52.6	38.7	43.8	22.4	43.8	38.4	39.7	23.5	22.2
		% P. m.	0.5	0.3	0.1	0.3	1.1	0.1	0.7	0.4	0.3	0.5		0.3	0.2		0.5		1.1		1.6	0.4	0.2	0.2
		Sp. #	7	5	5	6	4	5	7	5	6	6	4	6	6	6	6	4	6	5	6	6	5	6
		Sp. div.	0.93	0.83	0.76	0.86	0.90	0.74	1.02	0.92	0.82	0.95	0.88	0.85	0.88	0.78	0.91	0.85	0.95	0.97	0.98	1.04	0.80	0.81

TABLE 3. ANOVA summary table for total cover at sites off NELHA, West Hawaii. Sites 1, 2 and 6 were surveyed on twenty-two dates (N=220); sites 3, 4 and 5 were surveyed on twenty-one dates (N=210). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	SS	df	MS	F	P-value
1 - WAWAOLI	15'	Between Groups	34588.38	21	1647.07	15.093	0.000
		Within Groups	21607.40	198	109.13		
	20'	Between Groups	50499.42	21	2404.73	12.439	0.000
		Within Groups	38276.34	198	193.31		
	35'	Between Groups	67987.73	21	3237.51	26.932	0.000
		Within Groups	23801.53	198	120.21		
			SS	df	MS	F	P-value
2 - 18" PIPE	20'	Between Groups	55011.67	21	2619.60	20.807	0.000
		Within Groups	24928.56	198	125.90		
	25'	Between Groups	59725.95	21	2844.09	16.510	0.000
		Within Groups	34108.88	198	172.27		
	45'	Between Groups	31668.78	21	1508.04	7.449	0.000
		Within Groups	40084.88	198	202.45		
			SS	df	MS	F	P-value
3 - 12" PIPE S.	20'	Between Groups	62205.65	20	3110.28	19.933	0.000
		Within Groups	29490.35	189	156.03		
	30'	Between Groups	56478.17	20	2823.91	14.279	0.000
		Within Groups	37378.45	189	197.77		
	45'	Between Groups	115624.05	20	5781.20	37.004	0.000
		Within Groups	29527.83	189	156.23		
			SS	df	MS	F	P-value
4 - 12" PIPE N.	20'	Between Groups	36119.17	20	1805.96	14.206	0.000
		Within Groups	24026.45	189	127.12		
	25'	Between Groups	44480.21	20	2224.01	8.411	0.000
		Within Groups	49976.63	189	264.43		
	50'	Between Groups	88646.55	20	4432.33	22.225	0.000
		Within Groups	37691.65	189	199.43		
			SS	df	MS	F	P-value
5 - NPPE	20'	Between Groups	42421.38	20	2121.07	9.311	0.000
		Within Groups	43055.63	189	227.81		
	30'	Between Groups	56622.27	20	2831.11	11.096	0.000
		Within Groups	48222.80	189	255.15		
	50'	Between Groups	84577.97	20	4228.90	20.189	0.000
		Within Groups	39589.68	189	209.47		
			SS	df	MS	F	P-value
6 - HO'ONA BAY	10'	Between Groups	35166.41	21	1674.59	10.431	0.000
		Within Groups	31787.05	198	160.54		
	25'	Between Groups	51458.22	21	2450.39	5.086	0.000
		Within Groups	95399.41	198	481.82		
	60'	Between Groups	71365.38	21	3398.35	9.101	0.000
		Within Groups	73932.68	198	373.40		

TABLE 4. ANOVA summary table for *Porites lobata* cover at sites off of NELHA, West Hawaii. Sites 1, 2 and 6 were surveyed on twenty-two dates (N=220); sites 3, 4 and 5 were surveyed on twenty-one dates (N=210). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	*SS*	*df*	*MS*	*F*	*P-value*
1 - WAWAOLI	15'	Between Groups	12780.93	21	608.62	7.203	0.000
		Within Groups	16729.63	198	84.49		
	20'	Between Groups	17119.02	21	815.19	4.877	0.000
		Within Groups	33097.38	198	167.16		
	35'	Between Groups	13968.23	21	665.15	7.174	
		Within Groups	18357.68	198	92.72		
2 - 18" PIPE	20'	Between Groups	11715.73	21	557.89	6.583	0.000
		Within Groups	16779.78	198	84.75		
	25'	Between Groups	7284.06	21	346.86	5.720	0.000
		Within Groups	12007.28	198	60.64		
	45'	Between Groups	4157.95	21	198.00	1.622	0.047
		Within Groups	24164.48	198	122.04		
3 - 12" PIPE S.	20'	Between Groups	18832.37	20	941.62	9.470	0.000
		Within Groups	18793.05	189	99.43		
	30'	Between Groups	10661.67	20	533.08	3.611	0.000
		Within Groups	27901.08	189	147.62		
	45'	Between Groups	19653.51	20	982.68	10.065	0.000
		Within Groups	18452.08	189	97.63		
4 - 12" PIPE N.	20'	Between Groups	3888.25	20	194.41	3.674	0.000
		Within Groups	9999.85	189	52.91		
	25'	Between Groups	7111.50	20	355.58	2.043	0.007
		Within Groups	32892.40	189	174.03		
	50'	Between Groups	23954.32	20	1197.72	7.769	0.000
		Within Groups	29136.73	189	154.16		
5 - NPPE	20'	Between Groups	17221.81	20	861.09	7.722	0.000
		Within Groups	21076.63	189	111.52		
	30'	Between Groups	24507.33	20	1225.37	8.220	0.000
		Within Groups	28175.95	189	149.08		
	50'	Between Groups	30425.82	20	1521.29	10.469	0.000
		Within Groups	27463.45	189	145.31		
6 - HO'ONA BAY	10'	Between Groups	11064.88	21	526.90	5.129	0.000
		Within Groups	20341.85	198	102.74		
	25'	Between Groups	16471.77	21	784.37	1.780	0.023
		Within Groups	87234.93	198	440.58		
	60'	Between Groups	13628.88	21	648.99	2.649	0.000
		Within Groups	48507.98	198	244.99		

TABLE 5. ANOVA summary table for *Pocillopora meandrina* cover at sites off of NELHA, West Hawaii. Sites 1, 2 and 6 were surveyed on twenty-two dates (N=220); sites 3, 4 and 5 were surveyed on twenty-one dates (N=210). For site locations, see Figure 1.

SITE	DEPTH	SOURCE OF VARIATION	SS	df	MS	F	P-value
1 - WAWAOLI	15'	Between Groups	5846.78	21	278.418	9.554	0.000
		Within Groups	5770.01	198	29.141		
	20'	Between Groups	9581.50	21	456.26	11.266	0.000
		Within Groups	8018.75	198	40.49874		
	35'	Between Groups	4118.36	21	196.11	5.229	0.000
		Within Groups	7425.43	198	37.50		
2 - 18" PIPE	20'	Between Groups	17390.53	21	828.12	10.548	0.000
		Within Groups	15545.15	198	78.51		
	25'	Between Groups	23391.95	21	1113.90	12.737	0.000
		Within Groups	17315.27	198	87.45		
	45'	Between Groups	24952.26	21	1188.20	14.025	0.000
		Within Groups	16775.10	198	84.72		
3 - 12" PIPE S.	20'	Between Groups	10860.40	20	543.02	13.537	0.000
		Within Groups	7581.60	189	40.11		
	30'	Between Groups	21536.46	20	1076.82	14.963	0.000
		Within Groups	13601.28	189	71.96		
	45'	Between Groups	33486.41	20	1674.32	23.558	0.000
		Within Groups	13432.93	189	71.07		
4 - 12" PIPE N.	20'	Between Groups	15107.62	20	755.38	9.886	0.000
		Within Groups	14440.78	189	76.41		
	25'	Between Groups	12825.83	20	641.29	8.714	0.000
		Within Groups	13908.95	189	73.59		
	50'	Between Groups	17407.78	20	870.39	21.358	0.000
		Within Groups	7702.33	189	40.75		
5 - NPPE	20'	Between Groups	16544.08	20	827.20	1.783	0.025
		Within Groups	87677.85	189	463.90		
	30'	Between Groups	12525.98	20	626.30	4.094	0.000
		Within Groups	28911.13	189	152.97		
	50'	Between Groups	26346.37	20	1317.32	24.836	0.000
		Within Groups	10024.53	189	53.04		
6 - HO'ONA BAY	10'	Between Groups	13175.75	21	627.42	12.908	0.000
		Within Groups	9624.48	198	48.61		
	25'	Between Groups	2574.97	21	122.62	5.633	0.000
		Within Groups	4310.33	198	21.77		
	60'	Between Groups	35.52	21	1.69	1.379	0.132
		Within Groups	242.93	198	1.23		

TABLE 6. Matrix of Tukey HSD multiple comparison probablilities showing significant (P<0.05) differences between mean coral cover on transects in the vicinity of NELHA. Survey Dates followed by the same Association letter are not significantly different.

TRANSECT	1-15	TRANSECT	1-20	TRANSECT	1-35	TRANSECT	2-20	TRANSECT	2-25	TRANSECT	2-45
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
Mar-94	A	Dec-91	A	May-93	A	Mar-94	A	Oct-92	A	May-95	A
May-93	AB	Mar-94	AB	Oct-92	A	Dec-91	A	Oct-93	AB	Oct-92	A
May-94	AB	Oct-92	ABC	May-92	A	Sep-94	A	May-92	AB	May-92	A
Oct-92	AB	May-93	ABCD	Oct-93	AB	Jan-95	A	May-93	AB	Sep-94	AB
May-92	AB	May-94	ABCDE	May-94	ABC	May-94	A	Sep-94	AB	Oct-93	AB
May-95	AB	Jan-95	ABCDE	Mar-94	ABC	May-92	A	Dec-91	AB	Dec-91	ABC
Jan-95	AB	May-95	ABCDE	Dec-01	ABC	May-93	A	Mar-94	AB	Jan-95	ABC
Sep-94	ABC	Oct-93	ABCDE	Sep-94	ABC	Oct-93	AB	May-94	AB	May-99	ABC
Oct-93	ABC	Sep-94	ABCDEF	Jan-95	ABC	Oct-92	AB	May-95	ABC	May-94	ABCD
Dec-91	ABCD	May-92	ABCDEF	Nov-97	ABCD	May-95	ABC	Jan-95	ABCD	Mar-94	ABCD
May-99	ABCDE	May-99	ABCDEF	May-95	ABCD	Nov-97	BCD	Jul-08	BCDE	May-93	ABCDE
Nov-98	ABCDE	Jun-00	BCDEF	Jun-02	ABCD	May-99	BCDE	Oct-07	BCDE	Nov-97	ABCDEF
Dec-99	BCDE	Feb-01	BCDEF	May-98	ABCD	Jun-02	CDE	Nov-97	CDEF	May-98	ABCDEF
Dec-01	CDE	Nov-97	CDEF	May-99	BCD	Jun-00	DE	Dec-01	CDEF	Nov-98	ABCDEF
Jun-00	CDEF	Dec-01	CDEF	Dec-99	BCD	May-01	DE	Jun-00	DEF	Dec-99	ABCDEF
Nov-97	CDEF	Jun-02	DEF	Dec-91	CD	Dec-99	DE	Nov-98	DEF	Jun-02	BCDEF
Jul-08	DEFG	Nov-98	EF	May-01	D	Jul-08	DE	May-99	DEF	Jul-08	CDEF
May-98	EFG	May-98	EFG	Jun-00	D	Oct-07	DE	Dec-99	EF	Oct-07	CDEF
May-01	EFG	May-01	FG	Feb-01	D	Feb-01	DE	Jun-02	EF	May-01	DEF
Feb-01	EFG	Dec-99	FG	Nov-98	D	Nov-98	DE	Feb-01	EF	Jun-00	EF
Oct-07	FG	Oct-07	G	Oct-07	E	May-98	E	May-98	EF	Feb-01	F
Jun-02	G	Jul-08	G	Jul-08	E	Dec-01	E	May-01	F	Dec-01	F

TRANSECT	3-20	TRANSECT	3-30	TRANSECT	3-45	TRANSECT	4-20	TRANSECT	4-25	TRANSECT	4-50
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
May-95	A	Oct-92	A	May-94	A	Oct-92	A	Oct-92	A	Oct-92	A
Mar-94	A	Oct-93	A	May-92	A	Jan-95	A	May-92	AB	May-92	AB
Oct-93	A	May-95	A	Oct-92	AB	May-93	A	May-93	AB	May-93	AB
May-93	AB	May-94	A	May-93	AB	May-92	AB	May-95	ABC	May-94	AB
Oct-92	AB	Sep-94	AB	Mar-94	AB	Sep-94	ABC	Oct-93	ABC	Mar-94	AB
May-92	AB	May-92	ABC	May-95	AB	Mar-94	ABC	Jan-95	ABCD	Sep-94	AB
May-94	ABC	Mar-94	ABC	Jan-95	AB	May-94	ABC	Mar-94	ABCD	Oct-93	ABC
Jan-95	ABC	May-93	ABC	Sep-94	ABC	Oct-93	ABCD	Sep-94	ABCDE	May-95	ABC
Sep-94	ABCD	Jan-95	ABC	Oct-93	ABC	May-95	ABCD	May-94	ABCDE	Jan-95	ABC
May-99	ABCD	Jul-08	ABCD	May-99	BC	Jul-08	BCDE	Nov-97	ABCDEF	Nov-97	BCD
May-98	ABCD	Oct-07	ABCD	Nov-97	CD	Oct-07	BCDE	Jun-00	ABCDEF	Nov-98	CDE
Dec-99	ABCDE	May-99	ABCDE	Dec-99	DE	May-99	CDE	Dec-99	ABCDEF	May-99	DEF
Nov-98	ABCDE	May-98	BCDEF	Jun-00	DE	May-98	DE	May-01	BCDEF	Dec-99	DEF
Dec-01	BCDE	Nov-97	CDEF	Jun-02	DE	Jun-02	DE	Nov-98	CDEF	May-01	DEF
Jun-02	BCDE	Nov-98	DEF	Nov-98	DE	Jun-00	E	May-98	DEF	Dec-01	DEF
Jun-00	CDE	Jun-02	DEF	Feb-01	E	Nov-97	E	Jun-02	EF	May-98	DEF
Nov-97	DEF	Dec-01	EF	Dec-01	E	Nov-98	E	Jul-08	F	Jun-00	DEF
Feb-01	EF	Feb-01	EF	Oct-07	E	Dec-99	E	Oct-07	F	Jun-02	EF
May-01	FG	Dec-99	EF	Jul-08	E	Feb-01	E	Feb-01	F	Feb-01	EF
Oct-07	G	Jun-00	EF	May-98	E	Dec-01	E	Dec-01	F	Oct-07	F
Jul-08	G	May-01	F	May-01	E	May-01	E	May-99	F	Jul-08	F

TRANSECT	5-20	TRANSECT	5-30	TRANSECT	5-50	TRANSECT	6-10	TRANSECT	6-25	TRANSECT	6-60
Date	Association	Date	Association	Date	Association	Date	Association	Date	Association	Date	Association
May-92	A	May-92	A	May-92	A	May-94	A	May-94	A	Dec-91	A
May-95	A	Oct-92	AB	Oct-92	AB	Oct-93	A	May-95	A	Oct-92	A
May-93	AB	May-93	ABC	May-94	AB	Mar-94	A	Sep-94	A	May-92	AB
Oct-92	ABC	May-95	ABCD	Oct-93	AB	Jan-95	A	Oct-93	A	Oct-93	ABC
Mar-94	ABCD	Mar-94	ABCDE	May-93	AB	Sep-94	A	Oct-92	A	May-94	ABC
Jan-95	ABCDE	May-94	ABCDEF	Mar-94	AB	May-95	A	Jan-95	AB	May-95	ABC
Oct-93	ABCDE	Sep-94	ABCDEF	May-95	BC	May-93	AB	May-01	AB	May-93	ABCD
May-94	ABCDE	Oct-93	ABCDEFG	Jan-95	BCD	Dec-91	ABC	May-93	AB	Jan-95	ABCD
Sep-94	ABCDEF	Jan-95	ABCDEFG	Sep-94	BCDE	May-92	ABC	May-92	AB	Sep-94	ABCD
Feb-01	ABCDEFG	Jun-02	BCDEFGH	Dec-99	CDEF	May-99	ABC	Mar-94	ABC	Mar-94	ABCDE
Jul-08	ABCDEFG	Nov-97	CDEFGH	Dec-01	CDEF	Nov-97	ABC	Jun-02	ABC	Jul-08	ABCDEF
Oct-07	ABCDEFG	Nov-98	DEFGH	Nov-98	CDEF	May-98	ABCD	Jul-08	ABC	Oct-07	ABCDEF
Nov-98	ABCDEFGH	Dec-01	EFGH	Feb-01	CDEF	Oct-92	ABCD	Oct-07	ABC	Feb-01	ABCDEF
Jun-02	BCDEFGH	Jun-00	FGH	May-99	DEF	Nov-98	ABCDE	Dec-01	ABC	Dec-99	BCDEF
May-98	CDEFGH	May-01	FGH	Nov-97	EF	Dec-99	BCDE	Dec-91	ABC	Jun-00	CDEF
May-99	DEFGH	May-99	GH	May-98	EF	Jul-08	CDE	Jun-00	ABC	Dec-01	DEF
May-01	EFGH	May-98	GH	Oct-07	F	Oct-07	CDE	May-99	ABCD	Nov-97	DEF
Dec-01	FGH	Feb-01	GH	Jul-08	F	Jun-02	CDE	Dec-99	ABCD	Nov-98	EF
Jun-00	FGH	Oct-07	GH	May-01	F	Jun-00	CDE	Feb-01	ABCD	May-01	EF
Nov-97	GH	Jul-08	GH	Jun-00	F	May-01	DE	Nov-98	BCD	May-99	EF
Dec-99	H	Dec-99	H	Jun-02	F	Dec-01	DE	Nov-97	CD	Jun-02	EF
						Feb-01	E	May-98	D	May-98	F

TABLE 7. Cumulative sea urchin data for NELHA benthic monitoring program. For site and transect locations, see Figure 1.

SITE	TRANSECT	SPECIES	SURVEY NUMBER/DATE																					
			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
			12/91	5/92	10/92	5/93	10/93	3/94	5/94	9/94	1/95	5/95	11/97	5/98	11/98	5/99	12/99	6/00	2/01	5/01	12/01	6/02	10/07	7/08
1	15'	E. matheai	36	14	8	11	24	14	20	24	31	26	22	31	27	34	38	29	41	29	32	21	29	31
		H. mammillatus			1		1					2		1	1	2		2						
		T. gratilla			1							1	1	2	3	3						1	2	7
		E. diadema															2	1				1	1	2
	20'	E. matheai	9	40	30	17	34	29	25	31	35	41	35	39	42	31	29	32	26	24	37	26	31	29
		H. mammillatus				1	1																	
		E. diadema																		1	1	1	2	1
	35'	E. matheai	5		3	1	1	6	3	4	5	3	2	1	2	3	4	2	5	4	4	2	6	7
		H. mammillatus	1										1	1	1	2		2					1	1
		E. diadema																1						
		T. gratilla		2		1										1							2	
2	20'	E. matheai	19	2	4	3	8	4	6	3	2	4	3	5	4	2	5	6	8	11	12	14	8	11
	25'	E. matheai	8	5	3	11	13	6	14	21	28	24	27	32	35	39	19	32	31	29	19	21	22	32
		E. aciculatus				1		1	1							1								
		E. diadema															1	2						4
		T. gratilla																					1	
	45'	E. matheai	4	9	8	7	6	2	11	7	5	4	4	2	2	2	11	4	21	18	13	11	15	9
		E. diadema																					2	
3	20'	E. matheai		2	3	2	1		1	2	1	2	3	4	2	6	5	11	16	21	19	12	16	13
		E. diadema																					1	
	30'	E. matheai		15	4	6	11	8	5	3	2	2	2	3	3	4	4	8	11	14	15	11	16	12
	45'	E. diadema											1	2	2	3							1	
		E. matheai		2	1	1	1	1	1	1	4	1	3	2	1	1	5	5	8	6	11	9	4	6
4	20'	E. matheai		3	2	7	4	2	4	3	4	4	2	2	1	2	5	6	11	13	12	21	8	4
	25'	E. matheai		9	15	7	11	6	6	4	3	2	4	3	2	3	5	7	12	16	15	18	13	7
	50'	E. matheai		2	0	1	1	1	4	2	2	3	3	5	3	4	4	7	14	21	13	15	11	8
		E. diadema																					2	1
5	20'	E. matheai		7	7	7	4	4	3	1	2	5	4	6	2	6	8	11	21	25	18	11	12	13
		E. diadema																					3	
	30'	E. matheai		1	4	1	1	6	8	3	4	41	27	38	26	28	18	31	43	32	21	16	28	17
		H. mammillatus																		1			1	
	50'	E. matheai		1	4			2	4	1	3						5	2	9	11	13	7		3
6	10'	E. matheai	4	23	9	4	12	6	11	16	19	12	11	14	12	16	7	5	9	13	11	11	14	21
		H. mammillatus	2	2		2	1	2																3
		E. diadema				1														1				1
	25'	E. matheai	39	20	4	1	9	7	6	3	4	3	2	3	2	3	5	5	11	21	15	14	13	12
		H. mammillatus	7	3	4		1	1	1	1	2	2	2	4	5	2								
		T. gratilla																1						
	60'	E. matheai	7			1	1			1	3	4	2	2	4	4	3	6	12	19	12	9	15	10
		H. mammillatus	4		1	2		1	1	1	1	1	1	3	3	2								
		T. gratilla				3	1															1		1
		E. diadema																					2	
		TOTAL	145	162	116	99	147	109	135	132	160	187	162	205	185	204	183	218	309	330	293	253	282	266

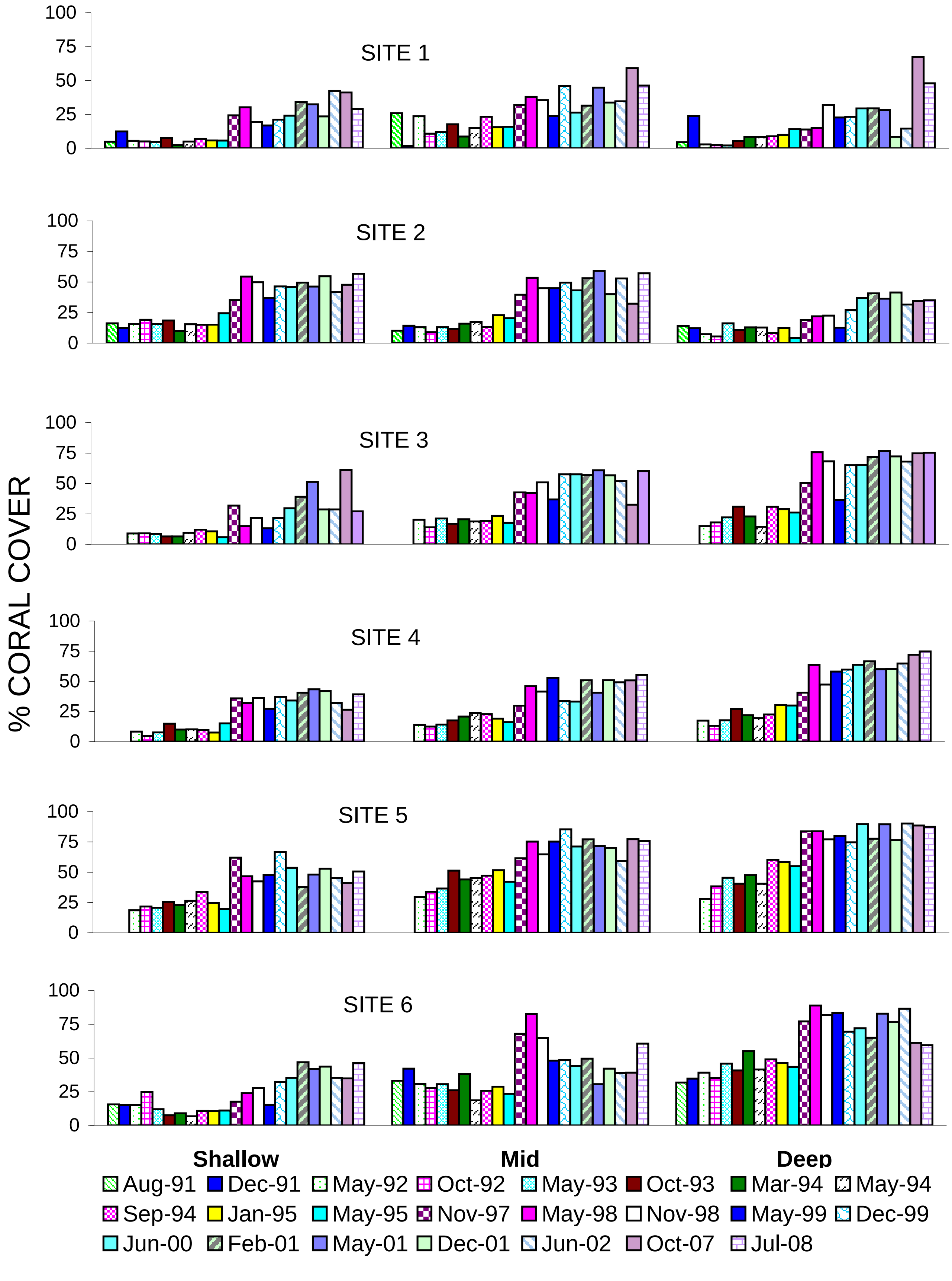


FIGURE 2. Bar graphs of percentage of total coral cover from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

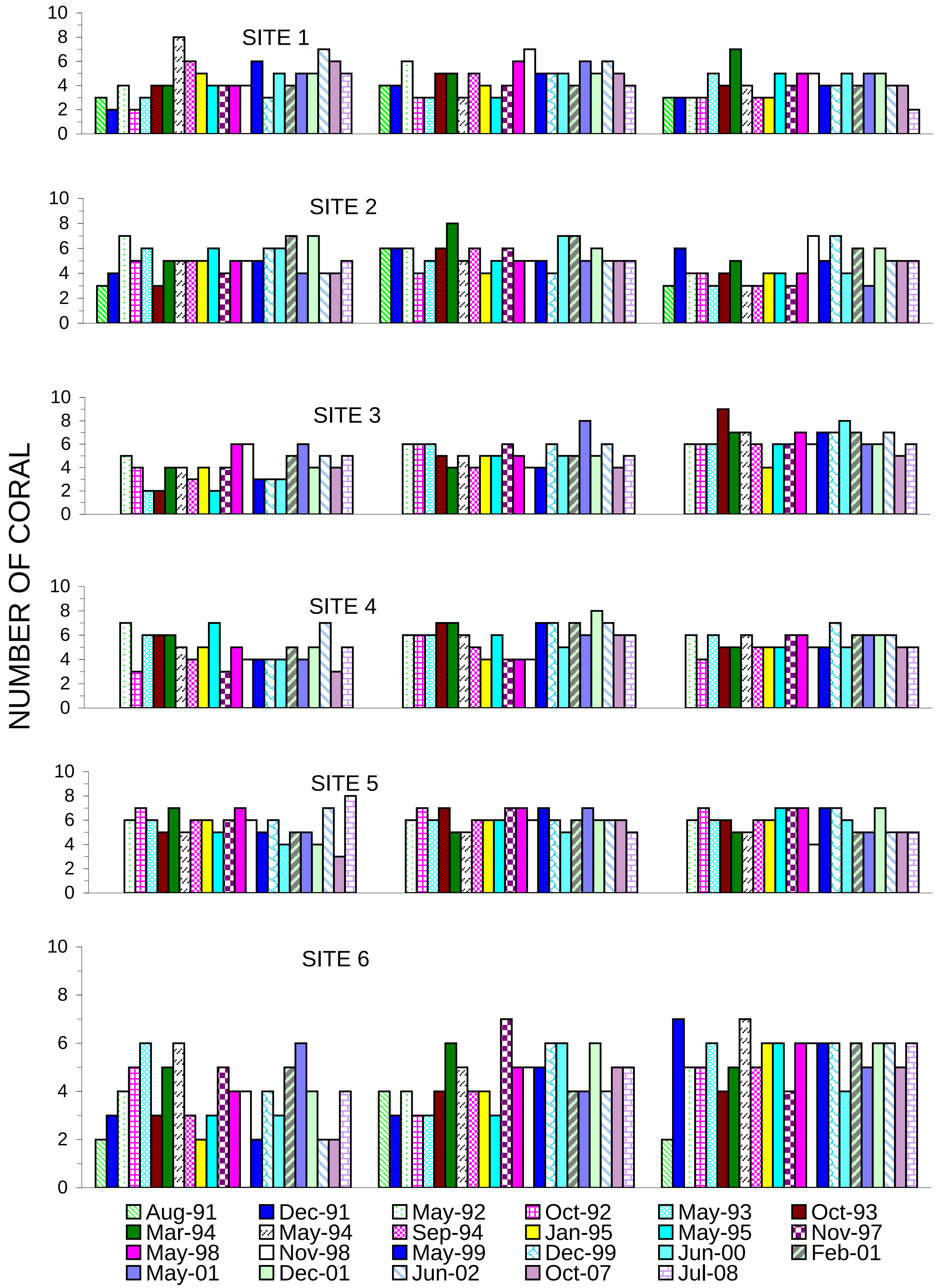


FIGURE 3. Bar graph of total number of coral species from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

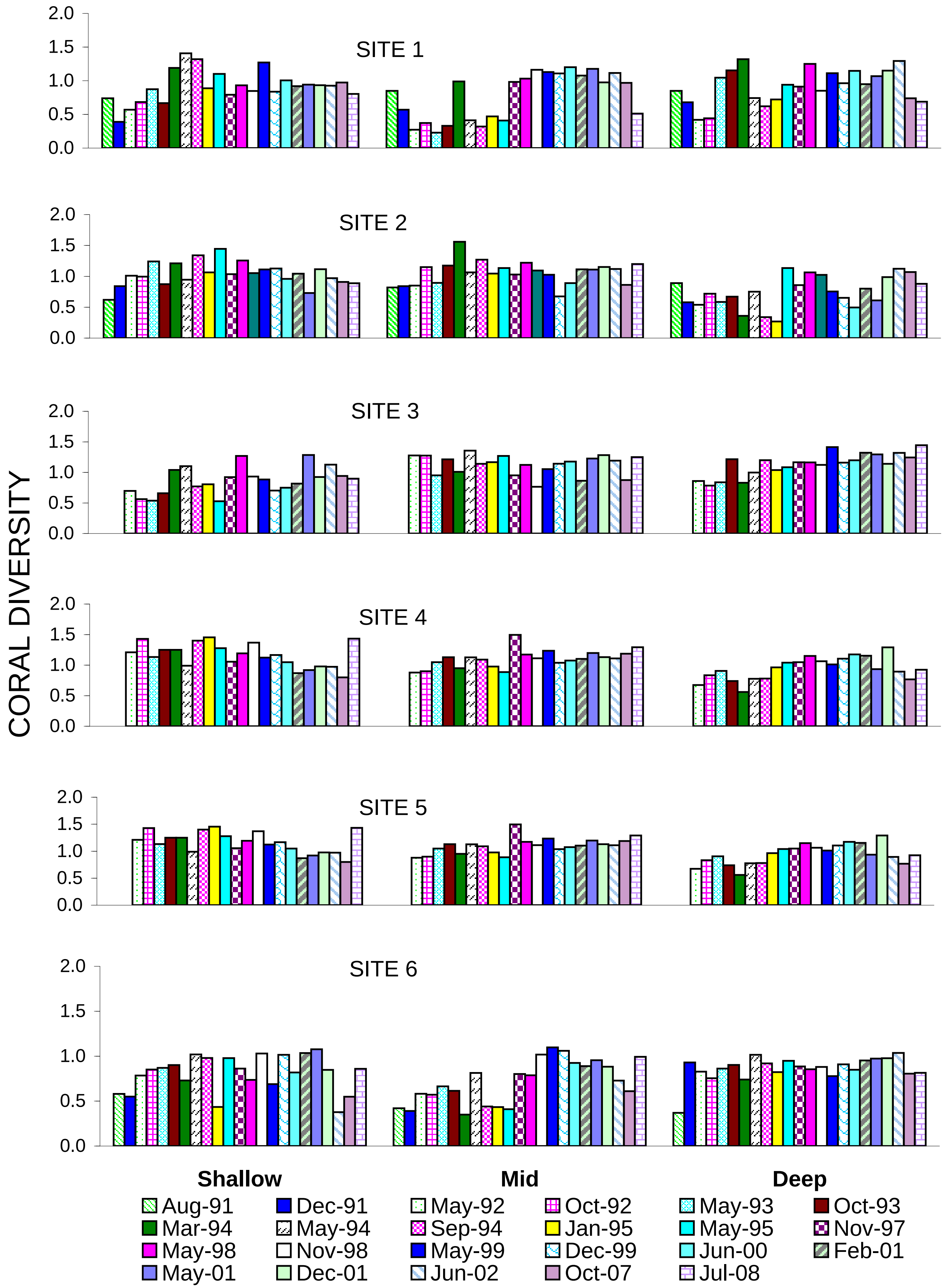


FIGURE 4. Bar graph of coral species diversity from three depths at six marine monitoring sites located in the vicinity of NELHA surveyed since December 1991 (Note: sampling suspended between June 1995 and October 1997). Sites 3, 4, and 5 were not surveyed in December 1991. For location of survey sites, see Figure 1.

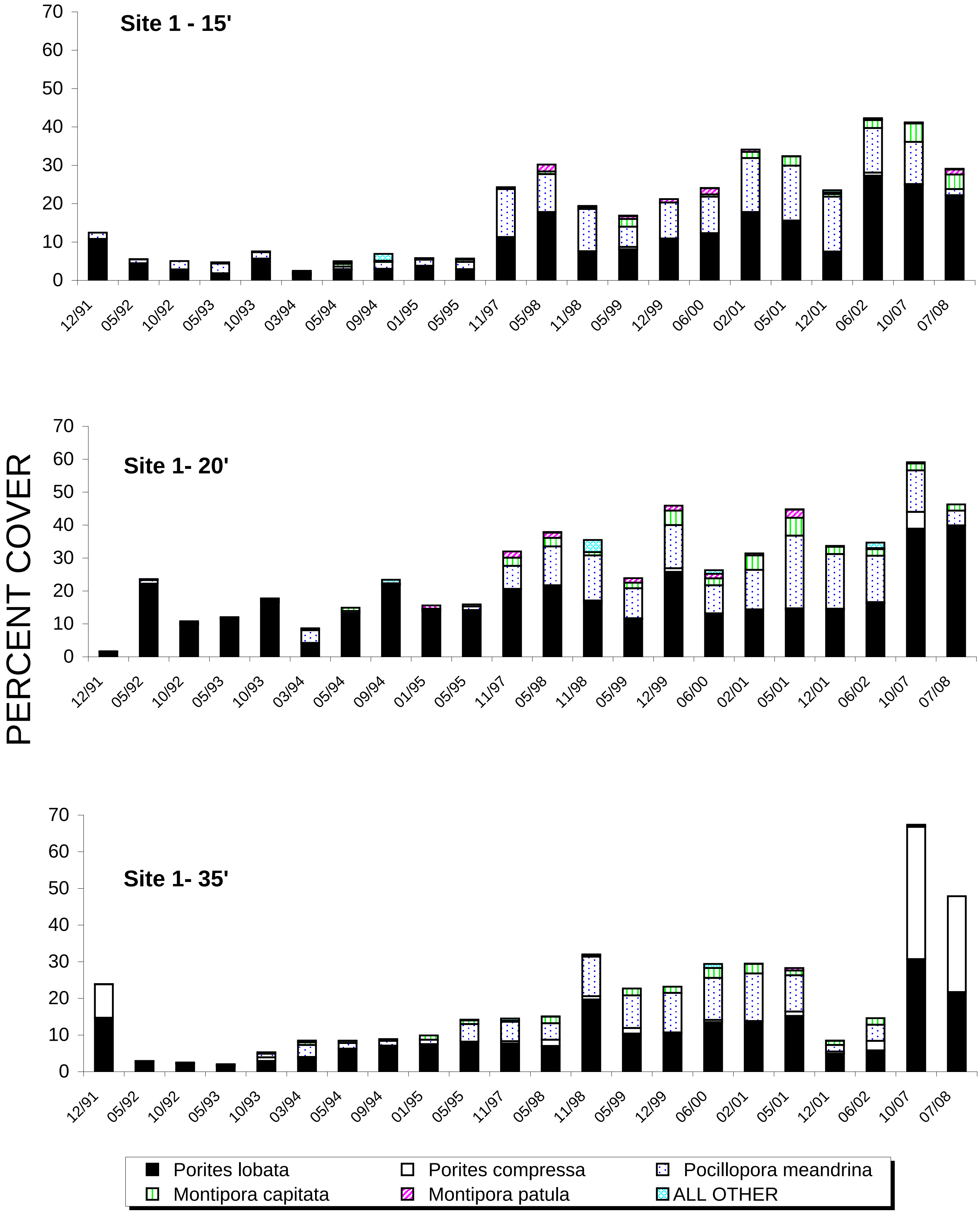


FIGURE 5. Bar graph showing percent cover of major coral species at three depths along the transect at Site 1. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. For location of Site 1, see Figure 1.

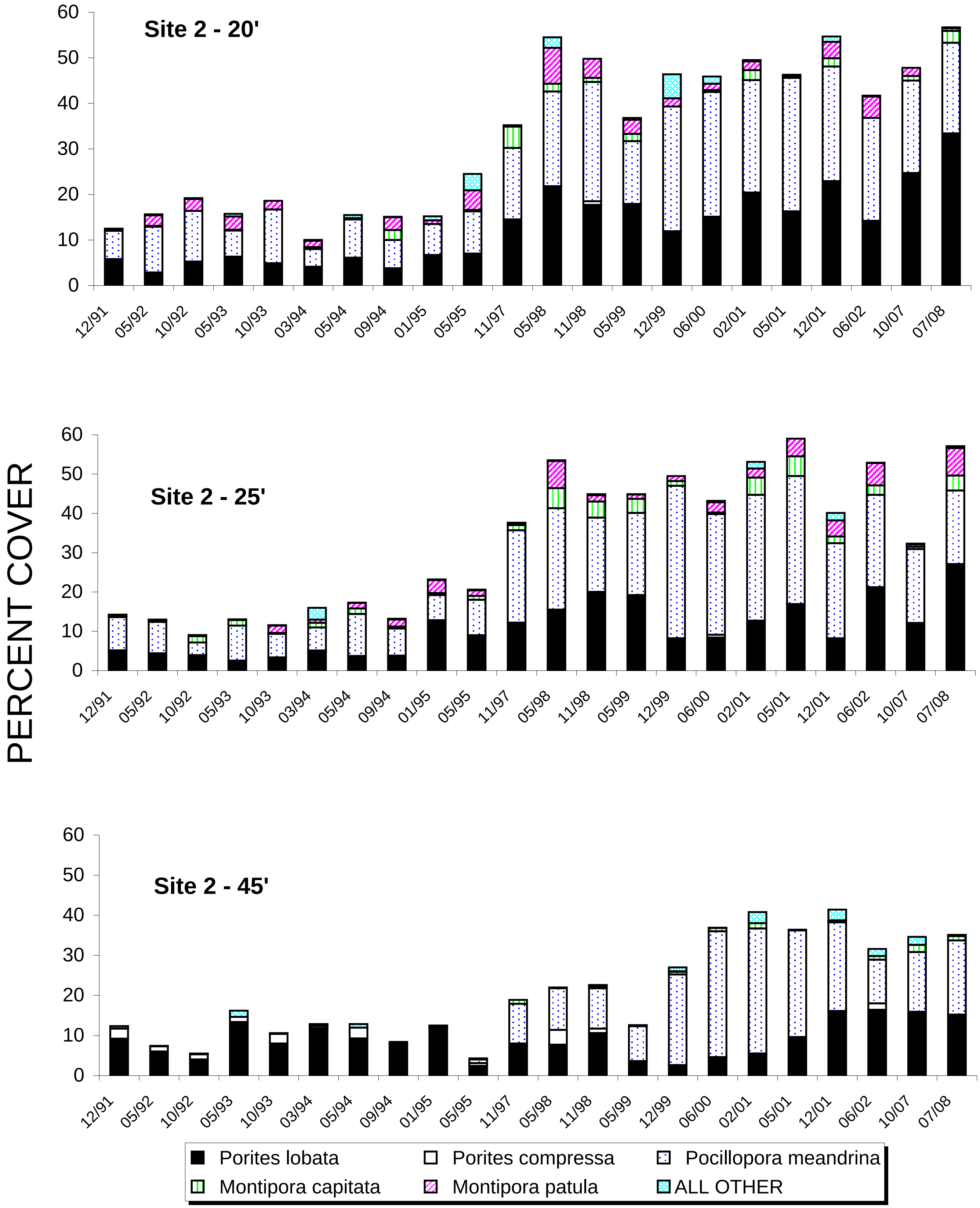


FIGURE 6. Bar graph showing percent cover of major coral species at three depths along the transect at Site 2. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. For location of Site 2, see Figure 1.

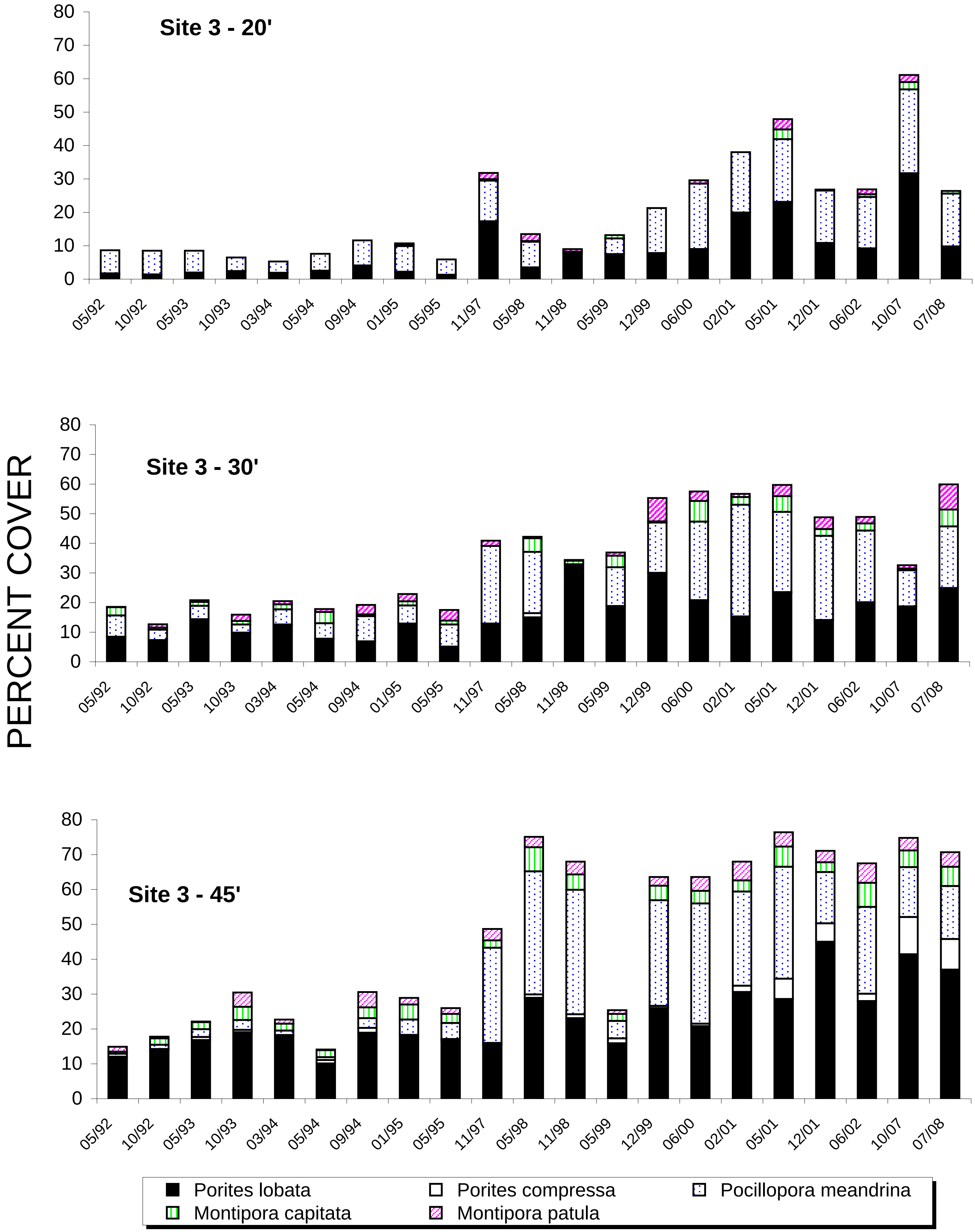


FIGURE 7. Bar graph showing percent cover of major coral species at three depths along the transect at Site 3. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axix scale change for deep transect. For location of Site 3, see Figure 1.

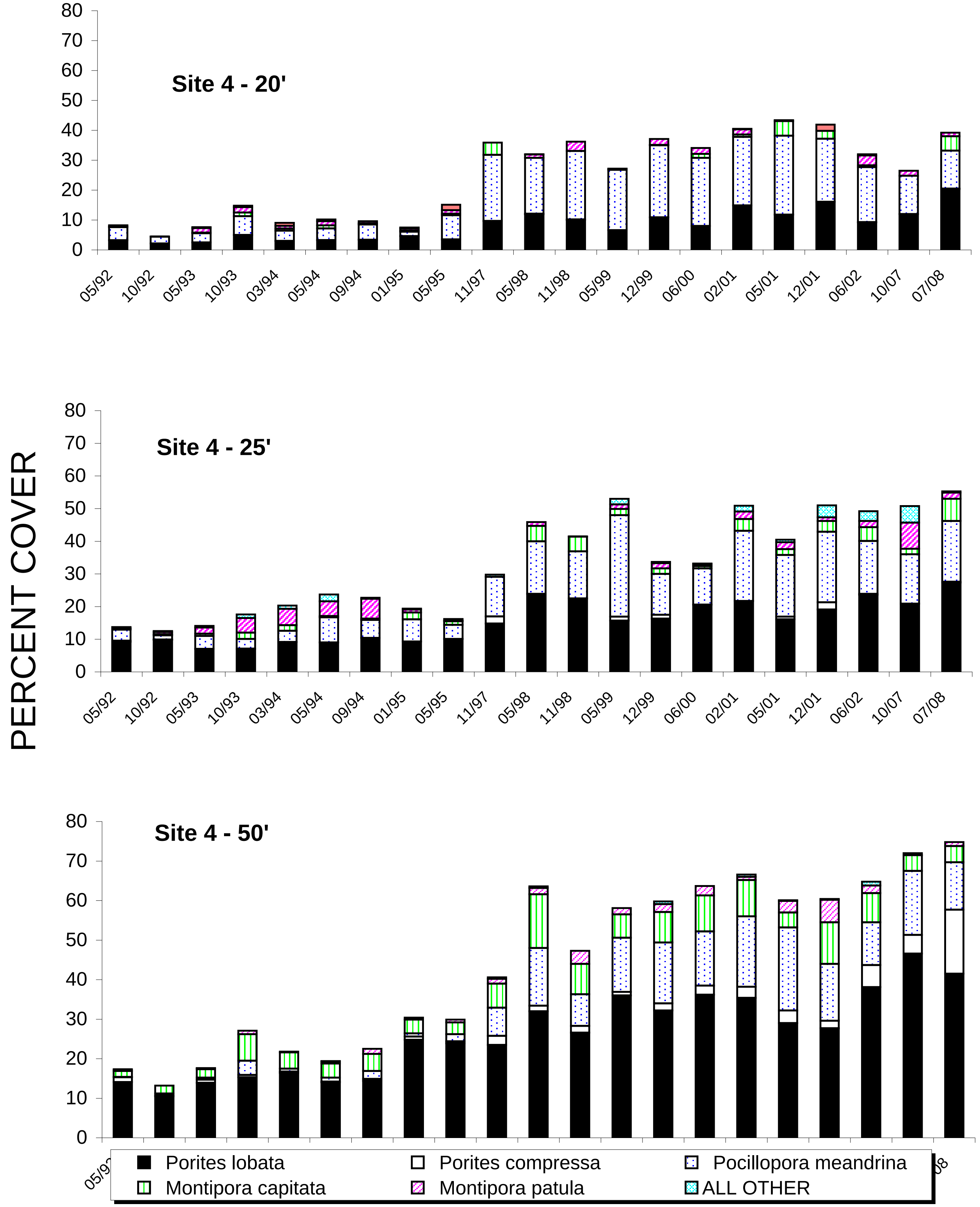


FIGURE 8. Bar graph showing percent cover of major coral species at three depths along the transect at Site 4. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for deep transect. For location of Site 4, see Figure 1.

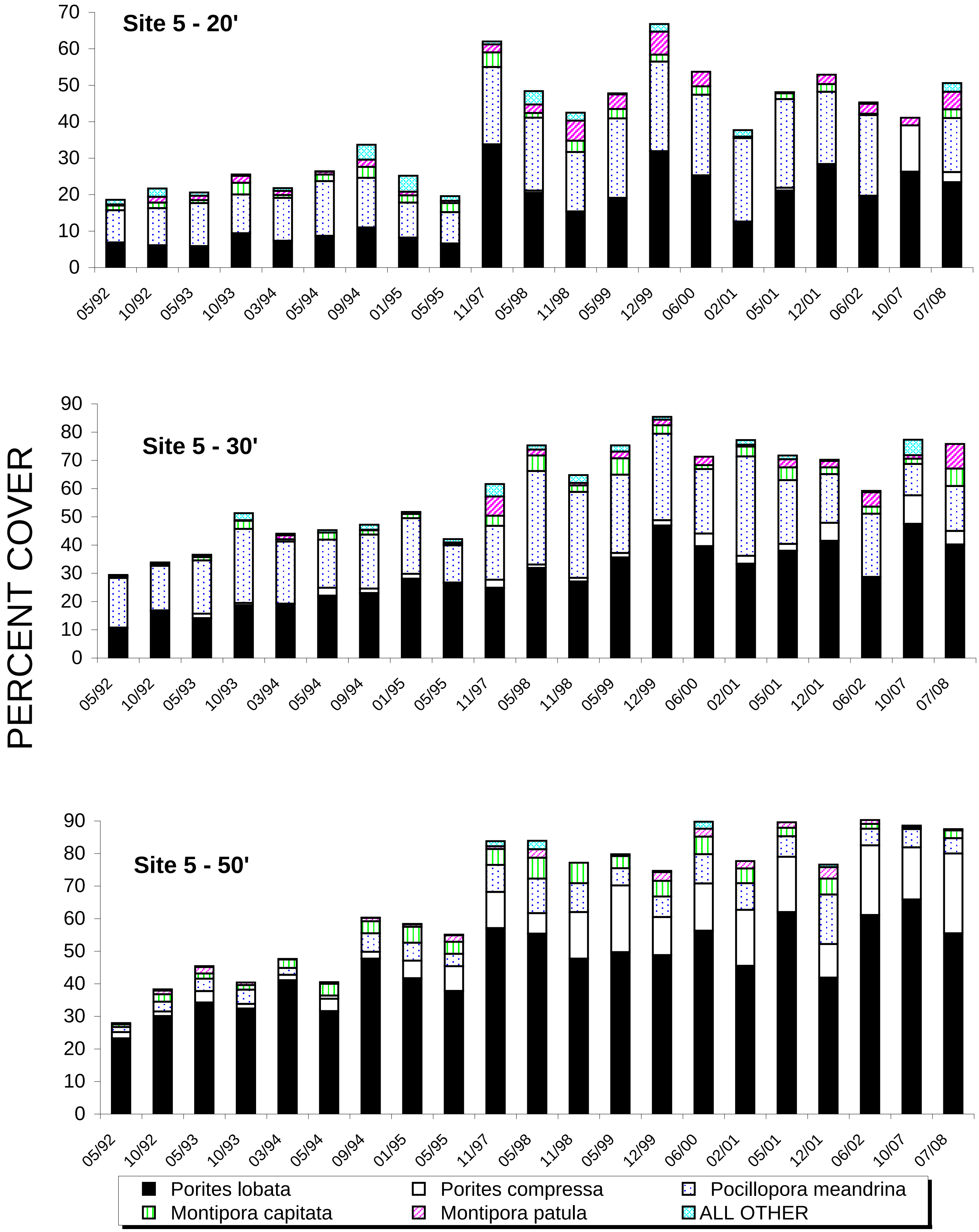


FIGURE 9. Bar graph showing percent cover of major coral species at three depths along the transect at Site 5. Surveys were conducted since May 1992 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for shallow transect. For location of Site 5, see Figure 1.

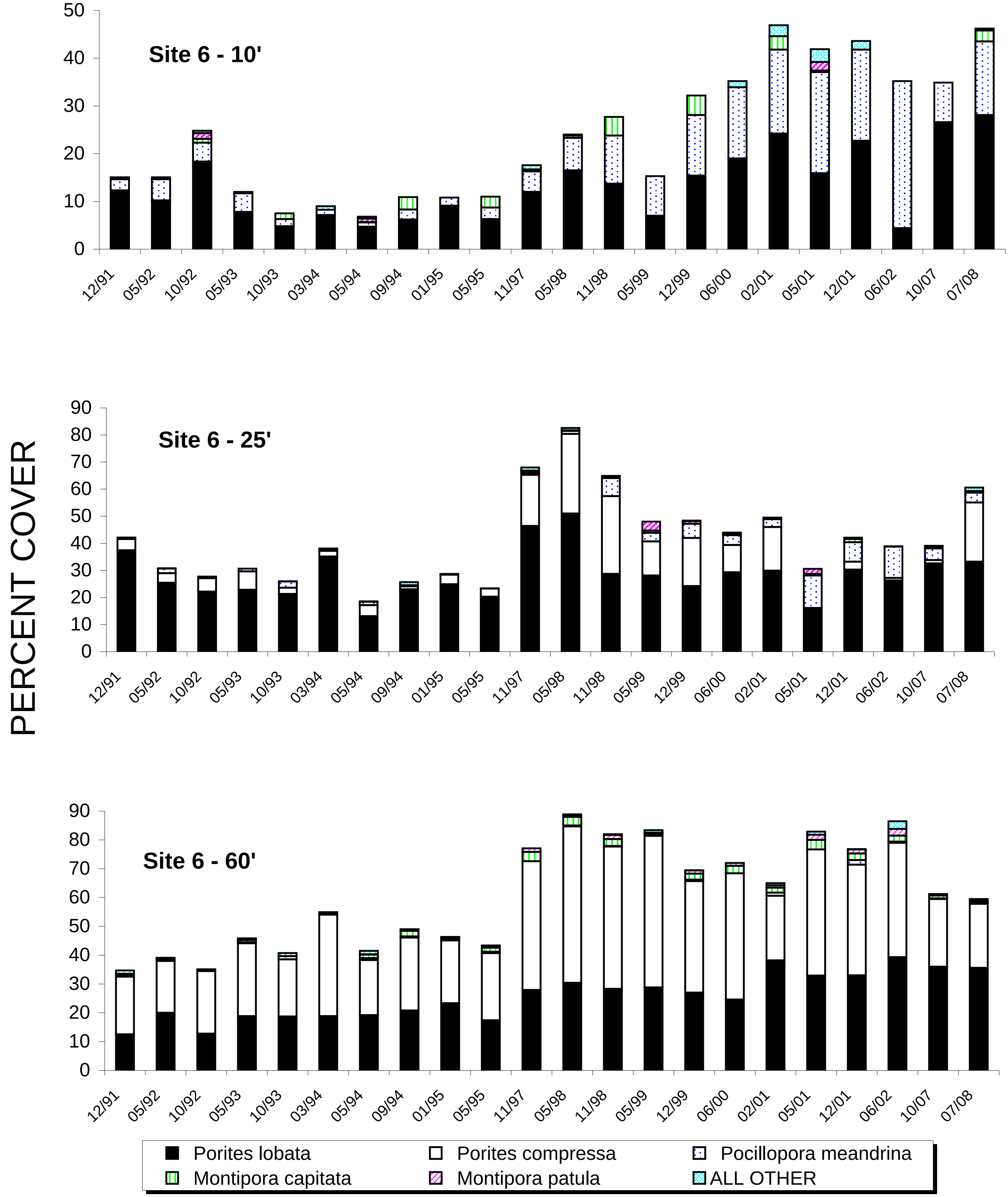


FIGURE 10. Bar graph showing percent cover of major coral species at three depths along the transect at Site 6. Surveys were conducted since December 1991 (Note: Sampling suspended between June 1995 and October 1997). Cover estimates are calculated as mean cover for ten random quadrats. Note y-axis scale change for shallow transect. For location of Site 6, see Figure 1.

APPENDIX A

NELHA BENTHIC MONITORING
JULY 2008

PHOTO-QUADRAT DATA

APPENDIX A-1. Percent cover of coral and non-coral substrata on transects surveyed at Site 1 (WAWALOLI) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	WAWALOLI	MEAN CORAL COVER	29.1 %
TRANSECT ID #:	1-1-15	STD. DEV.	13.0
DATE:	07/07/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.80

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	21.0	25.0	10.0	50.0	14.0	3.0	24.0	28.0	15.0	32.0	222.0
Pocillopora meandrina				6.0			2.0		6.0	2.0	16.0
Montipora capitata	2.0			4.0	4.0	22.0			4.0	2.0	38.0
Montipora patula								12.0	1.0		13.0
Pavona varians									2.0		2.0
QUAD CORAL TOTAL	23.0	25.0	10.0	60.0	18.0	25.0	26.0	40.0	28.0	36.0	291.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	66.0	66.0	80.0	36.0	67.0	60.0	54.0	36.0	32.0	54.0	551.0
Limestone	11.0	9.0	10.0	4.0	15.0	15.0	20.0	24.0	40.0	10.0	158.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	WAWALOLI	MEAN CORAL COVER	46.3 %
TRANSECT ID #:	1-2-20	STD. DEV.	22.3
DATE:	07/07/08	SPECIES COUNT	4
		SPECIES DIVERSITY	0.51

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	22.0	47.0	13.0	32.0	43.0	5.0	45.0	73.0	62.0	55.0	397.0
Porites compressa		2.0									2.0
Pocillopora meandrina		3.0	12.0	5.0	2.0		3.0	10.0		10.0	45.0
Montipora capitata	2.0	15.0				2.0					19.0
QUAD CORAL TOTAL	24.0	67.0	25.0	37.0	45.0	7.0	48.0	83.0	62.0	65.0	463.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	65.0	18.0	40.0	48.0	49.0	73.0	47.0	4.0	14.0	25.0	383.0
Limestone	11.0	15.0	35.0	15.0	6.0	15.0	5.0	13.0	24.0	10.0	149.0
Sand						5.0					5.0
Rubble											0.0

TRANSECT SITE:	WAWALOLI	MEAN CORAL COVER	47.9 %
TRANSECT ID #:	1-3-35	STD. DEV.	23.5
DATE:	07/07/08	SPECIES COUNT	2
		SPECIES DIVERSITY	0.69

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	8.0	6.0	56.0	18.0	6.0	36.0	52.0	21.0	4.0	10.0	217.0
Porites compressa	22.0	55.0	12.0	61.0	35.0	28.0	21.0	16.0		12.0	262.0
QUAD CORAL TOTAL	30.0	61.0	68.0	79.0	41.0	64.0	73.0	37.0	4.0	22.0	479.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt											0.0
Limestone	21.0	5.0	22.0		33.0	36.0	27.0	41.0		28.0	213.0
Sand				5.0	5.0			10.0	70.0		90.0
Rubble	49.0	34.0	10.0	16.0	21.0			12.0	26.0	50.0	218.0

APPENDIX A-2. Percent cover of coral and non-coral substrata on transects surveyed at Site 2 (18" PIPE) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	18" PIPE	MEAN CORAL COVER	56.7 %
TRANSECT ID #:	2-1-20	STD. DEV.	14.4
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.89

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	36.0	36.0	46.0	69.0	39.0	38.0	24.0	13.0	14.0	19.0	334.0
Pocillopora meandrina	18.0	24.0	16.0	12.0	22.0	24.0	12.0	22.0	27.0	22.0	199.0
Montipora capitata					8.0				18.0		26.0
Montipora patula						6.0					6.0
Pavona varians									2.0		2.0
QUAD CORAL TOTAL	54.0	60.0	62.0	81.0	69.0	68.0	36.0	35.0	61.0	41.0	567.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	24.0	26.0	22.0	4.0	3.0	10.0	56.0	57.0	27.0	28.0	257.0
Limestone	22.0	14.0	16.0	15.0	28.0	22.0	8.0	8.0	12.0	31.0	176.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	18" PIPE	MEAN CORAL COVER	57.1 %
TRANSECT ID #:	2-2-25	STD. DEV.	16.9
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	1.20

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	12.0	19.0	18.0	58.0	39.0	22.0	26.0	43.0	18.0	16.0	271.0
Pocillopora meandrina	22.0	22.0	28.0	21.0	18.0	17.0	4.0	28.0	27.0		187.0
Montipora capitata	24.0					8.0	6.0				38.0
Montipora patula	18.0	16.0	10.0				11.0		15.0		70.0
Leptastrea purpurea							5.0				5.0
QUAD CORAL TOTAL	76.0	57.0	56.0	79.0	57.0	47.0	52.0	71.0	60.0	16.0	571.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	2.0	27.0	28.0	8.0	27.0	29.0	38.0	25.0	15.0	69.0	268.0
Limestone	22.0	16.0	16.0	13.0	16.0	24.0	10.0	4.0	25.0	15.0	161.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	18" PIPE	MEAN CORAL COVER	35.1 %
TRANSECT ID #:	2-3-45	STD. DEV.	15.0
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.88

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	22.0	21.0	12.0	10.0	10.0	17.0	6.0	16.0	18.0	18.0	150.0
Porites compressa								2.0			2.0
Pocillopora meandrina	44.0	19.0	40.0	20.0	20.0		26.0			16.0	185.0
Montipora capitata		3.0	2.0	2.0	2.0				2.0		11.0
Montipora patula					3.0						3.0
QUAD CORAL TOTAL	66.0	43.0	54.0	32.0	35.0	17.0	32.0	18.0	20.0	34.0	351.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	19.0	36.0	41.0	65.0	62.0	78.0	54.0	77.0	75.0	51.0	558.0
Limestone	15.0	21.0	5.0	3.0	3.0	5.0	14.0	5.0	5.0	15.0	91.0
Sand											0.0
Rubble											0.0

APPENDIX A-3. Percent cover of coral and non-coral substrata on transects surveyed at Site 3 (12" PIPE SOUTH) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	12" PIPE SOUTH	MEAN CORAL COVER	27.1 %
TRANSECT ID #:	3-1-20	STD. DEV.	13.3
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.90

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	22.0	2.0		21.0		19.0	2.0		22.0	10.0	98.0
Pocillopora meandrina	18.0	3.0	21.0	13.0	8.0	21.0	18.0	14.0	16.0	26.0	158.0
Montipora capitata					1.0	2.0				5.0	8.0
Pavona varians					4.0						4.0
Porites rus									3.0		3.0
QUAD CORAL TOTAL	40.0	5.0	21.0	34.0	13.0	42.0	20.0	14.0	41.0	41.0	271.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt	60.0	95.0	75.0	66.0	82.0	54.0	61.0	68.0	59.0	56.0	676.0
Limestone			4.0		5.0	4.0	19.0	18.0		3.0	53.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE SOUTH	MEAN CORAL COVER	60.1 %
TRANSECT ID #:	3-2-30	STD. DEV.	13.9
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	1.25

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	25.0	24.0	45.0	21.0	21.0	35.0	14.0	22.0	26.0	16.0	249.0
Pocillopora meandrina	28.0	22.0	6.0	24.0	18.0	15.0	24.0	28.0	19.0	24.0	208.0
Montipora capitata		10.0		14.0	12.0	10.0	3.0		8.0		57.0
Montipora patula	14.0	21.0	32.0	10.0		8.0					85.0
Pavona varians										2.0	2.0
QUAD CORAL TOTAL	67.0	77.0	83.0	69.0	51.0	68.0	41.0	50.0	53.0	42.0	601.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt	23.0	18.0	17.0	9.0	18.0	24.0	34.0	35.0	22.0	38.0	238.0
Limestone	10.0	5.0		14.0	31.0	8.0	25.0	15.0	25.0	20.0	153.0
Sand				8.0							8.0
Rubble											0.0

TRANSECT SITE:	12" PIPE SOUTH	MEAN CORAL COVER	75.2 %
TRANSECT ID #:	3-3-45	STD. DEV.	14.8
DATE:	7/7/08	SPECIES COUNT	6
		SPECIES DIVERSITY	1.44

SPECIES	QUADRAT										SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	28.0	32.0	22.0	39.0	40.0	48.0	44.0	31.0	48.0	38.0	370.0
Porites compressa	6.0	28.0	12.0	16.0	8.0			10.0	6.0	2.0	88.0
Pocillopora meandrina	18.0	14.0	8.0	20.0	19.0	16.0	26.0		14.0	17.0	152.0
Pocillopora eydouxi			45.0								45.0
Montipora capitata	21.0	10.0	8.0	12.0					4.0		55.0
Montipora patula					20.0	15.0	4.0			3.0	42.0
QUAD CORAL TOTAL	73.0	84.0	95.0	87.0	87.0	79.0	74.0	41.0	72.0	60.0	752.0

	QUADRAT										SUBSTRATA
NON-CORAL SUBSTRATA	1	2	3	4	5	6	7	8	9	10	TOTAL
Basalt	27.0			13.0	3.0		22.0	25.0	22.0	30.0	142.0
Limestone		16.0	5.0		10.0	21.0	4.0	34.0	6.0	10.0	106.0
Sand											0.0
Rubble											0.0

APPENDIX A-4. Percent cover of coral and non-coral substrata on transects surveyed at Site 4 (12" PIPE NORTH) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	12" PIPE NORTH	MEAN CORAL COVER	39.2 %
TRANSECT ID #:	4-1-20	STD. DEV.	21.8
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	1.10

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	6.0	12.0	63.0	21.0	33.0	24.0	6.0	14.0	22.0	2.0	203.0
Porites compressa					2.0						2.0
Pocillopora meandrina	16.0	26.0	5.0	10.0	22.0	13.0	2.0		18.0	15.0	127.0
Montipora capitata	15.0		11.0		8.0				14.0		48.0
Montipora patula		12.0									12.0
QUAD CORAL TOTAL	37.0	50.0	79.0	31.0	65.0	37.0	8.0	14.0	54.0	17.0	392.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	60.0	50.0	21.0	69.0	21.0	38.0	92.0	86.0	38.0	78.0	553.0
Limestone	3.0				14.0	25.0			8.0	5.0	55.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE NORTH	MEAN CORAL COVER	55.3 %
TRANSECT ID #:	4-2-25	STD. DEV.	15.8
DATE:	7/7/08	SPECIES COUNT	6
		SPECIES DIVERSITY	1.15

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	18.0	14.0	12.0	31.0	35.0	22.0	80.0	50.0	6.0	5.0	273.0
Porites compressa							3.0				3.0
Porites brighami							4.0				4.0
Pocillopora meandrina	24.0	18.0	8.0	6.0	15.0	24.0	3.0	6.0	40.0	42.0	186.0
Montipora capitata		6.0	12.0		10.0	12.0		12.0	12.0	4.0	68.0
Montipora patula				12.0	2.0					5.0	19.0
QUAD CORAL TOTAL	42.0	38.0	32.0	49.0	62.0	58.0	90.0	68.0	58.0	56.0	553.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	44.0	34.0	52.0	34.0	33.0	36.0		32.0	32.0	32.0	329.0
Limestone	14.0	28.0	16.0	17.0	5.0	6.0	10.0		10.0	12.0	118.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	12" PIPE NORTH	MEAN CORAL COVER	74.8 %
TRANSECT ID #:	4-3-50	STD. DEV.	14.5
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	1.17

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	60.0	44.0	34.0	60.0	40.0	38.0	44.0	41.0	34.0	20.0	415.0
Porites compressa	8.0	32.0	22.0	6.0	14.0	23.0	31.0	9.0	11.0	6.0	162.0
Pocillopora meandrina	18.0	4	24.0	10.0	26.0	12.0	8.0			18.0	120.0
Montipora capitata	2.0	5.0			10.0	3.0	3.0	6.0	4.0	8.0	41.0
Montipora patula		2.0	4.0						4.0		10.0
QUAD CORAL TOTAL	88.0	87.0	84.0	76.0	90.0	76.0	86.0	56.0	53.0	52.0	748.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt						18.0	5.0	22.0	42.0	14.0	101.0
Limestone	12.0	13.0	16.0	24.0	10.0	6.0	4.0	12.0	5.0	34.0	136.0
Sand							5.0	10.0			15.0
Rubble											0.0

APPENDIX A-5. Percent cover of coral and non-coral substrata on transects surveyed at Site 5 (NPPE) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	NPPE	MEAN CORAL COVER	50.6 %
TRANSECT ID #:	5-1-20	STD. DEV.	15.7
DATE:	7/7/08	SPECIES COUNT	8
		SPECIES DIVERSITY	1.43

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	40.0	31.0	31.0	11.0	28.0	22.0	15.0	8.0	19.0	29.0	234.0
Porites compressa	12.0		4.0			12.0					28.0
Pocillopora meandrina	15.0	16.0	21.0	15.0	17.0		18.0	18.0	16.0	12.0	148.0
Montipora capitata	5.0		5.0			14.0					24.0
Montipora patula		27.0	6.0				15.0				48.0
Pavona varians	3.0			2.0							5.0
Leptastrea purpurea							4.0				4.0
Porites rus				15.0							15.0
QUAD CORAL TOTAL	75.0	74.0	67.0	43.0	45.0	48.0	52.0	26.0	35.0	41.0	506.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	12.0	20.0	28.0	43.0	55.0	27.0	43.0	74.0	65.0	59.0	426.0
Limestone	13.0	6.0	5.0	14.0		5.0	5.0				48.0
Sand											0.0
Rubble						20.0					20.0

TRANSECT SITE:	NPPE	MEAN CORAL COVER	75.8 %
TRANSECT ID #:	5-2-30	STD. DEV.	19.8
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	1.29

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	38.0	38.0	33.0	31.0	59.0	51.0	55.0	49.0	46.0	2.0	402.0
Porites compressa		13.0		3.0		6.0	22.0	4.0			48.0
Pocillopora meandrina	2.0	18.0	24.0	22.0	4.0	18.0	19.0	3.0	22.0	27.0	159.0
Montipora capitata	22.0	2.0	15.0		4.0			16.0		3.0	62.0
Montipora patula	16.0				27.0	22.0		22.0			87.0
QUAD CORAL TOTAL	78.0	71.0	72.0	56.0	94.0	97.0	96.0	94.0	68.0	32.0	758.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt		24.0	28.0	33.0					32.0	64.0	181.0
Limestone	22.0	5.0		11.0	6.0	3.0	4.0	6.0		4.0	61.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	NPPE	MEAN CORAL COVER	87.5 %
TRANSECT ID #:	5-3-50	STD. DEV.	6.8
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.93

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	65.0	45.0	46.0	49.0	38.0	63.0	71.0	59.0	54.0	65.0	555.0
Porites compressa	20.0	12.0	48.0	42.0	39.0	11.0	15.0	26.0	25.0	7.0	245.0
Pocillopora meandrina		13.0	2.0		12.0	9.0				11.0	47.0
Montipora capitata	4.0	3.0			3.0	6.0				8.0	24.0
Montipora patula					4.0						4.0
QUAD CORAL TOTAL	89.0	73.0	96.0	91.0	96.0	89.0	86.0	85.0	79.0	91.0	875.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt		16.0							21.0		37.0
Limestone	11.0	11.0	4.0	9.0	4.0	11.0	14.0	15.0		9.0	88.0
Sand											0.0
Rubble											0.0

APPENDIX A-6. Percent cover of coral and non-coral substrata on transects surveyed at Site 6 (HO'ONA BAY) in the vicinity of NELHA in July 2008. Each transect consists of 10 quadrats. For site and transect locations, see Figure 1.

TRANSECT SITE:	HO`ONA	MEAN CORAL COVER	46.2 %
TRANSECT ID #:	06-1-15	STD. DEV.	12.3
DATE:	7/7/08	SPECIES COUNT	4
		SPECIES DIVERSITY	0.86

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	26.0	41.0	61.0	19.0	18.0	22.0	42.0	24.0	22.0	6.0	281.0
Pocillopora meandrina	24.0	2.0	3.0	31.0	22.0	10.0	3.0	26.0	31.0	2.0	154.0
Montipora capitata		6.0	3.0	2.0						12.0	23.0
Montipora patula								4.0			4.0
QUAD CORAL TOTAL	50.0	49.0	67.0	52.0	40.0	32.0	45.0	54.0	53.0	20.0	462.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	39.0	51.0	29.0	26.0	60.0	55.0	50.0	30.0	47.0	80.0	467.0
Limestone	11.0		4.0	22.0		13.0	5.0	16.0			71.0
Sand											0.0
Rubble											0.0

TRANSECT SITE:	HO`ONA	MEAN CORAL COVER	60.6 %
TRANSECT ID #:	06-2-25	STD. DEV.	30.4
DATE:	7/7/08	SPECIES COUNT	5
		SPECIES DIVERSITY	0.99

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	65.0	16.0	52.0	65.0	31.0	44.0	22.0	24.0	8.0	5.0	332.0
Porites compressa	16.0			16.0	28.0	46.0	52.0	55.0	6.0		219.0
Pocillopora meandrina			3.0	10.0		2.0	6.0		7.0	8.0	36.0
Montipora capitata	2.0	2.0						2.0			6.0
Pavona varians					5.0		6.0	2.0			13.0
QUAD CORAL TOTAL	83.0	18.0	55.0	91.0	64.0	92.0	86.0	83.0	21.0	13.0	606.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt	9.0	82.0	24.0		21.0		14.0		33.0	7.0	190.0
Limestone	8.0		21.0	9.0	15.0	8.0		17.0	17.0		95.0
Sand									8.0	15.0	23.0
Rubble									21.0	65.0	86.0

TRANSECT SITE:	HO`ONA	MEAN CORAL COVER	59.5 %
TRANSECT ID #:	6-3-60	STD. DEV.	33.7
DATE:	7/7/08	SPECIES COUNT	6
		SPECIES DIVERSITY	0.81

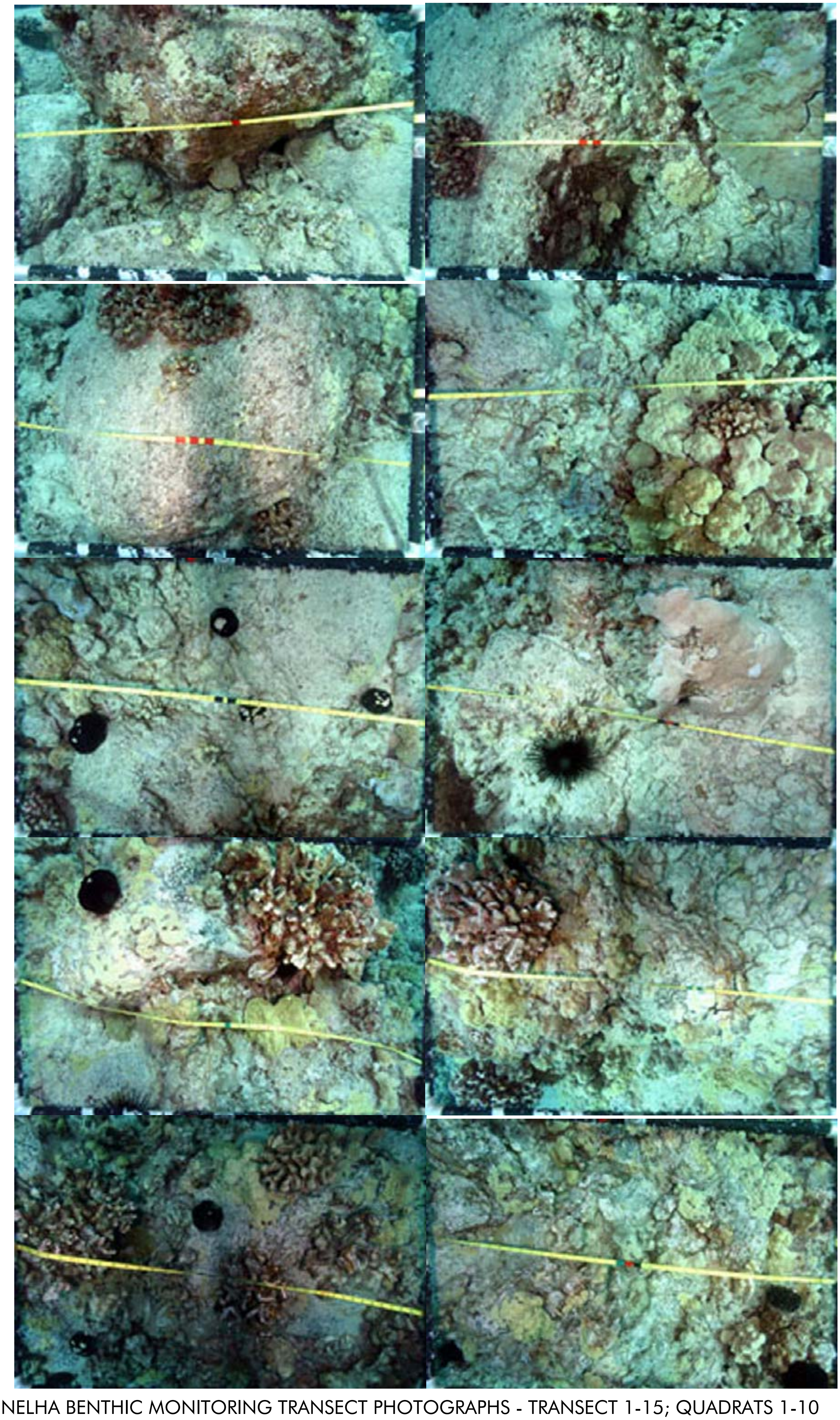
SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	60.0	60.0	59.0	44.0	20.0	35.0	39.0	20.0	8.0	11.0	356.0
Porites compressa	5.0	20.0	33.0	51.0	16.0	60.0	33.0	4.0			222.0
Pocillopora meandrina									2.0		2.0
Montipora capitata		2.0				3.0					5.0
Montipora patula	2.0				2.0						4.0
Pavona varians	2.0		4.0								6.0
QUAD CORAL TOTAL	69.0	82.0	96.0	95.0	38.0	98.0	72.0	24.0	10.0	11.0	595.0

NON-CORAL SUBSTRATA	QUADRAT 1	2	3	4	5	6	7	8	9	10	SUBSTRATA TOTAL
Basalt											0.0
Limestone	31.0	18.0	4.0	5.0		2.0	28.0				88.0
Sand											0.0
Rubble					62.0			76.0	90.0	89.0	317.0

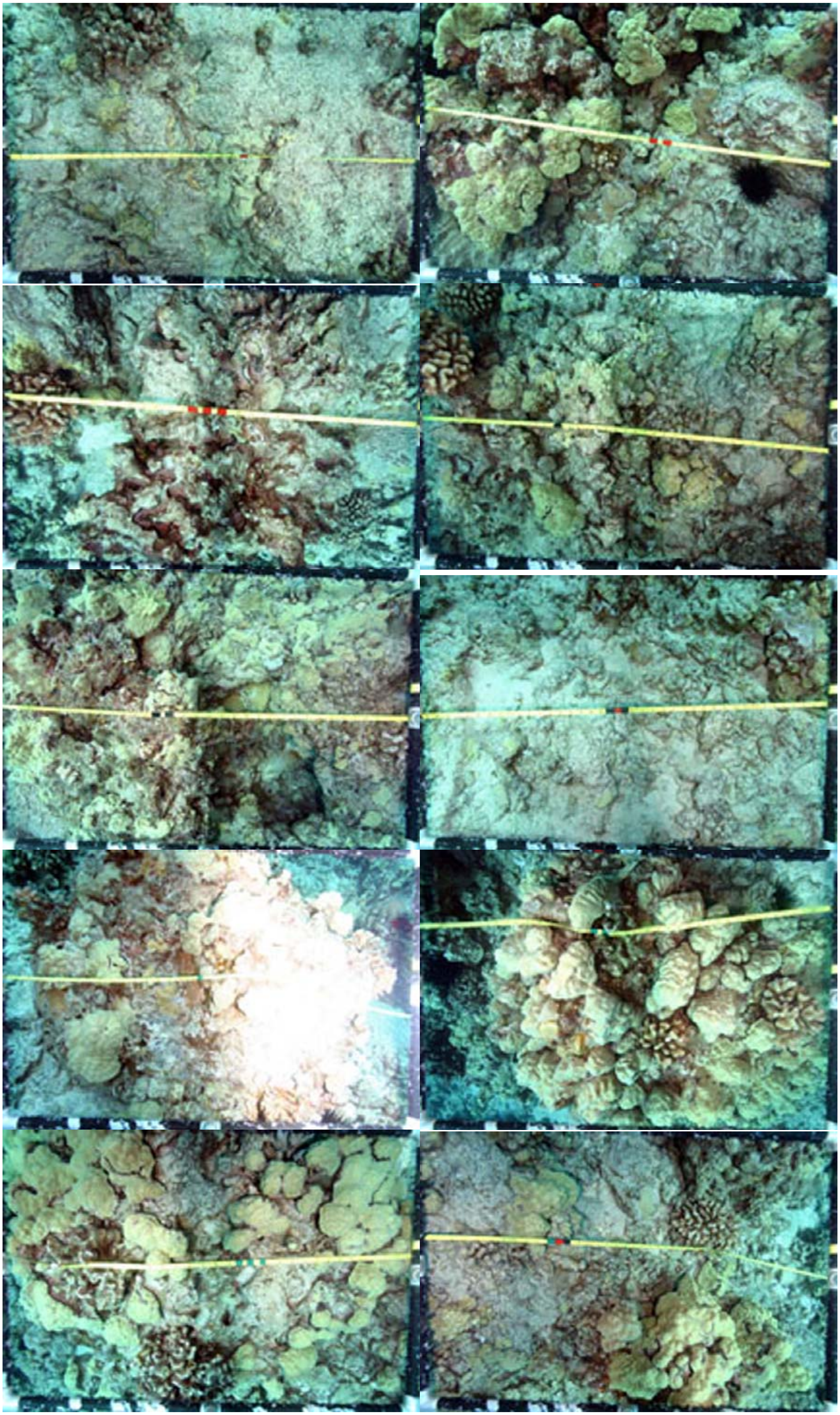
APPENDIX B

NELHA BENTHIC MONITORING
JULY 2008

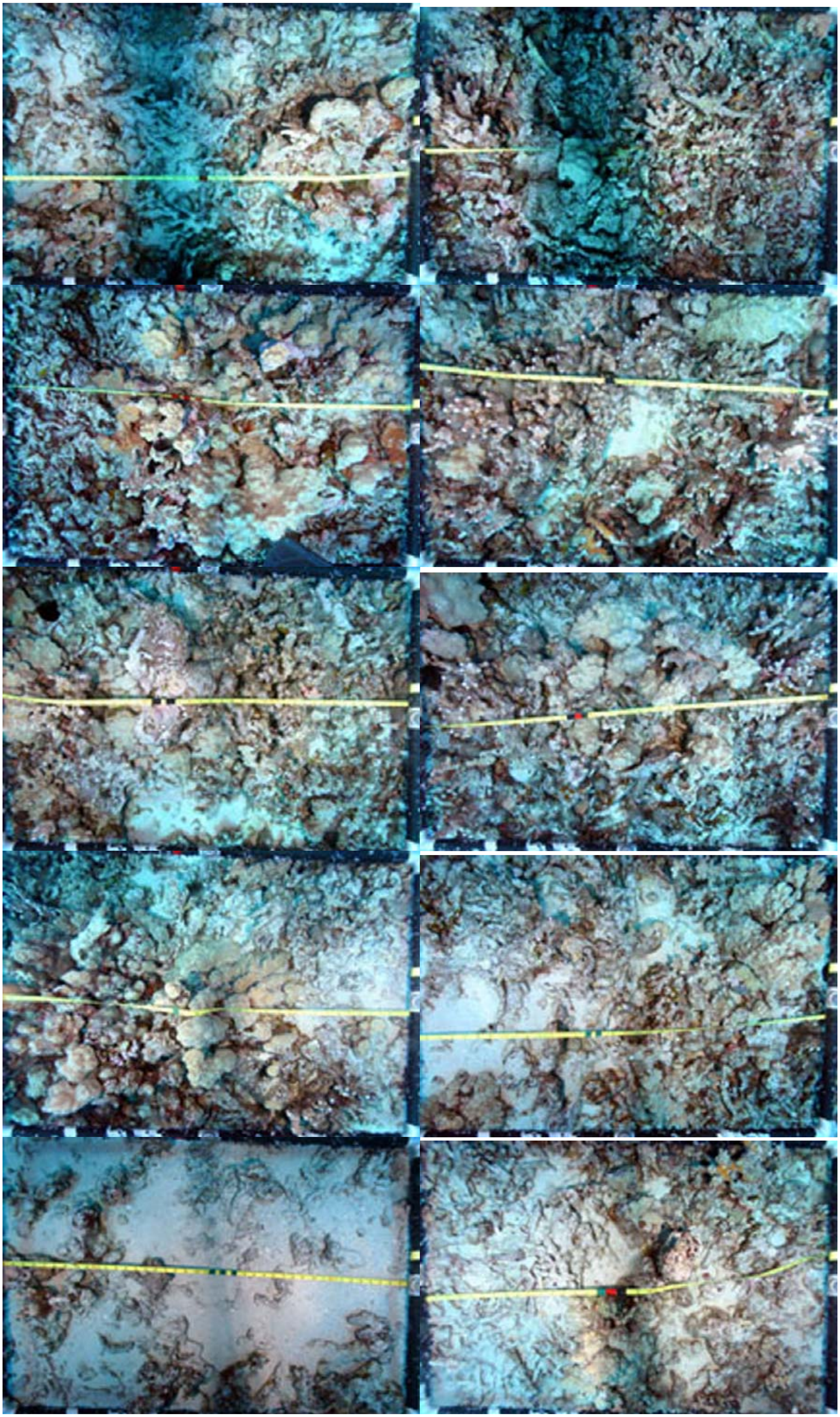
PHOTO-QUADRATS



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-15; QUADRATS 1-10
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 1-20; QUADRATS 1-10
JULY 2008



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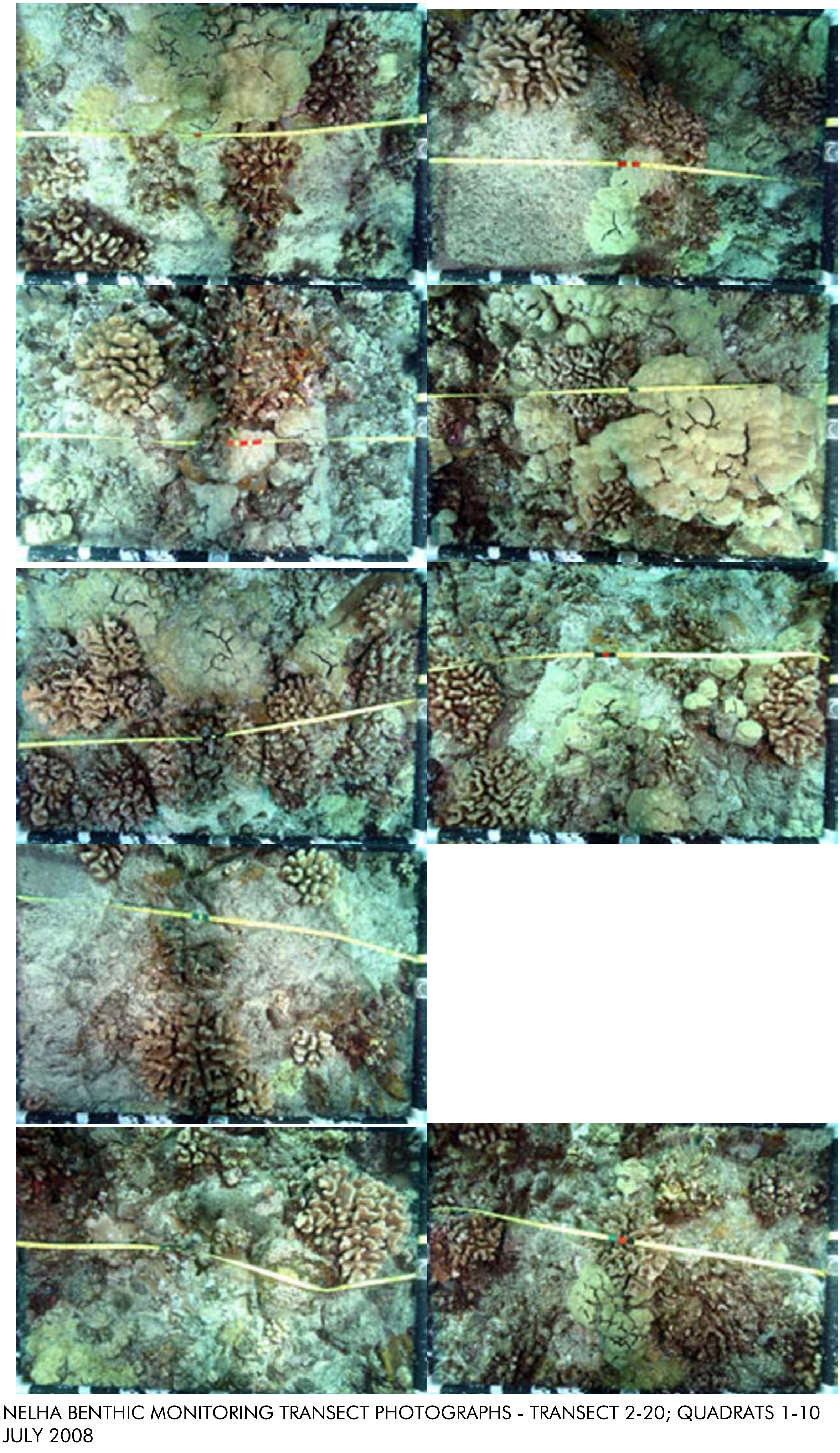
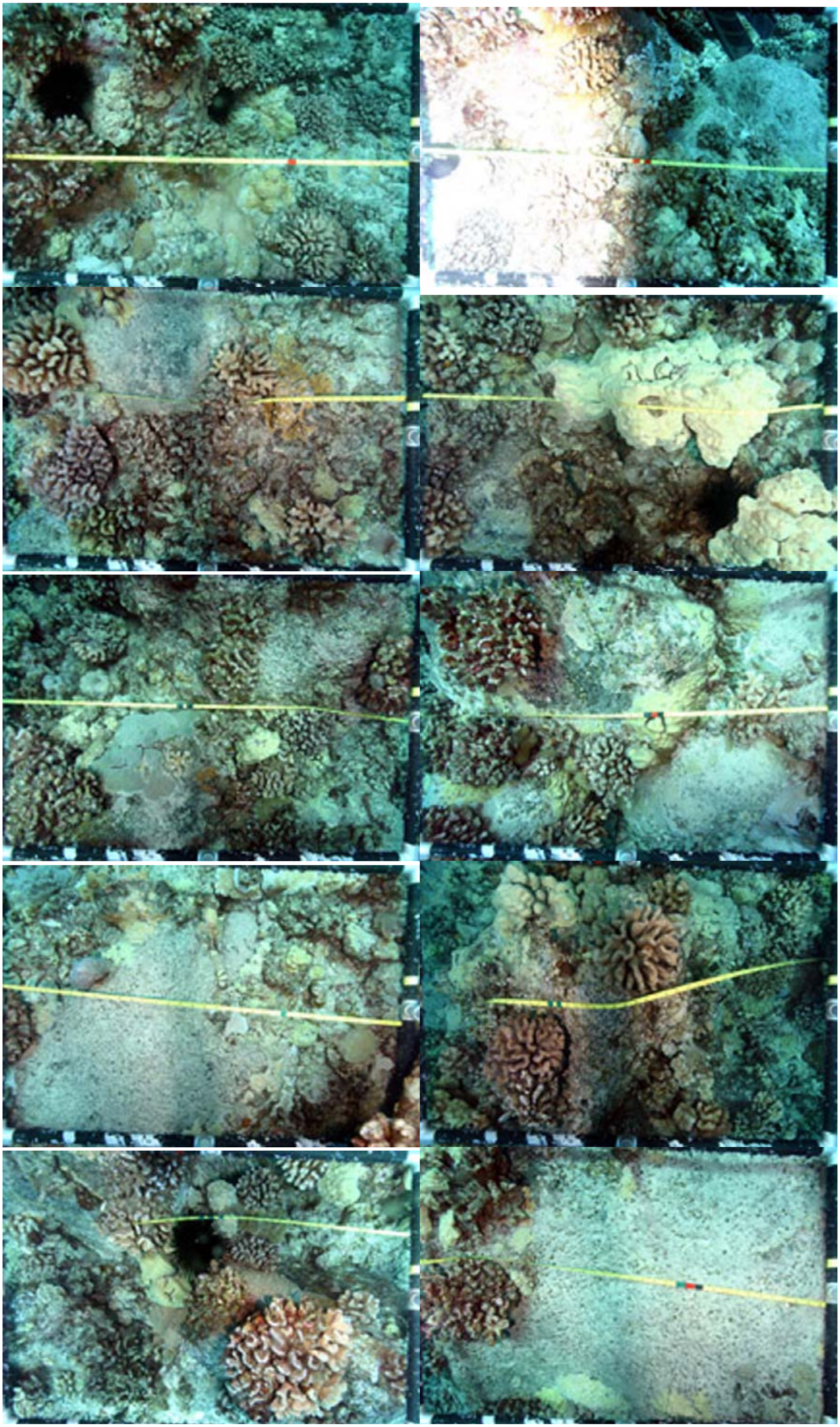
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-20; QUADRATS 1-10
JULY 2008



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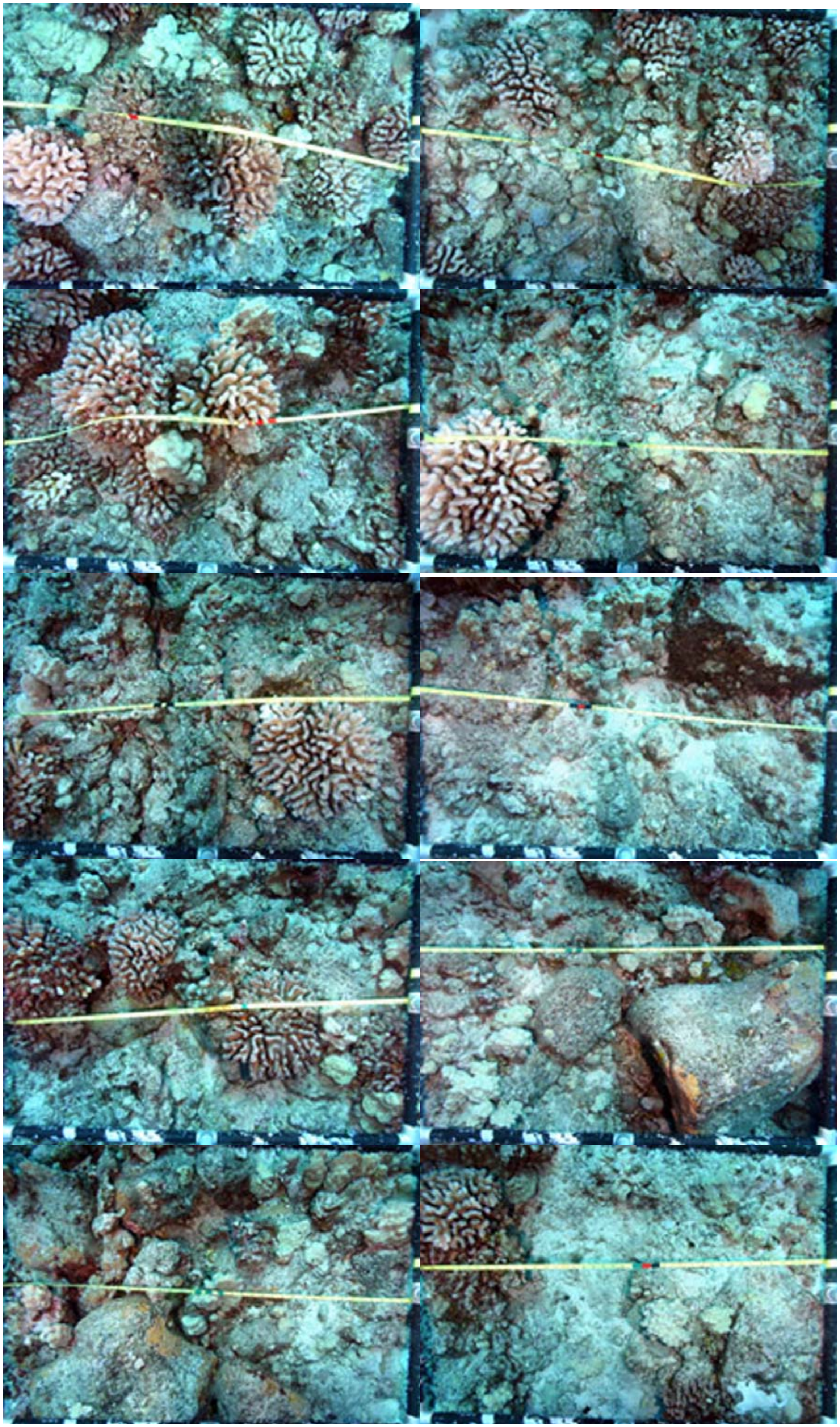
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 2-45; QUADRATS 1-10
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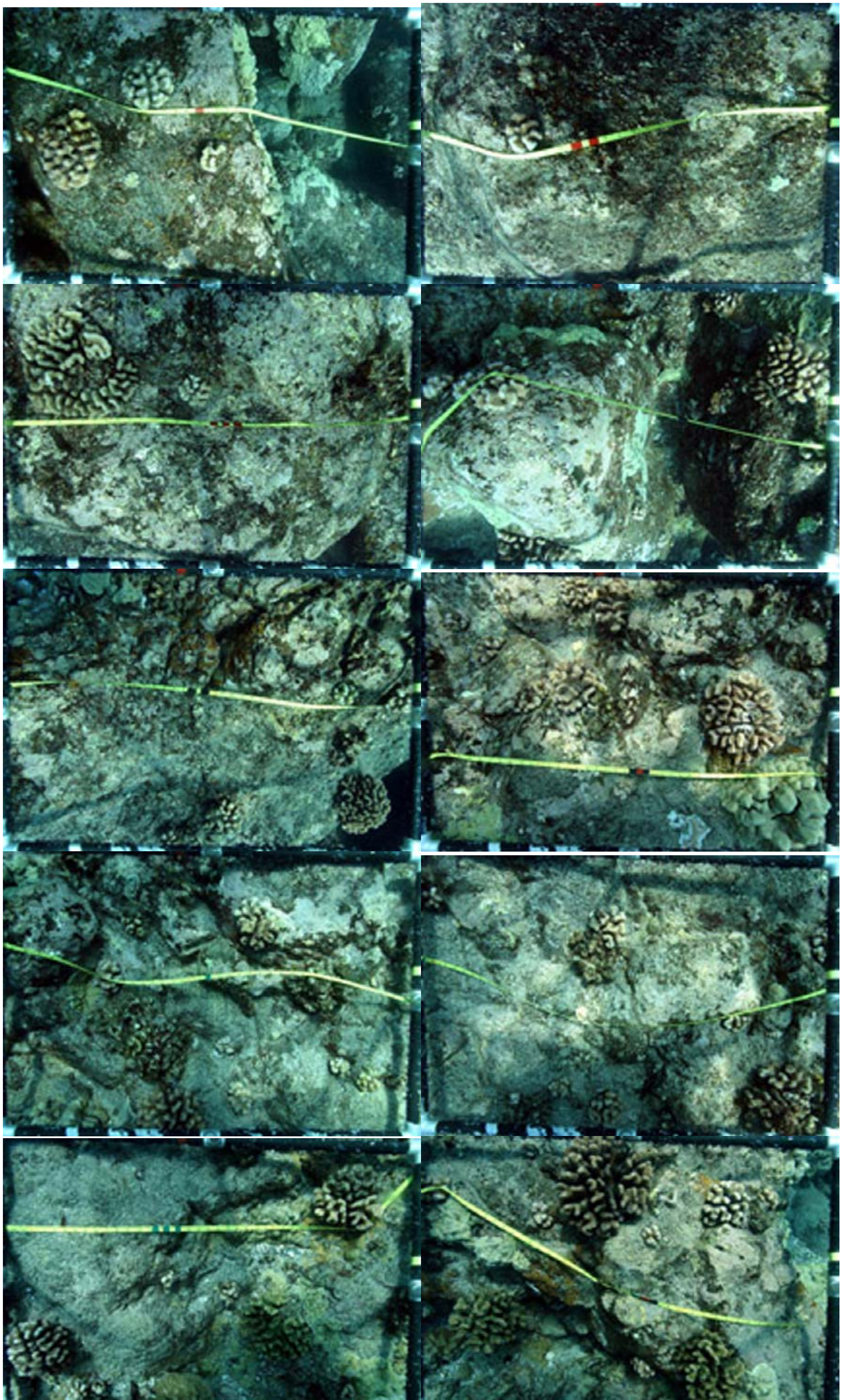

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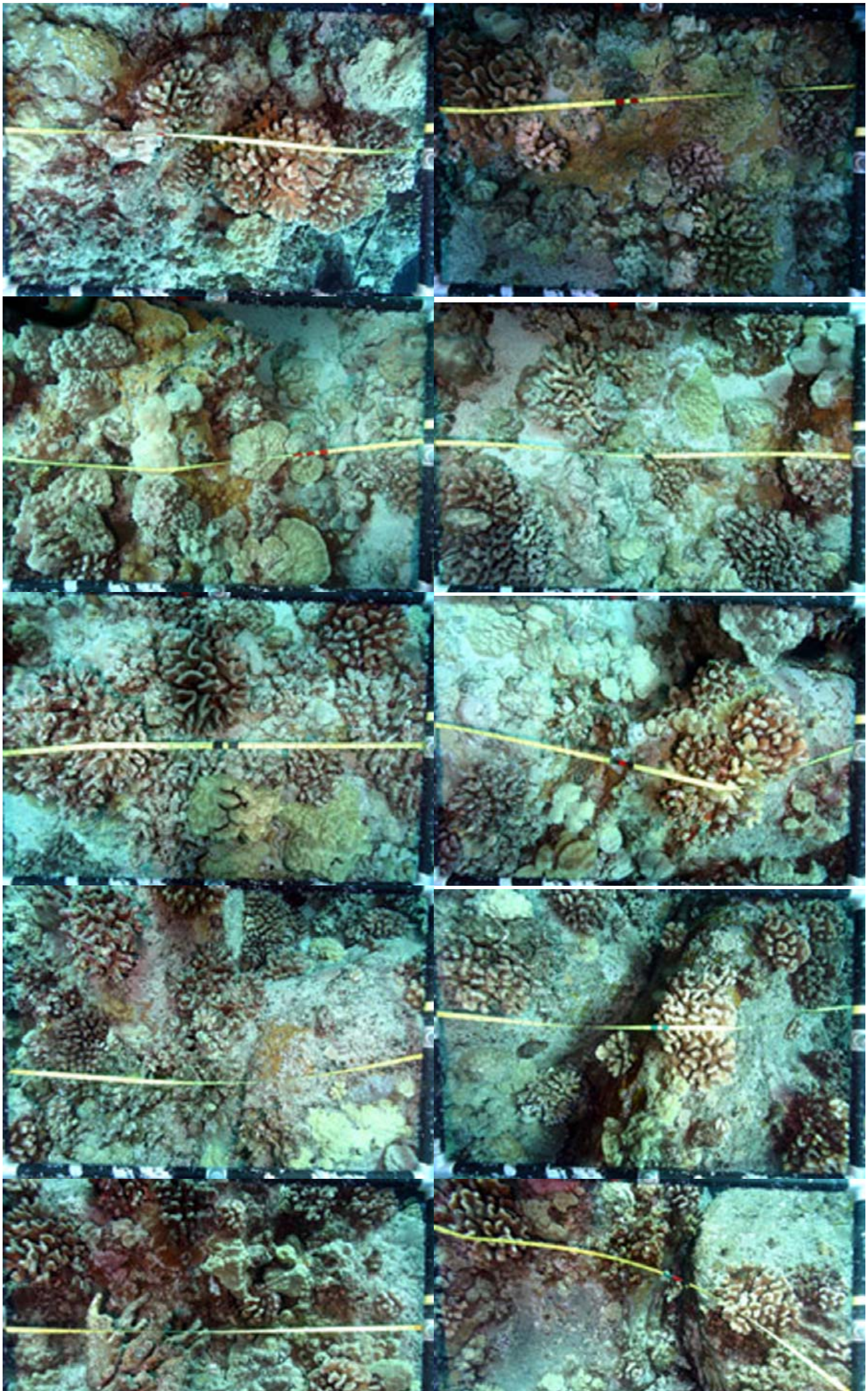

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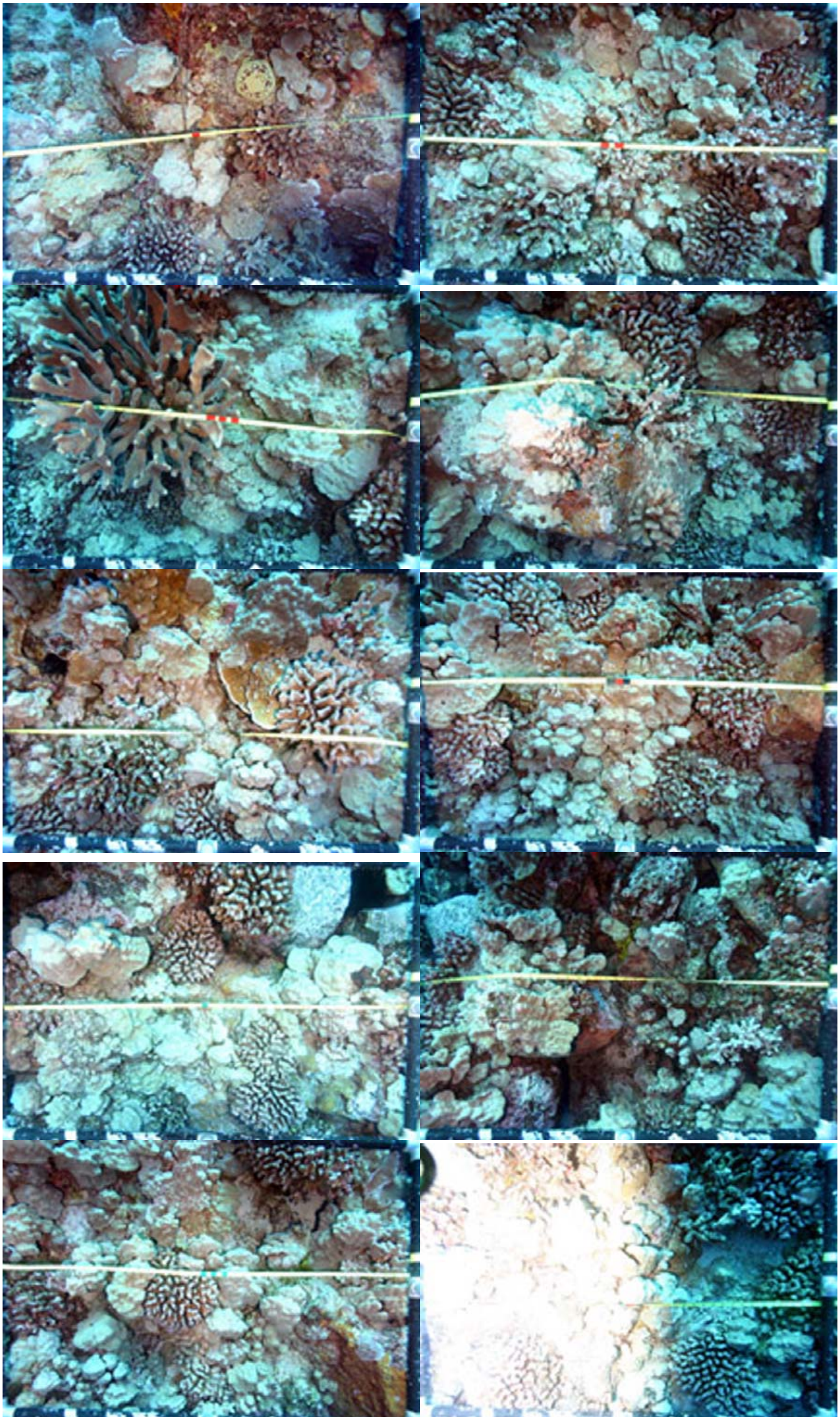

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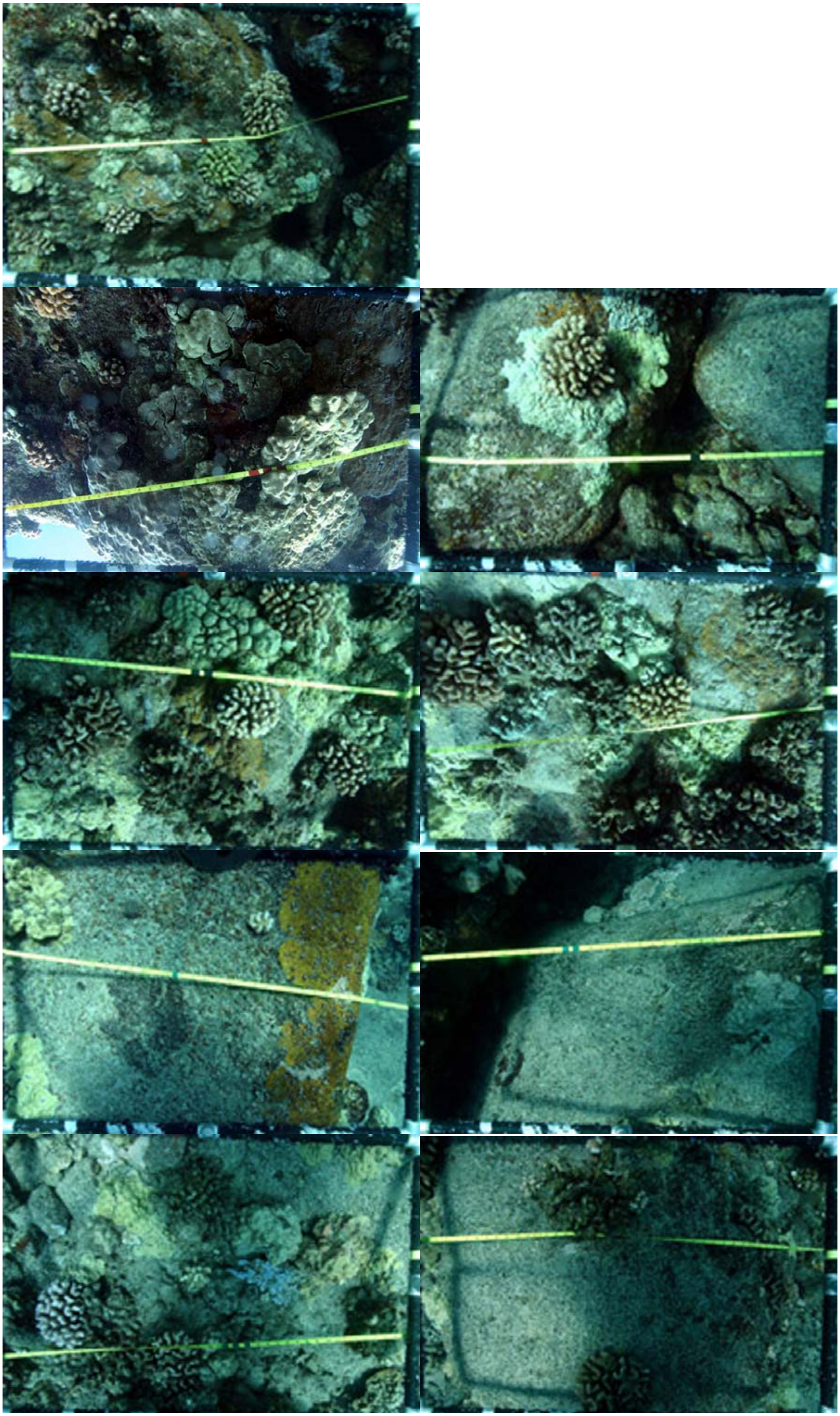

NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 4-20; QUADRATS 1-10
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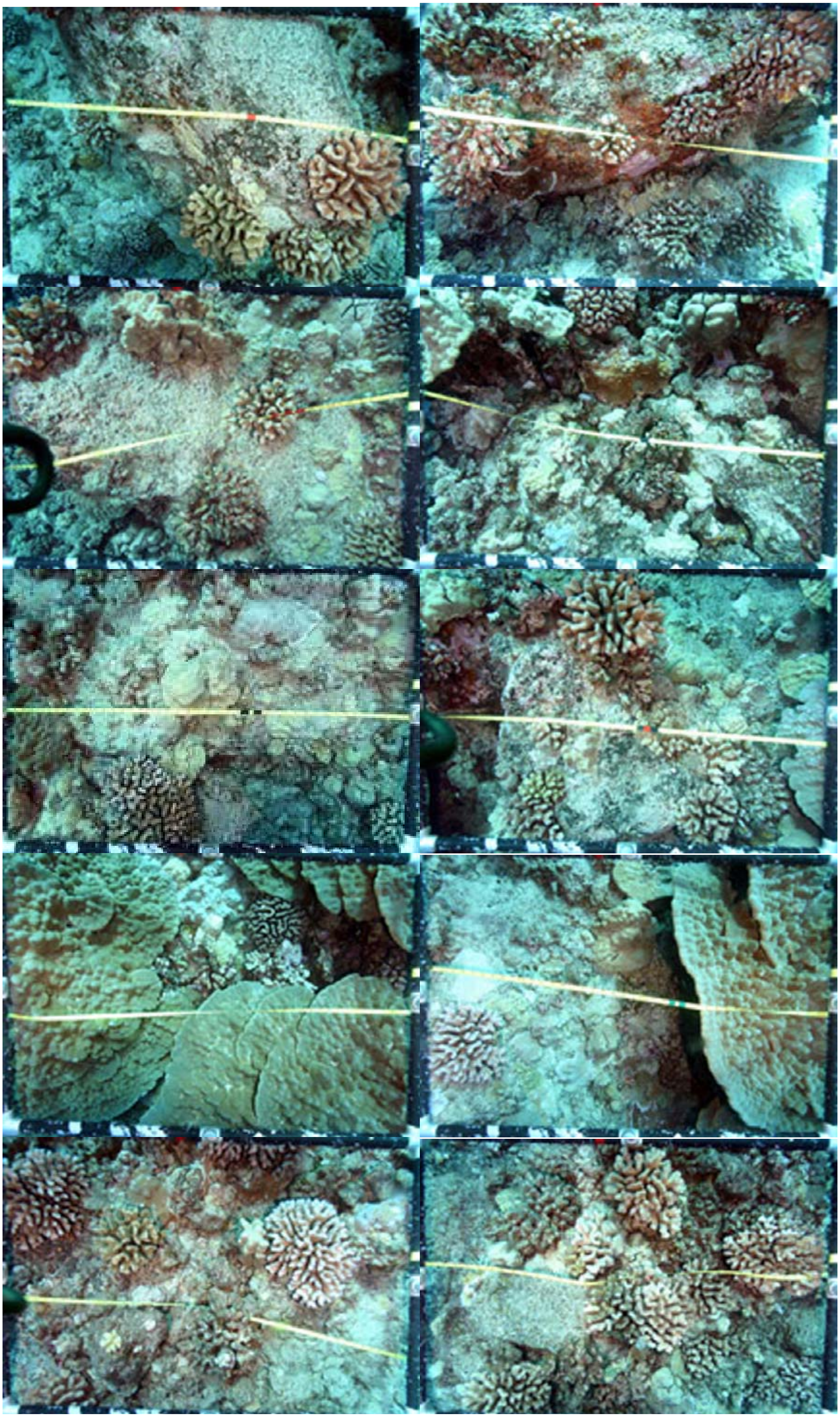

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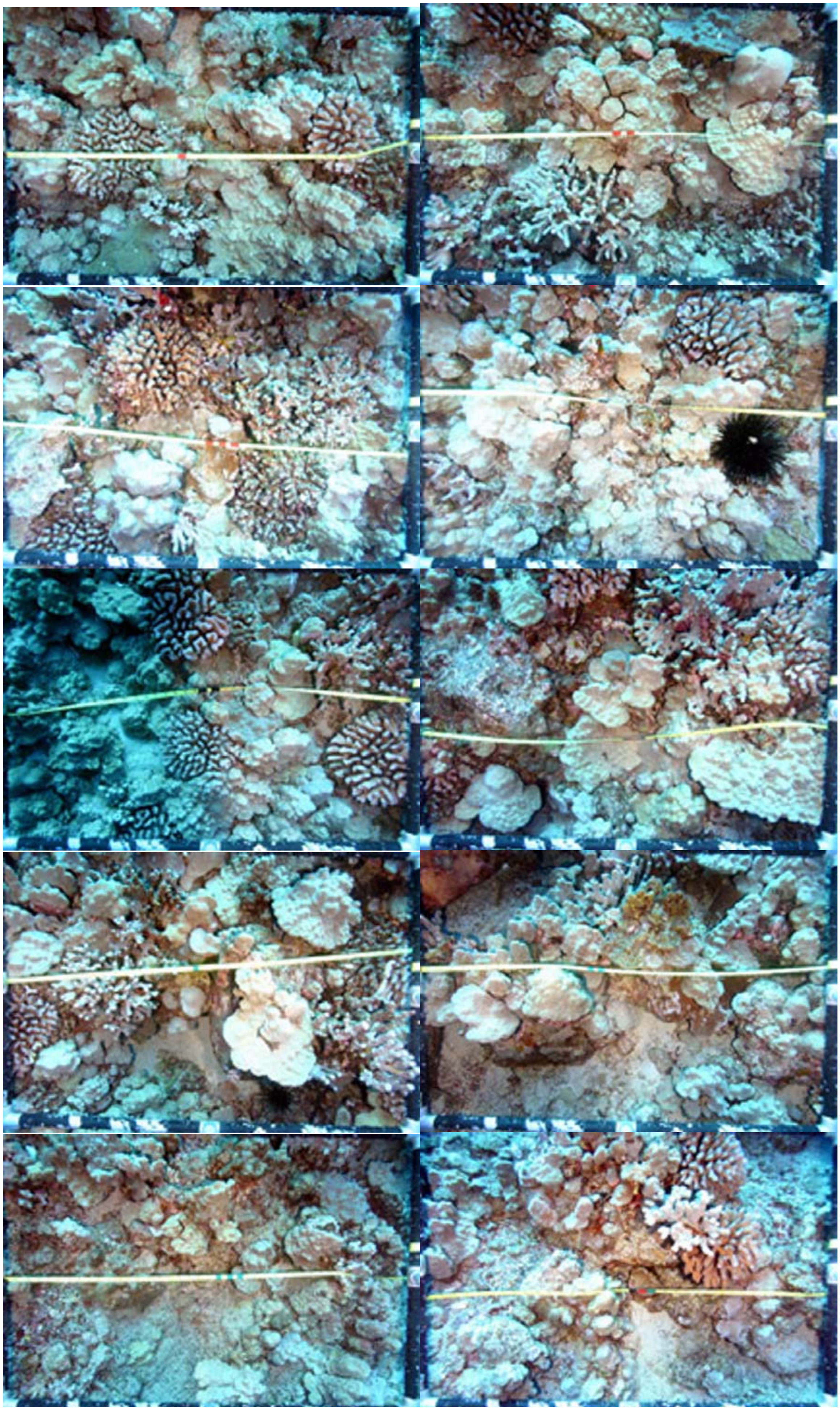
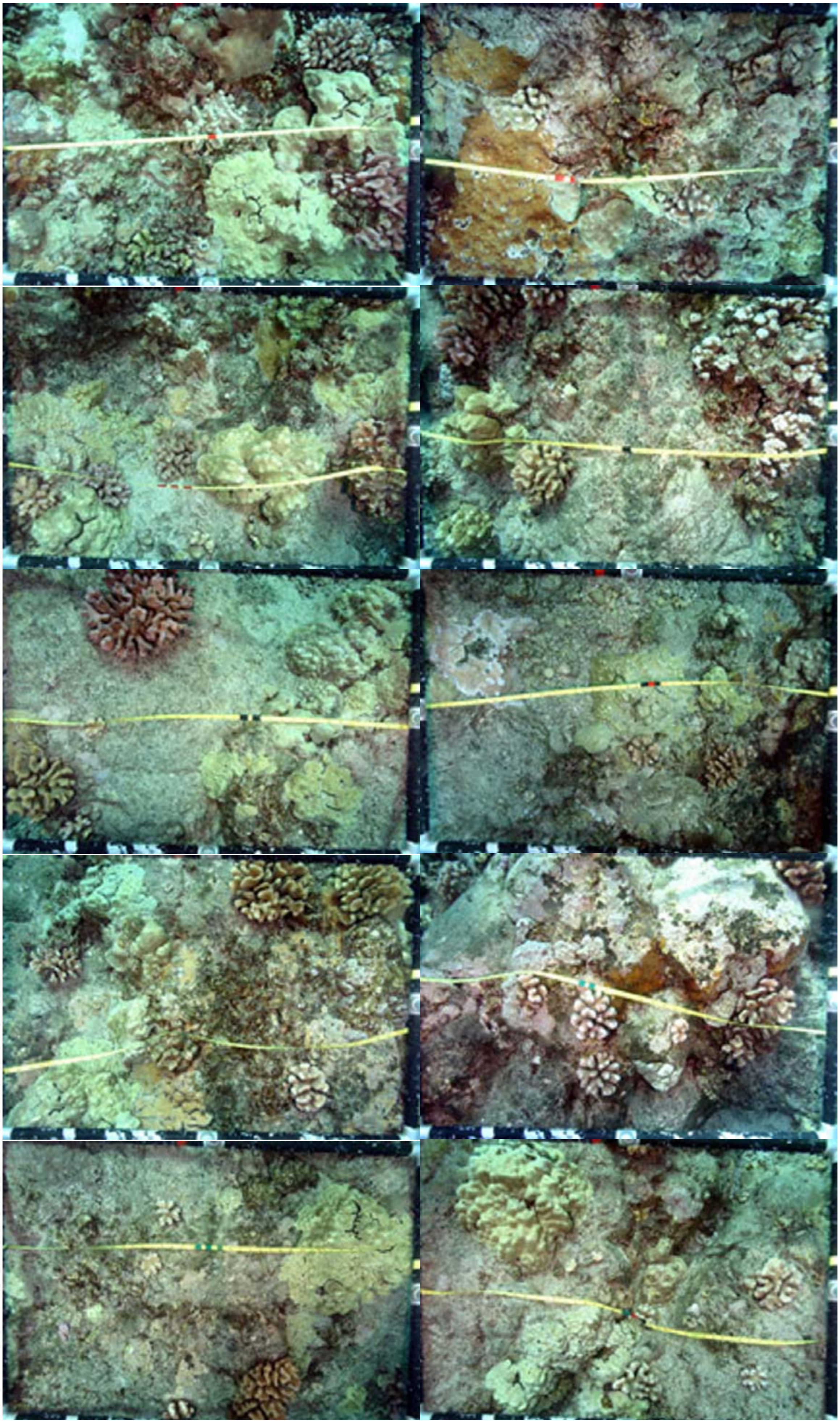
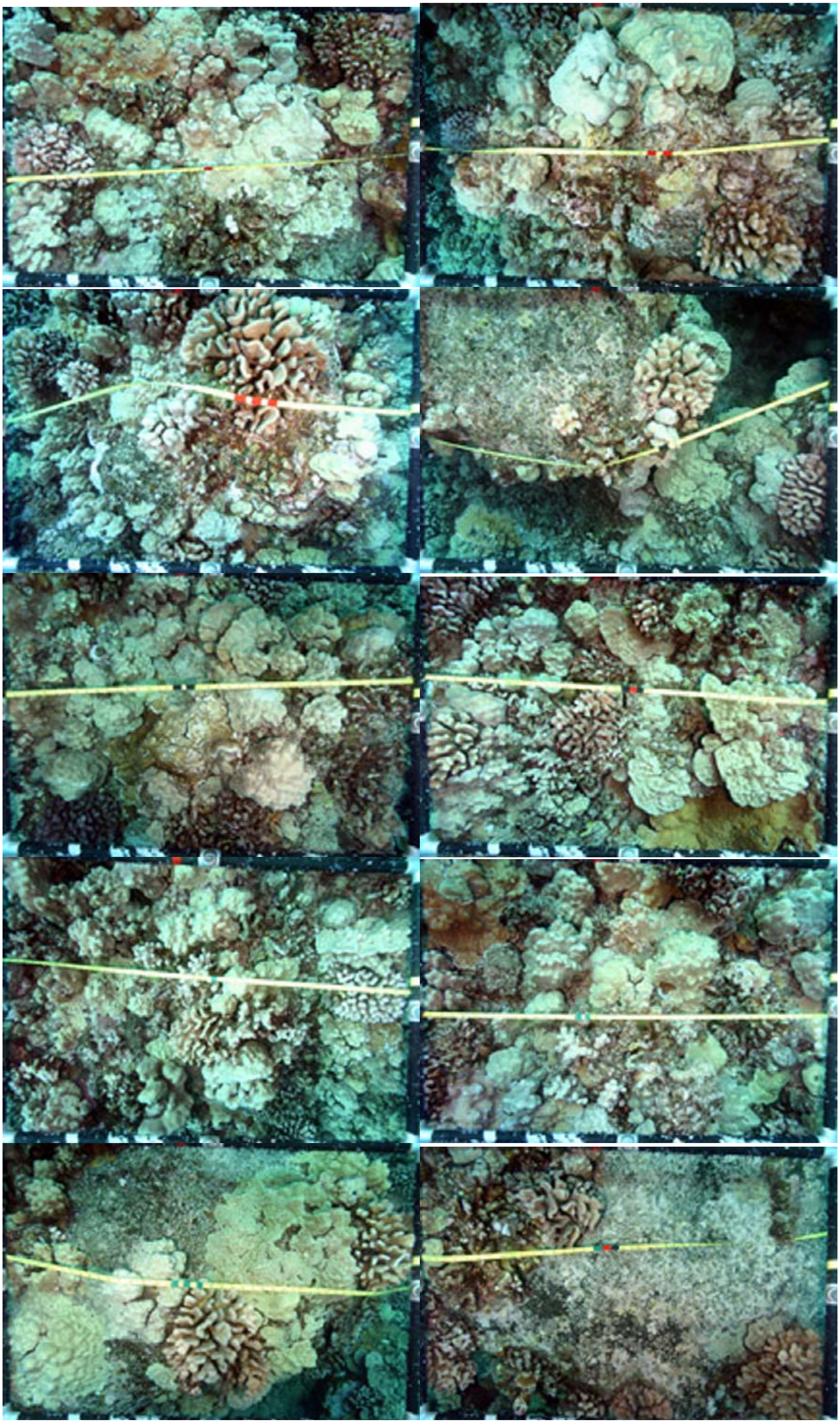
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 4-50; QUADRATS 1-10
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 5-20; QUADRATS 1-10 - JULY 2008



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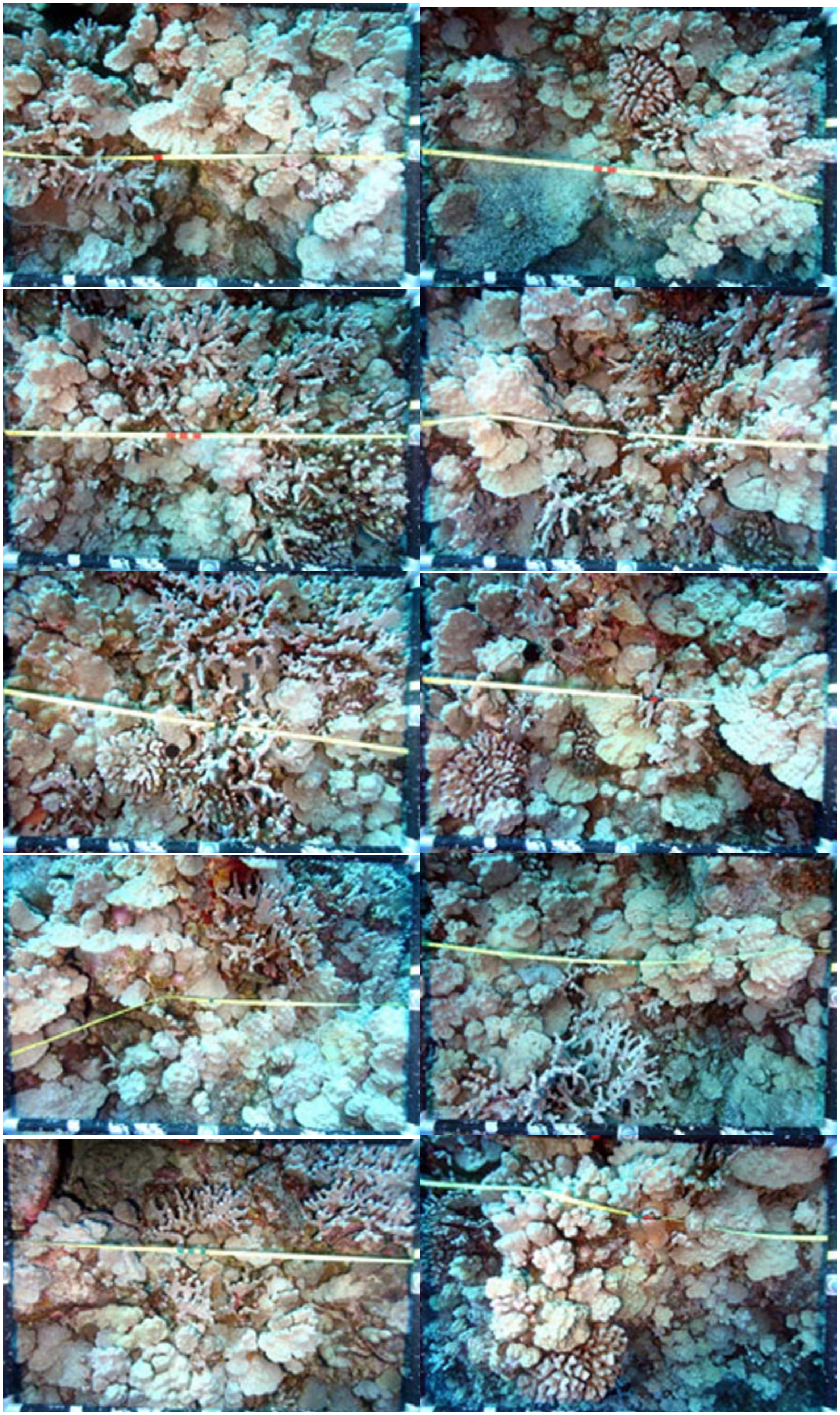
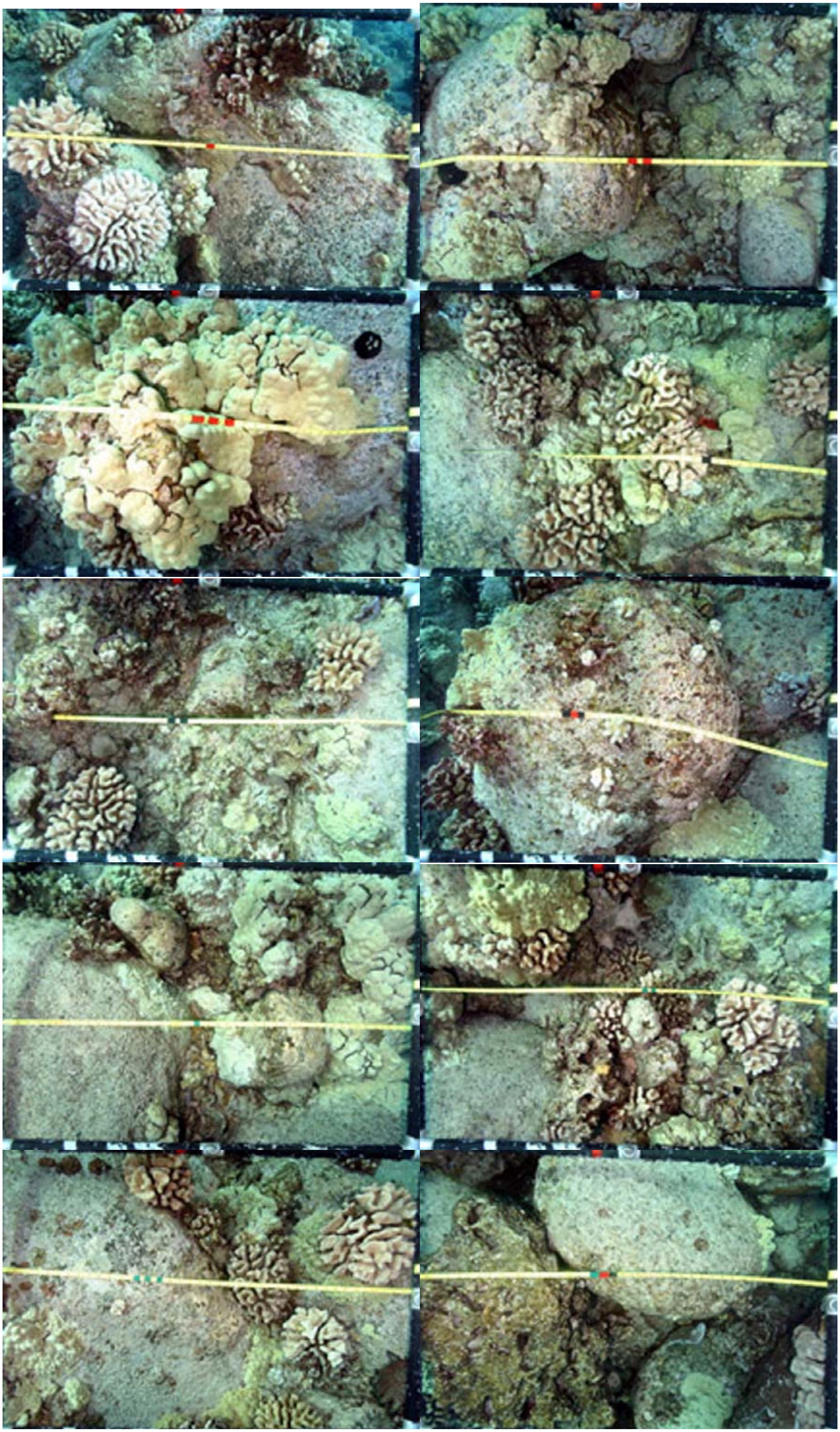
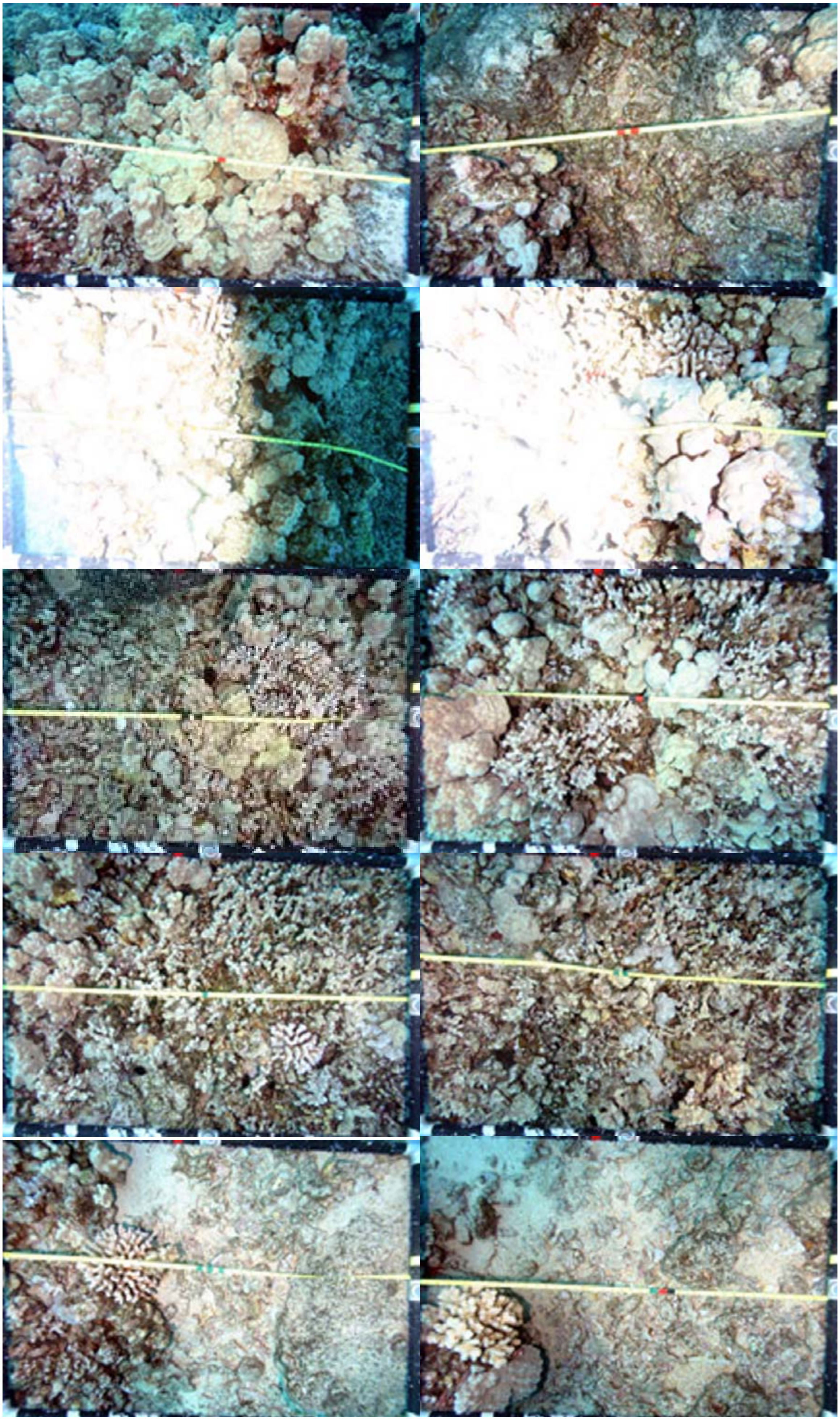


NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 5-50; QUADRATS 1-10
JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-10; QUADRATS 1-10 - JULY 2008



NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-25; QUADRATS 1-10
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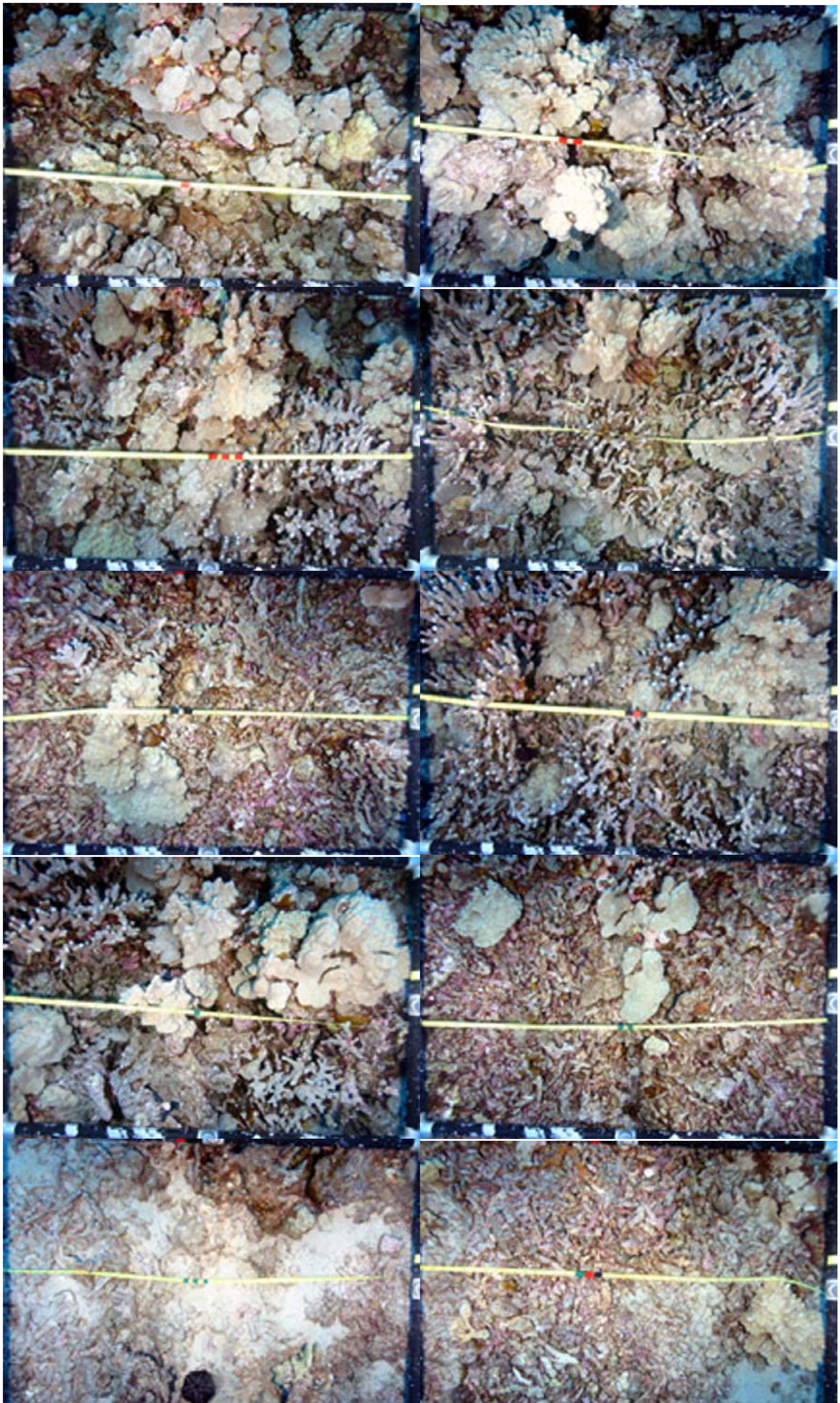

NELHA BENTHIC MONITORING TRANSECT PHOTOGRAPHS - TRANSECT 6-60; QUADRATS 1-10
JULY 2008