SAVING MAUI'S REEFS

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Abstract

Hawaiian coral reef ecosystems are coming under increasing pressure from natural and non-naturally occurring disturbances. Coral reefs in Hawaii exhibit low species diversity relative to other tropical regions but display fairly well developed fringing reefs. In an effort to detect spatial and temporal changes in the structure of the coral reef community, coral coverage and reef fish density and diversity were documented at selected sites along the Maui coastline using standard transect methodology and SCUBA. Physical parameters examined included: wave exposure, water motion, sedimentation levels and water quality (temperature, salinity, and turbidity). State and federal agencies in Hawaii are unable to conduct intensive, long term monitoring of coral reef ecosystems with current resources.

Findings to date indicate that natural factors such as wave energy can affect density patterns of reef organisms over a very short time period (e.g. 4-5 days). Human use patterns if intense enough may gradually alter both density and diversity over an intermediate time scale (2-5 years). Since 1994, when our sampling effort was pooled for each site, nine long-term monitoring sites have experienced varying degrees of change in coral coverage and fish density. Coral cover has declined at the northern sites, which experience high levels of human use, while the southern sites remain relatively stable. One intermediate site (Puamana Nearshore) that was devastated by Hurricane Iniki in 1992 has experienced a threefold increase in coral cover since 1994. Estimates of fish density, at northern sites with high human use, increased in 1995 and have remained relatively high. Surveys at southern sites by comparison have been more consistent throughout time.

For our long-term sites, species richness of coral was highest at Honolua Bay (18 spp.) and lowest at the Puamana Offshore site (6 spp.). Fish species richness is highest at Kahekili Park – Site 1 (99 spp.) and lowest at Olowalu Offshore and Nearshore (78 spp.). The highest coral coverage was found at Kahekili Park - Site 2 (56.4%) while the greatest number of fish per transect occurred at Kahekili Park – Site 1 (204.5/250m^2). The lowest coral coverage (1.2%) and fish density (10.7/250m^2) occurred at the Puamana Offshore site. The relationship between coral coverage and coral diversity in Hawaii indicates that when coral coverage exceeds 30%, stands of a few dominant species (e.g. *Porites* spp.) results.

Seasonal trends in water motion appear to be the major factor structuring coral reef communities around Hawaii. Sedimentation and water quality parameters, however, may not influence coral reef communities in high-energy environments due to flushing and rapid dilution. Sites with the highest sediment levels were either stable in terms of coral cover or increasing.

Monitoring reefs to develop indices of reef "health", examining human impacts and placement of artificial reefs to reduce stress on natural reefs will provide tools for more effective management of tropical ecosystems. This work takes on particular relevance within boundary waters of the Hawaiian Islands Humpback Whale National Marine Sanctuary and as nearshore development encroaches upon the marine habitat.

Objectives

The original intention of this project when we began in 1989 was to document spatial and temporal changes at selected reef sites along the Maui coastline in order to characterize the coral

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reef communities. Since that time we have broadened our scope to examine causal factors that might help explain the observed patterns in coral coverage and fish density. These factors have been delineated into natural (temperature, visibility, salinity, sediment influence, and wave exposure) and human-induced parameters (fish feeding impacts, protection from fishing, proximity to elevated nutrient levels from sewage, and overall human use patterns). In particular, we are trying to address the issue of coral reef health, how to assess it, and what factors contribute to the decline or recovery of a coral reef ecosystem. Our specific objectives for the 1997 project are outlined below.

1. Document coral species coverage and species richness in the daytime at Honolua Bay, Kahekili Park, Puamana and Olowalu and compare data with earlier baseline work to detect changes at each site over time.
2. Examine relative density and species richness of fish in the daytime at Honolua Bay, Kahekili Park, Puamana and Olowalu and compare data with earlier baseline work to detect changes at each site over time.
3. Analyze water quality characteristics (temperature, visibility and salinity) at each dive site and examine temporal trends for these values.
4. Measure physical parameters (sediment influence and water motion) at each of our dive sites to quantify the impact from these structuring factors.
5. Survey additional sites to characterize reef communities with respect along an environmental gradient reflecting degree of wave exposure.
6. Investigate changes in the trophic composition of the fish communities at Honolua Bay, Kahekili Park, Puamana and Olowalu.

<u>METHODS</u>

Study Areas:

The primary work area was within the waters bounded by the islands of Maui, Kahoolawe and Lanai in the state of Hawaii (Figure 1). The majority of the data was collected while SCUBA diving at relatively shallow depths (less than 20m). Specific sites were selected on the basis of prior surveys, levels of human use, accessibility and dive conditions. Long term (since 1991) monitoring sites included Honolua Bay, Puamana, and Olowalu (Figure 2). Water depths ranged from 3.2 meters at Honolua Bay during a low tide to 13.4 meters at Puamana (Table 1). Varying degrees of exposure to physical parameters, terrestrial run-off and public use influences these areas.

Methods:

All data were collected with assistance of SCUBA using several methods for analyzing the coral reef habitat. Coral diversity and percent coverage were examined using the quadrat method described by Reed (1980). Modifications of the quadrat method have been used quite extensively in the literature as a method to detect gross changes in the reef flat community structure (Dahl, 1981; Coyer and Whitman, 1990).

The quadrat grid was $1m^2$ in area and consisted of 1 inch PVC tubing fitted with nylon line spaced 10 centimeters apart to form a grid with 81 intersections. Each quadrat was placed on the substrate and spaced 10 meters apart on a single 50 meter transect line from a underwater reference mark (Prior to 1994 we used a 100 meter transect line). The 50 meter transect line, consisted of 1/4-inch diameter nylon rope that was marked at 1-meter intervals with weights every 10 meters. Placement of the quadrats was predetermined before each dive so that at least 20% of each transect was mapped during the season. Different species of coral as well as the substrate type found underneath each intersection was recorded on underwater slates (Appendix A). Coral species were identified using *Reef and Shore Fauna of Hawaii, Section 1: Protozoa Through Ctenophora* by Maragos (1977).

Fish population density and diversity were censused using a modified Brock transect method (Brock, 1954). It is generally recognized that conducting visual transects using SCUBA gear is one of the most effective ways to assess fish populations over nearshore, rocky intertidal or shallow reef habitats where collecting gear such as nets cannot be employed readily (Dewees, 1981; Bortone and Kimmel, 1991). Visual census techniques are advantageous because they do not disturb the habitat and are minimally disruptive to the organisms. The most severe limitation of visual estimates is underestimation of real abundance and diversity patterns. This is due in part to the cryptic nature of reef dwellers and the structural complexity of the reef ecosystem (Bortone and Kimmel, 1991). Therefore, emphasis in this report is placed on relative patterns at each of the selected sites over time.

Three 50-meter lines were laid out in a parallel arrangement, separated by 5 meter intervals which created two sample areas each 250m2. These lines were spooled out from the same underwater reference point used for the quadrat work. A 10 meter rope tethered to the two end divers was used to maintain the correct width for the transect area. The third diver swam in the center and laid out the dividing transect line while maintaining a compass heading. After the lines were positioned, the researchers returned to the start of the transect and allowed 10 minutes for the fish to acclimate. Two divers then proceeded down each corridor of the transect, and recorded the number of every species of fish seen. Data were tabulated on an underwater slate using common names (Appendix B). All fish identifications were standardized using the *Guide to Hawaiian Reef Fishes* by Randall (1985) and *Shore Fishes of Hawaii* by Randall (1996). Morning and afternoon samples were collected for each day of diving. After each dive, the data were transcribed from the underwater slates into a notebook for later computer entry.

Water quality characteristics at each site included; temperature, salinity, and turbidity (visibility). Temperature was measured using a handheld thermometer in the field. Water samples were collected and later analyzed for salinity using a refractometer. Horizontal visibility was measured using a secchi disk (diameter ~ 40cm) stretched between 2 divers at both the surface and bottom.

Physical parameters such as sedimentation and water motion have been monitored at the 4 long-term core areas since 1996. Sedimentation was measured using 6 sediment traps at each site. Each trap consisted of a 2" X 6" PVC tube capped at one end and placed on the bottom in planter trays that were anchored to the substrate. Sediment traps were exchanged once a month and then filtered, dried and weighed to determine quantity of sediment collected in $mg/cm^2/day$. The water motion experiments were conducted by measuring the rate of dissolution for plaster of

Paris clod cards in the field against a set of control cards in buckets not subjected to water movement. Preweighed clod cards are deployed once a month for a 6-hour time interval at each site and later dried and reweighed to calculate the dissolution rate.

Data analysis consisted of computer entry into MS-Access, indexed by survey number for all of the parameters measured. Thus, each survey contained information on coral coverage, fish density, physical parameters and trophic structure. Graphic representation of the data was done in Deltagraph for Windows and Statistica for Windows.

VOLUNTEER TASKS AND ACCOMPLISHMENTS

A total of 45 volunteers participated in the project over 8 two-week sessions sampling 701 coral quadrats across 13 dive sites from May 31, 1998 to September 26, 1998. An additional 229 fish transects were conducted at the same sites (Table 1). Volunteer contributions accounted for approximately 85% of the quadrat samples taken and approximately 75% of the fish transects conducted.

RESULTS

Beginning in 1994, we enhanced our survey effort by establishing more transects at each site. This improved our ability to detect trends in coral and fish density patterns by pooling this additional data at each site. The long term monitoring sites have experienced varying degrees of change in coral coverage and fish density (Tables 2, 3 and Figures 3, 4).

Table 1: Survey effort in 1998 at each of the dive sites (N=number of samples).

Survey Site	Depth (m)	Quadrats (N)	Transects (N)
Honolua Bay - South Reef	3.2	89	22
Honolua Bay - North Reef	3.4	99	23
Puamana – Offshore	13.4	73	33
Puamana – Nearshore	3.3	100	38
Olowalu – Offshore	7.5	59	25
Olowalu – Nearshore	3.4	68	28
Kahekili - Park Front Site 1	6.5	67	21
Kahekili - Control Site 2	6.5	49	18
Kahekili -Treatment Site 3	6.2	34	8
Makena - Five Graves	7.5	17	4
Makena - Maui Prince	9.1	16	4
Makena - Puu Olai	6.4	16	3
La Perouse - Natural Area Reserve	9.4	14	3

Totals		701	229

Honolua North and South are continuing to decrease in coral coverage since 1994. Fish densities on the other hand are fluctuating more dramatically with increases at Honolua South and decreases at Honolua North. Puamana offshore has remained depressed in terms of both coral coverage and fish density after Hurricane Iniki in 1992 yet the nearshore site is displaying a threefold increase in coral recovery with sporadic fish densities. Olowalu Nearshore is remaining relatively stable over the years in terms of both fish and coral. Olowalu Offshore has been quite stable over the same time period until this past year when coral coverage declined yet fish density stayed roughly the same. The reef fronting the park at Kahekili is remaining depressed in coral coverage but fish density is still above previous levels. Kahekili Site 2 remains stable for coral coverage and fish densities have returned to previous levels. Coral coverage and fish density has leveled off at Kahekili Site 3, which is consistent with the prior year.

Table 2: Coral coverage (%) at our long term monitoring sites from 1989 to 1998 using identical transect locations (N=number of quadrat samples).

Survey Site	1989†	1991†	1992†	1993†	1994	1995	1996	1997	1998
Honolua Bay - South	38.4	38.8	35.0	24.4	42.0	43.5	36.9	33.5	27.9
N	*14*	*9*	*16*	*71*	*77*	*72*	*119*	*68*	*89*
Honolua Bay - North	63.5	53.9	56.0	46.8	43.9	34.9	26.9	28.7	23.5
N	*15*	*11*	*12*	*72*	*69*	*111*	*128*	*85*	*99*
Puamana - Offshore	*	11.7	12.6	0.9	1.25	0.8	0.3	0.3	1.2
N		*11*	*16*	*63*	*77*	*93*	*68*	*37*	*73*
Puamana - Nearshore	*	*	*	*	4.2	7.2	6.3	10.4	12.5
N					*24*	*72*	*56*	*44*	*100*
Olowalu - Offshore	*	34.5	34.9	27.6	33.1	28.7	30.4	29.2	20.8
N		*32*	*30*	*53*	*62*	*58*	*92*	*81*	*59*
Olowalu - Nearshore	*	*	*	*	30.8	29.6	23.3	28.4	30.1
N					*68*	*91*	*74*	*60*	*68*
Kahekili-Park Front Site 1	*	*	*	58.6	57.1	44.1	50.6	51.7	49.6
N				*20*	*69*	*94*	*83*	*63*	*67*
Kahekili-Treatment Site 2	*	*	*	*	50.0	51.3	56.2	57.4	56.4
N					*61*	*72*	*84*	*61*	*49*
Kahekili-Treatment Site 3	*	*	*	*	36.7	23.8	25.1	31.5	32.7
N					*52*	*67*	*68*	*28*	*34*

* These sites were not sampled for coral cover during the year indicated.

† Only transects 1 and 4 were sampled during this year.

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Table 3: Fish density (#/250m2) at our long term monitoring sites from 1989 to 1998 using identical transect locations (N=number of transects sampled).

Survey Site (Transect #)	1989†	1991†	1992†	1993†	1994	1995	1996	1997	1998
Honolua Bay – South	144.7	167.5	110.8	124.3	123.5	181.5	160.0	178.5	188.9
N	*4*	*3*	*2*	*6*	*24*	*29*	*28*	*21*	*22*
Honolua Bay – North	177.4	214.9	123.3	154.6	144.3	250.3	236.5	220.2	169.6
N	*4*	*3*	*2*	*5*	*22*	*37*	*32*	*23*	*23*
Puamana – Offshore	*	56.9	67.5	12.5	18.0	16.6	11.7	19.0	10.7
N		*3*	*3*	*8*	*23*	*45*	*33*	*24*	*33*
Puamana – Nearshore	*	*	*	*	103.9	242.7	137.7	157.1	127.7
N					*20*	*37*	*33*	*24*	*38*
Olowalu – Offshore	*	117.3	106.8	111.0	138.2	115.7	122.8	127.1	113.0
N		*6*	*4*	*10*	*19*	*20*	*34*	*33*	*25*
Olowalu – Nearshore	*	*	*	*	114.7	140.5	172.1	138.1	141.8
N					*24*	*10*	*19*	*24*	*28*
Kahekili-Park Front Site 1	*	*	*	150.9	173.3	215.8	225.6	207.4	204.5
N				*2*	*23*	*26*	*25*	*18*	*21*
Kahekili-Treatment Site 2	*	*	*	*	168.8	174.3	176.6	213.7	177.6
N					*21*	*22*	*25*	*18*	*18*
Kahekili-Treatment Site 3	*	*	*	175.3	163.1	145.0	129.7	133.8	137.5
N				*1*	*16*	*20*	*16*	*10*	*8*

* These sites were not sampled for fish densities during the year indicated.

† Only transects 1 and 4 were sampled during this year.

For the long term monitoring sites, species richness (number of species) of coral was highest at Honolua South (18 spp.) and lowest at the Puamana Offshore site (6 spp.). Fish species richness was highest at Kahekili site 1 (99 spp.) with the lowest number of fish species observed at Olowalu Nearshore and Offshore (78 spp.). The highest coral coverage was again found at Kahekili site 2 (56.4%) while the lowest coral coverage (1.2%) was observed at the Puamana Offshore site. The relationship between coral coverage and coral species richness in Hawaii indicates that when coral coverage exceeds approximately 30%, stands dominated by a few species (e.g. *Porites* spp.) appears (Figure 4).

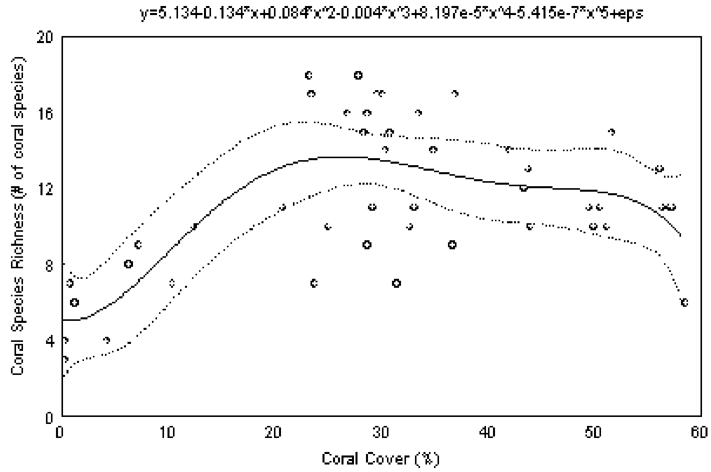

Figure 4: Relationship between coral coverage and coral species richness at the long term monitoring sites since 1994.

The greatest number of fish per transect occurred at Kahekili site 1 (204.5/250m^2) and the lowest fish density (10.7/250m^2) was observed at Puamana offshore. There is a positive linear correlation between the amount of coral and the density of fish present at any given site (Figure 5). This relationship has shifted in recent years, however, due to increases in fish density at the popular tourist sites coupled with a decrease in coral coverage.

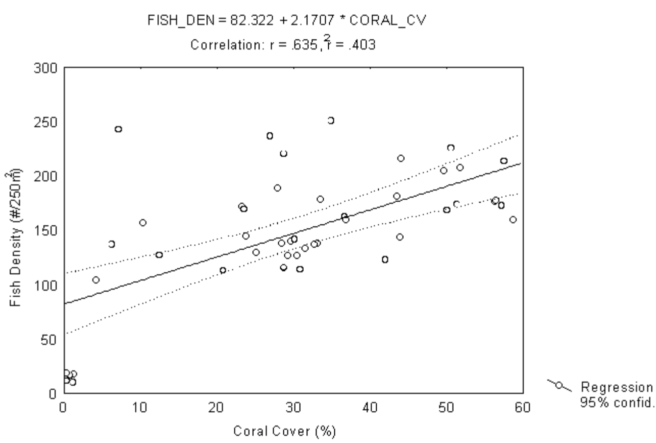

Figure 5: Relationship between coral coverage and fish density at the long term monitoring sites since 1994.

Physical Data from June to September

The 1998 El Nino event was one of the strongest ever recorded and some unusual effects were observed in Hawaii as a consequence. Average water temperatures continued to cool off from the previous years across all of our dive sites. The warmest month on average at all of the sites was August. Salinity measurements showed increases from previous years at both the surface and bottom and this can be traced to the lack of precipitation in 1998. Visibility has increase steadily at the majority of our dive sites since 1993. Several sites such as Kahekili site 2 had improved visibility during the warmest year (1996) but have since returned to 1993 levels. It is believed that the increase in water clarity at the majority of our sites is attributed to better land management practices and lower precipitation levels in the past few years. Further analysis of the wave record will clarify these hypotheses.

Table 4: Summary of abiotic data collected at our long term monitoring sites during the 1998 study period (Values are averaged at each site, N=number of samples at each site).

Survey Site	Location	Temp (° C)	Salinity (‰)	Visibility (m)	Sediment (mg)	Diffusion Factor
Honolua Bay - South	Surface (S)	25.2	35.0	16.0		
	Bottom (B)	25.1	36.3	19.8	5.79	13.07
N		*12*	*11*	*11*		
Honolua Bay - North	(S)	25.4	35.8	16.8		
	(B)	25.2	36.5	21.3	12.48	14.85
N		*11*	*7*	*10*		
Puamana - Offshore	(S)	26.1	36.0	27.0		
	(B)	25.5	36.4	28.3	111.80	15.86
N		*13*	*12*	*12*		
Puamana - Nearshore	(S)	26.6	36.6	15.3		
	(B)	25.9	36.7	19.4	293.88	24.57
N		*15*	*10*	*14*		
Olowalu - Offshore	(S)	25.4	36.4	27.3		
	(B)	25.3	36.7	23.6	169.54	11.76
N		*12*	*10*	*10*		
Olowalu - Nearshore	(S)	26.1	36.2	15.0		
	(B)	25.9	36.3	15.1	55.91	13.42
N		*14*	*13*	*11*		
Kahekili - Park Front Site 1	(S)	25.7	35.8	21.1		
	(B)	25.5	35.8	23.8	62.61	20.66
N		*12*	*7*	*10*		
Kahekili - Control Site 2	(S)	25.4	35.6	15.6		
	(B)	25.1	36.2	19.4	89.44	21.05
N		*8*	*6*	*7*		
Kahekili - Treatment Site 3	(S)	25.6	36.0	20.3		
	(B)	25.1	36.5	26.3	57.63	17.63
N		*5*	*4*	*4*		

Honolua Bay south reef continues to be the coldest site on average with the lowest salinity values on the surface. This is due to the groundwater and intermittent freshwater stream that empty into the bay. Visibility levels were characteristic of other nearshore areas at the same depth (3-4m) yet the source of the reduced light levels is not correlated with sediments collected in the traps. This area continues to have the lowest sedimentation of any of the sites. Water motion (Diffusion Factor) was low during the study period but storm events in the winter months may flush the sediments out of the bay system reducing the overall load.

Puamana nearshore had high temperatures and high salinity values indicating low levels of freshwater input. The visibility was similar to other sites at the same depth yet sedimentation was very high in comparison to the offshore site. This correlated well with the high water motion at the nearshore site due to the shallower depth. It did not appear, however, that water motion exceeded the critical level to move sediments completely offshore during high wave events like Honolua. The offshore site had high salinity and visibility measurements that are characteristic of open ocean water.

The Olowalu nearshore site as in years past continues to have the poorest visibility with some of the highest temperatures. Salinity levels were moderate for both sites. Olowalu offshore had three times the sediment load of the nearshore site and yet both sites had very low water motion compared with the other areas. This is most likely due to the lower relief of the offshore site thereby facilitating sediment collection.

The three sites at Kahekili were quite similar with respect to temperature and salinity and since these sites are in the middle of our North-South site gradient, the measured values were intermediate to the other locations. Visibility was relatively uniform yet site 2 with the lowest visibility also had the lowest salinity indicating freshwater input that would reduce water clarity. Sediment and water motion correlated very well. Site 2 with the highest water motion also had the highest sediment load while site 3 was the lowest in both categories.

Characterization of Additional Sites Surveyed

This season we continued to survey additional dive sites in South Maui representing a broader range of habitats, environmental gradients (i.e. seasonal wave exposure) and human use patterns (Figure 1). Table 5 displays the coral and fish characteristics of each site and the degree of human use. Five Graves in Makena is protected from wave action and is a popular dive and snorkel spot. This site has surprisingly low fish numbers when compared with other areas that are similar in coral coverage such as Maui Prince, also in Makena. The drop in coral cover at Five Graves may simply be an artifact of low sample size and needs to be investigated further. La Perouse is a marine reserve with high coral cover and low fish numbers when compared to our other dive sites such as Kahekili Park. This relationship was also observed at Puu Olai in Makena. The low fish numbers coupled with the high coral cover could be characteristic of this south Maui region, especially considering the low human use. We plan on continuing to compare coral and fish community structure over time at each one of these sites.

Table 5: Coral cover (%) and fish density (#/250m^2) at additional sites (N=number of transects sampled).

Survey Site	Coral cover (%)		Fish density (#/250m^2)		Human Use
	1997	1998	1997	1998	
*Makena - Five Graves	21.8	15.2	85.1	74.1	High
*Makena - Maui Prince	22.0	23.3	184.4	105.1	Medium
*La Perouse - Natural Area Reserve	45.0	45.0	114.0	121.2	Low
*Makena - Puu Olai	46.5	45.4	137.8	123.5	Low

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Trophic Composition of the Fish Community at our Long Term Sites

Herbivores, mobile invertebrate feeders and zooplanktivores (Table 6) dominate the majority of reef areas. The exceptions are the 2 sites at Olowalu which have a strong detrivore component. It is interesting to note that these 2 sites are the most stable of our long term sites in terms of both fish and coral. Our study sites are typical of tropical reef ecosystems where carnivores (Coralivores, Mobile Invertebrates, Piscivores, Sessile Invertebrates, and Zooplanktivores) as a group comprise approximately 50-70% of the entire fish fauna. Olowalu again was the exception where carnivores were estimated to be only 29.3% of the fish community at the nearshore site. Composition of the fish community is now being analyzed over time to examine fluctuations in the trophic structure at each of our sites.

There is also a strong, positive linear correlation between the number of fish that feed on coral (i.e. Coralivores) and the amount of coral cover present at a site. In other words, more coral equates to both higher numbers and a higher percentage of reef fish that feed primarily on the live coral tissue. The coralivores exemplify the relationship seen in Figure 5. It has been postulated that butterflyfish (Chaetodontidae) are good indicator species for the health of coral reefs (Crosby and Reese, 1996). Our findings indicate that the coralivore trophic group as a whole is a better predictor of coral coverage than the individual components (i.e. indicator species).

Table 6: Trophic composition (%) of the fish communities at the long term sites for 1998.

Survey Site	Coralivore	Detrivore	Herbivore	Mobile Inverts	Piscivore	Sessile Inverts	Zooplantivore
Honolua Bay - South Reef	5.3	.6	43.1	36.8	.6	.4	13.3
Honolua Bay - North Reef	4.2	.4	42.1	32.3	1.4	.4	19.2
Puamana - Offshore	.6	.3	27.3	40.9	3.7	2.9	22.9
Puamana - Nearshore	1.6	.1	26.7	36.3	1.9	.4	32.8
Olowalu - Offshore	6.2	18.8	43.1	19.0	.8	.8	11.3
Olowalu - Nearshore	2.9	16.2	51.5	27.5	.5	.7	.6
Kahekili - Park Front Site 1	8.8	4.7	39.4	27.2	.9	.6	18.3
Kahekili - Control Site 2	10.4	2.4	34.9	23.4	1.6	.3	26.9
Kahekili -Treatment Site 3	8.7	6.8	37.0	23.8	1.8	1.4	20.1

Summary of results to date

In general, it appears that certain sites are changing more than others are in terms of coral and fish. At this time we are uncertain of the exact causal mechanisms for the observed trends but by examining physical, biological and human-induced parameters we hope to clarify correlating variables. Listed below are the major observations to date for this study.

1. Since 1994, the long term monitoring sites have experienced varying degrees of change in coral coverage. Coral coverage for Kahekili Site 2 and 3, and Olowalu Nearshore appear to be stable while Honolua Bay and Olowalu Offshore are displaying downward

trends. Kahekili Site 1 remains depressed after an initial decline in 1995. Puamana Nearshore has experienced a threefold increase in coral coverage following Hurricane Iniki in the fall of 1992 while Puamana Offshore has not yet recuperated from this episodic event.

2. In areas of high coral coverage (>30%) species richness appears to go down and *Porites* spp. dominate. Species richness appears to be highest (e.g. Honolua South with 18 spp.) when coral coverage approaches 25-30% and a more even mixture of *Porites* spp and *Montipora* spp. exists. At low coral levels (<25%) *Porites* spp. and *Pocillopora* spp. are more prevalent. This may indicate that a threshold exists for coral coverage at various sites around Hawaii that results in monotypic stands when acute physical disturbances are rare.
3. Fish density levels increased at Honolua South while Kahekili Site 1 continued to display elevated numbers of fish. These sites are among the most popular snorkeling and diving spots along the West Maui coastline as indicated by our beach counts. This suggests that human activity (e.g. fish feeding) may influence the observed patterns. These observed increases in fish density, however, could also be the result of several excellent years for fish recruitment. Elsewhere, Honolua North continued to decline in fish density, which indicates that the raised numbers in 1995 may have been due to an excellent recruiting year. The other sites remained relatively stable from prior years.
4. Different fish species dominated at each of our long term sites depending on coral coverage. With high coral coverage (>30%) wrasses (e.g. *Thalassoma duperrey*), surgeonfish (e.g. *Acanthurus nigrofuscus*), and damselfish (e.g. *Chromis vanderbilti*) flourish. At 20-30% coral coverage, herbivorous surgeonfish (e.g. *Acanthurus nigrofuscus* and *Ctenochaetus strigosus*) are prevalent in greater numbers. Coral coverage between 5-20% displayed patterns similar to the high (>30%) coral cover areas. Below 5% no real species dominated with an assortment of puffers (*Canthigaster jactator*), wrasses (*Pseudojuloides cerasinus, Thalassoma duperrey* and *Stethojulis balteata*) and damselfish (*Chromis vanderbilti* and *Dascyllus albisella*) observed.
5. There appears to be a positive linear relationship that exists between coral coverage and fish density. In areas (e.g. Puamana both sites, Olowalu Offshore) not heavily influenced by direct human activities the correlation is quite strong. This model may be used as an index to assess reef health as ecosystems deviate from the relationship over time.
6. In 1998, the El Nino event cooled off temperatures substantially from prior years. The northernmost sites (Honolua Bay and Kahekili Park) displayed colder temperatures and slightly lower surface salinity measurements than the southern sites (Olowalu, Makena, La Perouse). Salinity measurements were generally higher than in previous years due to lower precipitation levels in 1998. Visibility was generally poorer in nearshore areas and at the surface due to resuspended sediments from higher water motion. Sites with the highest sediment collection rates generally had lower coral cover yet these areas were stable or increasing. The lowest sediment collection was in Honolua Bay that is experiencing a decline in coral cover. This area had low water motion during the summer but extremely high water motion in the winter that appears to flush out sediment from the bay system.

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7. At the more northerly sites (Honolua, Kahekili, and Puamana) wave exposure (i.e. water motion) is the principal structuring mechanism of the reef environment. At the south facing reefs (Olowalu, 3 sites at Makena, and La Perouse) biological factors and human activities appear to play a major role in shaping the reef.
8. Inclusion of additional sites suggested that fish populations are higher in areas (e.g. Makena – Puu Olai) with high coral cover and low human use compared to areas heavily used (e.g. Makena – Five Graves) and moderate coral cover.
9. The trophic composition of our study sites is remarkably similar and dominated by Herbivores (25-50%), Mobile Invertebrate Feeders (20-40%) and Zooplanktivores (10-30%). Olowalu is unusual in that Detrivores (15-20%) comprise a large portion of the fish population with a reduction in Mobile Invertebrate Feeders and Zooplanktivores. Continued monitoring in future years will clarify these changes in response to human activities such as fish feeding, fishing pressure and nearshore development.

DISCUSSION

The significance of this project is our ability to conduct intensive, long term monitoring of fragile coral reef ecosystems in Hawaii and detect changes in key components over time. Other agencies in Hawaii are simply unable to do this with current resources. At this stage of our research we are primarily interested in characterizing reef ecosystems in Hawaii from the standpoint of coral and fish density and clarifying the relationship with other factors (e.g. physical and human-induced) that might influence the observed patterns.

The quantity of data collected at our long-term sites was adequate to reach our research goals for this year. Kahekili Park holds special interest because of the ability to conduct long term monitoring studies at three biologically similar sites in close proximity that differ in their human use patterns. This site is also at the center of a controversial development that threatens the nearshore area but it is currently being re-evaluated after contentious litigation.

The phase we are moving into examines the cause and effect relationships between biological and physical factors. We will continue examining physical processes (i.e. water motion, sediment movement in and around reef areas and sedimentation levels) that structure coral reef ecosystems along the West Maui coastline. In addition, quantifying human use patterns should aid in interpretation of impacts at these sites. Being able to determine the relative importance of various factors and their temporal influences will clarify dynamics of coral reefs and their associated fish communities in Hawaii. As human development encroaches on the aquatic ecosystem it is imperative that we document impacts and suggest management strategies to reduce or alleviate deleterious effects. Ultimately we hope this data will help:

1. Provide credible data to agencies responsible for protecting Hawaii's coastal resources.
2. Support educational efforts from a scientific perspective that will enhance reef awareness.

SAVING MAUI'S REEFS

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PUBLICATIONS

The completed report will be submitted to the State of Hawaii Department of Land and Natural Resources Aquatic Division (DLNR), State of Hawaii Department of Health (DOH) and the Coastal Zone Management (CZM) group to supplement their existing databases of coastal resources. Additional copies will be distributed to appropriate departments within the University of Hawaii system, Hawaii Institute of Marine Biology, marine consulting firms, and county of Maui officials interested in the nearshore environment.

One paper titled, "Long Term Monitoring of Coral Reefs on Maui, Hawai'i and the Applicability of Volunteers" is slated for publication in the 1998 proceedings of the DLNR coral reef workshop (See enclosed copy). Another paper examining comparative methodologies for monitoring will be presented at the National Coral Reef Initiative conference in Ft. Lauderdale, Florida in April. Much of this current research effort will also be incorporated into my dissertation and chapters of this work will be submitted for publication in journals such as Pacific Science and Coral Reefs.

OTHER ACCOMPLISHMENTS AND BENEFITS

This project begins to document changes in coral reefs around areas of high human impact. Working with state and county agencies responsible for managing coastal resources we have begun to outline steps necessary to preserve our marine ecosystem. The following events highlight our local accomplishments:

1. Commercial marine consultants (Oceanit, Inc.) and developers (AMFAC, Inc.) utilize our data in their assessment of coastline development at Kahekili Park.
2. In 1998, our work in Honolua Bay was presented at the Earth Maui Nature Summit (June 13th) and to the board of directors for DLNR (April 9th).
3. A paper on the research project and the applicability of volunteers was presented in June at the International Coral Reef Monitoring Workshop sponsored by the University of Hawaii, DLNR and the East-West Center of the Pacific (See above).
4. The Pacific Whale Foundation continues to assist the Maui Ocean Center in development of exhibits and training of staff members for the aquarium.
5. We continue to work on 4 grants awarded to the Foundation from Coastal Zone Management and the National Oceanic and Atmospheric Administration (NOAA-CRI) through the Coral Reef Initiative. These grants focus on publishing an educational brochure on Hawaii's coral reefs, offering Naturalist courses on the marine environment and constructing a web site on the Internet to link coral reef research and education programs in Hawaii.
6. Members of our staff provide public testimony on various marine issues and serve on a number of community advisory boards from the State of Hawaii Coastal Zone Management team to the local Natural Area Reserve System advisory group (e.g. Ahihi-Kinau).

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7. These efforts have demonstrated effective community involvement in marine research and education. In addition to contributing to our understanding of the marine ecosystem in Hawaii, we now have enhanced the Pacific Whale Foundation's ocean outreach programs for the general public. These programs include educational marine excursions, on-site classroom visits, elderhostel lecture series and field trips with local school children.

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