BASELINE SURVEY OF KAUPULEHU BAY, HAWAII

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INTRODUCTION

Kahuwai Bay is located in the Ka'upulehu district of North Kona, the site of the Kona Village Resort. The bay is a shallow indentation contained by Kumukehu Point to the south and Mahewalu Point, formed during the 1801 Ka'upulehu lava flow to the north. A sandy beach is located at the center of the bay, bordered on the south by a wave bench and tide pools. Low basalt cliffs border the northern side of the bay. The fringing reef is broad platform about five meters deep which extends one kilometer offshore beginning at Mahewalu Point, continuing south for several kilometers. The platform is characterized by a flat basalt pavement with patches of Poritid corals, rubble, and coarse white sand. It is subject to moderate surge and water clarity is variable. An abrupt five meter drop-off leads to finger coral beds and rubble grading into gray sand which gradually slopes to deeper water. The region between Mahewalu Point and Kalaemano is a extension of this drop-off originating directly from the low sea cliffs, and is subject to heavy wave action and very clear water. In addition to the drop-off, this area has more vertical relief including large arches and caverns.

The bay and its offshore waters have remained virtually untouched by human activity due to its remote location, and the only published information about the reef ecosystem is included in the U.S. Army Corps of Engineers' 1981 West Hawaii Coral Reef Inventory. It states that the bay environment is pristine, with a very abundant and diverse fish population. The nature of this data is qualitative and personal observations by employees and guests of the resort suggest that the number of reef fishes in the bay, although excellent has been declining over the years. In May 1992 the resort determined that a quantitative baseline survey of the nearshore reef environment would be valuable as a reference to support protecting the bay.

The baseline study was conducted during the summer of 1992 by the University of Hawaii's Marine Option Program. The focus of the survey team was to establish at least eight permanent transect sites in several distinct areas of the bay to quantitatively estimate the abundance of corals, invertebrates, and fishes. Permanent transects will enable surveyors to revisit the sites on regular basis to monitor the bay's condition. Although very desirable, additional transects could not be conducted due to time and logistical constraints.

MATERIALS AND METHODS

Several reconnaissance dives were made to identify distinct regions within the area. It was determined that a minimum of four sites be surveyed as a starting point. A total of eight fifty-meter belt transects were deployed, with two transects in each of the following locations: 1. Inner reef; 2. Sand channel; 3. Drop-off; 4. Outer reef. The Drop-off data set was used as the control, since it is located in deeper water (10 m) seaward of the reef platform. Data from the two transects in each zone were treated as replicates to obtain mean substrate coverage's, biomass, and population densities.

Deployment of the transects were done by starting at prominent features such a mooring blocks or large coral heads, then laying the graduated plastic transect line (Plate 1) on a predetermined compass heading. The end of the line was marked with a strip of plastic and foil. Transects were located within the limits of the substrate type being sampled, avoiding borderline areas. The position of the starting point of each transect was plotted by taking compass bearings to two landmarks located on the Kona Village map (Figure 1).

Substrate

Estimation of substrate cover was done by placing a one meter square PVC quadrat over the substrate at five meter intervals along the line, with the bottom-left corner of the quadrat placed directly over the correct distance mark, starting at 0 m and ending at 50 m, for a total of eleven samples. The substrate within the quadrat was divided into four subzones, each totaling 100%. The total percentage of each substrate type from the four subzones were then added together, divided by four, and multiplied by 100% to find the total in each sample. The percentages of each type from all eleven samples are then combined, divided by eleven, and multiplied by 100% to find the mean percent coverage for the transect. The mean percent coverage of each type from the two transects in each zone was then combined, divided by two, and multiplied by 100% to find the mean percent coverage for the zone.

Invertebrates

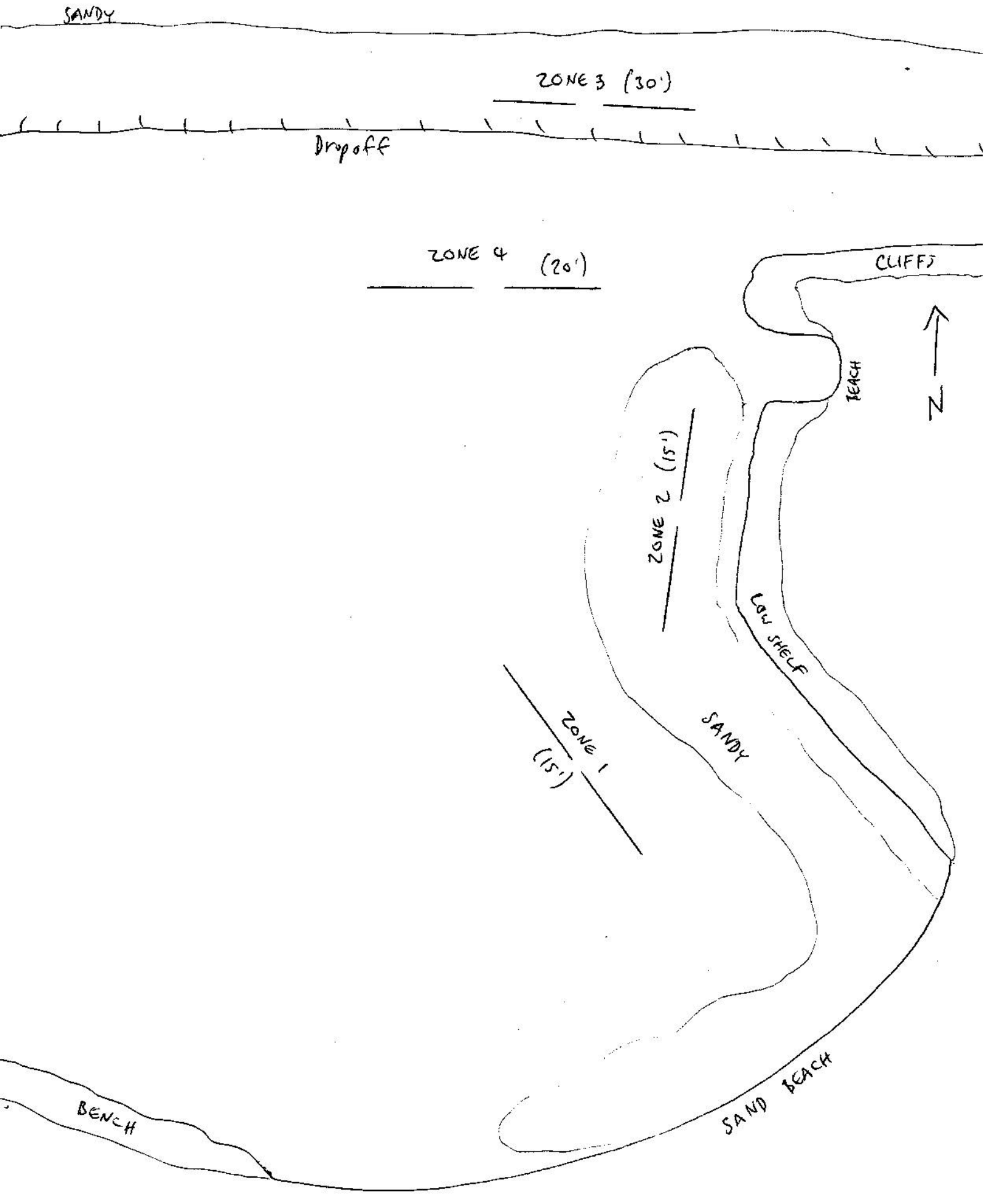
The invertebrate population (excluding corals, burrowing forms, plankton, and individuals less than one cm long) in each transect was estimated by counting all individuals along the length of the line, out to a distance of 2.5 meters on both sides, comprising a total sample area of 250 square meters. The total number of each species was then divided by 250, to determine the number of individuals per square meter. The totals of each species found in the two transects in each zone were then combined and divided by two to find the mean population and density for the zone.

Additional species observed in the immediate area outside of the transects were recorded.

Fishes

The fish population was surveyed by using a variation of the Modified Brock Method (Brock, 1982). All individuals observed along the length of the transect line, to six meters on both sides, from the ocean floor to the surface, were identified and counted, noting total lengths in inches. The data was used to determine the number of individuals, families, species, and biomass for each transect and zone. Biomass (the estimated wet weight of fishes in pounds per square acre of seafloor) was calculated with the formula X^3 Y Z (4047/600), where X = total length in inches, Y = number observed, Z = DAR constant (Appendix 2). Results from the two transects in each zone were combined to get the mean abundance and biomass for the zone. The Shannon-Weiner Index was used to find the species diversity for each zone.

Figure 1.


SANDY
ZONE 3 (30')
Dropoff
ZONE 4 (20')
CLIFFS
BEACH
N
ZONE 2 (15')
LOW SHELF
SANDY
ZONE 1 (15')
BENCH
SAND BEACH

RESULTS

Results of all surveys are summarized in Tables 1, 2, and 3. Table 1 lists the percent coverage of all substrate types in each zone. The estimated population density of macroinvertebrates (individuals per square meter) is listed in Table 2. Fish census results are briefly summarized in Table 3. For more detailed fish census results, see Appendix 1.

Zone 1, the rocky area just offshore of the sandy beach is low-relief basalt slab (70.6%) with horizontal fissures and a small amount of coarse sand (0.9%) and live corals (14.1%). Depth was 3 to 5 meters and subject to moderate surge, especially during the mid-day onshore winds. Visibility ranged from 10 meters in the morning to as little as 5 meters in the afternoon. Freshwater seeps along the shoreline did not appear to affect the water quality in the survey area (no noticeable plumes were observed), although a distinct freshwater lens was present closer to shore.

Porites lobata was the most common coral (10.7%), in addition to *Pocillopora meandrina* and four encrusting, surge-resistant species. Ten species of echinoderm were observed, with rock-boring urchins ($6.22/m^2$) being present in virtually every small crevice. In terms of population size, biomass and species diversity, Zone 1 was the highest of all zones. Sixty five species of fishes were observed, with a density of 30,469.5 individuals per hectare and estimated biomass of 390.8 kg per hectare. The species diversity index was 2.77. The most common fishes were *Hinalea lauwili*, *Maiko*, *Manini*, *Chromis vanderbilti* and *Humuhumu 'ele'ele*.

Although seaweeds were not recorded in this study, Zone 1 was the only location that frondose red and brown algae was common. During evening hours several Manta rays feed on plankton attracted by resort lights just a few feet from shore.

Zone 2 is located in the sand channel between Zone 1 and the rocky north shore of Kahuwai Bay at a depth of 5 meters. Water conditions were very similar, and the coarse sandy bottom (84.6%) was interrupted by a few outcrops of basalt (4.6%) with three species of live corals (0.9%), and scattered chunks of coral rubble (8.6%).

Most of the marine organisms observed were associated with hard substrate, except for the cone snails and *Awa* (*Chanos chanos*). Thirteen species of invertebrates were recorded, with Rock-boring urchins being most common. Twenty eight species of fishes were observed with an low of 1883.1 individuals per hectare, biomass of 254.5 kg per hectare, and low diversity index of 1.22. The most common fishes were *Alo'ilo'i*, *Maiko*, and

Manini. The majority of the biomass for this zone is attributed to a large *Awa* (207.9 kg/hectare) and Conger eel (20.6 kg/hectare) in the transect.

Zone 3 is at the foot of the dropoff adjacent to Mahewalu Point. It is dominated by fragile thickets of *Porites compressa* (33.0%) and massive or encrusting *Porites lobata* (33.4%) separated by pockets of clean white sand (20.4%) at an average depth of 10 meters. Coarse gray sand flats seaward of this zone slope gently toward greater depths. Visibility ranged from 15 to 30 meters during high tide.

Slate-pencil and collector urchins were the most common invertebrates with 0.97 and 0.73 individuals per square meter. Seventy four species of fishes representing twenty five families were observed here, making this zone the highest in number of species observed. However the species diversity index was only 1.26, which means that many of the species were represented by singletons. There were 19,164.8 individuals per hectare with a biomass of 232.8 kg per hectare. The most common species were *Kole*, *Maiko*, Yellow tangs, *Humuhumu 'ele'ele*, and *'U'u* (*Menpachi*). A medium White-tip reef shark accounted for 48.3 kg per hectare of biomass, the only shark observed during the survey dives.

Two small sharks were found resting under a large archway near Kalaemano. In addition, a Manta ray passed by during an afternoon dive but did not head for the beach to feed. It is not known where they go during the day, but local divers suggest that the rays reside near the same archway. The area did have an abundance of large, easily approachable game fish which leads us to believe that the area is virtually untouched. It is a truly spectacular dive site worth surveying.

The top of the reef platform about 25 meters away from and parallel to the dropoff constitutes Zone 4. It is a flat region dominated by lush mounds of *Porites lobata* (46.7%) and ten other species, with a combined total of 68.6% cover. Scattered pockets of coarse white sand covered traces of the underlying basalt platform.

Rock-boring and collector urchins had a population density of 1.04 individuals per square meter. Fifty four species of fishes were recorded with a diversity index of 1.37. Estimated abundance was 16,565.0 individuals per hectare with a biomass of 180.3 kg per hectare. The most common fishes were *Kole*, *Hinalea lauwili*, *Maiko*, and Pacific Gregory (*Stegastes fasciolatus*).

DISCUSSION

Kahuwai Bay has proved to be healthy in terms of population size and species diversity, especially with fishes. Undoubtedly, other species would be recorded if more transects were conducted farther offshore on the extensive fringing reef and drop-off. Personal observation of this outer reef revealed a *Porites lobata* dominated (>75% cover) environment rarely disturbed by human activity. Some of the Porites lobata colonies attain diameters of three meters or more and are truly breathtaking. Night dives conducted in Zone 3 revealed many nocturnal animals, especially mollusks and crustaceans.

The practice of fish feeding does not appear to be responsible for the large fish population in Zone 1, but rather the availability of holes for shelter and algal turf, which thrives in the shallows. The characteristic green-tinted water of the inner reef indicates nutrient input from freshwater seeps, favoring algal growth. The species observed during feeding times were primarily *Nenue*, *Papio*, Milletseed butterflyfishes, *Pualu*, and *Uhu*. These individuals were observed to inhabit the sand channel along the shoreline in front of Hale Moana, at least 50 meters away from our transects. These individuals were not observed in Zone 1. A pair of Threadfin and Lined butterflyfishes did however, appear in Zone 4 and were recognized as the same individuals accustomed to being fed near the beach shack. They would follow swimmers for extended periods, especially during the early morning hours when visibility was good. Although the fish population near the beach is attractive to hotel guests, the best quality diving is located along the drop-off near Mahewalu Point and north toward Kalaemano.

The most obvious threat to the marine life in the bay besides Kona storms is the fishing pressure and subsequent and often widespread damage to the fragile corals by tropical fish collectors which were observed operating in the area during this study. Fortunately, according to local residents, food fish captured in the immediate area have not been implicated in any cases of ciguatera poisoning.

CONCLUSION

As a whole, Kahuwai Bay's coral reef complex is outstanding with its lush coral beds offshore and the remarkable diversity and abundance of marine animals in residence. There are several actions which can be taken to insure the preservation of this priceless natural resource.

The first action would be consistent monitoring and documentation of the reef ecosystem by continuing to survey the transect sites established by

this baseline study, in addition to establishing more sites offshore and near Kalaemano.. In this way, annual or even seasonal trends may be identified and their causes investigated. If a cause is determined to be human-related, corrective action may be taken to prevent further alteration of the environment. In addition, information about the bay can be presented to resort guests and the public to reinforce the Kona Village Resort's commitment to preservation of the natural and archaeological riches with which it is endowed.

A desirable way of protecting Kahuwai Bay would be the establishment of the area as a Marine Life Conservation District (complete protection of all natural features) or Shoreline Fisheries Management Area (periodic restriction of consumptive activities).

Table 2. Invertebrate census results.				
	Individuals/square meter			
PHYLUM/Species	**1**	**2**	**3**	**4**
ANNELIDA				
Eurythoe complanata	0.088			
Spirobranchus giganteus		0.024	0.104	0.57
ARTHROPODA				
Calcinus sp.				
Podophthalmus sp.		0.002	0.002	
CHORDATA				
Tunicate	0.006			
ECHINODERMATA				
Chondrocidaris gigantea			0.006	
Culcita novaeguineae	0.004	0.002		
Echinometra mathaei	6.22	0.84	1.04	1.03
Echinometra oblonga	0.07	0.02		0.002
Echinothrix calamaris	0.014	0.01		
Echinothrix diadema	0.02			
Heterocentrotus mammillatus	0.196	0.014	0.974	0.824
Holothuria nobilis	0.006			
Linckia multifora	0.002			
Ophiocoma spp.	0.586	0.146	0.032	0.1
Tripneustes gratilla	0.024	0.338	0.732	1.038
MOLLUSCA				
Bivalve sp.		0.006		
Conus lividus	0.024			
Conus marmoreus		0.002		

Table 2. Invertebrate census results, p.2.				
	Individuals/square meter			
PHYLUM/Species	1	2	3	4
Conus pulicarius		0.002	0.004	0.002
Cypraea caputserpentis	0.006			
Cypraea tigris				0.004
Octopus cyanea			0.002	
Pinctada margaritifera			0.01	0.004
PORIFERA	0.09	0.054	0.072	0.034
TOTAL SPECIES	**15**	**13**	**11**	**10**

Table 3. Fish census results.						
Zone	**Species**	**Families**	**# Observed**	**#/hectare**	**Kg/hectare**	**Diversity**
1	65	18	915	30,469.50	390.83	2.77
2	28	14	56.5	1,883.14	254.51	1.22
3	74	25	575	19,164.75	232.81	1.26
4	54	18	497	16,565.01	180.27	1.37

Zone 1 Fish Census Results.							
	Transect					Biomass	
FAMILY / Species	1	2	Mean	#/hectare	Rank	Kg/hectare	Rank
ACANTHURIDAE							
Acanthurus achilles	0	2	1	33.3		0.0499994	
Acanthurus dussumieri	1	0	0.5	16.65		0.386359	
Acanthurus guttatus	1	0	0.5	16.65		0.4136314	
Acanthurus leucopareius	27	0	13.5	449.55		3.0090548	
Acanthurus nigrofuscus	242	246	244	8125.2	2	46.5539868	3
Acanthurus olivaceus	1	0	0.5	16.65		0.7590818	
Acanthurus triostegus	31	101	66	2197.8	3	11.7225866	
Acanthurus xanthopterus	6	0	3	99.9		73.5809352	2
Ctenochaetus strigosus	7	20	13.5	449.55		2.3045178	
Naso lituratus	6	6	6	199.8		15.431633	
Zebrasoma flavescens	40	12	26	865.8		24.0315298	5
Zebrasoma veliferum	2	0	1	33.3		4.4499466	
BALISTIDAE							
Melichthys niger	25	38	31.5	1048.95	5	44.0812892	4
Melichthys vidua	2	2	2	66.6		6.0317458	
Rhinecanthus aculeatus	1	0	0.5	16.65		0.7863542	
Rhinecanthus rectangulus	14	1	7.5	249.75		6.4408318	
Sufflamen bursa	2	2	2	66.6		1.6317986	
BLENNIIDAE							
Plagiotremus goslinei	2	0	1	33.3		0.045454	
CARACANTHIDAE							
Caracanthus maculatus	0	1	0.5	16.65		0.0136362	

Zone 1 Fish Census Results, p. 2.							
	Transect					Biomass	
FAMILY / Species	1	2	Mean	#/hectare	Rank	Kg/hectare	Rank
CHAETODONTIDAE							
Chaetodon auriga	2	7	4.5	149.85		2.6181504	
Chaetodon lunula	10	3	6.5	216.45		2.9408738	
Chaetodon miliaris	6	2	4	133.2		1.340893	
Chaetodon multicinctus	0	7	3.5	116.55		0.4818124	
Chaetodon ornatissimus	1	2	1.5	49.95		0.8363536	
Chaetodon quadrimaculatus	5	4	4.5	149.85		0.90908	
Chaetodon trifasciatus	0	3	1.5	49.95		0.3090872	
Forcipiger flavissimus	1	0	0.5	16.65		0.1545436	
Forcipiger longirostris	2	0	1	33.3		0.3090872	
CIRRHITIDAE							
Cirrhitops fasciatus	1	11	6	199.8		0.886353	
Paracirrhites arcatus	0	12	6	199.8		0.9227162	
Paracirrhites forsteri	0	2	1	33.3		0.7818088	
FISTULARIIDAE							
Fistularia commersonii	0	1	0.5	16.65		0.0409086	
LABRIDAE							
Cheilinus bimaculatus	0	3	1.5	49.95		0.0272724	
Cheilinus unifasciatus	0	2	1	33.3		0.136362	
Coris flavovittata	3	1	2	66.6		0.1499982	
Coris gaimard	0	1	0.5	16.65		0.1454528	
Coris venusta	1	1	1	33.3		0.0090908	
Gomphosus varius	1	11	6	199.8		0.3818136	
Halichoeres ornatissimus	0	2	1	33.3		0.0136362	

Zone 1 Fish Census Results, p. 3.							
	Transect					Biomass	
FAMILY / Species	**1**	**2**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Labroides phthirophagus	2	4	3	99.9		0.136362	
Novaculichthys taeniourus	0	1	0.5	16.65		0.3954498	
Stethojulis balteata	6	33	19.5	649.35		1.1908948	
Thalassoma duperrey	285	226	255.5	8508.15	1	83.7217226	1
LUTJANIDAE							
Lutjanus fulvus	2	0	1	33.3		2.0545208	
MULLIDAE							
Parupeneus bifasciatus	0	1	0.5	16.65		0.0499994	
Parupeneus cyclostomus	1	5	3	99.9		2.8226934	
Parupeneus multifasciatus	23	13	18	599.4		7.5408186	
MURAENIDAE							
Gymnothorax flavimarginatus	0	1	0.5	16.65		2.409062	
Gymnothorax meleagris	2	1	1.5	49.95		9.8135186	
OSTRACIIDAE							
Ostracion meleagris	1	1	1	33.3		0.3090872	
POMACENTRIDAE							
Abudefduf abdominalis	0	2	1	33.3		0.159089	
Abudefduf sordidus	1	0	0.5	16.65		0.5363572	
Chromis vanderbilti	49	42	45.5	1515.15	4	0.3454504	
Dascyllus albisella	5	0	2.5	83.25		0.0409086	
Plectroglyphidodon imparipennis	8	31	19.5	649.35		0.6863554	

Zone 1 Fish Census Results, p. 4.							
	Transect					Biomass	
FAMILY / Species	**1**	**2**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Plectroglyphidodon johnstonianus	2	10	6	199.8		0.3454504	
Stegastes fasciolatus	18	24	21	699.3		2.6317866	
SCARIDAE							
Scarus dubius	0	3	1.5	49.95		0.3954498	
Scarus psittacus	17	21	19	632.7		10.6089636	
Scarus sordidus	5	1	3	99.9		7.0271884	
SCORPAENIDAE							
Sebastapistes coniorta	8	14	11	366.3		0.4499946	
SERRANIDAE							
Cephalopholis argus	0	2	1	33.3		1.5317998	
TETRAODONTIDAE							
Canthigaster amboinensis	1	0	0.5	16.65		0.0954534	
Canthigaster jactator	3	4	3.5	116.55		0.113635	
ZANCLIDAE							
Zanclus cornutus	1	1	1	33.3		0.295451	
TOTALS	**883**	**947**	**915**	**30469.5**		**390.8271282**	
TOTAL SPECIES = 65			**TOTAL FAMILIES = 18**				

Zone 2 Fish Census Results.							
	Transect					Biomass	
FAMILY / Species	3	4	Mean	#/hectare	Rank	Kg/hectare	Rank
ACANTHURIDAE							
Acanthurus nigrofuscus	17	0	8.5	283.305	2	4.09086	4
Acanthurus olivaceus	2	0	1	33.33		0.363632	
Acanthurus triostegus	13	0	6.5	216.645	3	1.13635	
Naso lituratus	5	0	2.5	83.325		4.363584	3
Zebrasoma flavescens	6	0	3	99.99	5	1.227258	
BALISTIDAE							
Melichthys niger	2	0	1	33.33		1.36362	
Rhinecanthus aculeatus	0	1	0.5	16.665		0.090908	
Sufflamen bursa	3	3	3	99.99	5	2.590878	5
CARANGIDAE							
Carangoides orthogrammus	1	0	0.5	16.665		0.818172	
CHAETODONTIDAE							
Chaetodon auriga	2	0	1	33.33		2.227246	
Chaetodon lineolatus	2	0	1	33.33		4.09086	4
Chaetodon lunula	0	1	0.5	16.665		0.409086	
CHANDIDAE							
Chanos chanos	2	0	1	33.33		207.861142	1
CIRRHITIDAE							
Cirrhitops fasciatus	1	0	0.5	16.665		0.045454	
Paracirrhites arcatus	1	0	0.5	16.665		0.045454	

Zone 2 Fish Census Results, p. 2.							
	Transect					Biomass	
FAMILY / Species	3	4	Mean	#/hectare	Rank	Kg/hectare	Rank
CONGRIDAE							
Conger cinereus	0	1	0.5	16.665		20.590662	2
FISTULARIIDAE							
Fistularia commersonii	0	1	0.5	16.665		0.68181	
LABRIDAE							
Stethojulis balteata	3	0	1.5	49.995		0.045454	
Thalassoma duperrey	3	2	2.5	83.325		0.181816	
MULLIDAE							
Parupeneus multifasciatus	3	0	1.5	49.995		1.181804	
POMACENTRIDAE							
Chromis vanderbilti	7	0	3.5	116.655	4	0.045454	
Dascyllus albisella	1	20	10.5	349.965	1	0.636356	
Plectroglyphidodon imparipennis	1	0	0.5	16.665		0.045454	
Plectroglyphidodon johnstonianus	1	0	0.5	16.665		0.045454	
Stegastes fasciolatus	4	0	2	66.66		0.181816	
SCARIDAE							
Scarus psittacus	1	0	0.5	16.665		0.090908	
SCORPAENIDAE							
Sebastapistes coniorta	1	1	1	33.33		0.045454	

Zone 2 Fish Census Results, p. 3.							
	Transect					Biomass	
FAMILY / Species	3	4	Mean	#/hectare	Rank	Kg/hectare	Rank
TETRAODONTIDAE							
Canthigaster jactator	1	0	0.5	16.665		0.0136362	
TOTAL	**83**	**30**	**56.5**	**1883.145**		**254.5105822**	
TOTAL SPECIES = 28			**TOTAL FAMILIES = 14**				

Zone 3 Fish Census Results.							
	Transect					Biomass	
FAMILY / Species	5	6	Mean	#/hectare	Rank	Kg/hectare	Rank
ACANTHURIDAE							
Acanthurus achilles	2	0	1	33.33		0.0954534	
Acanthurus nigricans	0	1	0.5	16.665		0.0863626	
Acanthurus nigrofuscus	60	40	50	1666.5	2	6.4044686	
Acanthurus nigroris	0	2	1	33.33		0.2636332	
Acanthurus olivaceus	17	2	9.5	316.635		3.5635936	
Acanthurus triostegus	0	4	2	66.66		0.8590806	
Ctenochaetus hawaiiensis	1	0	0.5	16.665		0.3136326	
Ctenochaetus strigosus	202	147	174.5	5816.085	1	27.9223922	2
Naso brevirostris	3	0	1.5	49.995		3.2181432	
Naso lituratus	0	1	0.5	16.665		1.0272604	
Zebrasoma flavescens	51	47	49	1633.17	3	11.499862	5
Zebrasoma veliferum	0	2	1	33.33		2.5772418	
APOGONIDAE							
Apogon kallopterus	1	1	1	33.33		0.1681798	
AULOSTOMIDAE							
Aulostomus chinensis	1	1	1	33.33		0.3772682	
BALISTIDAE							
Melichthys niger	80	0	40	1333.2	4	23.045178	3
Melichthys vidua	0	3	1.5	49.995		2.590878	
Sufflamen bursa	1	4	2.5	83.325		1.7545244	
BLENNIIDAE							
Cirripectes vanderbilti	0	1	0.5	16.665		0.022727	

Zone 3 Fish Census Results, p. 2.							
	Transect					Biomass	
FAMILY / Species	**5**	**6**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Exallias brevis	0	1	0.5	16.665		0.0499994	
CHAETODONTIDAE							
Chaetodon lunula	4	0	2	66.66		2.1090656	
Chaetodon miliaris	0	5	2.5	83.325		0.3818136	
Chaetodon multicinctus	14	8	11	366.63		1.1181684	
Chaetodon ornatissimus	1	2	1.5	49.995		1.8454324	
Forcipiger flavissimus	13	4	8.5	283.305		1.4227102	
Forcipiger longirostris	1	1	1	33.33		0.3090872	
CIRRHITIDAE							
Paracirrhites arcatus	11	9	10	333.3		0.795445	
Paracirrhites forsteri	0	2	1	33.33		0.7363548	
FISTULARIIDAE							
Fistularia commersonii	1	1	1	33.33		0.1227258	
HEMIGALEIDAE							
Triaenodon obesus	0	1	0.5	16.665		48.2766934	1
HOLOCENTRIDAE							
Myripristis amaena	2	1	1.5	49.995		1.3454384	
Myripristis berndti	3	9	6	199.98		2.0408846	
Myripristis kuntee	49	9	29	966.57	5	14.6907328	4
Neoniphon sammara	1	0	0.5	16.665		0.636356	
Sargocentron diadema	1	0	0.5	16.665		0.1954522	

Zone 3 Fish Census Results, p. 3.							
	Transect					Biomass	
FAMILY / Species	**5**	**6**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
LABRIDAE							
Anampses chrysocephalus	0	1	0.5	16.665		0.0045454	
Cheilinus unifasciatus	4	5	4.5	149.985		4.5590362	
Coris gaimard	4	0	2	66.66		0.1227258	
Gomphosus varius	2	0	1	33.33		0.0272724	
Halichoeres ornatissimus	0	1	0.5	16.665		0.022727	
Labroides phthirophagus	1	2	1.5	49.995		0.0409086	
Macropharyngodon geoffroy	0	1	0.5	16.665		0.0318178	
Pseudocheilinus octotaenia	6	9	7.5	249.975		0.7454456	
Pseudocheilinus tetrataenia	1	0	0.5	16.665		0.022727	
Stethojulis balteata	0	2	1	33.33		0.045454	
Thalassoma ballieui	0	3	1.5	49.995		0.7590818	
Thalassoma duperrey	28	26	27	899.91		5.499934	
LETHRINIDAE							
Monotaxis grandoculis	6	9	7.5	249.975		9.5771578	
LUTJANIDAE							
Aphareus furca	0	1	0.5	16.665		1.227258	
Lutjanus fulvus	0	4	2	66.66		3.8544992	
MONACANTHIDAE							
Cantherhines dumerili	0	1	0.5	16.665		1.2863482	
MULLIDAE							
Mulloides flavolineatus	15	8	11.5	383.295		2.8272388	
Parupeneus bifasciatus	0	2	1	33.33		0.5272664	

Zone 3 Fish Census Results, p. 4.							
	Transect					Biomass	
FAMILY / Species	5	6	Mean	#/hectare	Rank	Kg/hectare	Rank
Parupeneus cyclostomus	0	2	1	33.33		0.3045418	
Parupeneus multifasciatus	35	5	20	666.6		8.5271704	
Parupeneus porphyreus	0	2	1	33.33		6.0362912	
MURAENIDAE							
Gymnothorax eurostus	0	1	0.5	16.665		0.3772682	
Gymnothorax meleagris	0	1	0.5	16.665		0.0772718	
OSTRACIIDAE							
Ostracion meleagris	0	1	0.5	16.665		0.2999964	
POMACANTHIDAE							
Centropyge potteri	5	10	7.5	249.975		1.3818016	
POMACENTRIDAE							
Chromis agilis	22	12	17	566.61		1.3136206	
Chromis hanui	2	6	4	133.32		0.1863614	
Chromis vanderbilti	5	2	3.5	116.655		0.0090908	
Plectroglyphidodon johnstonianus	14	13	13.5	449.955		0.8772622	
Stegastes fasciolatus	0	1	0.5	16.665		0.0409086	
SCARIDAE							
Scarus psittacus	19	2	10.5	349.965		2.0727024	
Scarus rubroviolaceus	0	1	0.5	16.665		0.6545376	
Scarus sordidus	3	0	1.5	49.995		2.2454276	

Zone 3 Fish Census Results, p. 5.							
	Transect					Biomass	
FAMILY / Species	**5**	**6**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
SCORPAENIDAE							
Scorpaenopsis cacopsis	2	0	1	33.33		6.5590122	
SERRANIDAE							
Cephalopholis argus	0	3	1.5	49.995		3.6908648	
SYNODONTIDAE							
Synodus binotatus	1	1	1	33.33		0.1272712	
Synodus variegatus	1	0	0.5	16.665		0.3454504	
TETRAODONTIDAE							
Arothron hispidus	0	1	0.5	16.665		2.7772394	
Canthigaster jactator	0	1	0.5	16.665		0.0045454	
ZANCLIDAE							
Zanclus cornutus	5	0	2.5	83.325		1.8499778	
TOTAL	**701**	**449**	**575**	**19164.75**		**232.8062972**	
TOTAL SPECIES = 74			**TOTAL FAMILIES = 25**				

Zone 4 Fish Census Results.							
	Transect					Biomass	
FAMILY / Species	7	8	Mean	#/hectare	Rank	Kg/hectare	Rank
ACANTHURIDAE							
Acanthurus achilles	11	21	16	533.28		2.409062	
Acanthurus nigrofuscus	0	56	28	933.24	5	4.227222	
Acanthurus nigroris	69	1	35	1166.55	3	8.590806	
Acanthurus olivaceus	1	1	1	33.33		0.68181	
Acanthurus triostegus	2	3	2.5	83.325		0.45454	
Ctenochaetus strigosus	77	79	78	2599.74	1	15.272544	4
Naso lituratus	14	1	7.5	249.975		22.227006	1
Zebrasoma flavescens	26	24	25	833.25		7.27264	
APOGONIDAE							
Apogon kallopterus	0	1	0.5	16.665		0.045454	
AULOSTOMIDAE							
Aulostomus chinensis	1	0	0.5	16.665		0.181816	
BALISTIDAE							
Melichthys niger	17	4	10.5	349.965		9.863518	5
Melichthys vidua	13	2	7.5	249.975		8.590806	
Sufflamen bursa	7	2	4.5	149.985		2.545424	
BLENNIIDAE							
Cirripectes vanderbilti	1	2	1.5	49.995		0.090908	
Exallias brevis	1	1	1	33.33		0.136362	
CHAETODONTIDAE							
Chaetodon auriga	4	1	2.5	83.325		2.636332	

Zone 4 Fish Census Results, p. 2.							
	Transect					Biomass	
FAMILY / Species	**7**	**8**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Chaetodon lineolatus	0	2	1	33.33		4.09086	
Chaetodon lunula	4	1	2.5	83.325		1.863614	
Chaetodon multicinctus	9	9	9	299.97		1.090896	
Chaetodon ornatissimus	3	5	4	133.32		2.681786	
Chaetodon trifasciatus	2	2	2	66.66		1.772706	
Chaetodon unimaculatus	0	2	1	33.33		0.22727	
Forcipiger flavissimus	2	4	3	99.99		0.409086	
CIRRHITIDAE							
Cirrhitops fasciatus	3	0	1.5	49.995		0.136362	
Paracirrhites arcatus	27	10	18.5	616.605		1.954522	
Paracirrhites forsteri	4	1	2.5	83.325		0.727264	
FISTULARIIDAE							
Fistularia commersonii	2	2	2	66.66		0.45454	
HOLOCENTRIDAE							
Myripristis amaena	6	0	3	99.99		1.272712	
Myripristis kuntee	14	1	7.5	249.975		2.545424	
Sargocentron punctatissimum	1	0	0.5	16.665		0.045454	
Sargocentron spiniferum	1	0	0.5	16.665		2.318154	
LABRIDAE							
Cheilinus unifasciatus	1	5	3	99.99		2.545424	
Gomphosus varius	9	13	11	366.63		0.90908	
Halichoeres ornatissimus	2	1	1.5	49.995		0.136362	
Labroides phthirophagus	8	1	4.5	149.985		0.136362	
Pseudocheilinus tetrataenia	0	1	0.5	16.665		0.045454	

Zone 4 Fish Census Results, p. 3.							
	Transect					Biomass	
FAMILY / Species	**7**	**8**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Stethojulis balteata	9	3	6	199.98		0.590902	
Thalassoma ballieui	0	1	0.5	16.665		0.272724	
Thalassoma duperrey	93	34	63.5	2116.455	2	18.045238	2
LETHRINIDAE							
Monotaxis grandoculis	4	2	3	99.99		5.818112	
MONACANTHIDAE							
Pervagor aspricaudus	1	0	0.5	16.665		0.090908	
MULLIDAE							
Mulloides flavolineatus	3	51	27	899.91		16.090716	3
Parupeneus bifasciatus	1	0	0.5	16.665		0.090908	
Parupeneus cyclostomus	2	0	1	33.33		0.818172	
Parupeneus multifasciatus	10	8	9	299.97		3.40905	
OSTRACIIDAE							
Ostracion meleagris	1	2	1.5	49.995		0.45454	
POMACENTRIDAE							
Abudefduf abdominalis	6	0	3	99.99		0.45454	
Chromis vanderbilti	13	0	6.5	216.645		0.090908	
Plectroglyphidodon johnstonianus	28	19	23.5	783.255		0.999988	
Stegastes fasciolatus	38	28	33	1099.89	4	5.772658	
SCARIDAE							
Scarus psittacus	21	3	12	399.96		9.681702	

Zone 4 Fish Census Results, p. 4.							
	Transect					Biomass	
FAMILY / Species	**7**	**8**	**Mean**	**#/hectare**	**Rank**	**Kg/hectare**	**Rank**
Scarus sordidus	3	2	2.5	83.325		4.681762	
SERRANIDAE							
Cephalopholis argus	3	3	3	99.99		2.227246	
TETRAODONTIDAE							
Canthigaster amboinensis	0	1	0.5	16.665		0.090908	
TOTAL	**578**	**416**	**497**	**16565.01**		**180.270564**	
TOTAL SPECIES = 54			**TOTAL FAMILIES = 18**				

Table 6. Substrate survey results.				
	Site			
Type	1	2	3	4
Montipora capitata	0.18		1.86	9.0
Montipora flabellata				0.23
Montipora patula	0.36		0.73	1.23
Pavona duerdeni	0.68			0.14
Pavona varians			4.45	3.05
Cyphastrea ocellina	0.3	0.07	0.32	0.36
Leptastrea purpurea				0.09
Pocillopora meandrina	1.84	0.45	0.86	2.02
Porites compressa			32.95	7.59
Porites lobata	10.75	0.41	33.41	46.73
Zoanthus pacificus				0.14
Total live corals	**14.11**	**0.93**	**74.58**	**68.58**
Calcareous algae	0.95	1.22	1	0.45
Basalt slab	70.61	4.64		
Coral rubble	13.41	8.64	3.95	2.73
Sand	0.91	84.57	20.45	28.25