MAMALA BAY STUDY

SHALLOW MARINE COMMUNITY RESPONSE TO POINT AND NON-POINT SOURCES OF POLLUTION IN MAMALA BAY, OAHU PART B: MICROMOLLUSCAN ASSEMBLAGES AND ALGAL BIOMASS

PROJECT MB-9

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15 June 1995

1 EXECUTIVE SUMMARY

The purpose of this study is to attempt to identify possible impacts of point (here primary treated sewage from two facilities) and non-point sources of water quality perturbations on shallow water marine communities in Mamala Bay, Oahu. Micromollusks and benthic algae provide the information on benthic community status. Micromollusk assemblages comprised of more than about 10% of the eulimid Balcis which is parasitic on echinoderms signal the presence of particulates in the water column; those with 10-15% pyramidellids and suspension feeders respectively indicate the presence of eutrophic conditions. Biomass and species composition of benthic algae also indicate benthic community status.

Permanently marked stations were established at each of three depths (approximately 7, 17 and 27 m) on transect lines at three sites, offshore of Waikiki, at Sand Island, and at Barbers Point. At each site sediments from which micromollusks were to be sorted and fleshy algae were retrieved at the three depths in winter 1994 (February-April), summer 1994 (August) and winter 1995 (February-March). The mollusks were sorted from four replicate sediment samples, counted, identified to the lowest taxonomic category possible, and analyzed for abundance, number of species, species composition, and trophic and habitat characteristics. Samples for determination of algal biomass and species composition were gathered adjacent to each transect site using scuba and a 45 cm diameter ring from which all macrothalloid algae were removed.

The results suggest that:

1. Micromollusk abundance is variable but species composition is consistent and the data are comparable with sample data obtained between 1967 and 1984 from the same or adjacent sites at similar depths. With one exception, none of the micromollusk assemblages recorded along the shoreline to a depth of 27 m appear to signal the occurrence of large numbers of particulate feeders such as sea cucumbers nor do the micromollusk assemblages reflect the occurrence of eutrophic situations.

2. Algal biomass varies with season, with greater biomass in winter than in summer. At the Waikiki site, biomass measurements which exceeded 300 g/m^2 (wet weight) only at one site do not approach the more than 2,000 g/m^2 reported in 1967 by Doty (1971) and at 3 - 34 g/m^2 dry weight are far diminished from the >200 g/m^2 cited by Chave, et. al. in (1973). Sargassum, although still a dominant on occasion at Waikiki, no longer occurs in the abundance formerly reported.

3. There is no direct evidence in either data set or that of the algae to indicate that point and/or non-point discharges of pollutants impact the benthic communities shoreward of the outfalls or in the vicinity of Waikiki at depths of between 7 and 27 m. The relatively large proportion of pyramidellids at the 7 m Barbers Point site and the substantial decline in benthic algal biomass at Waikiki since 1967, however, are of interest and should be further assessed.

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2 INTRODUCTION

2.1 History in Mamala Bay

Mamala Bay has been subject to human impact since the first western ships anchored offshore of Honolulu in the 1800's. The shoreline has been altered; channels dredged to debouch unwanted freshwater; breakwaters, and piers and other shoreline structures installed. Ships from large ocean liners to tugs and canoes ply its surface waters while submarines provide undersea adventure for thousands of tourists. The bottom of the bay has been dredged for harbors, and dredge spoils deposited in its offshore depths. The eastern section of the shoreline and its shallow waters comprises Waikiki Beach, the primary tourist destination in the State, providing for sunbathing, swimming, surfing, canoe surfing, snorkeling, and scuba diving. The Bay is the site of recreational and commercial fishing. The Bay is also the depository for waste waters, introduced by seepage in prewestern days, from cesspools in the 1920's and 1930's, and from sewage treatment plants since the 1940's.

MB-9 is a multifaceted project to determine the impact of present day use of the Bay. In this section of the project we emphasize those areas of the Bay most utilized by recreational swimmers, snorkelers, divers, and sun bathers: the shallow waters to depths of about 27 m and we provide data on the major components of the benthos which is what people see and feel: mollusks and algae.

2.2 Scope of Work

In this study, two components of the benthic communities, micromollusks and algae, obtained from the substrate at three stations along the shoreline of Mamala Bay at depths of 7, 17, and 27 m between February 1994 and April 1995 are described. Three permanently marked transect sites were situated to identify a control site and two sites adjacent to possible impact from point and non-point source pollutants (Figure 2.1): Waikiki Beach offshore of the War Memorial Natatorium is the control site, Sand Island shoreward of the City and County of Honolulu wastewater outfall and Barbers Point

shoreward of the City and County the Honouliuli wastewater outfall are the possible impact sites. The three sites were sampled in winter 1994 (February - April), summer 1994 (August), and winter 1995 (February - March). Replicate samples each of micromollusks and algae were sampled using standard methods (see Doty, 1971; Kay, 1975). Micromollusks were sorted, identified to species and counts summarized in terms of occurrence, seasonality, depth, habitat and trophic habits. Algae were retrieved from a randomly thrown "Doty ring", major components identified to genus, and wet and dry weights determined and converted to biomass per m^2. The data for both micromollusks and algae are compared with data obtained from earlier studies in Mamala Bay between 1967 and the 1980's.

2.3 Objectives

The objectives of this study are to census the components of the benthic communities in the shallow waters of Mamala Bay to identify possible impacts on these communities by point and non-point sources of pollution. In Mamala Bay, these sources include the two municipal wastewater outfalls (Sand Island and Honouliuli) which produce outflow high in particulate matter; and dredge and fill operations and other shoreline construction at both Sand Island and Honouliuli (Barbers Point). Non-point sources include stream flow, subtidal discharges of groundwater, and harbor input which may result in eutrophication or toxic impact on benthic communities but which are not necessarily high in particulate matter.

2.4 Project Organization

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Deborah Gochfeld, candidate for the Ph.D., Department of Zoology, University of Hawaii at Manoa. Research assistant: Jan. 1994-June 1995, field work, algal preparation, sorting micromollusks

David Gulko, candidate for the Ph.D., Department of Zoology, March 1994-August 1994: established transects, algal collection.

Reuben Wolff, candidate for the M.Sc., Department of Zoology, July 1994-May 1995, Graduate Research Assistant: established transects, algal collection, obtained sediment samples for micromollusks, sorted micromollusks, analyzed algae

2.5 Association with other Mamala Bay teams

All teams worked together in determining transect placement and, indeed, in several instances, used the same transect lines. Results and findings of the teams have been shared throughout the period of the contract.

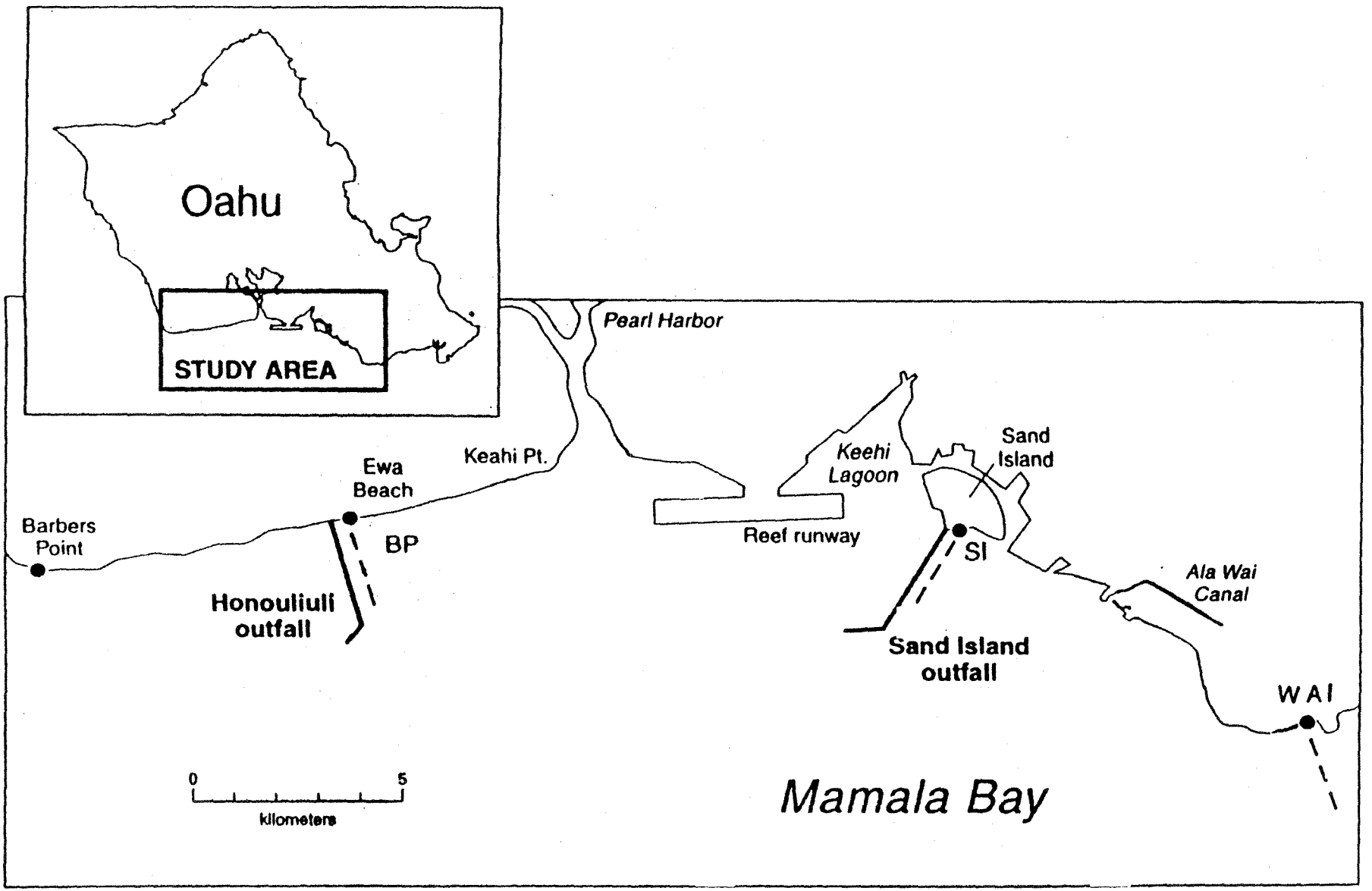

Figure 2.1 Micromollusk and Algal sampling areas, Mamala Bay, Oahu 1994 - 1995

3 METHODS

3.1 Task Summary

Micromollusks and algae were sampled at three sites on the coastline of Mamala Bay. The sites were selected to provide a control site and two sites possibly affected by point and non-point source impact on water quality in the bay. The assumptions are that micromollusks and algae would reflect impact of particulate matter and/or conditions of eutrophication. Micromollusk signals of the presence of high amounts of particulate matter include the presence of large numbers (>10% of the assemblage) Balcis, a member of the family Eulimidae which is parasitic on echinoderms. Signals indicating conditions of eutrophication include the occurrence of relatively large numbers (>20% of the assemblage) of pyramidellids and suspension feeders. Algal biomass is affected by increases in particulate matter (silt) and changes in nutrient input.

Tasks include:

1) establishment of permanent transects at three stations along the shoreline of Mamala Bay at depths of approximately 7, 17 and 27 m.

2) collection of algae and sediments with scuba gear on the transect lines in winter 1994, summer 1994, and winter 1995

3) sorting micromollusks from sediments for counts and identifications

4) preparation of algae for biomass determinations

5) summarizing the data

3.2 Task Methodology

3.2.1 Micromollusks.

Four replicates of sediments for micromollusk sampling were hand grabbed on the three transect sites with a plastic cup acting as a corer by scuba divers, temporarily stored in plastic bags, and transported to the laboratory where they were refrigerated. Processing followed EPA procedures which have been utilized in our laboratory since 1975 (Kay 1975, 1978, 1979, 1982), Kay and Kawamoto (1980, 1983), Nelson (1986) and Russo et al (1988): samples were washed in fresh water (to minimize loss of fine sediments), fixed in 75% isopropyl alcohol for 24 hours and then air dried. A subsample in a 25-cm^3 aliquot was removed from each mollusk sample for sorting and identification. Identification follows Kay (1979), to the lowest taxonomic level possible.

3.2.2 Algal Biomass

Four replicate samples of algae were obtained from the substrate on each of the three permanently marked transect lines by a scuba diver pulling the algae from the substrates within the diameter of a 45 cm ring. Algae were bagged in labeled plastic bags, washed on return to the laboratory, major components identified to genus, and algal weight determined in grams per m^2. Algae were subsequently oven dried and dry algal weight determined. Wet and dry algal weights were converted to biomass per m^2. Procedure for collection and biomass determination, follow Doty (1969) and Smith and Chave (1973).

4 RESULTS

4.1 Transect Sites

The Waikiki transect site lies just off the War Memorial Natatorium and runs from a depth of about 7 m to one of about 27 m over a relatively smooth limestone flat studded with algal turf and, at times, clumps of standing Sargassum. and sand-filled depressions. Sediments are white sand clouded with silt. Relatively strong tidal currents prevail and, during the summer months there is a strong southerly swell. This site has been extensively studied since the 1920's when Pollock (1928) described coral composition of the reef off Waikiki; the more recent reports of Doty (1969) and Chave and Stimson (1973) provide comparable data for comparison with the present data over time. Assemblages of micromollusks collected during the course of the Doty and Chave and Stimson studies are also used in this report for comparisons.

The transect site at Sand Island is also over a limestone flat which drops to sand at about 25 m. It is about 80 m east of the present Sand Island Wastewater discharge pipe and approximates the site of the old Sand Island Outfall (discontinued in 1977) which debouched on the reef at a depth of about 12 m. Tidal driven currents are often apparent. Data from an unpublished report by Kay (1979) provide comparative numbers for this report.

At the Barbers Point site, situated about 25 m east of the Honouliuli wastewater discharge pipe, the limestone flat is relatively smooth but studded with sand pockets. Unpublished data obtained by Kay in 1984 are compared with the present data.

4.2 Micromollusks

A total of 16,701 specimens of micromollusks mollusk specimens were counted from time-averaged assemblages. About 105 species are represented in the 27 samples censused. Summary data for abundance, species numbers, gastropod/bivalve numbers and trophic habits are listed in tables 4.1-4.9. Total abundance (6,863 shells) and mean species numbers (73) are highest at the Sand Island site, lowest (3,489 shells, 55 species)

at the Barbers Point site. Abundance ranges from a low of 0.33 shells per cm3 at the 27 m Waikiki station in February 1995 to 17.5 shells per cm3 at the 7 m Waikiki station in August 1994 (Figure 4.2.1). Number of species ranges from a low of 22 at the 27 m Waikiki site in February 1995 to 103 at Sand Island in February 1995 (Figure 4.1). Both abundance and species numbers appear to increase gradually with depth (Figure 4.1).

Although these sediment-retrieved assemblages represent time-averaged samples, the shells for the most part are fresh and with good color, indicating recent deposition. Variability in both abundance and species numbers in the micromollusk assemblages is very noticeable (Figure 4.1): at the Waikiki site, for example, the 1994 winter sample at 27 m shows high abundance but the 1995 winter sample at 27 m has virtually no shells in it (Figure 4.1), and those that are present are wave-worn. Also at the Waikiki site, the 7 and 17 m winter 1994 samples, the 17 m winter 1995 sample, and the 27 m summer 1994 sample consist of hundreds of shattered shells. At Barbers Point, only wave-worn shells were present in the 27 m winter 1995 sample and the 7m winter 1995 sample.

Despite the variability in numbers, there are several consistent features of the assemblages:

1) Epifaunal gastropods dominate the assemblages: 94% of the shells are gastropods (Tables 4.1 - 4.9).

2) Eleven species, all gastropod algal feeders or detritivores except for the bivalve Hemicardium mundum and the infaunal gastropod Caecum, dominate the assemblages at the three sites (Table 4.2 - 4.9), with four to six species (Tricolia variabilis, Cerithidium perparvulum, Vitricithna marmorata, Parasheila beetsi, Lophocochlias minutissimus, and Orbitestella regina) comprising approximately 50% of the nine assemblages at each site.

3) The eulimid Balcis, suspension feeders (primarily bivalves), and pyramidellids (parasitic on sponges and other sessile invertebrates), which are indicators of particulate matter and nutrients in the water column, comprise minor components of the assemblages: Balcis averages just over 1% of the assemblages, suspension feeders, 4-9%,

and pyramidellids 2-6% except at the 7 m Barbers Point station where they were consistently high in all three sampling seasons (i.e., 13% in winter 1994, 14% in summer 1994, and 20% in winter 1995).

4) Distribution of the major species components relative to depth falls into three patterns (Figure 4.2): species which are more abundant in shallow water at 7 m (Tricolia variabilis), species which are most numerous at the 17 m depth (Hemicardium fragum), and species with greatest abundance at 27 meters (Cerithidium perparvulum).

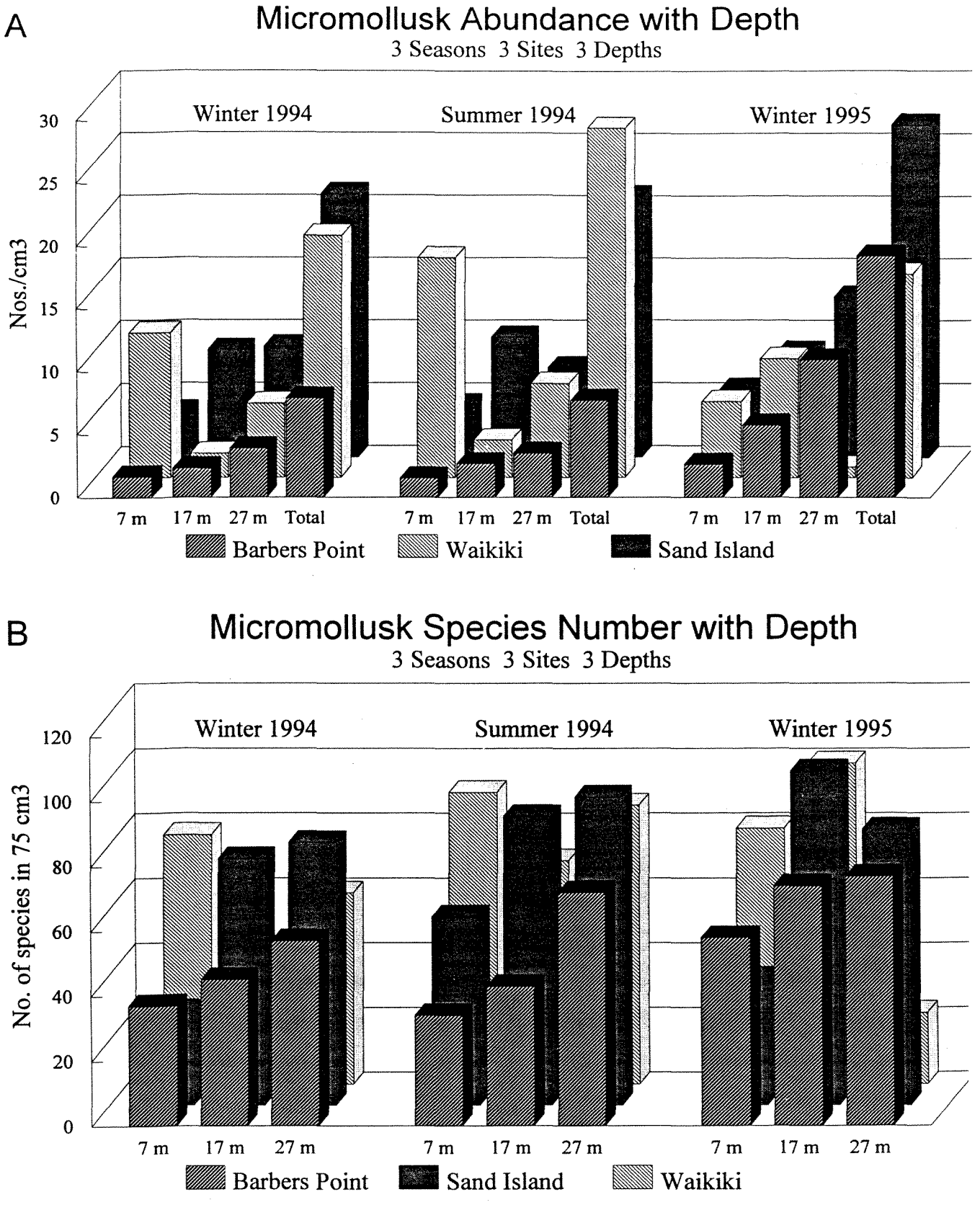

Figure 4.1 (A) Mean abundance of micromollusks with depth

(B) Species number of micromollusks per 75 cm^3 with depth

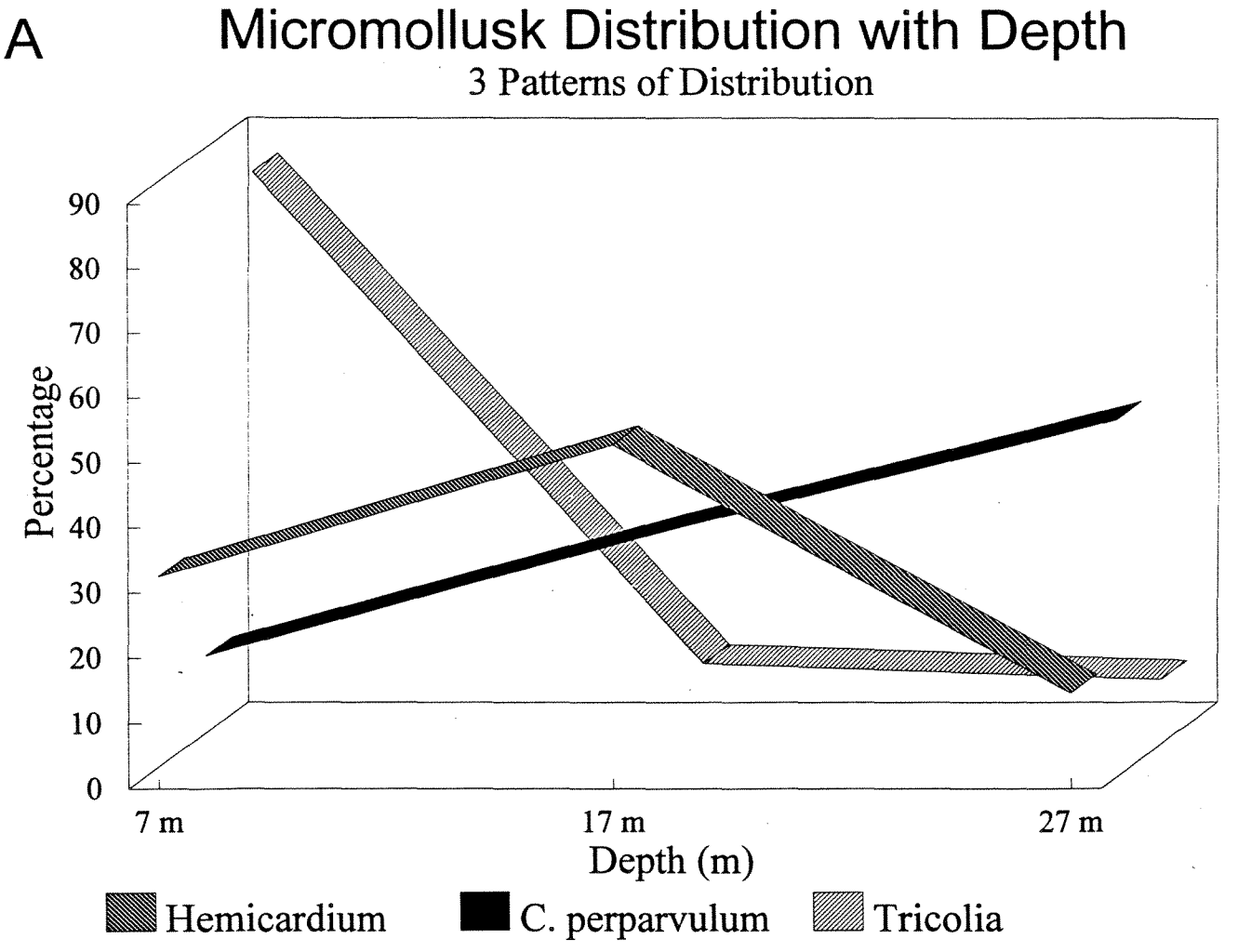

Figure 4.2. Patterns of mollusk distribution with depth

TABLE 4.1. Micromollusk summary data for the Waikiki 7 m site (4 replicates) and two 1971 samples from the same site.

	7 m W 1994	7 m S 1994	7 m W 1995	7.5 m Nov 1971**	7.5 m Nov. 1971***
Total Nos.	1151	1754	601	903	356
x Nos./cm 3	11.5	17.5	6.01	18.0	14.2
No. Species	77	90	79	59	34
Range Species Nos.	34-44	37-64	37-50	—	—
Percent Composition					
Gastropods	0.97	0.95	0.93	0.88	100
Bivalves	0.03	0.05	0.07	0.11	0
Infauna	0.06	0.04	0.11	0.16	0.001
Suspension Feeders	0.04	0.06	0.07	0.12	0.02
Dominant Species:					
Balcis	0.001	0.001	0.01	0	0
Caecum spp.	0.04	0.03	0.1	0.06	0.001
Cerithidium perparvulum	0.04	0.06	0.01	0.06	0.02
Diala varia	0.001	0.001	0.05	0.07	0
Hemicardium fragum *	0.01	0.02	0.001	0.05	0
Lophocochlias minutissimus	0.07	0.07	0.07	0.05	0
Orbitestella regina	0.11	0.06	0.01	0.05	0.11
Parashiela beetsi	0.04	0.05	0.01	0.03	0.02
Pyramidellids	0.02	0.02	0.03	0.01	0.001
Tricolia variabilis	0.38	0.39	0.06	0.22	0.36
Vitricithna marmorata	0.07	0.1	0.09	0.14	0.14

*bivalve
**Natatorium sample
Chave and Stimson 1973
*** Kapahulu Drain
Chave and Stimson 1973

Table 4.1 Micromollusks Waikiki 7 m Transect

TABLE 4.2. Micromollusk summary data for the Waikiki 17 m site (4 replicate a single sample collected in 1991.

	17 m W 1994	17 m S 1994	17 m W 1995	17 m Nov. 1971**
Total Nos.	190	296	942	185
x Nos./cm3	1.9	2.96	9.42	1.85
No. Species	40	69	99	34
Range Species Nos.	22-47	19-46	48-63	---
Percent Composition				
Gastropods	0.92	0.96	0.88	0.94
Bivalves	0.08	0.04	0.11	0.06
Infauna	0.14	0.09	0.16	0.09
Suspension Feeders	0.08	0.04	0.12	0.09
Balcis	0.001	0.02	0.001	0.01
Caecum spp.	0.03	0.07	0.03	0.02
Cerithidium perparvulum	0.26	0.15	0.17	0.001
Diala varia	0.05	0.07	0.02	0.04
Hemicardium fragum*	0.04	0.02	0.07	0.03
Lophocochlias minutissimus	0.09	0.08	0.14	0.02
Orbitestella regina	0	0.001	0.01	0.02
Parashiela beetsi	0.06	0.02	0.07	0.001
Pyramidellids	0.04	0.03	0.02	0.02
Tricolia variablis	0.04	0.04	0.06	0.05
Vitricithna marmorata	0.04	0.04	0.06	0.54

* bivalve
** Natatorium sample
Chave and Stimson 1973

Table 4.2 Micromollusks Waikiki 15 m Transect

TABLE 4.3. Micromollusk summary data for the Waikiki 27 m site (4 replicates).

	27 m W 1994	27 m S 1994	27 m W 1995
Total Nos.	587	745	83
x Nos./cm3	5.87	7.45	0.83
No. Species	59	86	22
Range Species Nos.	24-37	30-58	8-15
Percent Composition			
Gastropods	0.95	0.96	100
Bivalves	0.05	0.04	0
Infauna	0.1	0.11	0.001
Suspension Feeders	0.06	0.06	0.001
Dominant Species:			
Balcis	0.01	0.001	0
Caecum spp.	0.31	0.06	0
Cerithidium perparvulum	0.29	0.19	0.01
Diala varia	0.08	0.07	0
Hemicardium fragum*	0.01	0.01	0
Lophocochlias minutissimus	0.1	0.09	0
Orbitestella regina	0.02	0.001	0
Parashiela beetsi	0.01	0.01	0.001
Pyramidellids	0.02	0.17	0.001
Tricolia variablis	0.02	0.02	0.01
Vitricithna marmorata	0.05	0.07	0.001

* bivalve

Table 4.3 Micromollusks Waikiki 27 m Transect

TABLE 4.4. Micromollusk summary data for the Sand Island 7 m site (4 replicates) and a 2 replicate 1977 sample from the same site.

	7 m W 1994	7m S1994	7 m W 1995	10 m 1977**	10 m 1979***
Total Nos.	364	418	539	146	536
x Nos./cm 3	3.64	4.18	5.39	4.17	17.87
No. Species	29	58	39	28	50
Range Species Nos.	10-20	19-42	16-20	17-18	23-35
Percent Composition					
Gastropods	0.99	0.84	0.94	100	0.98
Bivalves	0.01	0.16	0.06	0	0.02
Infauna	0.02	0.1	0.06	0.02	0.05
Suspension Feeders	0.01	0.16	0.03	0.01	0.03
Dominant Species					
Barbis	0.001	0.01	0.01	0.02	0.005
Caecum spp.	0.001	0.04	0.01	0	0.04
Cerithidium perparvulum	0.01	0.04	0.05	0	0.12
Diala varia	0	0.01	0.001	0.03	0.04
Hemicardium fragum *					
Lophocochlias minutissimus	0	0.06	0.07	0.02	0.10
Orbitestella regina	0.26	0.19	0.21	0.001	0.04
Parashiela beetsi	0.03	0.04	0.03	0.02	0.08
Pyramidellids	0.01	0.03	0.02	0	0.01
Tricolia variabilis	0.39	0.07	0.31	0.08	0.28
Vitricithna marmorata	0.1	0.11	0.05	0.25	0.11

*bivalve
**Kay 1977
***Kay 1979

Table 4.4 Micromollusks Sand Island 7 m Transect

TABLE 4.5. Micromollusk summary data for the Sand Island 17 m site (4 replicates) and a 3 replicate 1975 sample from the same site.

	17 m W 1994	17 m S 1994	17 m W 1995	17.5 m 1975
Total Nos.	854	995	838	855
x Nos./cm 3	8.54	9.95	8.38	14.25
No. Species	76	89	103	83
Range Species Nos.	19-47	37-62	50-67	23-63
Percent Composition				
Gastropods	0.96	0.97	0.91	0.96
Bivalves	0.04	0.03	0.09	0.04
Infauna	0.08	0.08	0.2	0.06
Suspension Feeders	0.05	0.03	0.09	0.05
Dominant Species				
Balcis	0.01	0.03	0.01	0.01
Caecum spp.	0.03	0.03	0.07	0.01
Cerithidium perparvulum	0.12	0.14	0.03	0.11
Diala varia	0.01	0.06	0.03	0.04
Hemicardium fragum *	0.001	0.001	0.001	0.005
Lophocochlias minutissimus	0.15	0.08	0.05	0.04
Orbitestella regina	0.09	0.01	0.05	0.03
Parashiela beetsi	0.1	0.09	0.04	0.05
Pyramidellids	0.02	0.05	0.04	0.03
Tricolia variabilis	0.02	0.03	0.04	0.10
Virricithna margarata	0.14	0.2	0.15	0.24

* bivalve

Table 4.5 Micromollusks Sand Island 17m Transect

TABLE 4.6. Micromollusk summary data for the Sand Island 27 m site (4 replicates)

	27 m W 1994	27 m S 1994	27 m W 1995
Total Nos.	881	712	1280
x Nos./cm 3	8.81	7.12	12.8
No. Species	81	95	85
Range Species Nos.	32-52	33-53	39-59
Percent Composition			
Gastropods	0.95	0.93	0.95
Bivalves	0.05	0.07	0.05
Infauna	0.08	0.08	0.08
Suspension Feeders	0.06	0.08	0.05
Dominant Species			
Balcis	0.01	0.01	0.01
Caecum spp.	0.03	0.03	0.02
Cerithidium perparvulum	0.17	0.21	0.21
Diala varia	0.05	0.05	0.06
Hemicardium fragum *	0.001	0.001	0.001
Lophocochlias minutissimus	0.11	0.07	0.07
Orbitestella regina	0.03	0.01	0.001
Parashiela beetsi	0.09	0.07	0.05
Pyramidellids	0.01	0.02	0.02
Tricolia variabilis	0.03	0.02	0.04
Vitricithna marmorata	0.15	0.13	0.17

* bivalve

Table 4.6 Micromollusks: Sand Island 27m Transect

TABLE 4.7. Micromollusk summary data for the Barbers Point 7 m site (4 replicates)

	7 m W 1994	7 m S 1994	7 m W 1994
Total Nos.	166	154	262
x Nos./cm3	1.66	1.54	2.62
No. Species	37	34	58
Range Species Nos.	14-22	14-21	22-33
Percent Composition			
Gastropods	0.93	0.99	0.83
Bivalves	0.07	0.01	0.17
Infauna	0.14	0.08	0.23
Suspension Feeders	0.07	0.01	0.20
Dominant Species			
Balcis spp.	0.04	---	0.05
Caecum spp.	0.12	0.05	0.07
Cerithidium perparvulum	0.08	0.05	0.27
Diala varia	0.01	0.05	0.15
Hemicardium fragum*	0.01	0.02	0.03
Lophocochlias minutissimus	0.01	---	0.11
Orbitestella regina	---	---	0.02
Parashiela beetsi	---	0.02	0.02
Pyramidellids	0.13	0.14	0.20
Tricolia variablis	0.31	0.48	0.39
Vitricithna marmorata	0.12	0.05	0.29

* bivalve

Table 4.7 Micromollusks Barbers Point 7m Transect

TABLE 4.8. Micromollusk summary data for the Barbers Point 17 m site (4 replicates) and a 2 recplicate 1984 sample.

	17m W 1994	17m S 1994	17m W 1995	17 m May 1984
Total Nos.	232	267	574	232
x Nos./cm3	2.32	2.67	5.74	4.6
No. Species	45	43	74	33
Range Species Nos.	17-30	13-24	23-49	24-26
Nos./cm3	2.32	2.67	5.74	4.6
Percent Composition				
Gastropods	0.98	0.97	0.94	0.91
Bivalves	0.02	0.03	0.06	0.09
Infauna	0.13	0.08	0.13	0.13
Suspension Feeders	0.1	0.04	0.06	0.09
Dominant Species:				
Balcis	0.02	0	0.01	0
Caecum spp.	0.05	0.04	0.04	0.05
Cerithidium perparvulum	0.15	0.15	0.19	0.21
Diala varia	0.13	0.17	0.09	0.03
Hemicardium fragum*	0.001	0.001	0.001	0.02
Lophocochlias minutissimus	0.03	0.07	0.08	0.17
Orbitestella regina	0	0	0.01	0
Parashiela beetsi	0.04	0.05	0.08	0.14
Pyramidellids	0.001	0.02	0.02	0.04
Tricolia variablis	0.04	0.05	0.04	0.001
Vitricithna marmorata	0.19	0.15	0.16	0.09

* bivalve

Table 4.8 Micromollusks Barbers Point 17m Transect

TABLE 4.9. Micromollusk summary data for the Barbers Point 27 m site (4 replicates).

	27 m W 1994	27 m S 1994	27 m W 1995
Total Nos.	389	350	1095
x Nos./cm 3	3.89	3.5	10.95
No. Species	57	72	77
Range Species Nos.	25-34	22-50	33-50
Percent Composition			
Gastropods	0.91	0.93	0.95
Bivalves	0.09	0.07	0.05
Infauna	0.14	0.13	0.06
Suspension Feeders	0.09	0.09	0.06
Dominant Species			
Balcis spp.	0.001	0.001	0.001
Caecum spp.	0.07	0.05	0.02
Cerithidium perparvulum	0.25	0.19	0.16
Diala varia	0.13	0.07	0.07
Hemicardium fragum *	0.001	0.02	0.001
Lophocochlias minutissimus	0.05	0.05	0.04
Orbitestella regina	0.001	0.01	0.001
Parashiela beetsi	0.06	0.05	0.09
Pyramidellids	0.03	0.06	0.06
Tricolia variabilis	0.001	0.02	0.001
Vitricithna marmorata	0.14	0.12	0.07

*bivalve

Table 4.9 Micromollusks Barbers Point 27m Transect

4) Each of the three sites is characterized by peculiarities in abundance and species composition. At the Waikiki site where abundance and number of species falls between those of Sand Island and Barbers Point, the algal dweller Tricolia variabilis comprises an average of 20% of the assemblages, and the bivalve Hemicardium fragum comprises 1-2% of the assemblages. At the Sand Island and Barbers Point sites, with highest and lowest numbers of shells and species respectively, Cerithidium perparvulum and Vitricithna marmorata comprise 27-28% of the assemblages, Tricolia 8-9%, and Hemicardium is barely present.

Assemblages of micromollusks collected from Mamala Bay during earlier studies at the same or nearby transect sites between 1971 and 1975 provide numbers and species lists to which the 1994-1995 data can be compared. The earlier samples at Waikiki fronting the War Memorial Natatorium (Tables 4.1, 4.2), Sand Island on the old outfall site (Tables 4.4, 4.5), and Barbers Point adjacent to the outfall site (Tables 4.8) are all dominated by epifaunal gastropods, with the 11 dominant species and species groups represented in approximately similar proportions, with very few infaunal and/or suspension feeders or Balcis spp. present, and with Tricolia dominating at the Waikiki site and Cerithidium perparvulum and Vitricithna marmorata dominating at Sand Island and Barbers Point. The 1971 17 m sample at Waikiki (Table 4.1) is an especially good fit for the bivalve Hemicardium, which is present in noticeably greater abundance at Waikiki than elsewhere.

There are anomalies in the patterns, for example the 1971 Waikiki 17 m site with nearly 50% of the assemblage consisting of Vitricithna, but given the fact there is only one sample from that site, it probably is no different from anomalies that result in variability in abundance in the current data set, for example the 6% Tricolia figure in one of the Waikiki 7 m samplings (Table 4.1).

4.3 Benthic Algae

Mean algal biomass is higher at Waikiki than at Sand Island and Barbers Point in both winter samples, and approximates the weights for the summer samples at the other

stations. In winter 1995, algal biomass at the Waikiki 7 m station is noticeably low. Biomass is equally distributed at all four depths, except in winter 1995 when it is noticeably high at the Waikiki 17 m station and the Barbers Point 7 m station, and low at the Waikiki 7 m station.

Different species of algae dominate the algal assemblage both seasonally and by station and the number of dominant genera also differ at each site. Sargassum is dominant only at the Waikiki 7 and 17 meter stations in winter and summer 1994 and Pterocladia and Liagora dominates the samples only in winter 1994 at Sand Island. Lyngbya and Pterocladia are dominants at all three sites, Dictyospheria is dominant at Waikiki and Liagora at Sand Island. Barbers Point with a mean of 6 dominant genera over the sampling period is highest on the diversity list, Sand Island with a mean of 3.3 dominant genera is lowest on the list.

Doty (1969) reports mean algal biomass on a transect fronting the Waikiki War Memorial Natatorium as 2669.5 g/ m^2 in March 1967, 2882.10 g/ m^2 in August 1967, and 1248.5 g/ m^2 in January 1969, months of the year approximating those at which our samples were collected. Chave and Stimson (1973) sampling in the same area, reported dry algal weights as 223.2 g/ m^2 in the same area and noted a substantial decrease in biomass compared with the Doty figures. Algal biomass determinations in this study are an order of magnitude less than those of Doty (1969) and less than those of Chave and Stimson (1973).

Early reports on algal species on the Waikiki reef fronting the Natatorium all note the abundance of Sargassum (Pollock, 1929; Neal, 1930; Doty 1967, 1969, 1971) and Chave and Stimson (1973) comment on the major decline in algal biomass which they encountered in 1971-1972. Marine biologists who have worked in the area for more than 40 years have suggested that Sargassum in recent years "is not what it used to be" when a swim over the reef in the 1960's was a swim over a forest of Sargassum (personal observation). Neal (1930) and Chave and Stimson (1973) also note Dictyosphaeria and

Halimeda as dominant and abundant. Both are recorded as dominant at Waikiki in this study.

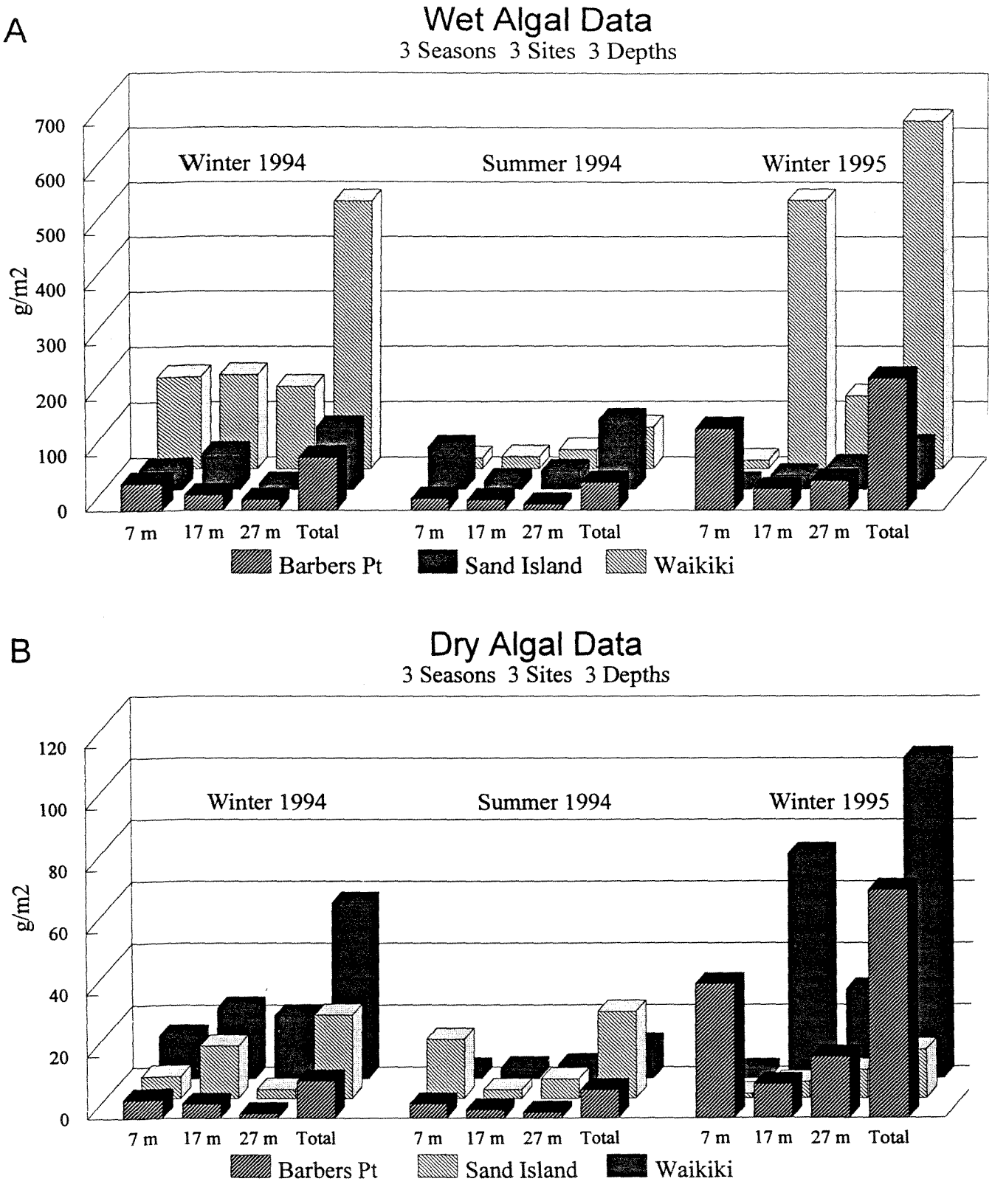

Figure 4.3 (A) Mean wet algal weight with season and depth, (B) mean dry algal weight

Table 4.10. Algal biomass at Waikiki, Winter 1994

Algae Data: Waikiki Control Site 3/3/94

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Waikiki	3.3.94	7 m	13	1	0.987	20.498	**19.511**	**122.685**	0.987	1.740	**0.753**	**4.735**	*Sargassum*
Waikiki	3.3.94	7 m	14	2	0.984	26.432	**25.448**	**160.017**	0.984	4.221	**3.237**	**20.354**	*Sargassum*
Waikiki	3.3.94	7 m	15	3	0.994	60.454	**59.460**	**373.884**	0.994	5.517	**4.523**	**28.441**	*Sargassum*
Waikiki	3.3.94	7 m	16	4	0.996	2.540	**1.544**	**9.709**	0.996	1.240	**0.244**	**1.534**	*Liagora (?)*
Waikiki	3.3.94	17 m	17	1	0.994	77.627	**76.633**	**481.868**	0.994	13.981	**12.987**	**81.662**	*Sargassum*
Waikiki	3.3.94	17 m	18	2	0.981	21.051	**20.070**	**126.200**	0.981	1.627	**0.646**	**4.062**	*Sargassum*
Waikiki	3.3.94	17 m	19	3	0.973	4.589	**3.616**	**22.737**	0.973	1.574	**0.601**	**3.779**	*Lyngbya, Sargassum*
Waikiki	3.3.94	17 m	20	4	0.979	8.967	**7.988**	**50.229**	0.979	1.144	**0.165**	**1.038**	*Sargassum*
Waikiki	3.3.94	27 m	21	1	0.980	6.273	**5.293**	**33.282**	0.980	1.099	**0.119**	**0.748**	*Pterocladia*
Waikiki	3.3.94	27 m	22	2	0.980	56.452	**55.472**	**348.808**	0.980	9.172	**8.192**	**51.511**	*Pterocladia, Lyngbya*
Waikiki	3.3.94	27 m	23	3	0.984	18.464	**17.480**	**109.914**	0.984	3.162	**2.178**	**13.695**	*Pterocladia (?)*
Waikiki	3.3.94	27 m	24	4	0.979	17.583	**16.604**	**104.406**	0.979	3.309	**2.330**	**14.651**	*Pterocladia, Dictyota*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	**Depth**	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
7 m	**26.491**	**166.574**	**7 m**	**2.189**	**13.766**
17 m	**27.077**	**170.259**	**17 m**	**3.600**	**22.635**
27 m	**23.712**	**149.103**	**27 m**	**3.205**	**20.151**
Total:	**25.760**	**161.978**	**Total:**	**2.998**	**18.851**

Table 4.11. Algal biomass at Waikiki, Summer 1994

Algae Data: Waikiki Control Site

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Waikiki	8.22.94	7 m	37	1	0.9947	1.9483	**0.9536**	**5.9962**	0.9953	1.1680	**0.1727**	**1.0859**	*Dictyota, unidentified*
Waikiki	8.22.94	7 m	38	2	0.9844	2.5648	**1.5804**	**9.9376**	0.9849	1.1914	**0.2065**	**1.2985**	*Laurencia, Microdictyon, Dictyota*
Waikiki	8.22.94	7 m	39	3	0.9840	4.7550	**3.7710**	**23.7120**	0.9858	1.4308	**0.4450**	**2.7982**	*Laurencia, Microdictyon, Dictyota*
Waikiki	8.22.94	7 m	40	4	0.9990	7.0788	**6.0798**	**38.2298**	1.0010	2.1072	**1.1062**	**6.9558**	*Laurencia, Dictyota*
Waikiki	8.22.94	17 m	41	1	0.9949	4.1902	**3.1953**	**20.0920**	0.9973	1.4597	**0.4624**	**2.9076**	*Pterocladia, Sargassum, Halimeda, Lyngbya, Laure*
Waikiki	8.22.94	17 m	42	2	0.9732	7.3284	**6.3552**	**39.9615**	0.9750	2.1074	**1.1324**	**7.1205**	*Sargassum, Lyngbya*
Waikiki	8.22.94	17 m	43	3	0.9860	2.1266	**1.1406**	**7.1721**	0.9869	1.1528	**0.1659**	**1.0432**	*Lyngbya, calcareous red algae*
Waikiki	8.22.94	17 m	44	4	0.9861	3.9929	**3.0068**	**18.9068**	0.9870	1.4121	**0.4251**	**2.6730**	*Sargassum, Lyngbya*
Waikiki	8.22.94	27 m	45	1	0.9829	3.5885	**2.6056**	**16.3840**	0.9842	1.4137	**0.4295**	**2.7007**	*Gracilaria, Dictyota*
Waikiki	8.22.94	27 m	46	2	0.9783	2.3870	**1.4087**	**8.8579**	0.9789	1.1508	**0.1719**	**1.0809**	*Gracilaria, Liagora*
Waikiki	8.22.94	27 m	47	3	0.9893	8.9869	**7.9976**	**50.2889**	0.9916	2.0824	**1.0908**	**6.8590**	*Gracilaria, Dictyota, Jania (?), Pterocladia*
Waikiki	8.22.94	27 m	48	4	0.9824	10.6587	**9.6763**	**60.8446**	0.9838	2.0472	**1.0634**	**6.6867**	*Gracilaria, Dictyota, Pterocladia*

Depth	mean Wet Wt (g)	mean Wet Wt g/m2	Depth	mean Dry Wt (g)	mean Dry Wt g/m2
7 m	**3.0962**	**19.4689**	**7 m**	**0.4826**	**3.0346**
17 m	**3.4245**	**21.5331**	**17 m**	**0.5465**	**3.4361**
27 m	**5.4221**	**34.0939**	**27 m**	**0.6889**	**4.3318**
Total:	**3.981**	**25.032**	**Total:**	**0.573**	**3.601**

Table 4.12. Algal biomass at Waikiki, Winter 1995

Algae Data: Waikiki Control Site 2/19/95

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Waikiki	2.19.95	7 m	81	1	0.9981	1.3702	**0.3721**	**2.3398**	0.9981	1.0546	**0.0565**	**0.3553**	*Pterocladia, Lyngbya, Laurencia*
Waikiki	2.19.95	7 m	82	2	0.9940	1.8094	**0.8154**	**5.1272**	0.9940	1.1233	**0.1293**	**0.8130**	*Lyngbya, Dictyota, unidentified turf*
Waikiki	2.19.95	7 m	83	3	0.9863	8.3190	**7.3327**	**46.1080**	0.9863	2.2724	**1.2861**	**8.0870**	*Pterocladia, unidentified turf , Laurencia*
Waikiki	2.19.95	7 m	84	4	1.0000	2.1394	**1.1394**	**7.1645**	1.0000	1.1506	**0.1506**	**0.9470**	*Lyngbya, Pterocladia, Dictyota*
Waikiki	2.19.95	17 m	77	1	5.3656	78.1595	**72.7939**	**457.7280**	5.3656	16.9265	**11.5609**	**72.6949**	*Dictyopteris*
Waikiki	2.19.95	17 m	78	2	5.8704	74.6299	**68.7595**	**432.3597**	5.8704	14.8875	**9.0171**	**56.6995**	*Dictyopteris*
Waikiki	2.19.95	17 m	79	3	5.5959	41.0785	**35.4826**	**223.1146**	5.5959	9.9183	**4.3224**	**27.1793**	*Dictyopteris*
Waikiki	2.19.95	17 m	80	4	5.6032	138.6000	**132.9968**	**836.2839**	5.6032	26.8352	**21.2320**	**133.5068**	*Dictyopteris, Lyngbya, Halimeda, Neomeris*
Waikiki	2.19.95	27 m	73	1	0.9850	25.4900	**24.5050**	**154.0874**	0.9850	6.2224	**5.2374**	**32.9328**	*Lyngbya, Halimeda*
Waikiki	2.19.95	27 m	74	2	0.9863	23.8845	**22.8982**	**143.9839**	0.9863	6.1190	**5.1327**	**32.2744**	*Pterocladia, Dictyota, Laurencia, Jania*
Waikiki	2.19.95	27 m	75	3	0.9940	18.3963	**17.4023**	**109.4257**	0.9940	4.7116	**3.7176**	**23.3763**	*Pterocladia, Laurencia, Jania, Neomeris*
Waikiki	2.19.95	27 m	76	4	0.9872	19.7726	**18.7854**	**118.1226**	0.9872	5.0759	**4.0887**	**25.7097**	*Lyngbya, Pterocladia, Laurencia*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	**Depth**	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
27 m	**20.8977**	**131.4049**	**27 m**	**4.5441**	**28.5733**
17 m	**77.5082**	**487.3716**	**17 m**	**11.5331**	**72.5201**
7 m	**2.4149**	**15.1849**	**7 m**	**0.4056**	**2.5506**
Total:	**33.6069**	**211.3204**	**Total:**	**5.4943**	**34.5480**

Table 4.13. Algal biomass at Sand Island, Winter 1994

Algae Data: Sand Island 2/19/94

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Sand Island	2.19.94	7 m	1	1	1.282	7.832	**6.550**	**41.186**	1.282	2.460	**1.178**	**7.407**	*Pterocladia, Liagora*
Sand Island	2.19.94	7 m	2	2	1.282	3.077	**1.795**	**11.287**	1.282	1.388	**0.106**	**0.667**	*Pterocladia, Liagora*
Sand Island	2.19.94	7 m	3	3	1.288	10.491	**9.203**	**57.868**	1.288	3.250	**1.962**	**12.337**	*Pterocladia, Liagora*
Sand Island	2.19.94	7 m	4	4	1.284	7.001	**5.717**	**35.948**	1.284	2.550	**1.266**	**7.961**	*Pterocladia, Liagora*
Sand Island	2.19.94	17 m	5	1	1.285	12.656	**11.371**	**71.501**	1.285	4.417	**3.132**	**19.694**	*Pterocladia, Liagora*
Sand Island	2.19.94	17 m	6	2	1.286	5.859	**4.573**	**28.755**	1.286	2.395	**1.109**	**6.973**	*Pterocladia, Liagora*
Sand Island	2.19.94	17 m	7	3	1.281	14.323	**13.042**	**82.008**	1.281	4.767	**3.486**	**21.920**	*Pterocladia, Liagora*
Sand Island	2.19.94	17 m	8	4	1.286	14.018	**12.732**	**80.059**	1.286	4.307	**3.021**	**18.996**	*Pterocladia, Liagora*
Sand Island	2.19.94	27 m	9	1	1.290	2.448	**1.158**	**7.282**	1.290	1.599	**0.309**	**1.943**	*Pterocladia, Liagora*
Sand Island	2.19.94	27 m	10	2	1.284	3.156	**1.872**	**11.771**	1.284	1.726	**0.442**	**2.779**	*Pterocladia, Liagora*
Sand Island	2.19.94	27 m	11	3	1.413	2.732	**1.319**	**8.294**	1.413	1.827	**0.414**	**2.603**	*Pterocladia, Liagora*
Sand Island	2.19.94	27 m	12	4	1.397	3.616	**2.219**	**13.953**	1.397	2.046	**0.649**	**4.081**	*Pterocladia, Liagora*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	**Depth**	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
7 m	**5.816**	**36.573**	**7 m**	**1.128**	**7.093**
17 m	**10.430**	**65.581**	**17 m**	**2.687**	**16.896**
27 m	**1.642**	**10.325**	**27 m**	**0.454**	**2.852**
Total:	**5.963**	**37.493**	**Total:**	**1.423**	**8.947**

Table 4.14. Algal Biomass at Sand Island, Summer 1994

Algae Data: Sand Island 8/94

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Sand Island	8.29.94	7 m	49	1	0.9953	3.5609	**2.5656**	**16.1325**	0.9966	1.5335	**0.5369**	**3.3760**	*Lyngbya, Dictyota*
Sand Island	8.29.94	7 m	50	2	0.9845	20.4290	**19.4445**	**122.2670**	0.9897	5.5692	**4.5795**	**28.7959**	*Dictyota, Laurencia, Jania*
Sand Island	8.29.94	7 m	51	3	0.9862	7.1353	**6.1491**	**38.6655**	0.9889	2.5180	**1.5291**	**9.6150**	*Dictyota, Laurencia, Pterocladia*
Sand Island	8.29.94	7 m	52	4	1.0013	21.4760	**20.4747**	**128.7449**	1.0026	6.4370	**5.4344**	**34.1715**	*Dictyota, Lyngbya, Jania, Laurencia*
Sand Island	8.29.94	17 m	53	1	0.9994	4.4984	**3.4990**	**22.0017**	0.9970	1.5717	**0.5747**	**3.6137**	*Gracilaria, Laurencia, Pterocladia*
Sand Island	8.29.94	17 m	54	2	0.9752	4.2286	**3.2534**	**20.4574**	0.9785	1.5221	**0.5436**	**3.4182**	*Gracilaria, Pterocladia, Laurencia, Dictyota*
Sand Island	8.29.94	17 m	55	3	0.9871	3.2228	**2.2357**	**14.0581**	0.9875	1.3373	**0.3498**	**2.1995**	*Lyngbya, Laurencia, Pterocladia, Gracilaria, Neomeri*
Sand Island	8.29.94	17 m	56	4	0.9872	2.2628	**1.2756**	**8.0210**	0.9875	1.2820	**0.2945**	**1.8518**	*Lyngbya, Laurencia*
Sand Island	9.7.94	27 m	57	1	0.9847	6.7067	**5.7220**	**35.9799**	0.9843	2.0699	**1.0856**	**6.8263**	*Lyngbya, Grateloupia, Laurencia*
Sand Island	9.7.94	27 m	58	2	0.9791	3.6608	**2.6817**	**16.8625**	0.9807	1.3669	**0.3862**	**2.4284**	*Lyngbya, Grateloupia, Gracilaria*
Sand Island	9.7.94	27 m	59	3	0.9914	4.3326	**3.3412**	**21.0095**	1.0066	1.7827	**0.7761**	**4.8801**	*Lyngbya, Liagora, Dictyota*
Sand Island	9.7.94	27 m	60	4	0.9837	10.2000	**9.2163**	**57.9521**	0.9844	2.6333	**1.6489**	**10.3683**	*Lyngbya, Grateloupia*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	**Depth**	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
7 m	**12.1585**	**76.4525**	**7 m**	**3.0200**	**18.9896**
17 m	**2.5659**	**16.1345**	**17 m**	**0.4407**	**2.7708**
27 m	**5.2403**	**32.9510**	**27 m**	**0.9742**	**6.1258**
Total:	**6.6549**	**41.8460**	**Total:**	**1.4783**	**9.2954**

Table 4.15. Algal biomass at Sand Island, Winter 1995

Algae Data: Sand Island 2/22/95

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Sand Islanc	2.22.95	7 m	93	1	1.0010	1.5303	**0.5293**	**3.3282**	1.0010	1.0996	**0.0986**	**0.6200**	*Laurencia, Pterocladia, Dictyota*
Sand Islanc	2.22.95	7 m	94	2	0.9910	2.3434	**1.3524**	**8.5039**	0.9910	1.2158	**0.2248**	**1.4135**	*Pterocladia*
Sand Islanc	2.22.95	7 m	95	3	0.9890	2.4888	**1.4998**	**9.4307**	0.9890	1.1870	**0.1980**	**1.2450**	*Laurencia, Pterocladia, Dictyota*
Sand Islanc	2.22.95	7 m	96	4	1.0038	4.3124	**3.3086**	**20.8045**	1.0038	1.4015	**0.3977**	**2.5007**	*Laurencia, Lyngbya*
Sand Islanc	2.22.95	17 m	89	1	0.9992	2.5842	**1.5850**	**9.9665**	0.9992	1.3704	**0.3712**	**2.3341**	*Pterocladia, Dictyota, Hypnea*
Sand Islanc	2.22.95	17 m	90	2	0.9766	4.1834	**3.2068**	**20.1644**	0.9766	1.5227	**0.5461**	**3.4339**	*Hypnea, Dictyota, Jania*
Sand Islanc	2.22.95	17 m	91	3	0.9876	3.1161	**2.1285**	**13.3840**	0.9876	1.4434	**0.4558**	**2.8661**	*Hypnea, Dictyota, Lyngbya*
Sand Islanc	2.22.95	17 m	92	4	0.9897	10.0743	**9.0846**	**57.1240**	0.9897	2.8418	**1.8521**	**11.6460**	*Lyngbya, Hypnea, Dictyota, Pterocladia*
Sand Islanc	2.22.95	27 m	85	1	0.9879	6.7497	**5.7618**	**36.2302**	0.9879	2.4078	**1.4199**	**8.9283**	*Lyngbya, Pterocladia, Laurencia*
Sand Islanc	2.22.95	27 m	86	2	0.9880	8.3695	**7.3815**	**46.4149**	0.9880	2.2745	**1.2865**	**8.0895**	*Lyngbya, Pterocladia, Jania, Laurencia*
Sand Islanc	2.22.95	27 m	87	3	0.9998	8.8266	**7.8268**	**49.2149**	0.9998	2.7950	**1.7952**	**11.2882**	*Lyngbya, calcareous red algae*
Sand Islanc	2.22.95	27 m	88	4	0.9898	6.8120	**5.8222**	**36.6100**	0.9898	2.2553	**1.2655**	**7.9575**	*Lyngbya, Pterocladia, Gracilaria, Laurencia, Neon*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	**Depth**	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
27 m	**6.6981**	**42.1175**	**27 m**	**1.4418**	**9.0659**
17 m	**4.0012**	**25.1597**	**17 m**	**0.8063**	**5.0700**
7 m	**1.6725**	**10.5168**	**7 m**	**0.2298**	**1.4448**
Total:	**4.1239**	**25.9313**	**Total:**	**0.8260**	**5.1936**

Table 4.16. Algal biomass at Barbers Point, Winter 1994

Algae Data: Barbers Pt 5/1/94

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Barbers Pt	4.30.94	7 m	25	1	0.973	14.436	**13.463**	**84.655**	0.973	2.827	**1.854**	**11.658**	*Halimeda, Codium*
Barbers Pt	4.30.94	7 m	26	2	0.993	11.443	**10.450**	**65.710**	0.993	2.497	**1.504**	**9.457**	*Halimeda, Pterocladia, Jania, Galaxau*
Barbers Pt	4.30.94	7 m	27	3	0.986	2.428	**1.442**	**9.067**	0.986	1.135	**0.149**	**0.937**	*Lyngbya*
Barbers Pt	4.30.94	7 m	28	4	1.289	7.009	**5.720**	**35.967**	1.289	1.546	**0.257**	**1.616**	*Halymenia, Desmia, Neomaris*
Barbers Pt	4.30.94	17 m	29	1	0.996	3.165	**2.169**	**13.639**	0.996	1.315	**0.319**	**2.006**	*Dictyota, Lyngbya*
Barbers Pt	4.30.94	17 m	30	2	1.075	6.539	**5.464**	**34.358**	1.075	2.080	**1.005**	**6.319**	*Pterocladia*
Barbers Pt	4.30.94	17 m	31	3	0.983	1.668	**0.685**	**4.307**	0.983	1.034	**0.051**	**0.321**	*Lyngbya*
Barbers Pt	4.30.94	17 m	32	4	1.406	10.377	**8.971**	**56.410**	1.406	2.938	**1.532**	**9.633**	*Lyngbya*
Barbers Pt	4.30.94	27 m	33	1	0.981	7.383	**6.402**	**40.256**	0.981	1.263	**0.282**	**1.773**	*Unidentified Sp., Symploca*
Barbers Pt	4.30.94	27 m	34	2	0.987	2.332	**1.345**	**8.457**	0.987	1.086	**0.099**	**0.623**	*Pterocladia*
Barbers Pt	4.30.94	27 m	35	3	0.985	1.608	**0.623**	**3.917**	0.985	1.025	**0.040**	**0.252**	*Dictyota*
Barbers Pt	4.30.94	27 m	36	4	1.002	4.583	**3.581**	**22.517**	1.002	1.501	**0.499**	**3.138**	*Lyngbya*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**
7 m	**7.769**	**48.850**
17 m	**4.322**	**27.178**
27 m	**2.988**	**18.787**
Total:	**5.026**	**31.605**

Depth	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
7 m	**0.941**	**5.917**
17 m	**0.727**	**4.570**
27 m	**0.230**	**1.446**
Total:	**0.633**	**3.978**

Table 4.17. Algal Biomass at Barbers Point, Summer 1994

Algae Data: Barbers Point 8/94

Site	Date	Depth	Cat	#Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Barbers P	9.9.94	7 m	61	1	0.9975	5.6421	**4.6446**	**29.2052**	1.0009	2.1198	**1.1189**	**7.0356**	*Dictyota, Pterocladia, Laurencia, Liagora*
Barbers P	9.9.94	7 m	62	2	0.9899	6.6327	**5.6428**	**35.4819**	0.9949	2.1525	**1.1576**	**7.2790**	*Lyngbya, Pterocladia, Dictyota, Halimeda, Cladophorops*
Barbers P	9.9.94	7 m	63	3	0.9881	3.2223	**2.2342**	**14.0486**	0.9864	1.4343	**0.4479**	**2.8164**	*Dictyota, Halimeda, Caulerpa, Liagora*
Barbers P	9.9.94	7 m	64	4	1.0027	1.8181	**0.8154**	**5.1272**	1.0017	1.1517	**0.1500**	**0.9432**	*Dictyota, Gracilaria, Pterocladia, Halimeda, Lyngbya*
Barbers P	9.9.94	17 m	65	1	0.9979	8.9990	**8.0011**	**50.3109**	0.9985	2.0635	**1.0650**	**6.6967**	*Lyngbya*
Barbers P	9.9.94	17 m	66	2	0.9791	1.0905	**0.1114**	**0.7005**	0.9766	0.9866	**0.0100**	**0.0629**	*Lyngbya*
Barbers P	9.9.94	17 m	67	3	0.9882	3.3393	**2.3511**	**14.7837**	0.9870	1.4037	**0.4167**	**2.6202**	*Lyngbya*
Barbers P	9.9.94	17 m	68	4	0.9882	2.2679	**1.2797**	**8.0468**	0.9879	1.1734	**0.1855**	**1.1664**	*Lyngbya*
Barbers P	9.9.94	27 m	69	1	0.9844	2.2742	**1.2898**	**8.1103**	0.9842	1.2075	**0.2233**	**1.4041**	*Gratelopia, Lyngbya, Gracilaria, Neomeris*
Barbers P	9.9.94	27 m	70	2	0.9810	2.5291	**1.5481**	**9.7345**	0.9818	1.2726	**0.2908**	**1.8286**	*Grateloupia, Gracilaria*
Barbers P	9.9.94	27 m	71	3	1.0083	1.8200	**0.8117**	**5.1040**	0.9918	1.1439	**0.1521**	**0.9564**	*Grateloupia, Gracilaria, Dicyota, Neomeris*
Barbers P	9.9.94	27 m	72	4	0.9850	3.8823	**2.8973**	**18.2182**	0.9862	1.5162	**0.5300**	**3.3326**	*Grateloupia, Gracilaria, Pterocladia, Cladophora, Neomeris*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	Depth	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
7 m	**3.3343**	**20.9658**	**7 m**	**0.7186**	**4.5186**
17 m	**2.9358**	**18.4605**	**17 m**	**0.4193**	**2.6366**
27 m	**1.6367**	**10.2917**	**27 m**	**0.2991**	**1.8804**
Total:	**2.636**	**16.573**	**Total:**	**0.479**	**3.012**

Table 4.18. Algal biomass at Barbers Point, Winter 1995

Algae Data: Barbers Pt 3/8/95

Site	Date	Depth	Cat #	Rep	Dish Wt (g)	Wet Wt + Dish (g)	**Wet Algal Wt (g)**	**Wet Wt g / m2**	Dry Dish Wt (g)	Dry Wt+Dish (g)	**Dry Algal Wt (g)**	**Dry Wt g / m2**	Major Components
Barbers P	3.8.95	7 m	105	1	1.0018	22.2486	**21.2468**	**133.5999**	1.0018	7.4052	**6.4034**	**40.2646**	*Halimeda, Lyngbya, Liagora*
Barbers P	3.8.95	7 m	106	2	0.9908	26.9311	**25.9403**	**163.1126**	0.9908	8.7679	**7.7771**	**48.9024**	*Halimeda, Caulerpa, Liagora*
Barbers P	3.8.95	7 m	107	3	0.9902	20.7799	**19.7897**	**124.4376**	0.9902	6.5025	**5.5123**	**34.6613**	*Halimeda, Caulerpa, Liagora, Hyypnea*
Barbers P	3.8.95	7 m	108	4	1.0068	27.5730	**26.5662**	**167.0483**	1.0068	8.7681	**7.7613**	**48.8031**	*Halimeda, Pterocladia, Liagora, Caulerpa, Borneteli*
Barbers P	3.8.95	17 m	101	1	1.0020	2.5686	**1.5666**	**9.8508**	1.0020	1.3806	**0.3786**	**2.3806**	*Lyngbya*
Barbers P	3.8.95	17 m	102	2	0.9830	9.7416	**8.7586**	**55.0741**	0.9830	3.3436	**2.3606**	**14.8435**	*Lyngbya, Hypnea, Gradilaria, Padina*
Barbers P	3.8.95	17 m	103	3	0.9911	11.9891	**10.9980**	**69.1554**	0.9911	4.3294	**3.3383**	**20.9912**	*Lyngba, Pterocladia, Jania, Gracilaria*
Barbers P	3.8.95	17 m	104	4	0.9916	3.8796	**2.8880**	**18.1597**	0.9916	1.7794	**0.7878**	**4.9537**	*Lyngbya, Hypnea, Jania*
Barbers P	3.8.95	27 m	97	1	0.9920	21.3953	**20.4033**	**128.2960**	0.9920	9.0636	**8.0716**	**50.7542**	*Lyngbya*
Barbers P	3.8.95	27 m	98	2	0.9928	7.9457	**6.9529**	**43.7198**	0.9928	3.6234	**2.6306**	**16.5412**	*Lyngbya, Pterocladia, Liagora Hypnea*
Barbers P	3.8.95	27 m	99	3	1.0011	4.1798	**3.1787**	**19.9877**	1.0011	1.8828	**0.8817**	**5.5441**	*Asparagopsis, Hypnea*
Barbers P	3.8.95	27 m	100	4	0.9910	4.0405	**3.0495**	**19.1753**	0.9910	1.9016	**0.9106**	**5.7259**	*Lyngbya, Hypnea, Jania, Pterocladia*

Depth	**mean Wet Wt (g)**	**mean Wet Wt g/m2**	Depth	**mean Dry Wt (g)**	**mean Dry Wt g/m2**
27 m	**8.3961**	**52.7947**	**27 m**	**3.1236**	**19.6414**
17 m	**6.0528**	**38.0600**	**17 m**	**1.7163**	**10.7923**
7 m	**23.3858**	**147.0496**	**7 m**	**6.8635**	**43.1578**
Total:	**12.6116**	**79.3014**	**Total:**	**3.9012**	**24.5305**

5 CONCLUSIONS

The numbers of micromollusks in the sediments are variable, that variability apparently associated with irregularity of sand deposition on the reef flat and with surf direction, sand scour, wave base, and the like. Species composition, however, is consistent: 94% of the shells in the assemblages are those of epifaunal gastropods, Tricolia is dominant at all three areas at the 7 m depth regime and indeed dominates the total assemblages at the Waikiki site. Cerithidium perparvulum and Vitricithna marmorata are dominant at the 17 and 27 m depths and dominate the total assemblages at Sand Island and Barbers Point. The eulimid Balcis, pyramidellids and suspension feeders which signal high particulate matter and/or high nutrient content in the water column comprise an average of less than 5% of the assemblages except for the 7 m station at the Barbers Point site. The low numbers indicate there is little or no impact of either particulate matter or nutrients in the water column on the benthic assemblages of micromollusks. These data are comparable with sample data from similar areas and depths in earlier studies from 1967 to 1975: abundance and species composition in the earlier samples reported match those reported here, with the same eleven species dominant and for the most part in about the same proportions.

Algal biomass varies with season, with greater biomass in winter than in summer. On the reef fronting the War Memorial Natatorium at Waikiki algal biomass is an order of magnitude less than was reported for 1967 by Doty (1971) and than that reported by Chave et al (1973) for 1971 and 1972. Algal diversity as indicated by numbers of dominant genera is highest at Barbers Point and lowest at Sand Island; the number of algal genera recorded on the Waikiki reef is similar to that reported in the earlier accounts, but the dominant alga of that section of the reef from 1928 into 1967, Sargassum, is virtually gone from the reef today.

The data reported here provide no evidence to indicate point and/or non-point discharge of pollutants impact the benthic communities shoreward of the outfalls or in the vicinity of Waikiki at depths of between 7 and 27 m with one possible exception., that of

the 7 m station at Barbers Point. The decline in algal biomass and the virtual disappearance of Sargassum from the reef is not easily explained. Doty (1971) suggested that storm waves were perhaps the factor most influential in regulating algal crop size, but that explanation is not sufficient to account for the decline in algal crop recorded here. Algal occurrence is also determined by water clarity and nutrient input. It would appear that either or both of these factors could be involved in the change in algal biomass and species composition.

6 RECOMMENDATIONS

Continuing monitoring of benthic assemblages in the shallow waters of Mamala Bay (those most utilized by residents and visitors alike) would appear to be a necessity, given the dynamics of shoreline construction and utilization, and the possibilities of problems resulting from seepage and stream flow. Benthic algae and mollusks are what people see, and as changes in both abundance and species composition of both signal changes in water quality, at least annual surveys and censuses should be undertaken at selected sites. The decline in algal biomass is noteworthy and an in-depth study of that decline should be undertaken in an attempt to determine its nature.

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