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¹² Abstract (Purpose, method, results, conclusions) <p style="margin-top: 10px;">Sand grab samples were collected from nine locations at and around existing and proposed ocean sewage outfalls and at a control station. The preserved samples were analyzed for abundance of invertebrates. Stations in the vicinity of the existing outfall (12 m deep) were characterized by high abundance of annelid tube worms which grew in huge, densely packed clusters. Foraminifera and the green algae <i>Halimeda</i> sp. were absent or in relatively low abundance.</p> <p style="margin-top: 10px;">In the vicinity of the proposed outfall (65 m deep) samples contained high abundance of <i>Halimeda</i> sp., moderate quantities of Foraminifera, and the solitary coral <i>Fungia fragilis</i>; no annelid worms were found. This pattern of abundance was similar to the control station. The pen shell <i>Pinna semicostata</i> was present at most deep water stations. Extensive beds of this mollusk are common in other regions along south O'ahu.</p>		

ANALYSIS OF SAND SAMPLES FROM THE
SAND ISLAND SEWER OUTFALL, MĀMALA BAY, O'AHU
(Interim Progress Report)

by
S. Arthur Reed

Technical Memorandum Report No. 60

May 1978

Interim Progress Report
for
BIOLOGICAL MONITORING AT
THE SAND ISLAND SEWAGE OUTFALL
for the
City and County of Honolulu, Hawai'i

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ABSTRACT

Sand grab samples were collected from nine locations at and around existing and proposed ocean sewage outfalls and at a control station. The preserved samples were analyzed for abundance of invertebrates. Stations in the vicinity of the existing outfall (12 m deep) were characterized by high abundance of annelid tube worms which grew in huge, densely packed clusters. Foraminifera and the green algae Halimeda sp. were absent or in relatively low abundance.

In the vicinity of the proposed outfall (65 m deep) samples contained high abundance of Halimeda sp., moderate quantities of Foraminifera, and the solitary coral Fungia fragilis; no annelid worms were found. This pattern of abundance was similar to the control station. The pen shell Pinna semicostata was present at most deep water stations. Extensive beds of this mollusk are common in other regions along south O'ahu.

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INTRODUCTION

As part of a study to assess the benthic biotic communities in the vicinity of the present and proposed sewage ocean outfall at Sand Island, sand sediments were examined from 35 samples taken from nine locations in Māhala Bay. Three stations (Fig. 1) were located near the site of the old outfall. Station 3 was at the outfall, and stations 14 and 15 were located, respectively, 400 m east and west of the outfall. Stations were also located at the site of the proposed new outfall (Sta. 8) and at four locations around the zone of mixing rectangle (Stas. 6-10). For comparative purposes, a station was also located off the navigation buoy at Diamond Head (Sta. 1).

METHODS

Samples were obtained by a Peterson dredge during two periods, December 1973 and February 1974. A second sampling was necessary due to a breakdown in the dredge retrieval winch during the initial field collecting. Station numbers and locations as well as depths of samples taken are shown in Table 1. Immediately upon retrieval, the samples were preserved in formaldehyde and delivered to the laboratory. Each sample was gently washed in fresh water to remove the formaldehyde, with great care being taken not to flush away any identifiable material. The wet sample was examined for any soft-bodied preserved organisms which were then removed and replaced in formaldehyde. The remaining sample was air dried and weighed. The entire sample was reexamined under a magnifying glass, and all hard parts and skeletal fragments were removed and sorted. Entire skeletons and fragments were identified taxonomically as completely as possible. Mollusk shells were not identified to species since another phase of this project has examined the micromolluscan assemblages in detail (Kay 1975).

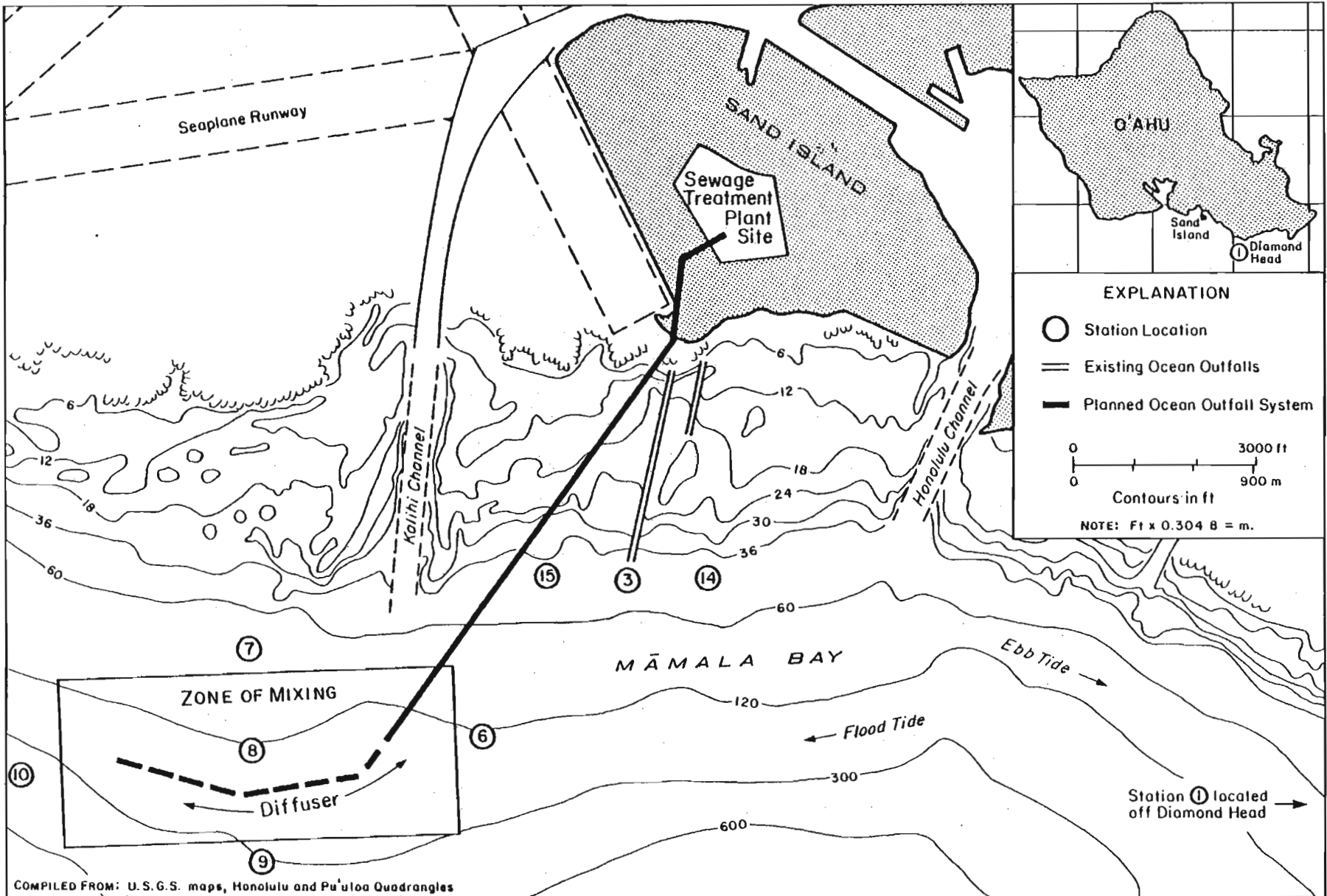


FIGURE 1. MAP OF STATIONS SAMPLED, MĀMALA BAY (SAND ISLAND), O'AHU.

TABLE 1. STATION NUMBERS, LOCATIONS, AND DEPTHS OF SAND SEDIMENT SAMPLES TAKEN, DIAMOND HEAD AND MĀMALA BAY, O'AHU

Station No.	Location	Sample		Depth (m)
		(1973)	(1974)	
1	Diamond Head buoy	A		50
		B		54
		C		46
		D		50
3	At old outfall	A		11
		B		11
		C		13
		D		12
14	400 m east of old outfall	A		13
		B		13
			BII	13
		C		6
			CII	12
		D		7
15	400 m west of old outfall	A		8
		B		7
		C		7
			CII	12
		D		6
			DII	13
		E		7
F		13		
6	New outfall zone, east	A		78
		B		70
		C		81
		D		93
		E		97
7	New outfall zone, north	A		21
		B		21
			CII	17
			DII	17
8	New outfall zone, center	A		60
		B		75
		C		70
		D		67
9	New outfall zone, south	A		109
		B		100
		C		95
		D		90
10	New outfall zone, west	A		67
		B		74
			CII	51
			DII	50

RESULTS

A summary of the groups of organisms found in the samples is shown by major taxa in Table 2. Abundance of organisms is represented by weight and percent of total sample weight. More detailed abundance data for each sample collection at the stations is given in Appendix A.

In the large majority of samples, organisms were identified by dead and eroded skeletons or small skeletal fragments. Only a small number of organisms were living at the time of collection. These included the calcareous green alga, *Halimeda* sp., a few foraminifers, the solitary coral *Fungia fragilis*, sipunculid worms, and annelid tube worms.

Station 1 at Diamond Head can be characterized by a relatively high abundance of the calcareous green algae, *Halimeda* sp., occurring as skeletal fragments and a few living specimens, and a comparatively high percentage by weight of foraminifers and ectoproct Bryozoa (Fig. 2). Notably absent from these samples are annelid tube worms and the molluscan pen shell *Pinna semicostata*.

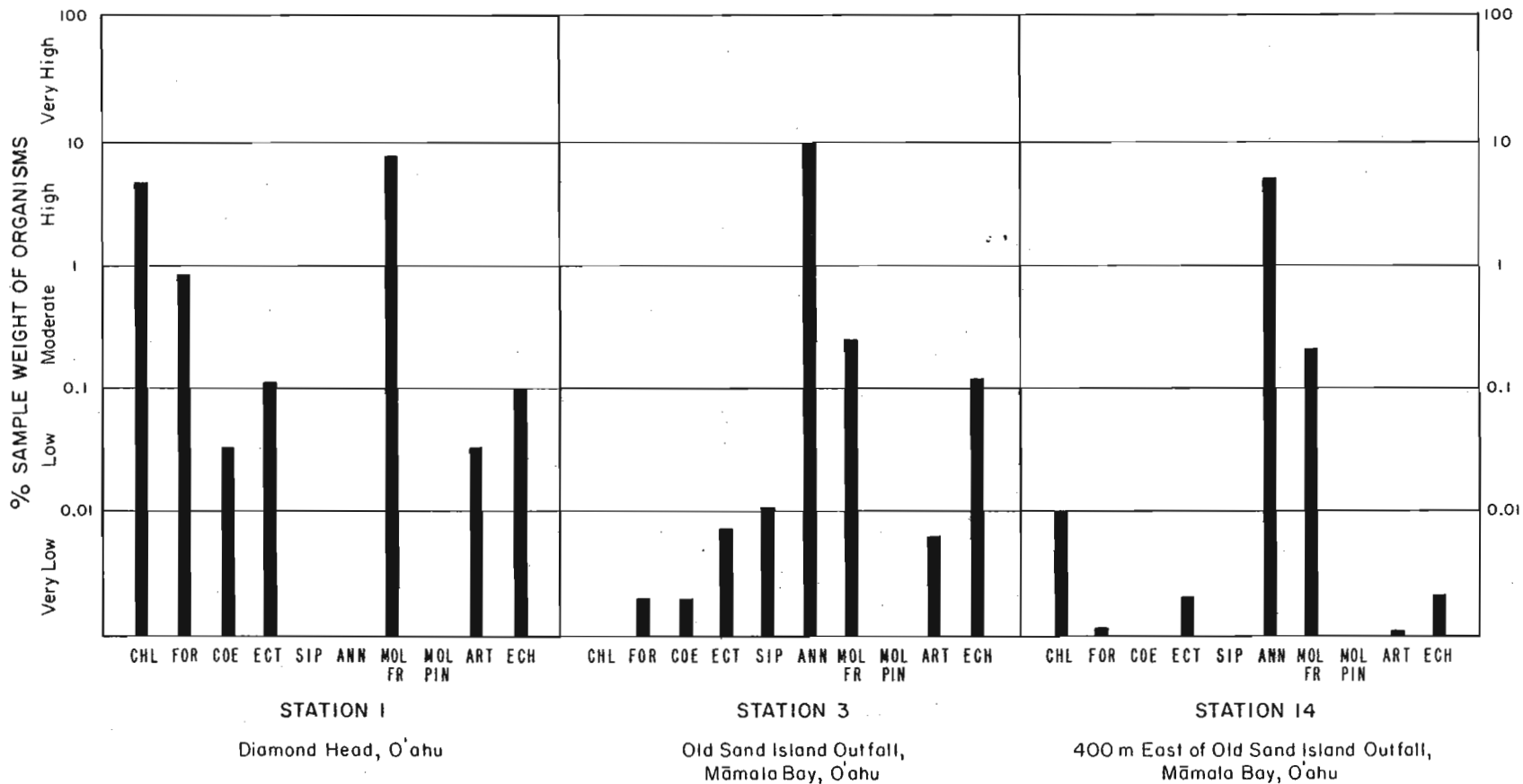
Stations 3, 14, and 15 in the near vicinity of the shallow water outfall were characterized by a remarkably high abundance of annelid tube worms, *Chaetopterus* sp. (Fig. 2). These worms grew in huge, densely packed clusters. On one occasion during a collecting field trip when the water upcurrent of the outfall was exceptionally clear, these clusters could be seen from the surface. They appeared as hemispherical mounds about a meter in diameter and were distributed over the bottom in closely packed, randomly arranged patches. Each mound probably contained hundreds of thousands of worms, based on counts from the dredge samples. *Halimeda* sp. and foraminifers were either absent or in relatively low abundance.

The high abundance of the suspension filter-feeding annelid tube worms

TABLE 2. SUMMARY OF ABUNDANCE BY WEIGHT AND PERCENT OF TOTAL SAMPLE OF ORGANISMS IDENTIFIED IN DREDGED SAND SAMPLES, DIAMOND HEAD AND MĀMALA BAY, O'AHU

Taxa	STATION																			
	Diamond Head*		Present Outfall				Proposed Outfall													
	1		3		14		15		6		7		8		9		10			
	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%	wt(g)	%		
CHLOROPHYTA																				
<i>Balimeda</i> sp.	549.8	4.7			2.6	0.01	7.3	0.04	34.3	0.61	0.1	0.004	44.6	0.91	5.7	0.49	0.1	0.01		
FORAMINIFERA	19.2	0.18	0.4	0.002	0.1	0.001	0.1	0.001	7.8	0.13			2.1	0.04	0.6	0.05	0.2	0.02		
COELENTERATA																				
Corals	3.8	0.032	0.3	0.002					1.0	0.02	0.1	0.004	1.2	0.02	0.5	0.04	0.6	0.06		
ECTOPROCTA																				
(Bryozoa)	12.7	0.11	0.8	0.007	0.4	0.002	0.1	0.001	0.1	0.002	0.1	0.004	1.4	0.03	0.6	0.05				
SIPUNCULIDA			1.2	0.01																
ANNELIDA			1060.0	9.8	980.0	4.9	920.0	5.1												
MOLLUSCA																				
Fragments	83.6	0.72	24.8	0.22	24.9	0.12	4.9	0.03	8.5	0.15			10.7	0.22			2.3	0.24		
<i>Pinna</i>									15.5	0.28	325.0	14.1	31.6	0.64	233.3	20.1	53.4	5.7		
ARTHROPODA	3.5	0.03	0.7	0.006	0.2	0.001	0.3	0.002					0.3	0.006						
ECHINODERMATA	11.5	0.1	12.4	0.11	0.4	0.002	0.5	0.003	0.6	0.01	0.1	0.004	0.9	0.02	0.1	0.009				
Total Sample Weight (g)	11 638.9		10 809.1		20 163.3		17 973.8		5 636.2		2 297.3		4 907.2		1 159.8		936.2			
Mean Station Depth (m)	50		12		11		9		84		19		68		99		71			

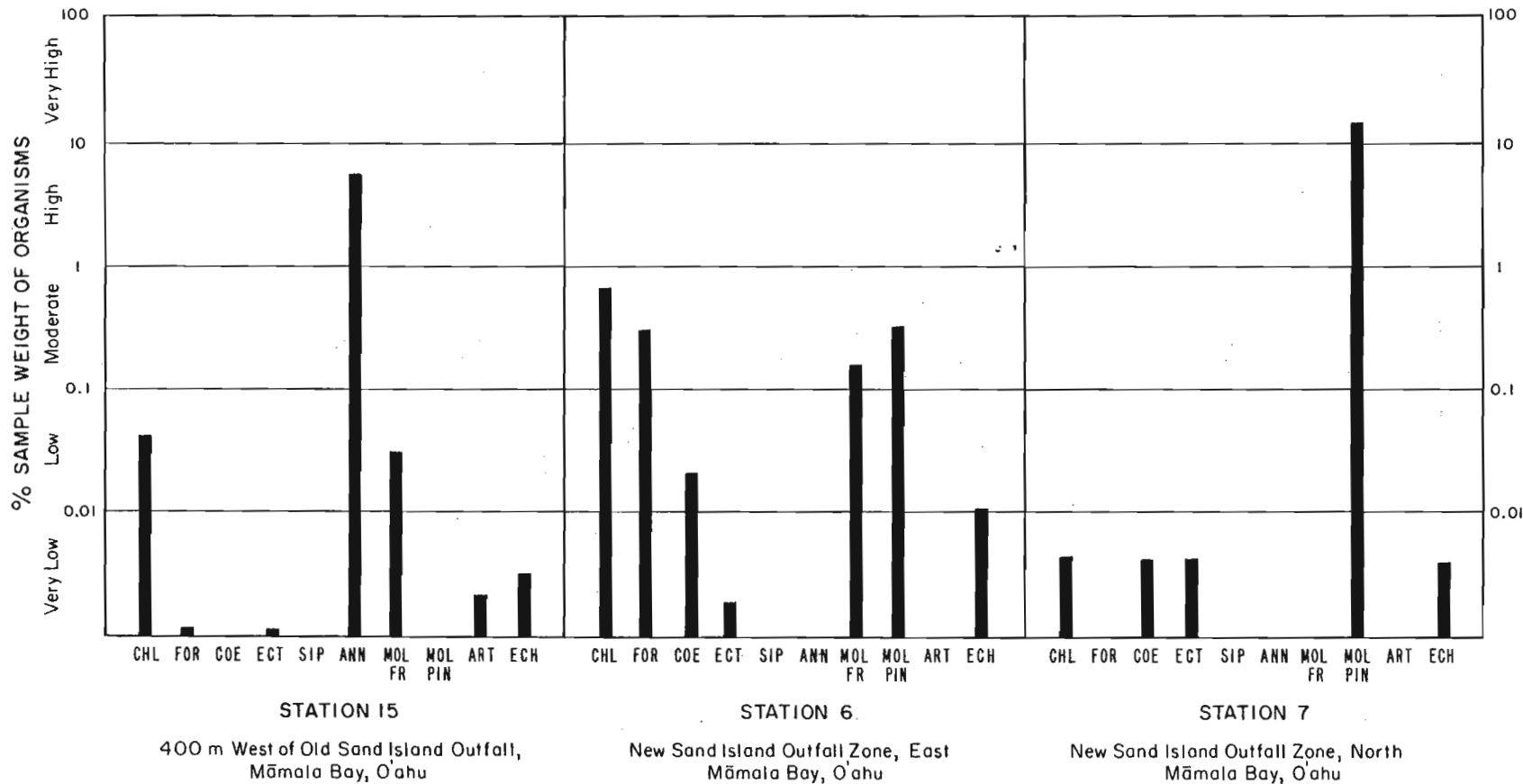
*Control Station



NOTE: Quantities are plotted on a logarithmic scale.

CHL = Chlorophyta, FOR = Foraminifera, COE = Coelenterata, ECT = Ectoprocta, SIP = Sipunculida, ANN = Annelida, MOL FR = Mollusca fragments, MOL PIN = Mollusca *Pinna semicostata*, ART = Arthropoda, ECH = Echinodermata.

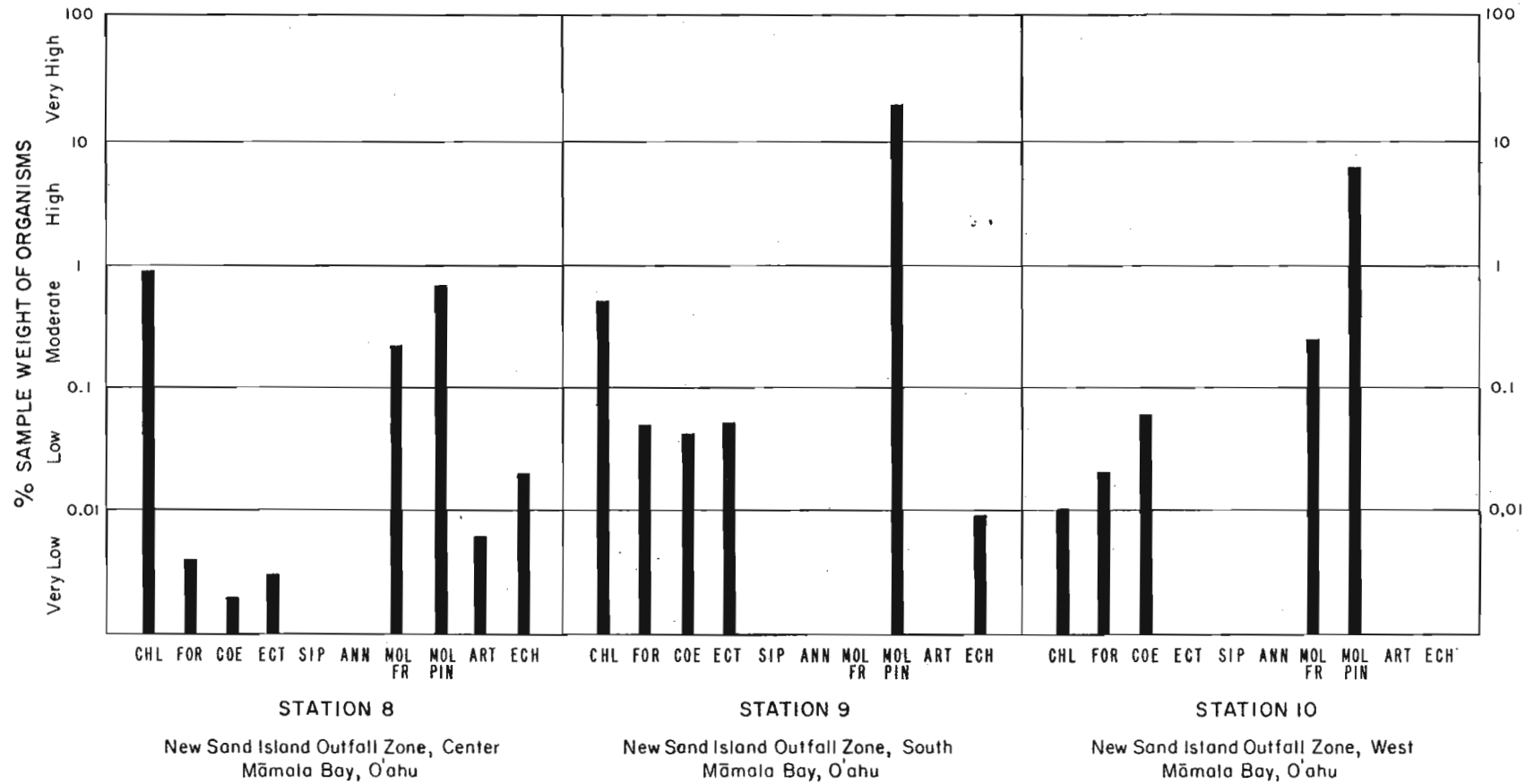
FIGURE 2. PERCENT ABUNDANCE BY WEIGHT OF MAJOR TAXA OF ORGANISMS IN SAND SAMPLES FROM EACH STATION



NOTE: Quantities are plotted on a logarithmic scale.

CHL = Chlorophyta, FOR = Foraminifera, COE = Coelenterata, ECT = Ectoprocta, SIP = Sipunculida, ANN = Annelida, MOL FR = Mollusca fragments, MOL PIN = Mollusca *Pinna semicostata*, ART = Arthropoda, ECH = Echinodermata.

FIGURE 2.—Continued.



NOTE: Quantities are plotted on a logarithmic scale.

CHL = Chlorophyta, FOR = Foraminifera, COE = Coelenterata, ECT = Ectoprocta, SIP = Sipunculida, ANN = Annelida, MOL FR = Mollusca fragments, MOL PIN = Mollusca *Pinna semicostata*, ART = Arthropoda, ECH = Echinodermata.

FIGURE 2.—Continued.

in the vicinity of the outfall can be used as an indicator of high stress conditions imposed on the benthic community by the highly nutrient sediment loading from the outfall.

Samples from stations at and surrounding the proposed outfall site were similar to each other in many respects (Fig. 2). With the exception of station 7, all stations registered relatively high abundance of *Halimeda* sp. and moderate quantities of foraminifers and the solitary coral *Fungia fragilis*. No annelid worms were found at any of these stations. This pattern of abundance was similar to that measured at control station 1 at Diamond Head. At station 7, on the shallow side of the proposed zone of mixing and nearest the active outfall, foraminifers were absent and coral was in low abundance.

Fragments of the pen shell *Pinna semicostata* were found in moderate or high abundance at all the stations surrounding the proposed outfall. Extensive beds of this mollusk have been commonly found in the deeper waters on sandy substrate in many locations around O'ahu including Nānākuli, Barber's Point, and Pōka'i Bay.

Certain problems were encountered in evaluating the data from the sand sample analysis. Determination of the number of living organisms was difficult or impossible in most cases. *Halimeda* sp. was rarely collected live but rather was gathered in the form of pieces and chips of the calcareous skeleton produced by this alga. Coral, mollusks, arthropods, and echinoderms (sea urchins) were also identified largely by the presence of small fragments of their skeletons. Furthermore, these fragments often could not be identified to species but rather were totaled and reported as major taxa. Since diversity indices require numbers of individuals within species, a diversity index for the stations could not be meaningfully calculated.

Analysis of sand samples cannot ascertain the condition of the major

components of the coral reef community: the coral organisms and the associated epibenthic, infaunal, and water column residents such as crabs, shrimp, worms, echinoderms, and fish. An exception is the analysis of micromollusks, which has yielded meaningful results in a number of recent studies (Kay 1973*a*, 1973*b*, and 1975).

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APPENDIX

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APPENDIX A. WEIGHT (IN GRAMS) OF ORGANISMS IN EACH SAND
SAMPLE COLLECTED FROM EACH STATION

APPENDIX TABLE A.1. STATION 1, DIAMOND HEAD, O'AHU

	SAMPLE			
	A	B	C	D
Chlorophyta <i>Halimeda</i> sp.	108.35	198.98	179.3	53.2
Foraminifera	6.07	1.94	9.9	1.3
Coelenterata Corals		1.28	2.4	
Ectoprocta (Bryozoa)	9.72	1.12	1.3	0.6
Sipunculida				
Annelida				
Mollusca Fragments <i>Pinna</i>	17.17	26.1	34.3	6.0
Arthropoda	1.67	0.74	0.9	0.2
Echinodermata	3.16	2.85	4.3	1.1

APPENDIX TABLE A.2. STATION 3, OLD SAND ISLAND OUTFALL,
MAMALA BAY, O'AHU

	SAMPLE			
	A	B	C	D
Chlorophyta <i>Halimeda</i> sp.				
Foraminifera		0.3		0.1
Coelenterata Corals			0.3	
Ectoprocta (Bryozoa)		0.2	0.6	
Sipunculida	1.2			
Annelida	582.0		478.0	
Mollusca Fragments <i>Pinna</i>		8.1		16.7
Arthropoda		0.4		0.3
Echinodermata		0.95		11.4

APPENDIX TABLE A.3. STATION 14, 400 m EAST OF OLD SAND ISLAND
OUTFALL, MĀMALA BAY, O'AHU

	SAMPLE					
	A	B	BII	C	CII	D
Chlorophyta						
<i>Halimeda</i> sp.			1.9		0.2	0.5
Foraminifera						0.1
Coelenterata						
Corals						
Ectoprocta						
(Bryozoa)					0.3	0.1
Sipunculida						
Annelida	365.5	379.8	152.9			81.8
Mollusca						
Fragments	12.9	2.2	2.2		1.7	5.9
<i>Pinna</i>						
Arthropoda					0.1	0.1
Echinodermata			0.1		0.3	

APPENDIX TABLE A.4. STATION 15, 400 m WEST OF OLD SAND ISLAND
OUTFALL, MĀMALA BAY, O'AHU

	SAMPLE					
	A	B	C	CII	DII	F
Chlorophyta						
<i>Halimeda</i> sp.		2.5	0.4		2.2	2.2
Foraminifera		0.1				
Coelenterata						
Corals						
Ectoprocta						
(Bryozoa)						0.1
Sipunculida						
Annelida				515.2	464.8	
Mollusca						
Fragments		1.5	0.8	0.5	1.9	0.2
<i>Pinna</i>						
Arthropoda					0.3	
Echinodermata		0.1			0.4	

APPENDIX TABLE A.5. STATION 6, NEW SAND ISLAND OUTFALL ZONE,
EAST, MĀMALA BAY, O'AHU

	SAMPLE				
	A	B	C	D	E
Chlorophyta <i>Halimeda</i> sp.			15.5	9.1	9.7
Foraminifera			0.7	3.5	3.6
Coelenterata Corals			0.1	0.4	0.5
Ectoprocta (Bryozoa)				0.1	
Sipunculida					
Annelida					
Mollusca Fragments <i>Pinna</i>			15.5	4.1	4.4
Arthropoda					
Echinodermata			0.1	0.2	0.3

APPENDIX TABLE A.6. STATION 7, NEW SAND ISLAND OUTFALL ZONE,
NORTH, MĀMALA BAY, O'AHU

	SAMPLE			
	A	B	CII	DII
Chlorophyta <i>Halimeda</i> sp.				0.1
Foraminifera				
Coelenterata Corals				0.1
Ectoprocta (Bryozoa)				0.1
Sipunculida				
Annelida				
Mollusca Fragments <i>Pinna</i>			209.6	115.4
Arthropoda				
Echinodermata				0.1

APPENDIX TABLE A.7. STATION 8, NEW SAND ISLAND OUTFALL ZONE, CENTER, MĀMALA BAY, O'AHU

	SAMPLE			
	A	B	C	D
Chlorophyta				
<i>Halimeda</i> sp.	1.7	1.2	11.3	30.4
Foraminifera	0.1	0.2	0.1	1.7
Coelenterata				
Corals			0.2	1.0
Ectoprocta (Bryozoa)		0.1	0.8	0.5
Sipunculida				
Annelida				
Mollusca				
Fragments		2.8	4.5	3.4
<i>Pinna</i>	31.6			
Arthropoda		0.1	0.1	0.1
Echinodermata			0.6	0.3

APPENDIX TABLE A.8. STATION 9, NEW SAND ISLAND OUTFALL ZONE, SOUTH, MĀMALA BAY, O'AHU

	SAMPLE			
	A	B	C	D
Chlorophyta				
<i>Halimeda</i> sp.	5.7			
Foraminifera	0.6			
Coelenterata				
Corals	0.5			
Ectoprocta (Bryozoa)	0.6			
Sipunculida				
Annelida				
Mollusca				
Fragments				
<i>Pinna</i>		116.2	66.4	50.7
Arthropoda				
Echinodermata	0.1			

APPENDIX TABLE A.9. STATION 10, NEW SAND ISLAND OUTFALL ZONE,
WEST, MĀMALA BAY, O'AHU

	SAMPLE			
	A	B	CII	DII
Chlorophyta				
<i>Halimeda</i> sp.	0.1			
Foraminifera	0.1	0.1		
Coelenterata				
Corals	0.4	0.2		
Ectoprocta (Bryozoa)				
Sipunculida				
Annelida				
Mollusca				
Fragments	2.3			
<i>Pinna</i>		53.4		
Arthropoda				
Echinodermata				