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[12]Abstract (Purpose, method, results, conclusions)

An ecological study of the benthic and fish communities at Mokapu, Oahu, was completed in the summer of 1980 approximately three years subsequent to the installation of an ocean outfall by the City and County of Honolulu. Data were obtained from five transects between Mokapu Point on the northeastern tip of Oahu to Alala Point, approximately 6 034 m (3.75 miles) south, at depths of 6 to 24 m (20-80 ft). This study is subsequent to an initial survey completed in 1975 prior to outfall construction. Results show little or no effect from the operation of the outfall on the benthic and fish communities. There are no significant differences in the abundance, diversity, or composition of fishes from 1975 to 1980 except at the outfall site where new substrate was formed by construction. Between the 1975 and 1980 studies there are some differences in coral species cover indices, which are attributed to patchy substrate distribution rather than stress from the sewage outfall. Differences in species composition and distribution of micromolluscan assemblages may also be explained, at least in part, by patchy distribution of the substrate. Analysis of micromollusk assemblages shows that the proportions of dominant species in the assemblages of shallow and deep waters have remained constant over the years of study. In general the biotic community has not changed in the area studied over three years and equilibrium seems to have been reached in the benthic and fish communities at least for the present. The construction of the outfall, surrounding rock substrate, and the swift removal of effluent by vigorous water movement have contributed, in the case of fish populations at least, to increases in abundance.

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BENTHIC ECOSYSTEMS AND FISH POPULATIONS
OFF THE MŌKAPU OUTFALL:
A THIRD POST-INSTALLATION STUDY

Anthony R. Russo

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Technical Memorandum Report No. 65

June 1981

Supplemental Report

for

An Ecological Study of the Benthos and Fish Population
Off the Mōkapu, O'ahu Ocean Outfall:
A Third Postinstallation Study

City and County of Honolulu Contract No.: F-637-78

Principal Investigator: Anthony R. Russo

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ABSTRACT

An ecological study of the benthic and fish communities at Mōkapu, O'ahu, was completed in the summer of 1980 approximately three years subsequent to the installation of an ocean outfall by the City and County of Honolulu. Data were obtained from five transects between Mōkapu Point on the northeastern tip of O'ahu to Alāla Point, approximately 6 034 m (3.75 miles) south, at depths of 6 to 24 m (20-80 ft). This study is subsequent to an initial survey completed in 1975 prior to outfall construction.

Results show little or no effect from the operation of the outfall on the benthic and fish communities. There are no significant differences in the abundance, diversity, or composition of fishes from 1975 to 1980 except at the outfall site where new substrate was formed by construction. Between the 1975 and 1980 studies there are some differences in coral species cover indices, which are attributed to patchy substrate distribution rather than stress from the sewage outfall. Differences in species composition and distribution of micromolluscan assemblages may also be explained, at least in part, by patchy distribution of the substrate. Analysis of micromollusk assemblages shows that the proportions of dominant species in the assemblages of shallow and deep water sites have remained fairly constant over the years of study.

In general the biotic community has not changed in the area studied over three years and equilibrium seems to have been reached in the benthic and fish communities, at least for the present. The construction of the outfall, surrounding rock substrate, and the swift removal of effluent by vigorous water movement have contributed, in the case of fish populations at least, to increases in abundance.

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BENTHIC ECOSYSTEM AND FISH POPULATION

Anthony R. Russo

INTRODUCTION

Since the installation of a sewage outfall off Mōkapu Point, O'ahu, Hawai'i in 1975, three ecological surveys of the area surrounding the discharge have been made. The first and second postinstallation surveys were respectively made in 1978 and 1979 (Russo, Dollar, and Kay 1979, 1980). The results of the third survey are presented in this report. Prior to the commencement of discharge in 1977, a preliminary survey of benthic and fish communities was completed in December of 1975 (Russo, Dollar, and Kay 1977). The outfall, which discharges 0.3 m^3/s (9 mgd) of advanced primary treated sewage, is 1 500 m in length, including the 293 m long diffuser, and lies in 26 to 31 m of water. The outfall site is located south of Mōkapu Point and north of Kailua Bay on O'ahu, Hawai'i (Fig. 1). Station A is located 1 600 m north of the outfall off Mōkapu Point, Station B coincides with the outfall, Station C is north of Kailua Bay and Mōkōlea Rock, Station D in Kailua Bay, and Station E off Alāla Point.

METHODS AND MATERIALS

Using scuba, fish counts were made along a 30 m transect line 3 m on both sides at depths of 6, 12, and 18 m. At Station B fish counts were made at 6, 12, 18, 26, and 30 m (on the diffuser). The number of species and their relative abundances were recorded for each count and similarity indices were used to measure constancy of fish community structure from one year to the next. See Russo, Dollar, and Kay (1980) for details and a discussion of the use of similarity indices in ecological surveys. Photographs were taken at the outfall and the presence of macroinvertebrates was recorded. Using $\frac{1}{4}$-m^2 quadrats thrown randomly at each dive site, macroscopic algae were cropped and later identified and weighed dry.

RESULTS AND DISCUSSION

Figure 2 shows the comparative standing stocks of total fish counted at each station for each year surveyed. There was no significant difference in

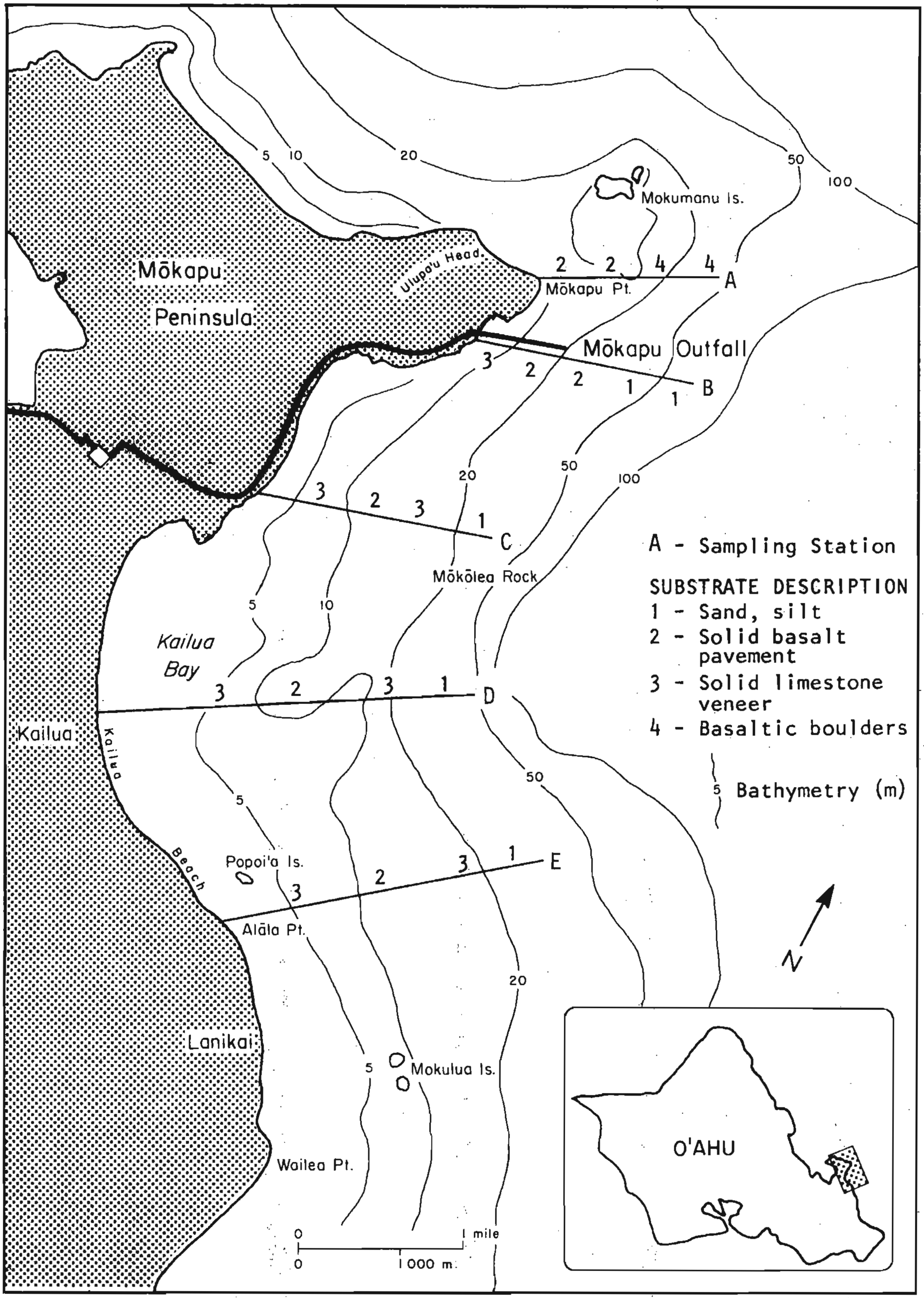
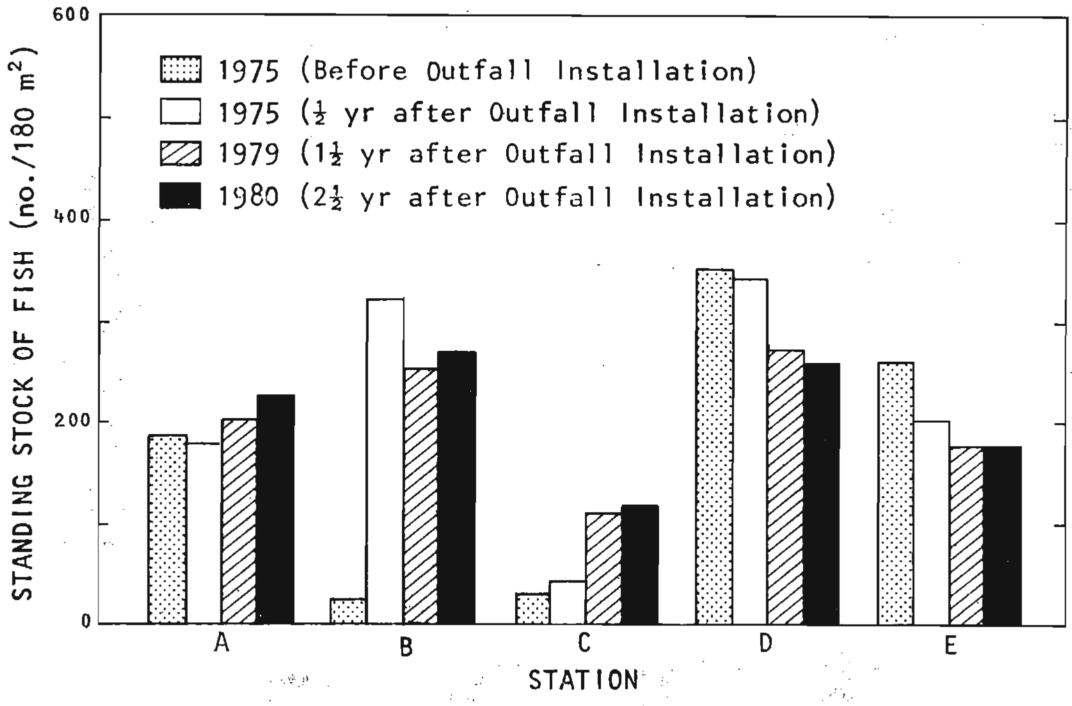


Figure 1. Sampling stations, Mōkapu, O'ahu, Hawai'i

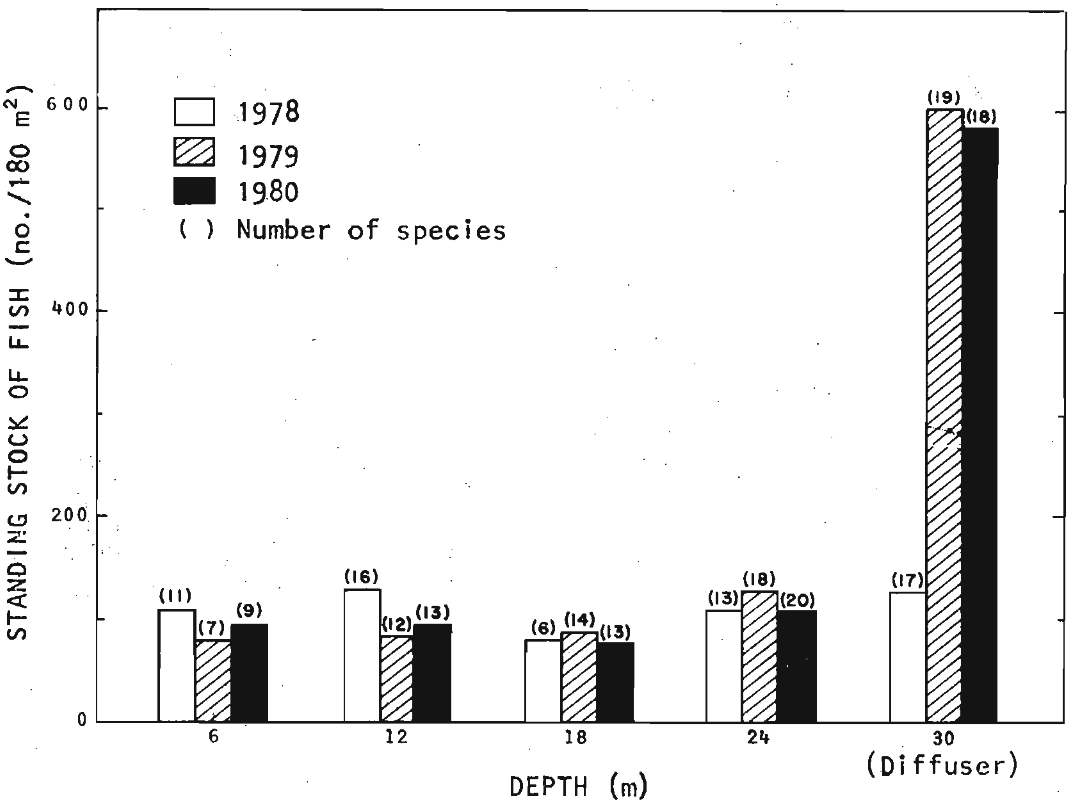


NOTE: Outfall became operational in December 1977.

Figure 2. Comparative standing stocks of total fish, Stations A-E, 1975, 1978-1980, Mōkapu, O'ahu, Hawai'i

fish abundance from between the 1979 and 1980 survey. Fish families which were predominant in 1979 did not change in relative numbers. The rudder-fish *Kyphosus bigibbus*, the lemon butterfly fish *Chaetodon miliaris*, the goatfishes *Mulloidichthys vanicolensis* and *Parupeneus porphyreus*, and the damselfish *Abudefduf abdominalis* were seen in 1980 along the outfall at depths from 18 to 26 m as in 1979. The snapper *Lutjanus kasmira* was seen in large numbers at these depths in 1979 and 1980. On the outfall the number of fish species and their relative abundances are shown in Figure 3. *Lutjanus kasmira* was still the dominant species over the diffuser representing approximately 90% of the relative abundance. Similarity indices comparing fish community structure in 1979 with 1980 show virtually no differences (Table 1). Indices over 0.50 indicate similarity between the 1979 and 1980 surveys (see Russo, Dollar, and Kay 1980, pp. 3, 5).

Plankton feeding fish were dominant over the outfall probably adapted to foraging for plankton and organic particles in the water column above the rocky substratum. Again, as in 1979, large aggregations of the plank-



NOTE: Ninety percent of fish counted in 1979 and 1980 were of one species, *Lutjanus kasmira*.

Figure 3. Relative abundance of fish, at Station B on the outfall, 1978-1980, Mōkapu, O'ahu, Hawai'i

tonivorous damselfish (*Abudefduf abdominalis*) were seen above the outfall. For a summary of fish abundance see Table 2.

In general the biomass of algae did not change from that recorded in 1979. *Lyngbya* was recorded in significant amounts (200 g/m^2 dry wt.) at depths between 18 to 31 m on the outfall. There was no apparent change in biomass from 1979. The presence of this blue-green filamentous algae probably indicates a utilization of the phosphate rich sewage effluent which was reported by Laws (1979).

Sea urchins were seen in aggregations along the outfall and under the rocks covering the outfall pipe. As in 1979 these urchins were predominantly of the genus *Echinothrix*. Counts indicate that there was no significant change (5-8/m^2) from the 1979 counts. Small coral heads (*Pocillopora meandrina*) were still present on the rocks over the outfall. Bryozoan colo-

TABLE 1. COMPARATIVE DATA FOR FISH POPULATIONS, MŌKAPU OUTFALL, 1978-1980, O'AHU, HAWAI'I

SUBSTATION	DEPTH (m)	SIMILARITY INDEX* SI (1978-1979)	MI (1978-1979)	SI (1979-1980)	MI (1979-1980)
A-20	6	.70	.75	.77	.77
A-40	12	.45	.77	.66	.75
A-60	18	.73	.85	.80	.83
Off Outfall					
B-20	6	.40	.78	.70	.77
B-40	12	.40	.75	.69	.73
B-60	18	0	--	--	--
On Outfall					
B-20	6	.67	.77	.71	.75
B-40	12	.50	.73	.68	.77
B-60	18	.32	.58	.72	.81
B-80	24	.46	.59	.69	.78
On Diffuser					
B-100	31	.45	.37	.76	.74
C-20	6	.41	.71	.67	.69
C-40	12	.40	.42	.58	.68
C-60	18	.31	.23	.67	.70
D-20	6	.50	.69	.67	.69
D-40	12	.53	.73	.73	.78
D-60	18	.63	.78	.65	.77
E-20	6	.50	.65	.66	.71
E-40	12	.57	.71	.69	.71
E-60	18	.50	.70	.72	.73

*SI = Sorensen similarity index, MI = Morisita similarity index.

nies (*Triphyllozoon hirsutum*) were observed near the diffuser but in smaller clumps and less abundance than recorded in 1978 when they were reported as very abundant. There is no explanation for this at this time. The fact that they are still present may indicate that the organic load of the surrounding water is still high enough to provide abundant material for filter feeding, while on the other hand the rapid dispersion of the effluent by water movement keeps the organic load low enough to prevent destruction of the bryozoans.

TABLE 2. FISH SPECIES LIST, 1975, 1978-1980, MŌKAPU OUTFALL, O'AHU, HAWAI'I

FAMILY AND GENUS		STATION A 20	STATION A 40	STATION A 60	STATION A 80	STATION B Outfall Off 20	STATION B Outfall On 20	STATION B Outfall Off 40	STATION B Outfall On 40	STATION B Outfall Off 60	STATION B Outfall On 60	STATION B Outfall On 80	STATION B Diffuser 100	STATION C 20	STATION C 40	STATION C 60	STATION D 20	STATION D 40	STATION D 60	STATION D 80	STATION E 20	STATION E 40	STATION E 60	GENUS TOTAL	FAMILY TOTAL
ACANTHURIDAE (Surgeonfishes)																									*1266*
Acanthurus achilles	1975	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	316*
(paku'iku'i, achilles tang)																									223†
A. leucopareius	1980	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	8	2	4	-	2	-	-	21	>437‡
(maikoiko)	1979	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1	-	3	-	-	15	290§
	1978	7	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	12	
A. mata (pualu)	1980	-	3	-	-	-	-	-	-	-	-	-	-	1	4	-	--	-	-	-	-	5	2	15	
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	7	-	-	20	
A. nigrofuscus	1980	5	14	4	6	-	-	-	-	-	-	-	-	4	-	7	--	6	2	-	15	7	-	70	
	1979	9	8	2	5	-	-	-	-	-	-	-	-	4	1	7	--	3	3	-	10	8	-	60	
	1978	37	5	8	-	20	-	-	5	-	-	-	9	-	14	-	14	5	2	-	16	-	-	136	
	1975	5	2	3	7	--	-	-	-	-	-	-	-	-	--	-	3	15	-	-	--	4	-	39	
A. nigroris (maiko)	1978	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	
A. olivaceus (na'ena'e)	1980	-	2	2	-	-	-	-	2	2	6	11	13	-	-	-	1	-	-	-	-	-	-	39	
	1978	-	2	-	-	-	-	-	5	-	-	18	>15	-	-	-	1	-	-	-	-	2	-	>43	
	1975	10	8	3	-	-	-	-	-	-	-	--	--	-	-	-	-	-	-	-	-	4	-	25	
A. triostegus[1]	1980	5	2	-	-	-	-	2	11	-	-	2	-	12	2	-	-	-	-	-	-	-	-	36	
(manini, convict tang)	1978	2	-	-	-	4	-	-	15	-	-	-	4	7	-	-	6	-	8	-	-	2	6	54	
	1975	10	15	-	-	3[2]	-	-	--	-	-	-	-	6	-	-	15	-	-	-	-	-	7	56	
Acanthurus spp.	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	
Ctenochaetus strigosus	1980	6	2	10	5	2	7	2	11	-	10	12	16	-	-	-	2	1	20	-	9	3	-	118	
(kole)	1979	8	-	9	10	2	8	2	8	-	14	15	14	-	-	-	-	3	26	-	8	2	-	129	
	1978	2	-	7	21	-	6	-	-	-	5	--	4	-	3	-	5	8	19	17	7	21	18	143	
	1975	8	-	7	--	-	-	-	-	-	-	--	-	-	-	-	-	10	16	--	4	40	25	110	
Naso literatus	1980	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	1979	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	1978	2	-	2	1	-	2	-	3	-	-	-	4	-	-	-	1	-	-	-	-	-	1	16	
	1975	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	4	-	11	
N. unicornis	1980	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	
(kala, unicorn fish)	1979	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
	1978	-	-	-	-	-	3	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	7	
Zanclus cornutus[3]	1980	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	5	
	1979	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	4	2	-	-	-	-	9	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	3	

*1980. †1979. ‡1978. §1975.
[1]Formerly, *A. sandvicensis*.
[2]No outfall.
[3]Formerly, *Z. canescens*.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A 20	40	60	80	STATION B Outfall Off 20	On 20	Off 40	On 40	Off 60	On 60	On 80	Diffuser 100	STATION C 20	40	60	STATION D 20	40	60	80	STATION E 20	40	60	GENUS TOTAL	FAMILY TOTAL
ACANTHURIDAE—*Continued*																									
Zebrasoma flavescens	1980	-	2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	
(lau'ipala, yellow tang)	1979	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	1	-	7	
	1978	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	4	
	1975	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	15	-	-	-	2	29	
AULOSTOMIDAE (Trumpetfishes)																									*10*
Aulostomus chinensis	1980	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	4	4*
	1979	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	3†
	1978	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1‡
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	2§
BALISTIDAE (Triggerfishes or humuhumus)																									*126*
Melichthys niger[1]	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	28*
M. vidua	1980	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	27†
(humuhumuhi'ukole,	1979	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	32‡
humuhumuuli)	1978	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	39§
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-	4	
Rhinecanthus aculeatus	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	
(humuhumunukunukuapua'a)	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
R. rectangulus	1980	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	-	-	-	-	-	3	
	1979	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	3	
	1978	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Sufflamen bursa[2]	1980	5	2	2	2	-	1	2	-	-	-	2	2	-	-	1	-	1	-	-	-	-	2	22	
	1979	3	3	3	1	1	-	2	-	-	-	2	2	-	1	1	-	1	1	-	-	-	2	23	
	1978	3	7	2	2	-	-	2	-	-	-	-	-	1	1	-	3	-	1	4	-	-	2	28	
	1975	3	8	-	-	-	-	-	-	-	-	-	-	-	1	-	1	5	2	-	-	6	5	31	
Balistes spp.	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	
BLENIIDAE (Comb-toothed fishes)																									*3*
Cirripectus variolosus	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2	2*
	1979																1							1	1†
CARANGIDAE (Jackfishes)																									*7*
Caranx ignobilis	1980	-	-	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	5	5*
(pa'u'u, ulua, papio [young])	1979	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2†
Caranx sp.	1979	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	

*1980. †1979. ‡1978. §1975.
[1]Formerly, *M. vidua*.
[2]Formerly, *Balistes* genus.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A				STATION B Outfall							Diffuser	STATION C			STATION D				STATION E			GENUS TOTAL	FAMILY TOTAL
		10	40	60	80	Off 20	On 20	Off 40	On 40	Off 60	On 60	On 80	100	20	40	60	20	40	60	80	20	40	60		
CIRRHITIDAE (Hawkfishes)																									*30*
Cirrhites spp.	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	7*
	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	10†
Paracirrhites arcatus	1980	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	9‡
	1979	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4§
	1978	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	6	
P. fosteri	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	1	-	-	-	-	4	
	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	1	1	-	-	-	-	7	
	1978	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	3	
	1975	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
CHAETODONTIDAE (Butterfly fishes)																									*7760*
Chaetodon fremblii	1980	-	-	-	-	4	-	-	2	-	4	-	-	-	-	-	-	-	-	-	-	1	5	16	>170*
	1979	-	-	-	-	2	-	-	2	-	2	-	-	-	-	2	-	-	-	-	-	1	3	12	>170†
	1978	-	-	-	3	-	-	1	2	-	-	2	2	-	-	2	2	-	-	-	-	1	1	16	>216‡
	1975	3	-	8	-	-	-	-	-	-	-	-	-	-	-	-	3	5	2	-	-	-	4	25	204§
C. kleinni[1]	1979	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	1978	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	
C. lunula	1980	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	7	
	1979	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	1978	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	-	-	-	1	6	
C. miliaris	1980	-	12	17	5	-	>25	-	16	-	3	8	10	-	2	-	-	3	-	-	-	-	1	>102	
	1979	-	15	12	5	-	>20	2	11	-	6	10	12	-	1	1	-	6	-	-	-	-	3	>104	
	1978	-	--	1	-	-	>30	-	>20	-	>20	>20	8	-	-	3	-	-	-	2	2	1	3	>110	
	1975	-	4	50	-	-	--	-	--	-	--	--	-	-	-	-	-	11	28	2	-	-	-	95	
C. multicinctus	1980	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1	5	2	-	-	-	-	11	
	1979	4	-	5	3	-	-	-	-	-	-	-	-	1	-	-	1	9	5	-	-	-	-	28	
	1978	4	-	6	5	-	-	-	-	-	-	-	-	-	-	-	1	8	-	1	-	3	4	32	
	1975	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	13	
Chaetodon sp.	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	
C. ornatissimus	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	2	4	-	9	
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	4	
C. quadrimaculatus	1980	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	2	-	-	5	
	1978	1	3	7	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	13	
	1975	4	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	17	

*1980. †1979. ‡1978. §1975.
[1]Formerly, *C. corallicola*.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A 20	A 40	A 60	A 80	STATION B Outfall Off 20	On 20	Off 40	On 40	Off 60	On 60	On 80	Diffuser 100	STATION C 20	C 40	C 60	STATION D 20	D 40	D 60	D 80	STATION E 20	E 40	E 60	GENUS TOTAL	FAMILY TOTAL
CHAETODONTIDAE—*Continued*																									
Chaetodon unimaculatus	1980	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	2	-	8	-	-	4	-	17	
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	13	2	-	7	-	30	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	--	-	-	10	8	21	
Forcipiger flavissimus	1980	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
	1979	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	-	11	-	-	2	-	17	
	1978	-	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	1	-	9	
	1975	4	-	8	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4	-	-	-	-	20	
F. longirostris	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2[1]	-	-	-	-	2	
DIODONTIDAE (Spiny Puffers)																									7
Diodon hystrix	1980	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	3	3*
('o'opukawa)	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1†
	1975	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	3	3§
FISTULARIIDAE (Flute mouth fishes)																									8
Fistularia commersonii[2]	1980	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	2	2*
	1979	-	-	-	-	-	-	-	-	-	4	-	-	-	1	-	-	-	-	-	-	-	-	5	5†
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1§
HOLOCENTRIDAE (Squirrelfishes)																									27
Adioryx sp.[3]	1980	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	15	15*
	1979	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	2†
Myripristis argyromus	1975	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10§
KYPHOSIDAE (nenues or rudder fishes)																									>126
Kyphosus biggibus[4]	1980	-	-	-	-	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	17	17*
	1979	-	-	-	-	-	-	-	-	-	-	4	15	-	-	-	-	-	-	-	-	-	-	19	19†
	1978	-	-	-	-	-	30	>20	-	-	>20	>20	--	-	-	-	-	-	-	-	-	-	-	>90	90‡
LABRIDAE (wrasses or hinaleas)																									954
Anampses cuvier[5]	1978	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	234*
A. chrysocephalus[6]	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	265†
Anampses spp.	1980	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	5	279‡
	1979	-	1	-	1	1	-	1	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	7	176§
	1978	-	-	-	-	2[1]	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	4	

*1980. †1979. ‡1978. §1975.
[1]No outfall.
[2]Formerly, *F. petimba.*
[3]Formerly, *Holocentrus* genus.
[4]Formerly, *K. cinerascens.*
[5]Formerly, *A. cuvieri.*
[6]Formerly, *A. rubrocaudatus.*

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A				STATION B								STATION C			STATION D				STATION E			GENUS TOTAL	FAMILY TOTAL
						Outfall							Diffuser												
						Off	On	Off	On	Off	On	On													
		20	40	60	80	20	20	40	40	60	60	80	100	20	40	60	20	40	60	80	20	40	60		
LABRIDAE—*Continued*																									
Bodianus bilunulatus	1980	1	2	1	-	1	-	-	2	-	1	1	-	-	-	-	1	-	1	-	-	1	2	14	
	1979	3	-	-	-	1	-	2	2	-	1	3	-	-	-	-	1	-	1	-	-	-	4	18	
	1978	-	-	-	-	-	-	-	2	-	-	5	-	-	-	-	1	-	1	-	-	-	2	11	
	1975	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	7	
Coris ballieui	1978	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	
C. flavovittatus (hilu)	1978	-	-	-	-	2[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	
C. gaimard (lolo)	1978	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	
Labroides phthirophagus	1980	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	3	
	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
	1975	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	7	
Stethojulis balteata[2]	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	
Thalassoma ballieui	1980	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	1	-	10	
	1979	1	-	-	-	-	-	1	-	-	-	-	2	-	-	-	1	3	1	-	1	3	-	13	
	1978	8	2	-	-	-	-	-	5	-	-	-	-	-	-	-	1	2	-	-	-	2	5	25	
	1975	2	5	19	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	1	5	6	42	
T. dupperey[3]	1980	20	17	7	17	6	10	3	-	-	-	6	11	15	11	9	22	8	3	-	20	14	3	202	
	1979	14	19	12	13	10	6	4	-	-	-	9	16	12	18	11	18	6	9	-	25	19	4	225	
	1978	18	30	21	20	29	-	3	4	4	-	5	3	2	6	--	18	15	9	10	12	17	4	230	
	1975	15	7	19	--	--	-	-	-	-	-	-	-	-	6	--	16	16	17	--	12	6	5	119	
LETHRINIDAE[4] (Snapperfish)																									*1*
Monotaxis grandoculis (Mu, mamamu)	1978	-	-	-	-	1[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1‡
LUTJANIDAE ('opakapakas or snappers)																									*>1246*
Lutjanus kasmira	1980	-	-	-	-	-	-	5	21	-	>20	>25	>500	-	-	-	-	5	13	-	3	-	-	>592	>592*
	1979	-	-	-	-	-	-	-	17	-	>15	35	>500	-	-	-	-	-	21	-	-	-	-	>588	>588†
	1978	-	-	-	-	-	-	-	--	-	--	10	>15	-	-	-	-	-	41	-	-	-	-	>66	>66‡
MONOCANTHIDAE (Filefishes)																									*151*
Pervagor spilosoma ('oili uwiwi)	1980	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	--	-	1	-	-	-	-	2	2*
	1979	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	--	-	1	-	-	-	-	3	3†
	1978	3	4	3	1	3	-	-	-	-	-	-	-	2	3	1	--	3	1	-	1	-	-	25	25‡
	1975	15	35	10	-	6[1]	-	-	-	-	-	-	-	5	15	10	10	3	-	-	4	6	2	121	121§

*1980. †1979. ‡1978. §1975.
[1]No outfall.
[2]Formerly, *S. axillaris*.
[3]Formerly, *T. duperreyi*.
[4]Formerly, SPARIDAE.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A				STATION B								STATION C			STATION D				STATION E			GENUS TOTAL	FAMILY TOTAL
						Outfall							Diffuser												
						Off	On	Off	On	Off	On	On													
		20	40	60	80	20	20	40	40	60	60	80	100	20	40	60	20	40	60	80	20	40	60		
MULLIDAE (Goatfishes)																									*>620*
Mulloidichthys	1980	-	2	2	22	-	-	-	-	-	-	-	--	-	-	-	-	1	1	-	1	2	3	34	>201*
flavolineatus[1]	1979	-	-	2	8	-	-	-	-	-	-	-	--	1	-	-	-	-	-	-	-	-	3	14	>193†
(weke, weke'a'a)	1978	-	-	1	-	-	-	-	-	-	-	-	>20	-	-	-	-	-	-	3	-	-	-	>24	>143‡
	1975	-	-	2	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	30	-	32	83§
M. vanicolensis[2]	1980	-	-	-	-	-	17	-	10	4	>25	2	>20	-	1	1	--	-	-	-	-	-	-	>80	
(weke'ula)	1979	-	-	-	-	2	12	-	13	4	>15	7	25	-	-	2	--	-	-	-	-	-	-	>80	
	1978	-	-	-	-	-	10	2	>20	-	>20	>20	--	-	-	-	--	-	-	-	-	-	-	>72	
	1975	-	-	-	-	-	--	-	--	-	--	--	--	-	-	-	10	-	-	-	-	-	-	10	
Parupeneus bifasciatus (munu)	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	
P. cyclostomas[3]	1980	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	3	
	1979	-	-	3	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	6	
P. multifasciatus	1980	9	-	-	3	-	2	-	-	11	-	7	3	-	-	8	1	13	1	-	1	2	7	68	
(moano)	1979	5	-	2	6	-	-	-	-	6	-	8	7	2	1	4	1	15	2	-	-	2	5	66	
	1978	2	1	6	7	-	-	2	3	-	-	-	4	-	-	4	2	--	3	3	-	1	-	38	
	1975	4	2	7	-	-	-	-	-	-	-	-	-	2	-	-	2	2	-	-	2	-	-	21	
P. porphyreus (kumu)	1980	-	-	-	-	-	3	-	1	1	-	4	5	-	-	-	-	-	2	-	-	-	-	16	
	1979	-	-	-	-	-	4	-	-	-	3	6	12	-	-	-	-	-	2	-	-	-	-	27	
	1978	-	-	-	-	-	5	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	8	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	6	6	20	
MURAENIDAE (Moray Eels or Puhis)																									*1*
Gymnothorax flavimarginatus (puhipaka)	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1*
MYLIOBATIDAE (Eagle Rays)																									*1*
Aetobatus narinari (hihimanu, eagle ray)	1978	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1	1‡
OSTRACIONTIDAE (Boxfishes or Cowfishes)																									2
Ostracion meleagris[4]	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2	2‡

*1980. †1979. ‡1978. §1975.

[1] Formerly, *M. samoensis*.

[2] Formerly, *M. auriflamma*.

[3] Formerly, *P. chryserydros*.

[4] Formerly, *O. lentiginosus*.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A 20	STATION A 40	STATION A 60	STATION A 80	STATION B Outfall Off 20	STATION B Outfall On 20	STATION B Outfall Off 40	STATION B Outfall On 40	STATION B Outfall Off 60	STATION B Outfall On 60	STATION B Outfall On 80	STATION B Diffuser 100	STATION C 20	STATION C 40	STATION C 60	STATION D 20	STATION D 40	STATION D 60	STATION D 80	STATION E 20	STATION E 40	STATION E 60	GENUS TOTAL	FAMILY TOTAL
POMACANTHIDAE[1] (Angelfishes)																									*124*
Centropyge potteri	1980	5	6	8	2	-	-	-	7	-	2	9	4	-	-	3	-	2	8	-	-	-	-	56	56*
	1979	-	3	5	2	-	-	-	5	-	1	4	6	-	-	-	-	-	5	-	-	-	-	31	31†
	1978	-	-	6	11	-	-	-	-	-	-	-	-	-	-	1	1	7	3	1	1	-	-	31	31‡
	1975	-	-	3	--	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	6	6§
POMACENTRIDAE (Damselfishes)																									*>811*
Abudefduf abdominalis	1980	-	-	-	-	-	12	-	8	-	>15	4	--	-	-	-	--	-	-	-	-	--	-	>39	>253*
(maomao)	1979	-	-	-	-	-	10	-	10	-	>15	6	--	-	-	-	--	-	-	-	-	--	-	>41	>208†
	1978	-	-	-	-	-	15	-	>20	-	10	-	>10	-	-	-	--	-	2	-	2[2]	--	-	>59	>241‡
	1975	-	-	3	-	-	--	-	--	-	--	-	--	-	-	-	18	-	10	-	-	12	-	43	109§
Chromis leucurus	1980	11	1	3	7	-	-	-	-	-	-	-	-	-	-	2	6	15	>50	-	-	-	-	>95	
	1979	5	3	10	5	-	-	-	-	-	-	-	-	-	-	-	-	20	40	-	-	-	-	83	
	1978	2	-	8	7	-	-	-	-	-	-	-	-	-	-	-	-	--	8	-	-	3	-	28	
	1975	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	4	
C. ovalis	1980	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2	
	1979	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3	
C. vanderbilti	1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	5	15	
	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	3	10	
C. verater	1980	-	4	6	-	-	-	-	-	-	2	4	12	-	-	-	-	-	--	--	-	-	-	28	
	1979	-	-	4	-	-	-	-	-	-	-	6	8	-	-	-	-	-	--	--	-	-	-	18	
	1978	-	2	-	-	-	5	-	-	-	3	-	6	-	-	-	-	-	29	26	-	-	-	71	
	1975	-	6	-	-	-	-	-	-	-	-	-	-	-	-	4	-	5	4	--	-	-	-	19	
Chromis spp.	1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	5	
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	18	-	-	-	-	20	
Dascyllus albisella	1980	-	-	-	-	-	-	-	2	-	-	-	-	-	5	10	-	-	-	-	-	-	-	17	
	1979	-	-	-	-	-	-	-	-	3	-	-	-	-	-	7	-	-	-	-	-	-	-	10	
	1978	-	-	2	-	-	-	-	-	-	-	3	-	-	-	2	-	-	-	-	-	-	-	7	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	
Plectroglyphidodon imparipennis	1980	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	2	-	5	
	1979	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	5	4	-	12	
	1978	1	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	4	
P. johnstonianus	1980	2	2	-	-	-	-	-	-	-	-	-	-	-	3	-	7	3	-	-	7	-	-	24	
	1979	-	5	-	-	-	-	-	-	-	-	-	-	-	4	-	5	6	-	-	6	-	-	26	
	1978	4	5	-	-	4	-	-	-	-	-	-	-	-	1	-	1	-	2	3	-	2	-	22	
	1975	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	7	

*1980. †1979. ‡1978. §1975.

[1]Formerly, CHAETODONTIDAE.

TABLE 2.—*Continued*

FAMILY AND GENUS		STATION A				STATION B								STATION C			STATION D				STATION E			GENUS TOTAL	FAMILY TOTAL
						Outfall							Diffuser												
						Off	On	Off	On	Off	On	On													
		20	40	60	80	20	20	40	40	60	60	80	100	20	40	60	20	40	60	80	20	40	60		
POMACENTRIDAE—*Continued*																									
Stegastes fasciolatus[1]	1980	1	-	-	-	-	-	-	-	1	-	-	-	1	-	1	2	-	11	-	7	4	-	28	
	1978	2	2	-	-	-	-	-	-	-	-	2	-	-	-	-	1	9	2	-	4	6	-	28	
	1975	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	5	-	5	2	-	28	
PRIACANTHIDAE (Big Eye Fishes)																									*8*
Priacanthus cruentatus ('āweoweo)	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	8	8§
SCARIDAE (Sharpbacked Puffers)																									*88*
Scarus spp.	1980	2	4	3	-	-	2	-	-	-	3	6	5	-	-	-	-	-	-	-	-	-	2	27	27*
	1979	2	6	5	-	-	3	-	-	-	-	5	4	-	-	-	-	-	-	-	-	-	-	25	25†
	1978	2	-	1	2	-	2	-	4	-	-	-	-	-	-	-	-	4	1	2	-	-	-	18	18‡
	1975	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	3	-	18	18§
SCORPAENIDAE																									*1*
Scorpaena coniorta	1978	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1§
TETRAODONTIDAE (Sharpbacked Puffers)																									*38*
Canthigaster coronata[2]	1980	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	7*
	1979	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2	13†
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	11‡
	1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2	7§
C. janthinopterus[3] (Jack Taylor)	1980	-	1	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	6	
	1979	-	1	1	1	-	-	-	-	-	-	-	-	1	2	1	3	-	-	-	-	1	-	11	
	1978	-	-	1	4	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1	-	1	-	10	
	1975	2	-	1	-	2[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	

*1980. †1979. ‡1978. §1975.
[1]Formerly, *Pomacentrus jenkinsi*.
[2]Formerly, *C. cinctus*.
[3]Formerly, *C. jactator*.
[4]No outfall.

SUMMARY

An analysis of fish community structure in 1980 shows no large changes from that recorded in 1979. The total numbers of fish recorded and species richness was essentially unchanged. On the outfall diffuser the snapper *Lutjanus kasmira* was the dominant species of fish as in 1979. There were no significant changes in algal biomass at all stations. *Lyngbya* was still the dominant macrophyte present along the outfall and its biomass has not significantly changed from 1979 to 1980. Macroinvertebrates are still dominated by aggregations of sea urchins (*Echinothrix*) and bryozoan colonies (*Triphyllozoan hirsutum*), and are abundant but in smaller numbers than in 1979.

In general the fish community has not changed and the biotic component of the surrounding outfall ecosystem seems to have reached equilibrium, at least for the present. Since outfall discharge commenced in 1977 no adverse widespread changes were recorded at any of the stations surveyed. The construction of the outfall, the surrounding rock substrata, and the swift removal of effluent by vigorous water movement have all contributed to a healthy environment which, in the case of fish populations at least, have shown increases in productivity.

CORAL COMMUNITIES

Steven J. Dollar

METHODS

As in the previous Mōkapu surveys, coral communities and associated macroinvertebrates were surveyed in 1980 using a continuous photographic transect technique. This method involves mounting a Nikonos underwater camera and an electronic strobe unit on a tubular aluminum frame that is secured a fixed distance from a 1 x 0.7 m rectangular quadrat which has the same proportion as a 35-mm transparency. The quadrat-frame assembly assures that each photoquadrat records the same area of benthos, and is positioned so that the transect line bisects the long axis of the rectangular quadrat. A diver with knowledge of resident species identifies and visually estimates the areal coverage of all organisms larger than approximately 2 cm within each quadrat. Color slide transparencies are sequentially exposed at 12 random points on a 30 m transect line secured to the bottom of depths of 6, 12, and 18 m. Following the period of field investigation, the transect slides are projected onto a grid of similar dimensions as the quadrat frame, and the percent bottom cover of each species and substratum type is estimated for each transect. Benthic cover is a useful parameter for biological studies because it is more directly related to successful competition for substrate space, photosynthetic area, and exposure to planktonic food resources. It may also avoid biases which numbers bestow to small individuals and biomass bestows to larger or heavier organisms (Bohnsack 1979).

The most significant error of photoquadrat methods is that two-dimensional photographs are used to produce estimates of three-dimensional structure and, therefore, are biased in favor of flat or encrusting species. Also, this method samples only those species that are exposed to the view of the camera so that cryptic forms as well as organisms that generally avoid open light are not sampled. Communities where a canopy conceals an extensive understory require removal of the canopy for accurate photoquadrats. However, the practical advantages of photoquadrat sampling are numerous: the methodology requires little field or laboratory training experience, most species are easily and accurately identified from transparencies, and projection onto a grid yields a relatively precise and accurate estimate of cover. Color transparencies provide a permanent record which are easily duplicated, quickly analyzed, stored in a small amount of space, and easily sorted and catalogued. The major advantage is that photoquadrats contain much more information than could possibly be recorded by a diver when underwater time is restricted by cost, exposure, depth, or weather. Also, this sampling does not disturb the organisms present, an asset for long-term repetitive studies where documentation of in situ changes is required.

A reconnaissance dive was also conducted on the outfall diffuser pipe at a depth of approximately 40 m to observe and photograph the dominant characteristics of the benthic and fish communities occupying this area.

In the previous three surveys, five stations were sampled at four depths. However, results of these surveys showed virtually no effects at the two stations located farthest east of the outfall (D, E) and at the deepest depth at all stations (24 m). Therefore, these sampling sites were eliminated from the 1980 surveys.

Following the quantification of the community assemblages, several statistical methods were applied to the data. The Shannon-Wiener index of diversity (Pielou 1969) was used to calculate species-cover diversity, symbolized by $H_C = -\sum_{i=1}^{s} pi/\ln/pi$, where pi = proportion of coral cover of the ith species and s = the number of species. To compare the degree of similarity of the coral community assemblages between the three survey periods, the Morisita (1959) similarity coefficient was employed. This index, C_λ, represents the similarity, in terms of percent cover, between temporally separated communities where

$$C_\lambda(p) = \frac{2\sum_{i=1}^{\infty} p_1 i\, p_2 i}{[\lambda_1(p) + \lambda_2(p)]\sum_{i=1}^{\infty} p_1 i \sum_{i=1}^{\infty} p_2 i} \quad \text{and} \quad \lambda_1(p) = \frac{\sum_{i=1}^{\infty} p_1 i^2}{\left(\sum_{i=1}^{\infty} p_1 i\right)^2}$$

$$\lambda_2(p) = \frac{\sum_{i=1}^{\infty} p_2 (i)^2}{\left(\sum_{i=1}^{\infty} p_2 i\right)^2}$$

and $p_1 i$, $p_2 i$ equal the percent coverage of species i in the samples I and II.

RESULTS

Reef coral abundance (percent bottom cover), species richness (number of species), species diversity and similarity coefficients of coral communities in each of four sample periods are shown in Table 3. Graphical repre-

TABLE 3. PERCENT OF BENTHIC COVER BY CORAL SPECIES, STATIONS A-C, 1975, 1978-1980, MŌKAPU OUTFALL, O'AHU, HAWAI'I

SPECIES		STATION A			STATION B			STATION C		
		20	40	60	20	40	60	20	40	60
Pocillopora meandrina	1980	0.87	5.80	2.36	1.14	1.05	0.08	0.14	1.20	2.68
	1979	12.60	4.46	5.54	4.31	2.04	0.04	1.46	0.15	0
	1978	7.62	10.78	3.54	0.83	0.14	0.44	1.90	4.20	2.50
	1975	23.00	13.83	7.24	17.34	9.50	8.63	3.21	1.91	0.87
P. eydouxi	1980	0	0.80	0.14	0	0	0	0.27	0	0
Porites lobata	1980	4.90	5.30	4.50	1.27	0.35	0.11	17.00	21.60	13.75
	1979	11.85	10.00	21.70	7.92	7.73	0.08	11.45	13.54	0
	1978	7.05	7.70	10.60	3.95	0.69	0.09	2.47	26.37	10.53
	1975	8.50	16.73	19.70	4.59	34.30	30.30	4.13	8.19	4.73
P. compressa	1980	0	0	1.68	0	0.02	0	0.91	0	1.00
	1979	0	0	4.92	0	0.92	0	1.38	35.23	22.15
	1978	-	0.09	1.15	0	0	0	0.14	0.98	0
	1975	0.02	0.05	0.20	0.22	0.36	0.51	0.30	5.28	15.2
P. (synaraea) convexa	1980	0.31	0	0	0	0	0	0	0	0.20
	1979	0	0	0	0	0	0	0	0	31.08
P. brighami	1979	0	0.15	0	0.12	0	0	0	0	0
Montipora verrucosa	1980	6.15	0	0.54	0.16	0.05	0	0.54	0	0.68
	1979	0.77	0.69	1.46	0.04	1.58	0	1.15	5.23	4.46
	1978	0.09	0	0.15	0.05	0	0	0.35	0.41	0.80
	1975	0	0.02	0.16	0	0.19	0.68	0.47	6.45	3.68
M. patula	1980	0	0.12	0	0.16	0	0	2.45	4.20	1.00
	1979	0.31	1.23	0.23	0.31	1.31	0	1.54	24.00	34.00
	1978	0.19	0	0	0.06	0	0	0	1.55	0
	1975	0	0.30	0.31	2.62	2.47	3.46	0.63	60.45	67.71
M. flabellata	1975	0	0	0.02	0	0	0	0	0	0
Leptastrea purpurea	1980	4.87	0	0	0	0	0	0	0	0
	1979	2.31	0	0.77	0	0	0	0	0	1.38
	1978	0	0	0	0	0	0	0	0.47	0
	1975	0	0	0	0	0.05	0	0	0.02	0.01
Pavona varians	1979	0	0	0	0	0	0	0	0	0.15
	1975	0	0	0	0	0	0.11	0	0.28	0
P. duerdeni	1979	0	0.15	0.85	0	0	0	0	0	0.15
	1975	0	0	0	0	0.46	0	0	0	0
Palythoa tuberculosa	1980	0	0.25	0.04	0	0	0	0	0	0
	1979	0	0	0.46	0.31	0	0	1.46	0.46	0
	1978	0.14	0	0.04	0.58	0	0	0	0.06	0
	1975	0	0.05	0	4.70	0	0.43	0.33	0.09	0
Anthelia edmondsoni	1979	0	0	0	0.08	0	0	0	0	0
Zoanthus sp	1979	0	0	0	0	0	0	0	0.04	0

TABLE 3.—*Continued*

SPECIES		STATION A 20	STATION A 40	STATION A 60	STATION B 20	STATION B 40	STATION B 60	STATION C 20	STATION C 40	STATION C 60
Total Coral Cover	1980	17.10	12.27	9.26	2.73	1.47	0.19	21.31	27.00	19.31
	1979	27.85	16.53	35.93	13.09	13.58	0.12	18.44	78.65	93.37
	1978	15.09	18.57	15.48	5.47	0.83	0.53	4.86	34.04	13.83
	1975	31.52	30.98	27.63	29.59	47.33	44.12	9.07	82.67	92.20
Difference in Coral Cover	1979-1980	10.70*	3.08*	26.0*	10.34*	12.11*	0.08†	2.86†	51.65*	3.82*
	1978-1979	12.76*	1.89	21.02*	7.62*	12.75*	0.41	12.68*	44.61*	78.97*
	1975-1978	16.62	12.41	13.32	24.01	43.43	43.60	4.81	48.63	77.79
	1975-1979	3.86	14.30	7.71*	16.3	30.68	44.01	8.47*	4.02	1.18*
	1975-1980	14.37	17.38	18.33	26.72	45.86	43.92	12.23†	55.67	72.95
Species Cover Diversity, H'	1980	1.30	1.22	1.26	1.05	0.76	0.69	0.24	0.61	0.99
	1979	1.08	0.99	1.27	0.94	1.26	0.64	1.07	1.25	1.30
	1978	0.47	0.94	0.63	0.61	0.45	0.36	1.00	0.82	0.55
	1975	0.62	0.76	0.71	1.14	1.21	0.95	1.27	0.95	0.85
Similarity Index, C_2	1980-1979	0.516	0.905	0.217	0.681	0.335	0.166	0.973	0.287	0.204
	1979-1978	0.987	0.852	0.971	0.970	0.910	0.610	0.895	0.340	0.006
	1979-1975	0.892	0.955	0.959	0.669	0.940	0.870	0.930	0.610	0.690
	1980-1975	0.243	0.982	0.821	0.087	0.357	0.152	0.749	0.317	0.158

*Higher cover in 1979.
†Higher cover in 1980.

sentation of these parameters on each transect line at each station are shown in Figures 1 to 6.

Comparison of total coral cover during the 1980 survey with the three subsequent years (Fig. 4) indicate that cover was generally lower in 1980 relative to 1979. However, the 1980 cover values are very similar to those collected in 1978. As reported earlier (Russo, Dollar, and Kay 1980), these trends appear to be artifacts of patchiness of the benthos coupled with inexact implication of transect line locations, rather than effects of sewage effluent in time and space. Plots of species diversity (Fig. 4) and species richness (Fig. 5) also do not indicate any clear pattern relative to distance of station from the outfall or time since discharge commenced. Morisita similarity indices (Fig. 6) show relatively low values (<0.5) between the 1980, 1979, and 1975 surveys at certain transects at each station. This low degree of similarity again appears to be an artifact of patchiness and small sample size rather than a distinct change in community structure.

This result can be clearly seen when the percent cover of four dominant coral species at each transect is examined (Figs. 7-9). It is apparent that distribution of these corals on transects shows similar patterns between the 1975 to 1979 and the 1978 to 1980 survey pairs. This pairing of alternate

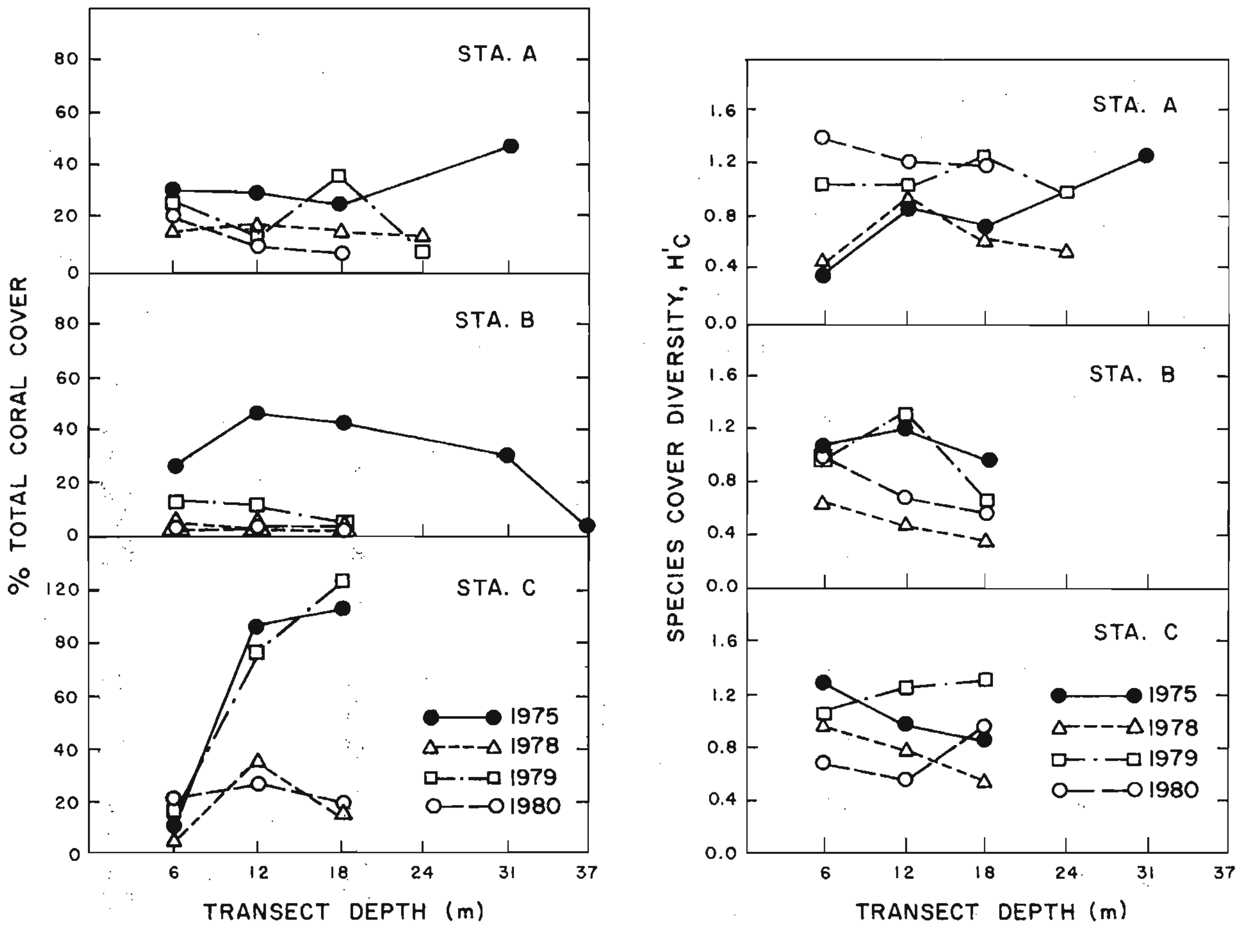


Figure 4. Variation of total coral cover and species cover diversity with depth at each transect, 1975, 1978-1980, Mōkapu Outfall, O'ahu, Hawai'i

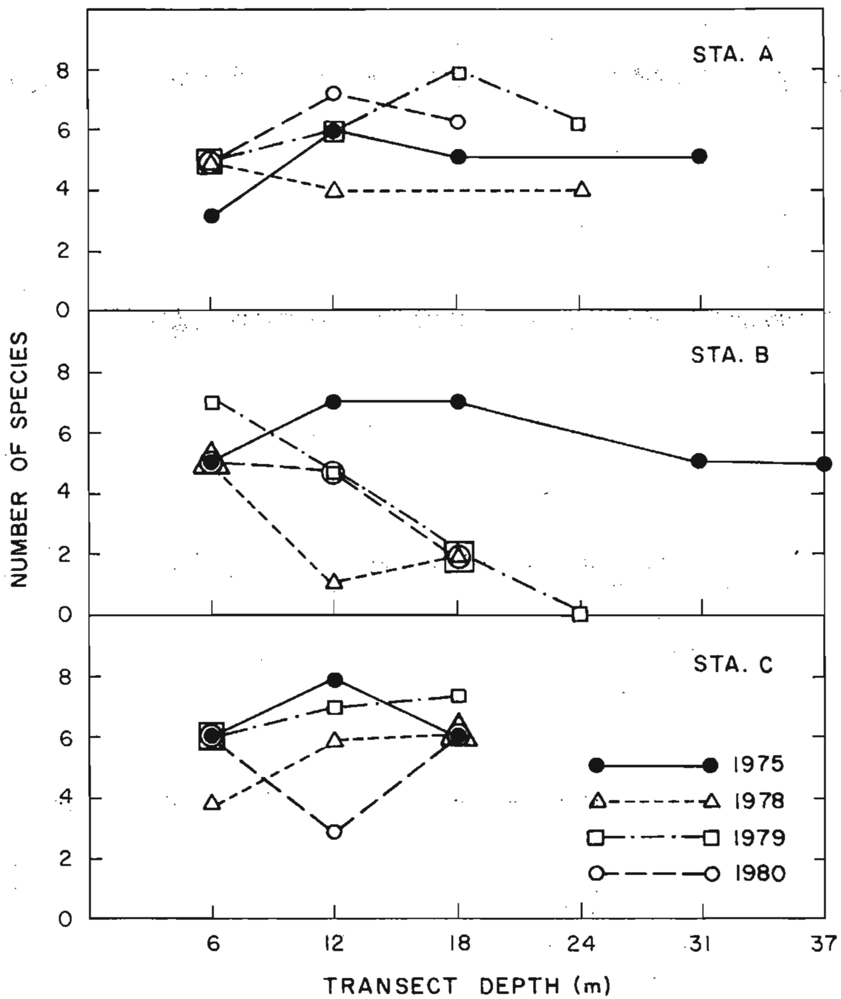


Figure 5. Total coral species richness (no. of species) for each transect, 1975, 1978-1980, Mōkapu Outfall, O'ahu, Hawai'i

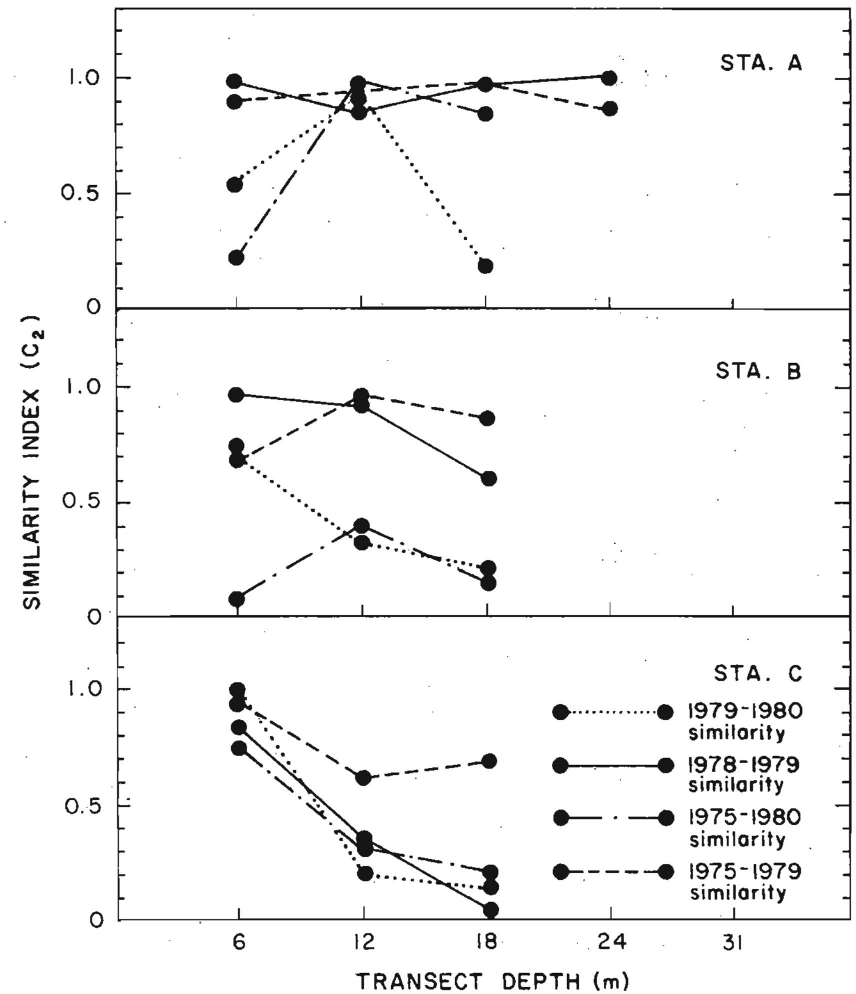


Figure 6. Morisita similarity index for coral cover at transect, 1979-1980, 1978-1979, 1975-1980, 1975-1979

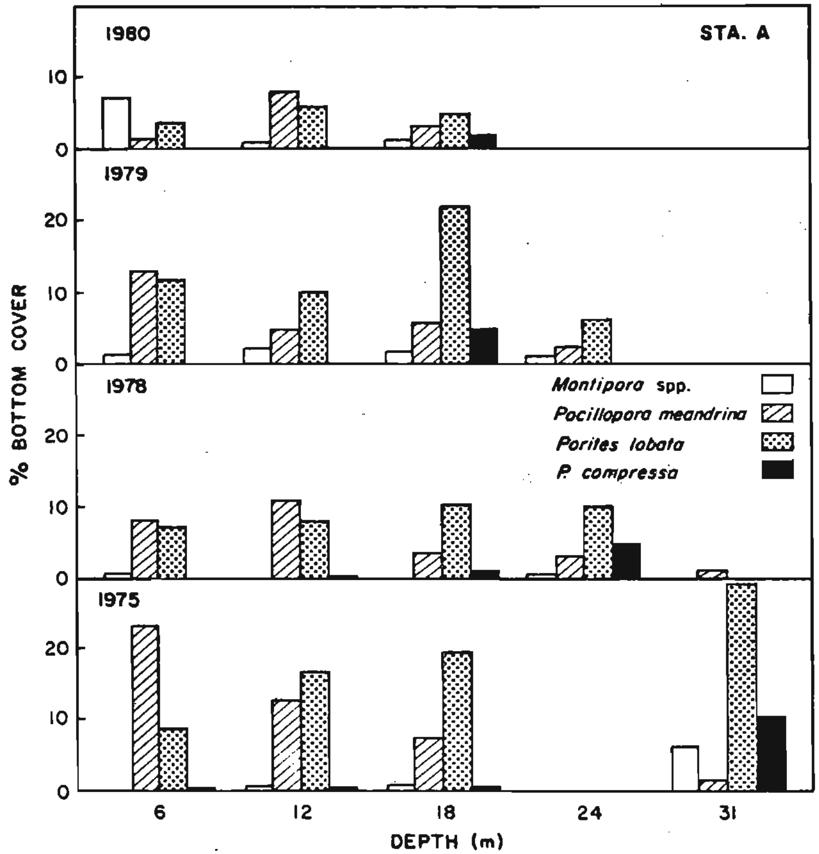


Figure 7. Percent cover of four dominant coral species, Station A, 1975, 1978-1980, Mōkapu Outfall, O'ahu, Hawai'i

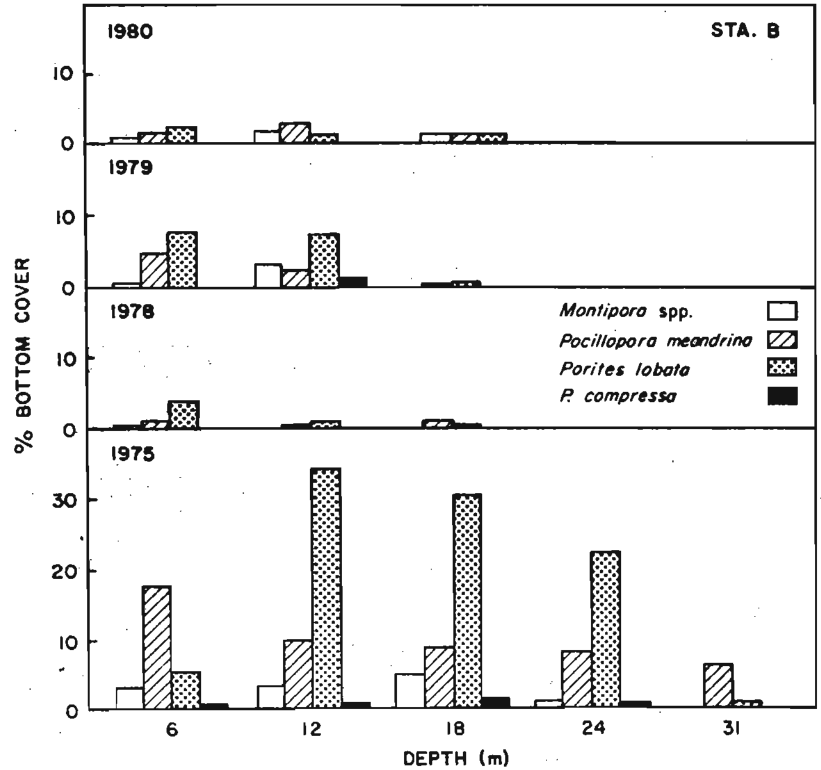


Figure 8. Percent cover of four dominant coral species, Station B, 1975, 1978-1980, Mōkapu Outfall, O'ahu, Hawai'i

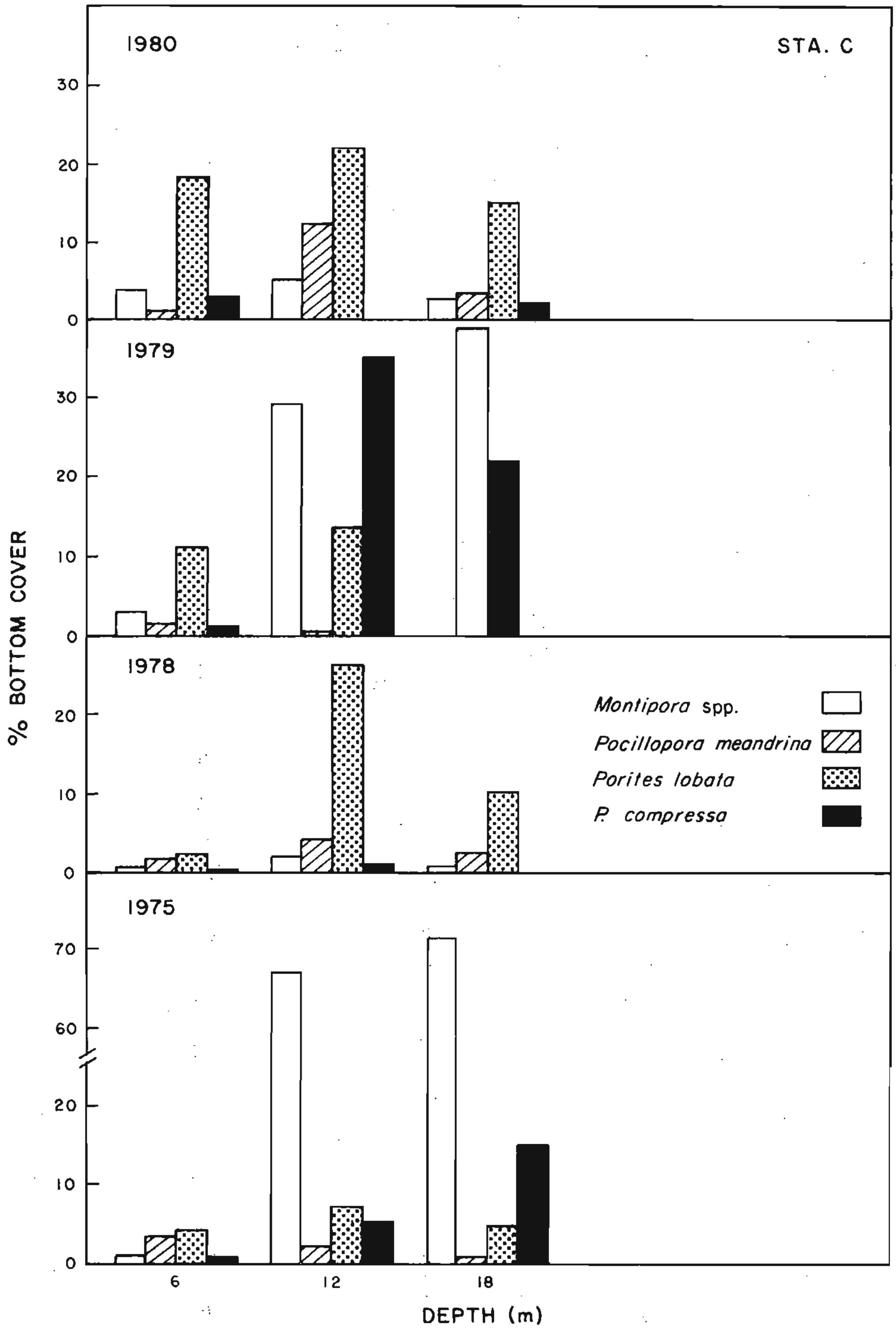


Figure 9. Percent cover of four dominant coral species, Station C, 1975, 1978-1980, Mōkapu Outfall, O'ahu, Hawai'i

year surveys indicates that the major variances in community structure observed in this monitoring program are not due to a sequential increase in sewage effluent but, rather, to an uneven distribution of coral substrate over the relatively featureless, nearshore shelf of the Kailua Bay area.

While quantitative methods do not delineate any clear patterns of environmental change to the benthos, several qualitative observations noted in the 1979 survey continued in 1980 to indicate what appears to be slight, sewage-related effluents. These include the uniform, short algal turf observed growing over previously bare limestone surfaces, especially at Station A. Also, the outfall pipe and armor rock continue to serve as a desirable habitat for coral colonization and other macroinvertebrates. *Pocillopora meandrina*, a pioneering coral species known to be an early colonizer on newly bared substrates, continues to be the major settler on the outfall structure from depths of 6 to 40 m. As in 1979, these new corals were numerous, but their small size (2-5 cm diameter) does not contribute substantially to increased coral cover in the very barren, flat region of the outfall.

Again, as in 1979, except for a few colonies near the diffuser there were no observations in 1980 of the bryozoan *Triphyllozoan hirsutum* that was relatively abundant in 1978. It was theorized that this drop in abundance may be due either to patchy distribution of the organism due to behavioral factors, such as gregarious larval settlement, or to environmental changes due to sewage. The main factors restricting bryozoans is sedimentation and availability of particulate organic material for feeding. While these factors did not appear to be significantly different in 1979 and 1980 compared to 1978 when the organism was extremely abundant, there may be subtle changes occurring with increased duration of discharge that is reflected in the disappearance of the bryozoan in recent years.

Other factors that were considered in the past to be potential responses to increased sewage discharge included substrate domination by the foloise green alga *Dictyosphaeria cavernosa*. This alga monopolized hard bottom cover in Kane'ōhe Bay in response to increased nutrient loads at the expense of reef corals. Results of observations in 1980 indicate that no such shift in substrate cover toward macroalgal domination is occurring in Kailua Bay in response to the Mōkapu Outfall.

Apparently, although increased nutrients in the water column are enhancing the growth of a thin film of blue-green algae (Russo, Dollar, and Kay 1980), they are not a factor that can result in an outbreak of the fleshy *Dictyophaeria*. The vigorous water movement, due to the high wave regime and consistent strong currents in the Mōkapu area, appears to be sufficient to keep Kailua Bay suboptimal for a *Dictyosphaeria* population increase.

DISCUSSION AND CONCLUSIONS

Marine environmental research dealing with man-induced perturbations has traditionally centered on delineating the extent of change in biotic community structure and water quality parameters. Such an approach has practical and direct management application in terms of defining a system's assimilative capacity, that is, at what level of perturbation can the ecosystem effectively and efficiently tolerate and/or process the potential pollutant without significant adverse effects. This information can provide scientifically based useful answers to the following questions: (1) Which areas affected by waste discharge are worthy of public concern and expenditure? (2) Which areas are so little affected that no action is required (Bascom, Mearns, and Word 1978)?

Results of four successive time series surveys conducted before and after sewage discharge commenced in Kailua Bay from the Mōkapu Pt. ocean outfall provide a good example of a marine environment that is not significantly affected by sewage effluent. Factors, such as low discharge volume, secondary treatment, high and consistent flushing rates, and naturally depauperate benthic community structure, combine to result in negligible detrimental impact, and, in fact, appear to be actually increasing the settlement rate of some corals by providing additional substrate complexity.

In conclusion, the Mōkapu ocean outfall appears to provide a very acceptable balance between utilization of the marine environment by man and maintenance of a high level of quality of the same environment.

MICROMOLLUSKS

E. Alison Kay

METHODS

Micromolluscan assemblages from Stations A, B, and C were analyzed as described previously (Russo, Dollar, and Kay 1977). Sediment samples obtained by hand by scuba divers at depths of 6 to 30 m were picked for shells under a binocular dissecting microscope from volumes of 25 cm^3. The micromollusks were then separated to species, counted and analyzed for species composition. Abundance was determined by dividing the number of shells by sediment volume. Figures for abundance are minimal in that they do not include fragments and juvenile shells too small for identification. Species composition is represented by relative abundance values for species and groups of species.

Similarity indices were computed for all sample pairs using a modification of the Sorenson similarity index and the similarity matrices reduced to dendrographs utilizing the program developed by Mueller-Dombois and Bridges (1975). Q mode analyses were produced where the arrangement of the hierarchy is by samples; similarity between groups of clusters on the dendrograph is represented by distance along the horizontal axis, and distance between any two adjacent samples on the vertical axis is proportional to dissimilarity.

RESULTS

Abundance and species composition of the micromolluscan assemblages for Stations A, B, and C are shown in Table 4 and Figure 10. In the dendrograph the samples are distinctly separated into two groups of stations, one generally at 6- to 12-m depths, the other at 18- to 27-m depths (Fig. 10).

As in the assemblages from the sampling efforts from 1975 to 1979, gastropods comprise the largest proportions (84-100%) of the assemblages, and most of the gastropods are epifaunal. The assemblages are thus made up largely of weed- or rubble-associated mollusks rather than representatives of infaunal assemblages.

At the shallow water stations average abundance is 5.4 shells/cm^3 and *Rissoina miltozona*, the Triphoridae, *Tricolia variabilis*, *Rissoina ambigua*,

TABLE 4. ABUNDANCE AND SPECIES COMPOSITION OF MICROMOLLUSKS, STATIONS A-C, 1980, MŌKAPU, O'AHU, HAWAI'I

	STATIONS							
	A		B			C		
	Depth (ft)							
	40	60	40*	60*	100†	20	40	60
No. of shells	241	281	128	75	393	179	61	69
Abundance								
No./cm^3	9.64	11.2	5.12	3.0	15.7	7.2	2.4	2.8
H'	3.5	3.7	3.2	3.0	3.5	3.2	2.9	3.1
% Composition								
Gastropods	99	97	99	93	84	100	98	94
Tricolia variabilis	10	3	9	14	2	4	12	6
Rissoina ambigua	8	3	5	8	<1	8	5	-
R. ephamilla	4	4	<1	3	5	-	-	1.5
R. miltozona	14	2	13	-	<1	35	18	11
Vitricithna marmorata	5	9	--	23	13	--	3	--
Bittium parcum/ zebrum	2	-	<1	--	--	15	2	--
Cerithidium perparvulum	<1	8	-	13	40	--	-	6
Diala varia	<1	2	2	--	18	--	-	8
Triphoridae	8	7	11	--	6	7	18	17

*Outfall.
†Diffuser.

and *Bittium* spp. are the dominant elements in the assemblages, comprising 47% of the assemblages. In the samples from the deep water clusters, average abundance is 9.96 shells/cm^3 and the dominant elements which comprise about 50% of the assemblages are the rissoids *Vitricithna marmorata*, *Diala varia*, *Tricolia*, and the Triphoridae. Abundance at the diffuser station (the 30-m depth sample on transect B included in the above figures) is 15.7 shells/cm^3.

COMPARISON OF MICROMOLLUSCAN ASSEMBLAGES

The repetitive surveys of five years permit comparison of sites and an assessment of the variability and stability of micromolluscan assemblages

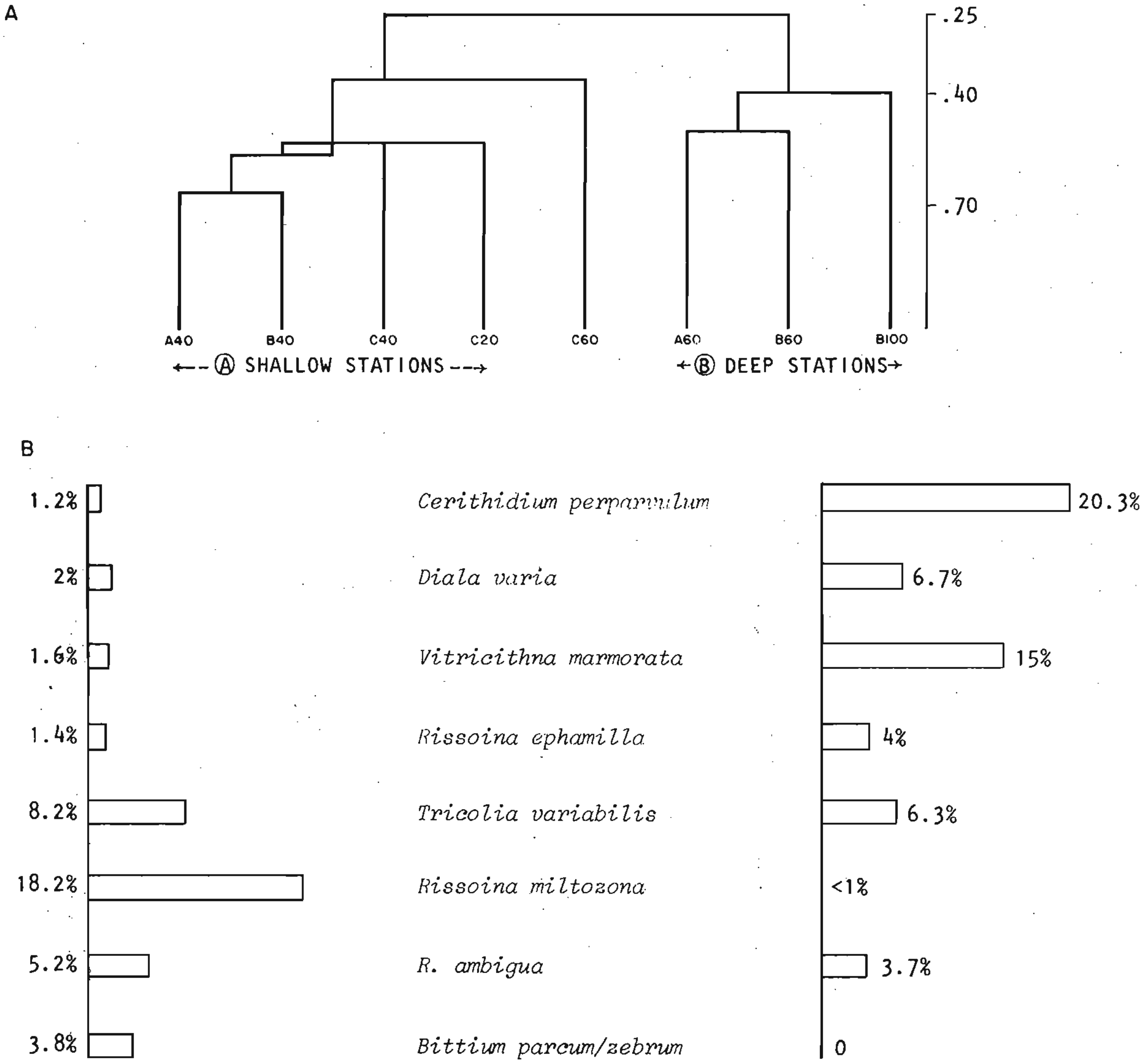


Figure 10. A. Dendrograph showing similarity indices between sites, Stations A-C; and B. Relative proportions of dominant species in assemblages, Mōkapu, O'ahu, Hawai'i

in the area.

The 1975 analysis indicated that the occurrence of several species of micromollusks appeared to be correlated with depth. Analysis of each year's transect data utilizing the Sorenson coefficient of similarity shows that the sites group into a shallow water series (6-18 m) and a deep water series (24-30 m). The distinction between these two depth groupings is especially marked in 1975, 1978, and 1980, but less noticeable in 1979. The proportions of dominant species in the assemblages for each of the two groups has remained fairly consistent over the years (Figs. 10-13), as has the ranking of the dominant species in each of the two depth groups (Table 5).

The variability which does appear both within samples and from year to year appears to reflect the variable nature of the substrate and habitat of the micromollusks (Russo, Dollar, and Kay 1980). The variability is largely associated with changing proportions of the same species of micromollusks and there has been no change in species composition to suggest that the diffuser discharge has produced effects such as, lowered salinity, anoxic conditions, or the build up of sludge, any one of which should be reflected by the occurrence of one or more indicator species. As confirmation of this conclusion, comparative data from 40 sediment samples from O'ahu are shown in Figures 14 and 15, and the mean range of the Mōkapu samples from each of the sampling years are shown for the two groups identified in the cluster analysis. The Mōkapu samples in general fit the pattern for both depth groups and habitats elsewhere on O'ahu.

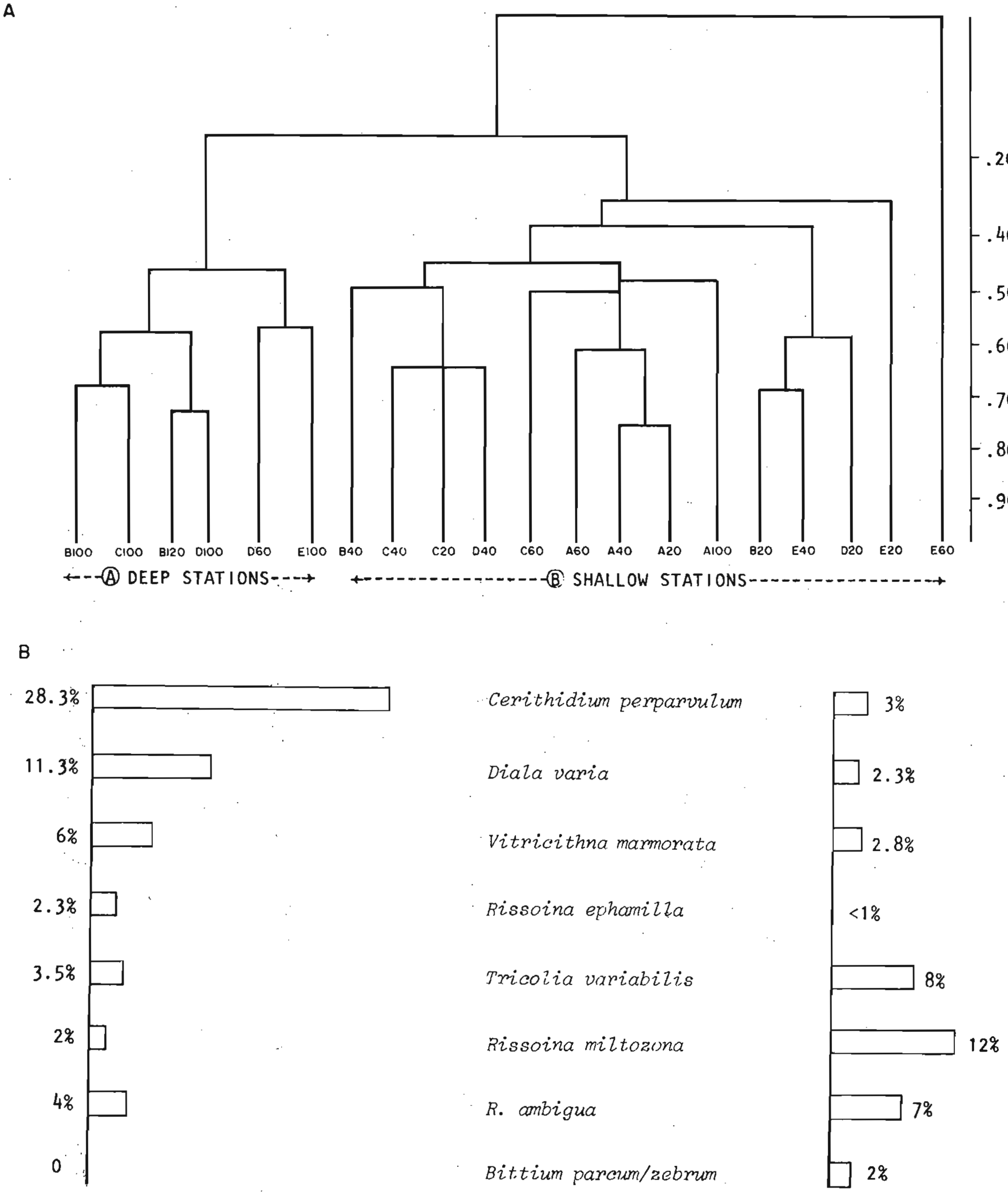


Figure 11. A. Dendrograph showing similarity indices between sites, Stations A-E; and B. Relative proportions of dominant species in assemblages, Mōkapu, O'ahu, Hawai'i

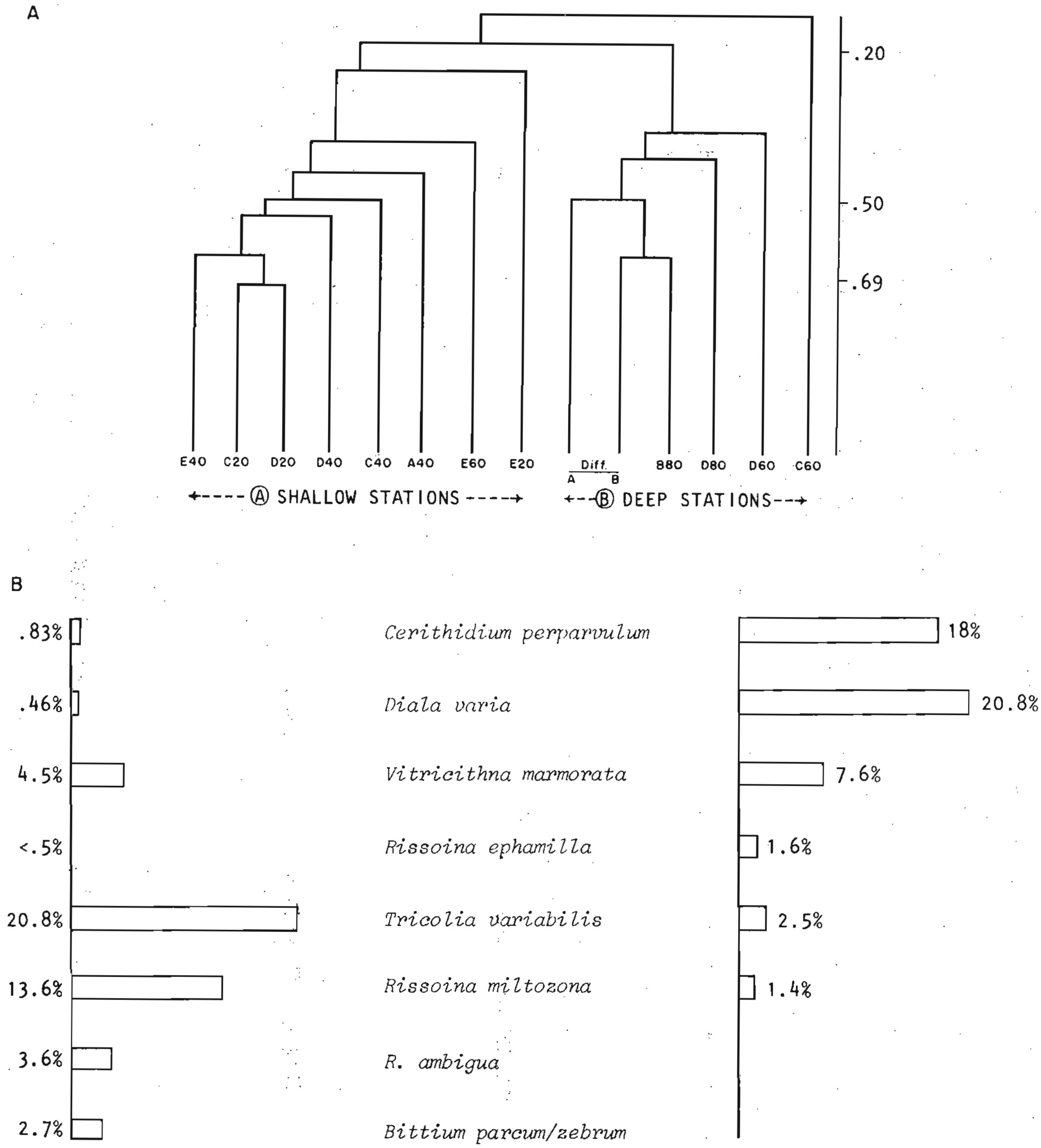
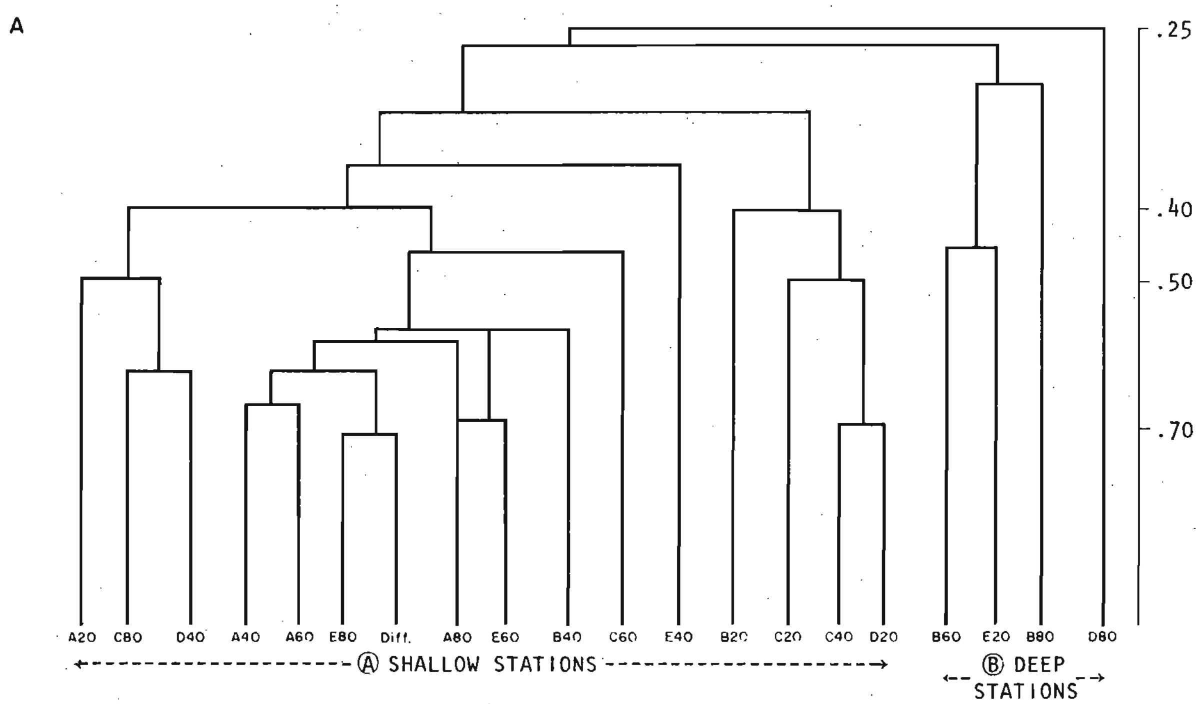


Figure 12. A. Dendrograph showing similarity indices between sites, Stations A-E; and B. Relative proportions of dominant species in assemblages, Mōkapu, O'ahu, Hawai'i



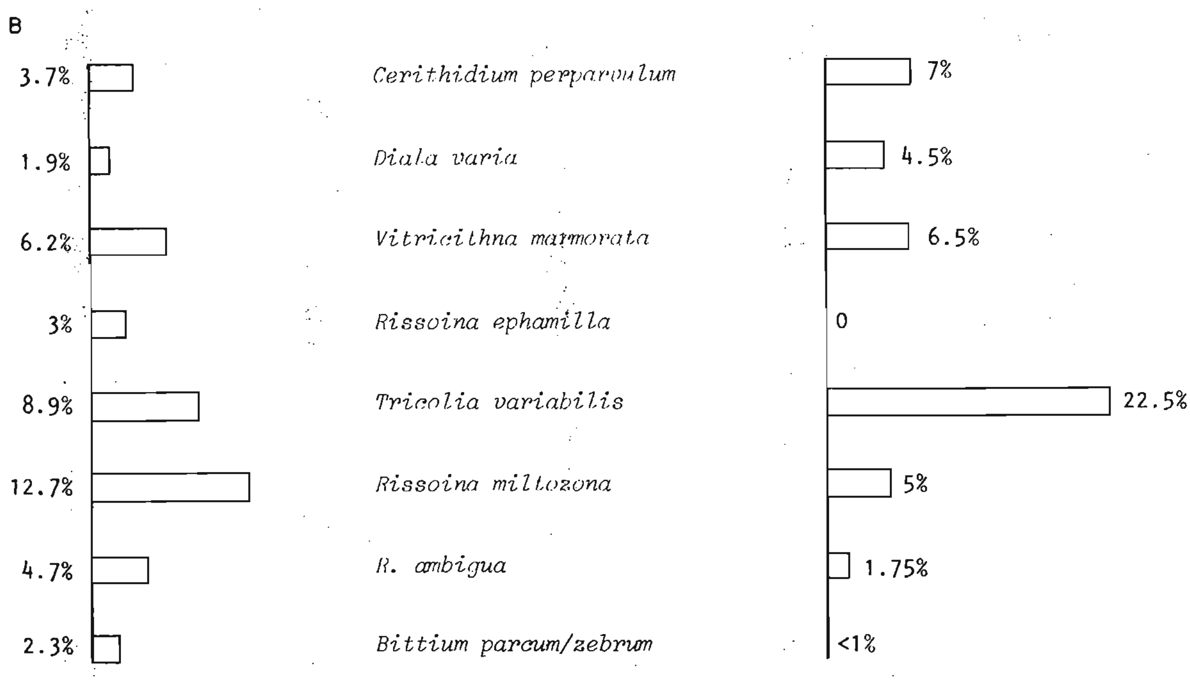
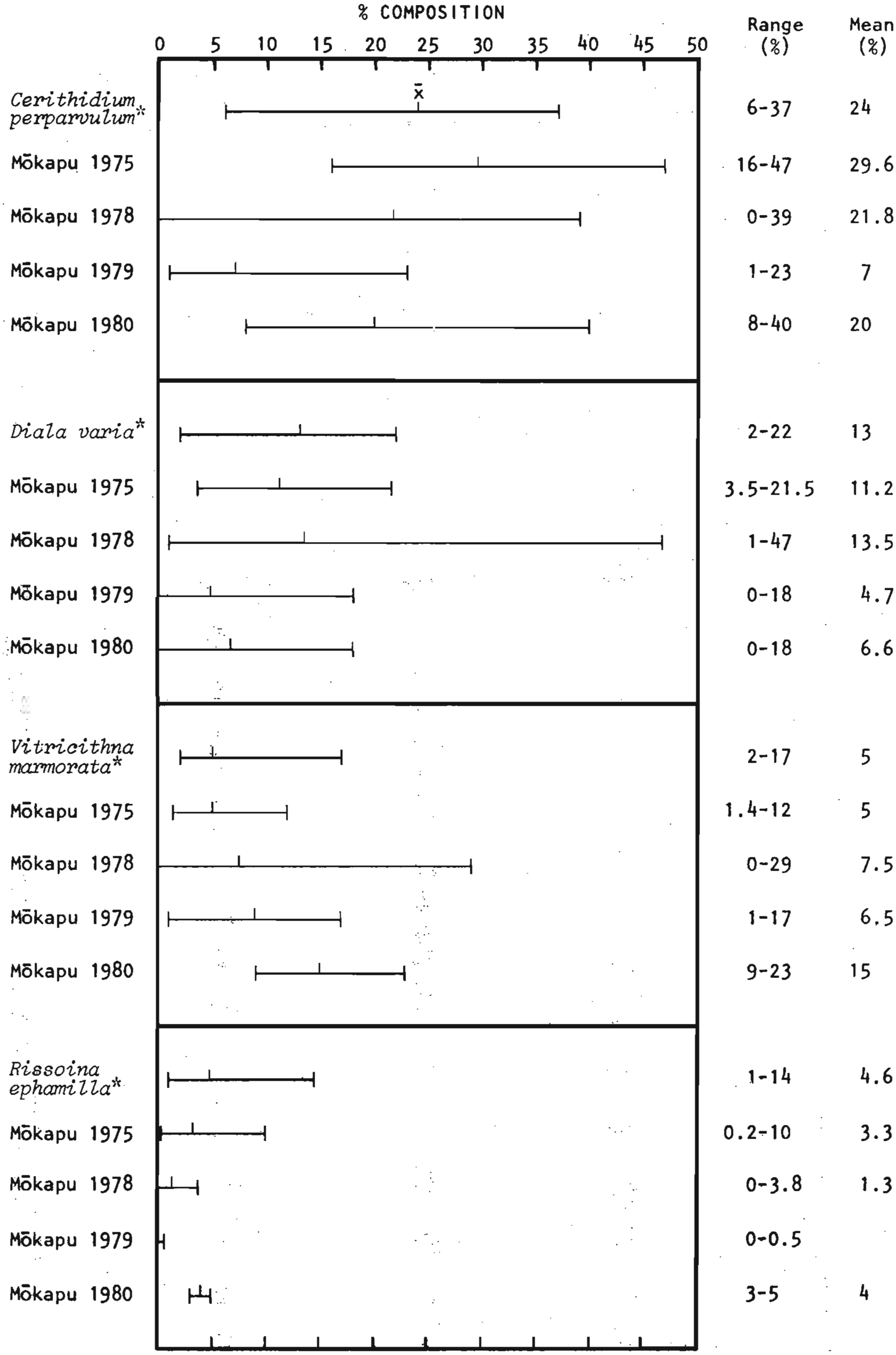


Figure 13. A. Dendrograph showing similarity indices between sites, Stations A-E; and B. Relative proportions of dominant species in assemblages, Mōkapu, O'ahu, Hawai'i

TABLE 5. MEAN ABUNDANCE AND RANKING OF SPECIES FOR SHALLOW- AND DEEP-WATER STATIONS, 1975, 1978-1980, MŌKAPU, O'AHU, HAWAI'I

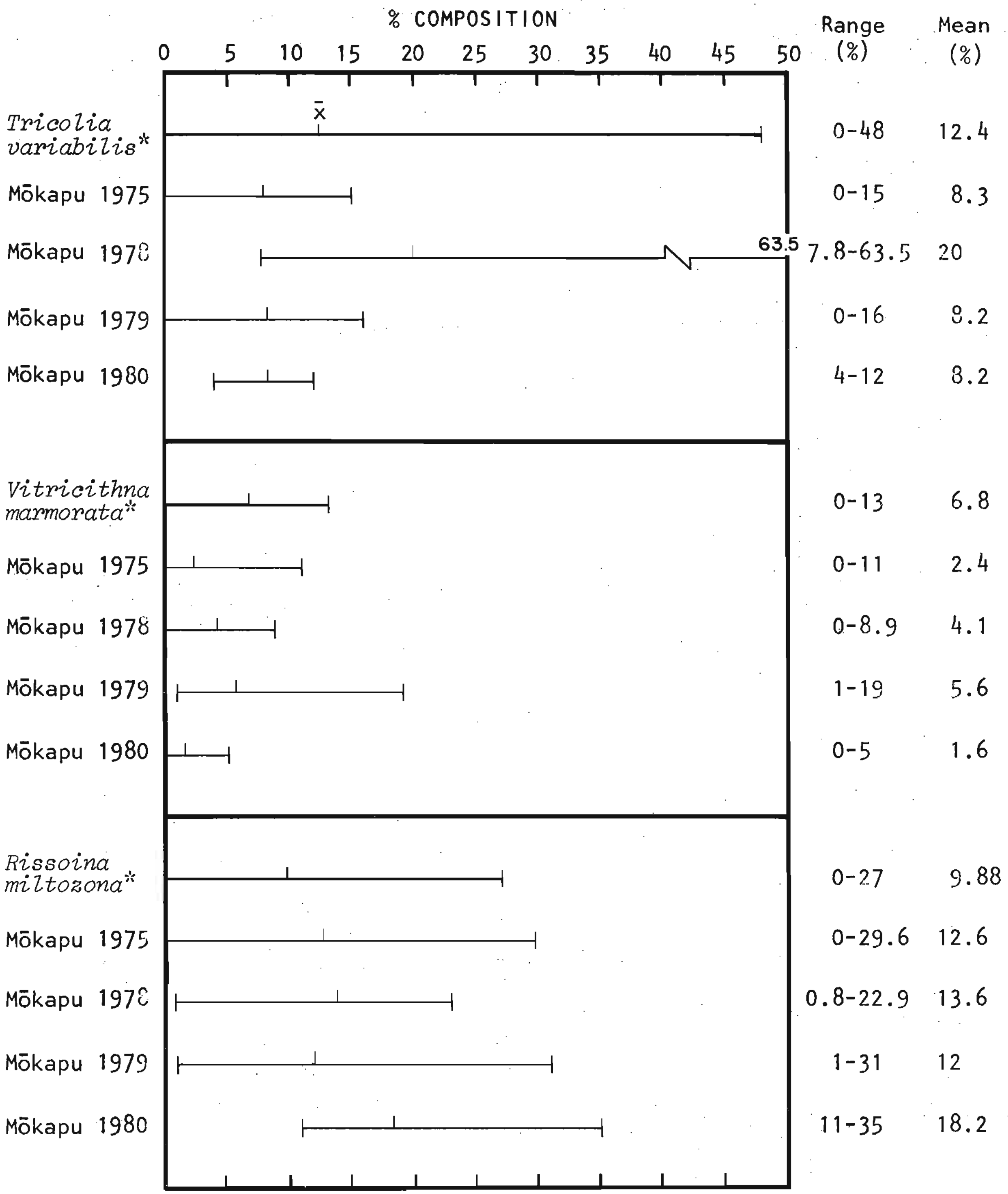
	SHALLOW WATER STATIONS*				DEEP WATER STATIONS†			
	1975	1978	1979	1980	1975	1978	1979	1980
Abundance (no./cm^3)	7.6	7.1	11.3	5.4	23.8	9.1	7.4	9.9
Ranking								
Rissoina miltozona	1	2	1	1	-	-	-	-
Triphoridae	2	5	2	2	4	3	4	4
Tricolia variabilis	3	1	3	3	5	4	1	3
Rissoina ambigua	4	4	5	4	-	-	-	-
Bittium parcum	5	3	6	5	-	-	-	-
Vitricithna marmorata	6	5	4	6	3	1	3	1
Cerithidium perparvulum	-	-	-	-	1	2	2	5
Diala varia	-	-	-	-	2	5	5	2

NOTE: Data derived from stations grouped in cluster analysis for each year.
*6-18 m (20-60 ft).
†24-37 m (80-120 ft).



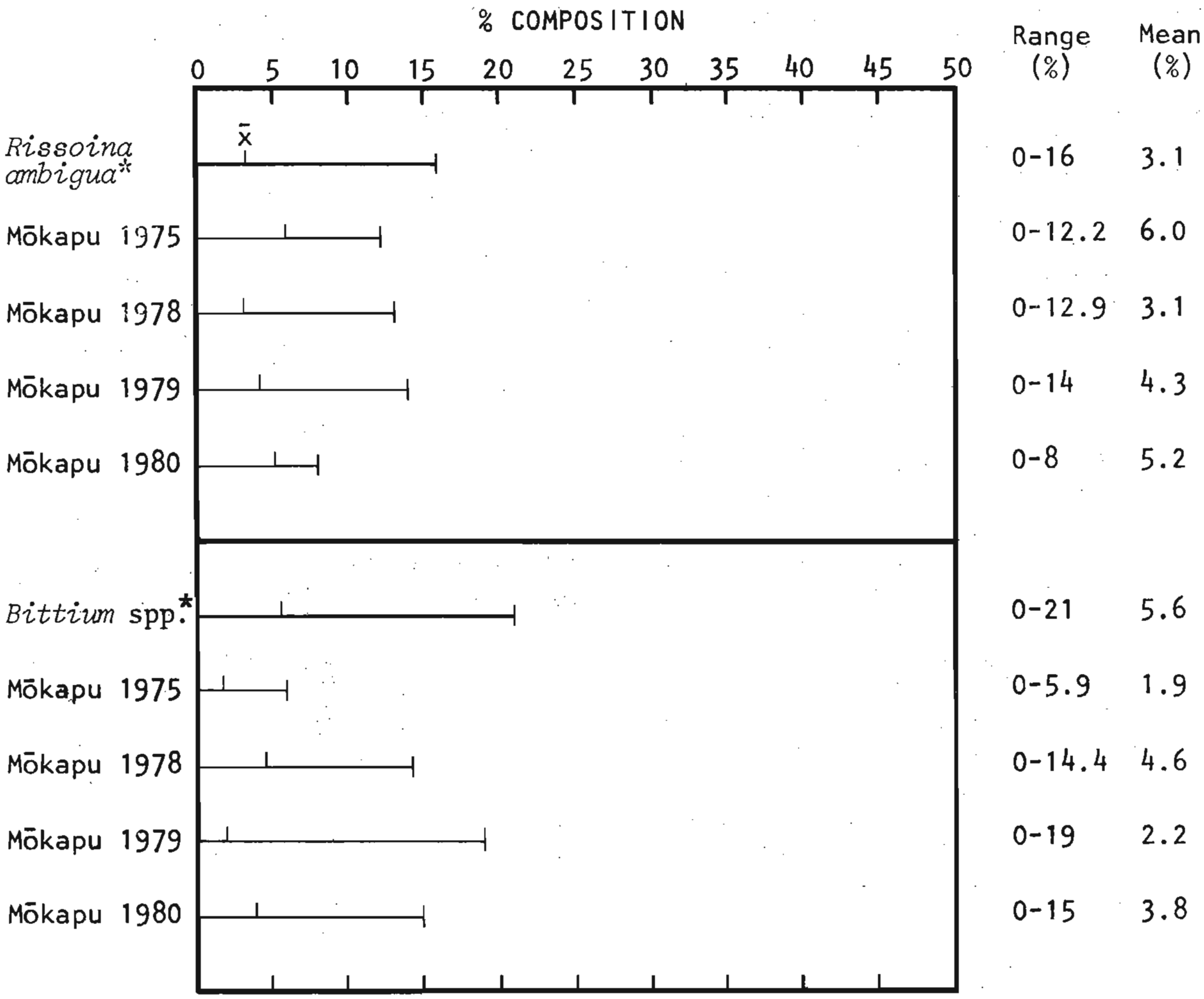
*Data from 40 samples around O'ahu, excluding Mōkapu.

Figure 14. Mean and range of percent composition of dominant species in deep water assemblages



*Data from 40 samples around O'ahu, excluding Mōkapu.

Figure 15. Mean and range of percent composition of dominant species in shallow water assemblages



*Data from 40 samples around O'ahu, excluding Mōkapu.

Figure 15.—*Continued*

REFERENCES

Bascom, W.; Mearns, A.J.; and Work, J.Q. 1978. Establishing boundaries between normal, changed and degraded areas. In *Southern California Coastal Water Research Project, Annual Report for 1978*, ed. W. Bascom, El Segunda, California, pp. 81-94.

Bohnsack, J.A. 1979. Photographic quantitative sampling of hard-bottom benthic communities. *Bull. Mar. Sci.* 29(2):292-306.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. *Mem. Fac. Sci. Kyushu Univ., Ser. E (Biol.)* 3(1):65-80.

Mueller-Dombois, D., and Bridges, K.W. 1975. *Integrated island ecosystem ecology in Hawaii: Spatial distribution of island biota introduction.* Tech. Rep. No. 66, Department of Botany, University of Hawaii, Honolulu, Island Ecosystem IRP, U.S. International Biological Program. iv + 52 p.

Pielou, E.C. 1969. *An introduction to mathematical ecology.* New York: Wiley Interscience.

Russo, A.R.; Dollar, S.J.; and Kay, E.A. 1977. *An inventory of benthic organisms and plankton at Mōkapu, O'ahu.* Tech. Rep. No. 101, Water Resources Research Center, University of Hawaii, Honolulu. v + 30 p.

______; Dollar, S.J.; and Kay, E.A. 1979. *Ecological observations off the Mōkapu, O'ahu, ocean outfall: A post-installation study.* Tech. Rep. No. 122, Water Resources Research Center, University of Hawaii, Honolulu. ix + 49 p.

______; Dollar, S.J.; and Kay, E.A. 1980. *Benthic ecosystem and fish population off the Mōkapu Outfall: A second postinstallation ecological study.* Tech. Rep. No. 132, Water Resources Research Center, University of Hawaii, Honolulu. vii + 45 p.