BIOLOGICAL COMMUNITIES IN TUMON BAY, 1977 - 1991

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1. INTRODUCTION

Tumon is the heart of Guam's tourism industry. The number of tourists visiting Guam has grown exponentially from around 200,000 per year in the mid 1970s to more than 700,000 per year in the early 1990s (Figure 1-1). Paralleling the increase in visitors has been the exponential growth in hotel capacity, from around 2,000 rooms in the mid 1970s to around 6,000 rooms in the early 1990s.

The vast majority of Guam's hotels are located in the Tumon Bay area, and this is where most visitors stay during their visit to Guam. Tourists staying in Tumon can take advantage of the variety of water-related entertainment and recreational opportunities provided by the marine environment: snorkeling, wind-surfing, sunbathing, swimming, canoeing, and going for a dinner cruise.

Tumon is also an important recreational area for residents of Guam. It is a popular fishing area in which a variety of fishing methods are used, including hook-and-line, spears, and several types of nets (Davis et al., undated). Fishing activity in Tumon Bay has fluctuated from year to year (Figure 1-2), but during the mid-1980s, annual fish catches averaged more than 12,000 kg (25,000 lbs). Annual fishing effort during that period averaged more than 21,000 person-hours, or nearly 60 person-hours of fishing per day.

Because of its importance for visitors and residents alike, the quality of the marine environment in Tumon Bay and the status of the marine communities living within the bay are of concern.

In 1977 and 1978, marine surveys were carried out in Tumon Bay which documented the abundance of the conspicuous groups of marine organisms (marine plants, corals and other macroinvertebrates, and fishes) along three transects running from the beach to the outer reef margin (Randall, 1978b; Amesbury, 1978).

Five reef zones, aligned parallel to the shoreline, were identified in Tumon during the 1977 study. These, in order of increasing distance from the beach, are 1) sand zone, 2) scattered coral zone, 3) coral zone, 4) pavement and pool zone, and 5) pavement zone.

Marine plant species richness and percent cover increased with distance from the beach, reflecting the greater availability of hard substrate for the attachment of algae (Tsuda et al., 1978). Species occurring within sand habitats were those with creeping rhizomes or holdfasts which anchor them in this substrate.

Coral species diversity and coral percent cover were, generally, highest in the coral zone in Tumon (Randall, 1978a). Coral distribution is principally influenced by substrate stability and exposure during low tides.

Sea cucumbers (Holothurians) were the dominant group of macroinvertebrates found in Tumon Bay (Birkeland, 1978). There was an increase in species richness with increasing distance from the beach. Cucumber density was greatest in the scattered coral zone, and was also high in the coral and pavement zones.

The 1977-78 fish surveys in Tumon indicated that fish species exhibited significant patterns of zonation in their distribution on the reef (Amesbury, 1978). Fish abundance increased with increasing distance from the beach and was greatest in the outer reef flat zones.

These same three transects (Figure I-3) were resurveyed in December of 1991. Most of the investigators involved in the 1991 surveys were the same as those who carried out the earlier surveys: R. T. Tsuda, marine plants; R. H. Randall, corals; and S. S. Amesbury, fishes. The invertebrates were surveyed in 1991 by A. M. Kerr and B. D. Smith; the earlier invertebrate surveys were performed by C. Birkeland.

The results of the surveys of each of the principal biological groups are presented in individual chapters below, and a final chapter discusses overall changes that have occurred in the biological communities of Tumon Bay over the fourteen year period between the two surveys.

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LITERATURE CITED

Amesbury, S. S. 1978. Studies on the biology of the reef fishes of Guam. University of Guam Marine Laboratory, Technical Report 49, 65p.

Birkeland, C. 1978. Other macroinvertebrates. In: R. H. Randall, ed. Guam's reefs and beaches. Part II. Transect studies. University of Guam Marine Laboratory, Technical Report 48, pp. 77-90.

Davis, G., R. F. Myers, and T. S. Sherwood. undated. The need and justification for marine conservation areas on Guam. Division of Aquatic and Wildlife Resources, Department of Agriculture, Government of Guam. 9p.

Randall, R. H. 1978a. Corals. In: R. H. Randall, ed. Guam's reefs and beaches. Part II. Transect studies. University of Guam Marine Laboratory, Technical Report 48, pp. 28-76.

Randall, R. H., ed. 1978b. Guam's reefs and beaches. Part II. Transect studies. University of Guam Marine Laboratory, Technical Report 48, 90p.

Tsuda, R. T., D. R. Lassuy, and S. E. Hedlund. 1978. Marine plants. In: R. H. Randall, ed. Guam's reefs and beaches. Part II. Transect studies. University of Guam Marine Laboratory, Technical Report 48, pp. 9-27.

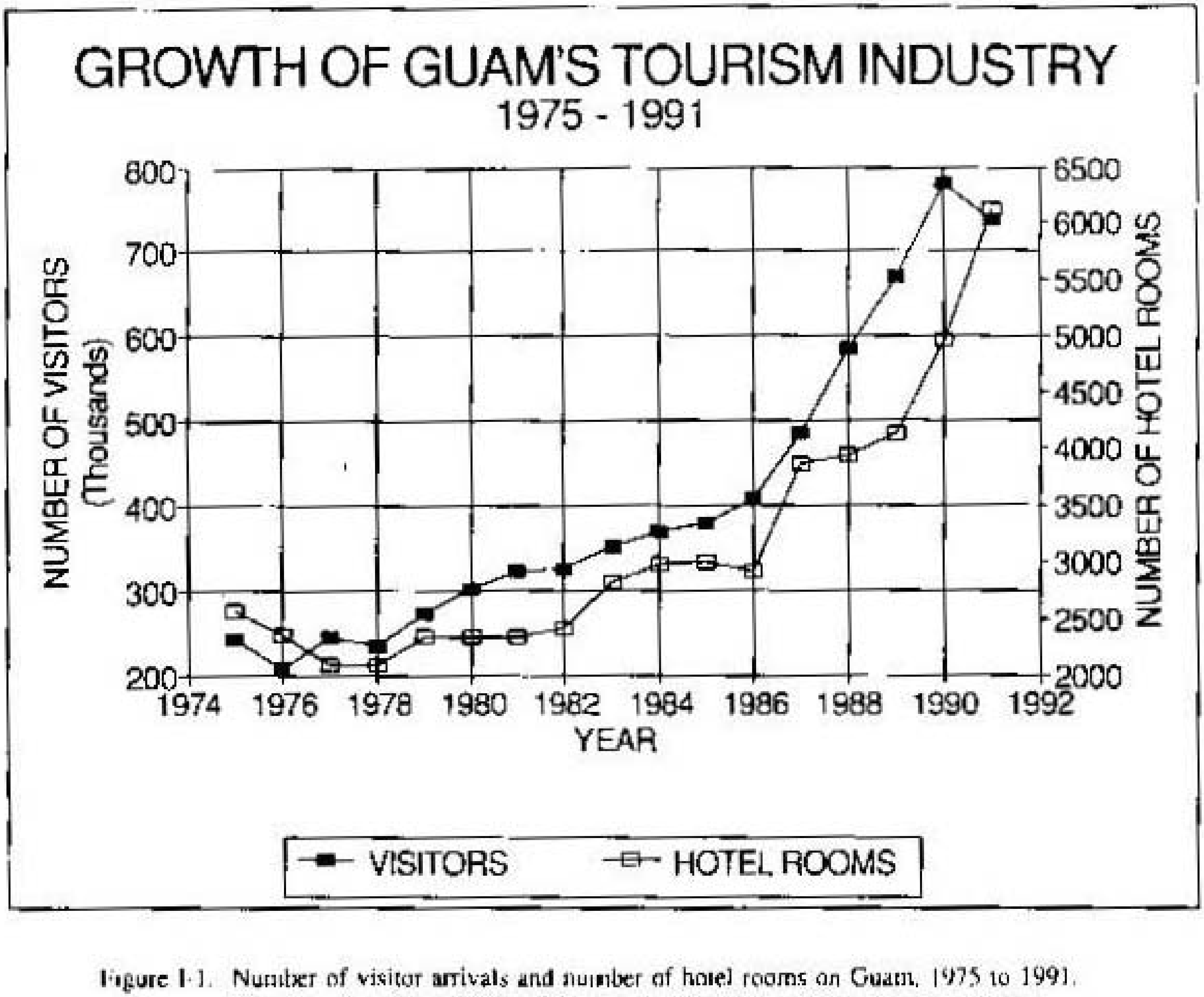

Figure I-1. Number of visitor arrivals and number of hotel rooms on Guam, 1975 to 1991. Based on data from Office of Economic Planning and Development, Guam Department of Commerce.

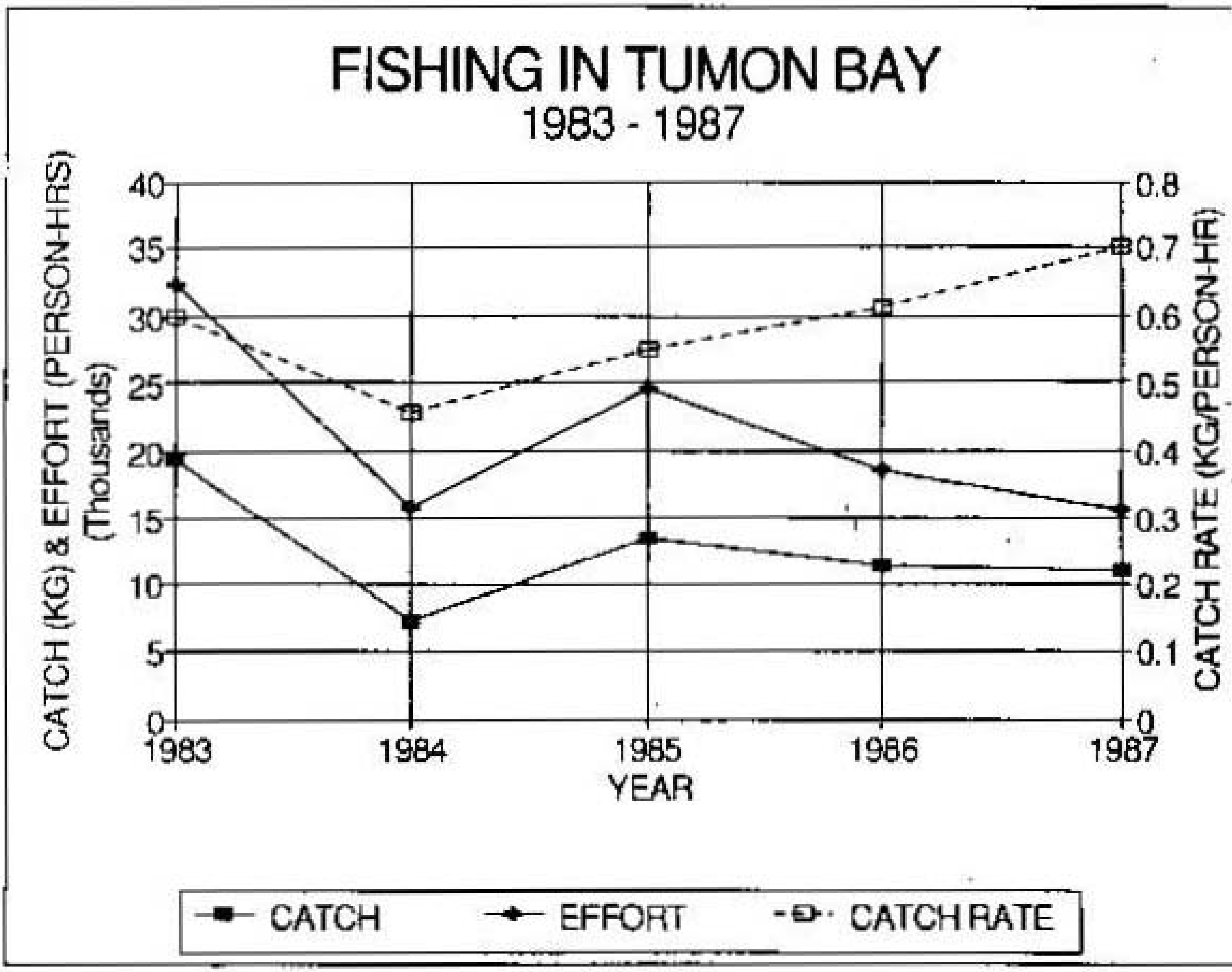

Figure 1-2. Catch, effort, and catch rate for fishing in Tumon Bay, 1983 to 1987. Based on data from Division of Aquatic and Wildlife Resources, Guam Department of Agriculture.

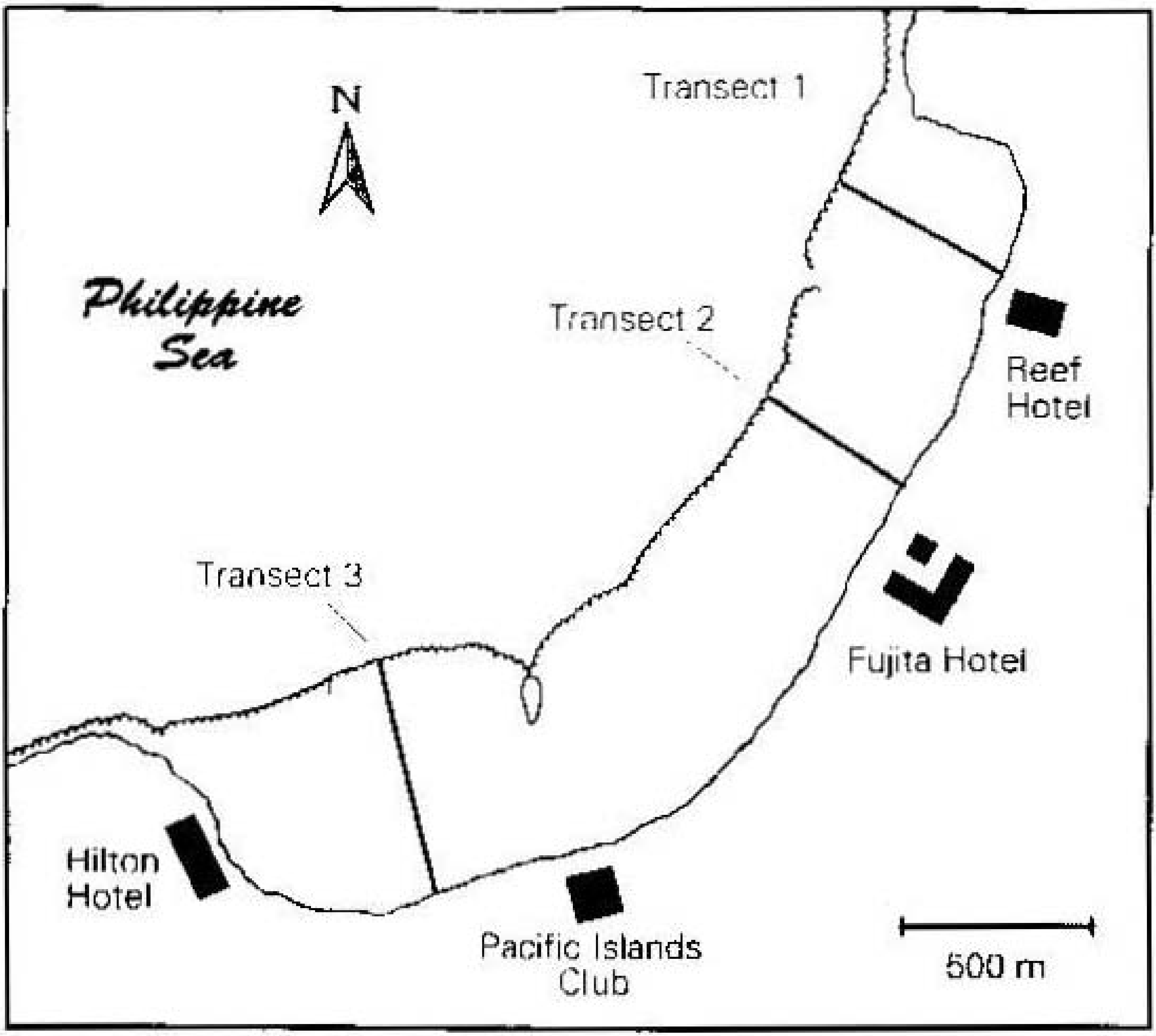

Figure 1-3. Location of biological survey transects in Tumon Bay.

II. MARINE PLANTS

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INTRODUCTION

During May/June and November/December 1977, the marine benthic algae of Tumon Bay were quantified during the dry and wet seasons along three transects located off the Guam Reef Hotel (Transect 1), the Fujita Beach Hotel (Transect 2) and the east end of Ypao Beach Park (Transect 3). The three transects in Tumon Bay were part of an overall species diversity study (i.e., marine plants; invertebrates, including corals; and fishes) conducted along 12 transects in five different bays (i.e., Tumon, East Agana, Agat, Fouha and Ylig) around the island of Guam by faculty and graduate students of the University of Guam Marine Laboratory. The results of the studies were published as technical reports and included sections on corals (Randall, 1978), invertebrates (Birkeland, 1978), marine plants (Tsuda et al., 1978) and a separate report on the marine fishes by Amesbury (1978).

The present study, conducted on 16-18 December 1991, attempts to quantify the marine plants along the same transect routes in Tumon Bay 14 years later. The primary objective was to provide a comparison of the species diversity, including the number of species and percent cover, of marine plants (i.e., marine benthic algae and seagrasses) in Tumon Bay between November/December 1977 and December 1991. Tumon Bay has developed considerably over the past 14 years, i.e., more hotels, condominiums and commercial retail stores.

The only algal monitoring program at repeated stations on the coral reefs of Guam was conducted by the Guam Environmental Protection Agency (Rowley, 1981, 1983; Rowley-Bultitude, 1984); the studies, however, did not include any transects in Tumon Bay. The green alga, _Enteromorpha clathrata_, which is viewed as a nuisance by many on Guam was the focus of a detailed ecological study by FitzGerald (1978) in Tumon Bay from October 1973 to December 1974. FitzGerald (1978) found that the standing crop of the green alga at any given period was dependent on antecedent events, i.e., wave height, wind-generated surge, and grazing by herbivores. The size of the substratum particle, e.g., coral rubble and shells, was also a critical factor in the distribution of _Enteromorpha_ within the intertidal zone along Tumon Bay.

ACKNOWLEDGMENTS

The author acknowledges Diane Carandang-Liberty and Claudine M. Camacho, Environmental Services, Duenas & Swavely, Inc., for their assistance in the development of the graph and table format.

METHODS

The quantitative sampling method used in the 1991 study was identical to that used in 1977, except that the quadrat was placed at 2-meter intervals instead of 1 meter intervals. Thus, the sampling technique obtained half the number of data points than was obtained in 1977. One additional difference was the shorter transect length of Transect 2; this transect was 50 meters shorter than the 500 meters traversed in 1977. The lengths of Transect 1 (500 meters long) and Transect 3 (570 meters long) remained the same. All transects were run perpendicular from the high water line on shore and extended to the outer reef flat.

The benthic plant assemblages were analyzed by placing a gridded quadrat (25 cm x 25 cm) at 2-meter intervals along the length of the transect. The quadrat frame consisted of 25 squares and, thus, provided 16 interior points where the grid line intersected. Each species of marine plant was recorded at every point at which it occurred. If no alga or seagrass was found under the points, whatever was present, e.g., sand, dead coral, live coral or other marine fauna, was recorded.

Percent cover was obtained by dividing the number of points at which the species was recorded as a percent of the total number of points per 10-meter segment. Five quadrats (x 16 points) yielded a total of 80 points, i.e., n/80 x 100 = percent cover. The coefficient of community (Oosting, 1956) was used to compare the species diversity among the transects and between the 1977 and 1991 samplings, i.e., number of species common to both sites divided by the total number of species at both sites x 100. Frequency values (percentiles) were derived by dividing the number of 10-m segments a particular species or item occurred by the total number of 10-m segments along the transect, i.e., Transect 1 (50 10-m segments), Transect 2 (45 10-m segments, Transect 3 (57 10-m segments).

The author's ability to distinguish different species of red algal turf has improved over the past 14 years, and, thus, the present study does not utilize the general category of "turf" which was used extensively (i.e., 27% cover) in 1977 for Transect 1. In the 1977 study (Tsuda et al., 1978), the term "turf" was used to describe less than 1% cover of the algae along Transect 2 and about 1% cover of the algae along Transect 3.

The crustose coralline algae was pooled in 1977 under the general category "crustose corallines". In the recent study, an attempt was made to separate the encrusting coralline algae at the species level based on descriptions furnished by Gordon et al. (1976).

RESULTS AND DISCUSSION

Substrata

Figures II-1, II-2 and II-3 present the percent cover of the sand, dead coral or reef pavement, and live coral which were quantified (Table II-1) along each of the three transects.

The quantification of these substrata types by the point-quadrat method meant that the substrata under the points were bare and free of any marine plants or invertebrates (e.g., sea cucumbers). The low percent cover of sand, dead coral or reef pavement along a given sector of the transect meant that a greater percent cover of marine plants inhabit the sector. On the other hand, the absence or low percent cover of live corals along a sector of the transect meant that few or no corals inhabit the area; marine benthic algae and seagrasses do not use live corals as substrata.

Sandy substratum was dominant (greater than 50% cover) from the high water line to a distance of 200 to 240 meters seaward, i.e., Transect 1 (200 m seaward), Transect 2 (240 m seaward) and Transect 3 (230 m seaward). Live corals (i.e., greater than 25% cover) were most conspicuous at the 300- to 370-m sector of Transect 2, and at the 260- to 280-m sector of Transect 3. Live corals were present on Transect 1; however, the percent cover never exceeded 19% within any of the 10 m long segments and live corals were encountered only within 8 of the 50 10-m segments (i.e., percent frequency of 16%).

The primary substrata type for the majority of algal growth are pieces of dead coral and reef pavement. Seagrasses and benthic algae which are adapted to the sand environment are few in number and characterized by large holdfasts (i.e., Halimeda macroloba), creeping rhizomes (i.e., Halophila minor), or flat mucous sheets (i.e., Schizothrix calcicola).

Species Diversity

A comparison of the number of marine plants species, excluding the crustose coralline algae, quantified during 1977 and 1991 along all three transects in Tumon Bay reveals that the 38 species recorded in 1991 compare favorably with the 34 species recorded in 1977 (Table II-2). The species composition recorded in 1977, however, was quite different than that found in the recent 1991 study. Only 20 of the 51 species (excluding crustose coralline algae) were identical, i.e., a coefficient of community value of 39%. The low number could be attributed to the use of the generalized term "turf" for species of filamentous like red algae (Rhodophyta) in 1977. As a means of utilizing more reliable numbers in the comparisons, a coefficient of community value was calculated for only species of Chlorophyta (green algae) and Phaeophyta (brown algae) quantified along the transects. These species are much easier to recognize in the field and, thus, serve as a more reliable basis for comparison. Only 12 of the 28 species of green and brown algae were identical, thus, yielding a similarly low coefficient of community value of 43%.

When the species composition of both green and brown algae observed during 1977 and 1991 were compared along each transect, the coefficient of community were, likewise, low - Transect 1 (5/19 = 26%), Transect 2 (5/17 = 29%), and Transect 3 (8/20 = 40%). Only five species were present along all three transects during both the 1977 and 1991 sampling periods - Microcoleus lyngbyaceus, Enteromorpha clathrata, Halimeda opuntia, Padina boryana (= P. tenuis) and Gelidiopsis intricata.

In the 1977 study, only six species were considered dominant, i.e., species with 3% cover or greater on any one transect. The dominant species included two blue-green algae (i.e., Microcoleus lyngbyaceus and Schizothrix calcicola), two green algae (Enteromorpha clathrata and Halimeda opuntia), and two species of brown algae (Padina boryana and Turbinaria ornata). Only two species, i.e., S. calcicola and P. boryana, were considered as dominant in both 1977 and 1991 (Table II-3). Six other species, three of which were not recorded in 1977, were considered dominant on at least one transect. The three species reported previously, but not considered dominant in 1977, were Boodlea composita, Jania capillacea, and Polysiphonia spp. The three other dominant species, reported for the first time, along the transects were Cladophoropsis sundanensis, Gelidiella acerosa and Laurencia sp.

The three species of crustose coralline algae encountered along the three transects were identified as Neogoniolithon frutescens, Porolithon onkodes and Porolithon sp. A fourth encrusting calcareous alga, Peyssonnelia rubra, was present along the three transects and is here considered as a "crustose coralline". The percent cover of "crustose coralline" algae observed in 1977 along Transects 1 and 3 seem to be comparable to that observed in the recent 1991 study. Less "crustose coralline" algae (i.e., 6% cover) were observed along Transect 2 during the recent 1991 study than during the 1977 study (i.e., 16% cover).

Zonation

Figures II-4, II-5 and II-6 provide comparisons of the number of species and percent cover of the marine plants (Table II-4) within 10 meter segments along the three transects quantified in 1977 and 1991. The pairs of values within 10-meter segments, obviously, do not represent the identical sites. Therefore, the general zonational trend should be examined, instead of focusing on the comparison of each pair of numbers, i.e., number of species and percent cover.

The dominant alga in the sandy area along the shoreline is Enteromorpha clathrata which varied in percent cover along the three transects: Transect 1 (28% cover between the high water line and 20 meters, Transect 2 (11% cover between the high water line and 70 meters, and Transect 3 (48% cover between 10 and 30 meters). FitzGerald (1978) discussed the correlation of standing crop of the green alga with wave height greater than 6 feet. The transect data between the 1977 and 1991 sampling period do not provide sufficient information to show either an increase or decrease of the percent cover of Enteromorpha over the 14-year period. The blue-green alga, Schizothrix calcicola, was a conspicuous alga in the sandy area between 40 and 120 meters in the inner reef along Transect 3 and covered 28% of the sandy substratum; it was absent along Transects 1 and 2.

Three other dominant algae in Tumon Bay during the December 1991 sampling were the foliose brown alga Padina boryana, the crunchy green alga Boodlea composita and the rigid red alga Gelidiella acerosa. Padina boryana was present on all three transects; however, it was most abundant (19% cover) between 250 and 360 meters along Transect 1. Padina boryana covered 4% of the area between 140 and 270 meters along Transect 2, and covered less than 1% of the area from 60 to 320 meters along Transect 3. Tsuda (1977) reported similar findings in Pago Bay and reported the zonation of Padina on both the inner reef flat and outer reef flat. Boodlea composita was absent along Transect 2 and covered less than 0.1% of the area along Transect

3. *Boodlea*, however, covered 14% of the area between the 260- and 420-meter sector of Transect 1. *Gelidiella acerosa*, a rigid upright red alga about 5 cm high, formed a thick mat on the coral pavement on the outer reef flat along Transects 1 and 3 only. *Gelidiella* covered 30% of the reef pavement between 300 and 500 meters along Transect 1, and covered 29% of the reef pavement between 410 and 570 meters along Transect 3.

CONCLUSIONS

The comparison of the marine plants quantified in 1977 and 1991 indicates that the species composition did change along all three transects. The change is not surprising since rare species (i.e., species with cover of less than 1%) can significantly change the species composition of an area. Ten of the 38 species (excluding crustose coralline algae) or 26% of the species sampled in 1991 were found along only one of the three transects and comprised less than 1% cover.

It is not possible to make a clear statement whether or not the standing crop of *Enteromorpha* and other algae in the area is increasing or decreasing. The green alga *Enteromorpha* has always been abundant off Ypao Beach, even prior to the presence of the large scale development in the area. The foliose brown alga, *Padina boryana*, has inhabited both the inner and outer reef flats of Tumon Bay, since the author's first observation in 1968. The large brown alga, *Sargassum polycystum*, which attains its greatest height during December to February (Tsuda, 1972) was rarely encountered during both the 1977 and 1991 studies. Although its scarcity during 1977 cannot be explained, the force of Typhoon Yuri on 28 November 1991 was obviously the factor which caused the long thalli of *Sargassum polycystum* to be detached from its substratum.

LITERATURE CITED

Amesbury, S.S. 1978. Studies on the biology of the reef fishes of Guam. Part I: Distribution of fishes on the reef flats of Guam. Part II: Distribution of eggs and larvae of fishes at selected sites on Guam. Univ. Guam Marine Lab., Tech. Rept. 49, 65 pp.

Birkeland, C. 1978. Other macroinvertebrates. p. 77-90. *In* R.H. Randall (Ed.), Guam's reefs and beaches, Part II. Transect studies. Univ. Guam Marine Lab., Tech. Rept. 48, ii + 90 pp.

FitzGerald, W.J. Jr. 1978. Environmental parameters influencing the growth of *Enteromorpha clathrata* (Roth) J. Ag. in the intertidal zone on Guam. Botanica Marina, 21: 207-220.

Gordon, G.D., T. Masaki and H. Akioka. 1976. Floristic and distributional account of the common crustose coralline algae on Guam. Micronesica, 12: 247-277.

Oosting, H.J. 1956. The study of plant communities, an introduction to plant ecology. W.H. Freeman and Co., San Francisco. vi + 440 pp.

Randall, R.H. 1978. Corals. p. 28-76. In R.H. Randall (Ed.), Guam's reefs and beaches, Part II. Transect studies. Univ. Guam Marine Lab., Tech. Rept. 48, ii + 90 pp.

Rowley, D.M. 1981. First annual report on the marine benthic algae and coral communities at nine biological stations around Guam. Guam Environmental Protection Agency, Tech. Rept. 34 pp.

Rowley, D.M. 1983. Second annual report on the marine benthic algae and coral communities at biological monitoring stations around Guam. Guam Environmental Protection Agency, Tech. Rept. 31 pp.

Rowley Bultitude, D. 1984. Third annual report on the marine benthic algae and coral communities at biological monitoring stations around Guam. Guam Environmental Protection Agency, Tech. Rept. 18 pp.

Tsuda, R.T. 1972. Morphological, zonational, and seasonal studies on two species of Sargassum on the reefs of Guam. Proc. Seventh Intern. Seaweed Symp., Sapporo, Japan, p. 40-44.

Tsuda, R.T. 1977. Zonational patterns of the Phaeophyta (brown algae) on Guam's fringing reefs. Proc. Third Intern. Symp. Coral Reefs, Miami, 1: 371-375.

Tsuda, R.T., D.R. Lassuy and S.E. Hedlund. 1978. Marine plants. p. 9-27. In R.H. Randall (Ed.), Guam's reefs and beaches, Part II. Transect studies. Univ. Guam Marine Lab., Tech. Rept. 48, ii + 90 pp.

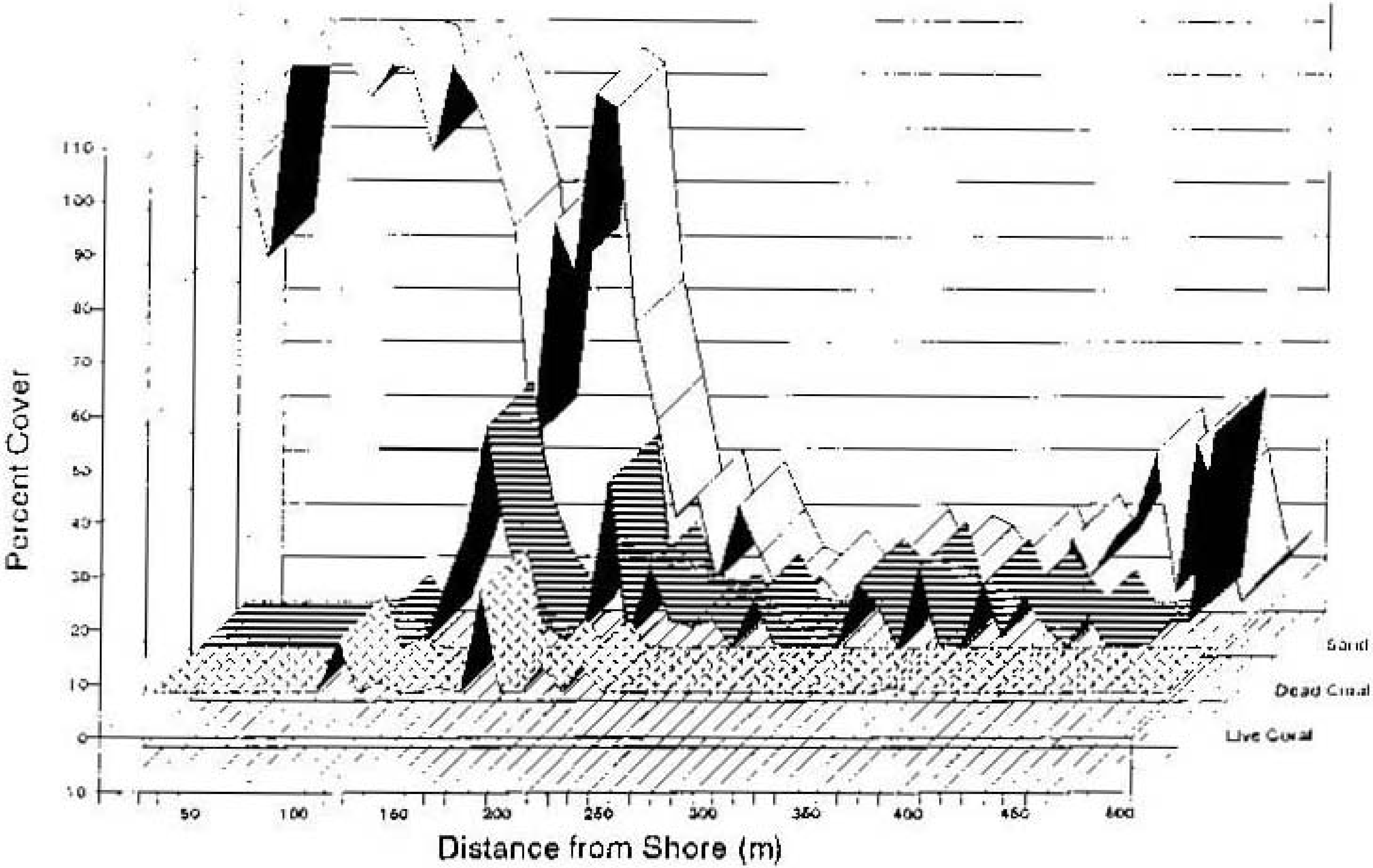

Figure D-1. Percent cover of sand (white ribbon), dead coral and reef pavement (hatched ribbon), and live coral (stitched ribbon) quantified within 10-meter intervals (0.25 meters wide) along Transect 1 in Tumon Bay during December 1991.

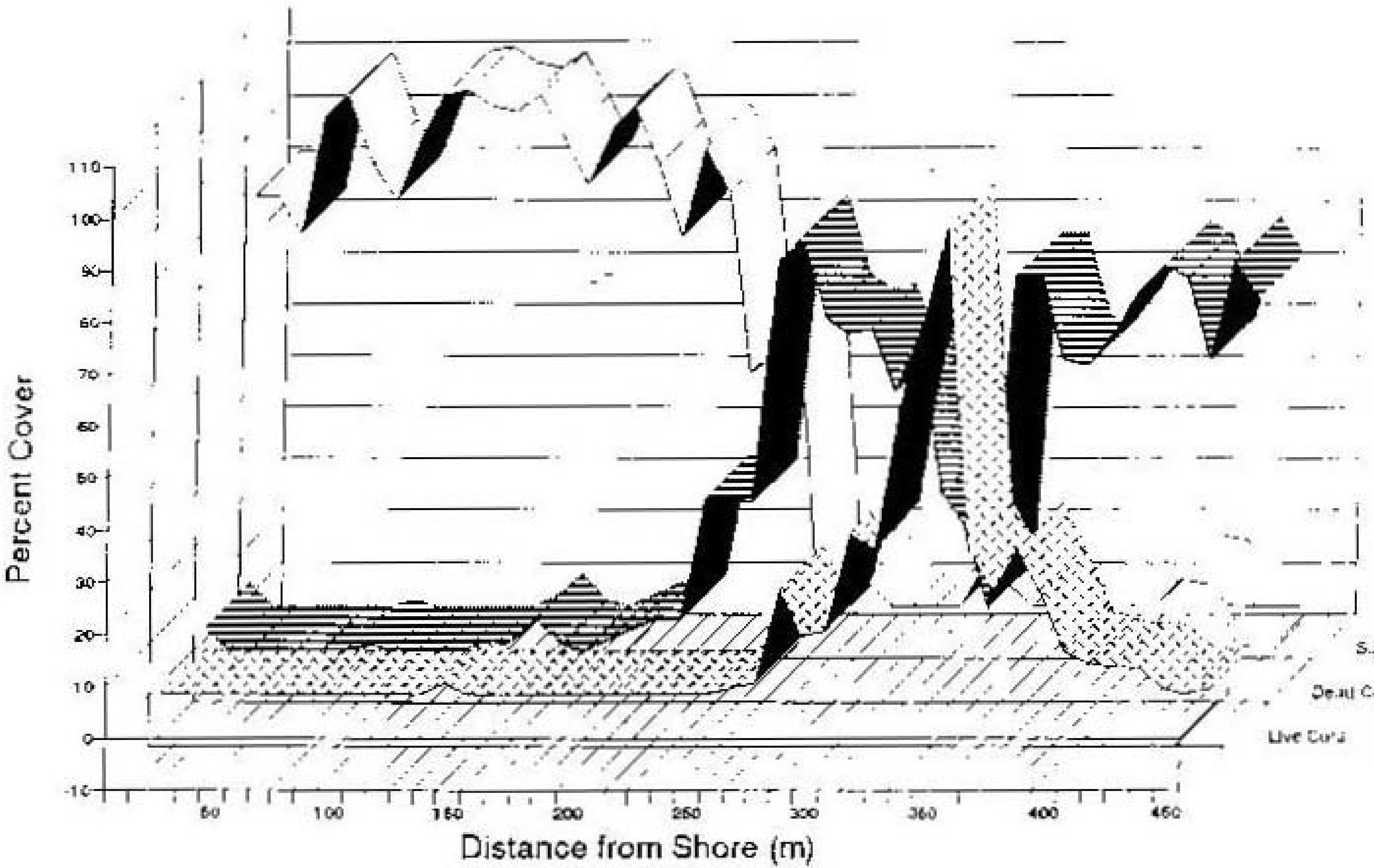

Figure II-2. Percent cover of sand (white ribbon), dead coral and reef pavement (hatched ribbon), and live coral (stitched ribbon) quantified within 10-meter intervals (0.25 meters wide) along Transect 2 in Tumon Bay during December 1991.

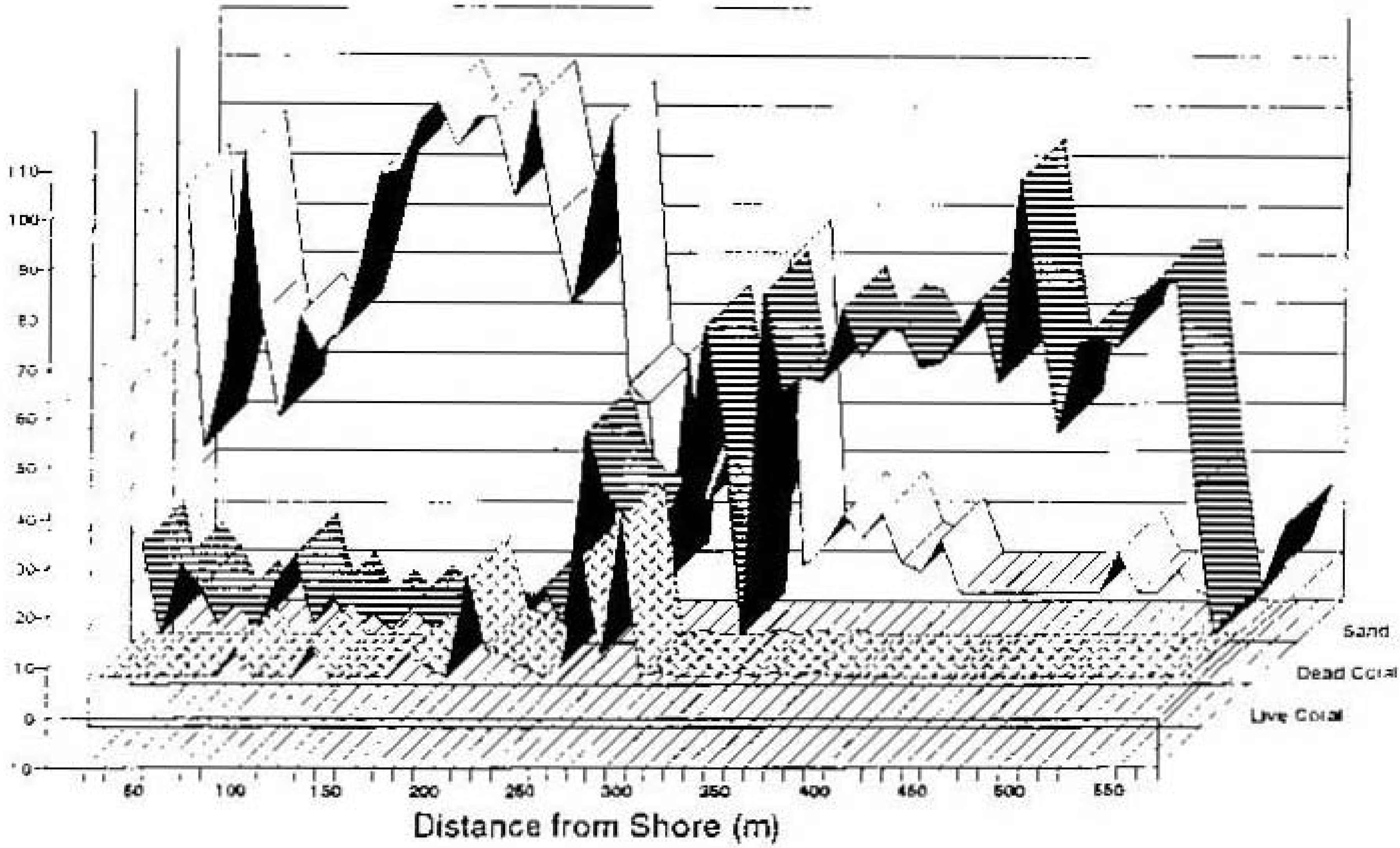

Figure II-3. Percent cover of sand (white ribbon), dead coral and reef pavement (hatched ribbon), and live coral (stitched ribbon) quantified within 10-meter intervals (0.25 meters wide) along Transect 3 in Tumon Bay during December 1991.

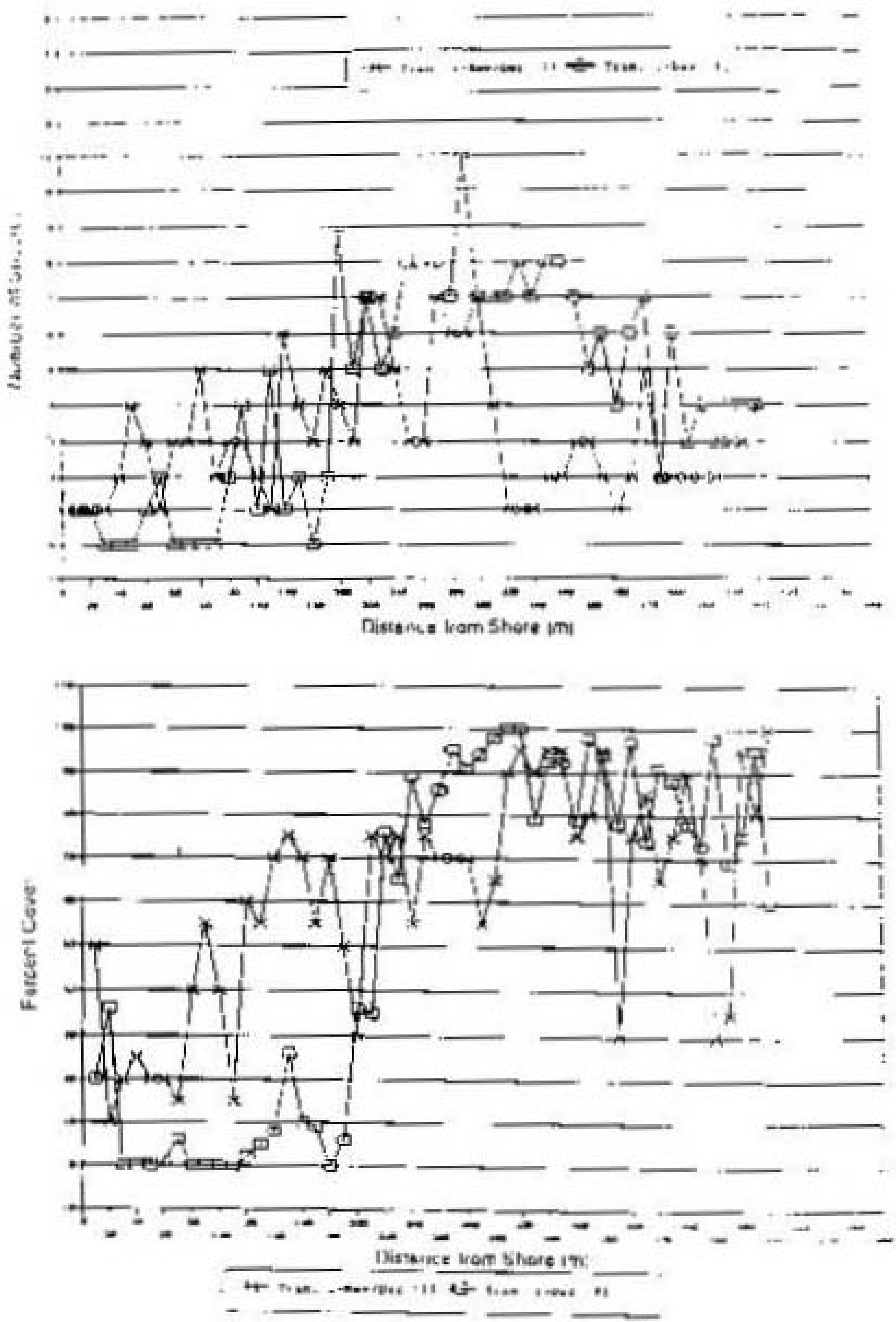

Figure II-4. Comparison of species diversity (i.e., number of species) and percent cover of marine plants quantified within 10-meter intervals (0.25 meters wide) along transect 1 in Tumon Bay during November/December 1977 (solid line) and December 1991 (dotted line).

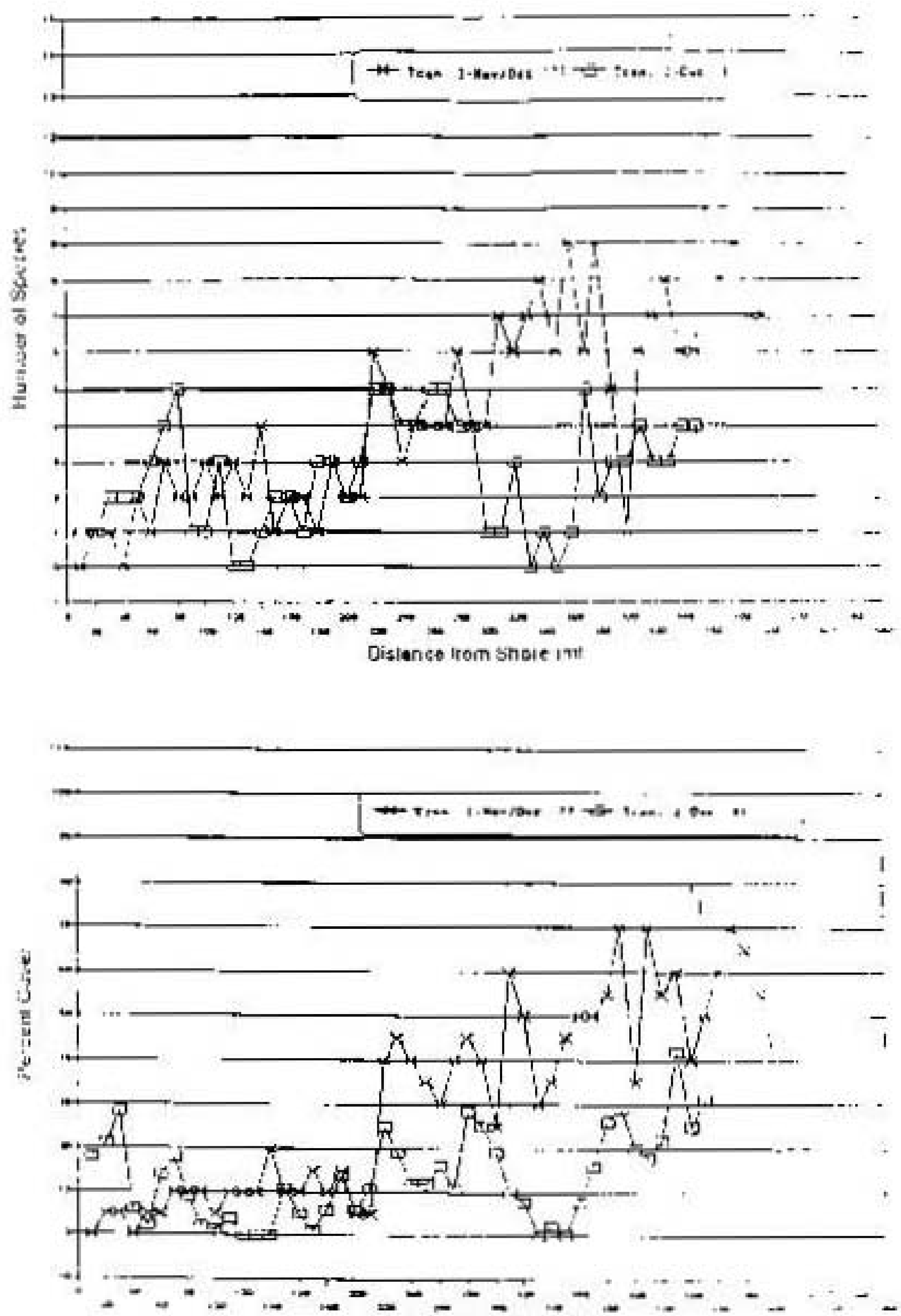

Figure II.5. Comparison of species diversity (i.e., number of species) and percent cover of marine plants quantified within 10 meter intervals (0.25 meters wide) along transect 2 in Tumon Bay during November/December 1977 (solid line) and December 1991 (dotted line).

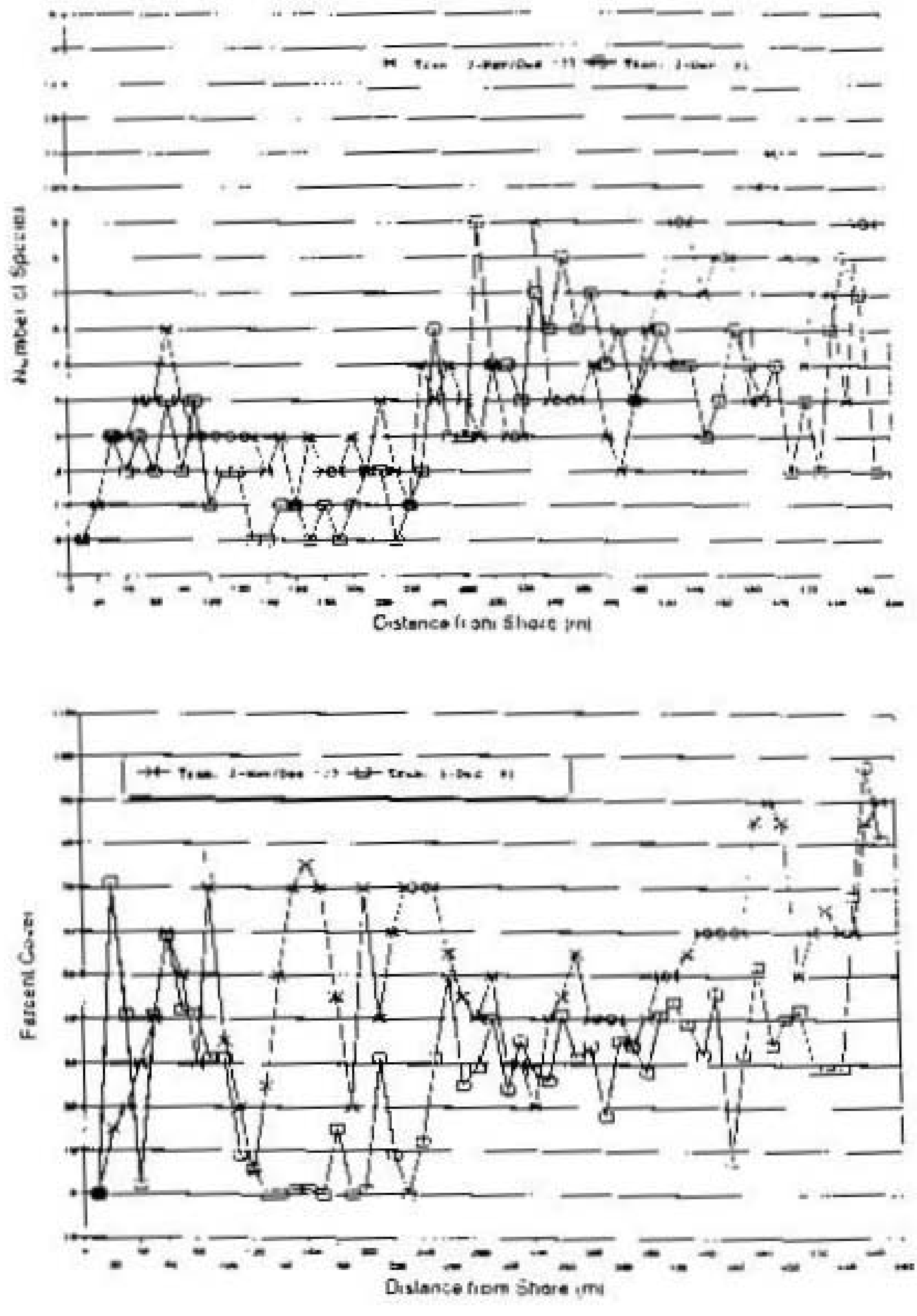

Figure II-6. Comparison of species diversity (i.e., number of species) and percent cover of marine plants quantified within 10-meter intervals (0.25 meters wide) along transect 3 in Tumon Bay during November/December 1977 (solid line) and December 1991 (dotted line).

Table II-1. Percent cover of sand (A), dead coral and reef pavement (B), live coral (C), and invertebrates (D) quantified along transects 1, 2, and 3 in Tumon Bay, December 1991.

[illegible]	Transect 1				Transect 2				Transect 3			
[illegible]	A	B	C	D	A	B	C	D	A	B	C	D
10	80	0	2	0	78	4	0	0	82	8	0	0
20	64	0	1	0	18	1	0	0	28	1	0	0
30	100	0	0	0	77	2	0	0	44	14	0	1
40	100	0	0	0	84	3	0	0	88	8	1	0
50	100	0	0	0	98	0	0	0	68	2	0	0
60	100	0	0	0	86	0	0	1	36	8	0	0
70	94	6	0	0	78	0	0	6	44	1	0	0
80	100	0	0	0	80	[illegible]	0	0	88	10	6	1
90	88	1	0	0	88	0	0	0	57	14	0	0
100	88	6	10	1	88	0	0	0	88	2	0	0
110	100	0	0	0	88	0	0	0	84	8	0	1
120	44	1	7	[illegible]	86	3	0	6	88	0	8	2
130	84	11	0	[illegible]	98	0	2	0	86	6	0	1
140	20	72	0	0	80	3	0	0	98	[illegible]	1	0
150	30	41	1	1	81	8	0	[illegible]	80	4	2	4
160	[illegible]	20	[illegible]	[illegible]	82	[illegible]	0	1	88	7	0	1
170	47	10	18	[illegible]	80	[illegible]	0	2	90	2	1	0
180	96	4	0	[illegible]	96	2	0	3	90	1	1	0
190	97	1	0	0	11	4	0	1	88	3	0	1
200	62	8	6	0	88	0	0	0	16	3	20	4
210	4	91	0	6	80	0	0	1	58	8	6	0
220	18	2	6	0	18	38	0	1	81	8	4	0
230	23	16	0	6	18	28	0	1	86	0	2	7
240	4	6	0	3	82	28	0	0	47	41	0	1
250	18	8	6		0	76	1	10	38	28	2	0
260	8	4	0	0	0	78	7	3	2	74	18	0
270	3	10	6	3	6	84	20	0	48	78	4	0
280	0	8	0	0	0	81	11	0	18	71	12	0
290	6	[illegible]	0	0	0	82	17	0	28	33	0	7
300	0	0	0	2	0	85	31	0	10	83	1	1
310	0	0	0	0	0	81	28	0	20	33	0	2
320	0	0	0	0	8	30	66	0	61	0	0	6
330	8	17	0	0	4	28	17	0	6	48	0	0
340	[illegible]	8	0	0	0	8	49	0	8	48	1	0
350	6	0	0	0	0	13	28	0	18	43	0	0
360	4	16	0	[illegible]	0	17	30	0	11	61	1	1
370	[illegible]	0	1	1	0	64	28	0	18	48	0	0
380	6	0	0	[illegible]	0	55	18	0	6	56		1
390	10	12	1	2	0	81	8	0	4	53	0	0
400	7	7	0	1	6	78	8	0	11	8	1	0
410	12	15	0	4	4	18	6	0	0	68	0	6
420	5	4	0	[illegible]	0	13	6	0	0	56	1	
430	12	0	[illegible]	0	0	58	1	0	0	44	0	0
440	8	6	0	[illegible]	0	46	0	0	0	68	0	0
450	28	7	0	[illegible]	0	88	1	0	0	64	0	3
460	[illegible]	0	[illegible]	0					0	87	0	0
470	10	1	0	0					1	56	0	3
480	20	5	0	[illegible]					1	41	0	6
490	[illegible]	5	1	2					8	68	1	1
500	5	40	0	2					7	60	0	0
510									0	58	0	0
520									3	68	[illegible]	1
530									1	[illegible]	1	[illegible]
540									1	11	1	2
550									1	28	1	1
560									2	[illegible]	[illegible]	0
570									3	[illegible]	0	0

Table II 2. Comparison of marine plant species quantified along three similar transects during November/December 1977 and December 1991.

Species	1977	1991
CYANOPHYTA (3 species)		
<u>Microcoleus</u> <u>lyngbyaceus</u> (Kuetz.) Crouan	X	X
<u>Schizothrix</u> <u>calcicola</u> (Ag.) Gomont	X	X
<u>Schizothrix</u> <u>mexicana</u> Gomont	X	X
CHLOROPHYTA (18 species)		
<u>Acetabularia</u> <u>parvula</u> Solms-Laubach [= <u>A</u>. <u>moebii</u> Solms-Laubach]	X	
<u>Boergesenia</u> <u>forbesii</u> (Harv.) Feldmann		X
<u>Boodlea</u> <u>composita</u> (Harv.) Brand	X	X
<u>Bryopsis</u> <u>pennata</u> Lamx.	X	
<u>Caulerpa</u> <u>cupressoides</u> (West) C. Ag.	X	
<u>Caulerpa</u> <u>racemosa</u> (Forsk.) J. Ag.	X	X
<u>Caulerpa</u> <u>serrulata</u> (Forsk.) J. Ag.		X
<u>Caulerpa</u> <u>sertularioides</u> (Gmel.) Howe	X	
<u>Cladophora</u> <u>fascicularis</u> (Mertens) Kuetz.	X	
<u>Cladophoropsis</u> <u>membranacea</u> (Ag.) Boerg.	X	X
<u>Cladophoropsis</u> <u>sundanensis</u> Reinbold		X
<u>Dictyosphaeria</u> <u>cavernosa</u> (Forsk.) Boerg.	X	
<u>Dictyosphaeria</u> <u>versluysii</u> W.v. Bosse		X
<u>Enteromorpha</u> <u>clathrata</u> (Roth) J. Ag.	X	X
<u>Halimeda</u> <u>macroloba</u> Decaisne	X	
<u>Halimeda</u> <u>opuntia</u> (L.) Lamx.	X	X
<u>Neomeris</u> <u>annulata</u> Dickie	X	X
<u>Ventricularia</u> <u>ventricosa</u> (J. Ag.) Olsen & J. West [<u>Valonia</u> <u>ventricosa</u> J. Ag.]	X	
PHAEOPHYTA (10 species)		
<u>Dictyota</u> <u>bartayresii</u> Lamx.	X	X
<u>Dictyota</u> <u>friabilis</u> Setchell		X
<u>Feldmannia</u> <u>indica</u> (Sonder) Womersley & Bailey		X
<u>Lobophora</u> <u>variegata</u> (Lamx.) Womersley	X	X
<u>Padina</u> <u>boryana</u> Thivy [= <u>P</u>. <u>tenuis</u> Bory]	X	X
<u>Ralfsia</u> <u>pangoensis</u> Setchell		X
<u>Sargassum</u> <u>cristaefolium</u> C. Ag.	X	
<u>Sargassum</u> <u>polycystum</u> C. Ag.	X	X
<u>Sphacelaria</u> <u>tribuloides</u> Menegh.	X	X
<u>Turbinaria</u> <u>ornata</u> (Turn.) J. Ag.	X	X

Table II-2. Continued.

Species	1977	1991
RHODOPHYTA (23 species)		
Acanthophora spicifera (Vahl) Boerg.	X	X
Actinotrichia fragilis (Forsk.) Boerg.		X
Amphiroa fragilissima Lamx.	X	
Ceramium gracillimum Griff. & Harv.		X
Chondria sp.		X
Galaxaura fasciculata Kjellm.	X	
Gelidiella acerosa (Forsk.) Feldmann & Hamel		X
Gelidiopsis intricata (C. Ag.) Vickers	X	X
Gelidium divaricatum Martens		X
Gelidium pusillum (Stackhouse) Le Jolis	X	
Gracilaria salicornia (C. Ag.) Dawson [= G. arcuata Zanard. sensu Tsuda, 1978]	X	X
Hypnea musciformis (Wulfen) Lamx. v. esperi J.Ag. [= H. esperi Bory]	X	
Jania capillacea Harvey	X	X
Laurencia sp.		X
Mastophora rosea (C. Ag.) Setchell		X
Polysiphonia spp.	X	X
Rhodymenia divaricata Dawson		X
Spyridea filamentosa (Wulfen) Harvey		X
Wurdemannia miniata (Duby) Feldmann & Hamel		X
"Crustose Coralline"		
Neogoniolithon frutescens (Foslie) Setchell & Mason	"X"	X
Peyssonnelia rubra (Greville) J. Ag.	"X"	X
Porolithon onkodes (Heydrich) Foslie	"X"	X
Porolithon sp.	"X"	X
ANTHOPHYTA (1 species)		
Halophila minor (Zoll.) den Hartog	X	X
Total, including corallines (55 species)	38	42
Total, excluding corallines (51 species)	34	38

Table II.3. Comparison of percent cover of marine plants quantified along three transects during 1977 and 1991.

Species			Transect 1		Transect 2		Transect 3	
			1977	1991	1977	1991	1977	1991
CYANOPHYTA								
Microcoleus	lyngbyaceus	(Kuetz.) Crouan	5	<1	<1	<1	2	<1
Schizothrix	calcicola	(Ag.) Gomont	17	-	<1		16	5
Schizothrix	mexicana	Gomont	-		<1	-	<1	<1
CHLOROPHYTA (18 species)								
Acetabularia	parvula	Solms-Laubach	-		-	-	<1	-
	[= A. moebii Solms-Laubach]							
Boergesenia	forbesii	(Harv.) Feldmann	-	-	-	-		<1
Boodlea	composita	(Harv.) Brand	<1	4	1	-	-	<1
Bryopsis	pennata	Lamx.		-	<1	-		
Caulerpa	cupressoides	(West) C. Ag.	-	-	<1	-	-	-
Caulerpa	racemosa	(Forsk.) J. Ag.	-	<1	<1	-	<1	-
Caulerpa	serrulata	(Forsk.) J. Ag.	-	<1	-	<1	-	-
Caulerpa	sertularioides	(Gmel.) Howe	<1	-	-	-	-	-
Cladophora	fascicularis	(Mertens) Kuetz.	-	-	-	-		-
Cladophoropsis	membranacea	(C. Ag.) Boerg.	-	<1	-	-	1	-
Cladophoropsis	sundanensis	Reinbold	-	3	-	<1	-	<1
Dictyosphaeria	cavernosa	(Forsk.) Boerg.	<1	-	<1	-	<1	-
Dictyosphaeria	versluysii	W. v. Bosse	-	<1	-	<1	-	-
Enteromorpha	clathrata	(Roth) J. Ag.	3	1	<1	2	<1	2
Halimeda	macroloba	Decaisne	<1	-	-		-	-
Halimeda	opuntia	(L.) Lamx.	1	1	2	1	<1	<1
Neomeris	annulata	Dickie	-	<1	<1	-	-	<1
Ventricularia	ventricosa	(J. Ag.)	<1	-	-		-	-
	Olsen & J. West							
	[= Valonia ventricosa J. Ag.]							
PHAEOPHYTA (10 species)								
Dictyota	bartayresii	Lamx.		<1	<1	<1	2	<1
Dictyota	friabilis	Setchell	-	-	-		-	<1
Feldmannia	indica	(Sonder)	-	-	-	<1	-	<1
	Womersley & Bailey							
Lobophora	variegata	(Lamx.) Womersley	-	-	-		<1	<1
Padina	boryana	Thivy	<1	5	3	1	12	6
	[= P. tenuis Bory]							<1
Ralfsia	pangoensis	Setchell	-	<1		-	-	-
Sargassum	crassifolium	C. Ag.		-	-	-	<1	<1
Sargassum	polycystum	C. Ag.	<1	-	<1	<1	<1	1
Sphacelaria	tribuloides	Menegh.	<1	-	<1	-	<1	<1
Turbinaria	ornata	(Turn.) J. Ag.	<1	<1	<1	-	7	-

Table II-3 (continued). Comparison of percent cover of marine plants quantified along three transects during 1977 and 1991.

Species			Transect 1		Transect 2		Transect 3	
			1977	1991	1977	1991	1977	1991
RODOPHYTA (23 species)								
Acanthophor	spicifera	(Vahl) Boerg.	<1	<1	<1	<1	-	<1
Actinotrichia	fragilis	(Forsk.) Boerg.	-	<1	-	-		-
Amphiroa	fragilissima	Lamx.	-	-	<1	-	<1	-
Ceramium	gracillimum	Griff. & Harv.		<1		<1	-	<1
Chondria	sp.		-	-	-	-	-	<1
Galaxaura	fasciculata	Kjellm.	-	-	<1	-	-	-
Gelidiella	acerosa	(Forsk.) Feldmann & Hamel	-	17	-	-	-	8
Gelidiopsis	intricata	(C. Ag.) Vickers	<1	2	<1	<1	<1	<1
Gelidium	divaricatum	Martens	-	2	-	<1	-	<1
Gelidium	pusillum	(Stackhouse) Le Jolis	<1	-	<1	-	<1	
Gracilaria	salicornia	(C. Ag.) Dawson	-	<1	<1	<1	-	<1
	[= G. arcuata Zanard. sensu Tsuda, 1978]							
Hypnea	musciformis	(Wulfen) Lamx.	2	-	<1	-	<1	-
	v. esperi J. Ag.							
	[= H. esperi Bory]							
Jania	capillacea	Harvey	-	5	-	-	-	2
Laurencia	sp.			7	-	-	-	-
Mastophora	rosea	(C. Ag.) Setchell	-	<1	-	-	<1	-
Polysiphonia	spp.		<1	5	-	<1	-	<1
Rhodymenia	divaricata	Dawson	-	2	-	-	-	<1
Spyridia	filamentosa	(Wulfen) Harvey	-	-	-	-	-	<1
Wurdemanni	miniata	(Duby) Feldmann & Hamel	-	<1	-	-	-	-
"Crustose	Coralline"		7	3	16	6	<1	2
ANTHOPHYTA (1 species)								
Halophila	minor	(Zoll.) den Hartog	-	<1	-	-	<1	-
TURF			27		<1	-	1	-

Table II-4. Number of species (A) and percent cover (B) of marine plants quantified within 10 meter intervals (0.25-meter wide) along Transects 1, 2 and 3 in Tumon Bay during November/December 1977 and December 1991 (second figure after slash (/)). The percent cover values were extracted from histogram (see Figures II-1 to 3) in Tsuda et al. (1978) and rounded off to the nearest 5%.

Distance from Shore	Transect 1 A	Transect 1 B	Transect 2 A	Transect 2 B	Transect 3 A	Transect 3 B
0-10	1/1	50/20	0/1	0/18	0/0	0/6
10-20	1/1	10/36	1/1	5/21	1/1	15/71
20-30	2/0	20/0	1/2	5/28	3/3	20/41
30-40	2/0	25/0	0/2	0/6	3/2	30/2
40-50	4/0	20/0	2/2	5/2	4/3	40/41
50-60	3/1	20/1	1/3	5/14	4/2	65/59
60-70	1/2	15/6	3/4	10/18	6/4	50/42
70-80	3/0	40/0	2/5	10/9	4/2	30/41
80-90	3/0	55/0	2/1	10/2	3/4	70/31
90-100	5/0	40/0	3/1	5/1	3/1	35/31
100-110	2/0	15/0	2/3	10/4	3/2	20/9
110-120	3/2	60/2	3/0	10/0	3/2	5/6
120-130	3/4	55/5	2/0	10/0	3/0	25/0
130-140	2/1	70/8	4/1	20/0	2/0	50/0
140-150	1/5	75/26	1/2	10/15	3/1	70/1
150-160	6/1	70/10	2/2	10/5	1/1	75/1
160-170	4/2	55/9	2/1	15/1	3/0	70/0
170-180	3/0	70/0	1/3	10/6	2/1	45/15
180-190	5/2	50/6	3/3	15/14	2/0	20/0
190-200	4/9	30/36	2/2	5/6	3/1	70/1
200-210	3/5	75/35	2/3	5/15	2/2	40/31
210-220	7/7	70/76	6/5	40/25	4/2	60/9
220-230	7/5	75/65	5/5	45/19	2/0	70/0
230-240	5/6	55/89	3/4	40/12	1/1	70/12
240-250	3/8	75/78	4/4	35/13	5/2	70/31
250-260	3/8	70/86	4/5	30/16	4/6	55/50
260-270	7/8	70/95	4/5	40/11	5/3	45/25
270-280	6/7	70/91	6/4	45/28	4/3	40/29
280-290	6/11	55/94	4/4	40/25	3/9	50/40
290-300	7/7	65/98	4/1	25/19	5/5	30/24
300-310	4/7	80/100	7/1	60/10	3/5	30/35
310-320	1/7	95/100	6/3	50/8	3/4	20/28
320-330	1/8	90/79	7/0	30/0	9/7	40/26
330-340	1/7	95/92	6/1	35/2	4/6	45/41
340-350	2/8	95/92	6/0	45/0	4/8	55/31
350-360	2/8	75/79	9/1	50/8	4/6	40/34
360-370	3/7	80/98	6/5	50/16	5/7	40/18
370-380	3/5	95/94	9/2	55/26	3/5	40/35
380-390	2/6	30/78	5/3	70/29	2/6	35/34
390-400	1/4	75/97	1/3	35/20	4/4	40/28

Table II-4. Continued.

Distance from Shore	Transect 1		Transect 2		Transect 3	
	A	B	A	B	A	B
400-410	2/6	85/74	6/4	70/18	6/5	50/41
410-420	5/7	65/91	7/3	55/22	7/6	50/44
420-430	2/2	75/88	8/3	60/42	9/5	55/39
430-440	2/6	90/78	6/4	40/25	9/5	60/32
440-450	2/3	70/73	6/4	50/31	7/3	60/46
450-460	2/4	30/98	10/-	60/-	8/4	60/8
460-470	2/3	35/69	8/-	70/-	8/6	60/32
470-480	3/4	95/75	9/-	65/-	4/5	85/52
480-490	3/4	80/95	7/-	55/-	10/4	90/34
490-500	4/4	100/60	7/-	40/-	11/5	85/40
500-510					8/2	50/42
510-520					5/4	60/29
520-530					8/2	65/29
530-540					7/6	60/29
540-550					4/8	60/68
550-560					9/7	85/98
560-570					9/2	90/81
No. Spp.*	18/28		24/16		22/29	

* Excluding "crustose corallines".

III. CORALS

Richard H. Randall

INTRODUCTION

In 1977 the Guam Coastal Management Program contracted the University of Guam Marine Laboratory to conduct a baseline marine survey of the marine plants, corals, other macroinvertebrates, and fishes on the shallow fringing reef flat platforms associated with Tumon, Agana, Agat, Fouha, and Ylig Bays. In 1991 the University of Guam was contracted by the Guam Department of Parks and Recreation to conduct a reassessment of the marine plants, corals, other macroinvertebrates, and fishes on the fringing reef flat platform along Tumon Bay, and compare the results with those of the first baseline survey of the bay that was conducted more than fourteen-and-a-half years ago. Since the first baseline assessment was conducted the land along Tumon Bay has undergone extensive commercial development, particularly by the construction of large tourist hotels. Recreational use of the adjacent shallow reef flat platform along Tumon Bay has also greatly increased as hotel development progressed.

For a review of previous studies of the community structure of the corals in Tumon Bay see pp. 28-30 in Randall, 1978.

Fieldwork transect assessments for the 1991 reassessment survey were conducted on December 17, 1991, for Transect 1; on December 16, 1991, for Transect 2 from 0 to 450 meters and on January 20, 1992, from 450 to 500 meters; and on December 18, 1991 for Transect 3. Fieldwork transect assessments for the 1977 baseline survey were conducted on June 20, 1977 for Transect 1; on May 27, 1977 for Transect 2 from 0 to 200 meters and on June 21, 1977 from 200 to 500 meters; and on June 8, 1977 for Transect 3.

METHODS

The coral communities were analyzed along the same three transects that were surveyed in 1977 (Figure III-1). Although permanent transect markers were not established on the reef flat platform during the 1977 survey, the shoreline locations from which the transects were extended from were still intact and recognizable. Transect 1, at the north end of the bay, was located at the south end of Gognga Beach where some large blocks buttressed the base of a limestone scarp along the shoreline. Sanvitores Monument and the Reef Hotel Complex lie a short distance inland along the scarp. The transect line was attached to the most seawardly situated of the large blocks along the shoreline and then laid out in a seaward direction normal to the shoreline to the outer margin of the reef flat platform, a distance of 500 meters. Transect 2, at the middle of the bay, was located where a road dead ends at the shoreline. The Fujita Hotel Complex lies a short distance inland along the south side of the road. The transect line was attached to a tree at the end of the road and then laid out in a seaward direction normal to the shoreline to the outer margin of the reef flat platform, a distance of 500 meters. Transect 3, at the south end of the bay, was located at the northern boundary of the Ypao Beach Park. From

the shoreline at the park boundary the transect line was laid out in a seaward direction normal to the shoreline to the outer edge of the reef flat platform, a distance of 570 meters.

The coral communities were analyzed along the three transects by using the point-centered or point-quarter technique of Cottam et al., 1953, as described in the "Corals" section of the University of Guam Marine Laboratory Technical Report No. 48, pp. 30-31 (Randall, 1978). This was the same method used in the 1977 baseline survey. Qualitative and quantitative observations and transect data were collected within the same framework of subzone divisions that were discriminated along the three transect areas during the 1977 baseline survey.

The coral species encountered during the point-quarter analysis indicate the predominate and common species within the transect areas. The presence of uncommon and rare species, not encountered during the point-quarter analysis, was determined for each transect by making ten-minute snorkel observations along each side of the transect line for each 100 meters of transect length. A list of species is compiled for each subzone discriminated along each of the three transects by combining those encountered during the point-quarter analysis with those observed from snorkel observations in Table III-1. A revised species list for the 1977 survey has been included in Table III-1 which incorporates a number of taxonomic name changes that have occurred since the earlier survey. Table III-1 also provides a list of species recorded from each of the subzones for the 1977 survey instead of just a tally of the number of species and genera that was given in the earlier report (Table III-2, pp. 50-51, in Randall, 1978).

Quantitative point-quarter analysis data of coral colony size distribution, frequency of occurrence, density, and percentage of substrate coverage are compiled for all the individual coral species that occurred within each subzone as well as the mean colony size, density, and percentage of substrate coverage values for the entire coral community of each subzone in Table III-2. Similar quantitative data in the 1977 survey report (Table III-3, pp. 52-56, in Randall, 1978) has been revised and included in this report as Table III-3 because of an error in calculating the density and percentage of substrate coverage values for the scattered coral subzone on the Tumon Bay Transect No. 3. The error occurred as a result of using only quadrants which contained corals (a total of 52 quadrants) instead of the total number of quadrants sampled within the subzone (a total of 148 quadrants), which resulted in a considerable overestimation of the density and substrate coverage values for the coral community in that subzone. The corrected density and substrate coverage values for this subzone has been incorporated into Table III-3 of this report.

Frequency distribution of coral colony diameters for each subzone is given in Table III-4 for the 1991 reassessment survey and in Table III-5 for the 1977 baseline assessment survey. Frequency distribution of coral colony growth forms for each subzone is given in Table III-6 for the 1991 reassessment survey and in Table III-7 for the 1977 baseline assessment survey.

Representative vertical profiles of the three Tumon Bay transects showing the reef zones and subzones, water depth, and general distribution of corals across the reef platform are shown in Figure III-2.

RESULTS AND DISCUSSION

Coral Distribution and Zonation Patterns

One of the most noticeable aspects of the coral communities along the Tumon Bay transects is their unequal distribution across the fringing reef flat platform from the shoreline to the outer seaward margin. Although less noticeable along the transects, there is also considerable community variation along the length of the fringing reef flat platform of Tumon Bay as well. At Transects 1 and 3, the outer third of the reef flat platform is slightly elevated in respect to the inner part and consequently at low tides is often partly or completely exposed, while the inner two-thirds remains covered by a shallow moat of water. On this basis, the reef flat platform can be divided into an inner subtidal moat zone and an outer intertidal platform zone. At Transect 2, the outer part of the reef flat is not elevated and thus the entire platform remains mostly submerged during low tides. At Transect 2, the inner four-fifths of the reef flat platform is similar to that at Transects 1 and 3, but the outer submerged fifth has an irregular topographic relief with holes, shallow troughs, and depressions up to two meters deep at places. This deeper outer part of the platform at Transect 2 has a more diverse coral community that contains many species normally found on the wave-washed reef margin and deeper off-platform reef slope zones, as well as species more or less restricted to shallow reef platforms. In this report this subtidal outer part of the platform at Transect 2 is called the outer reef flat zone and was not further subdivided.

Large areas of the reef flat platform lack corals, while other areas support communities ranging from a few widely scattered colonies and species to regions where the surface is dominated by a monotypic cover of a single species or a relatively diverse assemblage of species. Because of this variation in coral distribution it was necessary to divide the reef platform into a number of subzones in order to make a realistic quantitative assessment of the corals. The inner reef flat platform at the three transect areas was divided into a sand, scattered coral, and coral subzones. The sand subzone occupies the inner fourth the reef flat platform which consists of a truncated reef rock pavement veneered by a thin sandy layer, generally less than 10 cm thick, where corals are either absent or widely scattered. The scattered coral subzone occupies a region that extends seaward of the sand subzone to about the middle part reef flat platform where the layer of sandy sediments becomes thinner, intermixed with variable amounts of gravel- and rubble-sized clasts, and is somewhat patchy in distribution among local exposures of bare reef rock. Corals are generally present in the subzone, but are widely scattered and mostly small in size, except for a few microatoll-shaped colonies which are commonly only partly alive. The coral subzone occupies a region of variable width between the intertidal outer reef flat platform and the scattered coral subzone where coarse rubbly sediments are patchily distributed among areas of living and dead coral colonies and exposures of bare reef rock. Corals are generally common to abundant within the subzone and occur as scattered colonies and variable-sized patches composed of mixed species or monotypic thickets of arborescent and foliose species. The intertidal outer reef flat platform at Transects 1 and 3 were divided into a pavement and pool and pavement subzones. The pavement and pool subzone occupies a shoreward part of intertidal platform of variable width that consists of an irregular reef rock surface which retains water in shallow scattered depressions and holes during low tides. Boulder rubble commonly occupies parts of the subzone surface and corals are generally small in size, widely scattered, and restricted to holes and depressions that retain water during low tides. The pavement subzone consists of a relatively flat and featureless reef rock surface that completely exposes during low tides. Strong wave surge generally keeps sediments swept off the platform and corals are generally absent, but a few scattered holes that retain water during low tides may contain some small colonies, as well as minor amounts of sediments. The subtidal outer reef flat zone at Transect 2 was described above.

Representative vertical profiles show the reef platform zones discriminated along the three transect areas in Figure III-2.

Species Abundance

A total of 76 coral species representing 28 genera were recorded from the three combined transect areas during the 1977 survey, and from the same transects a total of 73 coral species representing 25 genera were recorded during the 1991 reassessment survey (Table III-1). Species that were recorded during the first baseline survey but not during the second reassessment survey include: 1) Seriatopora hystrix, Montipora acanthella, Pavona explanulata, Goniastrea pectinata, and Diploastrea heliopora, each from single observations in the subtidal outer reef flat zone at Transect 2; 2) Lobophyllia corymbosa from a single observation in the coral subzone at Transect 1; and 3) a single ahermatypic Polycyathus fulvus corallite that was collected from the roof of a small dark cavity in the coral subzone at Transect 2. Coral species that were recorded during the second reassessment survey but not during the first baseline survey include: 1) three occurrences of Psammocora (Encrusting sp. 1) and a single observation of Pocillopora verrucosa in the subtidal outer reef flat zone at Transect 2; 2) Acropora formosa that was commonly observed and recorded in 17 point-quarter quadrants in the sand and scattered coral subzones at Transect 3; and 3) a single occurrence of Millepora dichotoma in the pavement subzone at Transect 1. The presence of Acropora formosa on the Tumon Bay fringing reef flat platform appears to be recent recruit, since it was not recorded during the 1977 baseline assessment survey or during detailed surveys conducted by Randall (1971 and 1973) in the late 1960's and early 1970's.

Overall species and genus abundance recorded for each transect during the 1977 baseline survey was 25 species and 12 genera at Transect 1, 67 species and 26 genera at Transect 2, and 26 species and 12 genera at Transect 3; and during the 1991 reassessment survey was 23 species and 10 genera at Transect 1, 71 species and 25 genera at Transect 2, and 22 species and 11 genera at Transect 3 (Table III-1).

Species abundance within the various subzones discriminated along the three transects is given in Table III-1. Within the 14 subzones discriminated along the three transect areas, the 1991 reassessment survey revealed that species abundance had increased by 1 species in 1 subzone, 2 species in 3 subzones, 3 species in 2 subzones, 5 species in 1 subzone, 6 species in 1 subzone, and 10 species in 1 subzone since the earlier 1977 baseline assessment survey (Table III-1). The most noticeable increases in species abundance occurred in the inner reef flat sand and scattered coral subzones at Transects 1 and 3, and in the subtidal outer reef flat zone at Transect 2. In the sand subzones there were seven- and three-fold increases in the number of species recorded at Transects 1 and 3 respectively. Although there was an increase of 10 species recorded in the outer reef flat zone at Transect 2 during the 1991 reassessment survey, the effect was less noticeable because of the initial higher species abundance there (59 species) than on the inner reef flat where initial species abundance ranged from 1 to 5 species in the sand subzones and from 8 to 11 species in the scattered coral subzones. It is suspected that Acanthaster planci predation on corals that occurred between the 1977 and 1991 assessment surveys has been a major factor in reducing the number of species recorded from the outer reef flat at Transect 2. During the 1991 reassessment survey only a single A. planci starfish, 45 cm in diameter, was observed feeding on Pavona decussata in the outer reef flat zone at Transect 2.

There was little change recorded in species abundance between the 1977 and 1991 assessment surveys in the coral subzones at Transects 1-3, and in the outer reef flat subzones at Transects 1 and 3 (Table III-1).

Combining both the 1977 and 1991 surveys together yielded a total of 81 species representing 28 genera that were recorded from the overall fringing reef flat platform at Tumon Bay.

Colony Size, Density, and Substrate Coverage

Coral colony size distribution data (n = number of data, x = mean colony diameter, s = standard deviation, w = colony size range), density, and percentage of substrate coverage for the various subzones discriminated along Transects 1-3 are given in Table III-2 for the 1991 reassessment survey and in Table III-3 for the 1977 baseline survey. Between the 1977 baseline survey and the 1991 reassessment survey, the point-quarter assessment data indicates that within the 14 subzones discriminated along the three transect areas, mean coral colony diameter increased at 9 subzones, decreased at 4 subzones, and remained unchanged at 1 subzone; coral density increased at 10 subzones, decreased at 3 subzones, and remained unchanged at 1 subzone; and the percentage of substrate coverage by corals increased at 11 subzones, decreased at 1 subzone, and remained unchanged at 2 subzones (Tables III-2 and III-3).

Although there was an increase in coral colony size between the first and second assessment surveys in most of the subzone communities, there was a general trend for the mean colony size to be smallest in the sand subzones (no corals encountered during the 1977 survey), intermediate in the outer reef flat subzones, and largest in the scattered coral and coral subzones during both assessment surveys. A comparison of the frequency distribution of coral colony diameters in Tables III-4 and III-5 shows that although 209 more corals were encountered in the point-quarter transect quadrants during the 1991 assessment survey than during the 1977 baseline survey, the relative percentage of corals in each size class has remained nearly the same for both assessments. In both assessment surveys over 50 percent of the corals encountered on the transects were in the 0-5 cm size class and over 90 percent of the corals encountered were smaller than 20 cm in diameter.

The most significant changes in the community structure of corals on the fringing reef flat platform at Tumon Bay was an increase in coral density and percentage of substrate coverage recorded in most of the 14 subzone communities between the 1977 baseline assessment survey and the 1991 reassessment survey (Tables III-2 and III-3). Some of the most noticeable, but generally not the largest, increases occurred in the inner reef flat sand subzones where no corals were encountered at all in the point-quarter transect quadrants during the 1977 assessment survey. At Transect 1, over 22 percent of the 112 quadrants that occurred within the sand subzone contained corals within the search radius, and at Transect 2 over 66 percent of the 120 quadrants within the sand subzone also contained corals.

During each of the 1977 and 1991 point-quarter surveys, a total of 301 transect points were established along Transects 1-3 (98 points each along Transects 1 and 2 and 105 points along Transect 3), resulting in a total of 1204 sampling quadrants (4 at each point). Corals were recorded in 37.0 percent (446) of the quadrants during the 1977 baseline assessment survey and in 54.4 percent (655) of the quadrants during the 1991 reassessment survey. During the 1977 baseline assessment survey corals were not encountered in any of the point-quarter transect quadrants within the three inner reef flat sand subzones (324 quadrants), and in the outer reef flat pavement subzone at Transect 1 (84 quadrants), whereas during the 1991 reassessment survey the only subzone where corals were not encountered was in the inner reef flat sand subzone at Transect 2 (92 quadrants).

Coral Growth Form Distribution

For the overall bay the most conspicuous changes in colony growth form has been a reduction in the number of cespitose colonies from 305 (68% of the total community) to 161 (24.5% of the total community), and increases in the number of massive colonies from 35 (7.8% of the total community) to 109 (16.6% of the total community), encrusting colonies from 15 (3.4% of the total community) to 186 (28.4% of the total community), and foliose colonies from 44 (9.9% of the total community) to 127 colonies (19.4% of the total community) from the 1977 and 1991 surveys respectively (Tables III-6 and III-7). The change in the relative percentage of cespitose colony forms is a primarily the result of the large increase in the number of encrusting colonies of Leptastrea purpurea that were recorded in the sand and scattered coral subzones at Transects 1 and 3 where corals were absent during the 1977 survey, and from the increase in number of foliose Pavona species recorded from the coral subzone at Transect 2 during the 1991 survey (Tables III-2, 3, 6 and 7). There was also an increase in the number massive colony forms of Porites species recorded along the transects, particularly at Transects 1 and 3, during the 1991 survey.

Distribution Patterns of Coral Species on the Reef Flat Platform

Stylocoeiella armata is an inconspicuous species that forms small encrusting patches a few centimeters across in cryptic habitats. It was occasionally observed in the outer reef flat zone at Transect 2 during both assessment surveys.

The genus Psammocora is abundantly represented on the reef flat platform by P. contigua, P. stellata, and P. obtusangula. These three species form ramose clusters with closely-set branches, which may dominate local areas of the inner reef flat platform and outer reef flat platform at Transect 2. During both surveys Psammocora contigua, P. stellata, and P. obtusangula were most abundant in the coral subzone and outer reef flat platform zone at Transect 2, scattered to locally abundant in the scattered coral subzone at Transect 2, scattered to rare in the remaining inner reef flat subzones, and rare on the outer reef flat platform. A comparison of the quantitative transect data between the two surveys indicate a reduction in the number of Psammocora species in the coral subzone of Transect 2 during the 1991 survey, particularly of P. obtusangula, primarily because of the conspicuous increase in that subzone by pavonid species since the 1977 survey. These ramose Psammocora species fragment easily during storms, and the broken pieces are commonly transported shoreward by wave action. Because of their much larger initial size than newly settled planulae, these fragments have a greater chance of survival, which accounts partly for the colonies observed on the unconsolidated substrates in the sand and scattered coral subzones. Many of the colonies transported to inner parts of the reef flat platform later die, but immediately after storms, abundance of living fragments may be temporarily high. Psammocora digitata was represented by a single colony in the coral subzone at Transect 1 during the 1977 survey, and during the 1991 survey was again observed at the same Transect 1 location, and in the outer reef flat zone at Transect 2 where a scattered community of small columnar colonies was observed. The pink-colored encrusting colonies of Psammocora (nodulose sp. 1) were observed in the outer reef flat platform zone at Transect 2 during both surveys, but during the 1991 survey it appeared to be more abundant. Green-colored encrusting colonies of Psammocora (encrusting sp. 1) were only observed during the 1991 survey in the outer reef flat platform zone at Transect 2, where three colonies were recorded.

In the family Pocilloporidae, a single colony of Seriatopora hystrix was observed in the outer reef flat platform zone at Transect 2 during the 1977 survey, but during the 1991 survey it was not observed. The abundance and distribution of Pocillopora damicornis has remained about the same at Transects 1 and 2 during both surveys, but was less abundant in the scattered coral subzone at Transect 3 during the 1991 survey. Pocillopora danae and P. setchelli were only observed in the coral subzone and outer reef flat platform zone at Transect 2 during both surveys. Abundance and distribution of P. danae has remained about the same during both surveys, but the abundance of P. setchelli appeared to be slightly less in the coral subzone during the 1991 survey. Pocillopora damicornis is fairly successful at colonizing unconsolidated substrates by planulae settlement on larger pieces of stable rubble that are intermixed with the finer sand-sized sediments.

Although the family Acroporidae was the most diverse family of corals on the reef flat platform (19 species during the both surveys), the only species that were observed as common or abundant were Acropora aspera, A. acuminata, and A. formosa. At Transect 1, Acropora aspera was found to be more widely distributed during the 1991 survey, but substrate coverage was slightly lower than during the 1977 survey. At Transect 2, Acropora aspera was not observed in any of the four subzones and zones during the 1977 survey, but was observed in all four during the 1991 survey. There was a very noticeable increase in the abundance and substrate coverage by Acropora aspera at Transect 3 in all the inner reef flat subzones during the 1991 survey, particularly in the scattered coral subzone. Acropora acuminata was relatively uncommon during both survey periods, but had a greater range of distribution during the 1977 survey. Acropora acuminata is now most abundant in the shallow channel that cuts across the outer reef flat platform between Transects 1 and 2, where it occurs as scattered clumps. Acropora formosa was not recorded during the 1977 survey, but during the 1991 survey it was found to be quite common in the scattered coral subzone at Transect 3 and more widely scattered in the sand subzone at Transect 3 and outer reef flat platform zone at Transect 2. Either Acropora formosa has been recruited onto the Tumon Bay reef flat platform since the 1977 survey, or it was relatively rare then and not observed. In 1972 a series of exceptionally low tides killed many of the arborescent Acropora thickets on shallower parts of the reef flat platform. Acropora acuminata was particularly sensitive to prolonged exposure during the low tides. Before the series of low tides, Randall (1971 and 1973) reported A. acuminata as a common and more widespread species on the reef flat platform at Tumon Bay. Possibly A. formosa was mostly killed off during the 1972 low tides, but a few surviving clumps, that was unnoticed during the 1977 survey, have recolonized the inner reef flat subzones at Transect 3 and the outer reef flat platform zone at Transect 2. Arborescent Acropora species are found in greatest abundance in the inner reef flat coral subzone, but since they fragment easily during storms (and from people walking on the reef and from wind surfing boards and boat traffic), stems are transported shoreward to the scattered coral and sand subzones by wave transport where they can become established. Such transported colonies may survive and grow for a time, but because of periodic extreme low tides, water temperature elevation to sublethal or lethal levels, and storm wave surge from typhoons, all but the most tolerant species are killed at unpredictable intervals--a process that keeps coral density, substrate coverage, and species abundance low in subtidal moats of the sand and scattered coral subzones along the length of Tumon Bay. Montipora lobulata was recorded at the same five subzones during both surveys, and Montipora acanthella, which was recorded from a single occurrence during the 1977 survey was not observed during the 1991 survey. The remaining 8 species of Acropora and 6 species of Montipora that were recorded during both surveys were restricted to the deeper parts of the outer reef flat platform at Transect 2 and the coral subzone at Transect 3, where they are either rare or uncommon, sometimes represented by a single observation. Astreopora myriophthalma was only observed in the outer reef flat platform zone at Transect 2 during both surveys.

Of the six pavonid species observed on the reef flat platform, Pavona decussata is the most abundant and has the widest distribution, as well as a higher value of substrate coverage than any other coral on the overall reef flat platform (8.6% in the outer reef flat platform zone at Transect 2 during the 1991 survey and 4.7% in the coral subzone at Transect 2 during the

1977 survey). Pavona decussata forms large monotypic beds at many locations on the reef flat platform, particularly in the vicinity of the shallow channel that cuts through the outer platform between Transects 1 and 2, and at the present time it probably covers more substrate on the overall platform than any other species. Except in the coral subzone at Transect 3, Pavona decussata was considerably more abundant and had a wider range of distribution during 1991 survey than during the 1977 survey. The abundance of Pavona divaricata, P. venosa, P. varians, and Pavona (encrusting sp 1) have remained about the same during the two surveys, but except for Pavona (encrusting sp. 1) the remainder of the species had a wider distribution range during the 1991 survey. Pavona explanulata was only recorded during the 1977 survey from a single occurrence in a large hole on the outer reef flat platform zone at Transect 2.

In the family Poritidae, the two Goniopora species are rare and were observed during both surveys in the outer reef flat platform zone at Transect 2. Porites is the most diverse (12 species recorded during both surveys) and widespread genus on the overall reef flat platform. Small colonies of Porites species occasionally gain a refuge in size on the sandy-floored inner reef flat subzones by planula settlement on scattered pieces of more stable rubble, or by wave transport of small colonies and stems during storms. Such colonies sometimes grow and develop into flat-topped masses (microatolls) up to a meter or more in diameter, and are the only conspicuous relief features found on the sand-floored inner reef flat subzones. Stunted nodular colonies of Porites lutea and P. australiensis, growing in small holes that retain water, are the predominant species found in the harsh outer reef flat zones that become exposed during low tides. Ramose stem fragments, clumps of branches, and intact larger masses of Porites cylindrica are widely distributed, and at places are the predominant coral species in the inner reef flat subzones. Porites lutea, P. australiensis, P. cylindrica was found in more subzones at all three transect areas during the 1991 survey. The abundance of P. lutea and P. australiensis was also higher in most subzones at all three transect areas during the 1991 survey.

The 1991 survey showed that the abundance of P. cylindrica was higher in the coral subzone at Transect 2 and lower in the sand and scattered coral subzones at Transect 3; at Transect 1 abundance was noticeably higher in the sand subzone, about the same in the scattered coral subzone, and lower in the coral subzone. Porites annae, P. (S.) rus, and Porites (nodular sp. 1) were recorded in more subzones during the 1991 survey, and the abundance of the three species appeared to be greater in the inner reef flat subzones at Transect 2 as well. The distribution of Porites (massive sp. 1) was extended into the coral subzone at Transect 3, and abundance was higher in the coral subzone at Transect 2 during the 1991 survey. Porites lobata, P. lutea, P. superfusa, P. murrayensis, and P. (N.) vaughan are uncommon and rare species that were for the most part only observed in the outer reef flat platform zone at Transect 2 during both surveys. Although the small, pea-sized Stylaraea punctata colonies are difficult to observe, they are common on pieces of rubble in the inner reef flat subzones.

GENERAL SUMMARY

The following summary is based upon a comparison of the results of a 1977 baseline survey of the coral communities at the three transect areas shown in Figure III-1, and a reassessment survey conducted at the same three transect areas fourteen-and-a-half years later in 1991.

Beach Zone

Width of the shoreline beach deposits that lie between the intertidal toe (backwash plunge zone) of the beach on the reef platform and the vegetation strand line were measured at the three transect areas during both survey periods. Intertidal and supratidal beach widths for the two surveys are given in Table III 8.

The above comparisons indicate that there have been no noticeable changes in beach width at the three transect locations. Although the texture of the beach deposits were not analyzed, there appeared to be no qualitative change in either grain size or composition between the two surveys, or between the description of the samples collected and analyzed from the same three general transect areas by Emery (1962).

Fringing Reef Flat Platform Zones and Subzones

A comparison of coral species abundance, mean colony size, density, and percentage of substrate coverage are summarized in Table III-9 for the various zones and subzones that were discriminated along the lengths of Transects 1-3 on the Tumon Bay fringing reef flat platform.

CONCLUSIONS

The following statements are based primarily upon a comparison of the 1991 survey results with those of the 1977 survey.

1) Within the 14 subzones discriminated along the three transect areas, coral species abundance has increased in 10 and remained unchanged in 4, and the number of coral genera has increased in 7, decreased in 3, and remained unchanged in 4.

2) Within the 14 subzones, mean coral colony diameter has increased 9, decreased in 4, and remained unchanged in 1.

3) Within the 14 subzones, coral density has increased in 10, decreased in 3, and remained unchanged in 1.

4) Within the 14 subzones, the percentage of substrate coverage by corals has increased in 11, decreased in 1, and remained unchanged in 2.

5) Seventy six species of corals representing 28 genera were recorded from the three transect areas during the 1977 survey, and 73 species representing 25 genera were recorded from the same three transect areas during the 1991 survey.

6) Seven coral species were recorded from the three transect areas during the 1977 survey that were not observed during the 1991 survey, and 4 species recorded during the 1991 survey from the same transect areas that were not observed during the 1977 survey.

7) With regard to the frequency distribution of coral colony size classes, the relative percent of corals in each size class has remained nearly the same during both assessment surveys.

LITERATURE CITED

Cottam, G., J.T. Curtis, and B.W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology 34:741-757.

Emery, K.O. 1962. Marine geology of Guam. U.S. Geol. Surv. Prof. Pap. 403-B, 76 p.

Randall, R.H. 1971. Tanguisson-Tumon, Guam, reef corals before during, and after the Crown-of-Thorns starfish (Acanthaster planci) predation. Master of Science Thesis, Univ. of Guam, 119 p.

Randall, R.H. 1973. Reef physiography and distribution of corals at Tumon Bay, Guam, before Crown-of-Thorns starfish Acanthaster planci predation. Micronesica 9(1):119-158.

Randall, R. H., ed. 1978. Guam's reefs and beaches. Part II. Transect studies. University of Guam Marine Laboratory, Technical Report 48, 90p.

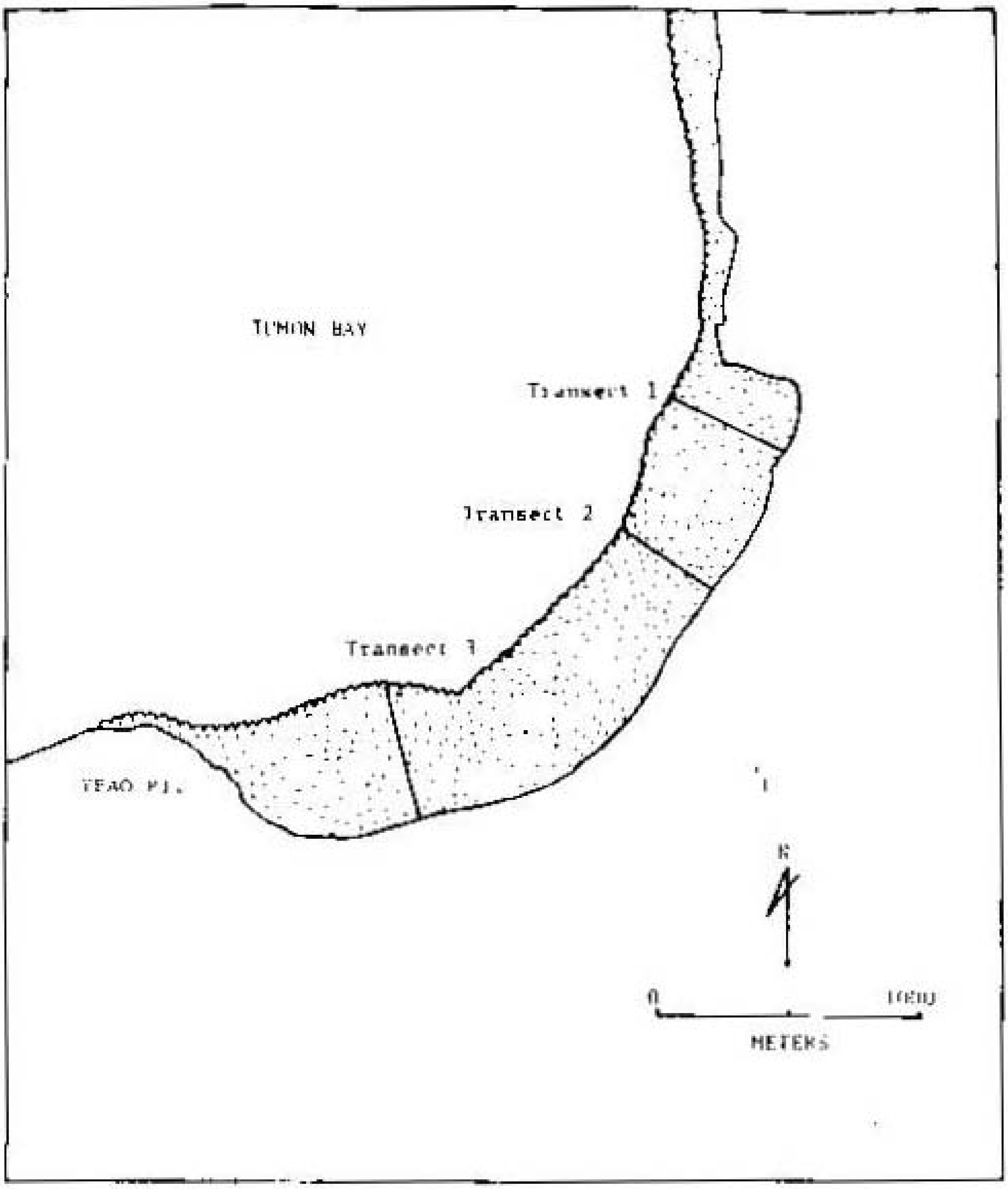

Figure III-1. Transect locations in Tumon Bay. Reef-flat platform is stippled.

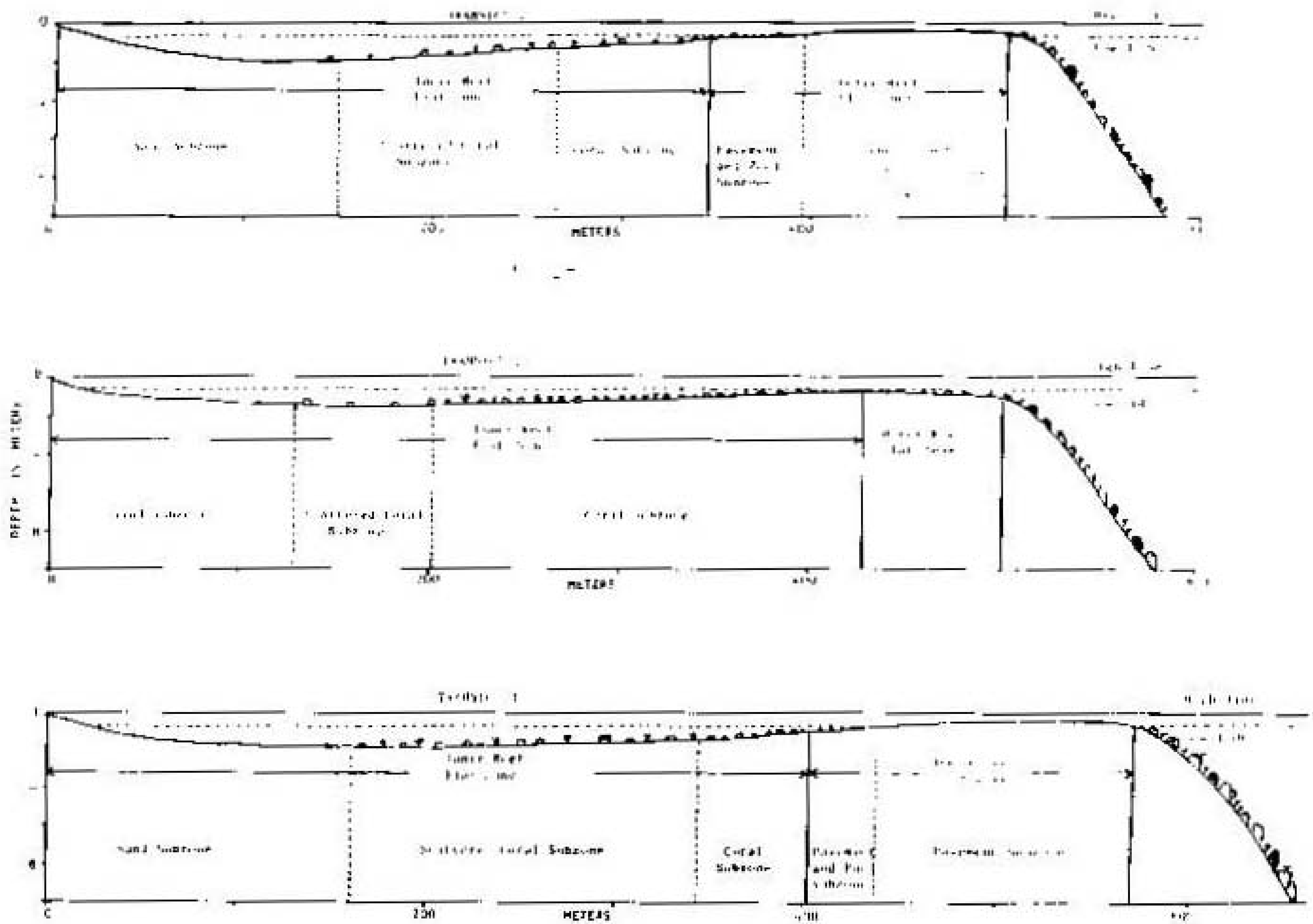

Figure III-2. Vertical profiles of Transects 1, 2, and 3 at Tumon Bay showing reef zones and subzones and the general distribution of corals. Solid vertical lines indicate reef flat zone boundaries, and vertical dotted lines indicate subzone divisions. Vertical exaggeration X 10.

Table III-1. Species list of corals for both the 1977 and 1991 surveys by subzones for Transects 1-3 located on the fringing reef flat platform at Tumon Bay. The list includes corals recorded on the transects as well as those observed within a 10 meter band on each side of the transects. A = Sand Subzone, B = Scattered Coral Subzone, C = Coral Subzone, D = Pavement and Pool Subzone at Transects 1 and 3 and the Outer Reef Flat Zone at Transect 2, and E = Pavement Subzone. An x indicates the species was observed and an o indicates the species was not observed.

	Transect 1									
Species — Subzones	A		B		C		D		E	
Survey Year	77	91	77	91	77	91	77	91	77	91
Class-ANTHOZOA										
Order-SCLERACTINIA										
Family-THAMNASTERIIDAE										
Psammocora contigua (Esper, 1797)			x	x	x	x	x	o	o	x
Psammocora digitata Milne Edwards & Haime, 1851					x	x				
Psammocora obtusangula (Lamarck, 1816)			x	x	x	x	x	o		
Psammocora stellata (Verrill, 1866)					x	x				
Family-POCILLOPORIDAE										
Pocillopora damicornis (Linnaeus, 1758)	x	x	x	x	x	x	x	x		
Family-ACROPORIDAE										
Acropora acuminata Verrill, 1864			x	o						
Acropora aspera (Dana, 1846)	o	x	x	x	x	x				
Montipora acanthella Bernard, 1897					x	o				
Montipora lobulata Bernard, 1897					x	x				
Family-AGARICIIDAE										
Pavona decussata Dana, 1846			x	x	x	x				
= *Pavona* (Foliose sp. 1)										
Pavona divaricata (Lamarck, 1816)			o	x	x	x	o	x		
Pavona varians Verrill, 1864					x	x	x	o		
Pavona venosa (Ehrenberg, 1834)			o	x	x	x				
= *Pavona* (*P.*) *obtusata* (Quelch, 1884)										
Family-PORITIDAE										
Porites annae Crossland, 1952	o	x	o	x	x	x	o	x		
Porites australiensis Vaughan, 1918			o	x	o	x	x	x	x	x
Porites cylindrica Dana, 1846	o	x	x	x	x	x				
= *Porites andrewsi* Vaughan, 1918										
= *Porites cocosensis* Wells, 1950										
Porites lutea Milne Edwards & Haime, 1851	o	x	x	x	x	x	x	x	x	x
Porites (Massive sp. 1)					x	x				
Porites (Nodular sp. 1)	o	x	o	x	o	x				
Porites (*Synaraea*) *rus* (Forskal, 1775)					o	x	o	x		
= *Porites* (*Synaraea*) *iwayamaensis* Eguchi, 1938										
Stylaraea punctata Klunzinger, 1879			x	x	x	x	x	x	x	o
Family-FAVIIDAE										
Goniastrea edwardsi Chevalier, 1971			x	o						
Goniastrea retiformis (Lamarck, 1816)					x	x				
Leptastrea bottae (Milne Edwards & Haime, 1849)					x	x				
Leptastrea purpurea (Dana, 1846)	o	x	o	x	x	x	x	x	o	x
Leptoria phrygia (Ellis & Solander, 1786)							o	x		
Platygyra daedalea (Ellis & Solander, 1786)					x	o				
Family-CARYOPHYLLIIDAE										
Euphyllia glabrescens (Chamisso & Eysenhardt, 1821)					x	o				
Order-COENOTHECALLIA										
Family-HELIOPORIDAE										
Heliopora coerulea (Pallas, 1766)			x	o						

Table 1. cont.

Species	Subzones / Survey Year	A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91	E 77	E 91
		Transect 1									
Class-HYDROZOA											
Order MILLEPORINA											
Family-MILLEPORIDAE											
Millepora dichotoma Forskal, 1775										o	x

Totals		A	B	C	D	E
Totals 1977	Species	1	11	22	8	3
	Genera	1	8	11	4	2
Totals 1991	Species	7	14	22	9	5
	Genera	4	7	9	6	4

Species	Subzones / Survey Year	A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91
		Transect 2							
Class-ANTHOZOA									
Order-SCLERACTINIA									
Family-ASTROCOENIIDAE									
Stylocoeniella armata (Ehrenberg, 1834)								x	x
Family- THAMNASTERIIDAE									
Psammocora contigua (Esper, 1797)		x	x	x	o	x	x	x	x
Psammocora digitata Milne Edwards & Haime, 1851								o	x
Psammocora obtusangula (Lamarck, 1816)		x	o	x	o	x	x	x	x
Psammocora stellata (Verrill, 1866)				x	o	x	x	x	x
Psammocora (Nodulose sp. 1)								x	x
Psammocora (Encrusting sp. 1)								o	x
Family-POCILLOPORIDAE									
Seriatopora hystrix Dana, 1846								x	o
Pocillopora damicornis (Linnaeus, 1758)		x	o	o	x	x	x	x	x
Pocillopora danae Verrill, 1864								x	x
Pocillopora setchelli Hoffmeister, 1929						x	x	x	x
Pocillopora verrucosa (Ellis & Solander, 1786)								o	x
Family-ACROPORIDAE									
Acropora acuminata Verrill, 1864								x	x
Acropora aspera (Dana, 1846)		o	x	o	x	o	x	o	x
Acropora formosa (Dana, 1846)								o	x
Acropora humilis (Dana, 1846)								x	x
Acropora cerealis (Dana, 1846)								x	x
= Acropora hystrix (Dana, 1846)									
Acropora irregularis (Brook, 1892)								x	x
Acropora azurea Veron & Wallace, 1984								x	x
= Acropora nana (Studer, 1878)									
Acropora digitifera (Dana, 1846)								x	x
= Acropora nasuta (Dana, 1846)									
Acropora squarrosa (Ehrenberg, 1834)								x	x
Acropora surculosa (Dana, 1846)								x	x
Acropora valida (Dana, 1846)								x	x
Astreopora myriophthalma (Lamarck, 1816)								x	x
Montipora hoffmeisteri Wells, 1954								x	x
Montipora lobulata Bernard, 1897				x	x	x	x	x	x
Montipora verrilli Vaughan, 1907								x	x
Montipora grisea Bernard, 1897								x	x
= Montipora (Tuberculate sp. 1)									
Montipora planiuscula (Dana, 1846)								x	x
= Montipora (Papillate sp. 2)									
Montipora (Tuberculate sp. 2)								x	x

Table 1. Cont.

Species	Subzones / Survey Year	A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91
Montipora Tuberculate sp. 5								x	x
= Montipora (Papillate sp. 1)									
Family-AGARICIIDAE									
Pavona decussata Dana, 1846		o	x	x	x	x	x	x	x
= Pavona (Foliose sp. 1)									
Pavona divaricata (Lamarck, 1816)						x	x	x	x
Pavona varians Verrill, 1864						x	x	o	x
Pavona venosa (Ehrenberg, 1834)						x	x	x	x
= Pavona (P.) obtusata (Quelch, 1884)									
Pavona explanulata (Lamarck, 1816)								x	o
= Pavona (Explanate sp. 1)									
Pavona (Encrusting sp. 1)						x	o	x	x
Family-PORITIDAE									
Goniopora fruiticosa Saville-Kent, 1893								x	x
= Goniopora arbuscula Umbgrove, 1939									
Goniopora tenuidens (Quelch, 1886)								x	x
Porites annae Crossland, 1952				o	x	o	x	x	x
Porites australiensis Vaughan, 1918						o	x	x	x
Porites cylindrica Dana, 1846		x	x	x	x	x	x	o	x
= Porites andrewsi Vaughan, 1918 &									
= Porites cocosensis Wells, 1950									
Porites lichen Dana, 1846								x	x
Porites lobata Dana, 1846								x	x
Porites lutea Milne Edwards & Haime, 1851		o	x	x	x	x	x	x	x
Porites murrayensis Vaughan, 1918								x	x
Porites superfusa Gardiner, 1898								x	x
Porites (Massive sp. 1)		x	o	x	x	x	x	x	x
Porites (Nodular sp. 1)				o	x	x	x	o	x
Porites (Synaraea) rus (Forskal, 1775)								x	x
= Porites (Synaraea) iwayamaensis Eguchi, 1938									
Porites (N.) vaughani Crossland, 1952								x	x
Stylaraea punctata Klunzinger, 1879		o	x	o	x	x	x		
Family-FAVIIDAE									
Cyphastrea serailia (Forskal, 1775)								x	x
Favia favus (Forskal, 1775)								x	x
Favia matthai Vaughan, 1918								x	x
= Favia pallida (Dana, 1846)									
Favia stelligera (Dana, 1846)						x	x		
Favites abdita (Ellis & Solander, 1786)								o	x
Favites flexuosa (Dana, 1846)						x	o	o	x
= Favites virens (Dana, 1846)									
Goniastrea edwardsi Chevalier, 1971								x	x
Goniastrea retiformis (Lamarck, 1816)						o	x	x	x
Leptastrea bottae (Milne Edwards & Haime, 1849)						x	o	x	x
Leptastrea purpurea (Dana, 1846)		o	x	o	x	x	x	x	x
Leptoria phrygia (Ellis & Solander, 1786)								x	x
Platygyra daedalea (Ellis & Solander, 1786)								o	x
Platygyra pini Chevalier, 1975								x	x
Diploastrea heliopora (Lamarck, 1816)								x	o
Family- OCULINIDAE									
Galaxea fascicularis (Linnaeus, 1767)						o	x	x	x
Family-MERULINIDAE									
Hydnophora microconos (Lamarck, 1816)								o	x
Family-MUSSIDAE									
Acanthastrea echinata (Dana, 1846)								x	x
Lobophyllia hemprichii (Ehrenberg, 1834)						x	o	o	x

Transect 2 (subzones A–D)

Table 1. Cont.

Species		Transect 2 A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91
	Subzones / Survey Year								
Family-CARYOPHYLLIIDAE									
Polycyathus fulvus Wijsman-Best, 1969						x	o		
= *Polycyathus verrilli* Duncan, 1889									
Order COENOTHECALLIA									
Family HELIOPORIDAE									
Heliopora coerulea (Pallas, 1766)						x	x	x	x
Class-HYDROZOA									
Order-MILLEPORINA									
Family MILLEPORIDAE									
Millepora tuberosa Boschma, 1966								x	x
= *Millepora foveolata* Crossland, 1952									
Millepora platyphylla Hemprich & Ehrenberg, 1834								x	x
Family-STYLASTERIDAE									
Distichopora gracilis Dana, 1846								x	x
= *Distichopora* sp. 1									
Totals 1977	Species	5		8		23		59	
	Genera	3		4		12		22	
Totals 1991	Species	7		11		23		69	
	Genera	6		7		12		23	

Species		Transect 3 A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91	E 77	E 91
	Subzones / Survey Year										
Class-ANTHOZOA											
Order SCLERACTINIA											
Family- THAMNASTERIIDAE											
Psammocora contigua (Esper, 1797)				x	x	x	x			o	x
Psammocora obtusangula (Lamarck, 1816)						x	x				
Psammocora stellata (Verrill, 1866)						x	x				
Family-POCILLOPORIDAE											
Pocillopora damicornis (Linnaeus, 1758)		x	x	x	x	x	x	x	x		
Family-ACROPORIDAE											
Acropora acuminata Verrill, 1864				x	o						
Acropora aspera (Dana, 1846)		x	x	x	x	x	x				
Acropora digitifera (Dana, 1846)						x	o				
= *Acropora nasuta* (Dana, 1846)											
Acropora formosa (Dana, 1846)		o	x	o	x						
Acropora squarrosa (Ehrenberg, 1834)						x	o				
Montipora lobulata Bernard, 1897						x	x				
Montipora (Tuberculate sp. 5)						x	o				
= *Montipora* (Papillate sp. 1)											
Family-AGARICIIDAE											
Pavona decussata Dana, 1846				x	x	x	x				
= *Pavona* (Foliose sp. 1)											
Pavona divaricata (Lamarck, 1816)				o	x	x	x				
Pavona varians Verrill, 1864				o	x	o	x				
Pavona venosa (Ehrenberg, 1834)						o	x				
= *Pavona* (*P.*) *obtusata* (Quelch, 1884)											
Family-PORITIDAE											
Porites annae Crossland, 1952		o	x	x	x	x	x				
Porites australiensis Vaughan, 1918				o	x	o	x	o	x	x	x
Porites cylindrica Dana, 1846		o	x	x	x	x	x				
= *Porites andrewsi* Vaughan, 1918 &											
= *Porites cocosensis* Wells, 1950											
Porites lutea Milne Edwards & Haime, 1851				x	x	x	x	x	x		x

Table 1. Cont.

Species	Subzones / Survey Year	Transect 3: A 77	A 91	B 77	B 91	C 77	C 91	D 77	D 91	E 77	E 91
Porites (Massive sp. 1)						o	x				
Porites (Nodular sp. 1)						x	x				
Stylaraea punctata Klunzinger, 1879		o	x	x	x	x	x				
Family-FAVIIDAE											
Favites abdita (Ellis & Solander, 1786)										x	o
Goniastrea retiformis (Lamarck, 1816)						x	x				
Goniastrea pectinata (Ehrenberg, 1834)						x	o				
Leptastrea bottae (Milne Edwards & Haime, 1849)				x	o						
Leptastrea purpurea (Dana, 1846)		o	x	x	x	x	x	x	x	o	x
Family-MERULINIDAE											
Hydnophora microconos (Lamarck, 1816)						x	o				
Family-MUSSIDAE											
Lobophyllia corymbosa (Forskal, 1775)						x	o				
Family-CARYOPHYLLIIDAE											
Euphyllia glabrescens (Chamisso & Eysenhardt, 1821)						o	x				
Order COENOTHECALLIA											
Family-HELIOPORIDAE											
Heliopora coerulea (Pallas, 1766)						o	x				
Class-HYDROZOA											
Order-MILLEPORINA											
Family-MILLEPORIDAE											
Millepora tuberosa Boschma, 1966								x	o		
= *Millepora foveolata* Crossland, 1952											
Totals 1977	Species	2		11		21		4		5	
	Genera	2		7		11		4		2	
Totals 1991	Species	7		13		21		4		4	
	Genera	5		7		11		3		3	

Table III-2. Coral size distribution, frequency, density, and percent of substrate coverage for Transects 1-3 located on the fringing reef flat platform at Tumon Bay. Data from the 1991 reassessment survey.

Coral Taxon	Colony Size Distribution (cm) n	$\bar{x}$	s	w	Freq.	Den. $/m^2$	Cover %
Tumon Bay - Transect 1							
Inner Reef Flat Zone (Sand Subzone 0 to 147 meters)							
*Porites cylindrica**	21	5.4	4.1	1.0-14.9	0.19	0.053	0.019
Acropora aspera	1	9.4	-		0.01	0.003	0.002
Leptastrea purpurea	3	3.3	0.3	3.0-3.5	0.03	0.008	0.001
Totals	25	5.3	3.8	1.0-14.9		0.064	0.022
Inner Reef Flat Zone (Scattered Coral Subzone 147 to 262 meters)							
Porites lutea	16	18.0	19.1	3.5-81.8	0.17	0.24	1.27
Porites annae	2	22.7	15.6	11.7-33.7	0.02	0.03	0.15
Porites australiensis	2	14.9	13.9	5.0-24.7	0.02	0.03	0.08
*Pavona venosa**	1	24.7		-	0.01	0.02	0.07
Pocillopora damicornis	14	5.7	3.7	2.0-12.4	0.15	0.21	0.07
Pavona divaricata	5	9.0	4.5	1.0-14.5	0.05	0.08	0.06
Leptastrea purpurea	17	3.6	1.0	2.0-5.9	0.18	0.26	0.03
Acropora aspera	1	14.3		-	0.01	0.02	0.02
*Porites cylindrica**	4	4.7	0.9	3.5-5.7	0.04	0.06	0.01
Totals	62	9.8	12.0	2.0-81.8		0.95	1.76
Inner Reef Flat Zone (Coral Subzone 262 to 343 meters)							
Porites lutea	8	27.1	21.4	6.3-70.5	0.11	0.15	1.35
Pavona varians	2	12.3	3.5	9.8-14.7	0.03	0.04	0.05
Porites (S.) rus	1	15.5	-	-	0.02	0.02	0.04
Leptastrea purpurea	16	3.4	1.3	1.4-5.9	0.25	0.30	0.03
*Porites cylindrica**	2	5.2	1.0	4.5-5.9	0.03	0.04	0.01
Pocillopora damicornis	3	2.8	0.3	2.4-3.0	0.05	0.06	0.004
Pavona decussata	1	5.0	-	-	0.02	0.02	0.003
Pavona divaricata	1	4.6	-		0.02	0.02	0.003
Totals	34	10.0	14.1	1.4-70.5		0.65	1.490
Outer Reef Flat Zone (Pavement and Pool Subzone 343 to 392 meters)							
Pavona divaricata	2	18.6	12.8	9.5-27.6	0.05	0.03	0.09
Porites lutea	2	15.4	16.8	3.5-27.1	0.05	0.03	0.09
Porites australiensis	2	8.4	4.0	5.5-11.2	0.05	0.04	0.02
Leptastrea purpurea	8	3.3	1.1	2.0-4.9	0.25	0.11	0.01
Porites (S.) rus	2	3.8	1.1	3.0-4.6	0.05	0.03	0.003
Totals	16	7.4	8.2	2.0-27.3		0.23	0.213
Outer Reef Flat Zone (Pavement Subzone 393 to 500 meters)							
Porites lutea	15	6.7	4.5	2.4-19.5	0.18	0.046	0.023
Millepora dichotoma	1	4.9	-	-	0.01	0.003	0.001
Porites australiensis	1	6.0	-	-	0.01	0.003	0.001
Totals	17	6.5	4.2	2.4-19.5		0.052	0.025

Table III-2. Cont.

Coral Taxon	Colony Size Distribution (cm) n	$\bar{x}$	σ	w	Freq.	Den. m^2	Cover %

Tumon Bay - Transect 2

Inner Reef Flat Zone (Sand Subzone 0 to 127 meters)

Only one colony of Acropora aspera encountered during the quantitative assessment

Inner Reef Flat Zone (Scattered Coral Subzone 127 to 202 meters)

Coral Taxon	n	$\bar{x}$	σ	w	Freq.	Den. m^2	Cover %
Porites lutea	2	23.0	1.5	21.9-24.0	0.03	0.009	0.038
Pocillopora damicornis	5	8.5	7.6	2.0-17.5	0.08	0.023	0.022
Montipora lobulata	1	20.6	-	-	0.02	0.005	0.015
Porites massive sp. 1	1	17.7			0.02	0.005	0.011
Pavona decussata	3	4.7	1.5	3.0-5.9	0.05	0.014	0.003
Leptastrea purpurea	1	3.0		-	0.02	0.005	0.001
Psammocora contigua	1	4.0	-	-	0.02	0.005	0.001
Totals	14	12.6	8.5	2.0-24.0		0.066	0.091

Inner Reef Flat Zone (Coral Subzone 202 to 427 meters)

Coral Taxon	n	$\bar{x}$	σ	w	Freq.	Den. m^2	Cover %
Pavona decussata	87	8.0	8.6	1.0-54.9	0.48	6.41	7.59
Porites cylindrica*	14	10.0	11.8	2.0-43.0	0.08	1.03	1.87
Psammocora contigua	15	6.2	2.9	3.0-13.9	0.08	1.10	0.40
Porites massive sp. 1	5	9.5	5.6	4.0-16.5	0.03	0.37	0.32
Pocillopora damicornis	8	6.4	4.4	1.4-12.5	0.04	0.59	0.27
Psammocora stellata	15	4.2	1.7	2.0-6.9	0.08	1.10	0.17
Porites annae	1	15.9	-	-	0.01	0.07	0.15
Psammocora obtusangula*	4	6.9	2.8	3.5-9.4	0.02	0.29	0.12
Porites australiensis	1	12.6	-	-	0.01	0.07	0.09
Porites lutea	5	4.3	2.4	2.4-8.5	0.03	0.37	0.09
Leptastrea purpurea	16	2.5	0.6	1.4-3.5	0.09	1.18	0.06
Pavona divaricata	1	7.9	-	-	0.01	0.07	0.04
Stylaraea punctata	1	1.0	-	-	0.01	0.07	0.01
Totals	173	7.4	7.5	1.0-54.9		12.72	11.16

Outer Reef Flat Zone (427 to 500 meters)

Coral Taxon	n	$\bar{x}$	σ	w	Freq.	Den. m^2	Cover %
Pavona decussata	15	12.3	9.2	1.0-32.4	0.25	4.76	8.63
Goniastrea retiformis	1	37.5	-	-	0.02	0.32	3.52
Porites lutea	1	33.4	-	-	0.02	0.32	2.79
Pocillopora damicornis	7	8.5	4.4	1.0-13.0	0.12	2.22	1.54
Montipora lobulata	1	19.4	-	-	0.02	0.32	0.94
Porites cylindrica*	1	19.0		-	0.02	0.32	0.90
Psammocora contigua	12	4.7	1.8	1.2-7.5	0.20	3.81	0.79
Acropora digitifera	2	9.8	3.9	7.0-12.5	0.03	0.63	0.51
Psammocora stellata	12	4.0	1.5	2.0-6.5	0.20	3.81	0.49
Acropora cerealis	1	11.8			0.02	0.32	0.35
Millepora platyphylla	2	6.4	1.9	5.0-7.7	0.03	0.63	0.21
Pocillopora setchelli	2	6.5	4.9	3.0-9.9	0.03	0.63	0.20
Psammocora sp. 1	1	6.1	-		0.02	0.12	0.10
Montipora caerulea	1	5.9	-	-	0.02	0.32	0.09
Stylocoeniella armata	1	4.5	-	-	0.02	0.12	0.05
Totals	60	8.5	8.0	1.0-33.4		19.05	21.11

Table III-2. Cont.

Coral Taxon	Colony Size Distribution (cm) n	x̄	s	w	Freq.	Den. m²	Cover %
Thuron Bay - Transect 3							
Inner Reef Flat Zone (Sand Subzone 0 to 162 meters)							
Acropora aspera	6	15.4	5.0	9.5-21.4	0.05	0.07	0.15
Acropora formosa	2	22.6	8.5	16.4-28.8	0.02	0.02	0.11
Leptastrea purpurea	69	2.6	1.8	1.0-10.4	0.58	0.85	0.06
Pocillopora damicornis	2	5.8	6.7	1.0-10.5	0.02	0.02	0.01
Porites cylindrica*	1	3.0	-	-	0.01	0.01	0.01
Totals	80	4.1	5.1	1.0-28.8		0.97	0.34
Inner Reef Flat Zone (Scattered Coral Subzone 162 to 347 meters)							
Pavona decussata	6	38.9	30.3	3.5-85.4	0.04	0.09	1.59
Acropora aspera	34	16.6	9.4	2.0-39.2	0.23	0.50	1.42
Porites cylindrica*	6	24.0	28.3	7.5-78.9	0.04	0.09	0.88
Acropora formosa	15	11.5	9.1	1.4-31.6	0.10	0.22	0.36
Porites lutea	6	15.2	12.6	3.0-31.5	0.04	0.09	0.25
Leptastrea purpurea	40	2.9	1.9	1.0-11.4	0.27	0.59	0.05
Psammocora contigua	2	9.6	6.5	5.0-14.2	0.14	0.03	0.03
Pavona divaricata	1	7.3	-	-	0.07	0.01	0.01
Pocillopora damicornis	2	7.5	2.1	6.0-8.9	0.014	0.03	0.01
Totals	112	12.2	14.5	1.0-78.9		1.65	4.60
Inner Reef Flat Zone (Coral Subzone 347 to 402 meters)							
Porites lutea	20	12.4	11.5	3.0-47.1	0.45	2.19	4.81
Porites cylindrica*	3	36.4	20.2	15.0-55.0	0.07	0.33	4.12
Porites australiensis	4	15.8	7.6	9.0-26.7	0.09	0.44	1.01
Leptastrea purpurea	7	3.5	2.8	1.0-9.2	0.16	0.77	0.12
Pavona venosa^c	2	6.7	4.5	3.5-9.9	0.05	0.22	0.10
Pavona divaricata	1	6.0	-	-	0.02	0.11	0.03
Psammocora contigua	1	2.0		-	0.02	0.11	0.01
Pavona decussata	4	5.4	2.3	3.0-8.1	0.09	0.44	0.11
Totals	42	11.6	12.4	1.0-55.0		4.61	10.31
Outer Reef Flat Zone (Pavement and Pool Subzone 402 to 437 meters)							
Porites lutea	8	8.0	5.4	3.2-20.0	0.29	0.20	0.14
Porites australiensis	2	8.7	1.0	8.0-9.4	0.07	0.05	0.03
Leptastrea purpurea	2	1.7	0.4	1.4-2.0	0.07	0.05	0.001
Totals	12	7.1	5.0	1.4-20.0		0.30	0.171
Outer Reef Flat Zone (Pavement Subzone 437 to 570 meters)							
Porites lutea	6	9.5	4.5	2.5-16.4	0.08	0.007	0.005
Leptastrea purpurea	1	2.0	-	-	0.01	0.001	0.001
Totals	7	8.4	5.0	2.0-16.4		0.008	0.006

In Randall, 1978 the following species names are equivalent:

* Porites cylindrica - Porites cocosensis
^b Psammocora obtusangula - Psammocora (Ramose sp. 1)
^c Pavona venosa = Pavona (P.) obtusata

Table III-3. Coral size distribution, frequency, density, and percent of substrate coverage for Transects 1-3 located on the fringing reef flat platform at Tumon Bay. Data from the 1977 baseline survey.

Coral Taxon	Colony Size Distribution (cm) n	x	s	w	Freq.	Den. m²	Cover %
Tumon Bay Transect 1							
Inner Reef Flat Zone (Sand Subzone 0 to 147 meters)							
(no corals encountered)							
Inner Reef Flat Zone (Scattered Coral Subzone 147 to 262 meters)							
Acropora aspera	19	13.9	8.6	5.0-34.0	0.21	0.129	0.303
Acropora acuminata	2	22.5	7.8	17.0-28.0	0.02	0.014	0.058
Pocillopora damicornis	15	4.7	3.0	1.0 11.0	0.12	0.102	0.024
Porites cylindrica[a]	3	8.7	2.1	7.0-11.0	0.03	0.020	0.012
Psammocora contigua	1	6.0			0.01	0.007	0.002
Psammocora obtusangula[b]	1	4.4	-	-	0.01	0.007	0.001
Totals	41	11.2	9.6	1.0-28.0		0.279	0.400
Inner Reef Flat Zone (Coral Subzone 262 to 343 meters)							
Porites cylindrica[a]	23	14.5	15.8	1.0-55.0	0.16	0.619	2.173
Porites lutea	1	19.0	-	-	0.02	0.027	0.077
Acropora aspera	4	6.3	2.1	4.0 8.0	0.06	0.108	0.036
Pavona divaricata	1	13.0	-	-	0.02	0.027	0.036
Leptastrea bottae	1	12.0	-	-	0.02	0.027	0.031
Pocillopora damicornis	7	4.0	2.0	1.0-7.0	0.11	0.188	0.029
Porites annae	2	6.5	0.7	6.0-7.0	0.03	0.053	0.017
Psammocora obtusangula[b]	3	5.0	2.0	3.0-7.0	0.05	0.080	0.018
Porites (Massive sp. 1)	2	5.5	0.7	5.0 6.0	0.03	0.053	0.013
Psammocora contigua	1	4.0	-	-	0.02	0.027	0.004
Psammocora stellata	1	3.0	-	-	0.02	0.027	0.002
Totals	46	11.1	12.7	1.0 55.0		1.216	2.416
Outer Reef Flat Zone (Pavement and Pool Subzone 341 to 392 meters)							
Psammocora obtusangula[b]	2	11.5	0.7	11.0-12.0	0.05	0.010	0.010
Pocillopora damicornis	1	12.0	-	-	0.03	0.005	0.006
Porites lutea	4	7.0	0.8	6.0-8.0	0.10	0.021	0.008
Totals	7	9.0	2.6	6.0 12.0		0.036	0.024
Outer Reef Flat Zone (Pavement Subzone 393 to 500 meters)							
(no corals encountered)							

Table III 3. Cont.

Tumon Bay Transect 2

Coral Taxon	Colony Size Distribution (cm) n	x̄	s	w	Freq.	Den. m²	Cover %
Inner Reef Flat Zone (Sand Subzone 0 to 127 meters)							
(no corals encountered)							
Inner Reef Flat Zone (Scattered Coral Subzone 127 to 202 meters)							
Porites (Massive sp. 1)	1	37.0			0.07	0.003	0.032
Psammocora stellata	6	5.3	2.7	3.0-10.0	0.40	0.019	0.006
Psammocora obtusangula[a]	2	7.5	3.5	5.0-10.0	0.13	0.007	0.004
Porites cylindrica[a]	1	3.0	-	-	0.07	0.003	0.001
Totals	10	8.3	10.4	3.0-37.0		0.032	0.043
Inner Reef Flat Zone (Coral Subzone 202 to 427 meters)							
Pavona decussata	26	11.8	11.2	2.0-46.0	0.14	1.99	4.69
Porites (Massive sp. 1)	1	57.0		-	0.01	0.08	2.54
Psammocora obtusangula[a]	80	3.3	1.9	1.0-11.0	0.44	6.14	0.67
[a]Pavona divaricata	3	14.0	10.0	4.0-24.0	0.02	0.23	0.48
Psammocora stellata	17	5.6	2.5	2.0-12.0	0.09	1.30	0.37
Pocillopora damicornis	18	4.5	3.1	1.0-11.0	0.10	1.38	0.29
Montipora lobulata	1	13.0	-	-	0.01	0.08	0.10
Heliopora coerulea	1	10.0		-	0.01	0.08	0.03
Pavona venosa[a]	1	8.0	-	-	0.01	0.08	0.03
Pocillopora setchelli	1	6.0		-	0.01	0.08	0.02
[a]Porites cylindrica[a]	1	2.0		-	0.01	0.08	0.01
Totals	173	6.1	7.4	1.0-57.0		13.28	9.02
Outer Reef Flat Zone (427 to 500 meters)							
Psammocora contigua	14	9.1	7.1	4.0-30.0	0.23	1.69	1.72
Millepora platyphylla	2	19.0	22.6	3.0-35.0	0.01	0.24	1.16
Goniastrea retiformis	2	17.5	0.7	17.0-18.0	0.03	0.24	0.58
Pocillopora damicornis	21	3.4	2.6	1.0-9.0	0.35	2.53	0.37
Montipora verrilli	1	19.0	-	-	0.02	0.12	0.34
Heliopora coerulea	1	18.0			0.02	0.12	0.31
Pavona decussata	4	6.0	5.0	4.0-15.0	0.06	0.48	[illegible]
Pocillopora setchelli	4	7.8	4.0	3.0-12.0	0.06	0.48	0.27
Acropora acuminata	1	10.0	-	-	0.02	0.12	0.09
Stylocoeniella armata	7	3.4	0.5	3.0-4.0	0.11	0.85	0.08
Porites (N.) vaughani	1	5.0	-	-	0.02	0.12	0.02
Psammocora obtusangula[a]	1	5.0	-	-	0.02	0.12	0.02
Psammocora stellata	1	2.0	-	-	0.02	0.12	0.01
Totals	60	7.0	6.7	1.0-35.0		7.23	5.28

Table III-3. Cont.

Tumon Bay - Transect 3

Coral Taxon	Colony Size Distribution (cm) n	x	s	w	Freq.	Den. m²	Cover %
Inner Reef Flat Zone (Sand Subzone 0 to 162 meters)							
(no coral encountered)							
Inner Reef Flat Zone (Scattered Coral Subzone 162 to 347 meters)							
*Porites cylindrica**	12	16.8	35.5	1.0-127.0	0.08	0.04	0.45
Acropora aspera	12	13.1	7.1	3.0-27.0	0.08	0.04	0.07
Pocillopora damicornis	23	3.8	2.6	1.0-9.0	0.16	0.08	0.01
Psammocora contigua	1	8.0	-	-	0.01	0.003	0.002
Acropora acuminata	2	4.0	1.4	3.0-5.0	0.01	0.007	0.009
Leptastrea purpurea	2	2.5	0.7	2.0-3.0	0.01	0.007	0.003
Totals	52	9.0	17.8	1.0-127.0		0.177	0.544
Inner Reef Flat Zone (Coral Subzone 347 to 402 meters)							
Pavona decussata	8	19.6	18.9	2.0-55.0	0.18	0.68	3.96
Porites lutea	8	24.3	13.1	4.0-50.0	0.18	0.68	3.95
*Porites cylindrica**	15	9.9	8.2	3.0-26.0	0.34	1.28	1.61
Pavona divaricata	2	14.5	12.0	6.0-23.0	0.05	0.17	0.38
Psammocora contigua	4	9.3	8.2	2.0-21.0	0.09	0.34	0.36
Pavona venosa'	1	12.0	-	-	0.02	0.09	0.10
Porites annae	1	4.0	-	-	0.02	0.09	0.01
Pocillopora damicornis	1	2.0	-	-	0.02	0.09	0.01
Totals	40	14.6	12.9	2.0-55.0		3.42	10.37
Outer Reef Flat Zone (Pavement and Pool Subzone 402 to 437 meters)							
Porites lutea	12	6.8	3.4	4.0-14.0	0.42	0.32	0.13
Pocillopora damicornis	1	3.0	-	-	0.04	0.03	0.01
Totals	13	6.5	3.4	3.0-14.0		0.35	0.14
Outer Reef Flat Zone (Pavement Subzone 437 to 570 meters)							
Porites lutea	4	8.0	2.9	5.0-11.0	0.04	0.001	0.001
Totals	4	8.G	2.9	5.0-11.0	0.04	0.001	0.001

In Randall, 1978 the following species names are equivalent:

* *Porites cylindrica* = *Porites cocosensis*
' *Psammocora obtusangula* = *Psammocora* (Rumone sp. 1)
Pavona venosa = *Pavona* (P.) *obtusata*

Table III-4. Frequency distribution of coral colony diameters by subzones at Transects 1-3 on the fringing reef flat platform at Tumon Bay during the 1991 survey.

Subzones* Size Range (cm)	Transect 1 A	B	C	D	E	Transect 2 A	B	C	D	Transect 3 A	B	C	D	E	Totals
0-5.0	14	32	20	11	7	0	6	81	24	67	50	14	5	2	331
5.2-10.0	9	11	6	2	3	1	2	69	19	5	17	14	6	3	162
10.1-15.0	8	10	1	1	2	0	0	15	9	3	14	4	0	1	62
15.1-20.0	0	2	4	0	1	0	3	8	4	1	7	4	1	1	38
20.1-25.0	0	3	0	0	0	0	3	4	0	1	8	1	0	0	20
25.1-30.0	0	0	0	2	0	0	0	1	0	1	5	1	0	0	10
30.1-35.0	0	4	0	0	0	0	0	1	3	0	5	0	0	0	12
35.1-40.0	0	0	1	0	0	0	0	0	1	0	2	2	0	0	6
40.0-45.0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	3
45.1-50.0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
50.1-55.0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
55.1-60.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Over 60.1	0	1	1	0	0	0	0	0	0	0	3	0	0	0	5
	25	62	34	16	17	1	14	173	60	89	112	42	12	7	655

* Subzones
A = Sand Subzone
B = Scattered Coral Subzone
C = Coral Subzone
D = Pavement and Pool Subzone (at Transects 1 and 2 and the Outer Reef Flat Zone at Transect 2)
E = Pavement Subzone

Table III-5. Frequency distribution of coral colony diameters by subzones at Transects 1-3 on the fringing reef flat platform at Tumon Bay during the 1977 survey.

Subzones* Size Range (cm)	Transect 1 A	Transect 1 B	Transect 1 C	Transect 1 D	Transect 1 E	Transect 2 A	Transect 2 B	Transect 2 C	Transect 2 D	Transect 3 A	Transect 3 B	Transect 3 C	Transect 3 D	Transect 3 E	Totals
0-5.0	0	13	22	0	0	0	5	113	34	0	29	12	7	1	236
5.1-10.0	0	12	13	4	0	0	3	38	16	0	21	9	4	3	113
10.1-15.0	0	7	3	3	0	0	0	11	3	0	6	3	2	0	38
15.1-20.0	0	5	4	0	0	0	1	4	5	0	2	2	0	0	23
20.1-25.0	0	1	0	0	0	0	0	2	0	0	1	8	0	0	12
25.1-30.0	0	1	0	0	0	0	0	2	1	0	2	2	0	0	8
30.1-35.0	0	2	0	0	0	0	0	0	1	0	0	2	0	0	5
35.1-40.0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
40.0-45.0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2
45.1-50.0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	3
50.1-55.0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
55.1-60.0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Over 60.1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	0	41	46	7	0	0	10	173	60	0	62	40	13	4	446

* Subzones
A = Sand Subzone
B = Scattered Coral Subzone
C = Coral Subzone
D = Pavement and Pool Subzone (at Transects 1 and 2 and the Outer Reef Flat Zone at Transect
E = Pavement Subzone

Table III-6 Frequency distribution of coral colony growth forms by subzones at Transects 1-3 on the fringing reef flat platform at Tumon Bay during the 1991 survey.

Subzones* / Colony Forms	Transect 1 A	B	C	D	E	Transect 2 A	B	C	D	Transect 3 A	B	C	D	E	Totals
Arborescent	1	1	0	0	1	1	0	0	0	8	49	0	0	0	61
Caespitose	21	20	5	6	0	0	6	57	35	3	10	4	0	0	161
Corymbose	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Massive	0	18	8	4	16	0	3	12	2	0	6	24	10	6	109
Encrusting	3	17	16	8	0	0	2	16	3	65	40	7	2	1	180
Columnar	0	1	1	2	0	0	0	0	1	0	0	2	0	0	7
Explanate Plates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foliose	0	5	2	2	0	0	3	88	15	0	7	5	0	0	127
Flabellate Plates	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Free (Fungiids)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaceloid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	25	62	34	16	17	1	14	173	60	80	112	42	12	7	655

* Subzones :
A - Sand Subzone
B = Scattered Coral Subzone
C - Coral Subzone
D = Pavement and Pool Subzone (at Transects 1 and 2 and the Outer Reef Flat zone at Transect 2)
E - Pavement Subzone

Table III-7. Frequency distribution of coral colony growth forms by subzones at Transects 1-3 on the fringing reef flat platform at Tumon Bay during the 1977 survey.

Subzones* Colony Forms	Transect 1 A	B	C	D	E	Transect 2 A	B	C	D	Transect 3 A	B	C	D	E	Totals
Arborescent	0	21	4	0	0	0	0	0	1	0	14	0	0	0	40
Cespitose	0	20	35	3	0	0	9	140	41	0	36	20	1	0	305
Corymbose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Massive	0	0	3	4	0	0	1	1	2	0	0	8	12	4	35
Encrusting	0	0	1	0	0	0	0	2	9	0	2	1	0	0	15
Columnar	0	0	2	0	0	0	0	1	0	0	0	1	0	0	4
Explanate Plates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foliose	0	0	1	0	0	0	0	29	4	0	0	10	0	0	44
Flabellate Plates	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3
Free (Fungiids)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaceloid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	0	41	46	7	0	0	10	173	60	0	52	40	13	4	446

* Subzones
A - Sand Subzone
B - Scattered Coral Subzone
C - Coral Subzone
D - Pavement and Pool Subzone (at Transects 1 and 2 and the Outer Reef Flat at Transect 3)
E - Pavement Subzone

Table III-8. Supratidal and intertidal beach widths (to the nearest meter) at Transects 1-3 measured during the 1977 and 1991 surveys.

	Supratidal Width (meters) 1977	Supratidal Width (meters) 1991	Intertidal Width (meters) 1977	Intertidal Width (meters) 1991
Transect 1	6	5	1	2
Transect 2	3	3	11	11
Transect 3	2	2	8	8

Table III-9. Summary of coral community characteristics within transects and zones.

Transect and Subzones	Species/Genera 1977	Species/Genera 1991	Colony Size (cm) 1977	Colony Size (cm) 1991	Density (m^2) 1977	Density (m^2) 1991	Percent Coverage 1977	Percent Coverage 1991
Transect 1								
Sand	1/1	7/4	0.0	5.1	0.00	0.06	0.00	0.02
Scattered Coral	11/6	14/7	11.2	9.8	0.28	0.95	0.40	1.76
Coral	22/11	22/9	11.[illegible]	10.0	1.24	0.65	2.44	1.49
Pavement & Pool	8/6	9/6	9.0	7.4	0.04	0.23	0.02	0.21
Pavement	3/2	5/4	0.0	6.5	0.00	0.05	0.00	0.03
Transect 2								
Sand	5/3	7/6	0.0	0.0	0.00	0.00	0.00	0.00
Scattered Coral	8/4	11/7	8.1	10.6	0.53	0.07	0.04	0.09
Outer Reef Flat	59/22	69/23	7.0	8.8	7.23	[illegible]	5.28	21.1[illegible]
Transect 3								
Sand	2/2	7/5	0.0	4.1	0.00	0.97	0.30	0.34
Scattered Coral	11/7	13/7	9.0	12.2	0.18	1.65	3.54	4.60
Coral	21/11	21/11	14.6	11.6	3.42	4.61	10.17	10.31
Pavement & Pool	4/4	4/3	6.5	7.1	0.35	0.11	0.14	0.17
Pavement	4/2	4/3	8.0	8.4	0.001	0.008	0.001	0.006

APPENDIX

The coral density and percentage of substrate coverage values given in Table 3, p. 55, in Randall, 1978, for Tumon Bay, Transect 3, Scattered Coral Subzone (162 to 347 meters), were incorrectly calculated. The corrected values for the above part of Table 3 are given below (see text for explanation).

Tumon Bay - Transect 3

Inner Reef Flat Zone (Scattered Coral Subzone 162 to 347 meters)

Coral Taxon	Colony Size Distribution (cm) n	x	s	w	Freq.	Den. m^2	Cover %
Porites cocosensis	12	16.8	35.5	1.0-127.0	0.08	0.04	0.45
Pocillopora damicornis	23	3.8	2.6	1.0-9.0	0.36	0.08	0.01
Acropora aspera	12	13.1	7.1	3.0-27.0	0.08	0.04	0.07
Acropora acuminata	2	4.0	1.4	3.0-5.0	0.01	0.007	0.009
Leptastrea purpurea	2	2.5	0.7	2.0-3.0	0.01	0.007	0.003
Psammocora contigua	1	8.0			0.01	0.003	0.002
Totals	52	9.0	17.8	1.0-127.0		0.177	0.544

IV. MACROINVERTEBRATES

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INTRODUCTION

Shallow tropical reefs contain a diverse invertebrate fauna. Excluding corals (see R. H. Randall, this study), echinoderms are the dominant members of most assemblages in terms of biomass. At Tumon the holothuroid Holothuria (Halodeima) atra forms dense near-shore aggregations. The response of these and other invertebrates to the development of Tumon as a center for tourism is of interest. This paper reports a resurvey of the conspicuous macroinvertebrates, particularly holothuroids, of Tumon Bay and compares the results with those of Birkeland (1978).

In 1977 the invertebrates in Tumon were inventoried as part of a larger survey documenting the diversity of reef-flat organisms there. Since that time, Tumon's shoreline has been considerably altered by man through the construction of numerous hotels and has experienced a corresponding increase in the use of the reef flat by bathers. To document the possible effects of these changes to the invertebrate fauna, the area was resurveyed in 1991.

The invertebrates could respond to development in several ways. There could be an overall loss in diversity, either in species richness or by shifts in the relative abundances of different species. In the latter case, for example, increased nutrients from rainwater runoff might result in a concomitant increase in deposit feeders, such as holothuroids, or suspension feeding molluscs and cnidarians. No such changes were observed however. We found that the abundances of conspicuous invertebrates were largely unchanged from the previous survey and, therefore, may have been little affected by the development occurring inland.

MATERIALS AND METHODS

Each species was counted within one meter of both sides of the transect line and recorded at 5 m intervals (2-m X 5-m quadrat) on transect 1. Abundances on transect 2 were recorded at 10-m intervals. Abundances on transect three were counted in 1-m X 10-m quadrats on both sides of the transect line. We examined beneath rocks and looked in crevices for cryptic and nocturnal species. For each transect we compared within-zone abundances with those recorded by Birkeland (1978) with a two-sample *t* test.

RESULTS

The distributions of the most abundant invertebrates are shown in Figure IV-1. The abundances for all species on each transect are tabulated in Table IV-1. Only one subzone showed a significant change in abundance from the initial survey in 1977: H. atra increased in the scattered coral subzone on transect 3 (Fig. 1). The gastropod Cerithium nodulosum was less numerous on all transects as were the diurnally cryptic holothuroids H. impatiens, H. hilla, and Stichopus horrens.

DISCUSSION

The abundance of most of the species in this survey were little changed from 1977. No trend was observed that might indicate the changes taking place along the shoreline were harmful to the invertebrates. In fact, several species were more common and occurred subzones where they were absent in 1977 (Fig. IV-1). The holothuroids Actinopyga echinites and Stichopus chloronotus increased in abundance and were found closer to shore than before. The echinoid Echinometra mathaei, an herbivore, was also much more common than in 1977. Variable recruitment may account for the differences in abundance of some invertebrates such as these. Other causes of increases in the densities of holothuroids are unstudied. Increased echinoid abundances, however, have been shown to be caused by overfishing or can occur during recovery from disease (Birkeland 1989).

We noted that nearshore (>50 m) abundances of holothuroids increased appreciably from north to south. The freshwater aquifer draining along the shoreline of northern Tumon can lower the salinity of reef-flat water to 20‰ at low tide (Quenga in Matson[1] 1991) and may prevent organisms from living in this area.

Most of the invertebrates on coral reefs are small, infaunal or nocturnal and were, therefore, not included in the present or previous surveys of Tumon. For example, 27 species of holothuroids have been found in the bay (A. Kerr, unpublished data), compared with the 12 species found in this survey (Table IV-1). Many of these, however, are reported from only one or two specimens. Since the functionally dominant taxon in a community (the most important ecologically) is usually also dominant in terms of biomass, the organisms reported here, while not the necessarily the most sensitive indicators of change, are probably those which would affect the largest changes in the rest of the reef-flat community if disturbance took place. A comprehensive monitoring of Tumon's invertebrate fauna for human-induced disruptions, however, would benefit from including counts of small and nocturnal animals.

The data may indicate that Tumon populations have been stable during the 14 years between surveys. Typhoons cause catastrophic reductions in reef-flat abundances of holothuroids on windward exposures on Guam (Doty, 1977). However, because of the prevailing wind direction of most cyclonic storms, leeward shores, such as Tumon, are little affected (Kerr, in press). Therefore, any large reductions in populations would be probably due to effects other than stormed-caused wave disturbance. Variable recruitment may account for the differences in abundance of some invertebrates. The shortage of an entire ecological group of organisms, the diurnally cryptic holothuroids, in this survey may mean that the present surveyors did not search as diligently in crevices as the previous investigator, or that climatic conditions varied between the sampling dates. Cryptic and infaunal holothuroids are much more visible during overcast days; we sampled mostly during sunny weather.

LITERATURE CITED

Birkeland, C.E. 1978. Other macroinvertebrates. In: R.H. Randall (ed), Guam's Reefs and Beaches. Part II. Transect Studies, pp. 77-90. Univ. Guam Tech. R. 48.

Doty, J.E. 1977. Fission in Holothuria atra and Holothurian Population Growth. Master's Thesis, Univ. Guam. 54. p.

Kerr, A.M. In press. Effects of typhoon-generated waves on windward and leeward assemblages of holothuroids. Proceedings of the Seventh International Coral Reef Symposium (abstract).

Matson, E.A. 1991. Nutrient chemistry of the coastal waters of Guam. Micronesica 24:109-135.

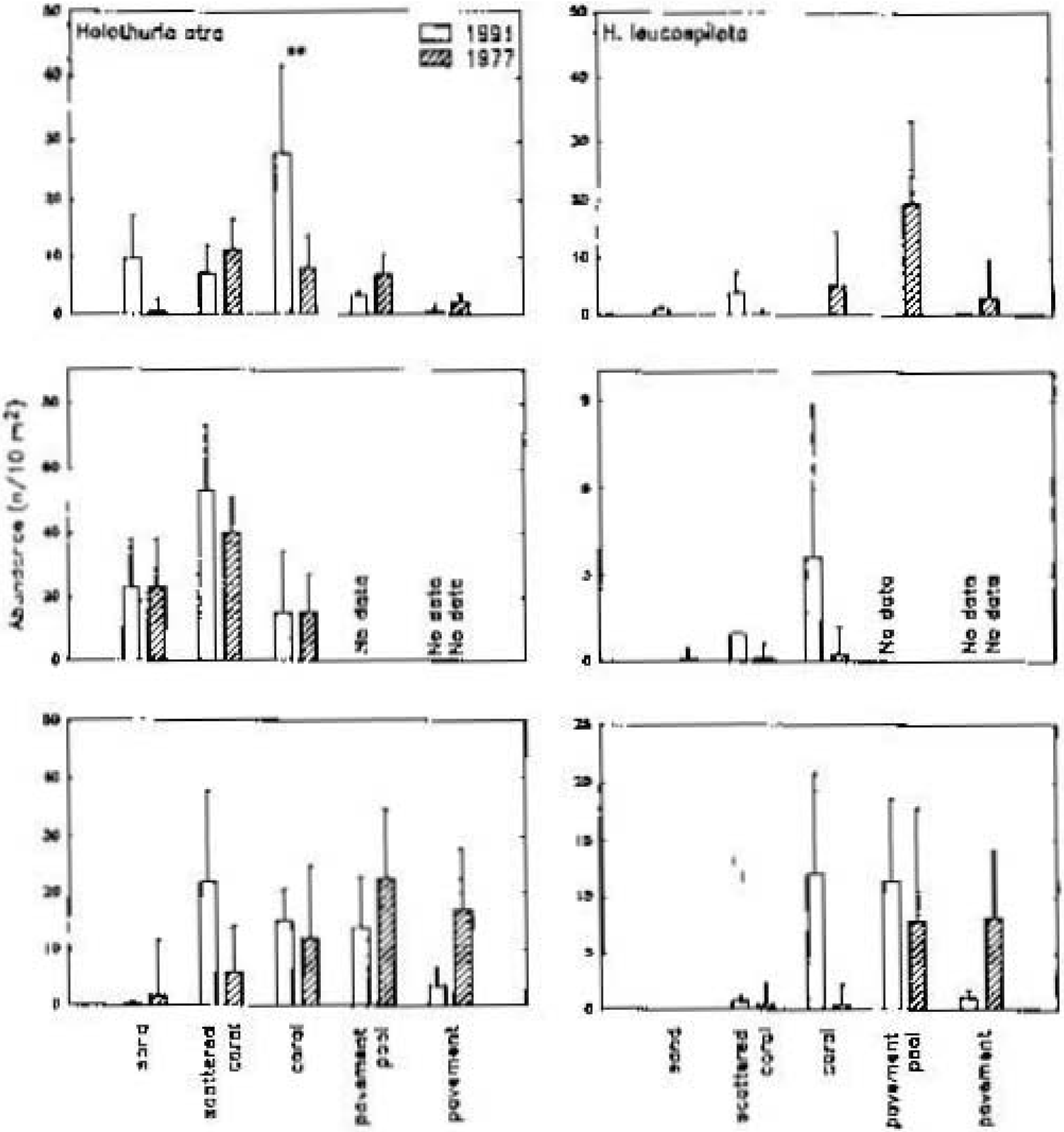

Figure IV-1. Abundances of the six most abundant invertebrates on the Tumon transects in each subzone in 1977 and 1991. The latin name on the top graph of each column indicates the organism pictured in the two graphs below. The top row of graphs are from transect one, the middle row from transect two, and the bottom row from transect three. All within transect and within subzone comparisons are not significantly different using a two-sample *t* test, except for *Holothuria atra* in the coral zone on transect 1 (**$P<.01$).

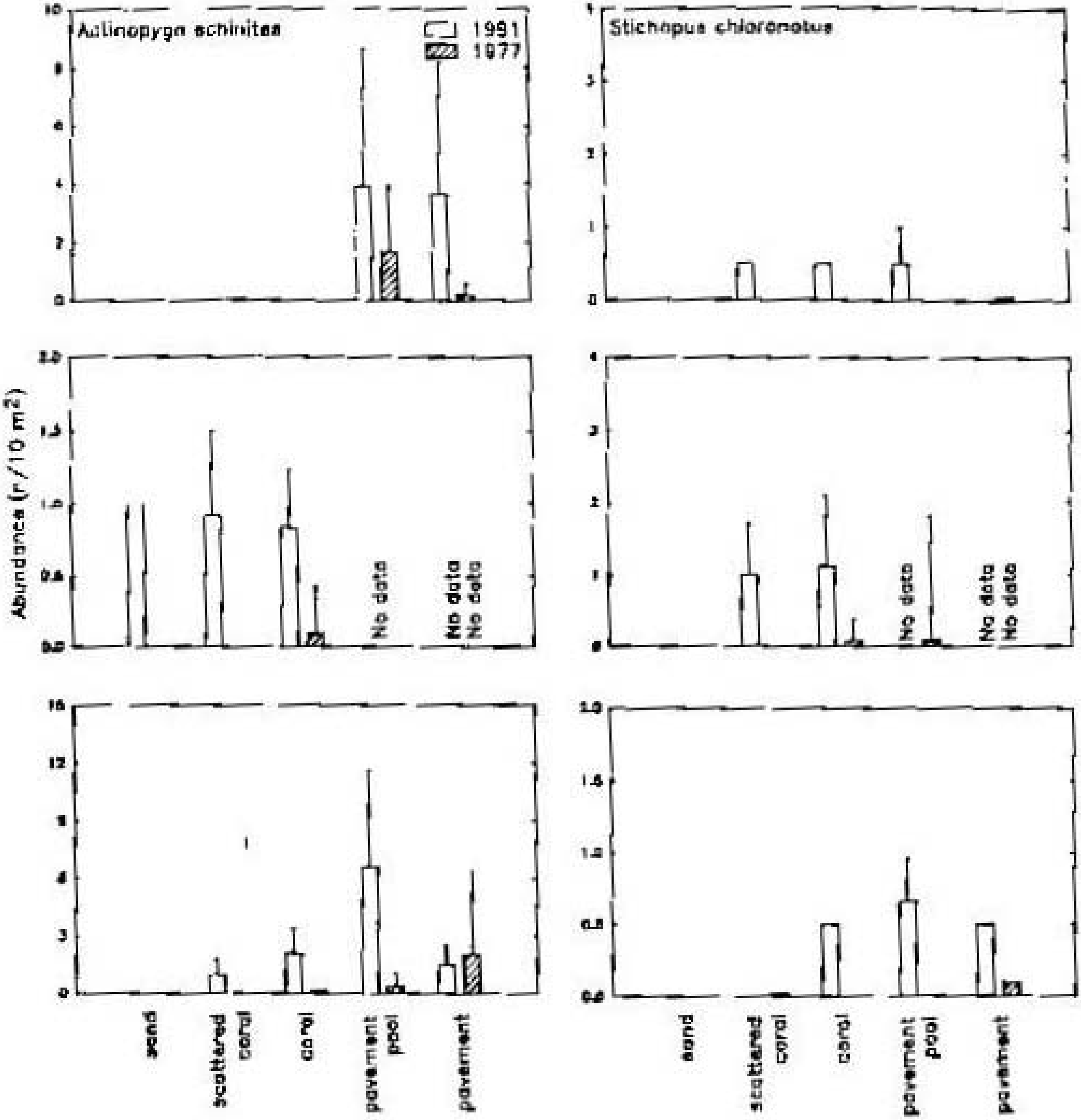

Figure IV-1 (cont.).

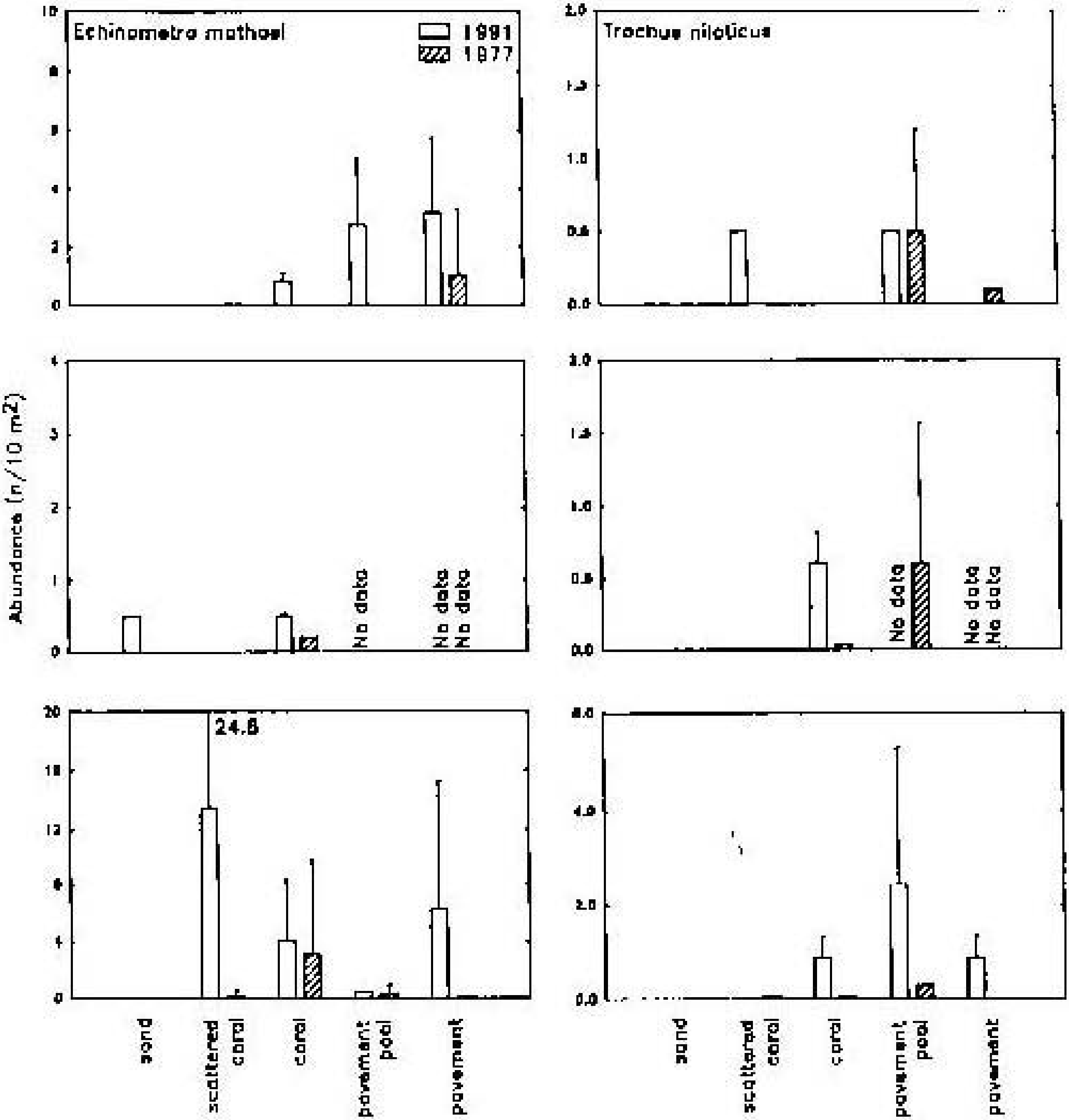

Figure IV-1 (cont.).

Table IV-1 Density (n/100 m2) of common invertebrate . Tumon Bay December 1991

Phylum / Class / Species	Transect 1 sand	Transect 1 scattere	Transect 1 coral	Transect 1 pave&p	Transect 1 pavement	Transect 2 sand	Transect 2 scattere	Transect 2 coral	Transect 3 sand	Transect 3 scattere	Transect 3 coral	Transect 3 pave&p	Transect 3 paveme
Mollusca													
Gastropoda													
Trochus niloticus	0	0	0	1	0	0	0	0.6522	0	0	1.25	8.5	2.5
Cerithium nodulosum	0	0.2273	0.625	1	0	0	0	0	0	0	0	0	0
Vasum spp	0	0	0	0	0.5556	0	0	0.1087	0	0	0	0	3.5714
Bivalvia													
Lima sp	0	0	0	0	0	0	0	0	0	0	0.1786	0	0.3571
Pinna muricata	0	0	0	0	0	0	0	0	0	0.2632	0.1786	0	0
Echinodermata													
Asteroidea													
Linckia laevigata	0	0	0	0	0	0	0	0	0	0.1316	0	0	[illegible]
Culcita novaguineae	0	0.2273	0	0	0	0	0	0.1087	0	0	0	0	[illegible]
Echinoidea													
Echinothrix spp	0	0	0	1.5	0	0	0	0	0	0	0.1786	0	1.0714
Diadema setosum	0	0	0	0	0.2778	0	0	0	0	0	0.1786	0	1.7857
Tripneustes gratilla	0	0	0	0	0.5556	0	0	0	0	0	0	0	0
Echinometra mathaei	0	0	1.5625	11	14.167	0.1786	0	0.6522	0	7.1053	16.071	0.25	27.143
Holothuroidea													
Holothuria atra	36.875	36.364	140.31	17.5	4.1667	116.96	266.43	76.739	1.6667	109.61	76.071	70.25	17.857
H. leucospilota	1.875	7.5	0	0	0.2778	0	1.4286	3.1522	0	1.1842	55.714	57.25	4.6429
Actinopyga echinites	0	0	0	15.5	16.111	0.3571	3.9286	1.087	0.4167	1.5789	10.357	33	6.4286
A. mauritiana	0	0	0	0	0	0	0	0.1087	0	0	0	0	0.3571
Bohadschia argus	0	0	0.3125	0	0	0.1786	1.4286	0.3261	0.4167	0.3947	1.0714	1.25	0.3571
B. marmorata	0	0	0.3125	0	0	0	0	0	0	0	0	0	0
Synapta maculata	0.1563	0	0	0	0	0	0	0	0	0.7895	0.8929	0.25	0
Stichopus chloronotus	0	0.9091	0.625	0.5	0	0	1.4286	2.9348	0	0	0.5357	1	0.3571
H. hilla	0	0	0	0	0	0	0.3571	0.1087	0	0	0.5357	0	0
A. obesa	0	0	0	0	0	0	0	0	0	0	0.1786	0	0
H. pervicax	0	0	0	0	0	0	0	0	0	0	0.1786	0	0
H. nobilis	0	0	0	0	0	0	0	0	0	0	0.1786	0	0
Ophiuroidea													
Ophiocoma erinaceus	0	0.4545	0.625	0	0.8333	0	0	0	0	0	0	0	0.3571
ophiuroid spp.	0	0	0.3125	0	0	0	0	0	0	0	0.7143	0.75	6.4286

V. FISHES

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INTRODUCTION

Surveys of fishes were carried out along two underwater transects in Tumon Bay in 1977 and 1978 as part of a wider study of Guam's coastal marine communities (Amesbury, 1978; Randall, 1978). In order that changes in the fish communities in Tumon Bay during the time since those earlier surveys could be documented, the same transects (as well as an additional one) were surveyed in December 1991.

MATERIALS AND METHODS

Fish communities were surveyed from December 16 to 18, 1991, along transect lines running from the shoreline out to the reef margin in locations at the northeast, central, and southwest parts of Tumon Bay. The length of the transect equalled the width of the reef flat at each location, except at transect 2 where the fish counts were terminated somewhat short of the reef margin because of insufficient water depth to permit visual observations.

Fish were enumerated by species within a 2-m wide corridor 1 m to either side of the transect line. Separate counts were made for each 10-m interval along the transect lines. For analytical purposes, reef zones were distinguished on the basis of physiography and substrate (Randall, this volume).

RESULTS

Present Fish Communities

A total of 1215 fishes of 46 species were counted along the three transects on the Tumon Bay reef flat (Table V-1). The overall density of fishes was almost identical at transects 2 and 3 (0.474 and 0.476 fish per m^2, respectively), while fish density at transect 1 (0.245 per m^2) was about half that of the other two transects. Fish species richness was less at transect 1 (22 species) than at either transect 2 (30 species) or transect 3 (32 species).

Fish were irregularly distributed along the transects, tending to be less abundant at either end of the transects (toward the beach and toward the reef margin) and more abundant in the middle zones of the reef flat (Figure V-1). This pattern was most accentuated along transect 3 but was also exhibited on the other two transects. A somewhat similar pattern can be seen in the distribution of species richness across the Tumon reef flat along the three transects (Figure V-2).

When viewed as cumulative number of fish seen while progressing from the beach to the reef margin along the transects, each transect exhibits a somewhat different pattern (Figure V-3): along transect 1, fish occur in small groups along the transect giving the cumulative curve a "stairstep" appearance; along transect 2, fish abundance is more evenly distributed along the transect and the cumulative curve exhibits a smoother profile; along transect 3, fish are distributed in a few rather large clumps, and the cumulative curve again looks like a set of stairs but with fewer, higher steps.

Figures V-4, 5, and 6 present similar analyses of the distribution of fish species along the transects from the beach to the reef margin. In these figures, the curve of "species added" indicates the cumulative number of fish species seen for the first time by the observer as he progressed along the transect out from the beach; the "species lost" curve indicates the cumulative number of species seen for the last time along the transect; and the "species added or lost" curve is the sum of the other two curves and represents the cumulative number of species distribution boundaries observed in each of the 10-m transect intervals censused. The curves can be used to elucidate patterns of zonation in the distribution of fish species across the reef flat: parts of the "species added or lost" curve which are relatively flat indicate zones where species composition is relatively constant; parts of the curve which rise sharply indicate boundaries between zones where species composition is changing rather abruptly; and parts of the curve which slope up more-or-less uniformly indicate regions where species composition is changing, but where clearly-defined zone boundaries, affecting several species simultaneously, are not apparent.

Examining this pattern along transect 1 (Figure V-4), it appears that few species of fish occur between the beach and 90 m, but between 90 and 100 m there is an abrupt increase of species. Species composition remains more-or-less constant until, at 140-150 m, an abrupt change occurs as several species drop out and a few additional ones appear. From there until 340 m, there is only a modest rate of change in species composition, but between 340 and 400 m several species drop out and new ones appear. This new community remains constant until 450 m after which species drop out one by one until the end of the transect at 500 m.

Along transect 2 (Figure V-5) there is a stepwise change in species composition from the beach edge out to 250 m. From 250 to 280 m there occurs an abrupt change in species composition with several species dropping out and being replaced with new ones. This assemblage remains constant until 310 m after which a gradual but marked change in species composition occurs until 390 m. The community remains constant after this until the remaining species drop out at the end of the transect.

Transect 3 (Figure V-6) begins with the stepwise appearance of several species until, at 190-200 m, a major shift in species composition occurs with the gain and loss of several species.

From that point on, species composition changes gradually with no abrupt boundaries until, at 520 m, species begin to drop out toward the end of the transect.

The changes in species composition indicated by these cumulative plots correspond broadly, but not exactly, to the reef habitat zonation pattern identified by Randall (1992) based on dominant substrate type and topography. Randall's reef flat zones, extending from the beach to the reef margin are designated as follows:

a) sand zone,
b) sand and scattered coral zone,
c) coral zone,
d) pavement and pool zone (not present on transect 2), and
e) pavement zone.

Comparison with Previous Surveys

The distributions of fish species by zone for each of the three transects are shown in Tables V-2, 3, and 4. For transects 1 and 2, the tables also present the corresponding data from the earlier 1977/1978 surveys.

Nearly twice as many fish species were seen along transect 1 in 1978 than were observed along that transect during the 1991 survey (41 to 22 species, respectively; Table V-2). The greatest difference in species richness appeared in the outer pavement zone (Figure V-7), but notable differences occurred also in the coral zone and sand zone. Some of the species seen in the pavement zone in 1978 which were not seen in 1991 were species which are characteristically found on the reef slope beyond the reef margin but which move into the pavement zone at high tide to feed on algae. Such species as the surgeonfishes Acanthurus lineatus, A. nigrofuscus, A. pyroferus, and A. triostegus and the damselfishes Plectroglyphidodon dickii, P. leucozona, and Stegastes fasciolatus are in this category. The difference in the occurrence of these species between the two surveys may reflect somewhat different tidal conditions on the days that the surveys were carried out.

Fish abundance was considerably lower along transect 1 in 1991 than it was in 1978 even when atherinids (small silvery schooling species) are eliminated from the 1978 totals (Table V-2). Fish abundance is most strikingly different in the outer reef flat zones (Figure V-8) and seems primarily to be a result of the lack of reef slope herbivores and the remarkably smaller numbers of the territorial damselfish Chrysiptera leucopoma).

Along transect 2, overall fish species richness was almost identical between 1977 and 1991, and was identical (30 species) when rabbitfishes (Siganidae), which were in the midst of a recruitment run in 1977, are eliminated from the data (Table V-3). Although the same number of fish species were seen along the whole transect in the two years, more species were seen in each reef flat zone in 1977 than in 1991 (Figure V-9). This indicates that the species seen in 1977 had broader distributions among zones than was the case in 1991.

Overall fish abundance along transect 2 was somewhat less in 1991 than in 1977 (Table V-3) and was less in each reef zone (Figure V-10), even when rabbitfishes are excluded. The lesser fish abundance in 1991 reflects reductions in the abundance of several groups including bottom-dwelling blennies and gobies, damselfishes, and juvenile parrotfish.

Fish were not surveyed along transect 3 during 1977/1978. The distribution of fish species by zone along this transect is presented in Table V-4, and abundance and species richness are shown in Figures V-11 and 12.

DISCUSSION

Comparison of fish abundance and species richness data from the 1977/78 and 1991 surveys suggests that the reef flat fish communities have declined during the period between surveys. The evidence is not completely unequivocal, however, and it is not entirely clear to what factors the decline, if in fact it has occurred, can be attributed.

Transect 1 shows the greatest indication of reduction in fish abundance and species richness over the 1978 - 1991 period (Table V-3, Figures V-7 and 8). On this transect, the greatest difference in fish abundance and species richness occurs on the outer pavement and pool and pavement zones and may be attributable to tide height differences between the two study periods. Although most of the fish species which are absent or in lesser abundance in these habitats in 1991 are herbivores, Tsuda's survey (this volume) of these habitats indicated that the percent cover of marine plants is unchanged between the two survey periods, suggesting that the differences in fish abundance are not attributable to differences in food availability.

The reduction in fish abundance and species richness from 1977 to 1991 along transect 2 is quite consistent: every reef zone exhibits fewer fish species and fewer fish in 1991 than in 1977 (Table V-4, Figures V-9 and 10). However, overall species richness has remained quite constant along this area, and fish abundance (excluding the rabbitfishes which were "running" during the 1977 survey) is reduced overall by approximately 30%.

Despite the somewhat ambiguous interpretation of the comparative data, it is clear that there is no indication that fish are <u>increasing</u> on the Tumon reef flat, and the most reasonable conclusion is that fish are probably declining. It would be prudent, then, to continue to monitor the condition of the fish communities within Tumon Bay to ensure that significant degradation of these communities does not occur without warning.

LITERATURE CITED

Amesbury, S. S. 1978. Studies on the biology of coral reef fishes of Guam. Part I: Distribution of fishes on the reef flats of Guam. Part II: Distribution of eggs and larvae of fishes at selected sites on Guam. Univ. Guam Mar. Lab., Tech. Rept. 49, 65 pp.

Randall, R. H., ed. 1978. Guam's reefs and beaches, Part II. Transect studies. Univ. Guam Mar. Lab., Tech. Rept. 48, 90pp.

Table V-1. Fish species enumerated along the three transects in Tumon Bay, December 1991.

		TRANSECTS 1	2	3	TOTAL
ACANTHURIDAE	Acanthurus lineatus		1		1
ACANTHURIDAE	A. triostegus	2		19	21
ACANTHURIDAE	Naso juveniles		6	1	7
APOGONIDAE	Apogon novemfasciatus	1	11	1	13
APOGONIDAE	Cheilodipterus quinquelineatus	5	1		6
BALISTIDAE	Rhinecanthus aculeatus	3	6	3	12
BLENNIIDAE	Salarias fasciatus	1		4	5
BOTHIDAE	Bothus pantherinus			2	2
CARANGIDAE	Caranx melampygus	1	1	1	3
CHAETODONTIDAE	Chaetodon citrinellus	3	5		8
CHAETODONTIDAE	C. ephippium			1	1
CHAETODONTIDAE	C. trifascialis			1	1
CHAETODONTIDAE	C. trifasciatus			1	1
FISTULARIIDAE	Fistularia commersonii		1	2	3
GOBIIDAE	Valecienneа strigata		3	1	4
HOLOCENTRIDAE	Neoniphon sammara			8	8
HOLOCENTRIDAE	Sargocentron diadema	2			2
LABRIDAE	Cymolutes praetextatus		3		3
LABRIDAE	Halichoeres margaritaceus	27	41	10	78
LABRIDAE	H. trimaculatus	63	113	36	212
LABRIDAE	Stethojulis bandanensis	20	18	6	44
LABRIDAE	S. strigiventor		1		1
LABRIDAE	Thalassoma hardwickii		1		1
LABRIDAE	juvenile		1		1
MUGILIDAE	Liza vaigiensis			1	1
MULLIDAE	Parupenous barberinus	4	12	4	20
MULLIDAE	juvenile			20	20
MURAENIDAE	Echidna nebulosa		1		1
NEMIPTERIDAE	Scolopsis lineatus		3		3
OSTRACIIDAE	Ostracion meleagris		1		1
POMACENTRIDAE	Abudefduf septemfasciatus		1	1	2
POMACENTRIDAE	Chromis viridis	13		68	81
POMACENTRIDAE	Chrysiptera biocellata	23	20	11	54
POMACENTRIDAE	C. glauca	9	29	26	64
POMACENTRIDAE	C. leucopoma	2	14	1	17
POMACENTRIDAE	Dascyllus aruanus	6	16	155	177
POMACENTRIDAE	Pomacentrus pavo	5			5
POMACENTRIDAE	Stegastes albifasciatus			5	5
POMACENTRIDAE	S. lividus			68	68
POMACENTRIDAE	S. nigricans	36	102	59	197
SCARIDAE	juveniles	8	9	22	39
SYNGNATHIDAE	Corythoichthys intestinalis	8	2	3	13
TETRAODONTIDAE	Arothron hispidus		2		2
TETRAODONTIDAE	Canthigaster bennetti		2		2
TETRAODONTIDAE	C. solandri	3		1	4
ZANCLIDAE	Zanclus cornutus			1	1
TOTAL FISH		245	427	543	1215
TOTAL SPECIES		22	30	32	46
TRANSECT LENGTH (M)		500	450	570	
FISH DENSITY (NO/SQ M)		0.245	0.474	0.476	

Table V-2. Fish counts by reef zone along transect 1. Zone A: sand zone; zone B: scattered coral zone; zone C: coral zone; zone D: pavement and pool zone; zone E: pavement zone.

		ZONE A (0-150)		ZONE B (150-260)		ZONE C (260-340)		ZONE D (340-390)		ZONE E (390-500)		SUM	SUM
		1978	1991	1978	1991	1978	1991	1978	1991	1978	1991	1978	1991
ACANTHURIDAE	A. lineatus	0	0	0	0	0	0	0	0	27	0	27	0
ACANTHURIDAE	A. nigrofuscus	0	0	0	0	0	0	0	0	4	0	4	0
ACANTHURIDAE	A. pyroferus	0	0	0	0	0	0	0	0	2	0	2	0
ACANTHURIDAE	A. triostegus	0	0	0	2	2	0	0	0	3	0	5	2
ACANTHURIDAE	juveniles	3	0	0	0	0	0	0	0	0	0	3	0
APOGONIDAE	A. novemfasciatus	7	0	0	0	1	0	1	1	0	0	9	1
APOGONIDAE	C. quinquelineata	0	5	0	0	0	0	0	0	0	0	0	5
ATHERINIDAE	unidentified	0	0	0	0	100	0	300	0	300	0	700	0
BALISTIDAE	R. aculeatus	1	0	0	0	0	1	0	1	0	1	1	3
BLENNIIDAE	S. fasciatus	0	0	0	0	0	0	0	1	0	0	0	1
BLENNIIDAE	unidentified	0	0	0	0	1	0	2	0	2	0	5	0
CARANGIDAE	C. melampygus	1	1	0	0	0	0	0	0	0	0	1	1
CHAETODONTIDA	C. citrinellus	0	0	0	1	2	0	0	2	0	0	2	3
CHAETODONTIDA	C. ephippium	1	0	0	0	0	0	0	0	0	0	1	0
FISTULARIIDAE	F. commersoni	0	0	1	0	0	0	0	0	0	0	1	0
GOBIIDAE	A. phalaena	2	0	0	0	0	0	0	0	0	0	2	0
GOBIIDAE	unidentified	9	0	6	0	8	0	0	0	0	0	23	0
HOLOCENTRIDAE	Myripristis sp.	0	0	0	0	0	0	0	0	1	0	1	0
HOLOCENTRIDAE	S. diadema	0	1	0	1	0	0	0	0	0	0	0	2
LABRIDAE	H. margaritaceus	0	0	0	0	0	0	0	1	57	26	57	27
LABRIDAE	H. marginatus	0	0	0	0	0	0	0	0	1	0	1	0
LABRIDAE	H. trimaculatus	11	6	31	12	10	19	11	8	0	18	63	63
LABRIDAE	S. bandanensis	2	4	3	2	5	1	30	2	14	11	54	20
LABRIDAE	T. quinquevittata	0	0	0	0	0	0	0	0	6	0	6	0
MUGILIDAE	L. vaigiensis	0	0	0	0	1	0	0	0	0	0	1	0
MULLIDAE	M. flavolineatus	1	0	0	0	1	0	0	0	0	0	2	0
MULLIDAE	P. barberinus	0	4	0	0	0	0	0	0	0	0	0	4
MULLIDAE	P. pleurostigma	0	0	0	0	0	0	0	0	2	0	2	0
NEMIPTERIDAE	S. lineatus	5	0	0	0	0	0	0	0	0	0	5	0
POMACENTRIDAE	A. septemfasciatus	0	0	0	0	1	0	0	0	0	0	1	0
POMACENTRIDAE	C. viridis	0	13	0	0	0	0	0	0	0	0	0	13
POMACENTRIDAE	C. biocellata	4	7	3	7	1	5	0	4	0	0	8	23
POMACENTRIDAE	C. glauca	0	0	0	0	23	0	20	0	4	9	47	9
POMACENTRIDAE	C. leucopoma	0	0	0	0	0	0	0	0	134	2	134	2
POMACENTRIDAE	D. aruanus	24	5	0	1	0	0	0	0	0	0	24	6
POMACENTRIDAE	P. dickii	0	0	0	0	0	0	0	0	3	0	3	0
POMACENTRIDAE	P. leucozona	0	0	0	0	0	0	0	0	9	0	9	0
POMACENTRIDAE	P. pavo	0	5	0	0	0	0	0	0	0	0	0	5
POMACENTRIDAE	S. albifasciatus	0	0	0	0	0	0	0	0	1	0	1	0
POMACENTRIDAE	S. fasciolatus	0	0	0	0	0	0	0	0	12	0	12	0
POMACENTRIDAE	S. nigricans	1	0	0	23	0	13	4	0	0	0	5	36
POMACENTRIDAE	juveniles	7	0	0	0	0	0	0	0	0	0	7	0
SCARIDAE	juveniles	0	8	0	0	0	0	0	0	5	0	5	8
SIGANIDAE	S. spinus	1	0	3	0	0	0	0	0	0	0	4	0
SYNGNATHIDAE	C. intestinalis	0	8	0	0	0	0	0	0	0	0	0	8
SYNODONTIDAE	Synodus sp.	0	0	0	0	0	0	0	0	1	0	1	0
TETRAODONTIDA	C. solandri	2	0	0	3	0	0	0	0	1	0	3	3
ZANCLIDAE	Z. cornutus	0	0	0	0	0	0	0	0	2	0	2	0
TOTAL SPECIES		17	12	6	9	13	5	7	8	22	6	41	22
TOTAL FISH		82	67	47	52	156	39	368	20	591	67	1244	245
TOTAL FISH (Excluding atherinds)		82	67	47	52	56	39	68	20	291	67	544	245

Table V-3 Fish counts by reef zone along transect 2. Zone A: sand zone; zone B: scattered coral zone; zone C: coral zone; zone D1: pavement zone; zone D2: pavement zone beyond end of 1991 transect.

		ZONE A (0-130)		ZONE B (130-200)		ZONE C (200-430)		ZONE D1 (430-450)		TOTALS (0-450)		ZONE D2 (450-500)
		1977	1991	1977	1991	1977	1991	1977	1991	1977	1991	1977
ACANTHURIDAE	A. lineatus								1	0	1	
ACANTHURIDAE	A. triostegus			1		9				10	0	
ACANTHURIDAE	C. striatus									0	0	3
ACANTHURIDAE	Naso juvenile						6			0	6	
APOGONIDAE	A. novemfasciatus	6		2		1	11	1		10	11	
APOGONIDAE	C. quinquelineata						1			0	1	
APOGONIDAE	unidentified	1								1	0	
BALISTIDAE	R. aculeatus	1	2	1	2	2	2			4	6	
BLENNIIDAE	P. tapeinosoma					1				1	0	
BLENNIIDAE	unidentified	15		2		14		3		34	0	
CARANGIDAE	C. melampygus		1							0	1	
CHAETODONTIDAE	C. citrinellus					1	5			1	5	
FISTULARIIDAE	F. commersonii					1	1			1	1	
GOBIIDAE	G. cauerensis	7		1		2				10	0	
GOBIIDAE	V. sirigata						3			0	3	
GOBIIDAE	unidentified	3		2		5				10	0	
HOLOCENTRIDAE	N. sammara	3		1						4	0	1
LABRIDAE	C. praetextatus		3							0	3	
LABRIDAE	H. margaritaceus					40	27	10	14	50	41	42
LABRIDAE	H. trimaculatus	11	7	8	12	90	94			109	113	1
LABRIDAE	S. bandanensis					9	18	1		10	18	2
LABRIDAE	S. singiventor				1					0	1	
LABRIDAE	T. hardwicki						1			0	1	
LABRIDAE	T. quinquevittatum									0	0	1
LABRIDAE	juvenile			1			1	1		2	1	1
MULLIDAE	M. flavolineatus					2				2	0	
MULLIDAE	P. barberinus	2			7	2	5			4	12	
MULLIDAE	P. multifasciatus					1				1	0	
MURAENIDAE	E. nebulosus		1							0	1	
NEMIPTERIDAE	S. ...			1			3			1	3	
OSTRACIIDAE	O. meleagris						1			0	1	
POMACENTRIDAE	A. septemfasciatus						1			0	1	
POMACENTRIDAE	C. biocellata	14	1	9	0	1	10			24	20	
POMACENTRIDAE	C. glauca					38	19		10	38	29	
POMACENTRIDAE	C. leucopoma					9	7	10	7	19	14	105
POMACENTRIDAE	D. aruanus			9	3	1	13			10	16	
POMACENTRIDAE	P. dickii									0	0	1
POMACENTRIDAE	P. lacrymatus									0	0	1
POMACENTRIDAE	S. albifasciatus	1				116		45		162	0	74
POMACENTRIDAE	S. fasciolatus									0	0	9
POMACENTRIDAE	S. nigricans			3		23	102			26	102	1
POMACENTRIDAE	juvenile	15		5		1				21	0	
SCARIDAE	juvenile					27	9			27	9	1
SIGANIDAE	S. argenteus	2		10		225		11		248	0	64
SIGANIDAE	S. spinus	74		72		562		33		701	0	806
SYNGNATHIDAE	C. intestinalis			2	2	1				3	2	
TETRAODONTIDAE	A. hispidus		2							0	2	
TETRAODONTIDAE	C. bennetti			1		4	2			5	2	
TETRAODONTIDAE	C. solandri			4		8				12	0	
TOTAL SPECIES		14	7	19	7	28	23	9	4	32	30	16
TOTAL SPECIES (Excluding siganids)		12	7	*17	7	26	23	7	4	30	30	14
TOTAL FISH		115	17	135	36	1196	342	115	32	1561	427	1113
TOTAL FISH (Excluding siganids)		79	17	53	36	409	342	71	32	612	427	243

Table V-4. Fish counts by reef zone along transect 3. Zone A: sand zone; zone B: scattered coral zone; zone C: coral zone; zone D: pavement and pool zone; zone E: pavement zone.

		ZONE A (0-160) 1991	ZONE B (160-350) 1991	ZONE C (350-400) 1991	ZONE D (400-440) 1991	ZONE E (440-570) 1991	TOTAL (0-570) 1991
ACANTHURIDAE	A. triostegus					19	19
ACANTHURIDAE	Naso juvenile			1			1
APOGONIDAE	A. novemfasciatus		1				1
BALISTIDAE	R. aculeatus	3					3
BLENNIIDAE	S. fasciatus		1	1		2	4
BOTHIDAE	B. pantherinus	1	1				2
CARANGIDAE	C. melampygus		1				1
CHAETODONTID	C. ephippium		1				1
CHAETODONTID	C. trifascialis		1				1
CHAETODONTID	C. trifasciatus		1				1
FISTULARIIDAE	F. commersonii	1				1	2
GOBIIDAE	V. strigata					1	1
HOLOCENTRIDA	N. sammara		8				8
LABRIDAE	H. margaritaceus					10	10
LABRIDAE	H. trimaculatus	3	14	4	2	13	36
LABRIDAE	S. bandanensis		2		1	3	6
MUGILIDAE	L. vaigiensis					1	1
MULLIDAE	P. barberinus	3				1	4
MULLIDAE	juvenile	20					20
POMACENTRIDA	A. septemfasciatus		1				1
POMACENTRIDA	C. viridis	21	47				68
POMACENTRIDA	C. biocellata	2	9				11
POMACENTRIDA	C. glauca				5	21	26
POMACENTRIDA	C. leucopoma					1	1
POMACENTRIDA	D. aruanus	9	146				155
POMACENTRIDA	S. albifasciatus					5	5
POMACENTRIDA	S. lividus		68				68
POMACENTRIDA	S. nigricans		59				59
SCARIDAE	juveniles		22				22
SYNGNATHIDAE	C. intestinalis		3				3
TETRAODONTID	C. solandri		1				1
ZANCLIDAE	Z. cornutus		1				1
TOTAL SPECIES		9	20	3	3	12	32
TOTAL FISH		63	388	6	8	76	543

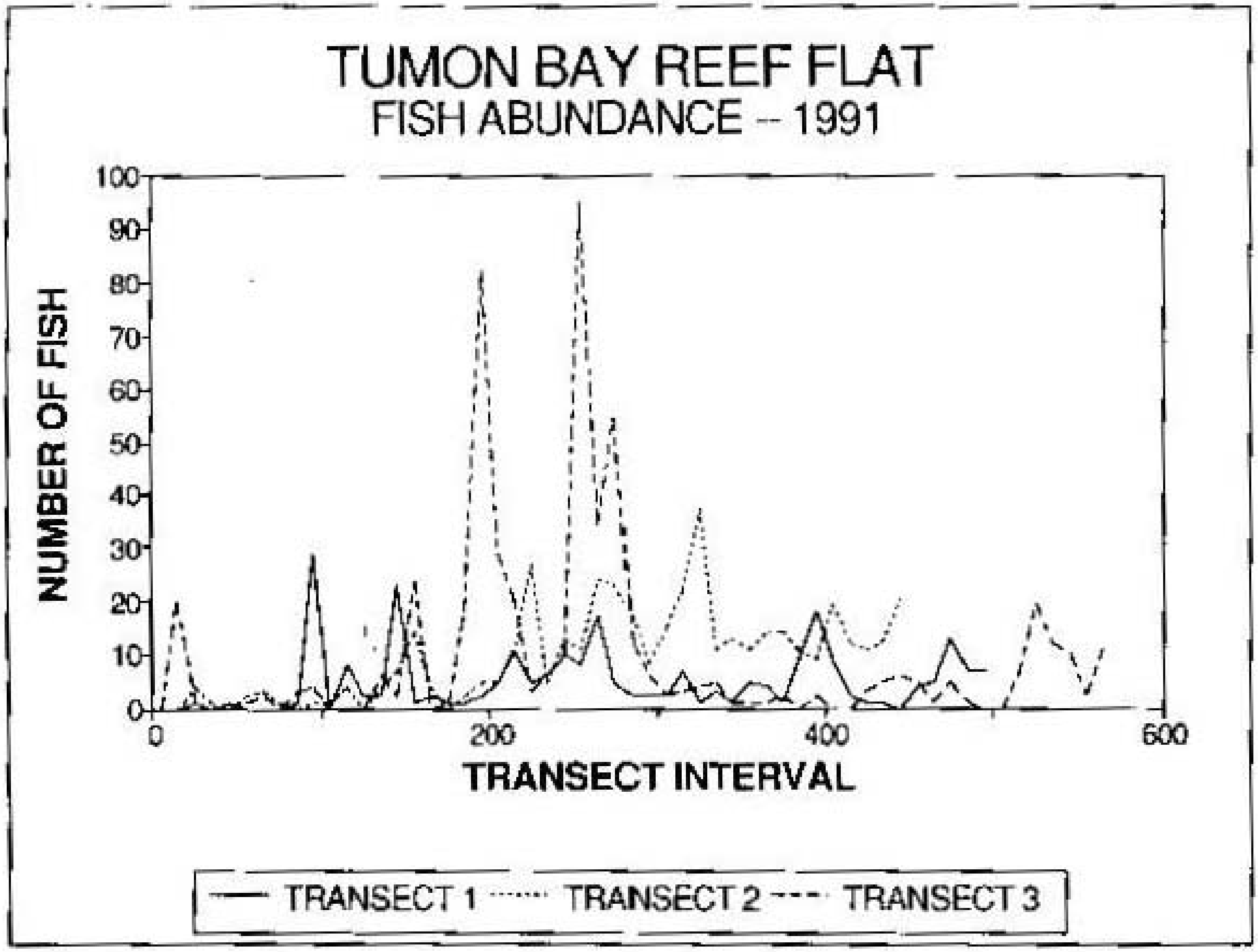

Figure V-1. Number of fish counted in each 10-m interval along transects 1, 2, and 3 (atherinids and siganids excluded as explained in text), December 1991.

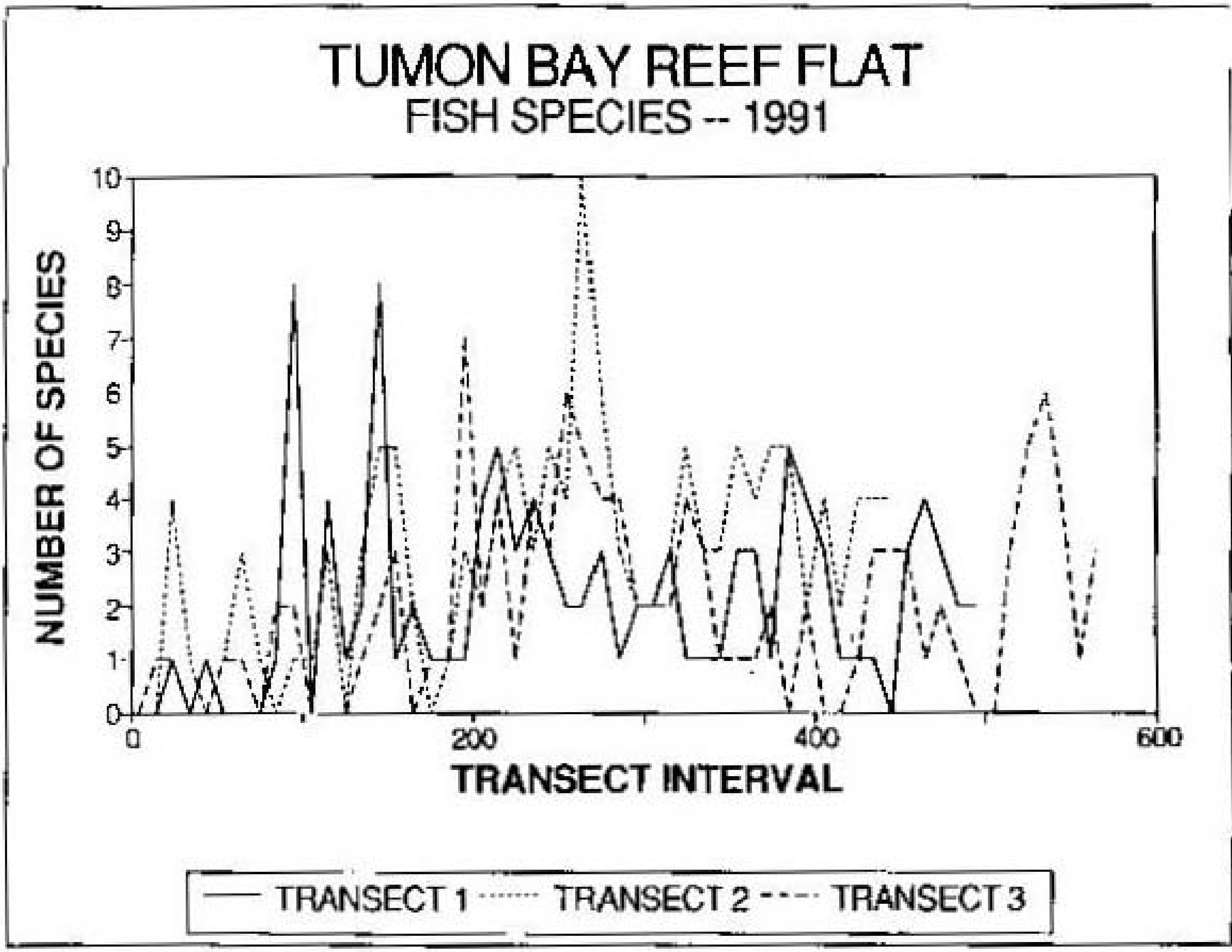

Figure V-2. Number of fish species observed in each 10-m interval along transects 1, 2, and 3 (atherinids and siganids excluded as explained in text), December 1991.

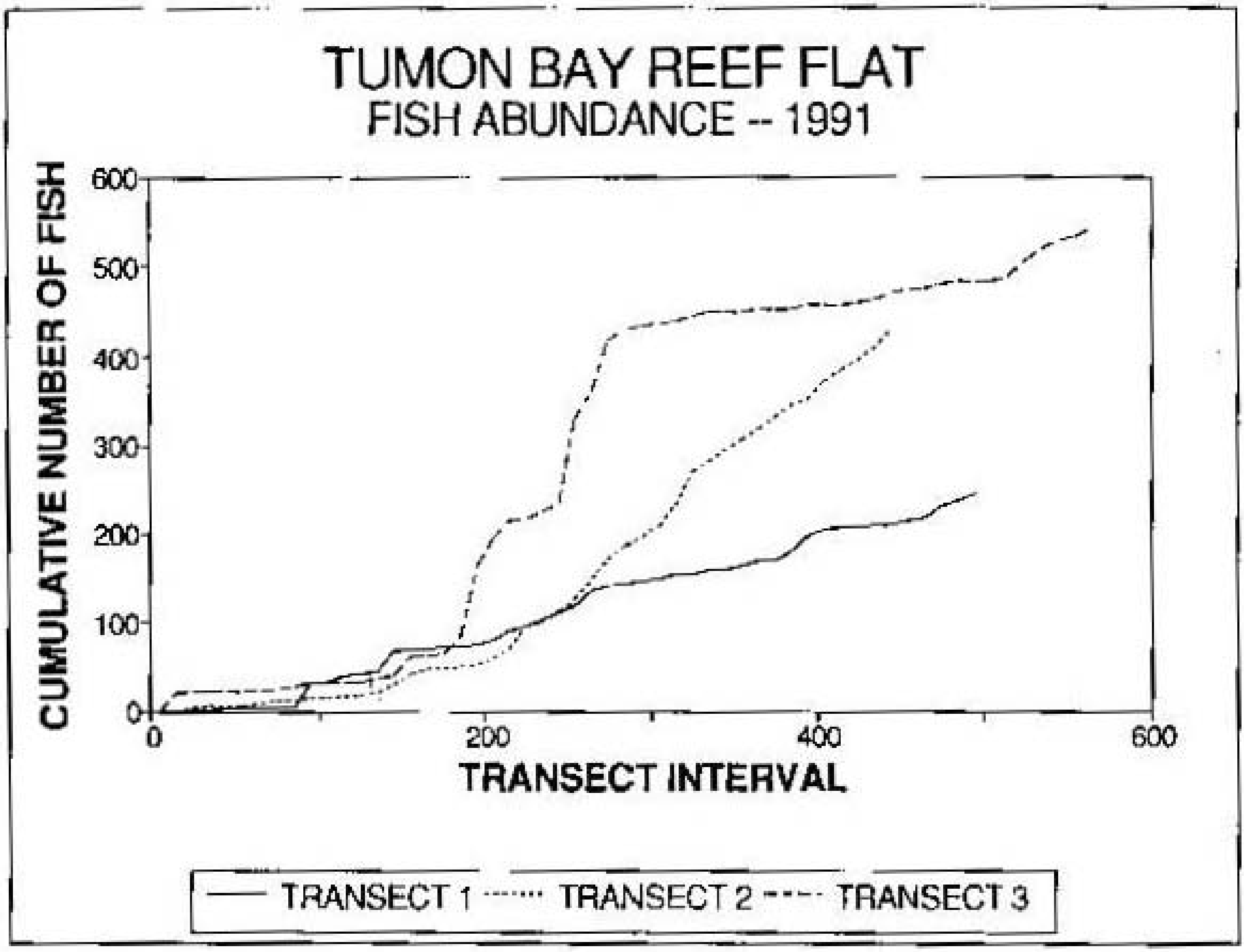

Figure V-3. Cumulative number of fish counted in each 10-m interval along transects 1, 2, and 3 (atherinids and siganids excluded as explained in text), December 1991.

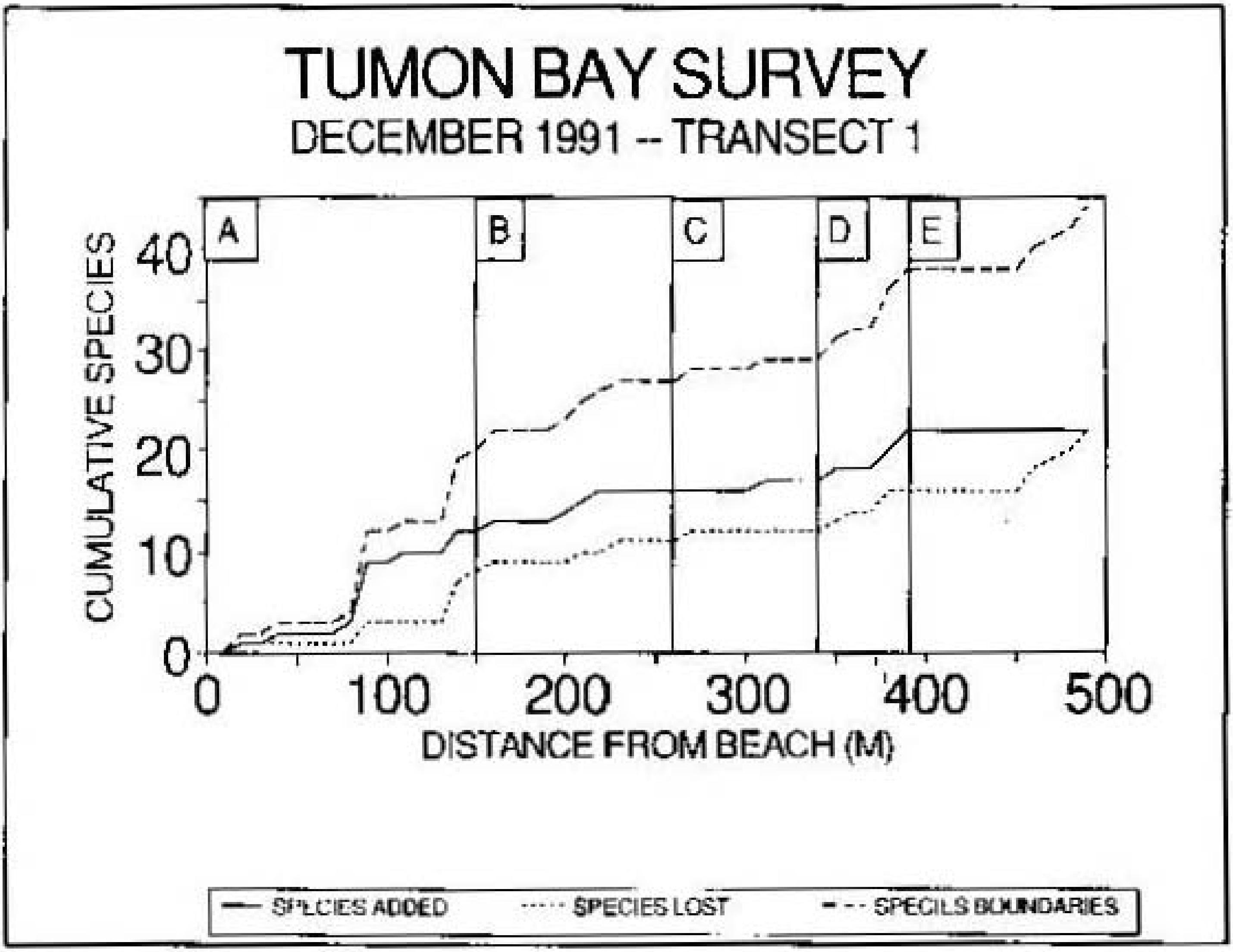

Figure V-4. Patterns of cumulative species boundaries (see text for explanation) along transect 1, December 1991.

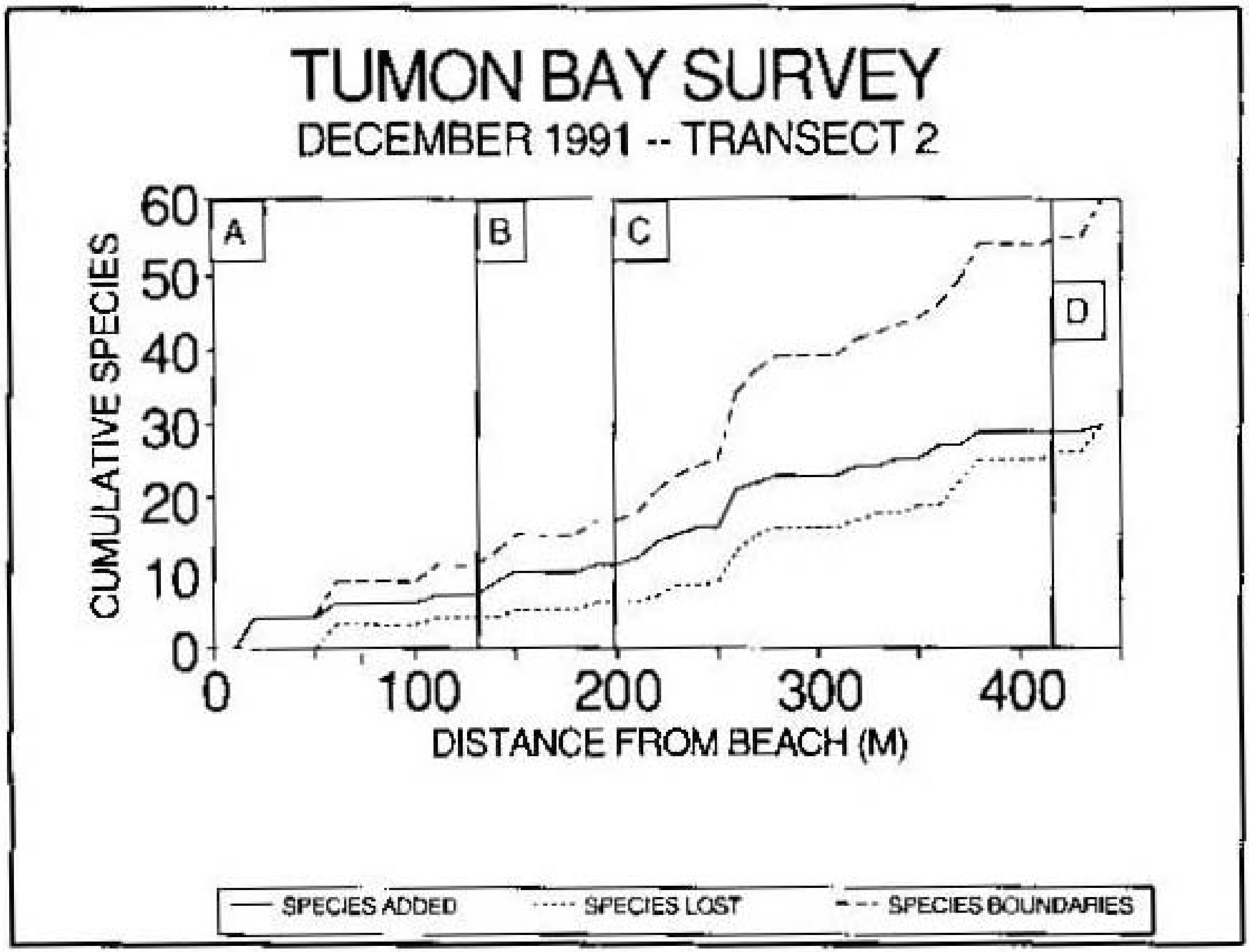

Figure V-5. Patterns of cumulative species boundaries (see text for explanation) along transect 2, December 1991.

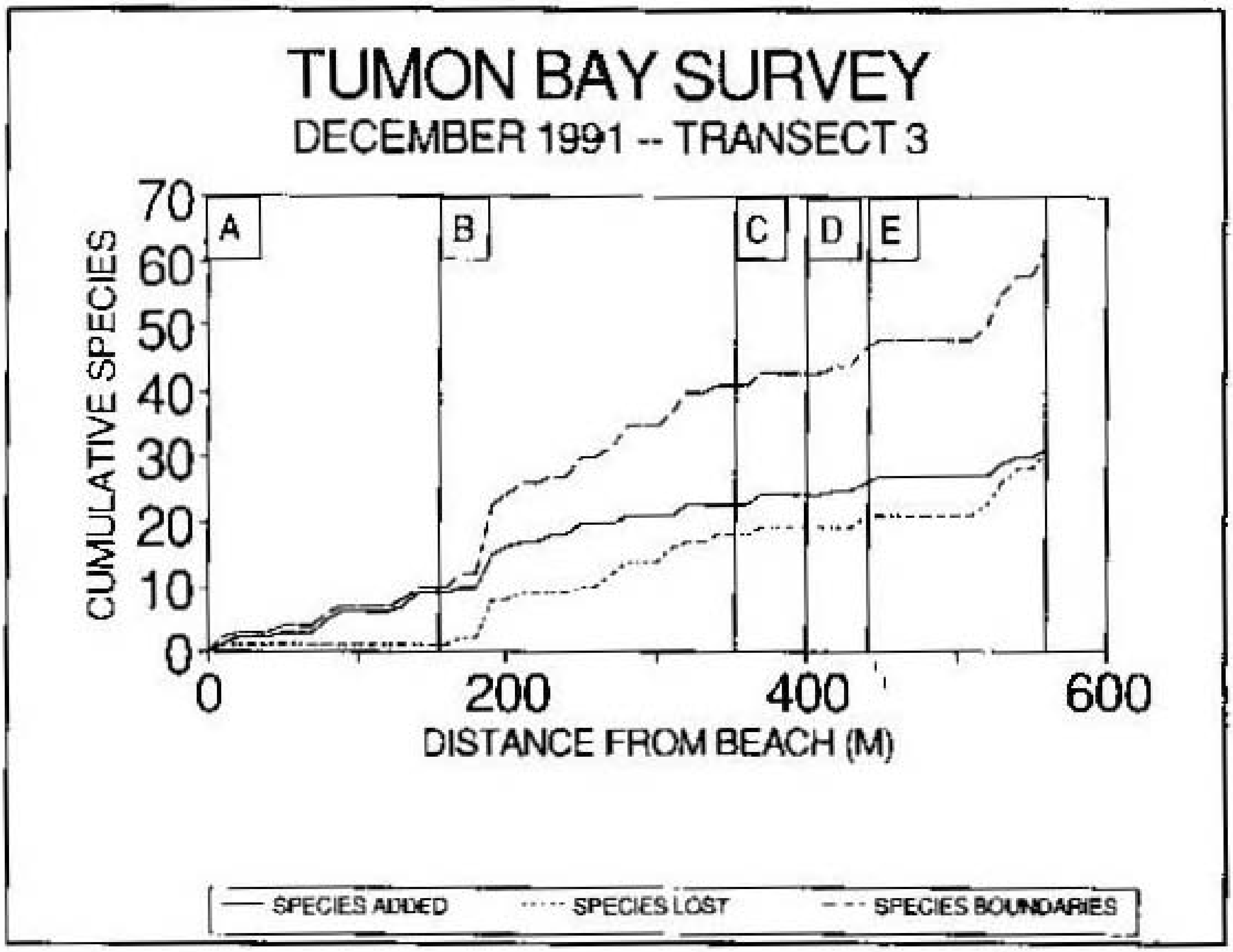

Figure V-6. Patterns of cumulative species boundaries (see text for explanation) along transect 3, December 1991.

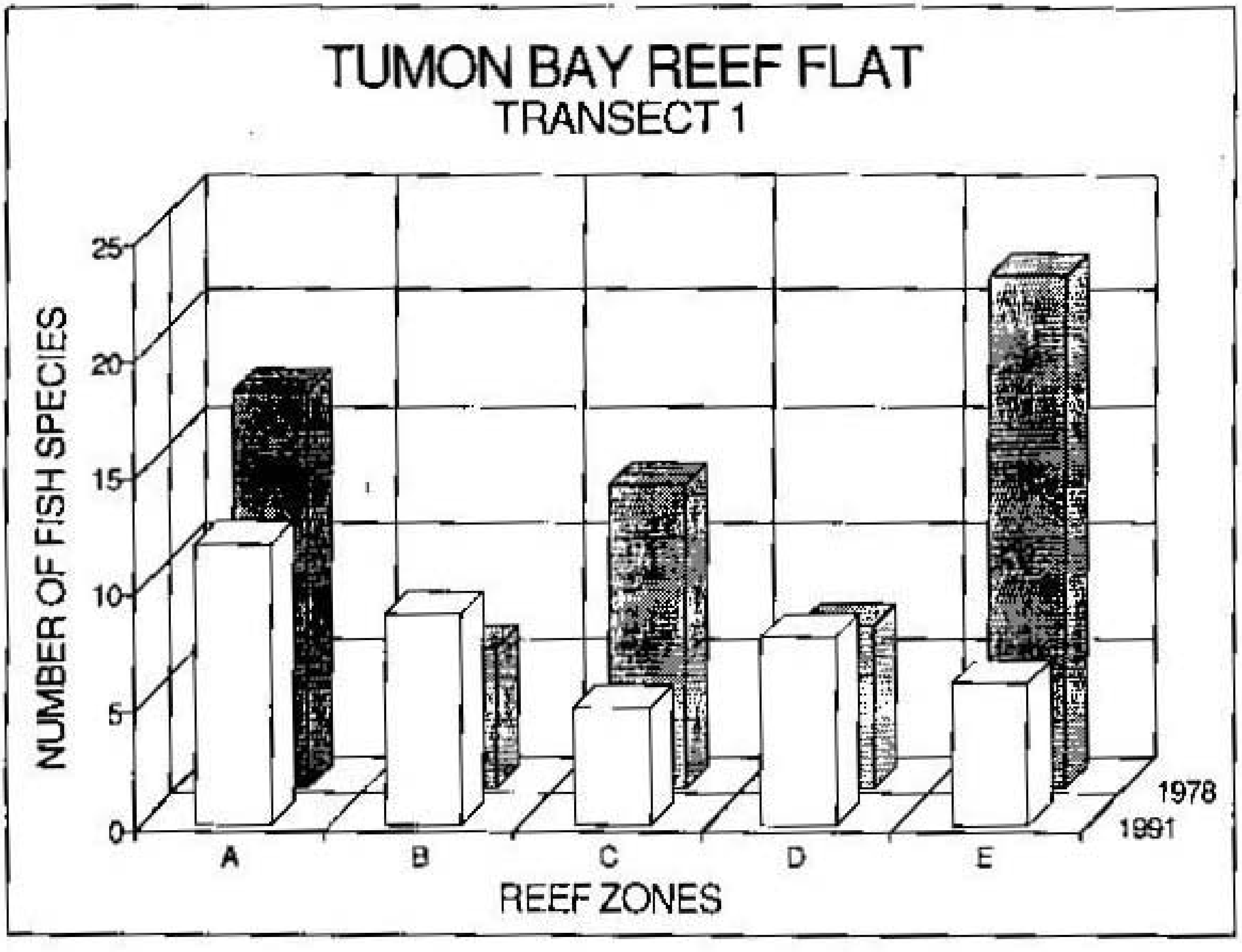

Figure V-7. Fish species richness within reef zones along transect 1 in 1978 and 1991. A = sand zone; B = scattered coral zone; C = coral zone; D = pavement and pool zone; E = pavement zone.

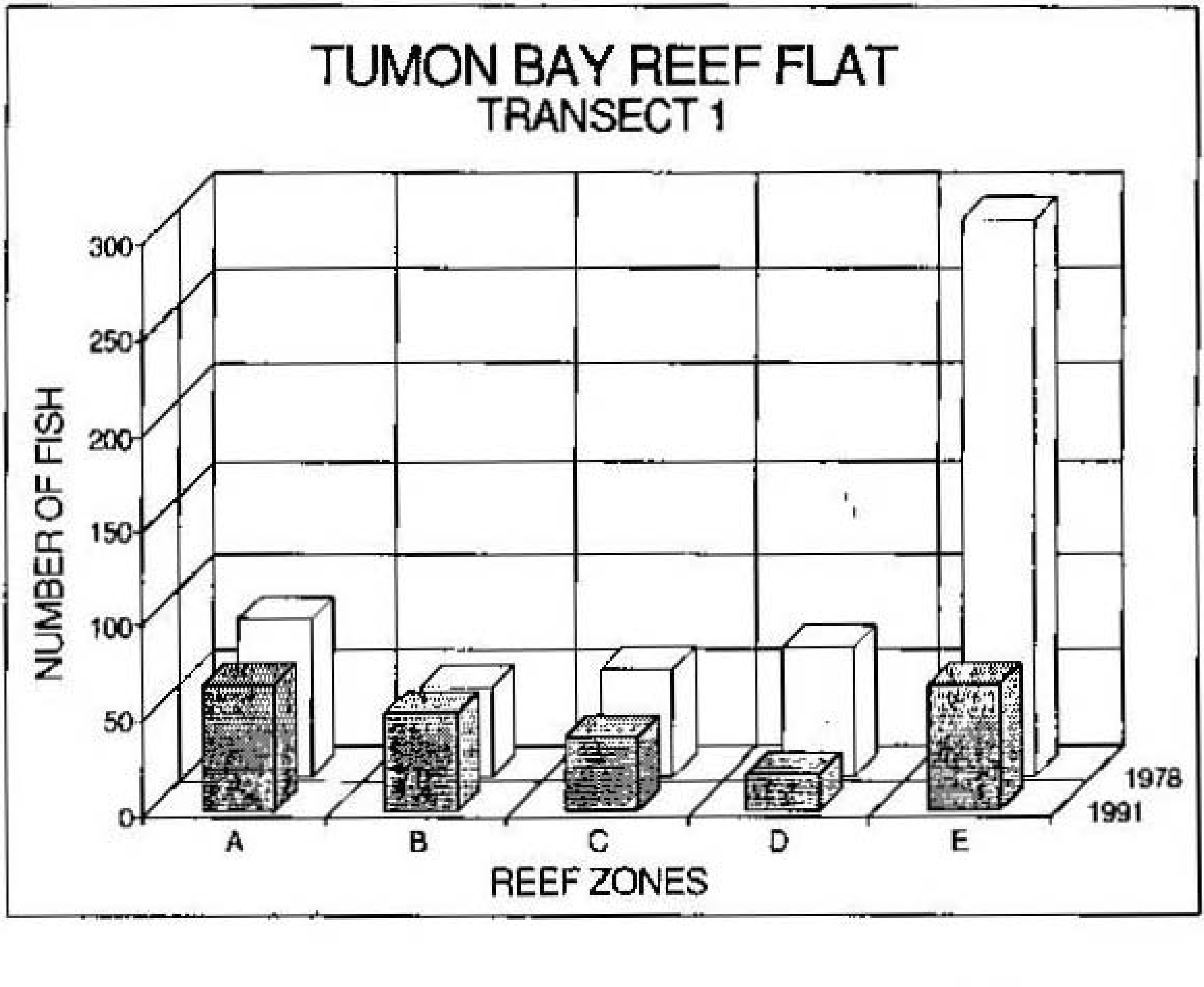

Figure V-8. Fish abundance within reef zones along transect 1 in 1978 and 1991. A = sand zone; B = scattered coral zone; C = coral zone; D = pavement and pool zone; E = pavement zone.

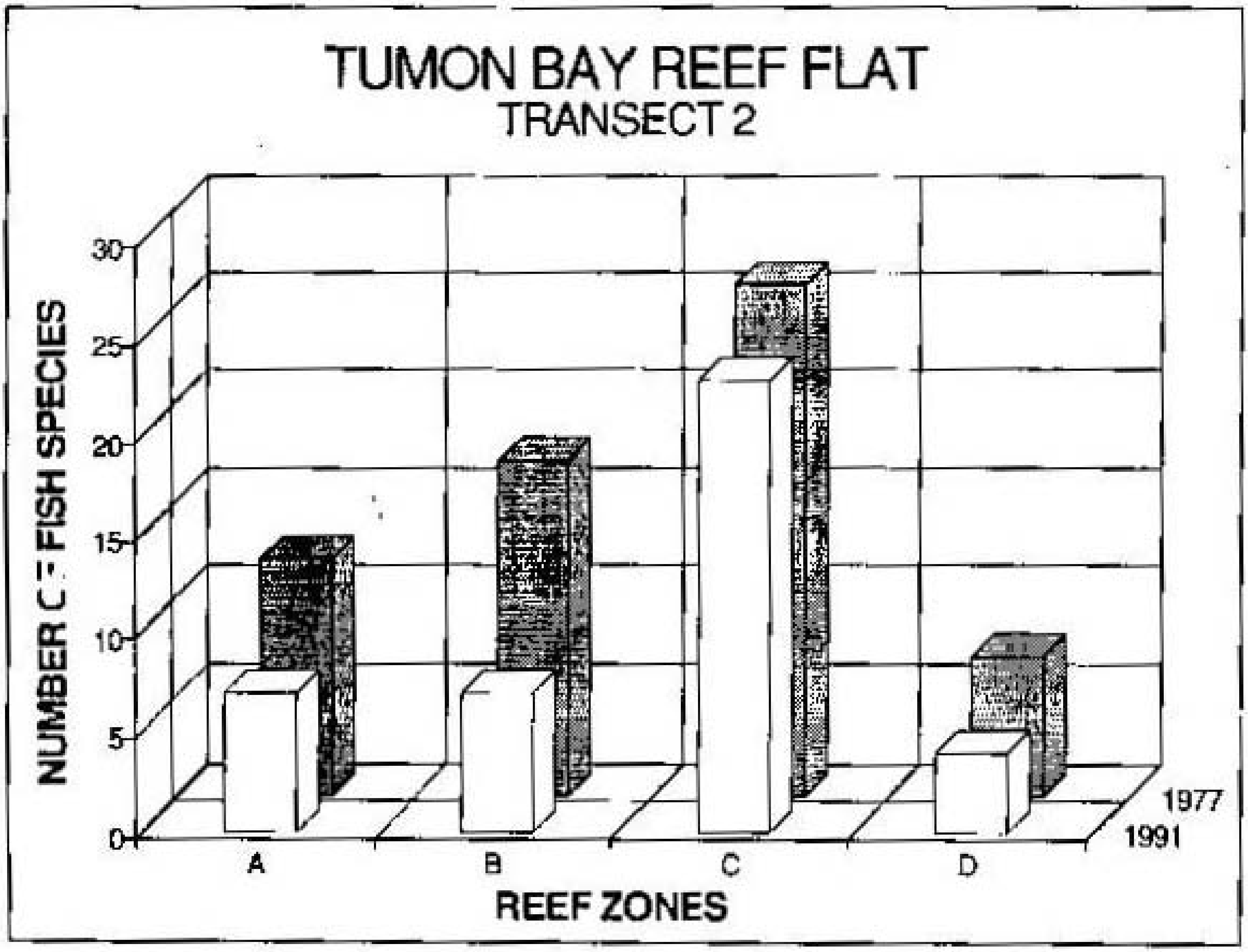

Figure V 9. Fish species richness within reef zones along transect 2 in 1977 and 1991. A = sand zone; B = scattered coral zone; C = coral zone; D = pavement zone.

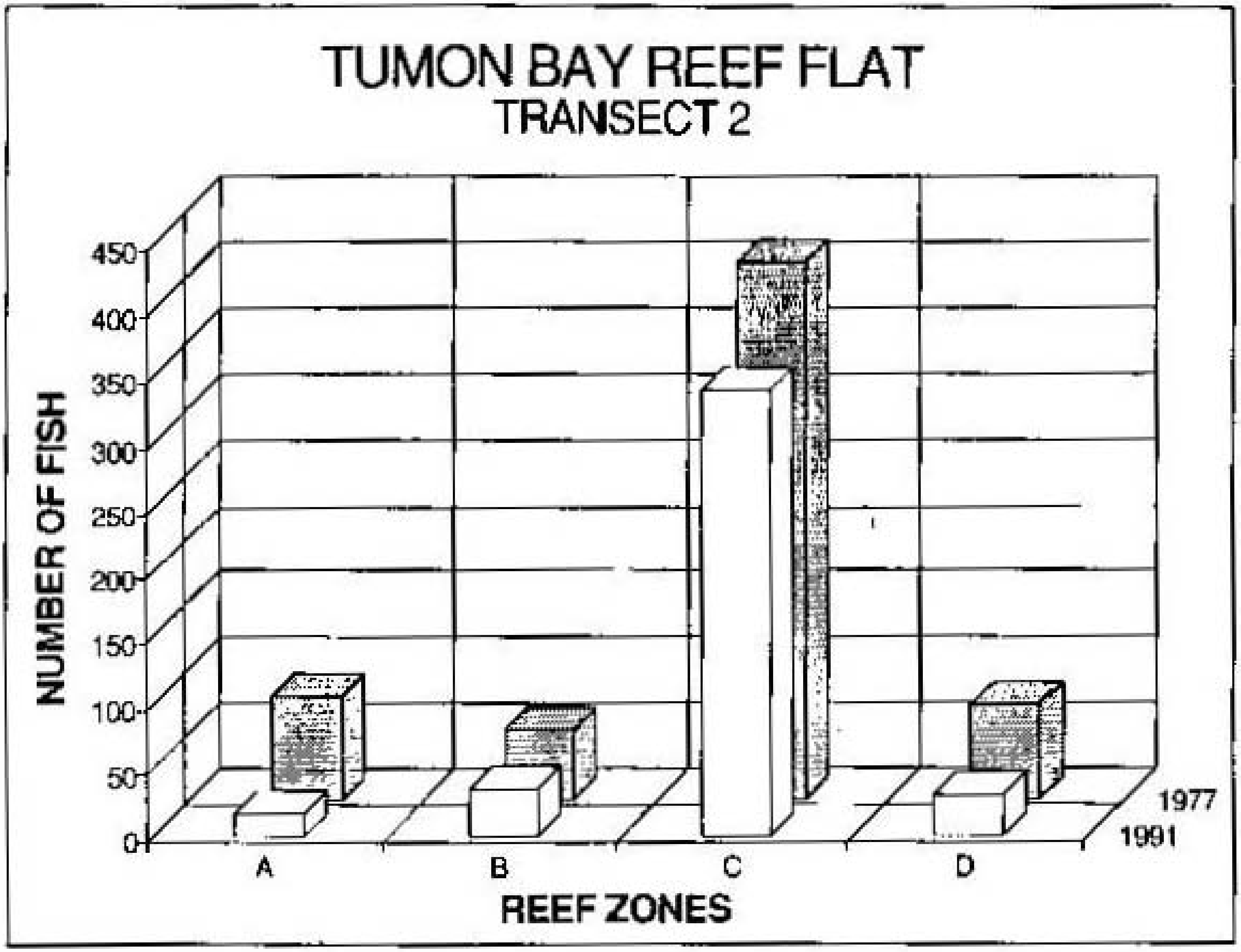

Figure V-10. Fish abundance within reef zones along transect 2 in 1977 and 1991. A = sand zone; B = scattered coral zone; C = coral zone; D = pavement zone.

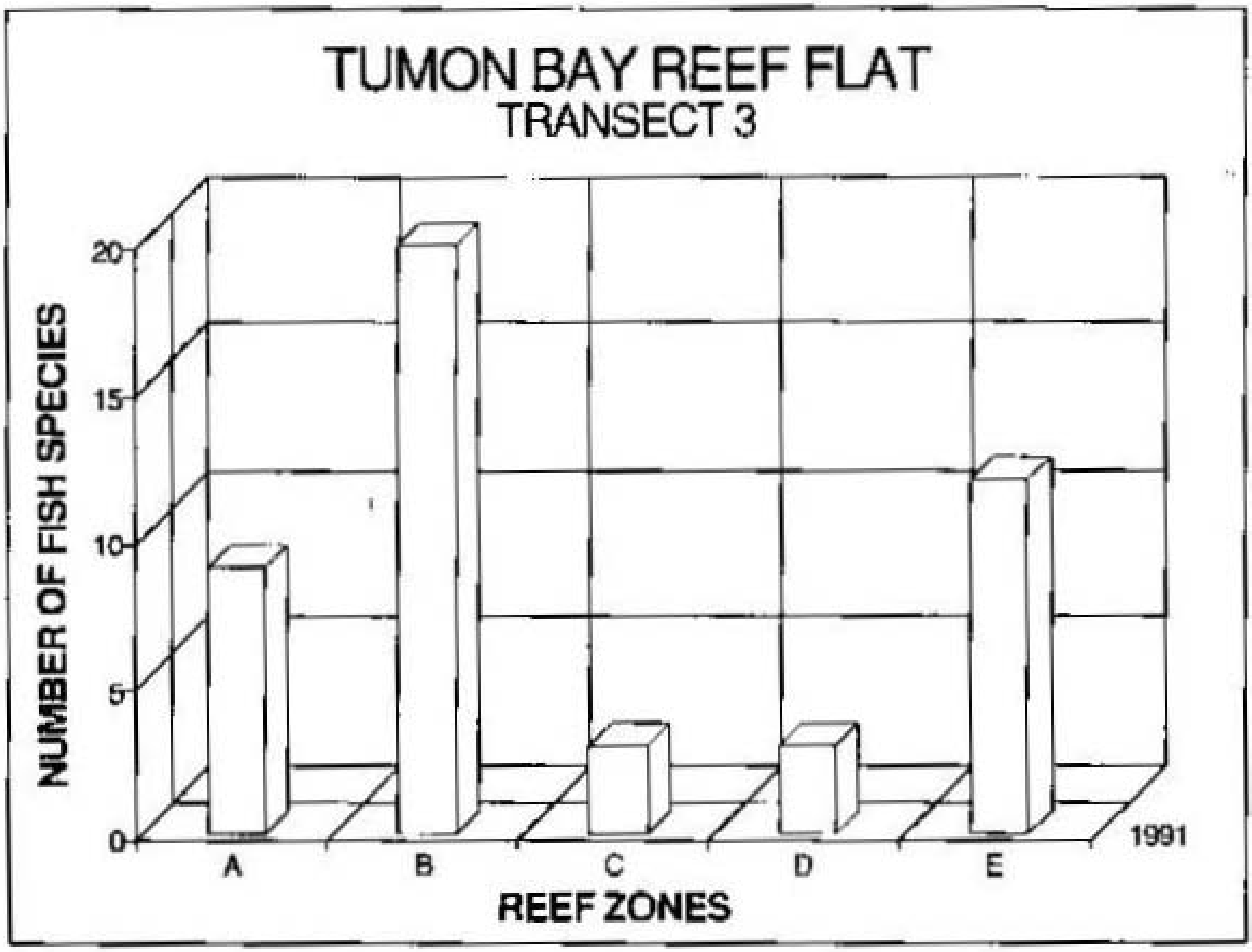

Figure V-11. Fish species richness within reef zones along transect 3 in 1991. A – sand zone; B = scattered coral zone; C = coral zone; D = pavement and pool zone; E = pavement zone.

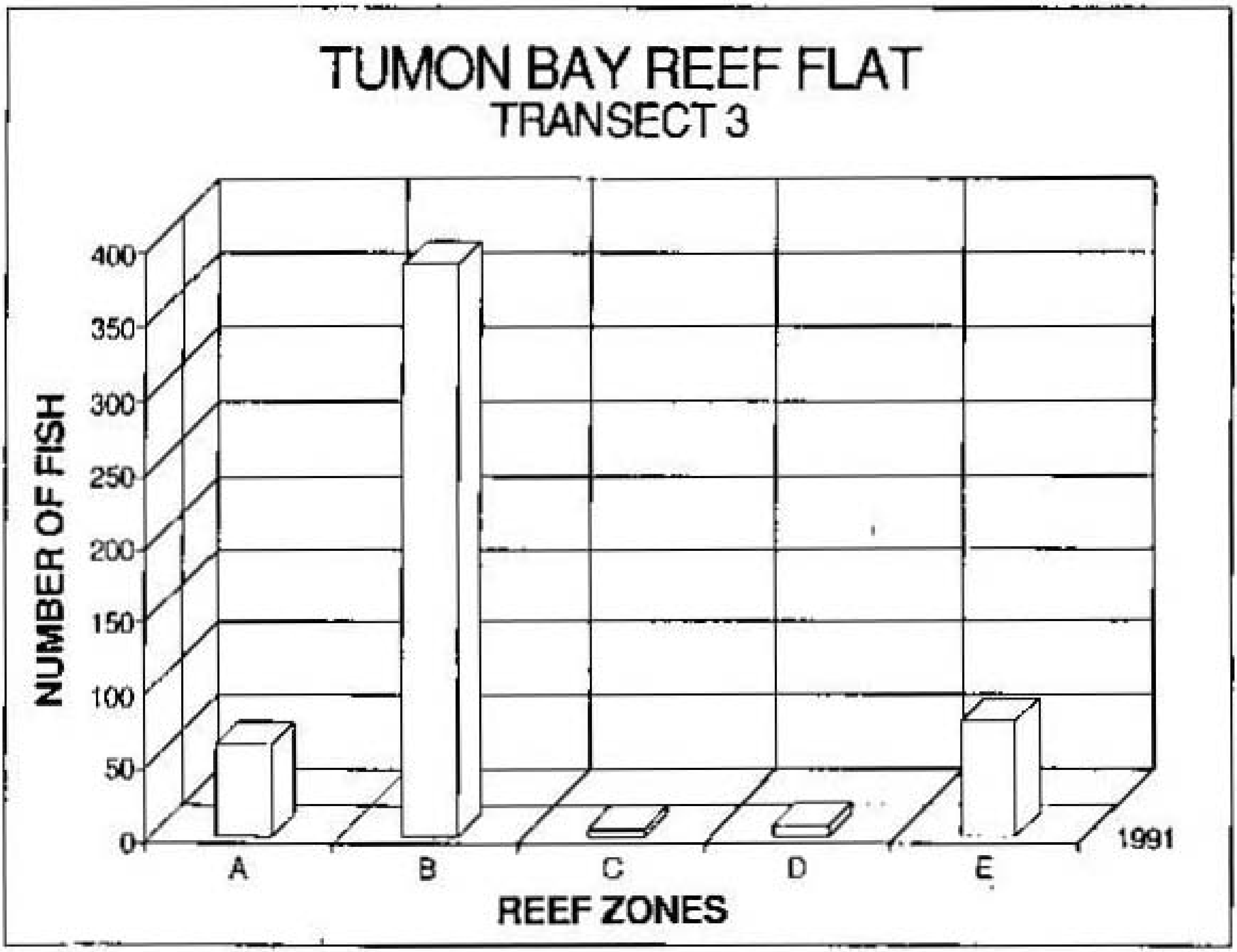

Figure V-12. Fish abundance within reef zones along transect 3 in 1991. A = sand zone; B = scattered coral zone; C = coral zone; D = pavement and pool zone; E = pavement zone.

VI. CONCLUSIONS

PRESENT STATE OF BIOLOGICAL COMMUNITIES

The reef flat habitats within Tumon Bay contain a relatively rich assemblage of marine species. The surveys conducted in December 1991 revealed the presence of 38 species of marine plants, 73 species of corals, 19 species of echinoderms and 5 species of conspicuous mollusks, and 46 species of fish along the three transects studied.

Five reef-flat zones were identified on the basis of depth, dominant substratum, and topographic characteristics. These zones are aligned parallel to the shoreline and are designated, from the beach out to the reef margin, as follows:

a) sand zone,
b) scattered coral zone,
c) coral zone,
d) pavement and pool zone, and
e) pavement zone.

Distributions of marine animals and plants showed zonal patterns related to this physiographic zonation and also showed strong variations associated with the locations of the transects within the bay. Percent cover of marine plants, for instance, varied more among transects than it did among reef zones (Figure VI-1), while species richness of marine plants had both zone-related and transect-related components to its variation (Figure VI-2).

Coral percent cover is unusually high in a few zones and transects and relatively low at most locations (Figure VI-3). Coral species richness, however seems to be strongly related to zones, with one very diverse area at the outer portion of transect 2 (Figure VI-4).

Macroinvertebrate densities peak in the coral zone on transects 1 and 3 and in the scattered coral zone on transect 2 (Figure VI-5); there is a similar zonal pattern of invertebrate diversity, with generally more species along transect 3 than the other transects (Figure VI-6). Fish abundance and diversity do not show any clearly consistent pattern among transects and zones (Figures VI-7 and VI-8).

Figures VI-9 through VI-14 show patterns of abundance and diversity of the four major biological groups along each of the three transects. These pattern exhibit little consistency among groups or transects.

Figures VI-15 to VI-26 show relationships of abundance and diversity among the four biological groups surveyed. Few clear-cut relationships emerge from these comparisons, except that fish diversity appears to be inversely related to marine plant diversity (Figure VI-23), while invertebrate diversity is positively related to marine plant diversity (Figure VI-22).

COMPARISON WITH 1977/78 SURVEYS

The earlier chapter of this report provide detailed comparisons between the results of the surveys in 1977/78 and those carried out in 1991. The major conclusions of these comparisons are summarized below.

1) The total number of marine plant species observed (excluding coralline algae which were lumped into a single category in 1977) changed little between the two survey periods, 34 species in 1977 and 38 species in 1991.

2) Algal species composition changed over the 14 year interval; of six species considered "dominant" in 1977, only two (the blue-green Schizothrix calcicola and the brown Padina boryana) continued to be considered dominant in 1991. However, six other species, scarce in 1977, were among the dominant marine plant species in 1991.

3) The green alga Enteromorpha clathrata was observed during both the 1977 and the 1991 surveys, but has not become significantly more or less abundant over the years.

4) Coral diversity has changed little over the 1977 to 1991 period; 28 genera and 76 species of corals were observed during the 1977 surveys, while 25 genera and 73 species were observed during the 1991 surveys.

5) Coral colony size has increased somewhat since 1977 in most areas survey, as has coral colony density and percentage of substrate coverage by corals.

6) There was little change in the abundance of invertebrate species between the two survey periods. One species, the common black sea cucumber Holothuria atra, was significantly more abundant in the coral zone along transect 1 in 1991 than it had been in 1977. Other invertebrate species showed minor increases or decreases in abundance over the years, but none of these variations was significant.

7) Fish species richness declined along the two transects censused during both survey periods, but the total number of fish species seen during the 1991 survey (46) was almost the same as the number seen during the 1977/78 surveys (48).

8) During 1977 rabbitfish (Siganus spinus and S. argenteus) juveniles were abundant in Tumon as a result of an earlier strong seasonal "run" of these fish. However, even excluding these fish from consideration, the 1991 surveys indicated overall fish abundances of some 30% less than during the 1977/78 surveys.

Overall, comparison of the two Tumon Bay surveys does not indicate that significant changes in the biological communities on the reef flats have occurred, with the possible exception of the approximately 30% decline in fish abundance. Such changes as have taken place cannot clearly be attributable to impacts of hotel construction and tourism development, but may also be influenced by typhoons, the crown of thorns starfish, and unpredictable variations in larval recruitment.

The continued ecological viability of reef communities within Tumon Bay is of importance to Guam for maintaining an attractive focus of tourist activities and for the preservation of an important area for recreational and subsistence activities of the local residents. The present study indicates that the marine biota on the Tumon Bay reef flats has not changed significantly over the past 14 years despite significant growth in tourism and hotel construction centering on the Tumon area. This is not to say, however, that Tumon Bay is immune from ecological degradation, and continuing efforts should be made to maintain the beauty and environmental quality of this area in order that it will remain an attraction for Guam's tourism industry. It would be valuable to continue the biological monitoring of the bay as the increasing rate of development of the Tumon area (see Figure 1-1) makes it possible that larger impacts could occur over shorter periods of time than has previously been the case.

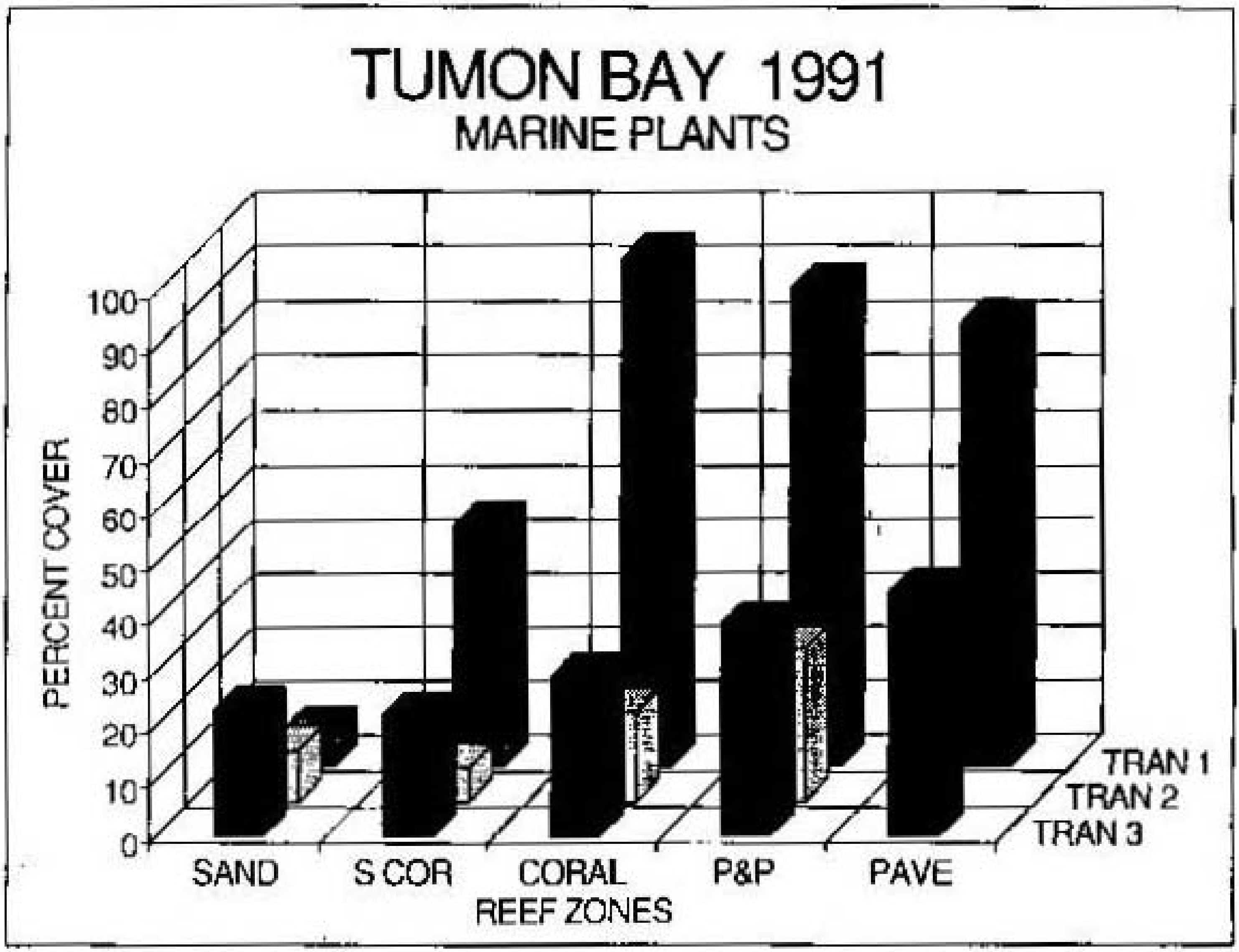

Figure VI-1. Percent of substrate covered by marine plants in reef-flat habitats along three transects in Tumon Bay, 1991.

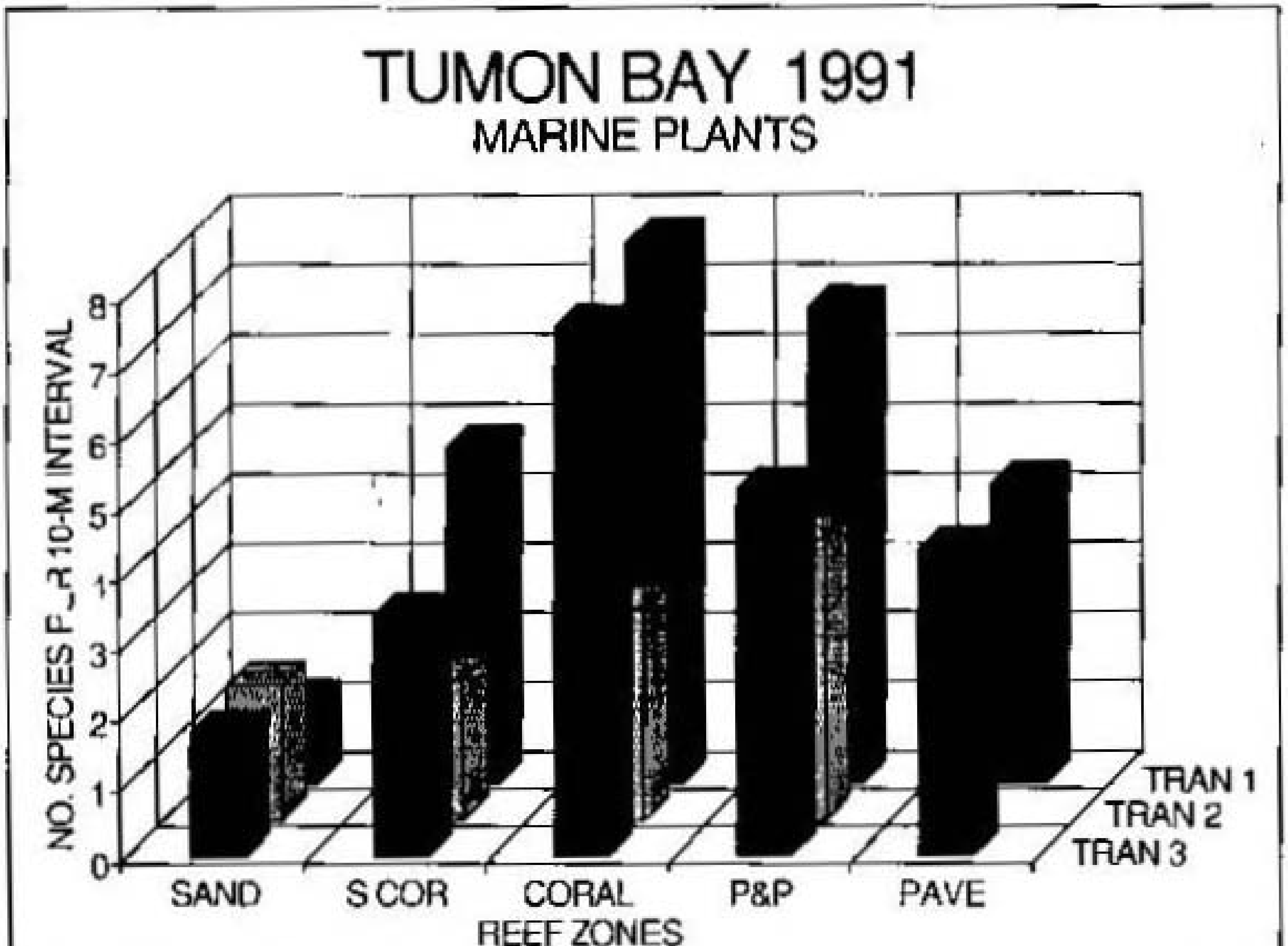

Figure VI-2. Mean number of marine plant species per 10-m interval in reef flat habitats along three transects in Tumon Bay, 1991.

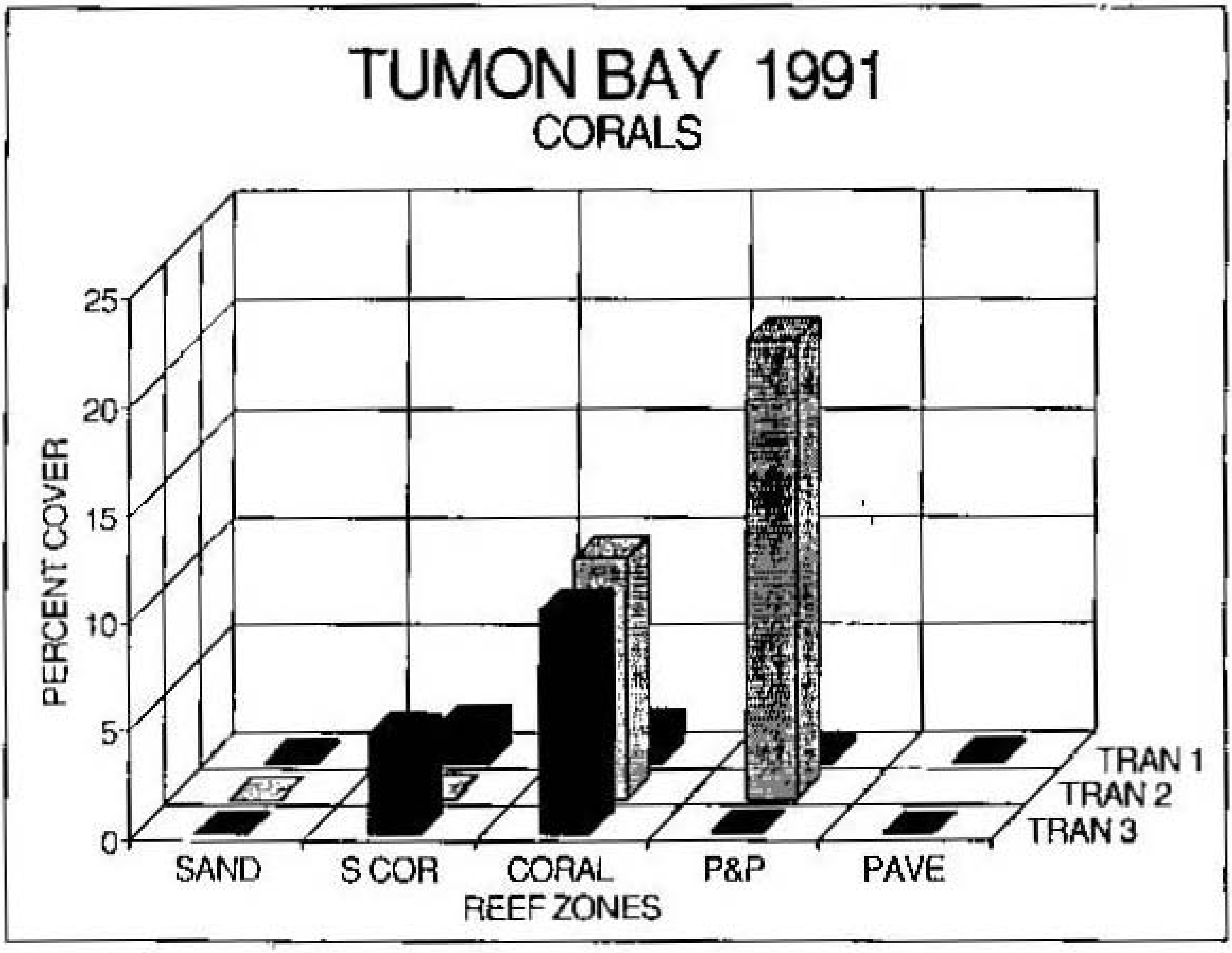

Figure VI-3. Percent of substrate covered by coral in reef flat habitats along three transects in Tumon Bay, 1991.

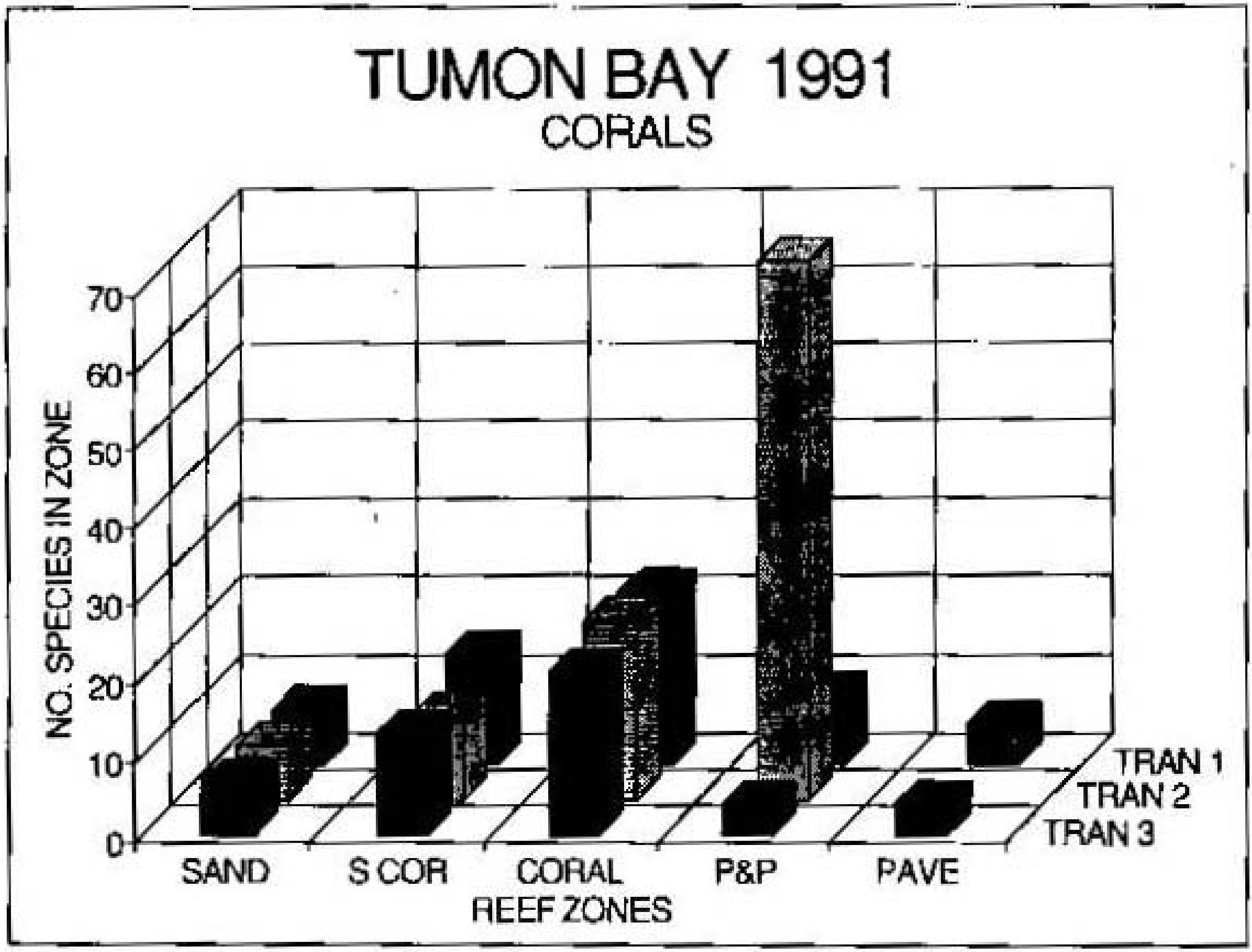

Figure VI-4. Number of coral species recorded in reef-flat habitats along three transects in Tumon Bay, 1991.

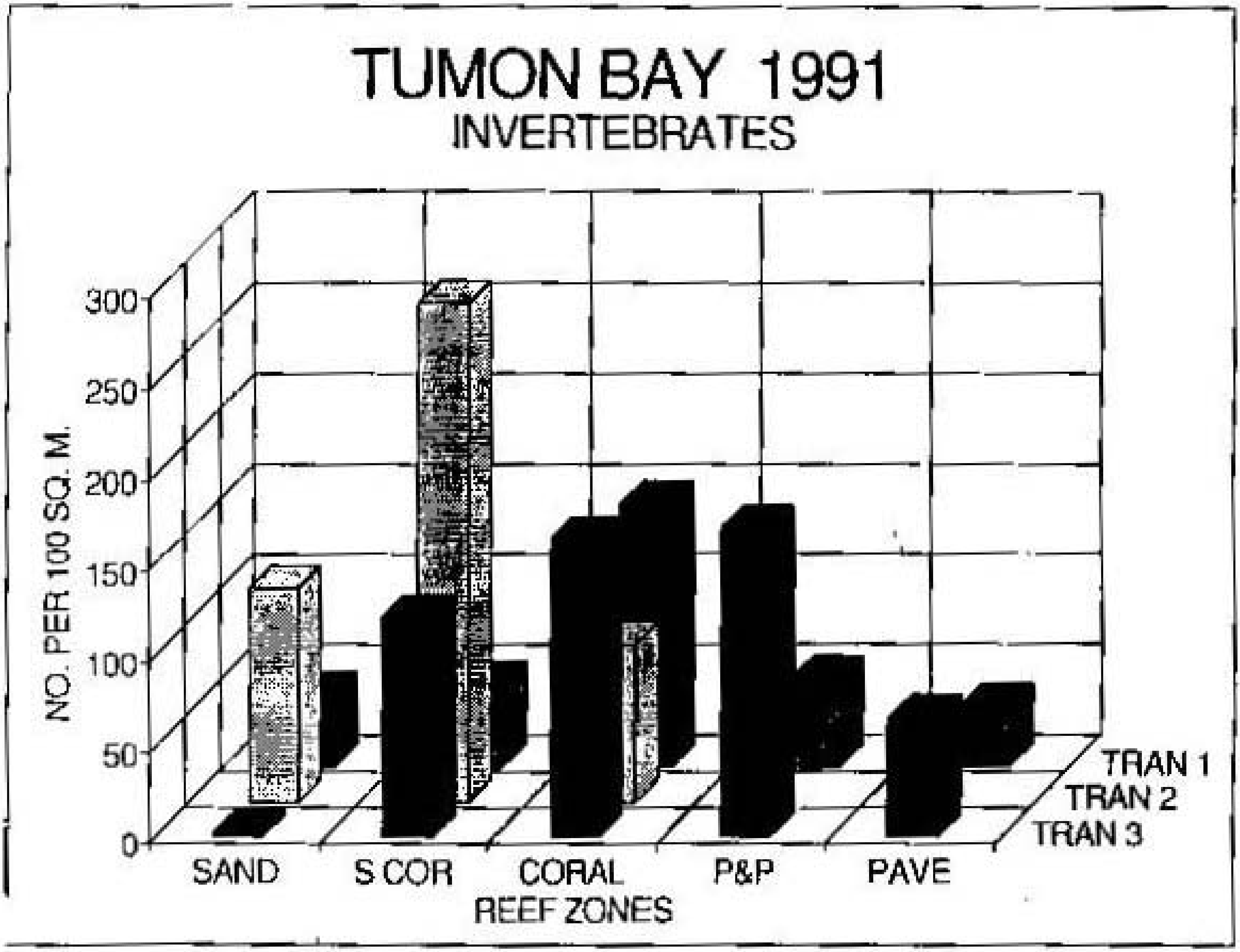

Figure VI-5. Macroinvertebrate density in reef-flat habitats along three transects in Tumon Bay, 1991.

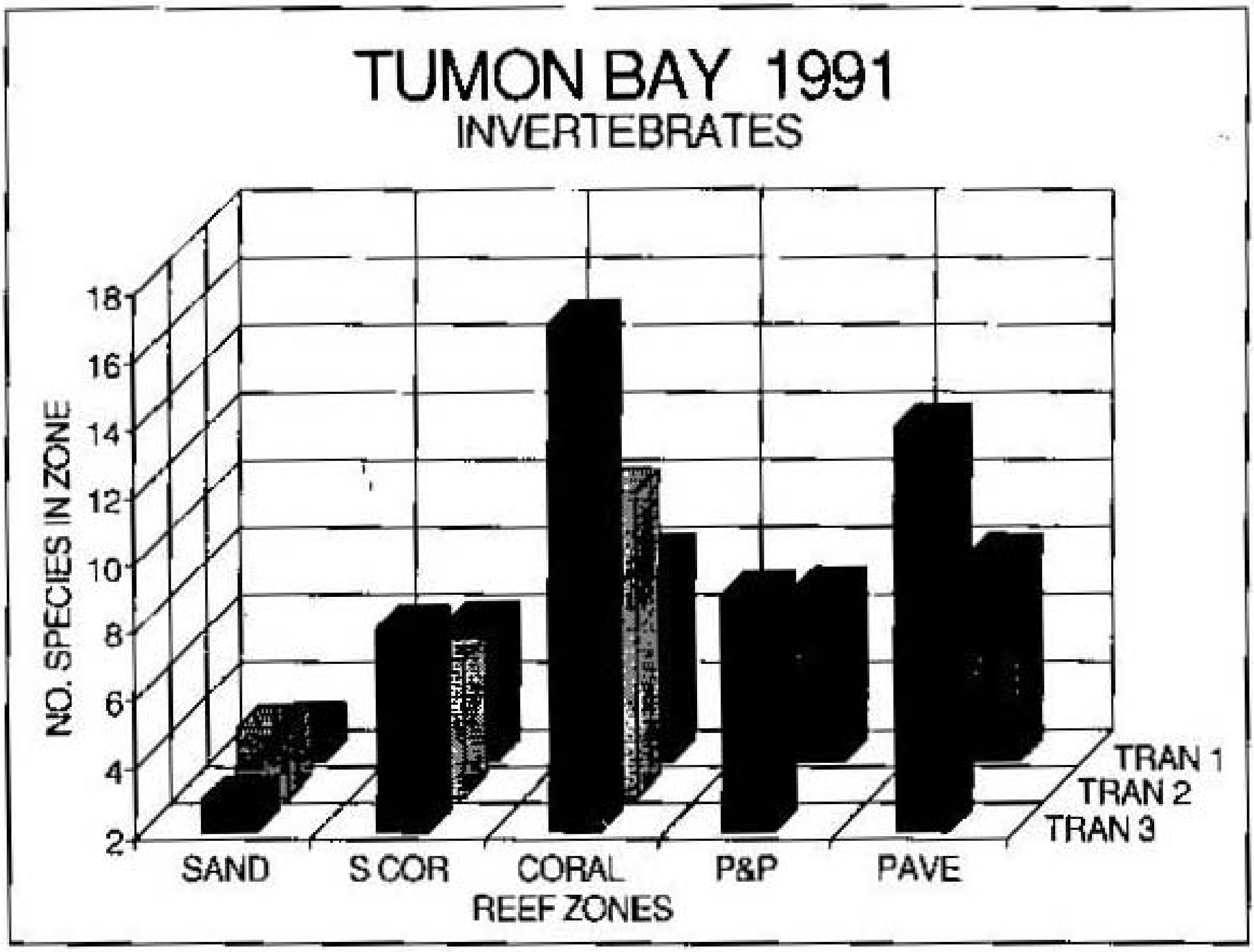

Figure VI-6. Number of macroinvertebrate species recorded in reef-flat habitats along three transects in Tumon Bay, 1991.

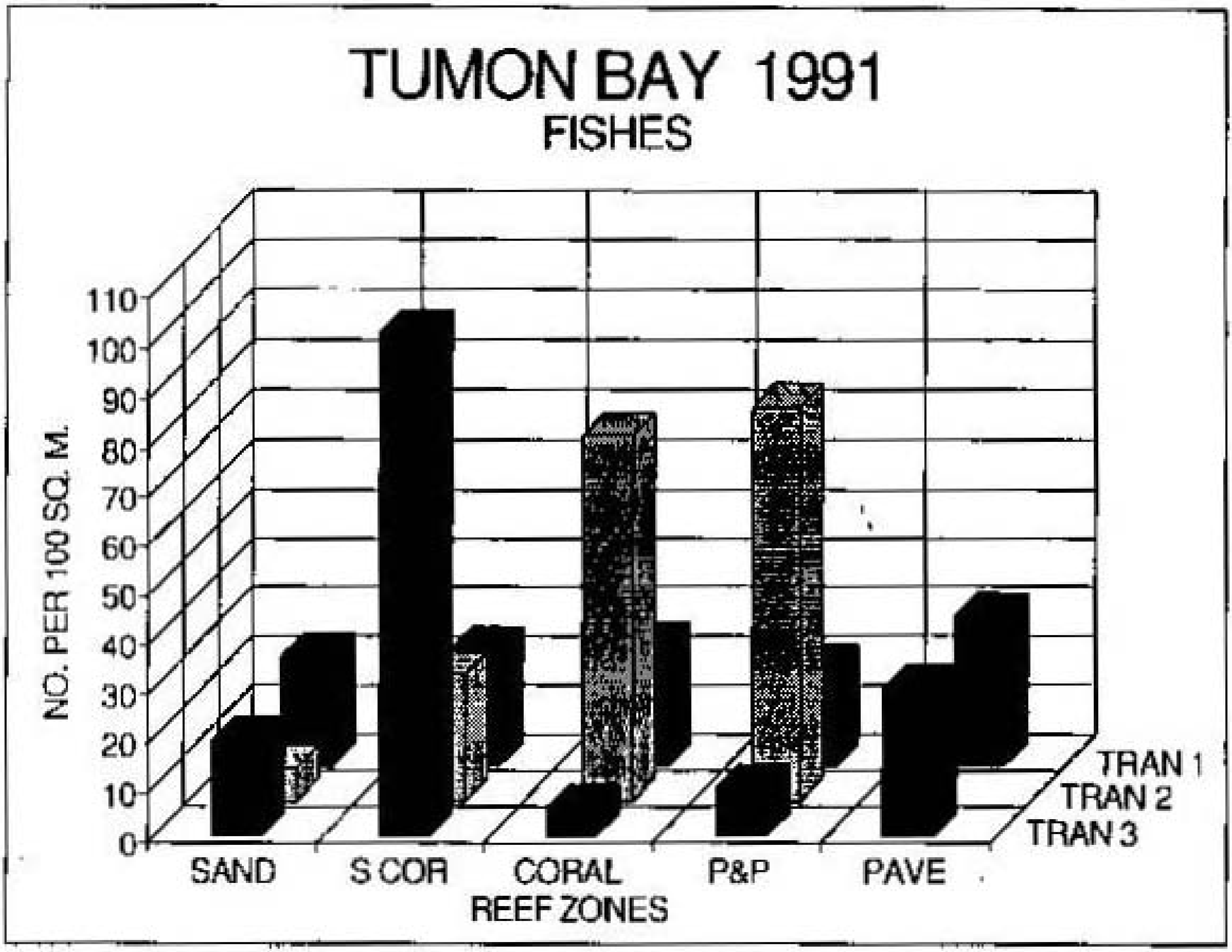

Figure VI-7. Fish density in reef-flat habitats along three transects in Tumon Bay, 1991.

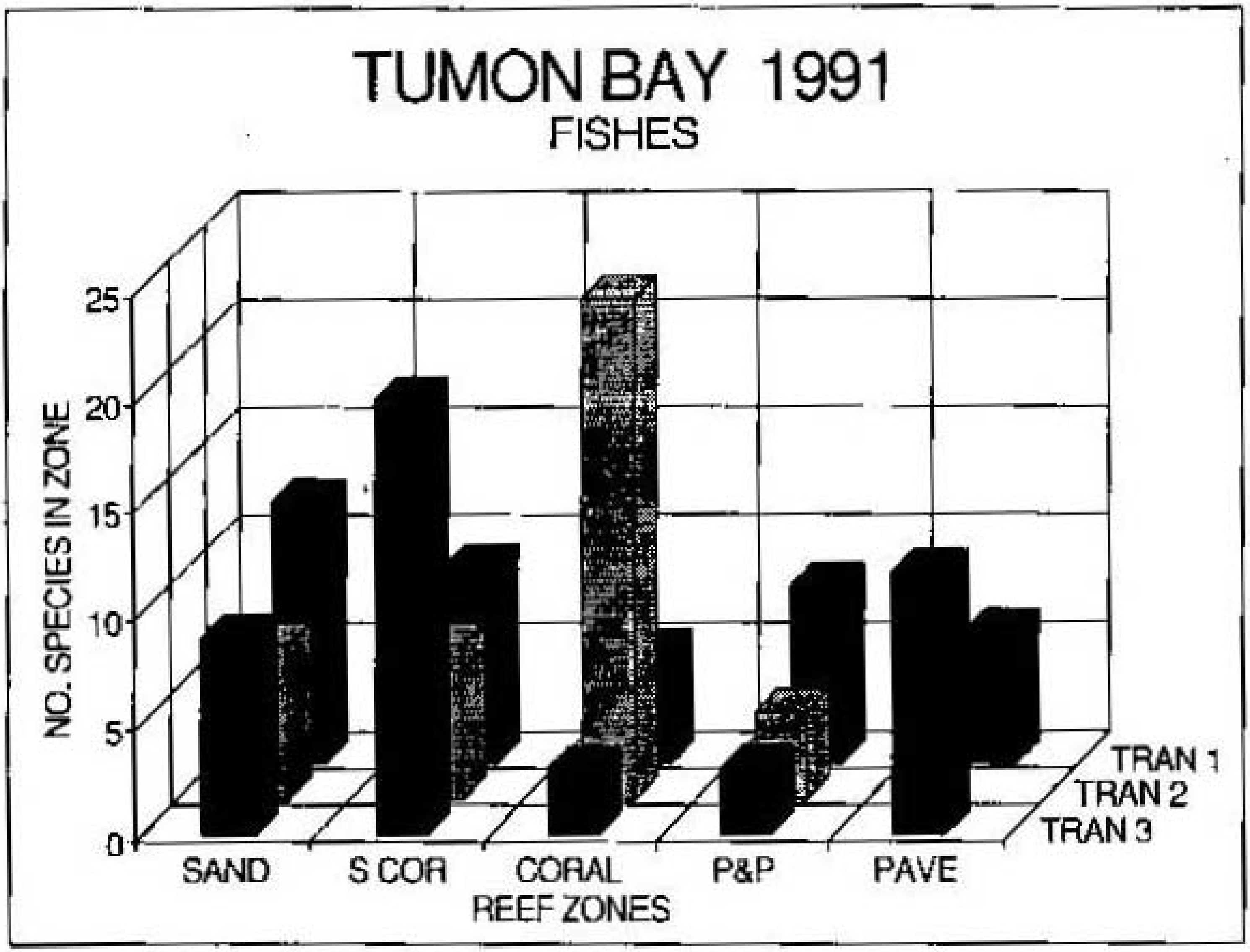

Figure VI.8. Number of fish species recorded in reef-flat habitats along three transects in Tumon Bay, 1991.

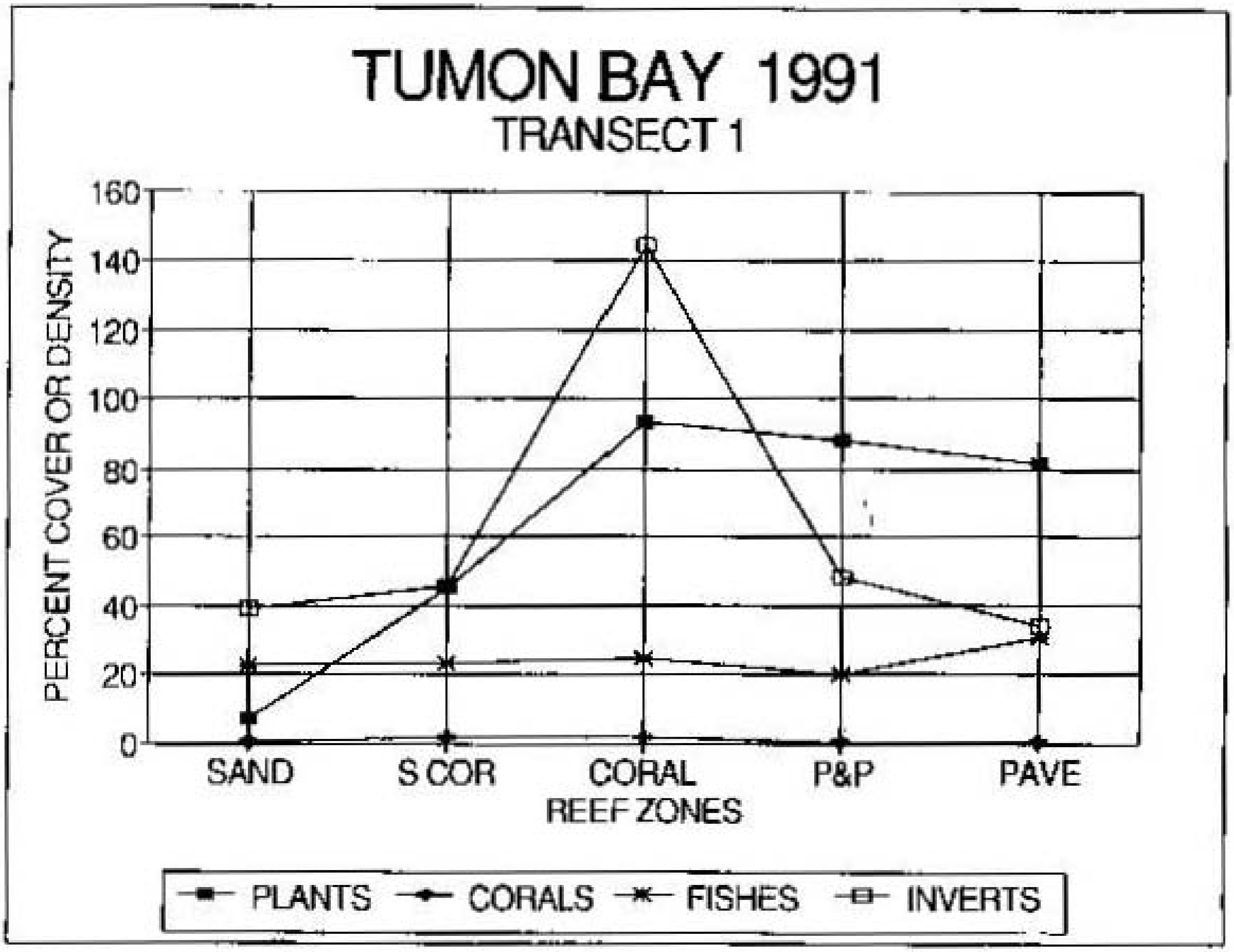

Figure VI-9. Percent cover of marine plants and corals and density (no. per 100 m^2) of macroinvertebrates and fishes in reef-flat habitats along Transect 1 in Tumon Bay, 1991.

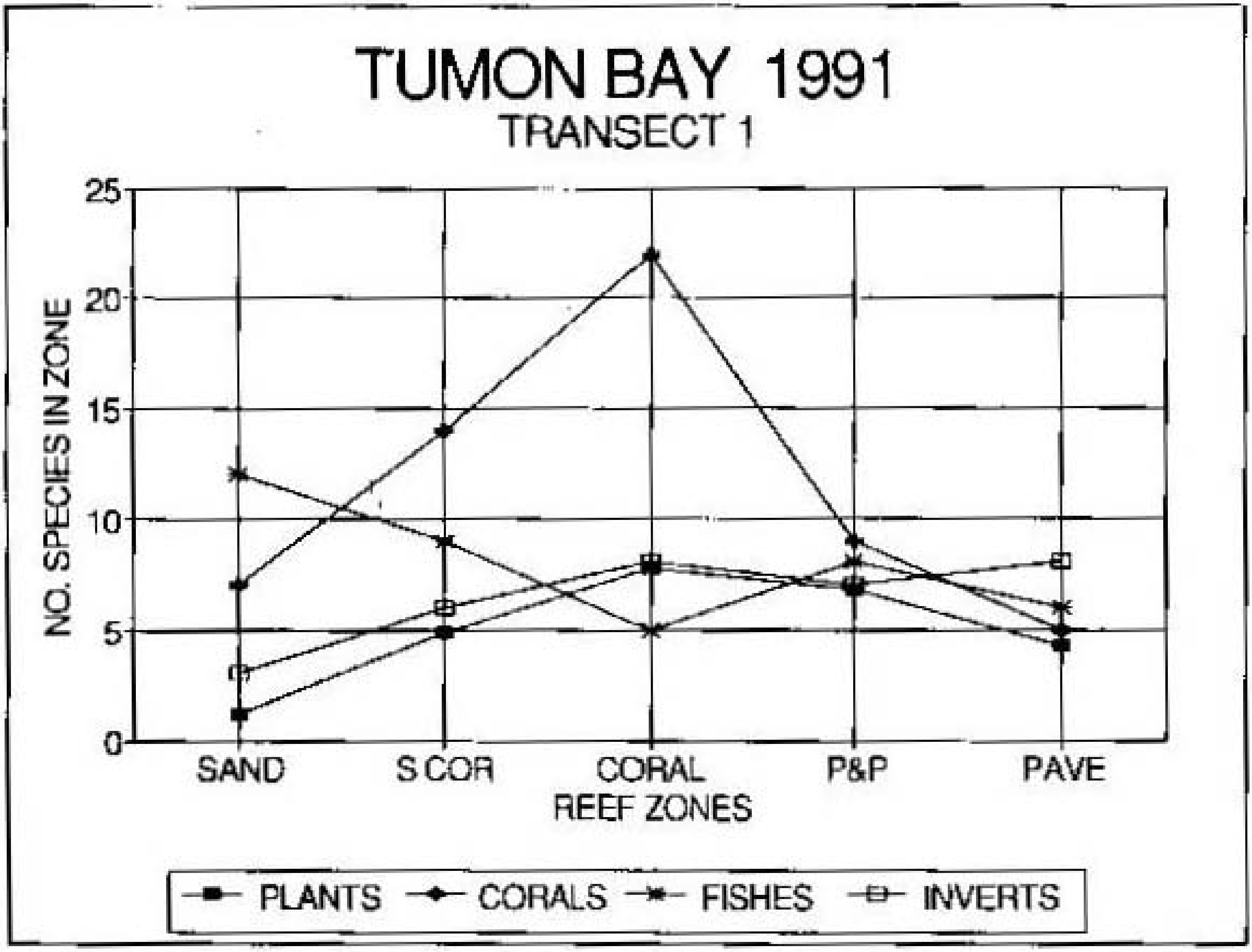

Figure VI-10. Number of species of corals, macroinvertebrates, and fishes and mean number of species per 10-m interval in reef-flat habitats along Transect 1 in Tumon Bay, 1991.

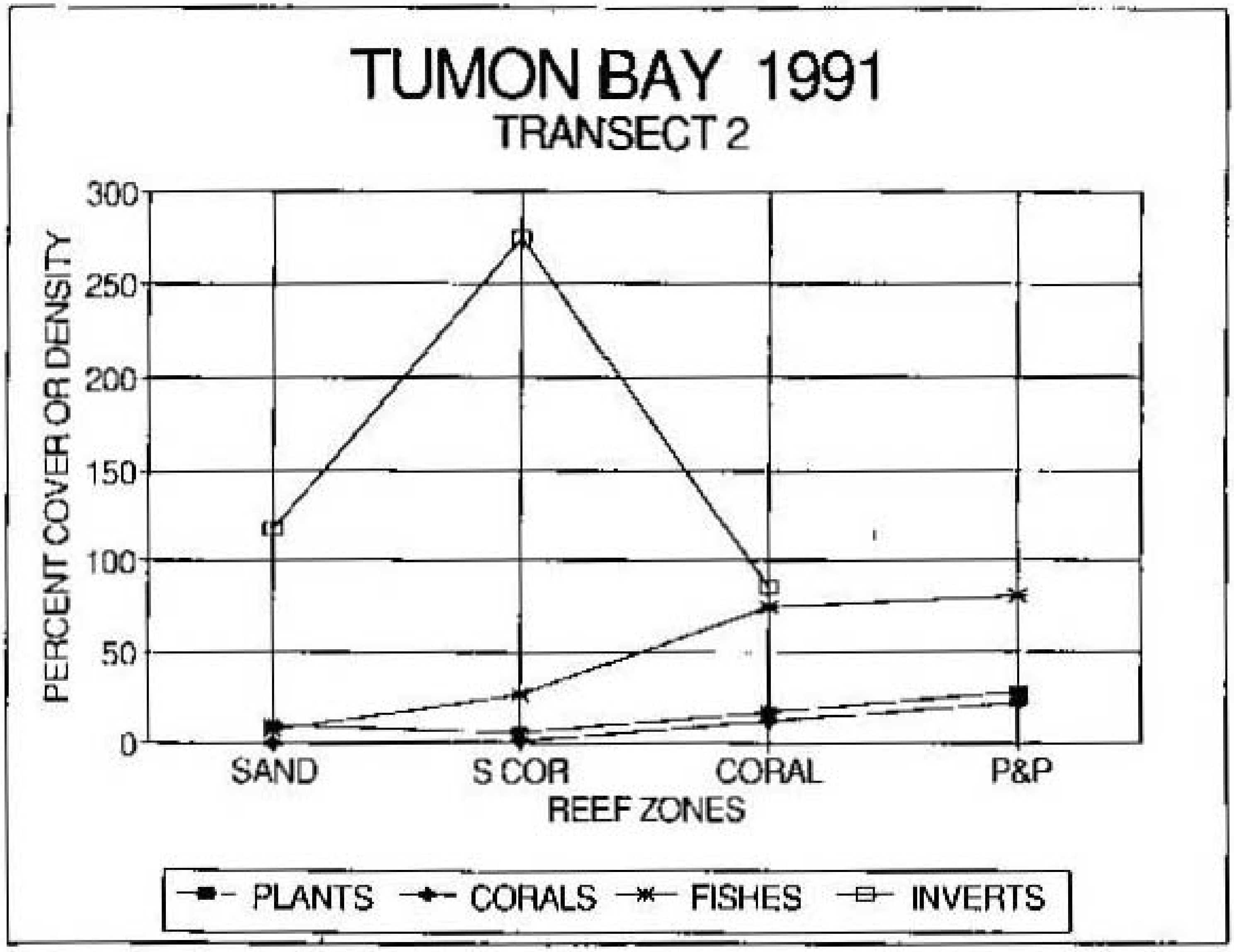

Figure VI-11. Percent cover of marine plants and corals and density (no. per 100 m^2) of macroinvertebrates and fishes in reef-flat habitats along Transect 2 in Tumon Bay, 1991.

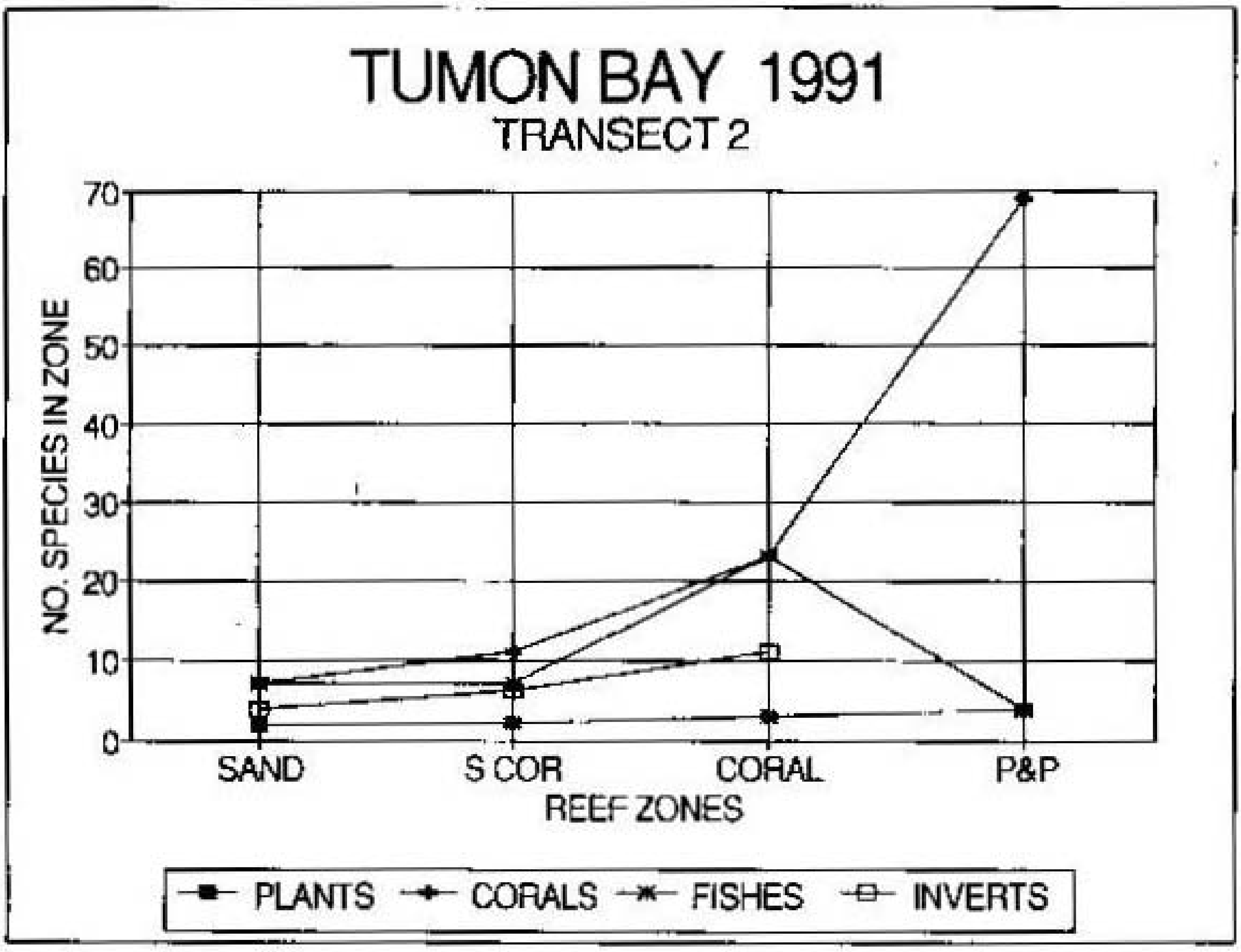

Figure VI-12. Number of species of corals, macroinvertebrates, and fishes and mean number of species per 10-m interval in reef-flat habitats along Transect 2 in Tumon Bay, 1991.

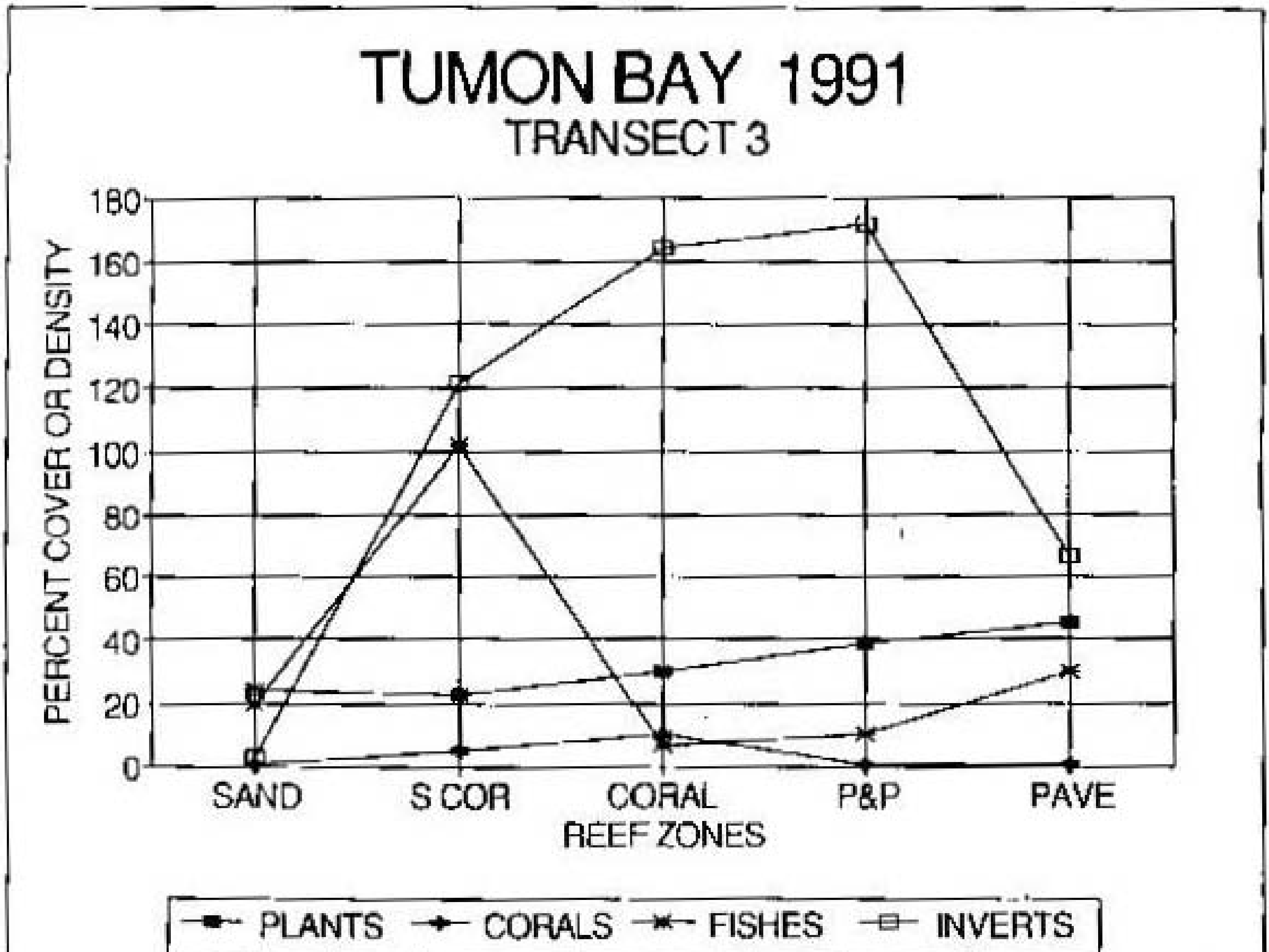

Figure VI-13. Percent cover of marine plants and corals and density (no. per 100 m²) of macroinvertebrates and fishes in reef flat habitats along Transect 3 in Tumon Bay, 1991.

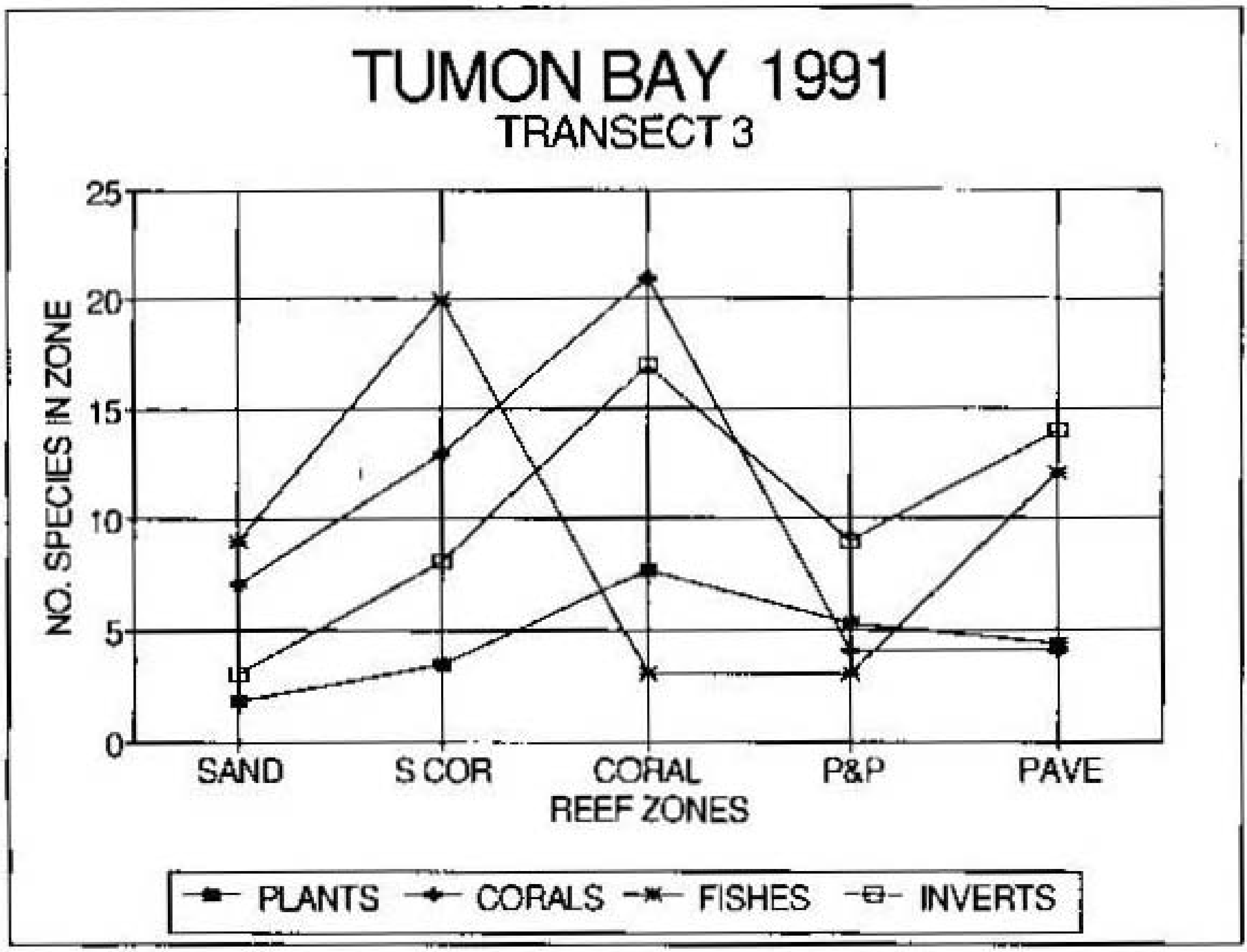

Figure VI-14. Number of species of corals, macroinvertebrates, and fishes and mean number of species per 10 m interval in reef-flat habitats along Transect 3 in Tumon Bay, 1991.

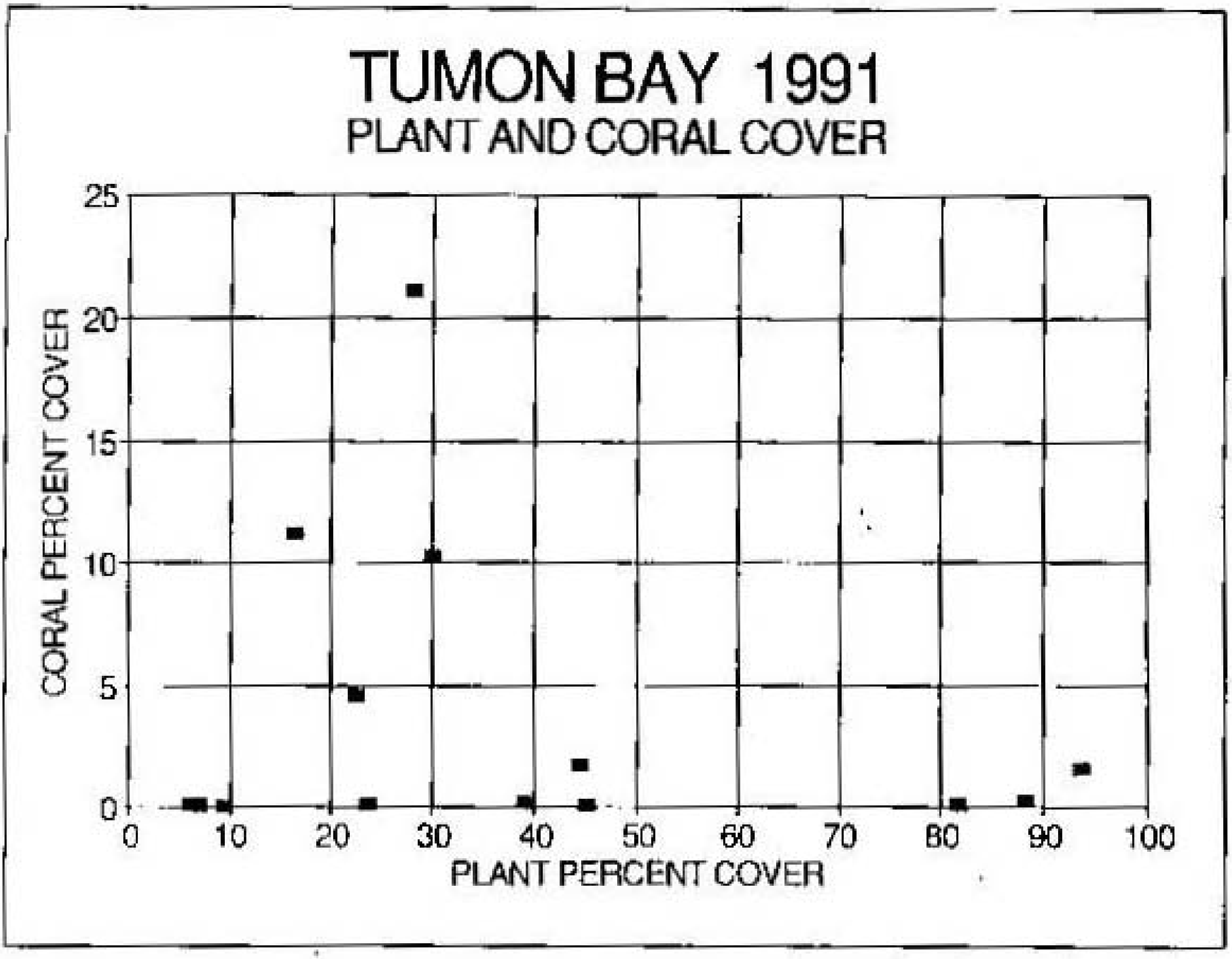

Figure VI-15. Relationship between percent cover of coral and marine plants among reef flat habitats in Tumon Bay, 1991.

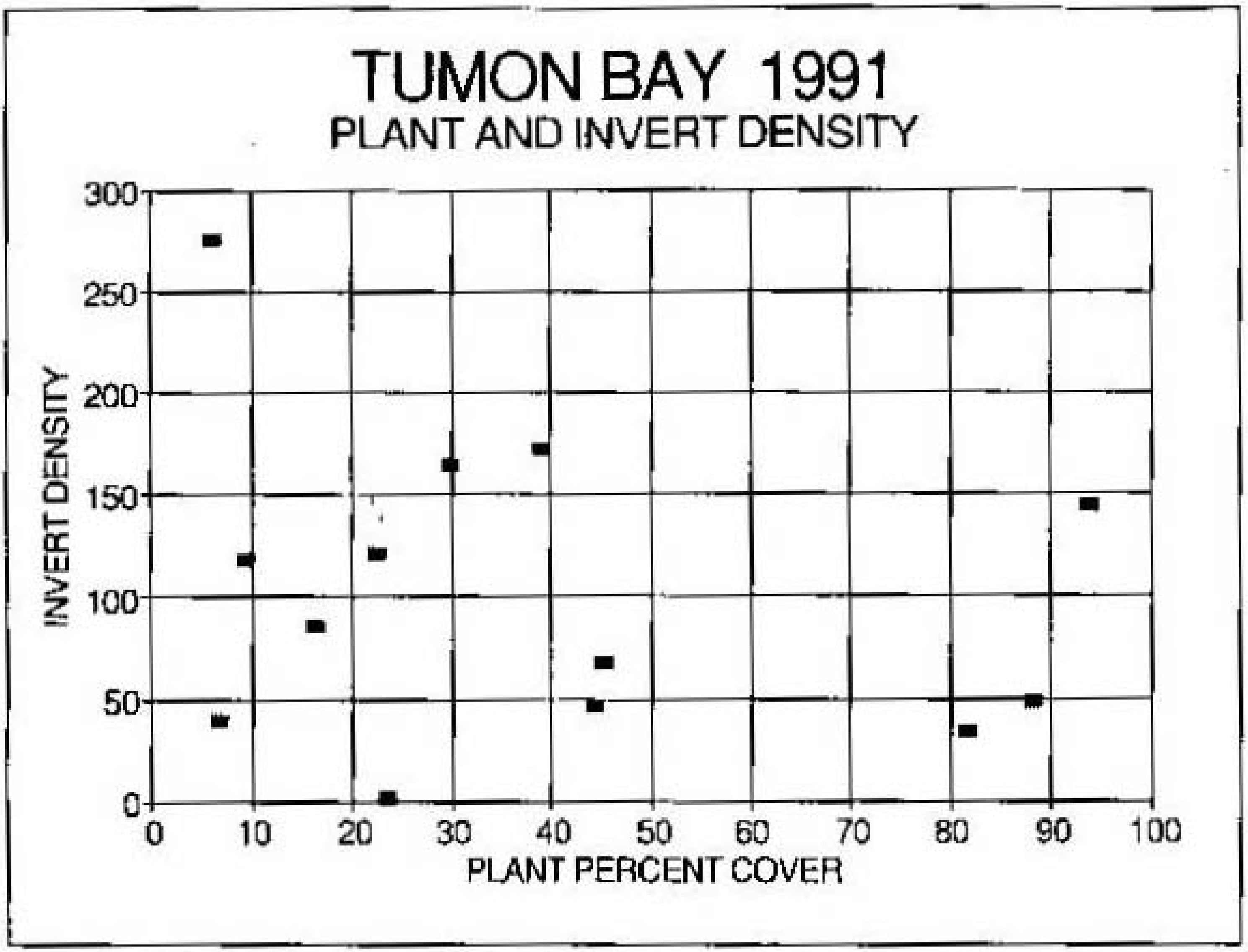

Figure VI 16. Relationship between percent cover of marine plants and invertebrate density among reef-flat habitats in Tumon Bay, 1991.

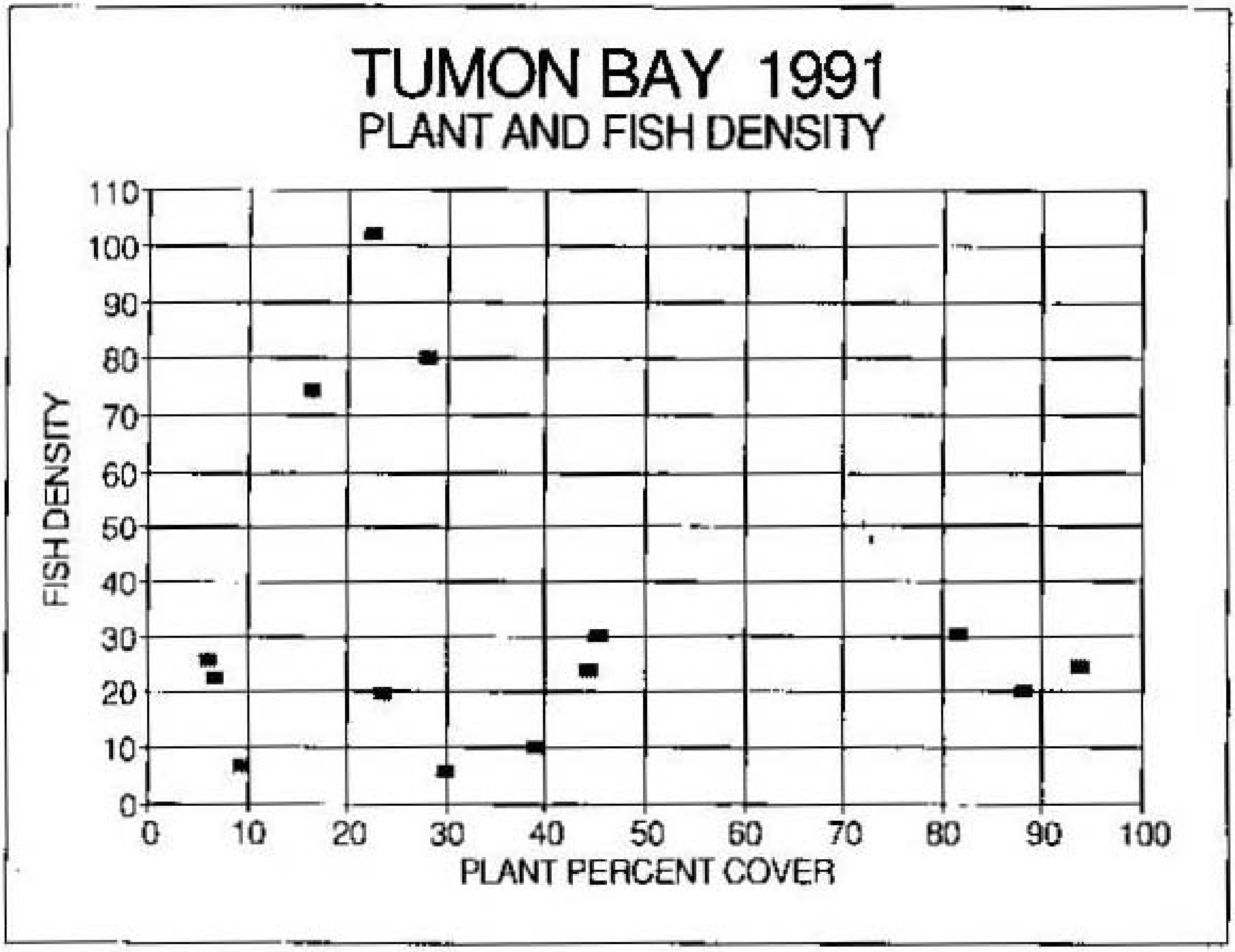

Figure VI-17. Relationship between percent cover of marine plants and fish density among reef-flat habitats in Tumon Bay, 1991.

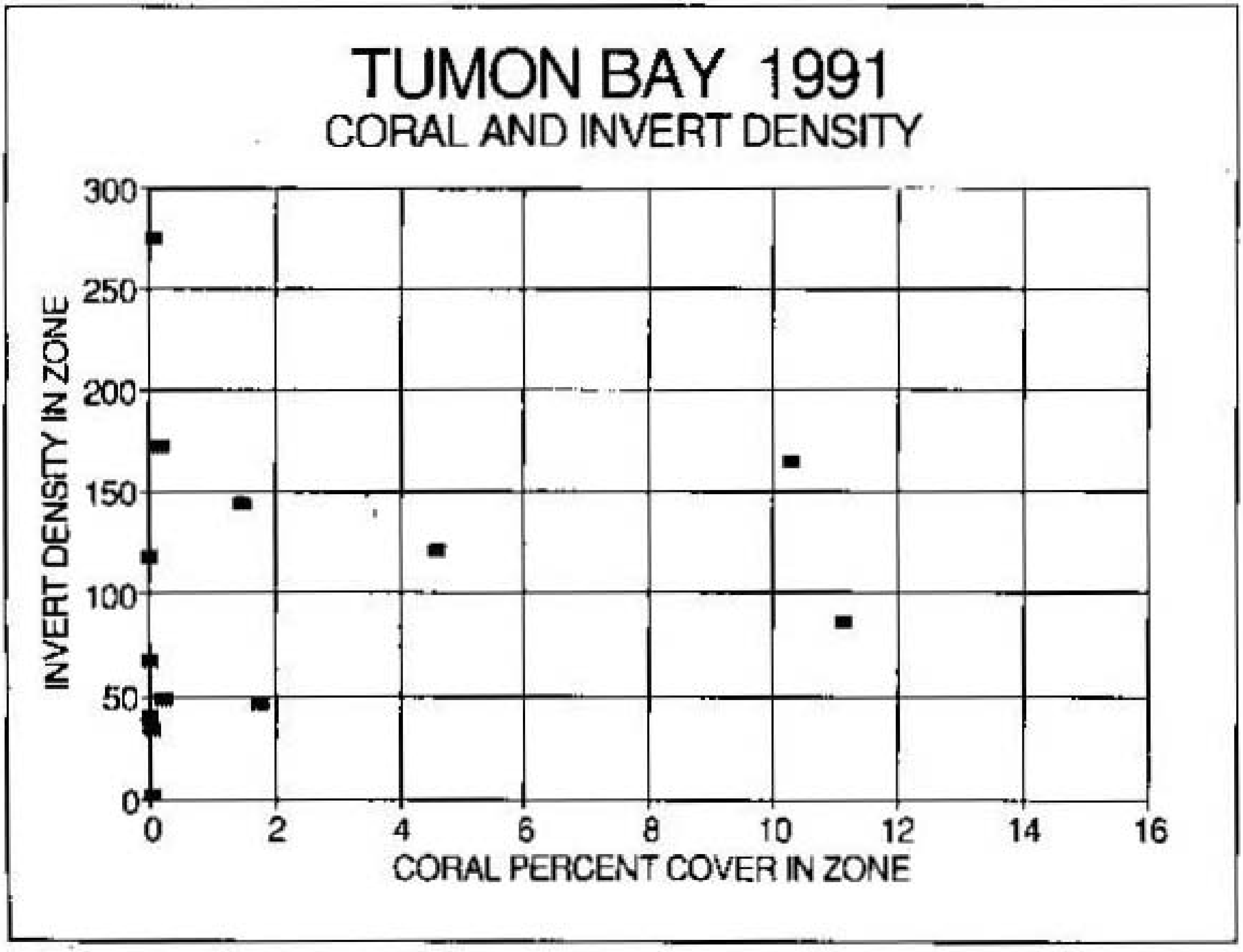

Figure VI-18. Relationship between percent cover of coral and invertebrate density among reef-flat habitats in Tumon Bay, 1991.

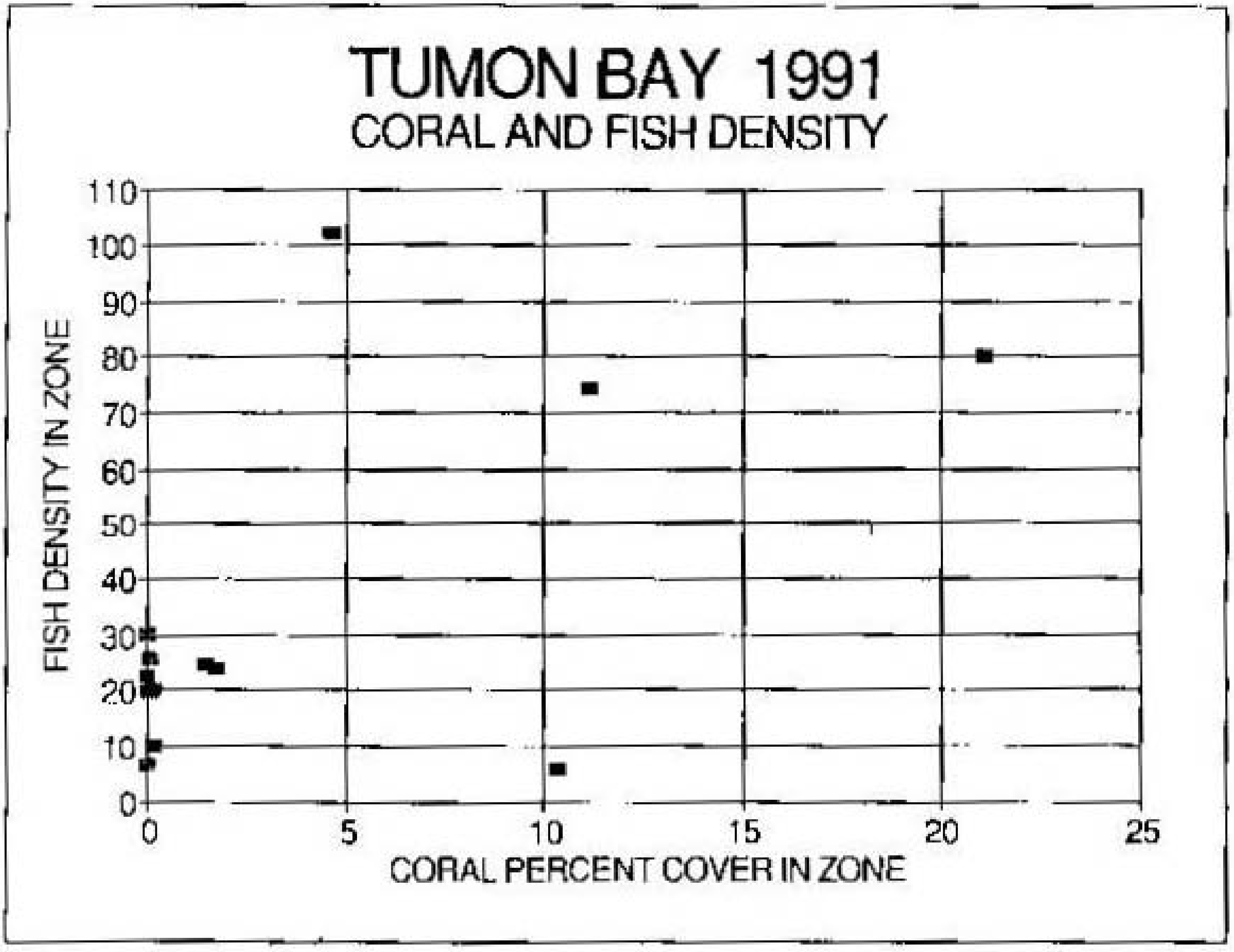

Figure VI 19. Relationship between percent cover of coral and fish density among reef flat habitats in Tumon Bay, 1991.

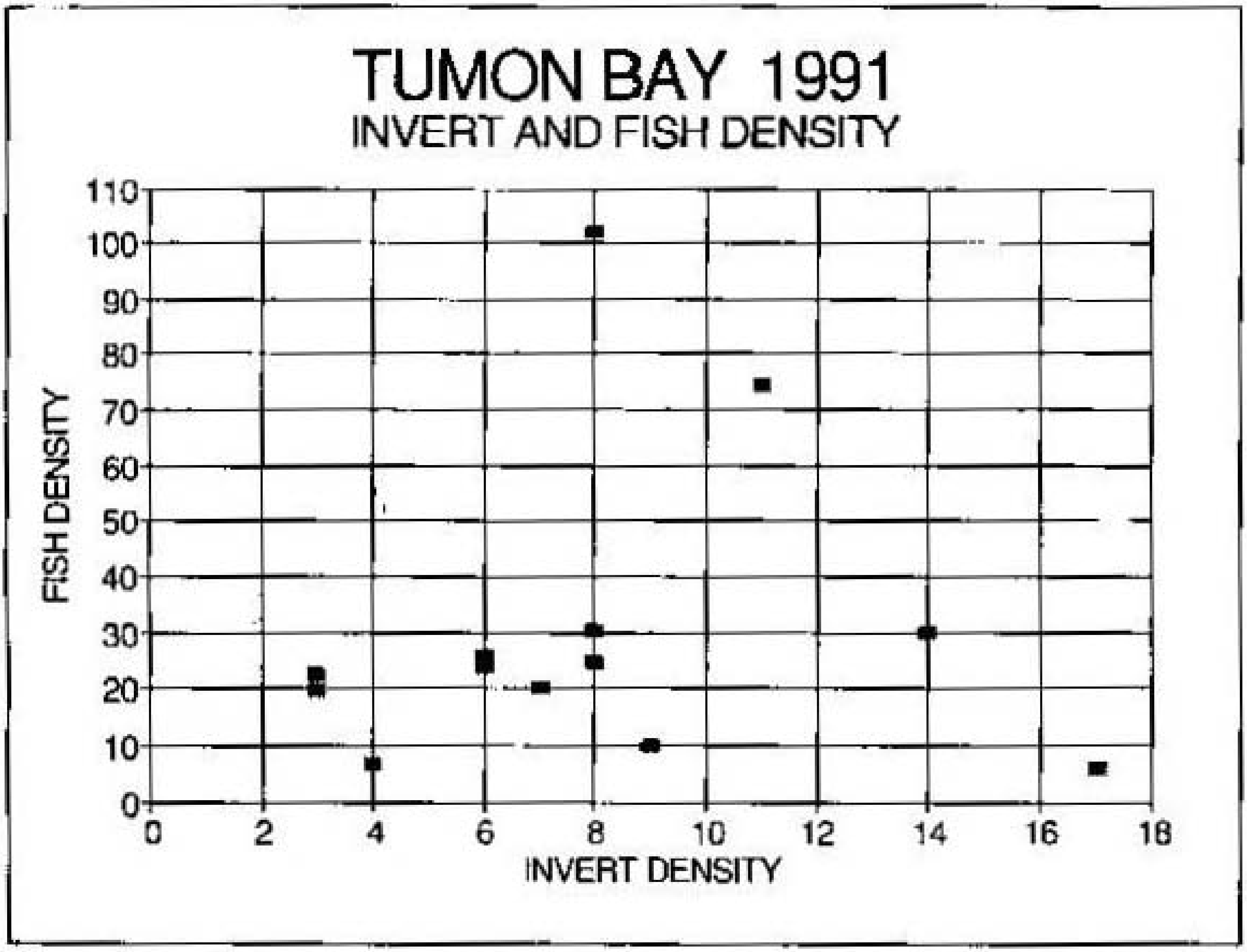

Figure VI-20. Relationship between invertebrate and fish density among reef-flat habitats in Tumon Bay, 1991.

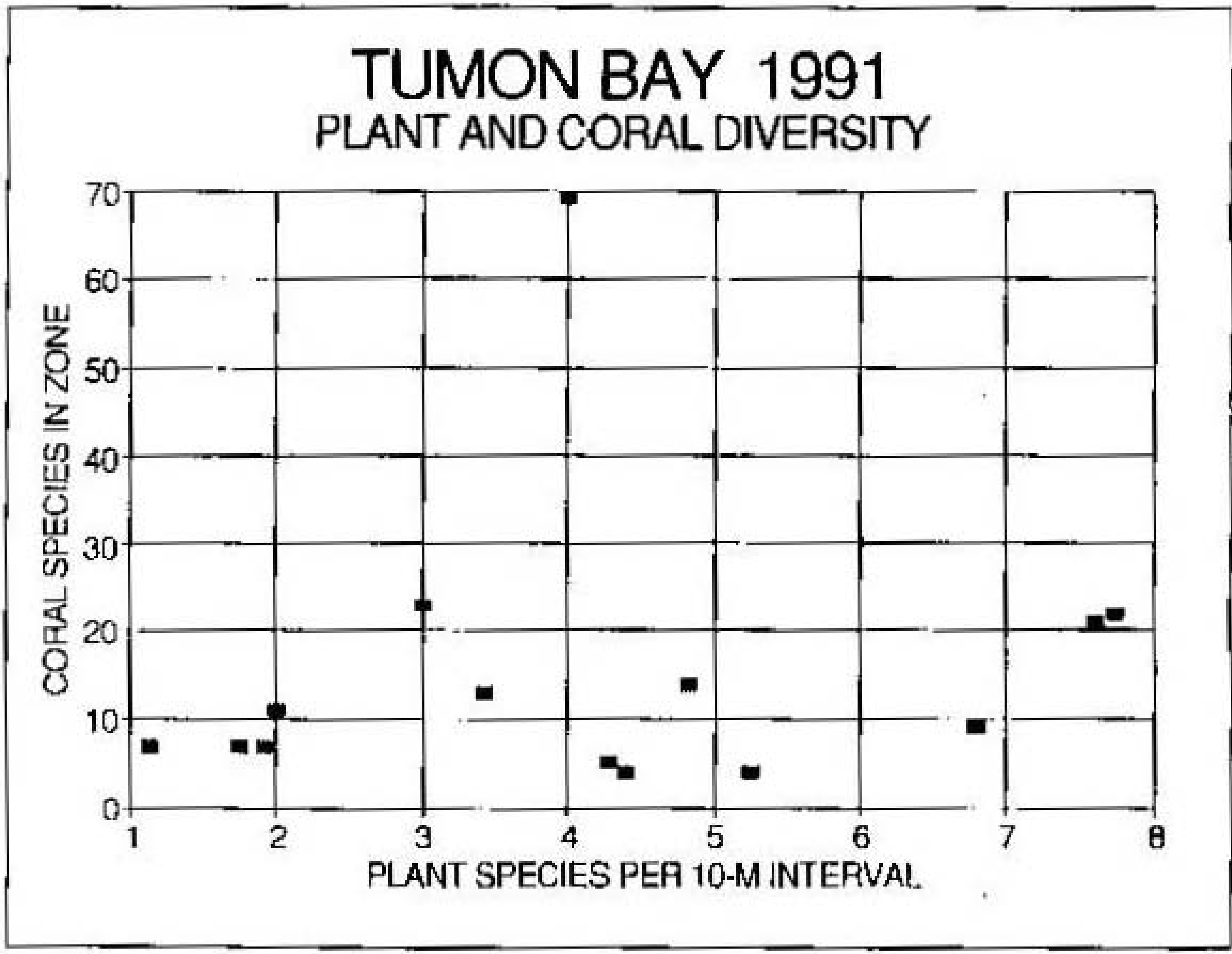

Figure VI 21. Relationship between mean number of plant species per 10-m interval and coral species richness in reef-flat habitats in Tumon Bay, 1991.

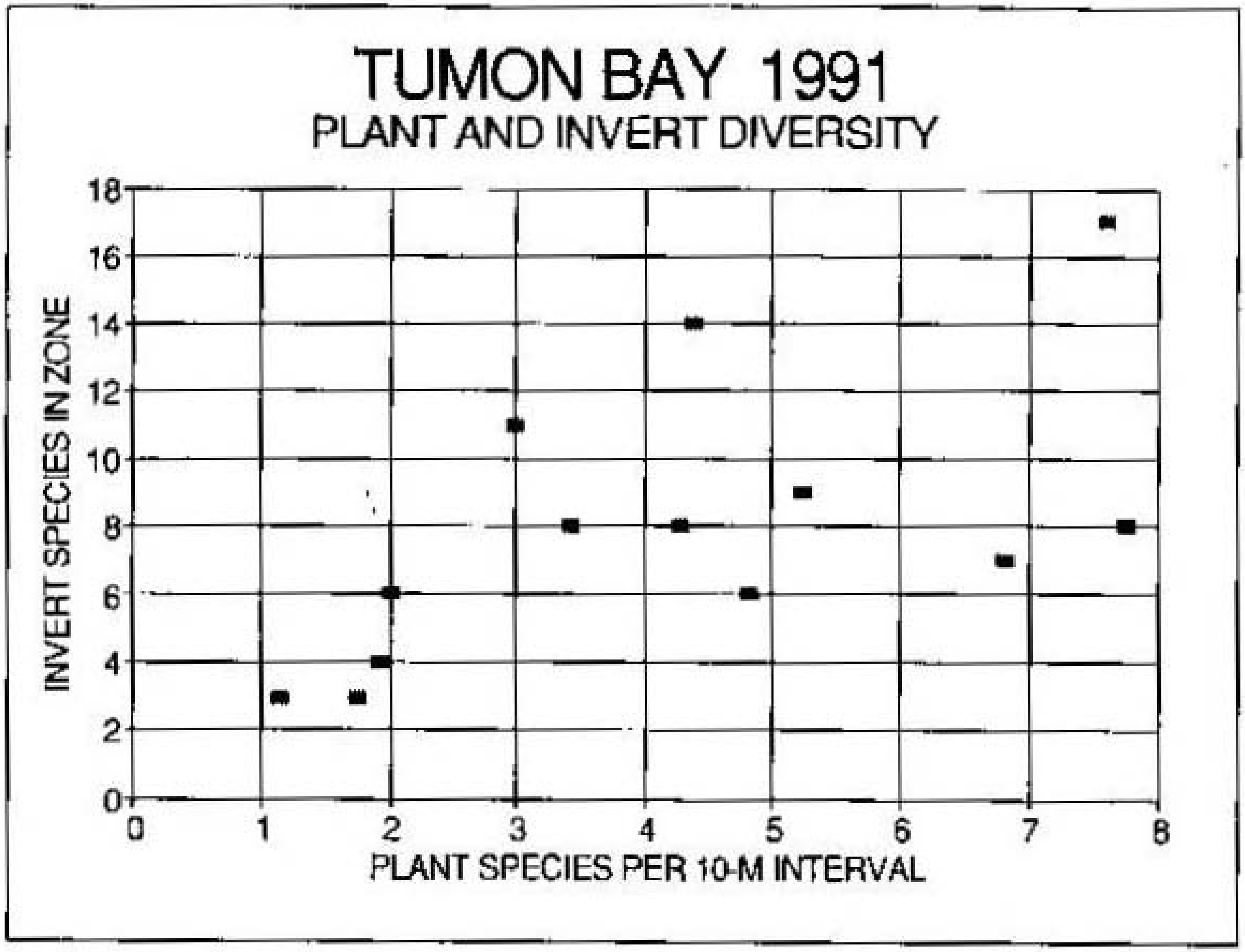

Figure VI-22. Relationship between mean number of plant species per 10-m interval and invertebrate species richness in reef-flat habitats in Tumon Bay, 1991.

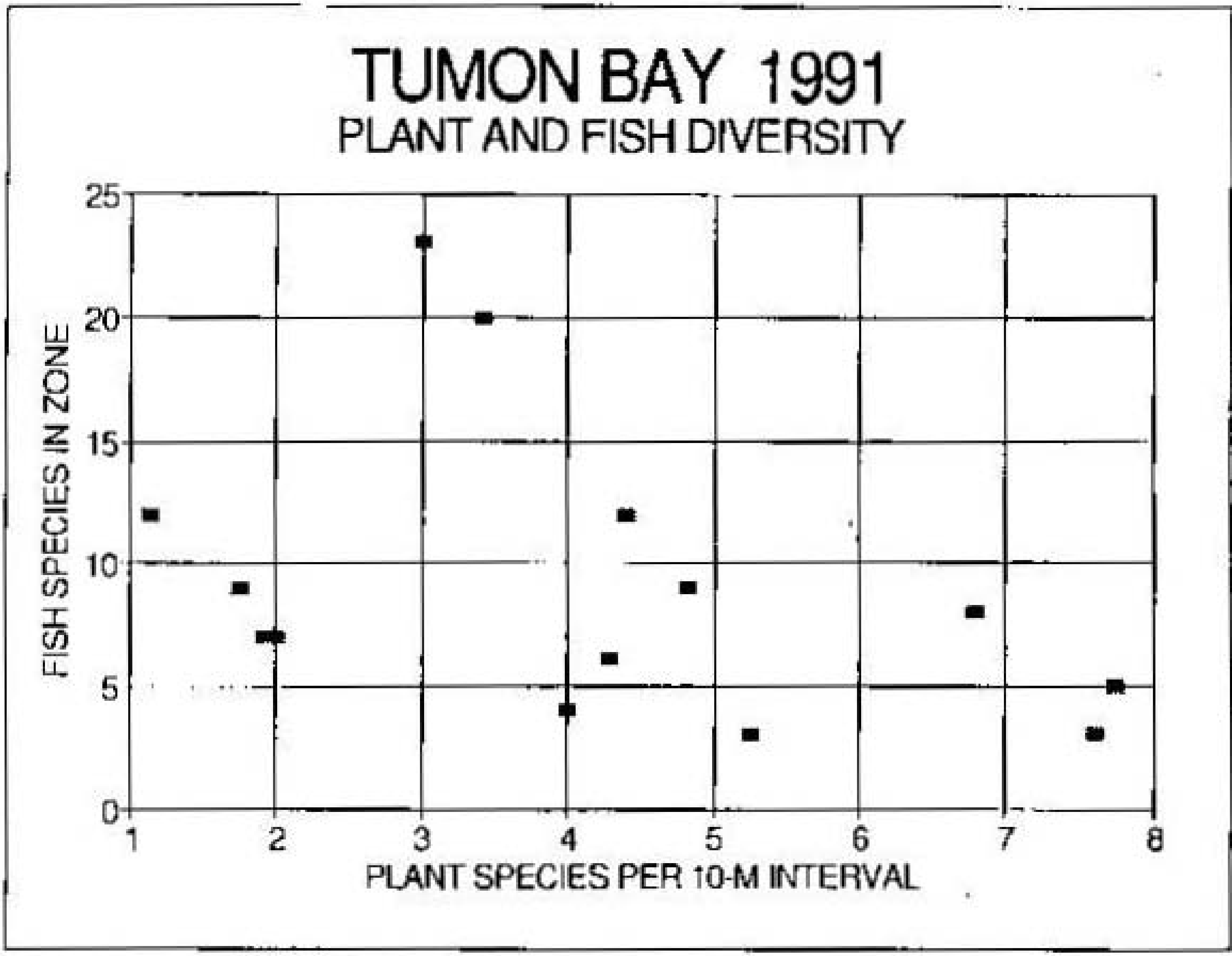

Figure VI-23. Relationship between mean number of plant species per 10 m interval and fish species richness in reef flat habitats in Tumon Bay, 1991.

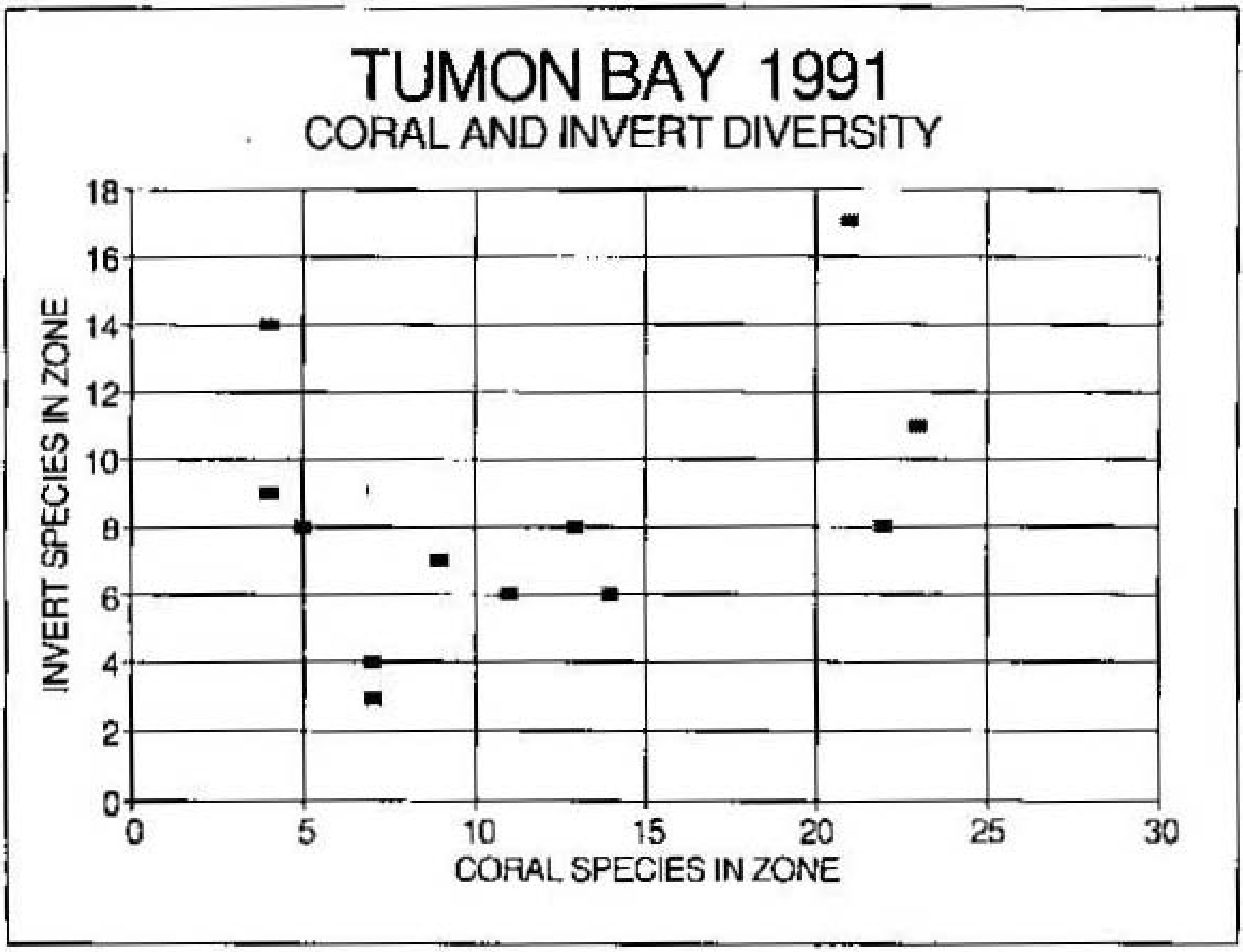

Figure VI-24. Relationship between coral and invertebrate species richness in reef-flat habitats in Tumon Bay, 1991.

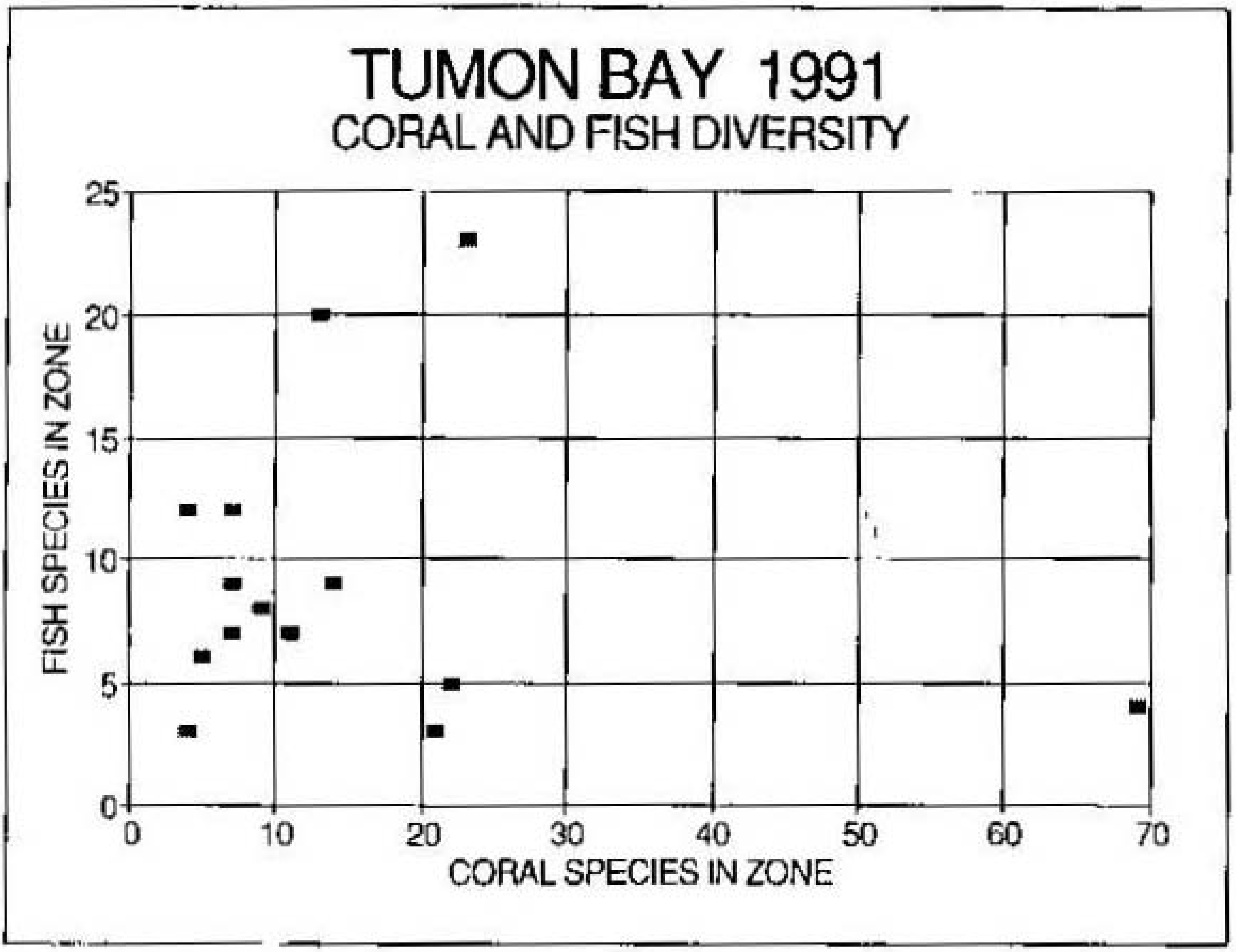

Figure VI-25. Relationship between coral and fish species richness in reef-flat habitats in Tumon Bay, 1991.

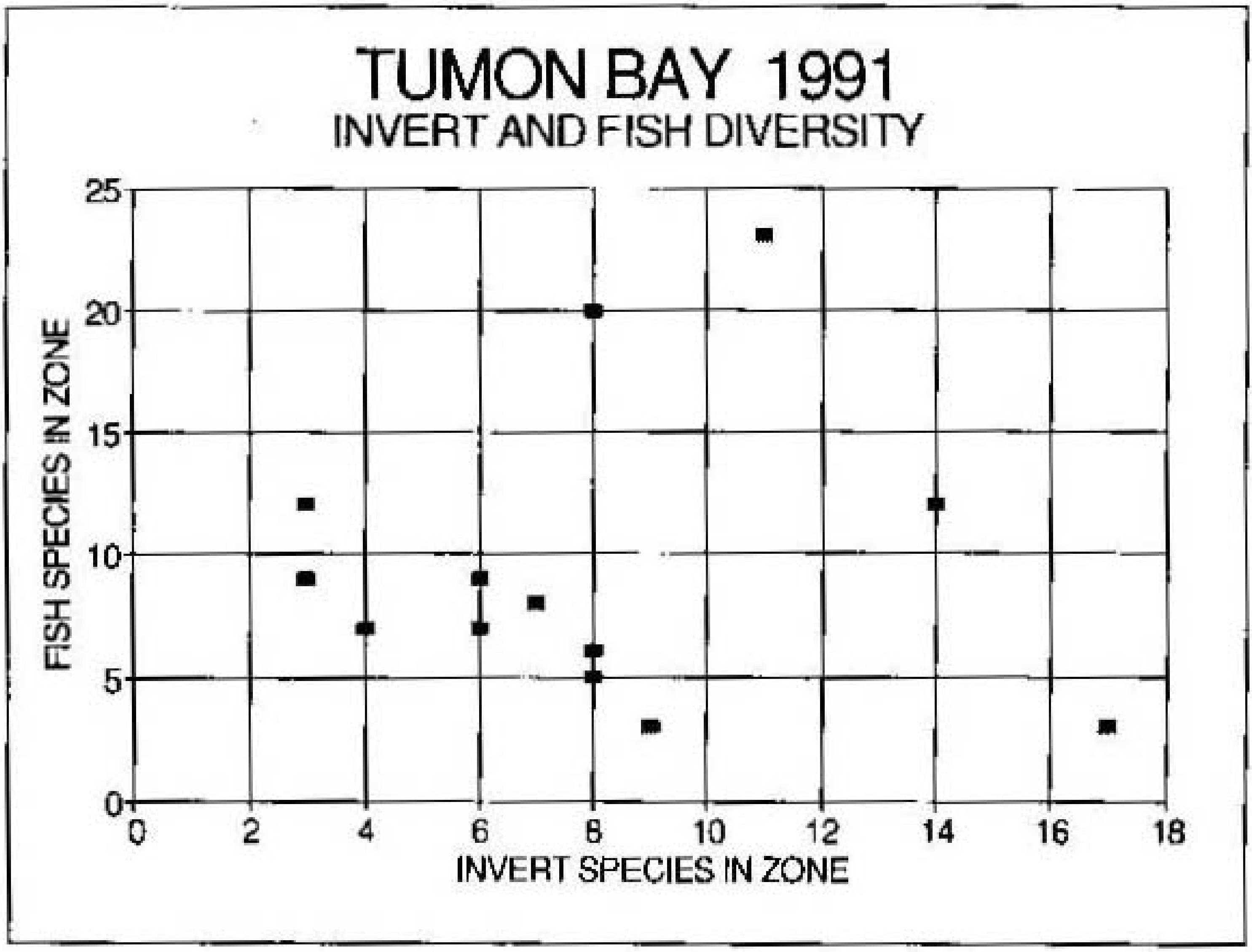

Figure VI-26. Relationship between invertebrate and fish species richness in reef-flat habitats in Tumon Bay, 1991.