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Abundance of Benthic Macroinvertebrates in Natural and Altered Estuarine Areas

GIL GILMORE and LEE TRENT

SEATTLE, WA
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NATIONAL MARINE FISHERIES SERVICE

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Abundance of Benthic Macroinvertebrates in Natural and Altered Estuarine Areas[1]

GIL GILMORE[2] and LEE TRENT[3]

ABSTRACT

The abundance of benthic macroinvertebrates during March-October 1969 in West Bay, Texas, was compared between 1) a natural marsh area, 2) an adjacent marsh area altered by channelization, bulkheading, and filling, and 3) an open bay area. Animals representing four phyla were caught. Abundance indices (areas combined) of the four groups in terms of numbers were 66.4% polychaetes, 29.6% crustaceans, 2.5% pelecypods, and 1.5% nemerteans; volumes were 44.0% polychaetes, 40.8% pelecypods, 10.7% nemerteans, and 4.4% crustaceans.

When all organisms were combined, they were slightly more abundant numerically and over twice as abundant volumetrically in the marsh than in the canals and were least abundant in the bay. Polychaetes were most abundant in the canals and least abundant in the bay; abundance was highest at stations with low to intermediate amounts of silt and clay or where vegetative matter was composed mostly of live sea grasses or detritus. Crustaceans were more abundant in the natural marsh than in the other two areas and showed a definite preference for sandy substrate in marsh areas. Pelecypods were numerically most abundant in the bay but volumetrically the marsh had the highest standing crop. Nemerteans were most abundant in the marsh and least abundant in the bay.

In general, the seasonal abundance of polychaetes and nemerteans varied little during the study, whereas crustaceans and pelecypods were abundant only during the spring and early summer. An exception to this seasonal abundance pattern was the reduction in numbers of polychaetes at the uppermost canal station where the habitat was apparently unsuitable due to low oxygen levels during the summer and early fall.

INTRODUCTION

Development of bayshore property into housing sites by dredging, bulkheading, and filling is occurring in many estuaries. When this property is developed, shallow bay and tidal marsh areas are dredged out or filled with spoil, thus changing the environment for marine organisms. The effects of the resulting environmental changes on the abundance of benthic organisms are poorly understood.

Some studies on the succession and abundance of benthic marine animals in canals following excavation indicate that succession may occur rapidly and that climax communities may be established within 2 yr (Brandt, 1897; Reish, 1956, 1957). For example, peaks in the number of species and specimens of benthic invertebrates were reached about 2 yr after seawater entered a newly constructed boat harbor in California, and the abundance and species diversity in the harbor 2 yr after opening were comparable to those in adjacent natural areas (Reish, 1961).

In other cases, however, climax communities may be altered or natural succession may not occur. Reish (1961) found that the benthic population in a boat harbor in California decreased markedly during the third year, probably because of low dissolved oxygen. Taylor and Saloman (1968) concluded that soft deposits in the canals of a Boca Ciega Bay housing development in Florida were in some way unsuitable for most benthic invertebrates that were found in the natural areas of the same bay. After 10 yr, recolonization of canal sediments by benthic organisms was negligible, and it appeared doubtful that soft sediments of the canals would ever support a rich or diverse infauna. The habitat in Boca Ciega Bay was, however, changed drastically by channelization of the natural bay area which was sandy and shallow, and had contained numerous turtle grass *(Thalassia testudinum)* beds and oyster reefs.

The objectives of our study were 1) to determine the relative abundance of benthic macroinvertebrates in three habitats: a natural marsh characterized by cord grass *(Spartina alterniflora)* and by sparse, submerged vegetation; a previously similar area altered by dredging, bulkheading, and filling; and an open bay area; and 2) to relate invertebrate abundance within each

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area to sediment particle size, amount of plant matter, and dissolved oxygen.

STUDY AREA AND METHODS

The study area in West Bay, Texas, a part of the Galveston Bay System (Fig. 1), included a natural marsh area, an open bay area, and an area that was similar to the natural marsh prior to alteration by channelization, bulkheading, and filling for the Jamaica Beach housing development. The developed area, which included about 45 hectares of emergent marsh vegetation, intertidal mud flats, and subtidal water area prior to alterations was reduced to about 32 hectares of subtidal water area by dredging and filling between 1958 and 1960. The water volume (mean low tide level) was increased from about 184,000 to about 394,000 cubic meters.

Six sampling stations—two in the canals of the altered area, three in the natural marsh, and one in the open bay—were established (Fig.1). The stations were numbered nonconsecutively and correspond to those reported by Trent, Pullen, and Moore (1972). Sampling was conducted in two zones, "shore" and "center," at each station except at the open bay station. In the altered area, shore samples were taken on each side of the canal at each station (1 and 4) 1 m away from each bulkhead; center samples were taken near the center of the canal along a transect perpendicular to the bulkheads. Replicate samples were taken from the center at each station, so that two samples were available from each zone for each sampling date; the average of the two samples was used as the observation in the statistical tests. Samples similar to those from the canal area were taken at stations 6, 7, and 8 in the intertidal zone adjacent to the cord grass and near the center of the bayou or lake along transects perpendicular to the shoreline. Replicate samples were taken at station 10 in the open bay.

Bottom samples were taken at 14-day intervals from 25 March to 21 October 1969, with a metal cylinder 14 cm long and 9.6 cm in diameter. To obtain a sample the cylinder was pressed about 11 cm into the bottom sediments, capped on each end with plastic lids, and brought to the water's surface. Each sample contained about 800 cm^3 of bottom materials and represented a surface area of 1/138 m^2.

The samples were refrigerated within 2 hr after collection. The following day, each sample was emptied into a sieve having a mesh size of 420 μm, and the material was washed until the fine sediments passed through the sieve. The remaining material, including macroinvertebrates, was stored in a 10% Formalin solution.

Macroinvertebrates and plant material in the preserved samples were separated from the shell and sand. Animal volume for each pair of samples was determined to the nearest 0.1 ml by displacement in a graduated 10-ml centrifuge tube containing a previously recorded volume of water. The volume of each phylum taken at each station and zone was determined at the end of the study by combining the individuals of a phylum from the 32 samples. The volume of plant material was determined to the nearest milliliter in a 30-ml graduated cylinder.

The animals were separated and identified, usually to family, and the number of individuals in each group was recorded for each pair of samples. As suggested by Holme (1964), only whole animals or portions of animals containing the anterior end were counted to avoid recounting the same animal.

The dissolved oxygen content of the water, taken 15 cm above the bottom at the center habitat of each station, was measured using a modified Winkler method. The water samples were taken about midday and midnight during the same 24-hr period that the bottom samples were collected.

Samples for sediment analyses were taken at each station and zone on 12 August. Particle-size compositions (percents by weight) were determined using a series of sieves and soil hydrometers. Ranges in particle size were: sand, 2.0-0.62 mm; silt, 0.061-0.004 mm; clay, 0.0039-0.001 mm.

STATION DESCRIPTION AND ENVIRONMENTAL DATA

Sampling stations were located at various distances from the West Bay shoreline (Fig. 1). Water depths (mean low tide level) in the shore zone ranged from 0.0 to 0.6 m and in the center zone from 0.2 to 1.6 m.

The percentage compositions of bottom sediments varied considerably between stations and between zones (Fig. 2). In the canals, silt and clay components were more abundant in the center than in the shore zone. In the marsh, compositions of sediments were similar between zones at stations 7 and 8, but at station 6 a higher percentage of silt and clay occurred in the center than in the shore zone.

The plant material taken in the samples was composed of live cord grass roots, attached marine grasses (mostly *Diplanthera wrightii),* algae (mostly *Ectocarpus* sp.), and detritus. In general, all organic matter collected at the canal stations (both zones) and in the open bay consisted of detritus and small amounts of attached algae. Cord grass roots were dominant in the samples from the shore of the marsh, whereas in the center, detritus was usually dominant, although attached grasses and algae were also present.

The volume of plant material was many times greater in the shore zone (stations 6, 7, and 8) of the marsh than in either zone within the canals (Fig. 3). Most of this vegetation, however, was not decomposed; thus, detrital and filter feeders could not utilize it.

Differences in the volume of plant material in the center zones of all stations indicated that a major source of plant material in the canals originated from an outside source. The lowest volume of plant material

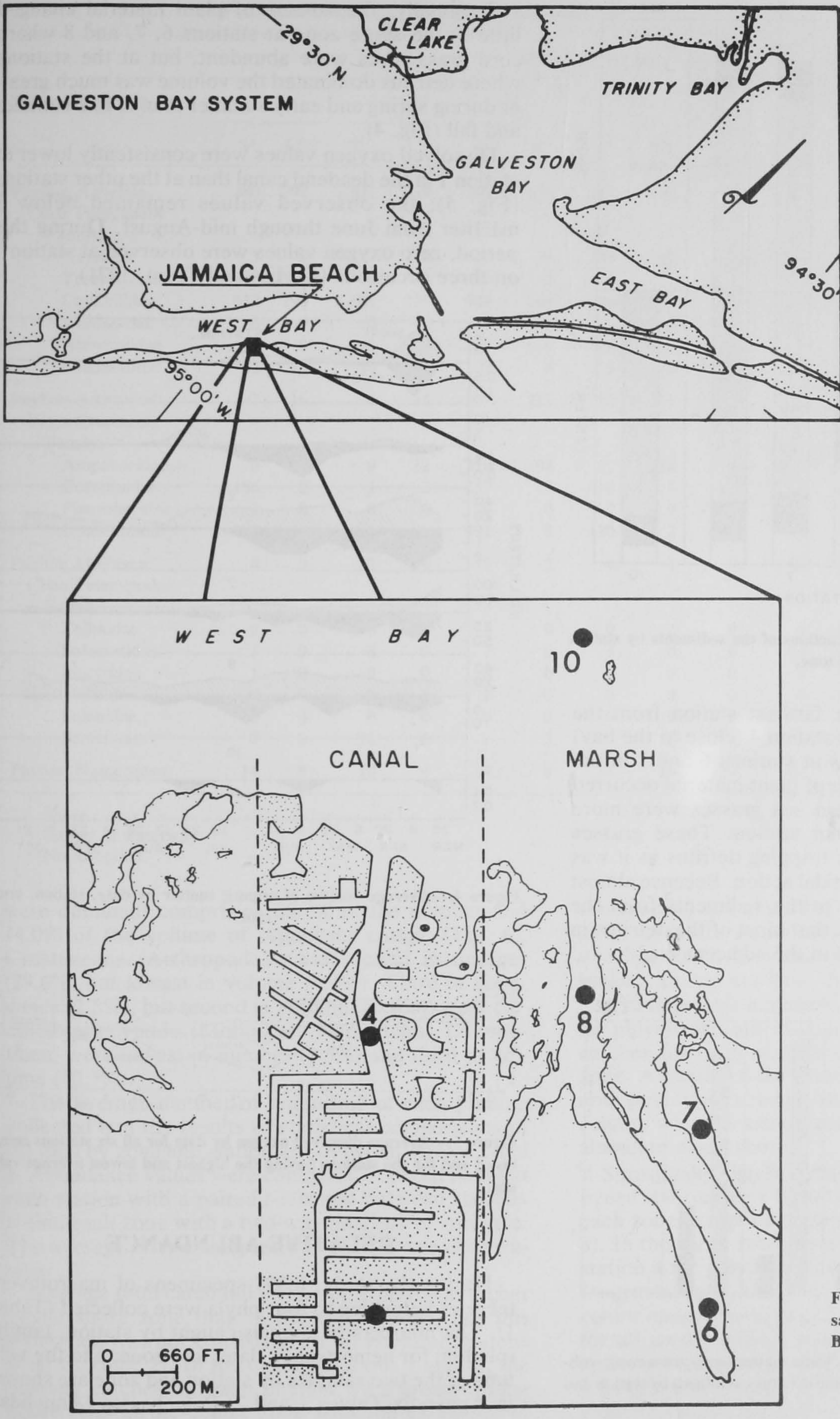

Figure 1.—Study area and sampling locations in the Jamaica Beach area of West Bay, Texas.

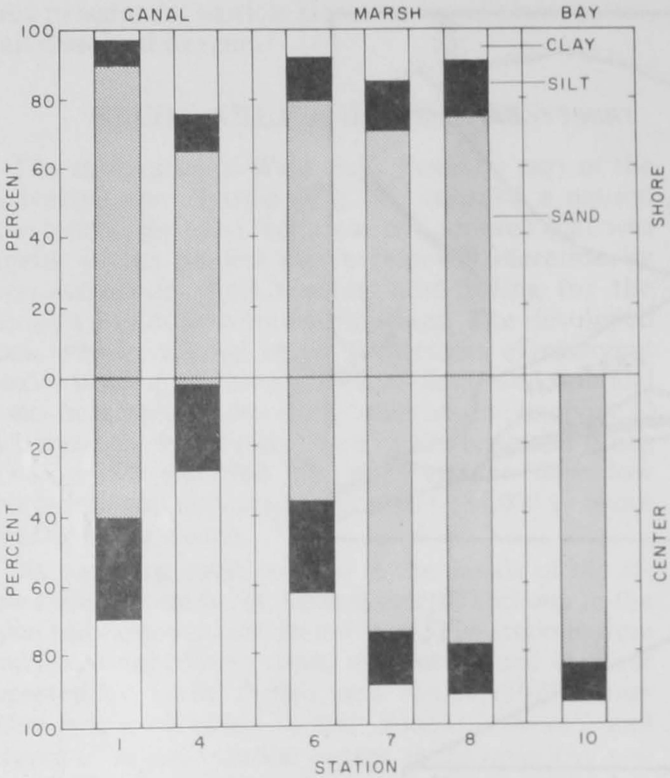

Figure 2.—Sand, silt, and clay fractions of the sediments by station and zone.

occurred at station 1, the farthest station from the open bay. Plant volume at station 4 (close to the bay) was similar to the volumes at stations 6 and 7 in the marsh. The highest volume of plant material occurred at station 8 where attached sea grasses were more abundant than at any other station. These grasses probably were effective in trapping detritus as it was flushed from the marsh by tidal action. Because almost no detritus was observed in the sediments from the open bay station, we think that most of the detritus in the altered area originated in the adjacent marsh.

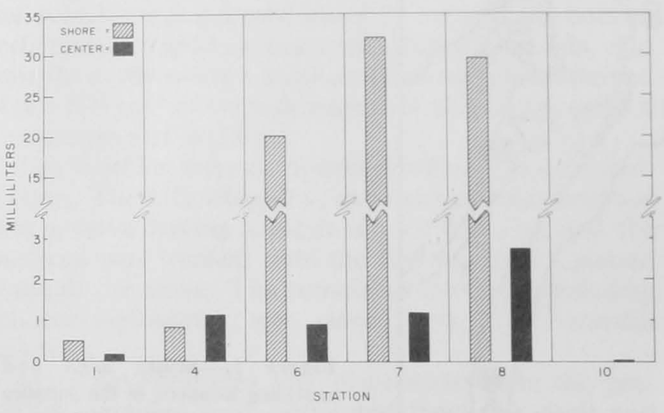

Figure 3.—Average volumes of organic matter (cord grass roots, submerged marine grasses, and organic detritus combined) by station and zone, March-October 1969.

Seasonally, the volume of plant material changed little in the shore zone at stations 6, 7, and 8 where cord grass roots were abundant, but at the stations where detritus dominated the volume was much greater during spring and early summer than in late summer and fall (Fig. 4).

Dissolved oxygen values were consistently lower at station 1 in the deadend canal than at the other stations (Fig. 5); the observed values remained below 3 ml/liter from June through mid-August. During this period, zero oxygen values were observed at station 1 on three occasions (Corliss and Trent, 1971).

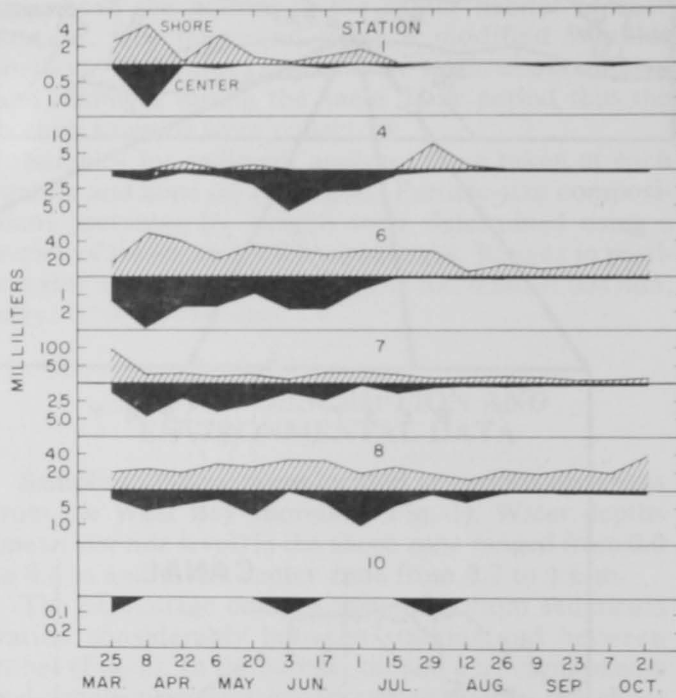

Figure 4.—Average volume of organic matter by date, station, and zone.

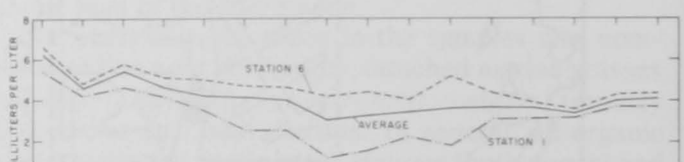

Figure 5.—Average dissolved oxygen by date for all six stations combined and for the stations having the highest and lowest average values.

RELATIVE ABUNDANCE

During the study, 8,397 specimens of macroinvertebrates belonging to four phyla were collected (Table 1). The numbers of animals caught by station, family (phylum for nemerteans), date, and zone, and the volume of the two samples by station and zone are shown in Appendix Tables 1 and 2. Polychaetes (Annelida)

Table 1.—List of taxonomic groups and total numbers of specimens collected by station and zone.

Taxonomic group	Station and zone 1 S[1]	1 C[2]	4 S[1]	4 C[2]	6 S[1]	6 C[2]	7 S[1]	7 C[2]	8 S[1]	8 C[2]	10 S[1]	10 C[2]	Stations combined S[1]	Stations combined C[2]
Phylum Annelida:	480	292	1,631	234	399	174	281	309	319	1,181	([3])	275	3,110	2,465
Class Polychaeta:														
Family:														
Nereidae	3	0	7	3	28	20	68	40	36	24	([3])	15	142	102
Terebellidae	0	0	3	1	7	2	3	6	8	12	([3])	2	21	23
Capitellidae	432	290	1,601	229	348	148	204	241	268	1,100	([3])	188	2,853	2,196
Maldanidae	0	0	0	0	0	0	2	0	0	6	([3])	0	2	6
Arenicolidae	0	0	0	0	7	0	0	2	3	0	([3])	0	10	2
Unidentified	45	2	20	1	9	4	4	20	4	39	([3])	70	82	136
Phylum Arthropoda:	197	16	11	34	967	123	240	235	322	333	([3])	4	1,737	745
Class Crustacea:														
Family:														
Ampeliscidae	0	0	9	32	318	98	92	228	64	313	([3])	4	483	675
Corophiidae	186	0	1	2	257	17	18	5	62	7	([3])	0	524	31
Pinnotheridae	2	0	0	0	0	0	0	0	0	0	([3])	0	2	0
Unidentified	9	16	1	0	392	8	130	2	196	13	([3])	0	728	39
Phylum Mollusca:	4	0	33	24	13	2	4	4	9	82	([3])	38	63	150
Class Pelecypoda:														
Family:														
Tellinidae	0	0	8	18	3	0	0	2	0	8	([3])	6	11	34
Solecurtidae	3	0	4	0	7	0	4	0	6	64	([3])	0	24	64
Mactridae	1	0	0	0	0	0	0	0	0	0	([3])	0	1	0
Mytilidae	0	0	0	0	2	0	0	0	0	0	([3])	0	2	0
Solenidae	0	0	0	0	0	0	0	0	0	0	([3])	8	0	8
Semelidae	0	0	21	6	1	2	0	2	3	10	([3])	24	25	44
Phylum Nemertinea:	14	0	10	6	19	8	14	14	29	10	([3])	3	86	41

[1] Shore.
[2] Center of waterway.
[3] No sampling.

were dominant comprising 66.4% of the number and 44.0% of the volume of organisms caught (Fig. 6). Crustaceans (Arthropoda) were second in number (29.6%) but lowest in volume (4.4%). Third in abundance (2.5%), but second in volume (40.8%), were calcified pelecypods (Mollusca). Nemerteans (Nemertinea) were lowest in number (1.5%) and third in volume (10.7%).

The average number of organisms of each phylum collected and the results of statistical comparisons of the data by zone and station are shown in Tables 2 and 3. Abundance values were compared between zones at each station with a paired t-test and between stations within each zone with a two-way analysis of variance. The average of two samples was used as the observation.

Average total catch (all phyla combined) was higher in the shore zone than in the center zone, but this difference was not consistent for all phyla or stations (Fig. 6, Table 2). In the canals (stations 1 and 4), the average catches for each phylum were greater along shore than in the center zone with the exception of crustaceans at station 4. Only 5 of the 16 differences, however, were statistically significant. Differences in average catch between zones in the marsh varied greatly among stations. At station 6 all phyla were caught in greater numbers along shore, significantly so for polychaetes and crustaceans. At station 7, average catches for each phyla were about the same in each zone. At station 8 the average numbers of polychaetes and pelecypods were significantly greater in the center, whereas nemerteans were significantly more abundant along shore.

Statistically significant differences in abundance between stations were found for each taxonomic group in each zone except nemerteans in the shore zone (Table 3). In the shore zone, average catches were highest at station 4 for polychaetes and pelecypods, at station 6 for crustaceans, and at station 8 for nemerteans. In the center zone, average catches were highest at station 8 for all groups except nemerteans, for which average catch was greatest at station 7.

In general, catches of polychaetes and nemerteans exhibited only slight seasonal variations; crustaceans

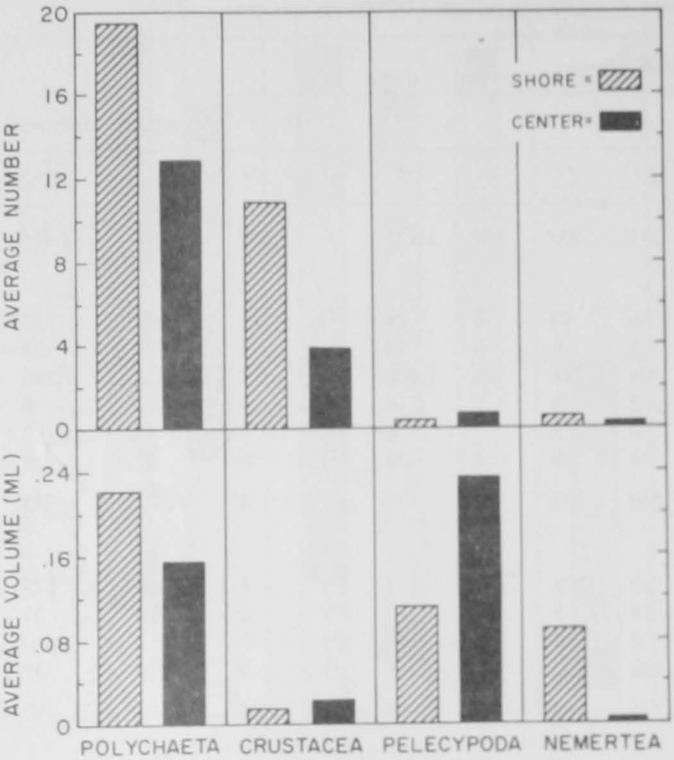

Figure 6.—Average numbers and volumes (stations combined) of organisms caught per sample by taxonomic group and zone, March-October 1969.

Table 2.—Comparisons between zones by taxon and station of the mean numbers of organisms collected (paired-comparison *t*-test).

Taxon	Station	Zone: Shore	Zone: Center	d.f.	*t*
		---- *Mean number* ----			
Polychaeta	1	15.00	9.12	14	1.97
	4	50.97	7.31	15	[1]8.46
	6	12.47	5.44	15	[1]3.12
	7	8.78	9.66	15	−0.67
	8	9.97	36.91	15	[1]−6.36
Crustacea	1	6.15	0.50	4	1.05
	4	0.34	1.06	5	−1.38
	6	30.22	3.84	11	[2]2.53
	7	7.50	7.34	10	0.05
	8	10.06	10.41	9	−0.06
Pelecypoda	1	0.12	0.00	3	[1]6.13
	4	1.03	0.75	10	0.90
	6	0.40	0.06	5	1.89
	7	0.12	0.12	3	0.00
	8	0.28	2.56	14	[2]2.31
Nemertinea	1	0.44	0.00	8	[1]6.42
	4	0.31	0.19	8	0.77
	6	0.59	0.25	9	1.36
	7	0.44	0.44	9	0.00
	8	0.91	0.32	12	[2]2.31

[1] 1% significance level.
[2] 5% significance level.

Table 3.—Comparisons between stations by taxon and zone of the mean numbers of organisms collected (two-way analysis of variance).

Zone	Taxon	Station 1	4	6	7	8	10	F-values: Block	F-values: Treatment
		---	---	---	*Mean number*	---	---		
Shore	Polychaeta	15.00	50.97	12.47	8.78	9.97	([3])	1.19	[1]57.75
	Crustacea	6.15	0.34	30.22	7.50	10.06	([3])	[1]3.25	[1] 4.62
	Pelecypoda	0.12	1.03	0.40	0.12	0.28	([3])	[2]2.02	[1] 4.75
	Nemertinea	0.44	0.31	0.59	0.44	0.91	([3])	0.61	1.68
Center	Polychaeta	9.12	7.31	5.44	9.66	36.91	8.59	1.06	[1]18.11
	Crustacea	0.50	1.06	3.84	7.34	10.41	0.12	[1]2.40	[2] 2.30
	Pelecypoda	0.00	0.75	0.06	0.12	2.56	1.19	[1]3.24	[1] 9.93
	Nemertinea	0.00	0.19	0.25	0.44	0.32	0.09	1.08	[2] 2.31

[1] 1% significance level.
[2] 5% significance level.
[3] No sample.

and pelecypods exhibited pronounced seasonal variation (Fig. 7-10). Catches of crustaceans and pelecypods were highest during spring and early summer. The significant F-values for blocks (seasons) for crustaceans and pelecypods and the nonsignificant F-values for polychaetes and nemerteans for the pooled station data (Table 3) substantiate these conclusions. The exception to this general pattern was the decline in abundance, or absence, of all groups at station 1 in the center zone during June through Sep-

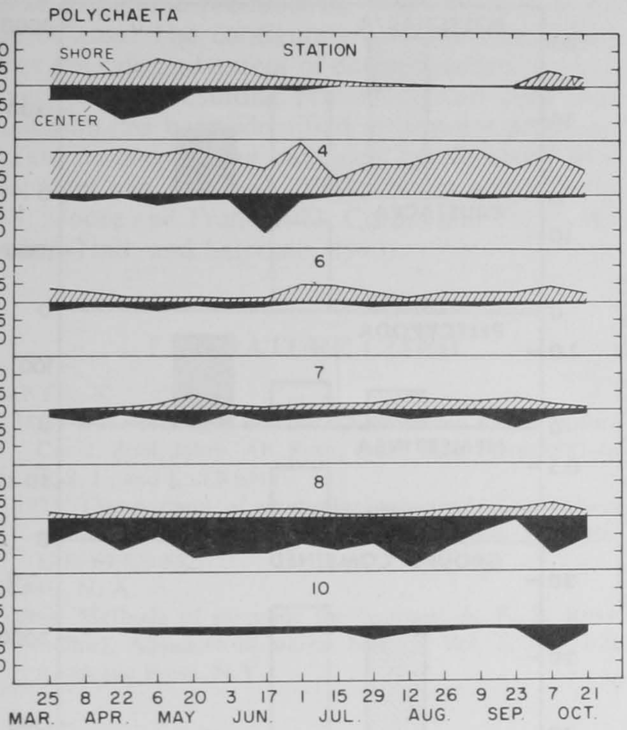

Figure 7.—Average number of polychaetes caught per sample by date, station, and zone.

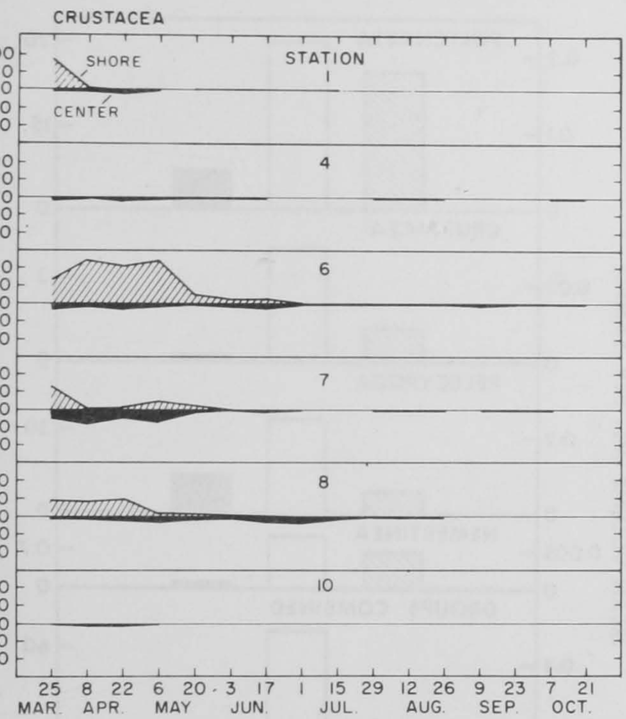

Figure 8.—Average number of crustaceans caught per sample by date, station, and zone.

tember. This lowered abundance was probably caused by low dissolved oxygen during this period (Fig. 5).

Benthic organisms in general were most abundant in areas with sediments composed of low to intermediate

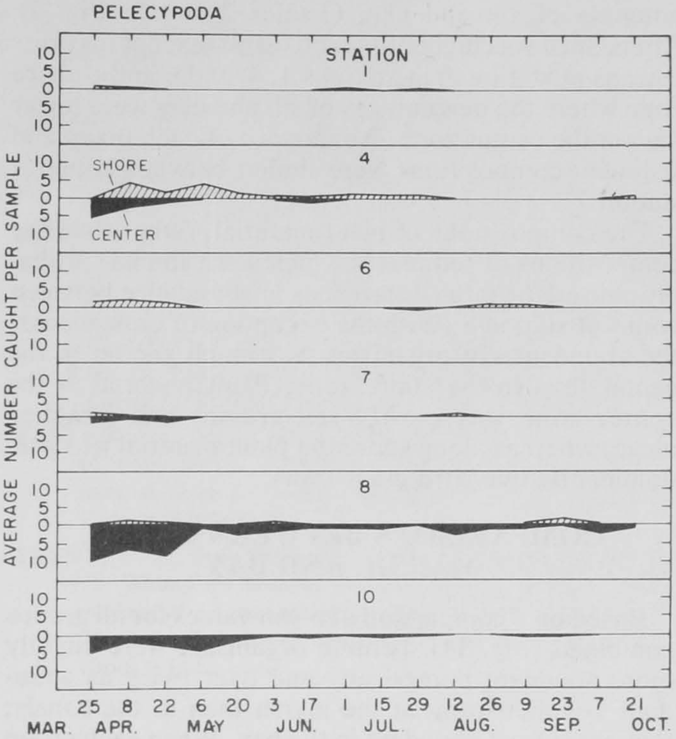

Figure 9.—Average number of pelecypods caught per sample by date, station, and zone.

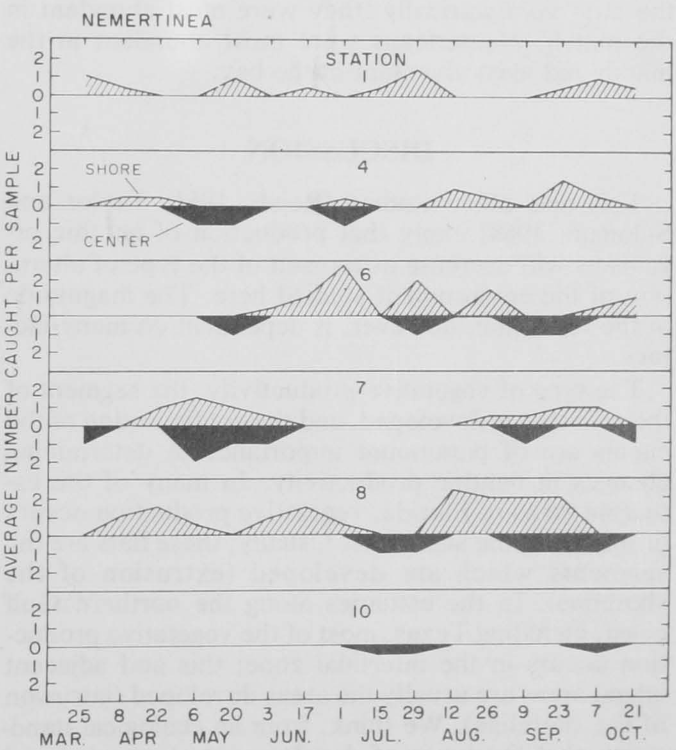

Figure 10.—Average number of nemerteans caught per sample by date, station, and zone.

amounts of silt and clay (Tables 2 and 3, Fig. 2). Abundance was higher for each taxon (except for crustaceans at station 4) at stations 1, 4, and 6 in the shore zone where the percentages of silt and clay were lower than in the center zone. Abundance of each taxon and sediment compositions were similar between zones at station 7.

The compositions of plant material, rather than the compositions of sediments which were similar, probably caused the large differences in abundance between zones at station 8. With the exception of crustaceans, the abundance of organisms was much greater in the center than in the shore zone. Plant material in the center zone was mostly sea grasses and attached algae, whereas along shore the plant material was predominantly live cord grass roots.

COMPARISONS BETWEEN CANAL, MARSH, AND BAY

Based on a comparison of mean values for all groups combined (Fig. 11), benthic organisms were slightly more abundant numerically and over twice as abundant volumetrically in the marsh than in the canals; they were least abundant in the bay. When each group was considered separately, however, numeric and volumetric abundance by area varied. Polychaetes were most abundant numerically in the canals, most abundant volumetrically in the marsh; they were least abundant in the bay. Crustaceans were over three times as abundant in the marsh as in the other two areas. Pelecypods were numerically most abundant in the bay; volumetrically, they were most abundant in the marsh. Nemerteans were most abundant in the marsh and least abundant in the bay.

DISCUSSION

This and other studies (Reish, 1961; Taylor and Saloman, 1968) imply that production of benthic organisms will decrease as a result of the type of alteration of the environment studied here. The magnitude of the reduction, however, is dependent on many factors.

The type of vegetative productivity, the segment of the area that is developed, and the configuration of the canals are of paramount importance in determining changes in benthic productivity. In many of the estuarine areas in Florida, vegetative production occurs primarily on the sand flats. Usually, these flats are the segments which are developed (extrusion of the shoreline). In the estuaries along the northern Gulf coast, including Texas, most of the vegetative production occurs in the intertidal zone; this and adjacent inland areas are usually the areas developed (intrusion of the shoreline). We think, from an ecological standpoint, that the types of developments (extruded and intruded) should be reversed in respect to the types of estuarine area described above. If reversed, the de-

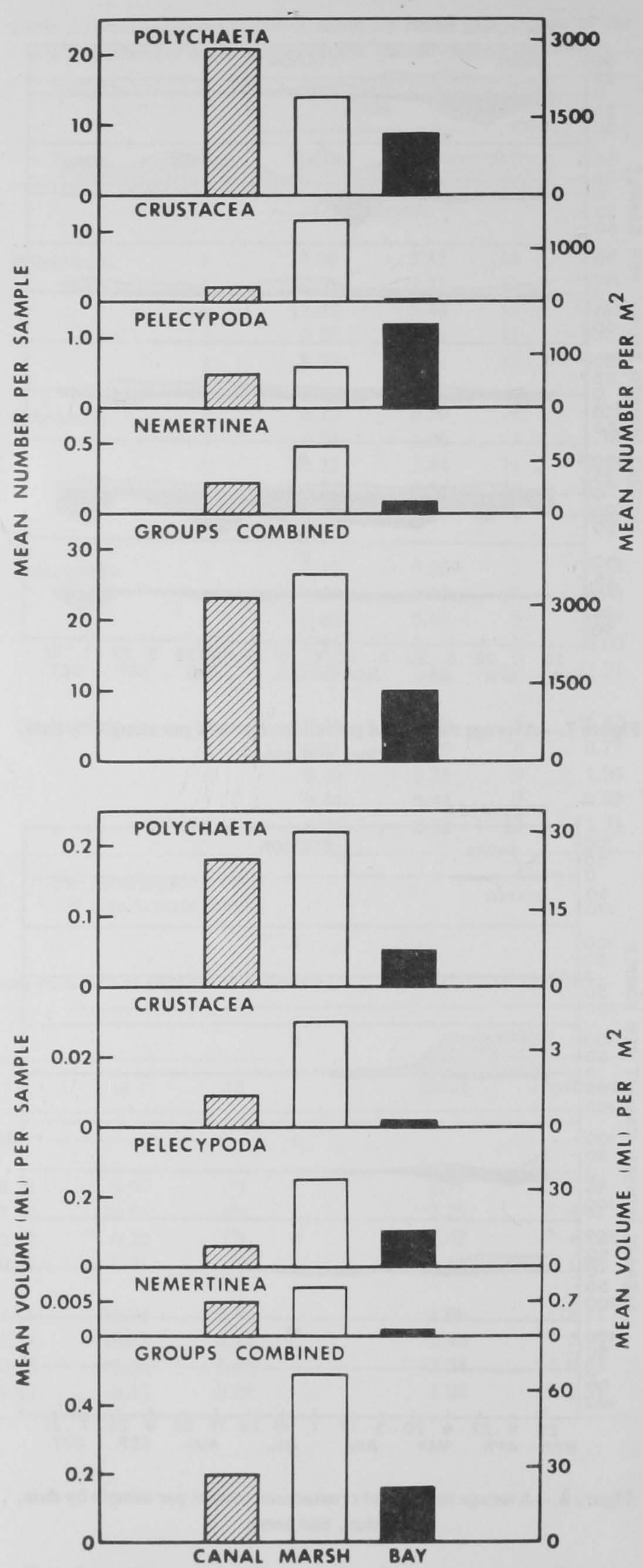

Figure 11.—Average numbers and volumes of benthic macroinvertebrates caught per sample by area, taxonomic group, and for the groups combined, March-October 1969.

crease in benthic productivity might be less in each type of area. The configuration of the canals determines the rate and extent of eutrophication. Low dissolved oxygen resulting primarily from poor water circulation has been identified as a major problem in relation to maintaining biological productivity in development canals (Reish, 1961; Taylor and Saloman, 1968; Moore and Trent, 1971; Corliss and Trent, 1971; Lindall, Hall, and Saloman, 1973).

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Appendix Table 1.—Numbers of animals caught by station, date, taxon, and volume of two samples in shore zone.

		Annelida						Arthropoda				Mollusca						Nemertinea	Totals	
Station	Date	Nereidae	Terebellidae	Capitellidae	Maldanidae	Arenicolidae	Unidentified	Ampiliscidae	Corophiidae	Pinnotheridae	Unidentified	Tellinidae	Solecurtidae	Mactridae	Mytilidae	Solenidae	Semelidae	Identified only to phylum	Number	Volume
1	25 Mar.			46					168	1	5		1					2	223	0.6
	8 Apr.			34					18		3		1					1	57	1.1
	22 Apr.			39							1								40	0.1
	6 May			76															76	0.5
	20 May			53														2	55	0.4
	6 June	2		65			3												70	0.3
	17 June			31														1	32	0.4
	1 July	1		20			1			1			1						24	1.8
	15 July			17														1	18	0.1
	28 July			10										1				3	14	0.2
	11 Aug.			5															5	0.1
	25 Aug.			3															3	0.1
	22 Sept.			1														1	2	0.1
	6 Oct.			9			37											2	48	0.2
	20 Oct.			23			4											1	28	0.4
	Total	3		432			45		186	2	9		3	1				14	695	6.4
4	25 Mar.			115			1	2	1										119	0.6
	8 Apr.			119								2	3				2		126	0.9
	22 Apr.	1		125			2	2			1	1					2	1	135	1.6
	6 May	2	1	111				1				4					4		123	0.8
	20 May			128								1					2		131	1.6
	6 June			97				2									1		100	1.7
	17 June			72													1		73	1.5
	1 July			145			5										2	1	153	2.5
	15 July		1	42													2		45	0.4
	28 July		1	84													2		87	0.6
	11 Aug.	3		80				2										2	87	0.7
	25 Aug.			118														1	119	0.5
	8 Sept.			127									1				2		130	0.7
	22 Sept.			70														3	73	0.5
	6 Oct.	1		101			11											2	115	0.9
	20 Oct.			67			1										1		69	0.7
	Total	7	3	1,601			20	9	1		1	8	4				21	10	1,685	16.2
6	25 Mar.	6		27				3	45		90	1	1						173	0.7
	8 Apr.	1		32		1		11	120		118		3						286	1.4
	22 Apr.		1	13				1	33		175	1	2		2				228	0.4
	6 May			10				185	57		8								260	0.2
	20 May	2		11				49	1										63	0.2
	6 June	7		2				23				1						1	34	0.4
	17 June		1	13				31										2	47	0.2
	1 July	1		46				7	1									6	61	0.8
	15 July	2		33															35	0.3
	28 July	2		27				3										3	35	0.4
	11 Aug.	1	2	6															9	0.3
	25 Aug.	1	1	26				3					1					3	35	2.1
	8 Sept.	1		27				1			1						1		31	0.5
	22 Sept.		2	23		2	2												29	0.3
	6 Oct.	1		39			7	1										1	49	1.1
	20 Oct.	3		13		4												3	23	0.6
	Total	28	7	348		7	9	318	257		392	3	7		2		1	19	1,398	7.4

Appendix Table 1.—Continued.

Station	Date	Annelida						Arthropoda				Mollusca						Nemertinea	Totals	
		Nereidae	Terebellidae	Capitellidae	Maldanidae	Arenicolidae	Unidentified	Ampiliscidae	Corophiidae	Pinnotheridae	Unidentified	Tellinidae	Solecurtidae	Mactridae	Mytilidae	Solenidae	Semelidae	Identified only to phylum	Number	Volume
7	25 Mar.			1					17		104		2						124	0.2
	8 Apr.	3		5				1			11		1						21	0.2
	22 Apr.	1		7			1	14			4							2	29	0.2
	6 May	2		12			2	44			6							3	69	0.6
	20 May	11	1	28			1	22			1							2	66	1.6
	6 June			13				2			3							1	19	0.3
	17 June	2	2	4				1	1										10	0.3
	1 July	5		11				2											18	0.2
	15 July	4		11															15	0.2
	28 July	9		6				1											16	0.7
	11 Aug.	10		20				3			1		1						35	7.5
	25 Aug.	7		21														1	29	0.6
	8 Sept.	3		15														1	19	0.5
	22 Sept.	6		36				2										2	46	0.5
	6 Oct.	2		14														2	18	0.4
	20 Oct.	3			2														5	0.1
	Total	68	3	204	2		4	92	18		130		4					14	539	14.1
8	25 Mar.		1	9			1		9		76								96	0.2
	8 Apr.	2		3		1			33		49		2					2	92	0.3
	22 Apr.	2		20		2	1	10	20		68		2					3	128	0.4
	6 May	4		15				18			3							1	41	0.3
	20 May			18				5											23	0.2
	6 June	3		9			1	18										2	33	1.3
	17 June	2		22				7										3	34	0.3
	1 July	1		26				1										1	29	0.3
	15 July			9															9	0.1
	28 July	3		3															6	0.4
	11 Aug.	1	4	14				5										4	28	0.2
	25 Aug.	6		18														3	27	0.3
	8 Sept.	3	2	26														4	35	1.2
	22 Sept.	4	1	30									2				1	4	42	4.5
	6 Oct.	5		31			1											2	39	0.7
	20 Oct.			15													2		17	0.4
	Total	36	8	268		3	4	64	62		196		6				3	29	679	11.1

Appendix Table 2.—Numbers of animals caught by station, date, taxon, and volume of two samples in center of waterway.

		Annelida						Arthropoda			Mollusca				Nemertinea	Totals	
Station	Date	Nereidae	Terebellidae	Capitellidae	Maldanidae	Arenicolidae	Unidentified	Ampiliscidae	Corophiidae	Unidentified	Tellinidae	Solecurtidae	Solenidae	Semelidae	Identified only to phylum	Number	Volume
1	25 Mar.			37						2						39	0.3
	8 Apr.			36						14						50	1.4
	22 Apr.			91												91	0.2
	6 May			72												72	0.8
	20 May			21												21	0.4
	6 June			15												15	0.4
	17 June			6												6	0.1
	1 July			8												8	0.1
	6 Oct.						2									2	0.1
	20 Oct.			4												4	0.1
	Total			290			2			16						308	3.9
4	25 Mar.			4				6			2			6		18	1.1
	8 Apr.			16							12				2	30	0.4
	22 Apr.			5				18	2		2					27	0.2
	6 May			31				2							2	35	0.2
	20 May			12												12	0.2
	6 June		1	13				2								16	0.2
	17 June			118							2					120	0.8
	1 July			18											2	20	0.2
	15 July	1														1	0.2
	8 Sept.			6												6	0.1
	6 Oct.			4												4	0.2
	20 Oct.	2		2			1	4								9	0.2
	Total	3	1	229			1	32	2		18			6	6	298	4.0
6	25 Mar.		2	21			2	28	6							59	0.8
	8 Apr.			11					11	3						25	0.4
	22 Apr.			12				34								46	0.2
	6 May			24				6		2						32	0.2
	20 May			11											2	13	0.1
	6 June	4		15				2		3						24	0.8
	17 June	4		10				25								39	0.6
	1 July	2														2	0.1
	15 July			2												2	0.1
	28 July			12										2	2	16	0.6
	11 Aug.	7		2												9	0.1
	25 Aug.			10												10	0.1
	8 Sept.			12											2	14	0.1
	22 Sept.			6											2	8	0.1
	6 Oct.	3					2	3								8	0.1
	Total	20	2	148			4	98	17	8				2	8	307	4.4

Appendix Table 2.—Continued.

Station	Date	Annelida: Nereidae	Annelida: Terebellidae	Annelida: Capitellidae	Annelida: Maldanidae	Annelida: Arenicolidae	Annelida: Unidentified	Arthropoda: Ampiliscidae	Arthropoda: Corophiidae	Arthropoda: Unidentified	Mollusca: Tellinidae	Mollusca: Solecurtidae	Mollusca: Solenidae	Mollusca: Semelidae	Nemertinea: Identified only to phylum	Totals: Number	Totals: Volume
7	25 Mar.		2	12				40	3	2				2	2	63	0.4
	8 Apr.			18		2	4	72	2							98	1.5
	22 Apr.			8				42			2					52	0.4
	6 May			22			2	62							4	90	0.6
	20 May			34			3	10							2	49	0.6
	6 June			4			2								2	8	0.2
	17 June			26				2								28	0.2
	1 July	10		10												20	0.8
	15 July			14												14	0.4
	28 July		4	4												8	0.2
	11 Aug.	12		12												24	0.6
	25 Aug.			14												14	0.2
	8 Sept.	2		15											2	19	0.2
	22 Sept.	5		34			7									46	0.4
	6 Oct.	11		4			2									17	0.4
	20 Oct.			10											2	12	0.6
	Total	40	6	241		2	20	228	5	2	2			2	14	562	7.7
8	25 Mar.			68				6		4		16		4		98	3.0
	8 Apr.		2	30				8		2		14				56	1.2
	22 Apr.		2	68			12	188	7	2	2	12		2		295	5.2
	6 May			48				53		2	2					105	2.8
	20 May	10	2	94				8		1	2	2		2		121	4.0
	6 June			98				2				4				104	7.0
	17 June	2	2	94				22			2					122	1.0
	1 July	6		54	6		4	24		2		2				98	2.6
	15 July			86			2	2				2			2	94	4.0
	28 July			70											2	72	0.4
	11 Aug.	4		132								6				142	16.4
	25 Aug.		2	84								2				88	0.4
	8 Sept.			40								2			2	44	0.2
	22 Sept.	2		2											2	6	0.2
	6 Oct.			74			21					2		2	2	101	0.8
	20 Oct.		2	58												60	0.6
	Total	24	12	1,100	6		39	313	7	13	8	64		10	10	1,606	49.8
10	25 Mar.			5							2		2	5		14	0.4
	8 Apr.			2				1					4			7	0.2
	22 Apr.			3				3			1		2	2		11	0.8
	6 May			16			2				3			7		28	0.6
	20 May		1	17										2		20	0.6
	6 June			19												19	0.1
	17 June	3	1	13											1	18	0.2
	1 July	3		8			6								1	18	0.2
	15 July			7										2		9	0.3
	28 July			36										1		37	0.3
	11 Aug.	5		19										3	1	28	0.2
	25 Aug.			13			10									23	0.2
	8 Sept.			6			7							1		14	0.2
	22 Sept.	4		14										1		19	0.3
	6 Oct.			8			28									36	0.2
	20 Oct.			2			17									19	0.3
	Total	15	2	188			70	4			6		8	24	3	320	5.1