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C.B. Subrahmanyam
Florida A&M University

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MACROINVERTEBRATE COLONIZATION OF THE INTERTIDAL HABITAT OF A DREDGE SPOIL ISLAND IN NORTH FLORIDA

C. B. Subrahmanyam
Wetland Ecology Program
Florida A & M University
Tallahassee, FL 32307

Abstract: Macroinvertebrate colonization of the intertidal habitat of a dredge spoil island was studied for one year by collecting triplicate 0.0625-m² x 10-cm core samples of substratum from four stations established relative to the slope of the habitat. Fauna first colonized the subtidal site, and after lapses of time appeared respectively at low, mid and high-tide stations. The total abundance and diversity of the assemblage increased significantly in the latter half of the year mainly due to the appearance of late colonizers at low and mid-tide stations. The temporal abundance patterns at the four stations were variable. Several species that initially appeared at low tide station later aggregated at other stations. While no discrete species groups formed at each station, the relative abundances of several species were related to tidal exposure gradient. This phenomenon was reflected in the species dominance hierarchy at the four stations and spatial distributions in the intertidal zone. Equilibrium between extinction and immigration rates of species did not occur within the year. The intertidal assemblages as a whole did not show stability of species composition or species abundance.

INTRODUCTION

The material dredged for deepening a boat channel in Dickerson Bay, near Panacea, was dumped in October 1975 on one side of the channel over a *Thalassia* bed and a sandbar. Within a month, the dredge spoil developed into a 1-ha island with a 4,796-m² intertidal zone. A fortuitous opportunity thus became available to study the infaunal macroinvertebrate colonization of a new habitat. It was expected that some useful information may be obtained on the spatial and temporal patterns of species during the developmental stages of an intertidal community, even though a similar natural site was unavailable in the vicinity for making comparisons. The hypothesis was that discrete species assemblages with respect to tidal elevation might develop, perhaps with some overlap of species occurrence among the four chosen sampling sites. Differential vertical distribution of species in intertidal areas has been reported for a natural habitat (Holland and Dean, 1977), for a recolonized habitat (Dauer and Simon, 1976a, 1976b), and for a newly colonized marsh habitat (Cammen, 1976).

The available literature pertains to colonization patterns of species on submerged dumps (McCall, 1977; Rhoads *et al.*, 1977, 1978), recolonization of dredged sea floor (Reish, 1961, 1962, 1963; Taylor and Salomon, 1968; Taylor *et al.*, 1970; Connor and Simon, 1979), recolonization of a previously defaunated intertidal habitat (Dauer and Simon, 1976a, 1976b; Simon and Dauer, 1977), species abundance patterns on sea floor following pollution (Dean and Haskins, 1964; Leppakowski, 1971; Rosenberg, 1976) and recruitment patterns following natural annual defaunation (Santos and Simon, 1980). The only study on colonization of a new intertidal habitat is that of Cammen (1976), who observed differences in species composition relative to elevation between bare and planted dredge spoils.

The present report deals with the colonization sequence of macroinvertebrates and the temporal and spatial variations of their abundance in the intertidal zone of the dredge spoil.

MATERIALS AND METHODS

The location of the dredge spoil island at the mouth of Dickerson Bay, which was bordered by *Juncus* marshes, is shown in Fig. 1. In November 1975 a transect 16-m long and 30-m wide was established for the study. Because water at high tide ascended horizontally 16 m above the mean low level over the slope of the intertidal zone, one station was located 8 m below mean low (subtide station = ST), the second at mean low (low-tide station = LT), the third 8 m above mean low (mid-tide station = MT), and the fourth 8 m above mean low MT at high level (high-tide station = HT). Stakes driven in sand at 8 m intervals marked station locations. The tidal amptitude of the bay averaged 120 cm. At high tide, the normal water depths at ST, LT, MT and HT respectively were 1 m, 50 cm, 20 cm and 10 cm. At low tide, both MT and HT were exposed, LT was moist and ST was always submerged.

Exact sampling locations for each month at each station were determined from a grid using a table of random numbers. Triplicate sediment samples, collected from the grassbed and sandbar prior to dredging and from the four stations in November 1975, were analysed for grain size distribution (Folk, 1966) and carbon and nitrogen contents (Soil Survey Manual, 1951). One-way ANOVA was used to test site differences in these soil characteristics.

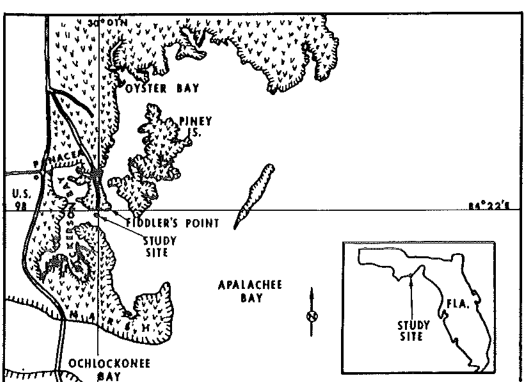

Figure 1. The location of the dredge spoil island near Panacea in the Dickerson's Bay, an arm of the Apalachee Bay in north Florida.

From November 1975 to November 1976, monthly triplicate 0.0625-m^2 x 10-cm core samples of substratum were collected from the four stations. Specimens retained on both 1 mm and 0.5 mm mesh screens were preserved in the field in 10% sea water formalin stained with rose bengal (Mason and Yevich, 1967). For species counts, if any specimens were not whole, only the heads of crustaceans and broken worms were considered, and oligochaetes were treated as a single taxon. During the study period, salinity varied between 20 and 30‰ and water temperature between 12 and 30°C.

Various computations and statistical analyses used for specific purposes are as follows: (a) simple linear corrletations between species numbers (S) and numbers of organisms (N) to determine their relationship; (b) one-way hierarchial classification ANOVA using raw species counts from monthly triplicate samples (not averages) to test differences in N and S among stations over the 13 months; (c) Sander's (1960) technique to determine the dominance sequence of species at each station based on their biological importance (BI) in monthly samples; (d) derivation of information content measures-diversity H′ (Shannon-Weaver), species richness D and evenness of species distributions J′ to evaluate development of the community in terms of the number of colonizing

Table 1. Sediment analysis of a sand bar and seagrassbed before dredging, and the four stations in the intertidal zone of the island shortly after construction. Particles size analysis: sø = standard deviation, sk = skewness, k_g = kurtosis.

	Mean Grain Size		Median Grain Size		Statistics			Soil Factors			
Area	ø	mm	ø	mm	sø	sk	k_g	%Sand	%Clay-Silt	%N	%C
Sand Bar	1.76	0.30	1.75	0.30	0.82	-0.10	0.98	97.9	2.1	0.02	0.16
Grassbed	2.20	0.22	2.10	0.23	1.16	0.60	0.97	91.8	8.2	0.05	0.58
Sub Tide	1.38	0.40	1.45	0.37	0.85	-0.02	1.10	99.9	0.1	0.01	0.10
Low Tide	1.23	0.42	1.30	0.41	0.72	-0.18	1.21	99.5	0.5	0.01	0.10
Mid Tide	1.73	0.31	1.80	0.29	0.83	-0.13	0.96	99.3	0.7	0.01	0.09
High Tide	1.45	0.37	1.50	0.36	0.78	-0.52	1.09	99.6	0.4	0.00	0.05

Coarse sand = 0.5 to 2 mm diameter; Medium sand = 0.25 to 0.5 mm; Fine sand = 0.05 to 0.25 mm.

species and their relative abundances; (e) similarity index Cλ (Morisita, 1959; Horn, 1966) to assess degree of overlap of species in temporal and spatial context; and (g) technique of Cairnes *et al.*, (1969) to derive extinction and immigration rates of species and to detect any trends of equilibrium between the two rates.

RESULTS

Table 1 shows the characteristics of substratum of the original grassbed and sandbar and the four stations. Only the grassbed sediments contained significantly higher silt-clay and organic contents than the sandbar and spoil island sediments. The sediment at the four stations was composed of moderately sorted medium sand and traces of silt-clay, nitrogen and carbon. Though median grain size at MT was the smallest, the soil characteristics were not significantly different among ST, LT, MT and HT (ANOVA, P>0.05). The grain size composition of the sediments did not change significantly at the end of the study period.

Patterns of Abundance

Figure 2 represents seasonal trends in total density (all species) and density partitioned into major taxonomic groups. The most obvious trend was that only at ST initial abundance was high followed

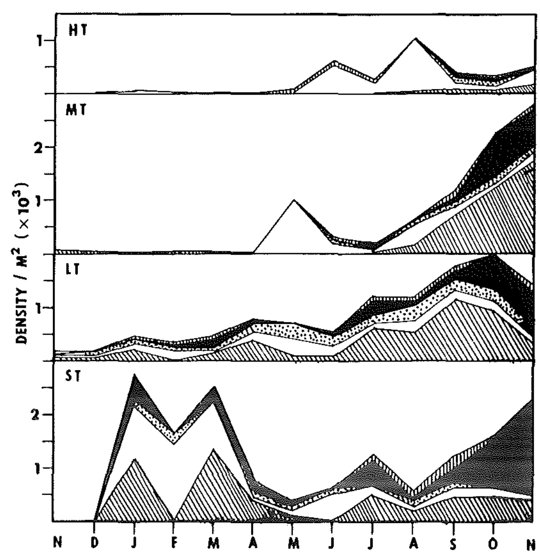

Figure 2. Seasonal patterns of total community abundance at subtide (ST), low tide (LT), mid tide (MT) and high tide (HT) stations partitioned into polychaetes (slanted bars), crustaceans (blank), molluscs (stipled), oligochaetes (solid) and other (vertical bars).

by a decrease and a subsequent increase in the last two months. At LT and MT densities were low in the beginning but rose in the last four months. At HT, a general decrease in the last four months was seen. There was also a five month time lag between the colonization of ST and LT, and MT and HT.

The five taxa showed different temporal patterns: Polychaete abundance decreased with time at ST but increased at LT, MT and HT; crustacean density dropped in the latter part of the year at all the stations except LT; molluscs maintained low abundance at all stations, but oligochaete density increased in the last four months at ST, LT and MT. Because of these patterns of differential colonization of the four groups, the relative monthly proportions of these taxa were highly variable at each station.

The average densities of the entire community as well as those of polychaetes, crustaceans, molluscs and oligochaetes showed a decreasing trend from ST to HT and the coefficients of variation of relative abundances (N) and number of species (S) were extremely high, especially at MT and HT (Table 2). The F values in ANOVA indicated significant differences among the four stations for total and molluscan abundances, and highly significant differences among months except for molluscs (Table 3).

The monthly fluctuations of the total and polychaete, crustacean and molluscan densities were closely related to those of species numbers except at HT as indicated by the significant correlation coefficients (Table 4). This positive association between N & S is evident from the graphic representation in Figure 3.

Patterns of Diversity

The fluctuations of diversity (H'), species richness (D) and evenness (J') for the total community are illustrated in Fig. 4. At ST and LT diversity fluctuated moderately but at MT and HT in increased signicantly toward the end of the year. Species richness, on the other hand, registered elevation at all stations in the latter part of the year. Evenness varied

Table 2. The mean (per sample = $0.0625 m^2$), variance (S^2) & coefficient of variation (C.V.) of community parameters at the four tide level stations on Panacea Island in 1975-76 for various taxa.

STATION·ITEMS		N			S			H'			D			J'		
		m	s^2	C.V.	m	s^2	C.V.	m	s^2	C.V.	m	s^2	C.V.	m	s^2	C.V.
SUB.	Total	110.7	1065.8	88.5	13.6	54.1	54.0	1.6	0.7	51.6	1.7	0.8	51.2	0.4	0.07	72.2
	Polychaetes	24.0	115.9	134.6	5.7	19.9	78.2	1.2	0.7	73.0	0.8	0.4	78.5	0.5	0.13	76.6
	Crustaceans	22.1	177.0	172.8	3.7	4.9	59.8	0.8	0.2	59.3	0.5	0.08	58.0	0.5	0.11	66.0
	Molluscs	3.3	3.0	152.2	1.8	4.0	110.8	0.5	0.4	120.5	0.3	0.1	125.6	0.4	0.2	115.2
	Oligochaetes	18.9	143.2	189.9	—	—	—	—	—	—	—	—	—	—	—	—
LOW	Total	75.0	1084.1	131.7	19.5	68.3	42.4	2.0	0.2	22.6	2.7	0.9	35.7	0.4	0.03	42.8
	Polychaetes	22.5	101.4	134.2	9.5	23.3	50.7	1.6	0.4	38.0	1.5	0.5	46.3	0.6	0.03	27.9
	Crustaceans	12.0	16.3	101.0	4.8	6.3	52.3	1.1	0.3	52.3	0.8	0.2	51.9	0.5	0.09	58.8
	Molluscs	2.4	1.4	153.3	2.5	6.3	100.0	0.7	0.6	115.9	0.6	0.3	123.0	0.4	0.2	102.2
	Oligochaetes	9.0	38.8	209.6	—	—	—	—	—	—	—	—	—	—	—	—
MID	Total	53.4	923.7	107.7	10.1	120.2	108.6	1.2	0.6	63.6	1.4	2.0	103.1	0.5	0.14	73.9
	Polychaetes	19.5	170.8	201.1	4.0	26.3	128.3	0.6	0.7	132.3	0.6	0.6	136.2	0.2	0.08	140.0
	Crustaceans	11.1	71.1	227.8	3.5	9.3	86.8	0.6	0.4	104.0	0.5	0.33	109.6	0.3	0.11	106.4
	Molluscs	1.2	1.1	260.8	1.5	5.3	153.0	0.4	0.4	165.7	0.5	0.2	173.7	0.2	0.1	159.1
	Oligochaetes	9.9	96.8	295.5	—	—	—	—	—	—	—	—	—	—	—	—
HIGH	Total	15.3	62.1	154.5	4.5	20.3	100.0	0.7	0.5	109.2	0.6	0.5	83.1	0.4	0.06	66.2
	Polychaetes	1.2	1.6	313.1	1.2	5.6	198.3	0.3	0.3	200.0	0.2	0.2	215.0	0.4	0.13	100.0
	Crustaceans	12.6	56.1	178.4	2.0	4.5	106.1	0.4	0.2	105.3	0.3	0.08	100.0	0.3	0.13	116.1
	Molluscs	0.6	0.3	391.1	0.2	0.2	219.4	0.0.	—	—	—	—	—	—	—	—
	Oligochaetes	0.3	0.2	383.5	—	—	—	—	—	—	—	—	—	—	—	—

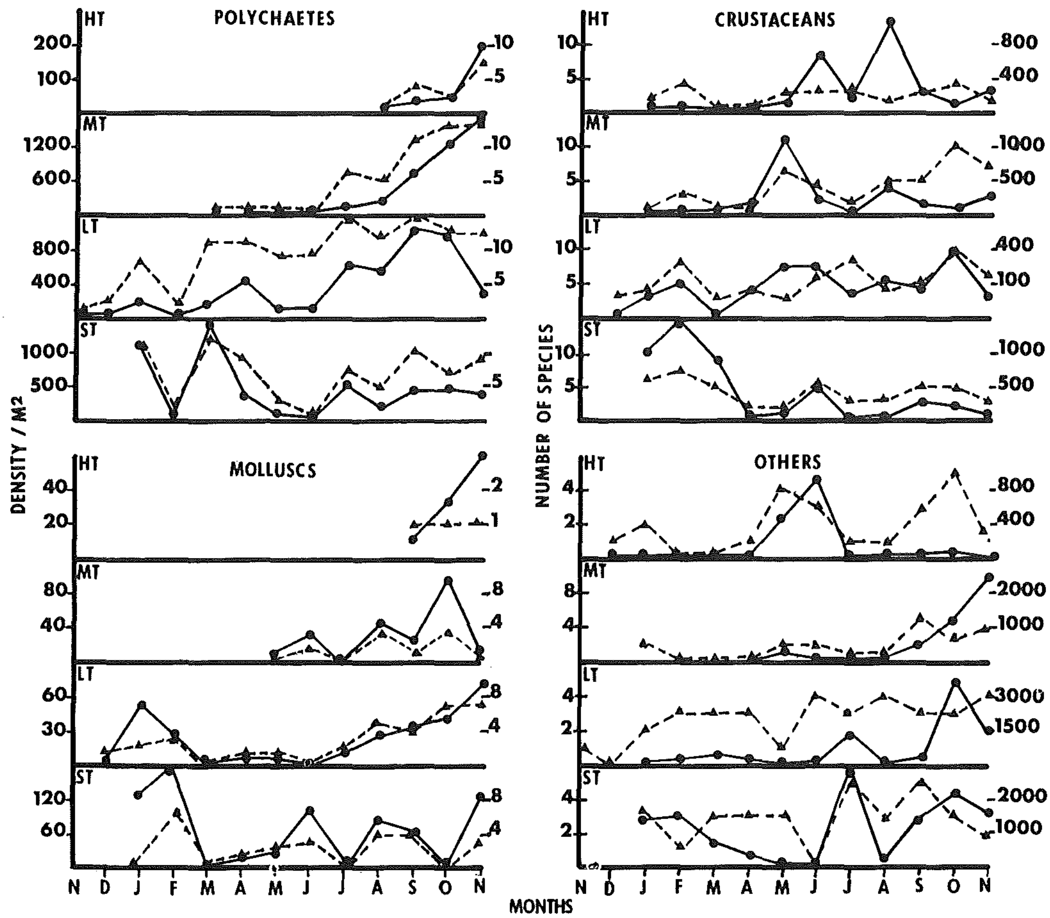

Figure 3. Seasonal patterns of total abundance (solid line) and numbers of species (broken line) of the four taxonomic groups at the four intertidal stations on dredge spoil island.

Table 3. One way heirarchial classification analysis of variance of total density, and densities of various taxa. Degrees of freedom for differences among stations = $^{3}/_{48}$; for months within stations (experimental error) = $^{48}/_{14}$. Means (per sample), and coefficient of variation for densities, over 13 months & 4 stations are also given.

Item	Source	F Value	Mean/sample (std. deviation)	C.V.%
Total density	stations	3.70*	63.6/129.9	204.5
	months	6.72**		
Polychaetes	stations	2.27	16.5/43.2	261.8
	months	4.55**		
Crustaceans	stations	0.98	14.7/35.4	240.8
	months	2.61**		
Molluscs	stations	3.37*	1.9/4.3	226.3
	months	0.99		
Oligochaetes	stations	1.87	9.5/34.8	366.3
	months	3.42**		

* Significant at 0.05 level; ** Significant at 0.01 level.

Table 4. Coefficients of correlation (r) between density (N) and species numbers (S) during colonization of dredge spoil island (df = 12) * = P < 0.05; ** = P <0.01.

TAXON	STATIONS			
	ST	LT	MT	HT
All Taxa	0.74**	0.77**	0.84**	0.45
Polychaetes	0.86**	0.77**	0.92**	—
Crustaceans	0.76**	0.63*	0.48	0.29
Molluscs	0.82**	0.53*	0.92**	—
All Taxa over all stations 0.91**				

less at LT than at the other three sites, and particularly at MT initial evennes was higher. Coefficients of variations indicated (Table 2) that both H′ and D were the most variable at HT and the least at LT, and J′ changed almost to the same extent at ST and MT and least at ST. It appears therefore that evenness accounted largely for diversity fluctuations at ST and LT, and species richness influenced diversity more than J′ at MT and HT (Table 2). The mean diversity for the year was highest at LT, and considerably lower at HT. The same trend is seen for species richness. The mean evenness, on the other hand, was not significantly different at the four stations (Table 2). This suggests that species diversity was negatively related to tidal elevation, at least in the earlier part of the study.

The diversity patterns of the three taxonomic groups-polychaetes, molluscs and crustaceans-present a slightly different picture. Based on coefficients of variation, polychaete H′ varied most at HT, crustacean H′ at both MT and HT, molluscan H′ at MT. Species richness was the most variable at HT for crustaceans, and at MT for molluscs (Table 2). It appears therefore that the monthly fluctatuations of H′ were largely influenced by either D or J′ and not by both to the same degree for the three groups at different stations.

Patterns of Species

The species that appeared in the first or second month after the island was established (pioneers) were: polychaetes *Glycera americana, Capitella capitata,* and *Macroclymene elongata*; isopods *Apanthura magnifica* and *Cyathura polita;* amphipods *Ampelisca verrilli* and *Monoculodes edwardsi;* bivalves *Brachidontes exustus, Amygdalum papyria*, and *Gemma gemma purpurea*; and *gastropod Haminoea succinea.* Of these, *C. capitata*, *C. polita* and *B. exustus* disappeared the following month. The rest and oligochaetes later became important members of the intertidal community. Of the 24 species

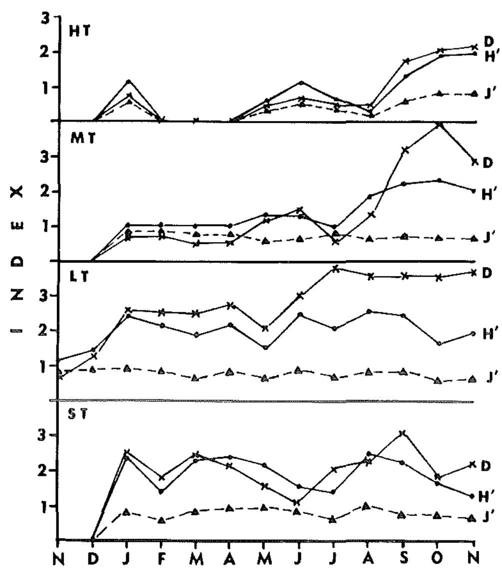

Figure 4. Seasonal patterns of total community diversity (H′), species richness (D) and evenness (J′) at the four intertidal stations on dredge spoil island.

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encountered in the sandbar before dredging and 20 in the grassbed, seven and 14 species respectively never appeared on the spoil island. The pioneers on the island mentioned earlier were not noticed either in the sandbar or grassbed but have been reported from the general area (Menzel, 1971).

During the year, the total number of species encountered were 51 at ST, 63 at LT, 51 at MT and 25 at HT. A complete list and their relative numerical abundances are available from the author.

The temporal and spatial patterns of the 12 dominant species are illustrated in Fig. 5. Three categories of seasonal patterns were recognized: (a) initial high abundance followed by a decline in the latter part of the year (*Sabella microphthalma, Ampelisca verrilli, Monoculodes edwardsi*); (b) low initial and higher densities in the second half of the year (*Apanthura magnifica, Exosphaeroma productatelson, Scoloplos fragilis, Laeonereis culveri, Nerine agilis, Aricidea fragilis*); and (c) low abundance throughout the year with small monthly fluctuations (*Glycera americana, Maldane sarsi, Eteone heteropoda*).

The seasonal patterns of these species also showed different vertical profiles (related to tide levels) (Fig. 5). *Glycera americana, A. magnifica, Maldane sarsi, Sabella microphthalma* and A. verrilli first occurred at ST (in high density) and at LT (in low density), but the

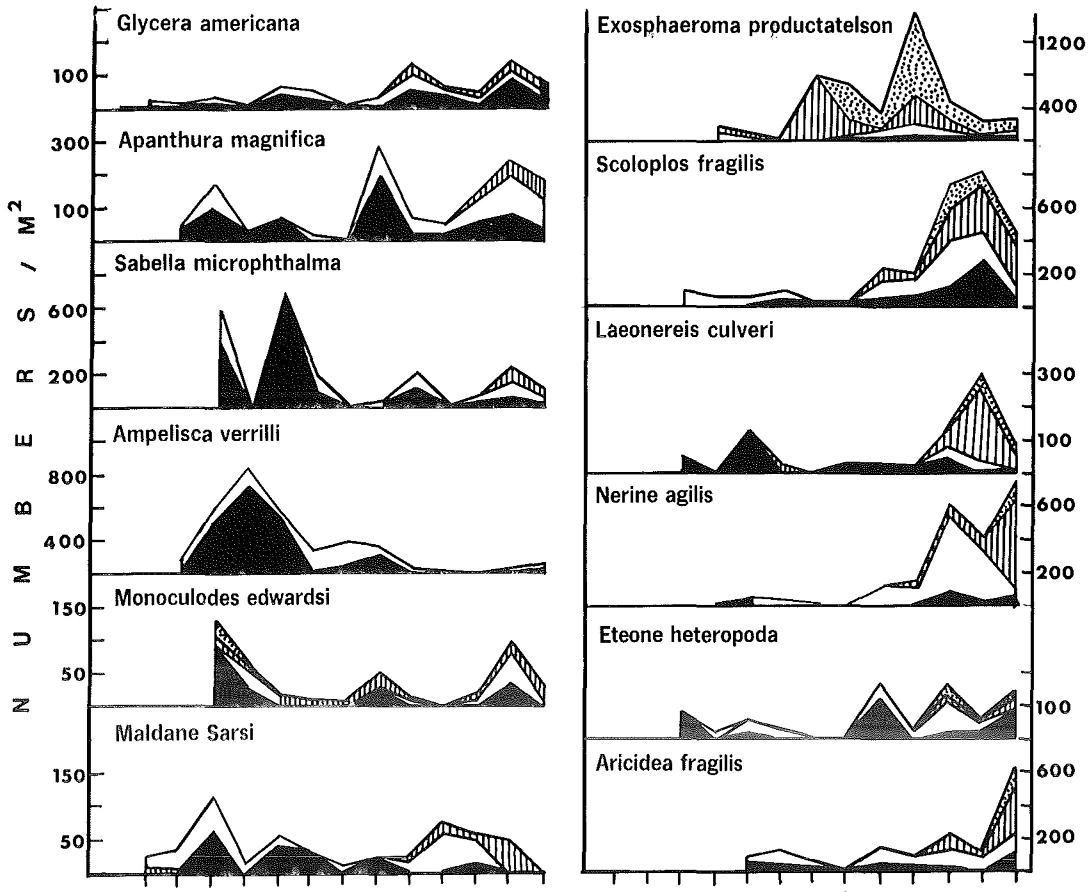

Figure 5. Seasonal and spatial distribution patterns of twelve numerically dominant infaunal macroivertebrates in the intertidal zone of dredge spoil island. ST = solid black, LT = blank space, MT = vertical bars, HT = stipling.

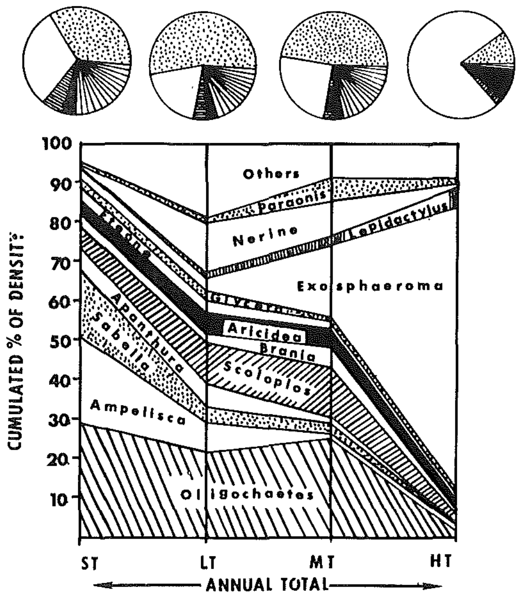

Figure 6. Vertical distribution of important species in relation to tide level based on annual cumulative density percentages, and the proportions of the five taxonomic groups at ST, LT, MT, HT in pie diagrams. Stipled = polychaetes, vertical lines = oligochaetes, black = others, horizontal lines = molluscs, blank = crustaceans.

first three spread to MT toward the end of the year. The locus of abundance of these species however was ST. *Monoculodes edwardsi* appeared at all sites initially (high density at ST) but later disappeared from HT. *Exosphaeroma productatelson* colonized MT first and maintained fairly large densities at MT and HT. *Laeonereis culveri, Scoloplos fragilis, Nerine agilis, Eteone heteropoda* and *Aricidea fragilis* occurred initially at ST or LT but toward the end of the year spread vertically to all stations.

The species that occurred only at a particular station once or twice and never established constant populations were: at ST-*Pinnixia chaetopterana, Fabricia* sp., *Ampelisca abdita, Corophium louisianum, Brachidontes exustus,* and *Tharyx setigera;* at LT-*C. polita, Phacoides* sp., *Anachis avara, Arabella iricolor, Diopatra cuprea, Polydora ligni, Tagelus plebius,* and *Tellina* sp., and at MT-*Olivella* sp., and *Apoprionospio pygmaea.* Tabanid larvae persisted at HT and were unique to the site.

When the temporal patterns of the important species are summarized on an annual basis, the spatial distributions in relation to tide levels become clear even though most of the species occurred at all sites (Fig. 6). The relative proportions of the four major taxa at the four tide levels also were variable. Polychaete and mollusc abundance dwindled at HT while crustacean ratio was higher. The ratios at ST, LT, MT and HT respectively were as follows: polychaetes 33.7%, 53.5%, 47.8% and 9%; crustaceans 31.3%, molluscs 3.7%, oligochaetes 22.9% and others 3.0%. The species included in the "other" category were not identical for the four stations. At ST and LT nemertines, tanaidaceans and brachiopods constituted "others," and at MT and HT tabanid larvae were also part of this group.

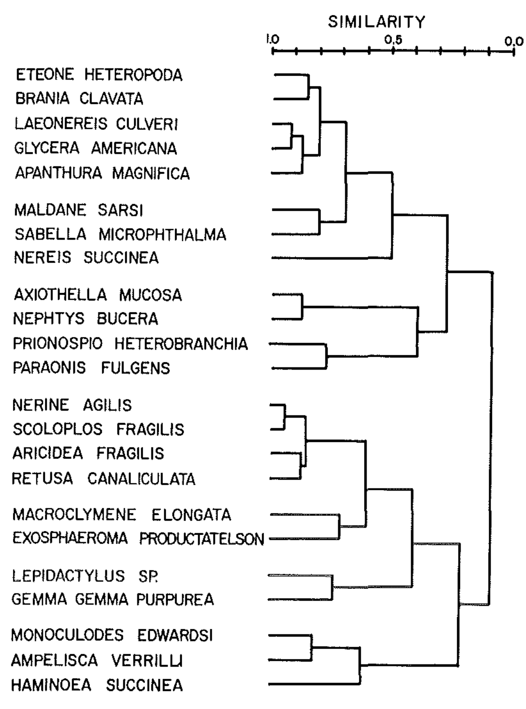

Figure 7. Dendrogram representing temporal and spatial associations of infaunal species in the intertidal zone of dredge spoil island. Clusters represent species that cooccur on monthly basis.

The dominant species at each station are arranged in hierarchial sequence based on BI and numerical percentage ratios in Table 5. It is seen that the percentage-basėd and BI sequences were not similar which is to be expected. Shifts in dominance among the four stations were obvious, and these correlated with the spatial patterns of important species in the intertidal zone (Figs. 5 & 6). Polychaete species dominated in abundance and biological importance at ST, LT and MT.

The overlap of species occurrence among the four stations were also reflected in the Morisita's Index of Affinity. Similarity between adjacent stations increased with progression of time as follows: ST and LT from 0.67 in January to 0.90 in October; LT and MT from 0.24 in January to 0.75 in October; MT and HT from 0.09 in May to 0.80 in August. The annual mean index values were 0.64 for ST and LT, 0.31 for LT and MT and 0.34 for MT and HT.

Another aid to understand station similarities was the examination of cooccurrence of species in space and time. Cluster analyses revealed seven species groups shown in Fig. 7. The group I species occurred at least at three stations and in greater number toward the end of the year (Fig. 7). Group II species was more numerous initially and declined later. Species in group III occurred in small numbers throughout the year. The density of group IV species rose significantly during the last three months, and spread among all four stations. *Macroclymene elongata* was more abundant at ST and LT, and *Exospaeroma productatelson* at MT and HT

Table 5. The dominant species at four tide level stations of dredge spoil island based on Biological Importance (BI), frequency of occurrence ($^F/_{13}$), numerical percentages (%) and their rankings (R)

SPECIES	BI	F	R	%	R	SPECIES	BI	F	R	%	R
SUBTIDE						**LOW TIDE**					
Oligochaetes	74	10	1	28.8	1	Oligochaetes	66	10	1	21.4	1
Ampelisca verrilli (A)	56	7	2	21.8	2	*Scoloplos fragilis* (P)	60	9	2	9.6	3
Aricidea fragilis (P)	48	8	3	2.8	7	*Ampelisca verrilli* (A)	56	8	3	7.7	4
Apanthura magnifica (I)	45	9	4	4.5	5	*Apanthura magnifica* (I)	55	10	4	5.6	6
Sabella microphthalma (P)	44	6	5	11.0	3	*Aricidea fragilis* (P)	50	9	5	6.1	5
Scoloplos fragilis (P)	43	8	6	5.1	4	*Nerine agilis* (P)	40	7	6	12.4	2
Glycera americana (P)	29	6	7	1.8	9	*Maldane sarsi* (P)	43	9	7	2.4	9
Exosphaeroma productatelson (I)	27	5	8	1.6	10	*Glycera americana* (P)	37	7	8	2.4	9
Brania clavata (P)	24	5	9	3.9	6	*Macroclymene elongata* (P)	34	5	9	2.3	10
Monoculodes edwardsi (A)	23	4	10	1.3	11	*Axiothella mucosa* (P)	29	6	10	1.0	12
Axiothella mucosa (P)	23	4	10	1.1	12	*Sabella microphthalma* (P)	29	7	10	4.0	7
Eteone heteropoda (P)	22	4	11	2.5	8	*Exosphaeroma productatelson* (I)	25	6	11	3.6	8
Haminoea succinea (G)	22	4	11	1.6	10	*Eteone heteropoda* (P)	19	5	12	2.2	11
Laeonereis culveri (P)	20	4	12	1.6	10						
MID TIDE						**HIGH TIDE**					
Exosphaeroma productatelson (I)	69	8	1	17.4	2	*Exosphaeroma productatelson* (I)	58	6	1	73.4	1
Scoloplos fragilis (P)	43	5	2	12.8	3	*Tabanid* larvae (In)	46	7	2	3.2	3
Nerine agilis (P)	40	5	3	9.1	4	*Scoloplos fragilis* (P)	26	4	3	2.2	5
Oligochaetes	33	4	4	24.7	1	Oligochaetes	24	3	4	1.5	6
Monoculodes edwardsi (A)	32	4	5	0.7	14	*Gemma gemma purpurea*	23	3	5	3.2	3
Maldane sarsi (P)	25	4	6	0.9	13	*Lepidactylus* sp. (A)	21	3	6	5.3	2
Aricidea fragilis (P)	20	4	7	5.0	6	*Monoculodes edwardsi* (A)	20	2	7	0.9	8
Lepidactylus sp. (A)	20	3	7	1.9	9	*Uca pugilator* (D)	18	3	8	0.7	9
Leaonereis culveri (P)	20	3	7	4.6	7	*Ampelisca verrilli* (A)	17	2	9	0.4	10
Ampelisca verrilli (A)	16	4	8	1.2	11	*Paraonis fulgens* (P)	14	2	10	0.9	8
Paraonis fulgens (P)	15	2	9	5.8	5	*Eteone heteropoda* (P)	10	2	11	0.4	10
Eteone heteropoda (P)	14	2	10	1.2	11	*Aricidea fragilis* (P)	8	1	12	3.0	4
Glycera americana (P)	11	3	11	1.0	12						
Sabella microphthalma (P)	8	3	12	1.4	10						
Brania clavata (P)	7	1	13	4.1	8						

TAXA: A = amphipod, D = decapod, G = gastropod, I = isopod, In = insect, P = polychaete (group V). *Lepidactylus* sp. and *Gemma gemma purpurea* were less common, and were noticed mostly at MT and HT (group VI). All the three species in group VII has similar seasonal patterns of density and were important only at two stations. These species groups thus reveal the associations reflecting their temporal and spatial distribution patterns.

Immigration Patterns

The data on species numbers computed for the three major taxa over all stations for each month exhibited a general increase in the number of species during the last four months of the year: polychaetes 23-40, crustaceans 14-26, molluscs 6-15. An equilibrium between immigration and extinction was not discernable from the data set as seen from the plots for each station (Fig. 8). Both these processes fluctuated temporally, however, recurring species numbers also increased toward the latter part of the year (19-24 polychaetes, 10-13 crustaceans, 7 molluscs). Though some species occurred regularly, immigration and extinction were appararently active throughout the period of study.

DISCUSSION

The dredge island replaced an existing grassbed and sandbar that supported stable infaunal communities. The sandbar substratum was essentially

Table 6. Importance heirarchy of infaunal macroinvertebrates based on density (N/m²) in the sand bar and grassbed in Panacea Harbor, Florida, before dredging.

SANDBAR			GRASSBED		
Species	N	%	Species	N	%
Ampelisca verrilli	256	22.9	Ampelisca verrilli	1824	36.5
Apanthura magnifica	240	21.4	Sabella microphthalma	784	15.7
Glycera americana	80	7.2	Axiothella mucosa	544	10.9
Oligochaetes	64	5.8	Onuphis sp.	528	10.6
Nereis succinea	48	4.3	Arabella iricolor	272	5.8
Bowmaniella disimilis	48	4.3	Diopatra cuprea	240	4.8
Exosphaeroma productatelson	48	4.3	Erichsonella attenuata	160	3.3
Sabella microphthalma	32	2.9	Laeonereis culveri	144	2.9
Monoculodes edwardsi	32	2.9	Hippolyte zostericola	128	2.6
Polinices duplicatus	32	2.9	Ophuiroid	112	2.2
Prunum apicinum	32	2.9	Grandidierella bonnieroides	48	1.0
Eteone heteropoda	16	1.4	Nassarius vibex	48	1.0
Scoloplos fragilis	16	1.4	Amphicteis gunneri	32	0.6
Oxyurostylis smithi	16	1.4	Lysianopsis alba	32	0.6
Cerapus sp.	16	1.4	Laevicardium mortoni	16	0.3
Micropanope sp.	16	1.4	Crepidula convexa	16	0.3
Geukensia demissa	16	1.4	Apanthura magnifica	16	0.3
Pseudocyrena floridana	16	1.4	Pagurus longicarpus	16	0.3
Nassarius vibex	16	1.4	Penaeus duorarum	16	0.3
Olivella pusilla	16	1.4	Glycera americana	16	0.3
Retusa canaliculata	16	1.4			
Phasocolosoma gouldi	16	1.4			
Nemertine	16	1.4			
TOTAL	1120		TOTAL	4992	

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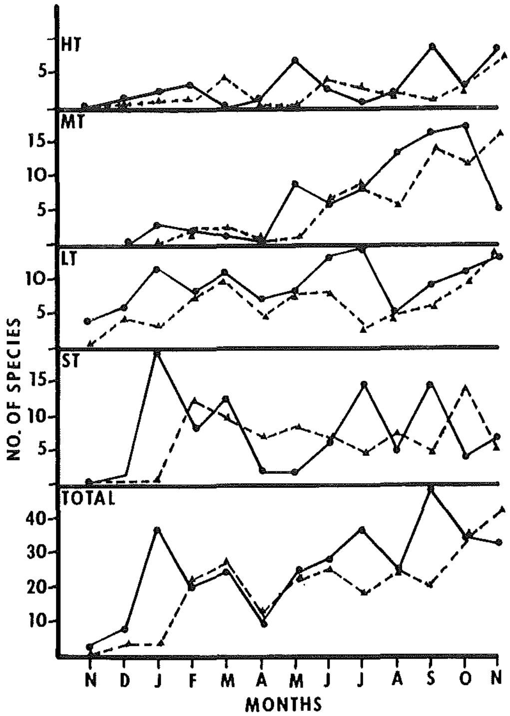

Figure 8. The immigration (solid line) and extinction (broken line) rates of species in the total community and at ST, LT, MT, and HT in the intertidal zone of dredge spoil island.

similar to that of the island's intertidal zone, but the grassbed sediment was different (Table 1). It was expected several of the sandbar species rather than the grassbed species would colonize the island's intertidal habitat. This proved to be true when faunal lists were compared (Table 6). Only *A. verrrilli, A. magnifica, G. americana* and *S. microphthalma* were common to the three habitats, and 17 of 24 sandbar species, and only six of 20 grassbed species appeared on the island. Ten of the 17 sandbar species became numerical dominants. No species from the adjacent marshes were expected to occur on the island because of obvious difference between the two habitats. However, 10 of 53 infaunal marsh species (Subrahmanyam and Coultas, 1980) colonized the island and four became numerical dominants — *S. fragilis, E. heteropoda, H. succinea* and *L. culveri.* Either these species are ubiquitous or are able to adapt to new environments as oppportunists. It was not surprising to find *A. mucosa, A. fragilis, B. clavata, N. agilis, M. sarsi, M. elongata, P. fulgens* (polychaetes), *G. gemma purpurea* (mollusc) and *Lepidactylus* sp., *M. edwardsi* (amphipods) and *E. productatelson* (isopod) on the island because they had been reported either from Apalachee Bay area or other sandy sediments (Carpenter, 1951; Schultz, 1969; Menzel, 1971; Bousfield, 1973; Leblanc, 1973). One noteworthy observation was the apparent allopatric distributions of two sphaeromid isopods *Sphaeroma quadridentatum* and *E. productatelson,* two anthurid isopods *C. polita* and *A. magnifica,* and two gammarid amphipods *G. bonnieroides* and *A. verrilli,* respectively in the salt marshes and sandy intertidal zone of the spoil island. This could very well be a case of niche segregation among related species, or differential adaptation to physical conditions.

More suspension feeders than deposit feeders were expected to colonize the spoil because of small grain size and negligible silt-clay in the sediments. However, out of 94 species collected only two polychaetes and the ten bivalves were filter feeders according to published information (Sanders, *et al.*, 1962; Santos and Simon, 1974; Barnes, 1980). Sanders (1958) established the optimal criteria of 0.18 mm grain size and 50-90% silt-clay for suspension and deposit feeders respectively. Whether these criteria are applicable to all estuarine environments is doubtful because several authors have not found a convincing relationship between the two substrate optima and trophic types (McNulty *et al.*, 1962; Nichols, 1970; Johnson, 1971; Bloom *et al.*, 1972; Santos and Simon, 1974; Kay and Knight, 1975;

Whitlatch, 1977; Subrahmanyam and Kruczynski, 1979; Subrahmanyam and Coultas, 1980). Probably, the deposit feeders on the island depended on tidal transport of organic material for nutrition, even though we found some detritus in the sand in the eighth month after the island was formed.

The numerical abundance generally increased in the latter half of the year even though seasonal fluctuations were seen. This was mostly due to the increasing number of species that were able to maintain relatively stable populations. This can be surmised with some confidence because of the significant correlation between species numbers and total abundance. A disadvantage is obvious in that comparisons of seasonal fluctuations of the present intertidal assemblage abundance with those of a natural community cannot be made because one was not available in the vicinity. Nevertheless, both species numbers and abundance could have stabilized later on because some authors have reported such trends (Cammen, 1976; Rhoads *et al.*, 1977; McCall, 1977). Stability in species numbers did not obviously occur because immigration and extinction rates did not reach an equilibrium within 13 months. Dauer and Simon (1976b) found such an equilibrium within 17 months. On the present study site, numerical abundance appears to have mainly increased due to the colonization of a greater number of species in the latter half of the year and to some extent to the recurrence of some of the earlier colonizers. In contrast, community abundance in natural communities rises both due to elevation in the densities of a few dominats and influx of species (Lie and Evans, 1973; Orth, 1973; Holland and Polgar, 1976; Subrahmanyam *et al.*, 1976; Whitlach, 1977). Even though total abundance may fluctuate by two to three orders of magnitude, a certain norm of species numbers characterizes stable communities (Peterson, 1975).

These abundance patterns are reflected in the seasonal trends of "information" content indices H′, D and J′. Though several ecologists are wary of using these indices, they are useful to understand the devlopment of community structure. In theory, more information occurs when abundance is more or less evenly allocated to species categories and loss of information occurs when relative abundances of species are reduced. Equitability measure can be used to evaluate how evenly numbers are allocated to species categories (McErlean *et al.*, 1973). Present data show elevation of H′, and D in the latter half of the year and "leveling off" of J′. Three categories of species abundance were also noticed, namely initial high, moderately fluctuating, and final high. It is possible that low initial diversity was due to fewer colonizers represented by high numbers, as shown by high evenness, and the latter elevation in diversity and species richness and decrease in evenness were due to late colonizers and persistence of some of the early colonizers. As the dominance hierarchy settled in, diversity increased, but evenness decreased due to higher relative proportions of the dominants, even though total community abundance and number of species increased.

Three modes of temporal patterns are depicted in Fig. 5. Several other species, not dominants, also fell into one of the three categories. The data suggest a successional pattern because as species with high initial densities declined subsequently (eg. *S. microphthalma* and *A. verrilli*), other species were increasing in abundance (eg. *S. fragilis, L. culveri*), and some others increased or decreased in the interval (eg. *M. edwardsi* and *M. sarsi*). To a large extent these temporal

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patterns reflect breeding activities of colonizers. In the absence of a second year's data, because erosion of LT precluded continuation of the study beyond 13 months, it is not conclusive whether low abundance of these species in certain months was due to reproductive quiescence or due to competition and predation as suggested by some investigators (Young *et al.*, 1976; Rhoads *et al.*, 1978). Further, whether during colonization of dredge spoils a succession of trophic types (shallow burrowing polychaetes to surface deposit feeders to deep burrowers) should occur as put forward by Rhoads *et al.*, (1978) is not certain because during all stages of colonization, a variety of trophic types appeared on the island (information of trophic types from Sanders *et al.*, 1962; Barnes, 1980). Perhaps, the sequential appearance of trophic types on submerged dumps and intertidal spoils may not be comparable. Lastly, the fluctuations in species abundance might also probably reflect the success and failure of species to adapt to the harsh intertidal environment.

Discrete species groups were expected to develop at each of the tide level stations perhaps with some overlap of distribution among them. Present data do not show differenct species assemblages with respect to tide levels, but variable proportions of abundance of the four taxonomic groups at the four stations (Fig. 6). Undoubtedly, the initial site of colonization was ST (Fig. 2) because it was least stressful but some species spread, in course of time, to the other two or three stations. The result was that several species occurred at all stations but their relative numerical proportions varied as reflected in the dominance hierarchy sequence at each site (Table 5). No site had species that were absent at other sites, except transient ones that appeared in small numbers for one or two months. Based on the data, it appears that the entire intertidal assemblage can be considered as one unit, not four distict groups, that is composed of species showing zonation only in their abundance patterns (Fig. 6). Dauer and Simon (1976a) also observed variable distributional trends in relation to tidal height during the recolonization of a defaunated habitat. This conclusion is well supported by the increasing station similarity, and the species clustering that reflect their temporal and spatial similarities (Fig. 7). It is possible that both larval settlement and adult dispersal shaped these spatial patterns as observed by Santos and Simon (1980). But, it is not entirely possible to determine why most of the species on the island were not represented by comparable densities at each station, instead of abundance gradients, because no density dominants were entirely restricted to one particular tide level unlike the findings of Dauer and Simon (1976a). Among several factors known to influence establishment of infauna (Thorson, 1966; Rhoads and Young, 1970; Mileikowsky, 1974; Sheltema, 1974; Young *et al.*, 1976; Borrowsky, 1980; Santos and Simon, 1980; Hannan, 1981), it is possible larval settlement and adult dispersal might have played a great role because the species encountered are known to produce planktonic larvae or brood their eggs (Barnes, 1980). Cammen (1976), in his 10 month study, also found similarities in species abundance patterns at comparable elevations between dredge spoil and natural marsh sites. It may be speculated that, given longer time, spatial partitioning by species could have occurred resulting in recognizable distinct species assemblages at different tide levels as has been observed in natural communities (Subrahmanyam *et al.*, 1976; Holland and Dean, 1977; Leber, 1982). In this study what was observed relates to initial stages (seral stages) of colonization of the new intertidal habitat, during which most of the species did not prefer particular tide levels to form discrete assemblages, the total species abundance was largely governed by immigration of new species, and a stable community in terms of abundance and species numbers did not develop in a year.

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LITERATURE CITED

Barnes, R. D. 1980. Invertebrate zoology. Fourth edition. W. B. Saunders Co., Philadelphia.

Bloom, S. A., Simon, J. L., Hunter, V. D. 1972. Animal sediment relations and community analysis of a Florida estuary. Mar. Biol. 13: 43-56.

Borrowsky, B. 1980. Reproductive patterns of three intertidal salt-marsh gammaridean amphipods. Mar. Biol. 55: 327-334.

Bousfield, E. L. 1973. Shallow-water gammaridean amphipoda of New England. Comstock Publishing Associates, Ithaca.

Cairns, J. Jr., Dahlberg, M. L., Dickson, K. L., Smith, N., Waller, W. T. 1969. The relationship of freshwater protozoan communities to MacArthur-Wilson equilibrium model. Amer. Nat. 103: 439-454.

Cammen, L. M. 1976. Macroinvertebrate colonization of *Spartina* marshes artificially established on dredge spoil. Estuar. Coast. Mar. Sci. 4: 357-372.

Carpenter, D. C. 1951. A study of the ecology distribution and taxonomy of the polychaetous annelids of the Alligator Harbor Area, Franklin Co., Florida. M.S. Thesis, Florida State University, Tallahassee, Florida.

Conner, W. G., Simon, J. L. 1979. The effects of oyster shell dredging on an estuarine benthic community. Estuar. Coast. Mar. Sci. 9: 749-758.

Dauer, D. M., Simon, J. J. 1976a. Habitat expansion among polychaetous annelids repopulating a defaunated marine habitat. Mar. Biol. 37: 169-177.

__________., Simon, J. J. 1976b. Repopulation of the polychaete fauna of an intertidal habitat following natural defaunation: species equilibrium. Oecologia 22: 99-117.

Dean, D., Haskins, H. H. 1964. Benthic population of the Raritan River estuary following pollution abatement. Limnol. Oceanogr. 9: 551-563.

Folk, R. L. 1966. A review of grain-size parameters. Sedimentology 6: 3-26.

Gilmore, G., Trent, L. 1974. Abundance of benthic macroinvertebrates in natural and altered in estuarine areas. NOAA Tech. Rept. NMFS SSRF-677.

Hannan, C. A. 1981. Polychaete larval settlement: correspondance of patterns in suspended for collectors and in adjacent natural habitat in Monterey Bay, California. Limol. Oceanogr. 26: 159-171.

Holland, A. F., Dean, J. M. 1977. The community biology of intertidal macrofauna inhabiting sandbars in the north inlet area of South Carolina, U.S.A. In: Coull, B. C. (ed). Ecology of marine benthos. University of South Carolina Press, Columbia, p. 423-438.

__________., Polgar, T. T. 1976. Seasonal changes in the structure of an intertidal community. Mar. Biol. 37: 341-348.

DOI: 10.18785/negs.0701.04

Horn, H. S. 1966. Measurement of 'overlap' in comparative ecological studies. Amer. Natur. 100: 419-424.

Johnson, R. G. 1971. Animal-sediment relations in shallow water benthic communities. Marine Geol. 11: 93-104.

Kay, D. G., Knight, R. D. 1975. The macroinvertebrate fauna of the intertidal soft sediments of south each England. J. mar. biol. Ass. U.K. 55: 811-832.

Leber, K. M. 1982. Seasonality of macroinvertebrates on a temperate, high wave energy sandy beach. Bull. Mar. Sci. 32: 86-98.

Leblanc, D. J. 1973. The ecology, diversity, biomass of near-shore polychaetes in Ochlockonee Bay, Florida. M.S. Thesis, Florida State University, Tallahassee, Florida.

Leppakowski, E. 1971. Benthic recolonization of the Bornholm Basin (Southern Baltic) in 1967-71. Thalassia Jugosl. 7: 171-179.

Lie, U., Evans, R. A. 1973. Long term variability in the structure of subtidal benthic communities in Puget Sound, Washington, U.S.A. Mar. Biol. 21: 122-126.

Mason, W. T. Jr., Yevich, P. P. 1967. The use of phloxine B and rose bengal stains to facilitate sorting benthic samples. Trans. Amer. Fish. Soc. 86: 221-223.

McCall, P. L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. J. Mar. Res. 35: 221-226.

McErlean, A. J., O'connor, S. G., Mihursky, J. A., Gibson, C. I. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Estuar. Coast. Mar. Sci. 1: 19-36.

McNulty, J. K., Work, R. C., Moore, H. B. 1962. Some relationships between the infauna of the level bottom and the sediment in south Florida. Bull. Mar. Sci. 12: 322-332.

Menzel, R. W. 1971. Checklist of marine fauna and flora of the Apalachee Bay and St. George's Sound area. Dept. Oceanogr. Fla. St. Univ., Tall., Fla..

Mileikovsky, S. A. 1974. On predation of pelagic larvae and early juveniles of marine bottom invertebrates and their passing alive through their predators. Mar. Biol. 26: 303-311.

Morisita, M. 1959. Measuring interspecific association and similarity between communities. Mem. Fac. Sci. Kyushu. Univ. 3: 65-80.

Nichols, F. H. 1970. Benthic polychaete assemblages and their relationship to the sediment in Port Madison, Washington. Mar. Biol. 6: 48-57.

Orth, R. J. 1973. Benthic infauna of eelgrass, *Zostera marina* beds. Chesapeake Sci. 14: 258-269.

Peterson, G. H. 1975. Stability of species and of community for the benthos of two lagoons. Ecology 56: 958-965.

Reish, D. J. 1961. A study of the benthic fauna in a recently constructed boat harbor in southern California. Ecology 42: 84-91.

__________. 1962. A study of succession in a recently constructed marine harbors in southern California. Proc. First. National coastal and Shallow Water Res. Conf. Baltimore-Los Angeles-Tallahassee: Long Beach State College, 570-572.

__________. 1963. Further studies on the benthic fauna in a recently constructed boat harbor in southern California. Bull. South. Calif. Acad. Sci. 62: 23-32.

Rhoads, D. C., Young, D. K. 1970. The influence of deposit feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28: 150-177.

__________., Aller, R. C., Goldhaber, M. B. 1977. The influence of colonizing benthos on physical properties and chemical diagenesis of the estuarine seafloor. In: Coull, B. C. (ed). Ecology of marine benthos, Unversity of South Carolina Press, Columbia, p. 113-138.

Rhoads, D. C., McCall, P. L., Yingst, J. Y. 1978. Distribance and production on the estuarine seafloor. Amer. Scientist 66: 577-586.

Rosenberg, R. 1976. Benthic faunal dynamics during succession following pollution abatement in a Swedish estuary. Oikos 27: 414-427.

Sanders, H. L. 1958. Benthic studies in Buzzard Bay. I. Animal-sediment relationships. Limnol. Oceanogr. 3: 245-258.

__________. 1960. Benthic studies in Buzzard Bay. III. The structure of the soft bottom community. Limnol. Oceanogr. 5: 138-153.

__________., Goudsmit, E. M., Mills, E. L., G. R. Hampson. 1962. A study of the intertidal fauna of Barnstable Harbor, Massachusetts. Limnol. Oceanogr. 7: 63-79.

Santos, S. L., Simon, J. L. 1974. Distribution and abundance of the polychaetous annelids in a south Florida estuary. Bull. Mar. Sci. 24: 669-689.

Santos, S. L., Simon, J. L. 1980. Marine Soft-bottom community establishment following annual defaunation: larval or adult recruitment? Mar. Ecol. Prog. Ser. 2: 235-241.

Scheltema, R. S. 1974. Biological interactions determining larval settlement of marine invertebrates. Thalassia Jugosl. 10: 263-296.

Schultz, G. A. 1969. The marine isopod crustaceans. Wm. C. Brown Co., Dubuque.

Simon, J. L., and Dauer, D. M. 1977. Reestablishment of a benthic community following natural defaunation. In: Coull, B. C. (ed.) Ecology of Marine Benthos, Unversity of South Carolina Press, Columbia, p. 139-154.

Soil Survey Staff. 1951. Soil Survey Manual. U.S.D.A. Handbook 18, Washington, D. C..

Subrahmanyam, C. B., Coultas, C. L. 1980. Studies on the animal communities in two north Florida salt marshes. Part III. Seasonal fluctuations of fish and macroinvertebrates. Bull. Mar. Sci. 30: 790-818.

__________., Kruczynski, W. L. 1979. Colonization of polychaetous annelids in the intertidal zone of a dredged material island in north Florida. In: Grassle, J. F., Patil, G. P., Smith, W. K., Taillie, C. (eds.) Ecological Diversity in Theory and Practice. Statistical Ecology Series, Vol. 6. International Cooperative Publishing House. Bartonsville, p. 279-296.

__________., Kruczynski, W. L., Drake, S. H. 1976. Studies on the animal communities in two north Florida salt marshes. Part II. Macroinvertebrate Communities. Bull. Mar. Sci. 26: 172-195.

Taylor, J. L., Salomon, C. H. 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U.S. Fish and Wildl. Fish. Bull. 67: 213-241.

__________., Hall, J. R., Salomon, C. H. 1970. Mollusks and benthic environments in Hillsborough Bay, Florida. U.S. Fish and Wildl. Fish Bull. 68: 191-202.

Thorson, G. 1966. Some factors influencing the recruitment and establishment of marine benthic communities. Neth. J. Sea. Res. 3: 267-293.

Whitlatch, R. B. 1977. Seasonal changes in the community structure of the macrobenthos inhabiting the intertidal sand and mud flats of Barnstable Harbor, Massachusetts. Biol. Bull. 152: 275-294.

Young, D. K., Buzas, M. A., Young, M. W. 1976. Species densities of macrobenthos associated with seagrass: A field experimental study of predation. J. Mar. Res. 34: 577-592.

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