THE QUALITATIVE AND QUANTITATIVE ANALYSIS OF THE BENTHIC FLORA AND FAUNA OF BARNEGAT BAY BEFORE AND AFTER THE ONSET OF THERMAL ADDITION

Ninth Progress Report

March 1974

R. E. Loveland, Department of Zoology
P. Edwards, Consulting Algologist, Dept. of Botany
J. J. Vouglitois, Department of Zoology
D. Palumbo, Department of Zoology

Report #9 to N. J. Public Utilities Commission

Rutger's University, New Brunswick, New Jersey

Budget Statement, 4 April 1974 -

	Alloted	Committed	Balance
I. Salary			
a) Principal Investigator	$3,000.00	$3,000.00	$0.00
b) Full-time employees	5,400.00	6,930.00	-1,530.00
c) Part-time employees	1,800.00	495.38	1,304.62
d) Consulting algologists fee	300.00	0.00	300.00
II. Equipment and Repair			
a) Salinometer probe (replace)	525.00	(292.00)*	525.00
b) Repair equipment	200.00	61.50	138.50
III. Supplies			
a) Boat and experimental supplies	200.00	245.19	-45.19
b) Miscellaneous	500.00	500.00**	0.00
IV. Operation			
a) Vessel upkeep	480.00	65.10	414.90
b) Mileage	520.00	564.72	-44.72
c) Towing fee	125.00	53.10	71.90
V. Publication and data analysis			
a) Xerox rental	650.00	11.90	638.10
b) Computer aid	1,740.00	0.00	1,740.00
VI. Indirect costs	3,060.00	3,060.00	0.00
		Balance	$3,513.11***

*funds obtained elsewhere

**carry over from 1972 deficit in all categories

***agrees within $14.10 of records kept by Principal Investigator

Bibliography of Publications and Reports Resulting from Project 27-4656

The following publications and reports were partially or entirely supported by Contract 27-4656 to Rutgers University by Jersey Central Power and Light.

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Loveland, R.E., K. Mountford, E.T. Moul, D.A. Busch, P.H. Sandine & M. Moskowitz, 1971. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Seventh Progress Report, June 1970, Contract 27-4656, from Jersey Central Power and Light, 37pp.

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Sandine, Phillip H., 1973. Zooplankton of Barnegat Bay: the effect of the Oyster Creek Nuclear Power Plant. M.Sc. Thesis, Rutgers University, Department of Zoology, New Brunswick, N.J.

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Benthic Algae

During the period covered by this report (1 June-31 Dec. '73) we collected 18 samples of benthic algae on two dates (11 July and 15 August 1973). The locations of the nine stations for each date are indicated in Figure 1, which are exactly the stations sampled previously in our algae study. Because of the enormous amount of time necessary to sort, identify and weigh each sample, we were limited to only two collecting dates during the summer. All species identifications were confirmed by Dr. Peter Edwards of the Rutgers Botany Department. Analysis of the data was similar to previous study periods and is given below.

1. Ordination Table I lists the relative rank-order of the species of algae collected during the summer of 1973. The species listed are just those which occurred in sufficient quantity to be sorted and weighed. Additional species, too small or fragile to be quantified, will be given in an appendix to this report. The rank-order for this time period was based on contribution of each species to the total weight of all species collected. Thus, *Ulva lactuca* ranked first since it comprised the greatest total weight of any species identified. Comparing the list in Table I with previous data (see Figure 1, Progress Report #8, August 1972), we find that 12 species which ranked among the top 15 previously are still among the top 15. In other words, only three species have moved into the top 15 dominant species of benthic algae. These three species are *Spyridia filamentosa*, *Cladophora sp.*, and *Enteromorpha linza*. Two of these (*Spyridia* and *Enteromorpha*) appear because of a tendency to mis-identify these species in previous years (Edwards made the final taxinomic determination in the present study). *Spyridia* is easily confused with *Ceramium* and *Enteromorpha linza* must be carefully distinguished from *Enteromorpha intestinalis*, especially when size differences are not readily apparent.

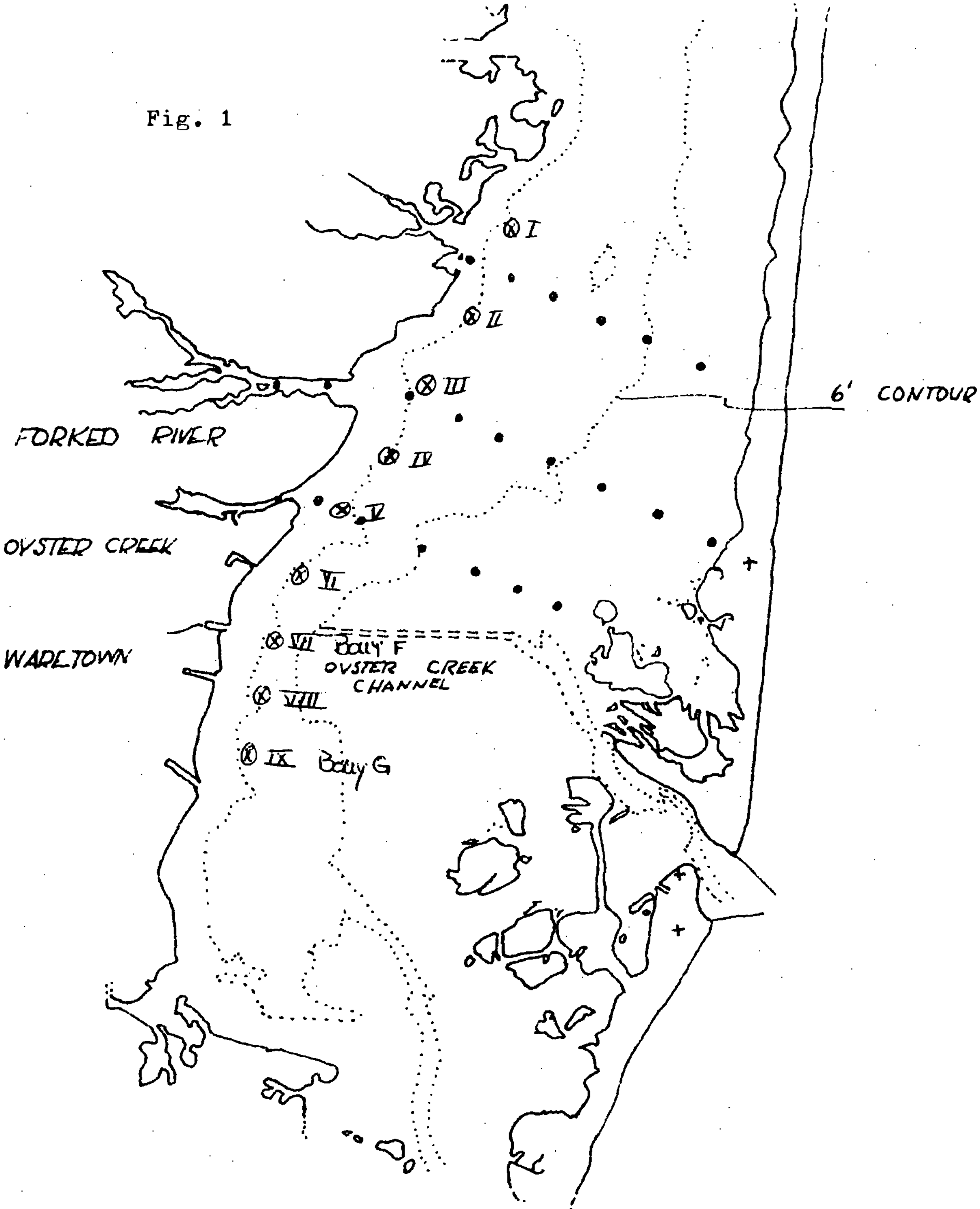
Two species which were previously in the top 15 dominant have not been found during 1973. *Ruppia maritima* (a vascular plant) was not found at any station; it is generally more common in the sandy, easterly flats of the bay. *Callithamnion* is a very small form and was not identified for quantitative sorting.

Nevertheless, we find that most species which have been dominant in Barnegat Bay since 1965 are still the dominant forms in 1973. This is true whether one considers the frequency rank (i.e., probability of encountering the species in a sample, irrespective of biomass) or the biomass rank (i.e., the total amount of biomass contributed by a species to the entire collection). In short, those species encountered most frequently are also occurring in greatest abundance.

There is one species which is of interest with respect to rank in the collection, and that is *Codium fragile*. It will be recalled that Codium did not appear in Barnegat Bay until 1965. It ranked 10th among all species by 1968 and then became the most common algal species in Barnegat Bay by 1972.

Algae Cruise 73 7 6
73-2

Fig. 1



BARNEGAT BAY, N. J.

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Table I - Relative rank-order (by total dry weight of each species over 2 dates X 9 stations) checklist of algal species in Barnegat Bay, July-August 1973.

Rank	Species	Total Dry Weight(gms)	% of Grand Total
1	*Ulva lactuca*	1,542.25	42.42
2	*Enteromorpha intestinalis*	601.40	16.54
3	*Gracilaria foliifera* & *verrucosa*	315.51	8.68
4	*Codium fragile*	287.21	7.90
5	*Ceramium* sp.	277.68	7.64
6	*Spyridia filamentosa*	194.22	5.34
7	*Champia* sp.	174.59	4.80
8	*Zostera marina* *	125.02	3.44
9	*Polysiphonia* sp.	30.84	0.85
10	*Polysiphonia nigrans*	24.91	0.69
11	*Agardhiella tenera*	22.77	0.63
12	*Ceramium rubrum*	13.23	0.36
13	*Cladophora* sp.	13.07	0.35
14	*Enteromorpha linza*	12.60	0.34
15	*Chaetomorpha* sp.	0.01	0.0003
	Total=	3,635.31	

* vascular plant

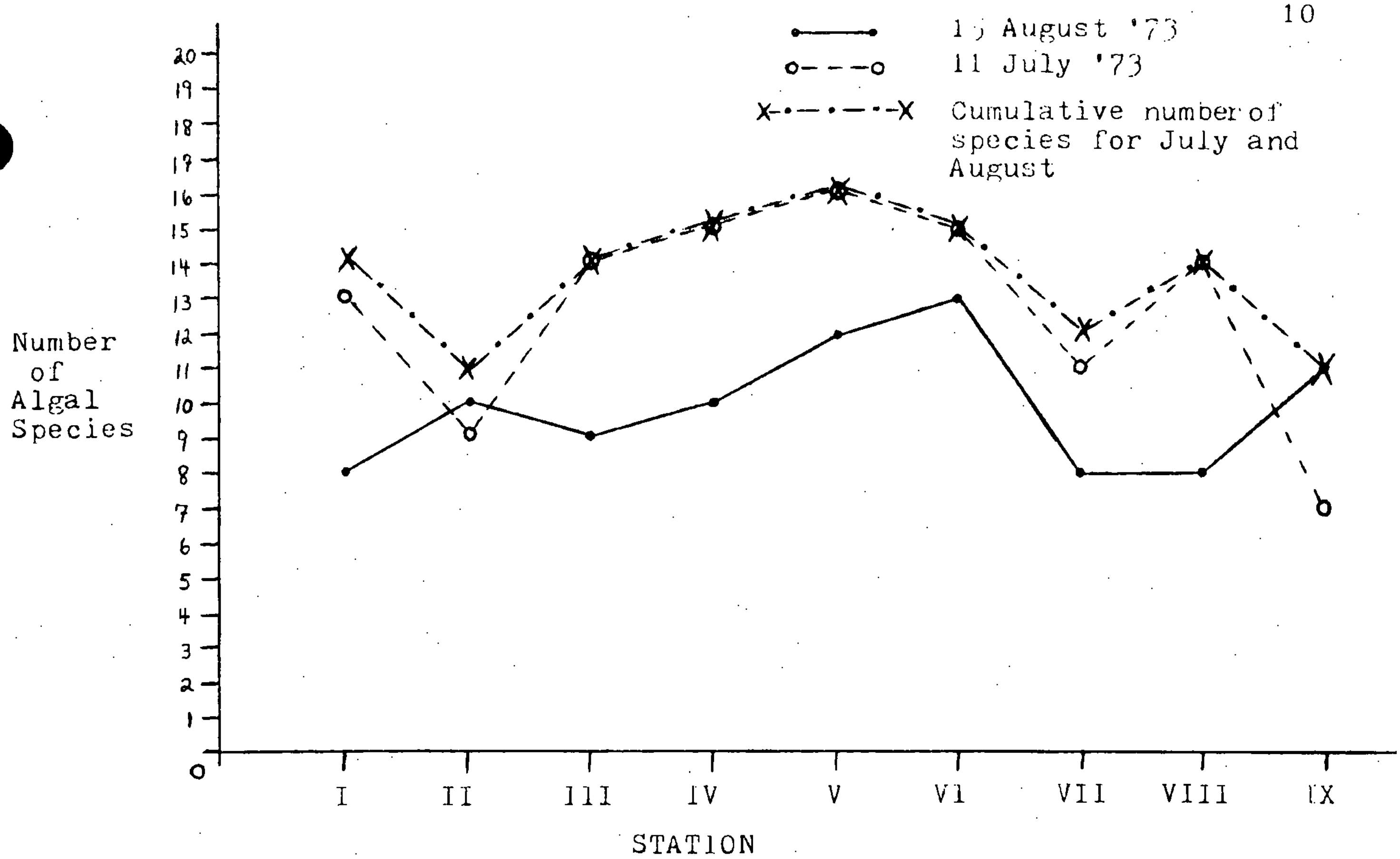
Table II- Number of species of macroalgae collected at each station in the bay sampling area.

Station	11 July '73	15 August '73	July + August Cumulative #
I	13	8	14
II	9	10	11
III	14	9	14
IV	15	10	15
V	16	12	16
VI	15	13	15
VII	11	8	12
VIII	14	8	14
IX	7	11	11
	$\bar{X}$= 12.7	$\bar{X}$= 9.9	

Table III-Dominant species of macroalgae at each station in the bay sampling area based on percent of total dry weight of each sample.

Station	Date	Species	% of Total Dry Weight of Sample
I	11 Jul.	_Ulva lactuca_	87.53
	15 Aug.	_Gracilaria foliifera_ & _verrucosa_	52.79
II	11 Jul.	_Ulva lactuca_	39.30
	15 Aug.	_Ulva lactuca_	44.22
III	11 Jul.	_Ulva lactuca_	74.46
	15 Aug.	_Ulva lactuca_	38.95
IV	11 Jul.	_Ulva lactuca_	65.76
	15 Aug.	_Ulva lactuca_	38.84
V	11 Jul.	_Ulva lactuca_	91.16
	15 Aug.	_Ulva lactuca_	13.65
VI	11 Jul.	_Ulva lactuca_	63.24
	15 Aug.	_Ulva lactuca_	40.07
VII	11 Jul.	_Ulva lactuca_	20.18
	15 Aug.	_Zostera marina_*	50.75
VIII	11 Jul.	_Enteromorpha intestinalis_	34.33
	15 Aug.	_Ceramium_ sp.	13.18
IX	11 Jul.	_Ulva lactuca_	73.54
	15 Aug.	_Ceramium_ sp.	29.62

*vascular plant



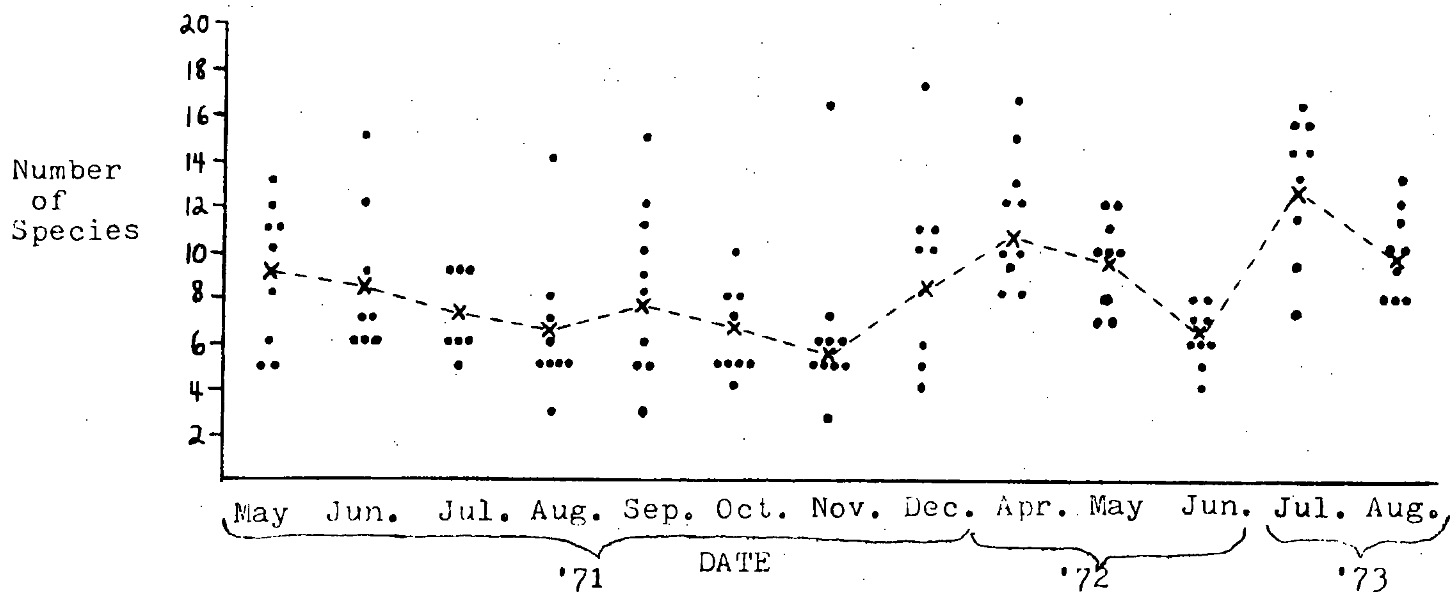


Fig. 2A Number of species of macroalgae vs. station in the bay sampling area.

2B Number of species of macroalgae vs. time in the bay sampling area.

Table IV - Total dry weight of algae (grams) at each bay station, July and August, 1971 & 73 (4 cruises).

Station	July '71	Aug. '71	$\bar{X}$ '71	11July'73	15Aug.'73	$\bar{X}$ '73
I	162.15	46.30	104.23	180.17	174.58	177.38
II	41.60	18.20	29.90	21.63	371.35	196.49
III	181.85	315.48	248.67	30.08	353.80	191.94
IV	—	86.01	—	105.69	536.23	320.96
V	146.80	75.56	111.18	110.63	218.06	164.35
VI	177.10	19.10	98.10	124.36	54.36	89.36
VII	303.30	33.19	168.25	912.47	18.68	465.58
VIII	295.10	69.76	182.43	1,093.66	328.37	711.02
IX	243.70	114.27	178.99	287.84	222.50	254.67
	$\bar{X}$ = 193.95	$\bar{X}$ = 84.43		$\bar{X}$ = 318.50	$\bar{X}$ = 253.10	
	$\bar{\bar{X}}$ = 140.19			$\bar{\bar{X}}$ = 285.80		

Fig. 3 - Dominant algal species (based upon the species which contributed the largest amount of biomass to the sample) vs. station for each of two sampling dates.

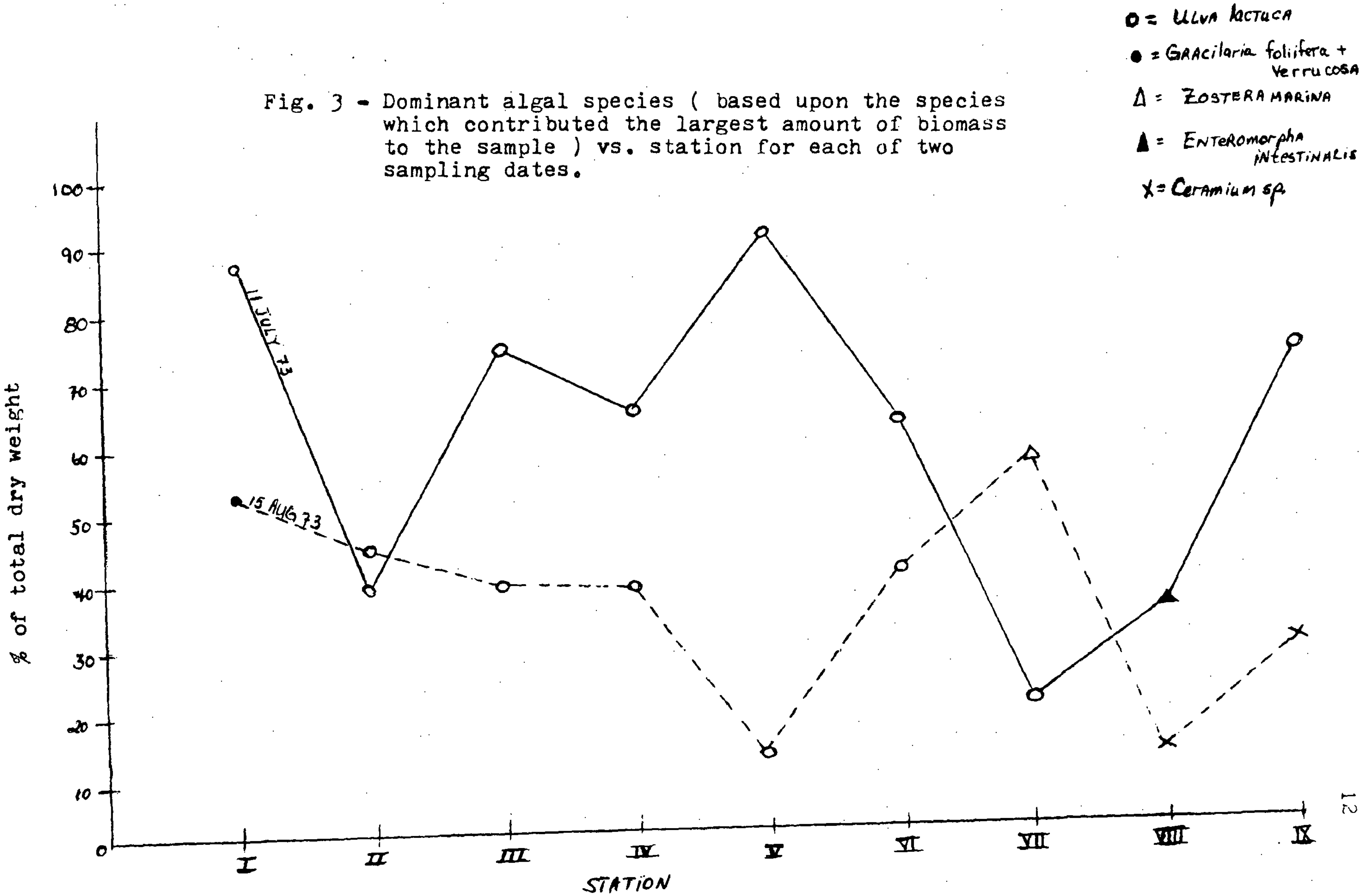
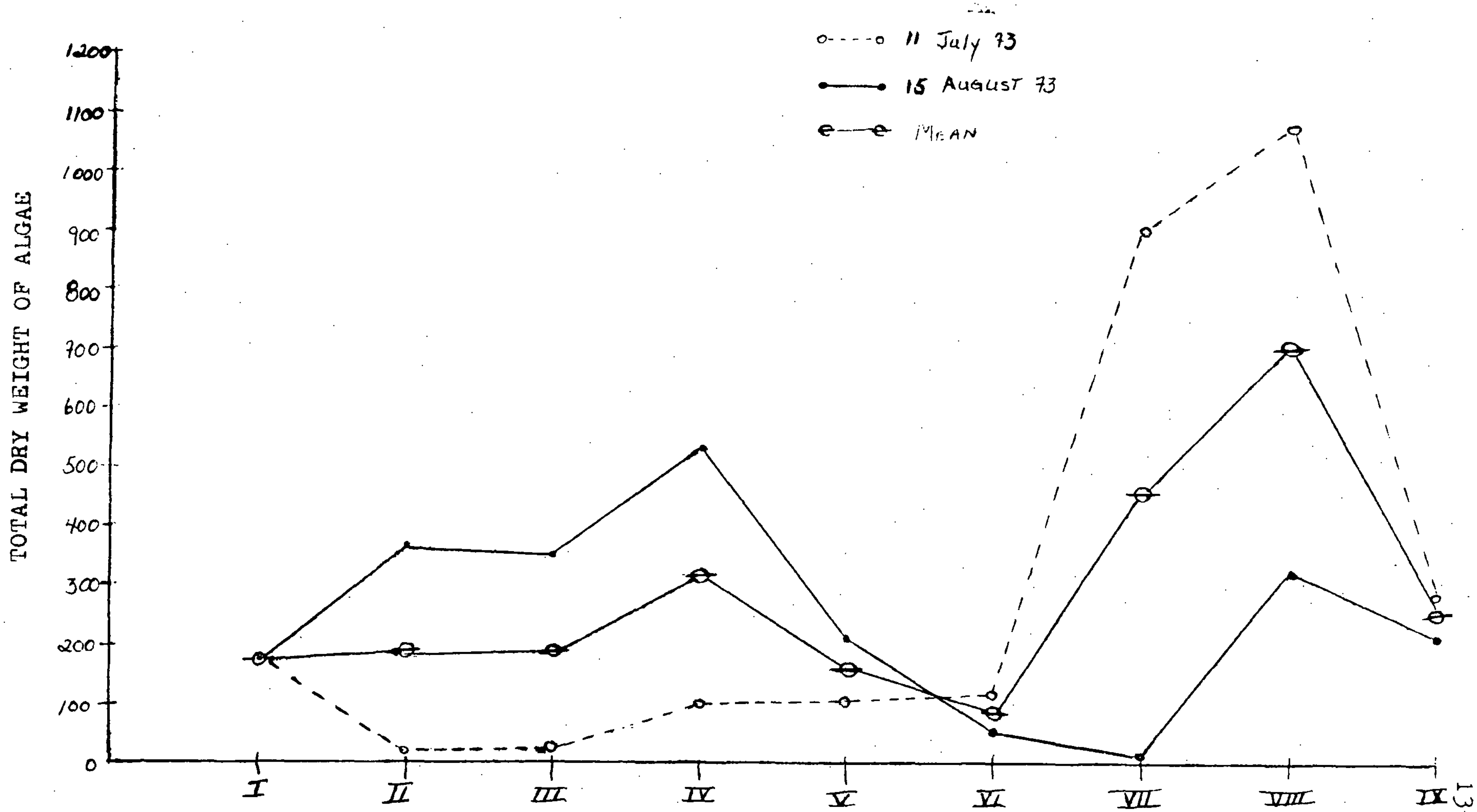


Fig. 4 - Total dry weight, per sample, of algae vs. station for each of two sampling dates.



However, during the late summer of 1972, we noticed less and less Codium in our benthic samples. During the summer of 1973 we found relatively few specimens of Codium; but whenever it was found, large pieces of the plant were retrieved. Overall, Codium has dropped in rank first to fourth position. It appears that this once "weedy" species is beginning to be out-competed by the endemic species (such as Ulva, Enteromorpha and Gracilaria). Of course, it must be pointed out that Codium is still abundant locally, especially in the sandy parts of the bay where clearer water is found (e.g., off Island Beach and in the vicinity of Waretown).

Diversity and Evenness. Because of the lack of sufficient qualitative data, as of this writing, we cannot present data on diversity and evenness.

Dominant species. In Table II, the number of dominant species are indicated by station; these data are plotted in Figure 2. It can be seen in Figure 2A that the number of species per station for the two dates follow similar patterns, with no major differences in species number along the axis of the bay. These data are compared with similar data for 1971 and 1972 in Figure 2B. Although there appears to be a slight increase in the average number of species found in 1973 over the previous two years, this difference does not appear to be significant. Thus in most samples we continue to find that 9-13 species of benthic algae comprise the average sample in the bay. Generally, as before, the fewest total number of species occurs in August to September, when water temperatures are often highest.

Total Biomass. In Table III, the dominant species of algae are listed by date and station. In this case, we have given the species name of the single species which contributed the largest amount of biomass to the sample. These data are then plotted in Figure 3. It can be seen that Ulva lactuca may comprise up to 87% (dry weight) of the sample; on the other hand, Ulva may still be the dominant single species in a sample when it comprises as little as 13% of the total dry weight. Obviously, the diversity and evenness will be very different in two samples where the same dominant single species occurs in differing amounts. Although Ulva is the singlemost dominant species in Barnegat Bay, the proportion of this species to a particular sample, varies along the axis of the bay. Furthermore, Ulva is not always the most important species by weight, even though it appeared to contribute the most weight to the sample in thirteen out of 18 stations. Only Gracilaria and Zostera ever comprise more than 50% of the sample by weight, and this occurred in only one sample each during the summer.

In Table IV we have listed the dry weight, per sample, of algae by station for July-August of 1971 and 1973. The data for 1973 are plotted in Figure 4. Although the southern end of the transect generally yields higher biomass values per sample, this pattern is not necessarily consistent (see, e.g., Station III in August 1971). We attribute the apparent bimodal distribution of algae, using biomass as a criterion, to two factors: A) the community of algae in the southern end of the transect is dominated by species that "prefer" clearer, higher saline water (viz, Champia, Ceramium, Spyridia, Gracilaria). These species, when collected, often fill the dredge tightly and are packed in a very dense fashion within the basket of the dredge. B) At the nothern end of the transect where Ulva and Enteromorpha are the dominant species, the dredge often comes up with a lot of mud and large chunks of algae, which do not pack well.

Station VII, located at the end of the Oyster Creek Channel, generally exhibits smaller biomass of algae per sample, although the number of species present is not significantly lower. This station often is characterized by large numbers of starfish (Asterias forbesi) in the sample, although no relationship between algae and starfish is implied. Also, the intensity of channel dredging is probably high in this vicinity.

It is of interest to note that the average sample in July contains more algae than a sample in August. Furthermore, the algae samples for 1973 contained about twice the amount, on the average, of algae for all samples as those of 1971 (viz., 285 grams dry weight for 1973 vs. 140 grams dry weight for 1971 in the period July-August).

Summary. We have not performed the detailed statistical analysis of the algae data because of unfinished backlog. However, certain observations regarding benthic algae can be made.

1. The dominant species of algae in middle Barnegat Bay remain constant over time. There is a remarkable consistency of the rank of certain species, both by frequency and biomass, throughout the bay. Species number and biomass appear to decrease during the late summer (August-September).

2. The introduced species, Codium fragile, seems to have reached its peak in Barnegat Bay. Few large plants were encountered anywhere in 1973, although smaller fragments were often observed. The sandy banks around Waretown seem to have been the location of the center of the population. In biomass, Codium was not dominant at any station. It has moved from ranking first among all collected algae, to fourth in abundance. The decrease in Codium could result from increased competition from other common species (viz., Ulva and Gracilaria).

3. The proportion of each species of algae to a particular sample is an unpredictable variable. While Ulva was generally the single dominant in a sample, its contribution to a sample varied between 13% and 87%. In other words, each sample had a different proportion of its component algal species. The reasons for these community differences are unclear; however, the southern end of the bay has a community composition dominated by red algae, while the northern end is dominated by green algae.

4, We have not observed any major changes in the distribution of benthic algae in Barnegat Bay. In fact, there seems to be a general increase in the biomass of algae in 1973 over previous years.

Table V New Species Reported for Barnegat Bay (Middle Region).

Aeginella longicornis (tentative)
Amathia dichotoma
Ampelisca adbita (tent)
Ampelisca vadorum
Ampelisca verrilli
Amphipholis squamata new 73
Amphithoe longimana (tent) new 73
Amphithoe rubricata (tent)
Amphitrite cirrata (tent)
Arabella iricolor
Asabellides oculata
Autolytus cornutus

Balanus eburneus (tent)
Batea catharinensis (tent)
Busycon carica (tent)

Carinoma tremephoros
Cerapus tubularis
Chiona cingenda (tent)
Corophium tuberculatum
Crassostrea virginica
Cucumaria pulcherrima (tent) new 73

Dysponetus pygmaeus (tent)

Edwardsia elegans (tent)
Eulelia viridis (tent)

Gammarus lawrencianus
Glycera capitata
Golfingia improvisa

Halcampoides sp (tent)
Halichondria panicea (tent)
Haliplanella luciae (tent)
Harmothoe oerstedi (tent)
Hyale prevosti (tent)

Ichthyobdella rapax (tent)
Ischyrocerus anguypes (tent)

Jassa falcata

Libinia dubia
Lysianopsis alba

Maera danae (tent)
Modiolus modiolus (tent)

Obelia commissuralis (tent)
Ophiglycera gigantea (tent)

Palaemonetes pugio (tent) new 73
Panopeus herbstii (tent)
Polycirrus medusa
Pontogenia inermis (tent)

Sabella crassicornis (tent)
Spiochaetopterus oculatus
Stauronereis rudolphi new 73
Stylarioides plumosa

Tanystylum orbiculare (tent)
Terebellides stroemi
Thuiaria argentea
Thuiaria robusta
Turbonilla interrupta

Table VI Benthic invertebrates to be deleted from previous checklists.

Delete	Changed to
Ampelisca spinipes	Ampelisca vadorum & A. abdita
Aphrodite aculeata	Harmothoe imbricata
Batea secunda	Batea catharinensis
Cerebratulus sp.	Carinoma tremephoros
Corophium cylindricum Corophium volutator	Corophium tuberculatum
Drilonereis longa	Arabella iricolor
Erichthonius difformis	Jassa falcata
Gammarus locusta	Gammarus lawrencianus
Golfingia gouldii	Golfingia improvisa
Goniadella gracilis	Glycinde solitaria
Harmothoe extenuata	Harmothoe imbricata
Harmothoe nodosa	Harmothoe oerstedi
Hypaniola grayi	Asabellides oculata
Jassa mamorata	Jassa falcata
Libinia sp.	Libinia dubia
Lumbrinereis tenuis	Arabella iricolor
Melinna cristata	Asabellides oculata
Onuphis quadricuspis	Diopatra cuprea
Polycirrus sp.	Polycirrus medusa
Scoloplos armiger Scoloplos sp.	Scoloplos fragilis
Sthenelais leidyi Sthenelais limicola	Sthenelais boa
Stylarioides arenosa	Stylarioides plumosa
Talorchestia longicornis	Erichthonius sp.
Turbonilla sp.	Turbonilla interrupta

Table VII Complete revised benthic invertebrate list of Barnegat Bay, 1974

3200000000	Phylum Porifera		
3203000000	Class Demospongiae		
		3203060101	Cliona celata
		3203080101	Halichondria bowerbanki
		3203080102	Halichondria panicea (tentative)
		3203010100	Haliclona sp.
		3203020101	Microciona prolifera
3300000000	Phylum Cnidaria		
3301000000	Class Hydrozoa		
	Order Athecata		
		3301270102	Hydractinia echinata
			Pennaria tiarella
		3301030301	Tubularia crocea
	Order Thecata		
		3301440000	Campanularidae (unidentified species)
		3301440202	Obelia commissuralis (tentative)
		3301560301	Thuiaria argentea
			Thuiaria robusta
3303000000	Class Anthozoa		
	Order Actiniaria		
		3303430101	Diadumene leucolena
		3303400101	Edwardsia elegans (tentative)
			Halcampoides sp. (tentative)
		3303450101	Haliplanella luciae (tentative)
		3303410101	Haloclava producta
		3303460101	Metridium senile -
			Sagartia luciae
			Sagartia modesta
	Order Ceriantharia		
		3303900101	Cerinathus americanus
	Phylum Platyhelminthes		
3500000000	Class Turbellaria		
		3505020101	Euplana gracilis
		3505010201	Stylochus ellipticus
4000000000	Phylum Nemertea		
4001000000	Class Anopla		
		4001020101	Carinoma tremaphoros -
		4001030101	Cerebratulus lacteus -
5900000000	Phylum Sipunculoidea		
		5901010101	Golfingia improvisa
		5901010100	Golfingia sp.

Phylum Annelida

Class Polychaeta

4802000000 Order Phyllodocida

4802050000 Family Phyllodocidae

4802050102 Eteone heteropoda

4802050101 Eteone lactea

Eulalia viridis (tentative)

4802060201 Eumida sanguinea

4802050401 Paranaitis speciosa

4802050501 Phyllodoce arenae

4802050504 Phyllodoce maculata

4802020000 Family Polynoidae

4802020103 Harmothoe imbricata

Harmothoe oerstedi (tentative)

4802020202 Lepidonotus squamatus

4802030000 Family Sigalionidae

4802030101 Sthenelais boa

4802040000 Family Chrysopetalidae

Dysponetus pygmaeus (tentative)

4802140000 Family Glyceridae

4802140101 Glycera americana

Glycera capitata (tentative)

4802140102 Glycera dibranchiata

4802150000 Family Goniadidae

4802150101 Glycinde solitaria

Goniada maculata (tentative)

Ophioglycera gigantea (tentative)

4802130000 Family Nephtyidae

4802130202 Nephtys incisa

4802130204 Nephtys picta

4802110000 Family Syllidae

4802110101 Autolytus cornutus

4802090000 Family Hesionidae

4802090201 Gyptis vittata

4802090401 Podarke obscura

4802120000 Family Nereidae

4802120401 Nereis arenaceodonta

4802120501 Nereis dumerillii (Tentative)

4802120404 Nereis pelagica

4802120403 Nereis succinea

4802120405 Nereis virens

4803000000 Order Capitellida

4803030000 Family Capitellidae

4803030101 Capitella capitata

4803030301 Notomastus latericeus

4803050000 Family Maldanidae

4803050101 Clymenella torquata

4803050102 Clymenella zonalis

4803050301 Maldane sarsi

4803050201 Maldanopsis elongata

4806000000 Order Spionida

4805020000 Family Spionidae

4805020202 Polydora ligni
4805020501 Scolecolepides viridis
4805020602 Scolelepis squamata
4805020701 Spio filicornis (tentative)
4805020702 Spio setosa (tentative)

4805050000 Family Chaetopteridae

4805050201 Spiochaetopterus oculatus

4805060000 Family Sabellariidae

4805060101 Sabellaria vulgaris

4806000000 Order Eunicida

4806010000 Family Onuphidae

4806010101 Diopatra cuprea

4806020000 Family Eunicidae

4806020101 Marphysa sanguinea

4806040000 Family Arabellidae

4806040101 Arabella iricolor

4806060000 Family Dorvilleidae

4806060101 Stauronereis rudolphi

4809000000 Order Ariciida

4809010000 Family Orbiniidae

Orbinia norvegica (tentative)
4809010201 Scoloplos fragilis
4809010202 Scoloplos robustus

4810000000 Order Cirratulida

4810010000 Family Cirratulidae

4810010101 Cirratulus grandis
4810010303 Tharyx acutus (tentative)

4812000000 Order Terebellida

4812010000 Family Pectinariidae

4812010101 Pectinaria gouldii

4812020000 Family Ampharetidae

4812020101 Asabellides oculata

4812030000 Family Terebellidae

Amphitrite cirrata (tentative)
4812030102 Amphitrite johnstoni (tentative)
4812030101 Amphitrite ornata
4812030501 Pista cristata
4812030503 Pista palmata
4812030601 Polycirrus eximius (tentative)
4812030602 Polycirrus medusa (tentative)
4B Terebellides stroemi

4813000000 Order Flabelligerida

4813010000 Family Flabelligeridae

Stylarioides plumosa

4815000000 Order Sabellida

4815010000 Family Sabellidae

4815010302 Sabella crassicornis (tentative)
4815010301 Sabella microphthalma

4815020000 Family Serpulidae

4815020101 Hydroides dianthus

? some confusion

Phylum Arthropoda
00000000 Class Xiphosurida
5001010101 Limulus polyphemus
00000000 Class Pycnogonida
5201010101 Callipallene brevirostris
5201040101 Tanystylum orbiculare (tentative)
00000000 Class Crustacea
5307000000 Subclass Cirripedia
? Order Thoracica
Balanus balanoides
5807110102 Balanus eburneus (tentative)
5307110103 Balanus improvisus
? Subclass Malacostracea
5313000000 Order Mysidacea
5313010301 Heteromysis formosa
5313010101 Neomysis americana
5314000000 Order Cumacea
5314030201 Oxyurostylis smithi
5315000000 Order Tanaidacea
5315010101 Leptochelia savignyi
5316000000 Order Isopoda
5316000101 Cyathura polita
5316020401 Edotea triloba
5316020201 Erichsonella attenuata
5316020202 Erichsonella filiformis
5316020301 Idotea baltica
5316260301 Lironeca ovalis
5317000000 Order Amphipoda
5317340000 Family Lysianossidae
5317340301 Lysianopsis alba
5317020000 Family Ampeliscidae
5317020101 Ampelisca abdita (tentative)
5317020104 Ampelisca macrocephala
5317020102 Ampelisca vadorum
5317020103 Ampelisca verrilli
53 Family Calliopiidae
Calliopius laeviusculus (tentative)
5317210000 Family Gammaridae
5317210101 Elasmopus laevis
5317210206 Gammarus lawrencianus
5317210205 Gammarus mucronatus
Maera danae (tentative)
5317210402 Melita nitida
5317100000 Family Bateidae
5317100101 Batea catharinensis (tentative)
Family Pontogeneiidae
Pontogenia inermis
5317470000 Family Talitridae
Hyale prevosti (tentative)
5317150000 Family Corophiidae
5317150101 Cerapus tubularis
5317150204 Corophium tuberculatum
5317150300 Ericthonius sp. (tentative)
5317150402 Unciola irrorata (tentative)
5317040000 Family Ampithoidae
5317040101 Ampithoe longimana (tentative)
Ampithoe rubricata (tentative)
5317040201 Grubia compta (Cymadusa compta)

5317270000 Family Ischyroceridae

5317270101 Jassa falcata

Ischyrocerus anguipes

5317060000 Family Aoridae

5317060101 Lembos smithi (tentative)

5317060301 Microdeutopus gryllotalpa

[redacted] 5317810000 ~~Order~~ Family Caprellidae

5317810101 Aeginella longicornis (tentative)

5 Caprella geometrica

Caprella linearis

5319000000 Order Decapoda

Infraorder Caridea

5319170000 Family Hippolytidae

5319170103 Hippolyte zostericola

5319200000 Family Crangonidae

5319200101 Crangon septemspinosus

5319130000 Family Palaemonidae

5319130303 Palaemonetes pugio (tentative)

5319130304 Palaemonetes vulgaris

5319660000 Family Majidae

5319660101 Libinia dubia

5319590000 Family Cancridae

5319590102 Cancer irroratus

Infraorder Brachyura

5319600000 Family Xanthidae

5319600101 Eurypanopeus depressus (tentative

5319600301 Neopanope texana

5319600401 Panopeus herbstii (tentative)

5319600501 Rhithropanopeus harrisi

5319580000 Family Portunidae

5319580301 Callinectes sapidus

Carcinus maenas

5319580602 Ovalipes ocellatus

Infraorder Anomura

5319440000 Family Paguridae

5319440205 Pagurus longicarpus

4900000000 Phylum Mollusca

4904000000 Class Gastropoda

Subclass Prosobranchia

Order Mesogastropoda

Bittium alternatum

4904550102 Crepidula convexa

4904650101 Crepidula fornicata

4904550104 Crepidula plana

4904500102 Epitonium rupicola

Littorina saxatilis

4904660101 Polinices duplicatus

4904490101 Triphora nigrocincta

Order Neogastropoda

4904760101 Anachis avara

4904790102 Busycon canaliculatum

4904790101 Busycon carica

4904740101 Eupleura caudata

4904760201 Mitrella lunata

4904800103 Nassarius obsoletus

4904800102 Nassarius trivitattus (tentative)
4904800101 Nassarius vibex
4904940201 Urosalpinx cinerea

Subclass Opisthobranchia

Order Cephalaspidea

4905010101 Acteon punstostriatus (tentative)
4905120101 Haminoea solitaria
4905150301 Turbonilla interrupta
4905130201 Retusa canaliculata

Order Nudibranchia

4905560101 Corambella obscura
4905560100 Corambella sp.
4905890101 Cratena pilata
4905890100 Cratena sp.
4905 Cuthona concinna

4908000000 Class Bivalvia

Subclass Prionodesmata

Order Protobranchia

4908110101 Nucula proxima
4908010101 Solemya vellum
4908120101 Yoldia limatula

Subclass Pteriomorphia

Order Prionodontia

4908220102 Anadara ovalis

Order Pteroconchida

4908300101 Acquipecten irradians
4908350101 Crassostrea virginica
Modiolus demissus
4908250101 Modiolus modiolus (tentative)
4908250401 Mytilus edulus-

Subclass Telodesmata

Order Heterodontida

Chiona cingenda (tentative) ←
4908710101 Ensis directus
4908550501 Gemma gemma
4908540101 Laevicardium mortoni
4908570201 Macoma balthica
4908570203 Macoma tenta
4908550301 Mercenaria mercenaria
4908720201 Mulinia lateralis
4908750101 Mya arenaria
4908560101 Petricola pholadiformis
4908550401 Pitar morrhuara
4908720101 Spisula solidissima
4908600102 Tagelus divisus
4908570101 Tellina agilis
Tellina versicolor (tentative)

00000000 Phylum Ectoprocta

6601030l-- Amathia dichotoma
6601030201 Bowerbankia gracilis (tentative)
6602040101 Bugula turrita
6602030102 Electra hastingsae
6602020100 Membranipora sp.

Phylum Echinodermata 6800000000

6801000000 Class Asteroidea

6801500101 Asterias forbesi

6803000000 Class Ophiuroidea

6803210301 Amphipholis squamata

6802000000 Class Echinoidea

6802300101 Arbacia punctulata

6804000000 Class Holothuroidea

6804010101 Cucumaria pulcherrima (tentative)
6804500101 Leptosynapta tenuis
Leptosynapta roseola (tentative)
6804010201 Thyone briareus

6900000000 Phylum Hemichordata

6901010101 Saccoglossus kowalewskyi

Phylum Chordata
Subphylum Urochordata
7201000000 Class Ascidiacea

7201030101 Bottryllus schlosseri
7201040101 Mogula manhattensis
7201020201 Perophora viridis

7100000000 Phylum Chaetognatha

7101010101 Sagitta elegans

Invertebrates

Our study of invertebrates during 1973 included observations in six principle subject areas: 1) Quantitative samples taken at four bay locations and two creeks (a total of 52 samples); 2) Qualitative samples taken at five bay locations (a total of 30 samples); 3) A designed experiment, using pre-determined radii in the vicinity of Oyster Creek (a total of 60 samples); 4) A continuation study of the invasion of untreated wood by Bankia (a total of 48 samples); 5) A summary of a study in oyster growth near the power plant (a total of over twelve thousand observations); and finally, 6) A careful taxonomic review of recorded invertebrates from Barnegat Bay. Each of these topics will be dealt with below.

1) Taxonomy. Since 1965, a type specimen collection of the benthic invertebrates of Barnegat Bay has been assembled and updated. During the winter of 1973-74, a careful review of the type collection was made in order to validate the species collected. In addition, a large data matrix has been complied which lists all species ever collected in Barnegat Bay and their frequency of appearance.

Table V lists the species which are reported for the first time from the middle region of Barnegat Bay. The reason that this list is longer than usual is because of corrections made in the taxonomy of previously recorded species. One notes that only five new species were reported in 1973; these species have never been previously reported by the present authors during the course of this study. Alas, 29 species are reported as being tentatively identified. This is because the specimen was either in very poor condition, or we are being conservative in our judgement (we need the assistance, obviously, of independent experts for confirming our type collection).

Table VI lists those species where identifications have been proven to be incorrect. With the use of better keys and more patience in identification (a notably time consuming task), we have been able to demonstrate that previous identifications were in error. We have gone through our original data and noted corrections in taxonomy wherever necessary.

Table VII lists in phylogenic sequence all of the species of benthic invertebrates found in the current study. This list is our most accurate compilation of the species recorded for middle Barnegat Bay. Whenever a species identification was not absolutely clear, we have concluded that the identification was tentative. We expect to eventually offer a list of the species of invertebrates according to their habitat and abundance in Barnegat Bay. In addition, several species found in our fouling and/or plankton studies may not be listed in Table VII.

2) Quantitative samples. On five dates, during the period 18 July- 23 October 1973, we sampled four regions in the bay (Stouts Creek, Forked River, Oyster Creek, and Waretown, totaling 52 samples). At each region we sampled three stations, and at each station a sample consisted of seven consecutive grabs with a Ponar dredge. Hydrographic data was taken and the volume of the sample was recorded. The sample was washed through nested screens(2mm.) and the organisms present were placed in

plastic containers and packed in ice. All sorting identification was preformed using live material. Each sample was weighed for total dry biomass. Diversity and eveness calculations were performed on all samples.

Table VIII lists the average number of species and mean diversity of all samples collected in 1973 and compares these data to previous years. Review of Table 7 in Progress Report No. 8 indicates a general trend for the bay; i.e., there are about 20 species of invertebrates, on the average, taken per sample. In late summer 1972, we found that the Forked River and Oyster Creek areas experienced an increased number of species per sample. However, during the sampling period of 1973, the average sample in the bay still showed about 20 species per sample (estimated in orders of magnitude). There seems to be a slight increase in the average number of species, per sample, in the bay between the period 27 August 1969-26 June 1972 and the period 12 July 1972-23 October 1973. However, the overall pattern, based on all data between 27 August 1969-23 October1973, still indicates about 20-22 species of invertebrates taken per seven ponar grabs with a Ponar at one location in the bay.

The canal or creek stations continue to demonstrate about half the number of species as normally found in the bay. The canals are generally disturbed areas and the existence of stress (thermal as well as turbulent) may contribute to the lower species number. Nevertheless, we still find about ten speceis, on the average, per sample in the canals.

Figures 5,6,8, and 9 all demonstrate a phenomenon which was readily observable in the field during our collecting trips. Generally speaking, 1973 was not a rich year for invertebrates in Barnegat Bay in comparison to 1972. All stations showed a distinct decrease in the number of species (Figure 5), diversity (Figure 6), biomass/m^2 (Figure 8), and number of individuals per meter squared(Figure 9). This decrease seemed most notable in the density of individuals in the sediment, and was found at all locations in the bay. Associated with the decreased richness, we found a decreased dominance--this is reflected in the increase of eveness(figure 7). The summer of 1973 was not unusual relative to 1972--in fact, both summers were preceeded by relatively mild winters with little or no snowfall. Because the decrease in species richness and abundance was widespread (both in the bay and in the canal), it is difficult to speculate on the possible cause. As will be demonstrated presently, we feel that thermal stress has not played a significant role--to the best of our persent understanding of Barnegat Bay--in the dimunition of species numbers and individuals. The changes observed over the past two years are seen more readily in the estimate of density rather than species numbers. Interestingly enough, while we observed a decrease in the invertebrate populations and biomass, the benthic algae experienced one of the best years yet. Such natural cycles are not uncommon and we expect that the benthic fauna will improve in the future.

However, as a word of caution, we continue to observe a decrease in dominance in the invertebrate community. The prior dominants Mulinia and Pectinaria still have not made a significant comeback since their crash (July 1970 for Mulinia) Also, it is possible that we are beginning to observe real changes in the nature of Barnegat Bay. There is no doubt in our mind that Barnegat Bay was used by people more during

MEAN NUMBER OF INVERTEBRATE SPECIES AND MEAN DIVERSITY INDICES FOR THREE TIME PERIODS FROM 27 AUGUST 1969 THROUGH 23 OCTOBER 1973

STATION	12 July 72-16 Aug 72			18 July 73-23 Oct 73		
	TOT # Samples	Mean Diversity	Mean # Species	Tot # Samples	Mean Diversity	Mean # Species
S.C.	6	1.626	25.33	13	2.423	22.30
F.R.	6	2.693	34.83	13	2.663	22.38
O.C.	7	2.370	31.14	13	2.629	24.00
F.R. canal	3	1.823	12.67	3	1.338	11.00
O.C. canal	3	1.920	14.67	3	1.594	9.33

STATION	* Mean Values for above time period, 12 July 72-23 Oct 73			** For comparison, from Report #8, Means for 27 August 69-26 June 72		
	Tot # Samples	Mean Diversity	Mean # Species	Tot # Samples	Mean Diversity	Mean # Species
S.C.	19	2.025	23.82	113	1.8794	21.01
F.R.	19	2.678	28.61	105	1.8928	21.72
O.C.	20	2.500	27.57	130	1.7496	20.61
F.Rcanal	6	1.581	11.84	42	1.1984	11.34
O.Ccanal	6	1.757	12.00	41	1.4332	11.02

STATION	!* Grand Means to date, time period 27 August 69-23 Oct 73		
	TOT # Samples	Mean Diversity	Mean # Species
S.C.	132	1.916	21.71
F.R.	124	2.089	23.44
O.C.	150	1.937	22.35
F.R.canal	48	1.294	11.46
O.C.canal	47	1.514	11.26

NOTE: * These values are means of means for each of 2 time periods.
** These values are means of means for each of 6 time periods.
!* These values are means of means for each of 8 time periods.

Figure 5 Comparison of the number of species per seven ponar grabs at each station for 1972 and 1973

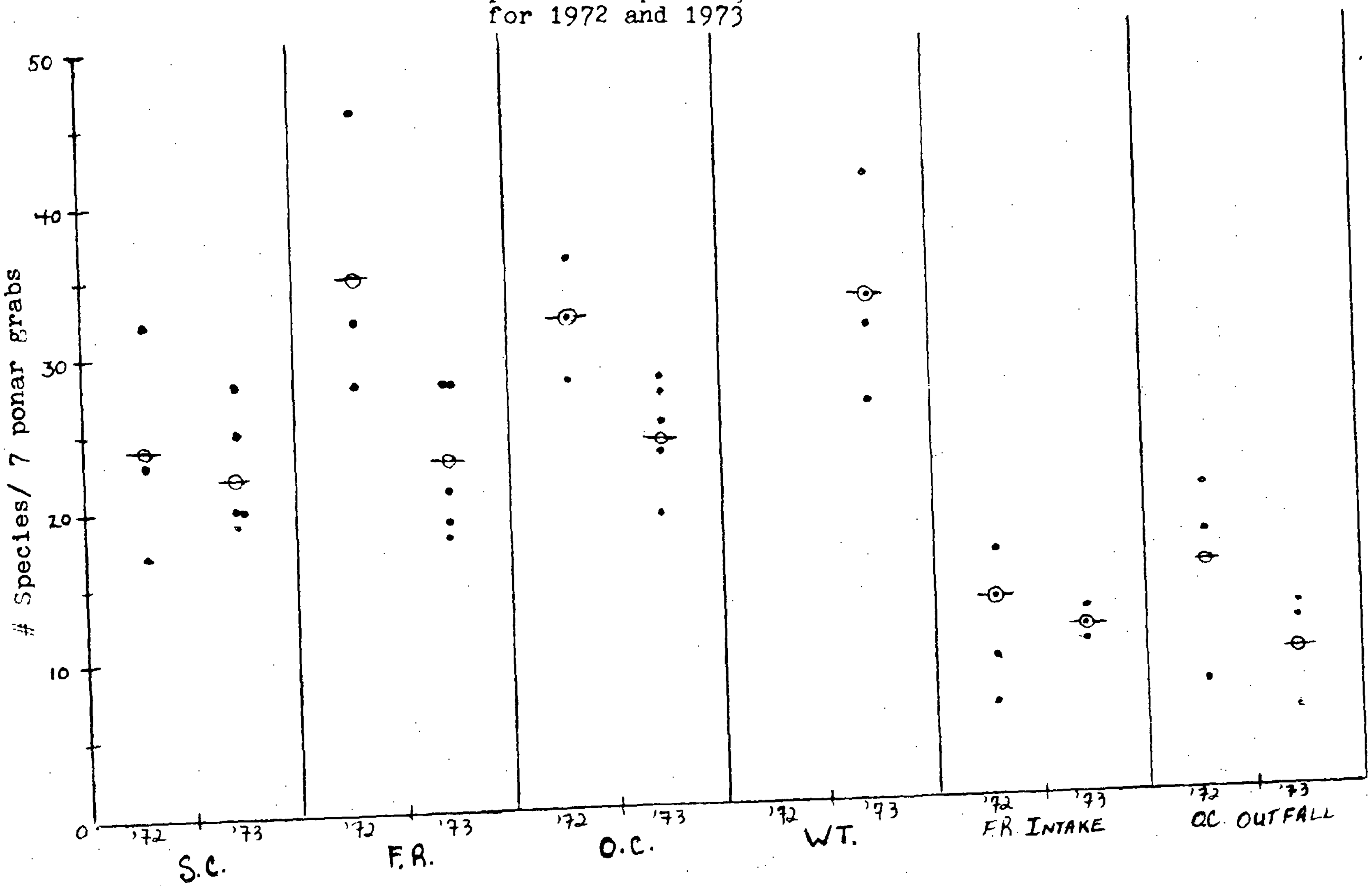


Figure 6 Comparison of the diversities at each station for the years 1972 and 1973

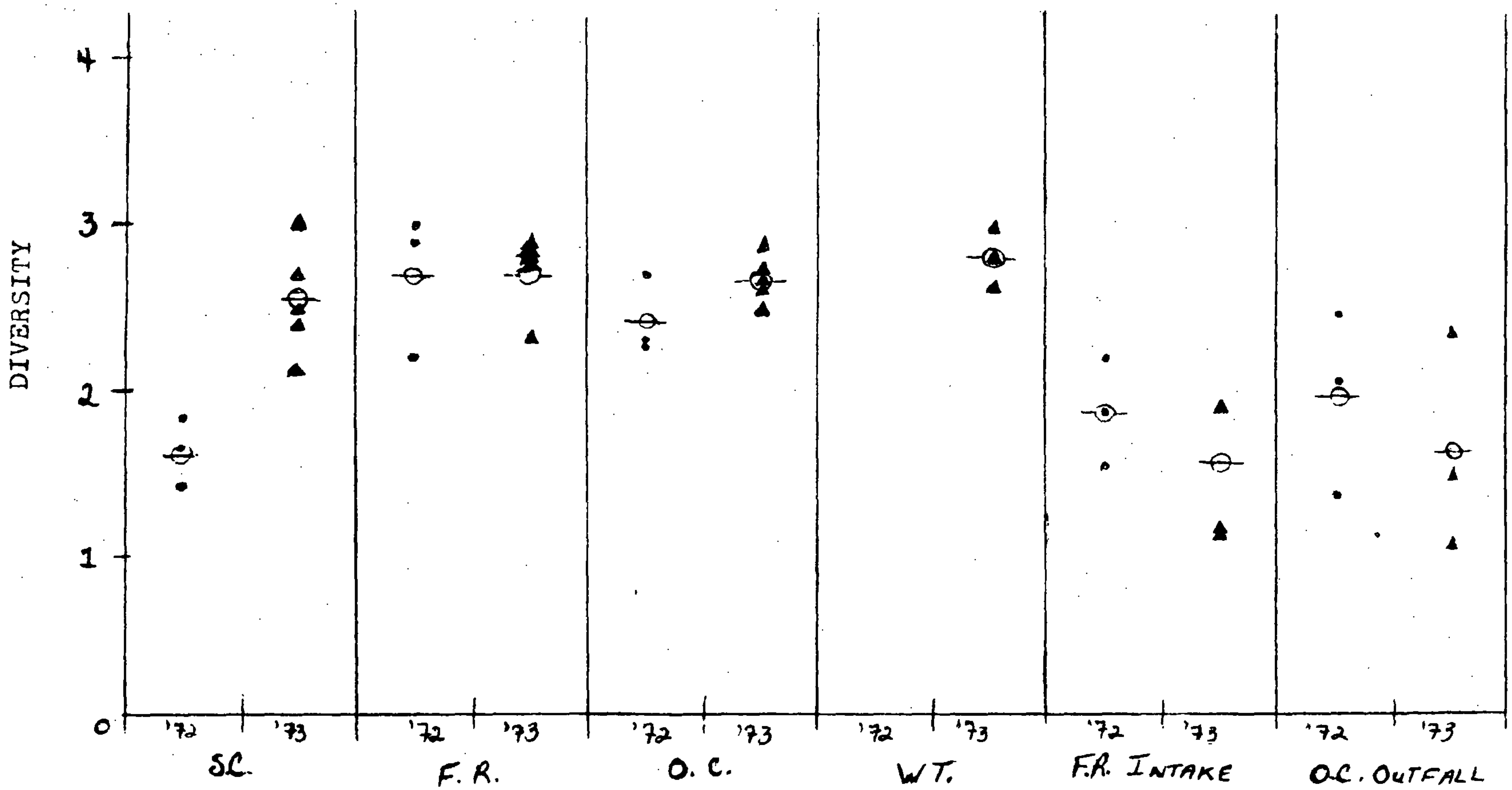
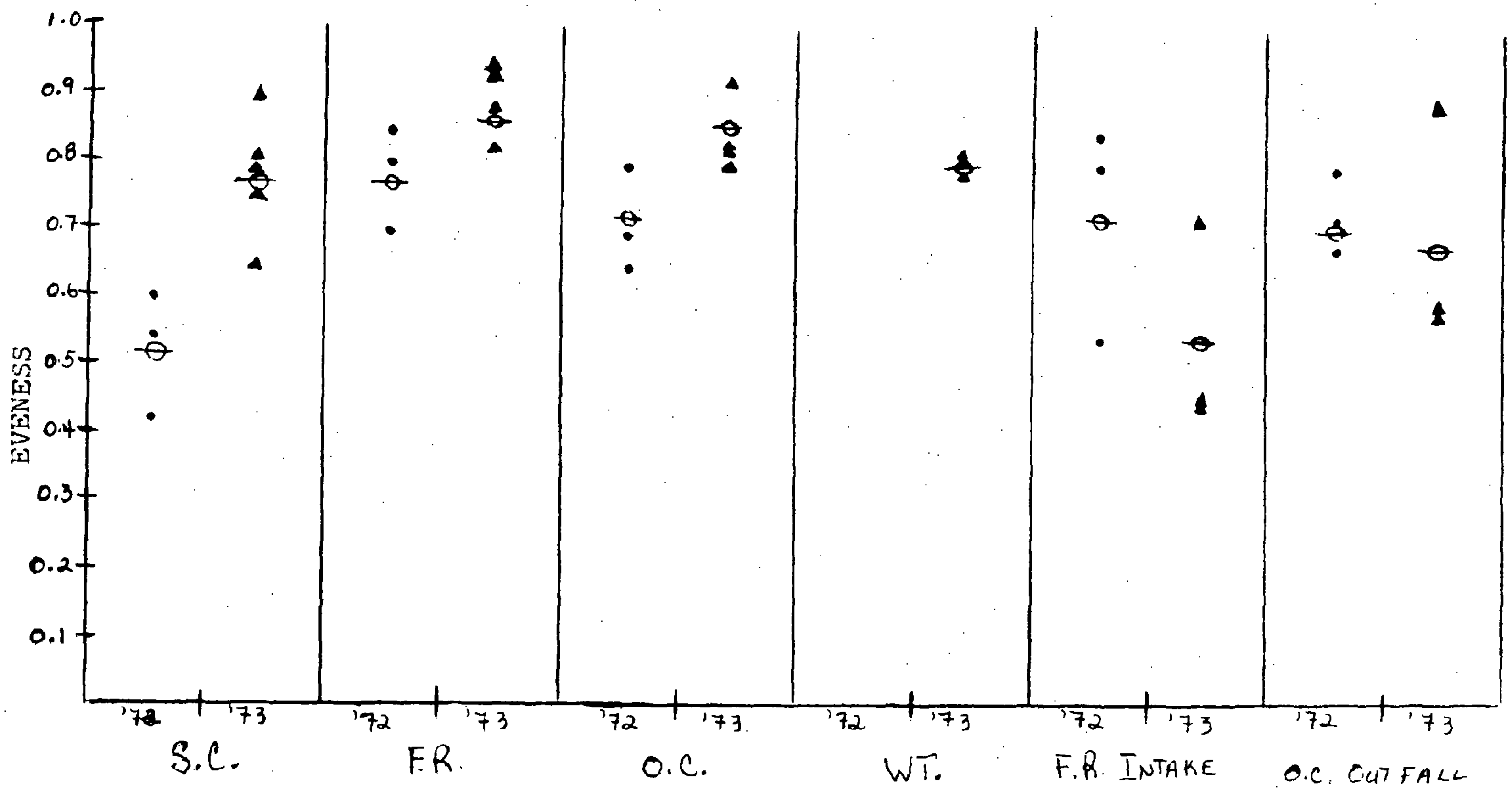


Figure 7   Comparison of eveness values for each station for the years 1972 and 1973



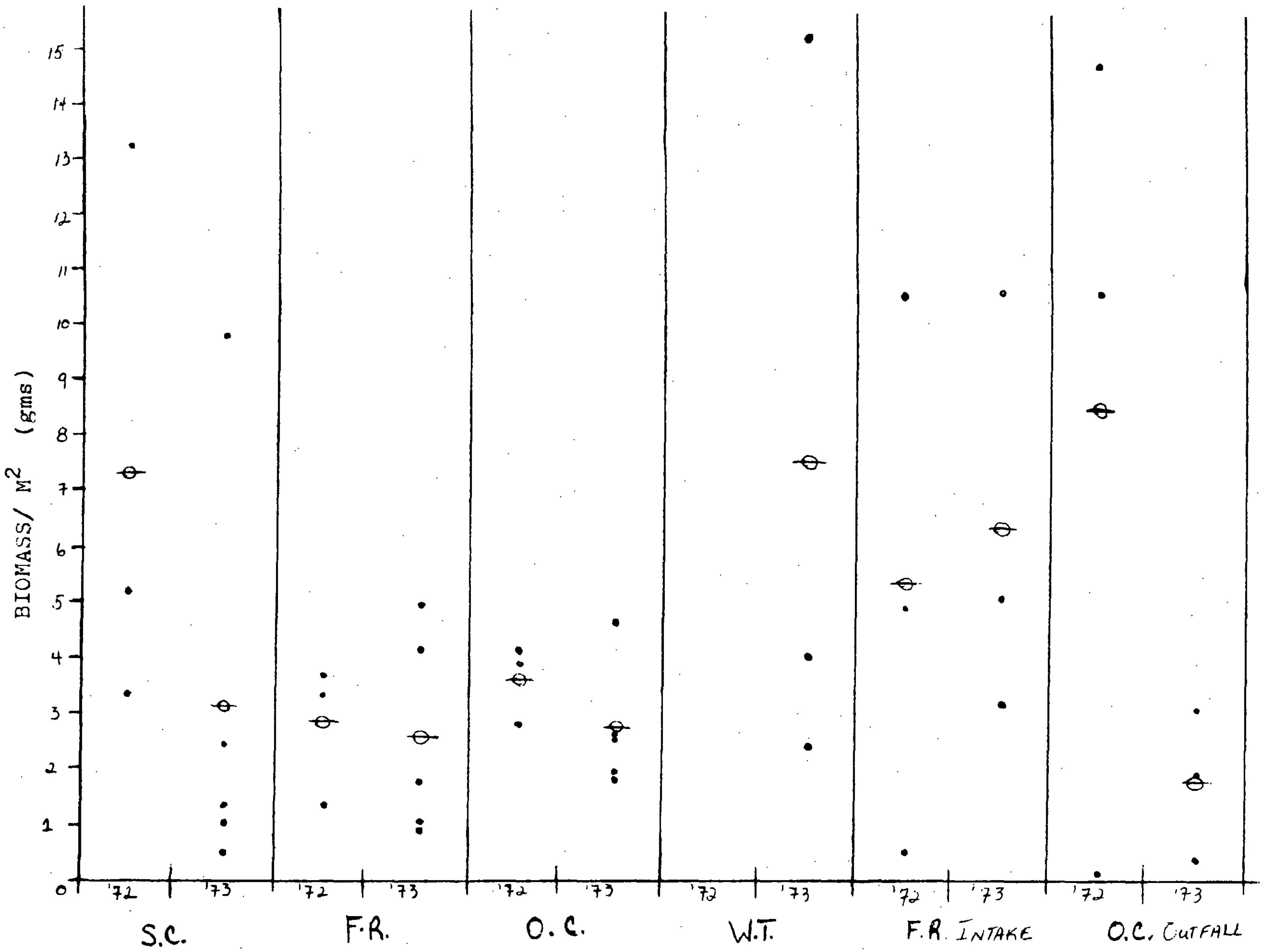


Figure 8 Comparison of biomass per square meter measured in grams at each station for the years 1972 and 1973

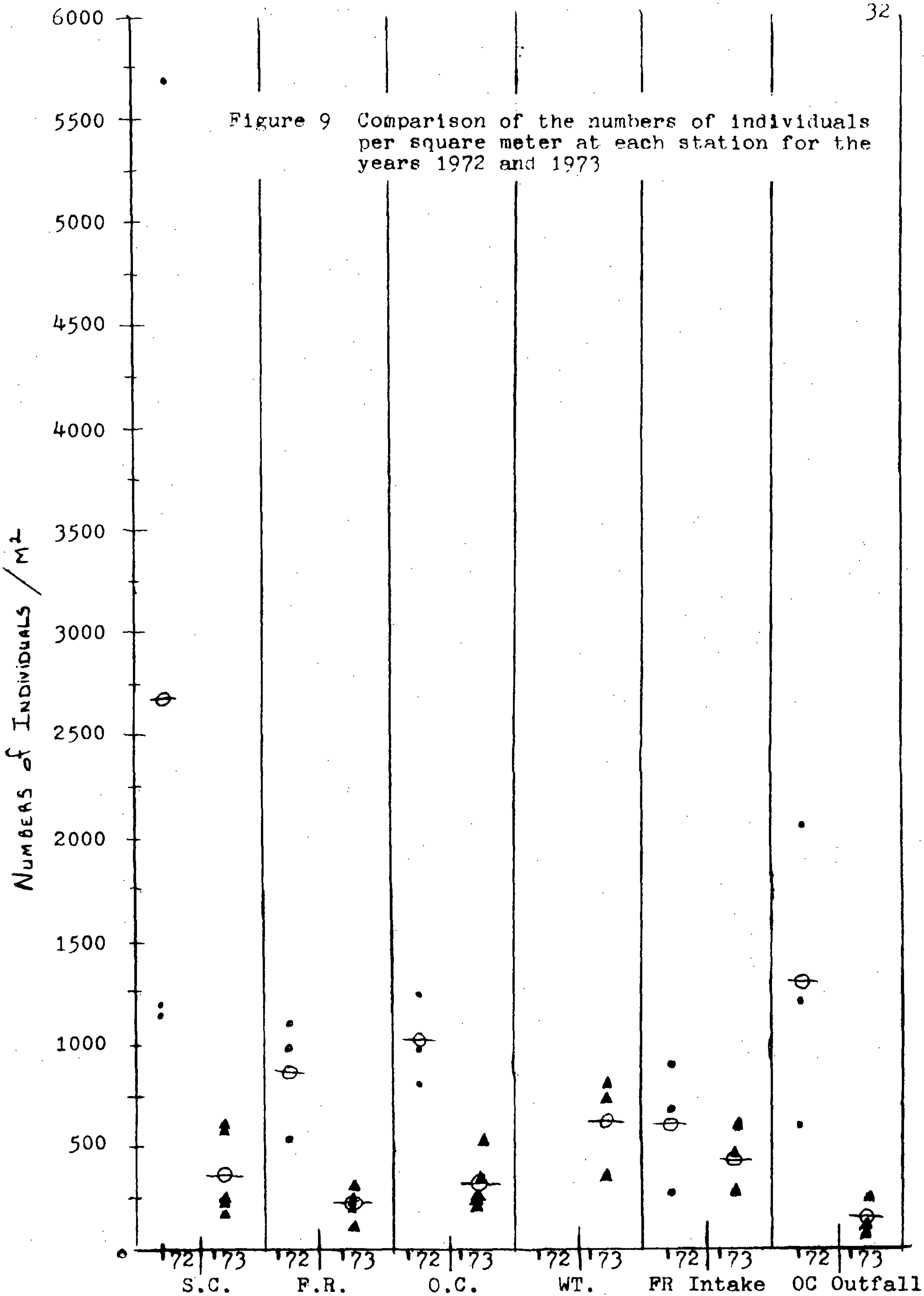


Figure 9 Comparison of the numbers of individuals per square meter at each station for the years 1972 and 1973

the past summer than we have ever noticed before. The boating activity is extremely high and the amount of debris which we found floating and in our bottom samples increased in 1973. Of course, we cannot validate this with cold hard data, but it is apparent to us that Barnegat Bay may soon reach the threshold of its resilience to its use by man. We urge that careful consideration be given to the continued development of Barnegat Bay because there are aspects here which are just not being measured.

3) Qualitative samples. On two dates (28 July and 11 September 1973), five transects were surveyed for benthic invertebrates. On each transect (see Table X for positions in Bay) three stations were sampled. Each station consisted of a 2.5 minute trawl with a small oyster dredge (wire basket) on a line perpendicular to the shore line. All species were sorted live on board, and a random quantity was brought back to the lab for identification of small and/or encrusting forms. We were primarily interested in those species which generally are at or on the surface of the bottom sediments. Table IX gives the distribution of species number by date and station. Using this data, an analysis of variance was performed in an attempt to detect differences due to position in bay or time of sampling. As might be expected, there were no differences in any effect measured; that is, the samples were remarkably uniform over date, station and direction (east to west or north to south). This region of the bay, between Stouts Creek and Oyster Creek, is rather uniform in average sediment composition, species composition and hydrographic analysis (except, of course, for the thermal effects in the vicinity of Oyster Creek). It should be recalled that while sediments do vary locally, on the average the three regions (Stouts Creek, Forked River and Oyster Creek) are rather similar. Also, even though the mouth of Oyster Creek reported the lowest species number, this value was not significantly lower than other regions in the bay. It is apparent, however, that the transect directly off Oyster Creek had fewer species, on the average, than any other transect, although the significance of this is not clear.

Figure 10 is a plot of the data obtained during the qualitative sampling program. No patterns are apparent here; generally, we find fewer species sampling the epifauna than we do when we sample the infauna (15 vs. 20).

4) Radii study. In attempt to assess the local effects of the thermal plume emanating from Oyster Creek on the benthic organisms, we performed the following designed field observation. On four dates,(6 July, 2● August, 29 September and 13 November 1973), a series of stations were selected on transect which radiated away from the mouth of Oyster Creek. Transect I ran parallel to the shoreline, south toward Waretown; Transect III ran perpendicular (straight out into the bay); Transect V ran parallel to the shore, north toward Forked River; Transect II was 45° between I and III; Transect IV was 45° between III and V. On each transect we made three stations: Station A in the vicinity of Light 3 off Oyster Creek, Station B, about 0,25 miles from A, and Station C, 0.5 miles from A. These stations could also be arranged as five stations on each of three circumferential transects: Transect A (five stations near Light 3), 0.25 miles from mouth of Oyster Creek; Transect B,(five stations), 0.5

Location	Station	28 July	11 Sept
S.C.	3	17	8
S.C.	2	14	24
S.C.	1	18	26
½ btwn S.C.+F.R.	4	17	17
½ btwn S.C.+F.R.	5	16	22
½ btwn S.C.+F.R.	6	15	23
F.R.	9	21	30
F.R.	8	15	9
F.R.	7	17	24
½ btwn F.R.+O.C.	10	24	10
½ btwn F.R.+O.C.	11	10	14
½ btwn F.R.+O.C.	12	14	21
O.C.	15	12	12
O.C.	14	20	20
O.C.	13	8	6

Table IX Numbers of species collected at each of 15 Bay stations for 28 July and 11 Sept, 1973. Encircled numbers represent stations.

Table X

QUALITATIVE INVERTEBRATE STUDY

NUMBER OF SPECIES

STATION	28 July 73		11 Sept 73		
1	18		26		
2	14	$\bar{X}$=16.3	24	$\bar{X}$=19.3	
3	17		8		
4	17		17		
5	16	$\bar{X}$=16.0	22	$\bar{X}$=20.6	
6	15		23		
7	17		24		
8	15	$\bar{X}$=17.6	9	$\bar{X}$=21.0	
9	21		30		
10	24		10		
11	10	$\bar{X}$=16.0	14	$\bar{X}$=15.0	
12	14		21		
13	8		6		
14	20	$\bar{X}$=13.3	20	$\bar{X}$=12.6	
15	12		12		
	$\bar{X}$=15.8		$\bar{X}$=17.7		$\bar{\bar{X}}$=16.7

STATION LOCATIONS

O.C.		F.R.		S.C.
13	12	7	6	1
14	11	8	5	2
15	10	9	4	3

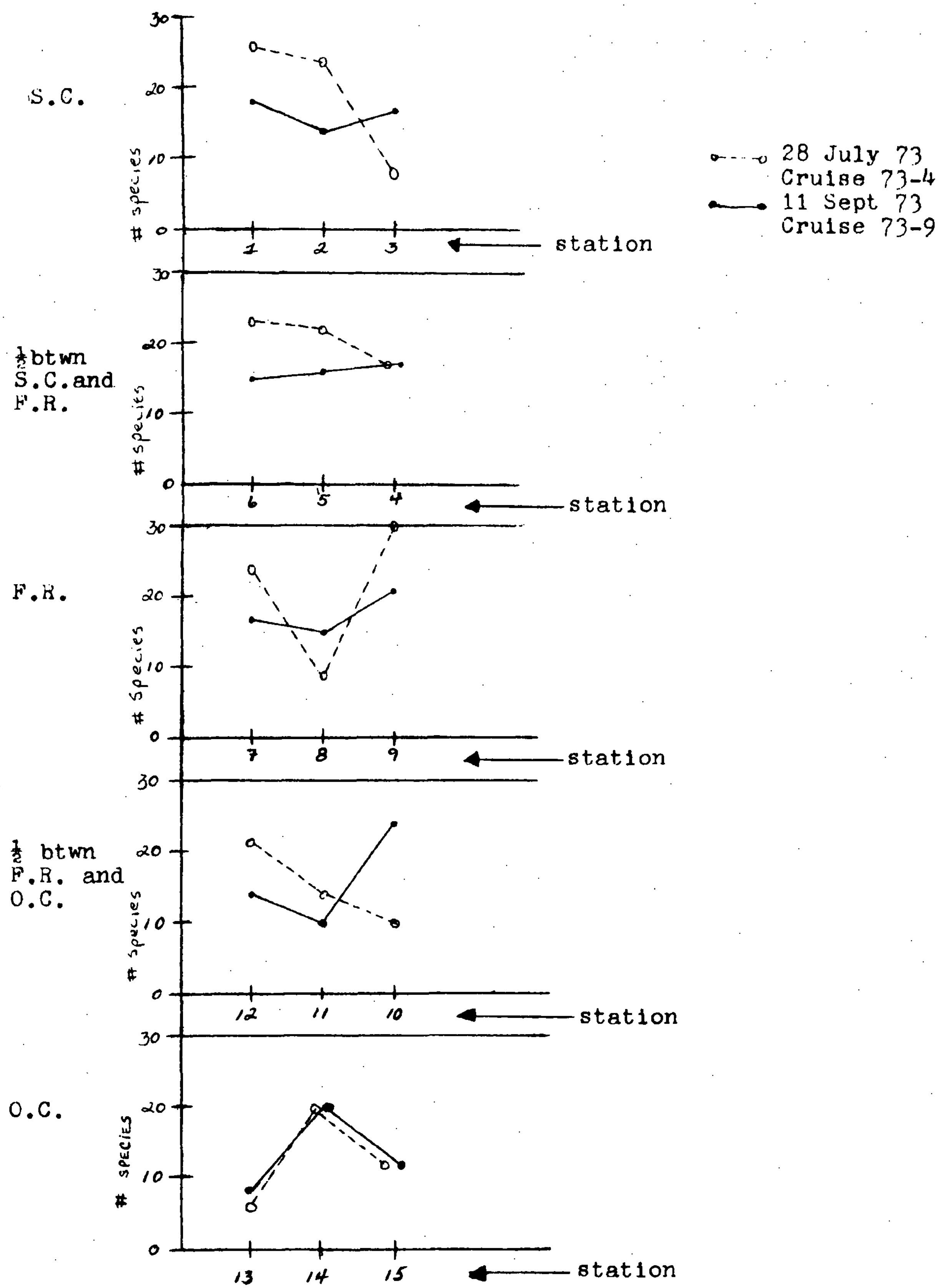


Figure 10 Plots of the numbers of species for each station from the two qualitative cruises made in 1973

miles from the mouth; Transect C (five stations), 0.75 miles from the mouth. At each station, 7 ponar grabs were made, hydrographic analysis and station locations were noted. From the data generated in this study, an analysis of variance was performed to answer certain questions listed presently. The raw data from this study is presented in Figures 11-20.

The results of the analysis of variance are given in Figures 21-22. A discussion of the factors analyzed follows.

1. Number of species. The average number of species on the inner circumference (Circumferential Transect A) was significantly higher ($P < .01$) for all dates(Figure 21A); this was particularly true when comparing Transect A with B (26.75 species vs. 19.95 species). With respect to date, August showed a significantly higher ($P < .05$) number of species at all stations than did the July, September and November collections. With respect to the radii transects, no transect was significantly different from any other (over all dates). Finally, there were no interactions that were significant.

2. Number of individuals/M^2. With respect to date, August showed higher densities of individuals for all stations compared with September and November (525/M^2 vs. 179 and 307/m^2, respectively). However, no transect was significantly different from other transects over all dates--this was true for both radiating transects and circumferential transects. There were also no significant interactions.

3. Diversity index. The degree of species richness of the inner transect is reflected in its significantly higher diversity index. In fact, both Transects A and C were significantly higher (Figure 21 B) than Transect B (2.632 and 2.538 vs. 2.185). Again we found that there were no significant differences due to radii positions; nor were there differences in the stations from date to date. Finally, there were no significant interactions.

4. Biomass. If one compares the total dry weight of those organisms caught with 7 ponar grabs, we find that the August collection was significantly higher in biomass than either the September or November collections (1.2495 grams vs. 0.4475 and 0.5855 grams, respectively). There were no significant differences due to radii or circumference; also, there were no significant interactions.

5. Temperature. As one might expect, there were significant differences from station to station for both circumferential transects and radiating transects. The inner most circumference (Transect A) was significantly warmer ($P < 0.01$) than the outer two circumferential transects (i.e., A>B,C, or 22.1° > 20.9° , 20.3° C; see Figure 21D). With respect to radiating transects, we found that there was a significant ($P < 0.05$) drift of warmer water in a northeasterly direction. That is, the warm water plume coming out of Oyster Creek bent to the left (headed north and east) when it entered the bay (see Figure 22A). This seemed to be the case on all four dates; however, on all trips we experienced strong southerly wimds. Of course, as expected, we found differences in surface temperature due to date (July, 29.37° > August, 26.77° > September, 21.56° > November, 6.74° C).

With respect to bottom temperature, we did not find any significant drift of warm water. However, we did find a circumference effect; that is, the inner circumference was significantly higher ($P < 0.01$) than the outer two circumferential transects (see Figure 21C). Also, the temperatures on the bottom decreased over the four dates (July, 27.04° > August, 24.89° > September, 21.15° > November, 8.27° C).

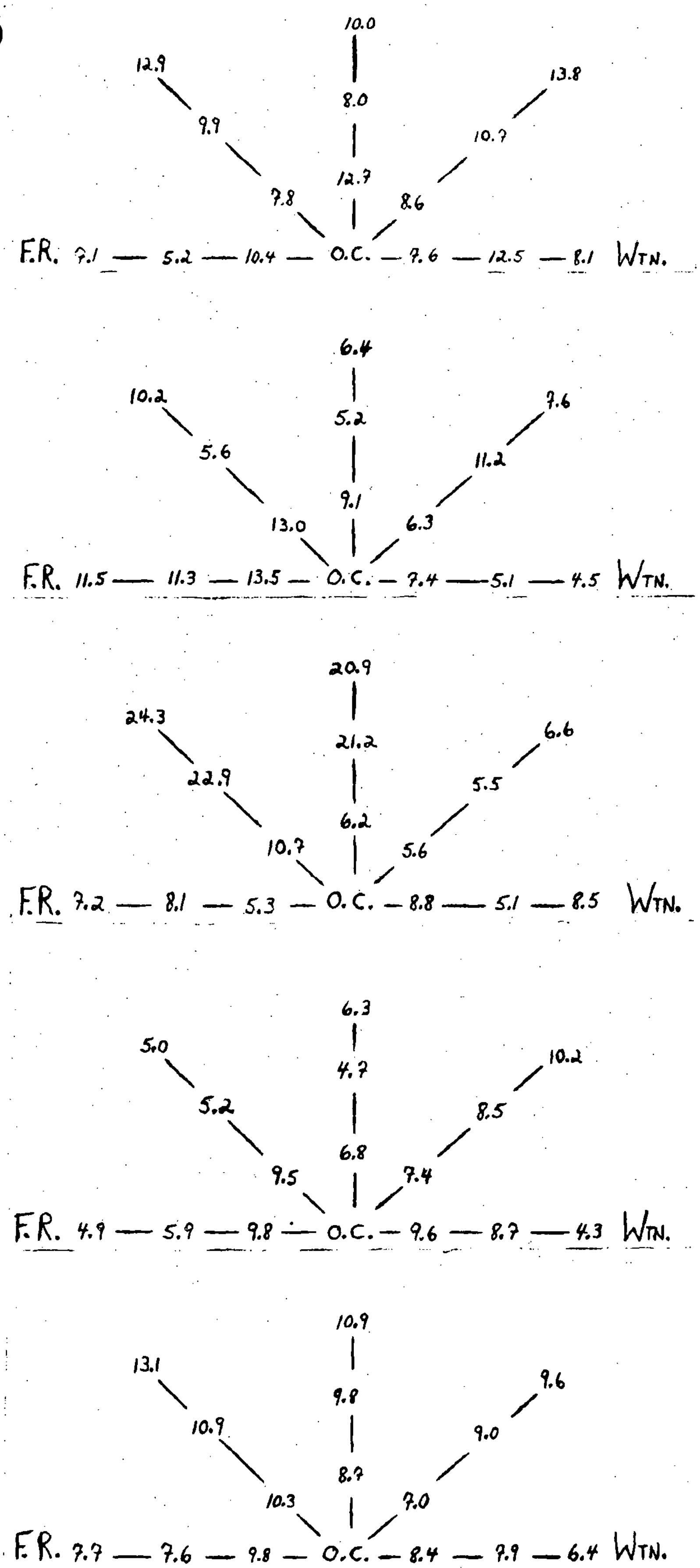
6. Salinity. We found that there was a significant ($P < 0.05$) influx of higher salinity water from the southeast, (Figure 22B), correlated with the loss of warmer water to the northeast. That is, we found evidence of entrainment of southerly bay water into the middle portion of the bay. This was only significant on the surface and was probably due to strong southerly winds. We found that surface salinity did not vary significantly from one circumferential transect to another. However, salinity increased from one date to the next (July, 19.03 < August, 21.40 < September, 25.08 < November, 26.02 0/00).

Bottom salinity showed a significant ($P < 0.01$, 0.05) increase as one moved away from the region of Oyster Creek. Since the bottom temperature was higher near the mouth, then there is a probability that some vertical mixing is occurring where the warm water from Oyster Creek intercepts the bay. Oyster Creek has a slightly lower salinity than the bay water because fresh water from Forked River is drawn into the coolant water by the pumping action of the power plant. Again we found that bottom salinity increased throughout the summer and fall (July, 21.72, August, < 21.93 September, 26.55, November, 26.60 ‰).

7. Light. Penetration of light, as measured by a standard Secchi disc, demonstrated a lower light ($P < 0.01$) transparency near the mouth of Oyster Creek and increasing clarity as one moves away from the Creek (see Figure 21F). There were no differences due to radii; and no significant interactions occurred. The water in September was significantly clearer than in July and August (3.86 > 3.47, 3.26).

Discussion. All factors measured and analyzed (statistically) indicate that the region around Light 3, immediately off the mouth of Oyster Creek, is a biologically richer place than adjacent regions. We, of course, are restricting our comments here to bottom fauna. What emerges is an indication that warmer, low salinity, high detritus-containing water appears to flow from the mouth of Oyster Creek. The power plant causes water to be pulled in from the bay near the mouth of Forked River; this water mixes with fresh water from the north branch of Forked River. As the water passes up the south branch of Forked River, a great deal of turbulence occurs due to swift currents. The water is then heated on its passage through the condensers. No doubt some organisms are either killed or damaged, especially the plankton. This results in a raised detrital load in Oyster Creek--which then passes directly into the bay. Once the thermal plume hits the bay, some mixing with bottom water occurs, but most of the water is carried out into the bay. In the present study, there was a significant northerly drift of the thermal plume. Those benthic invertebrates near the mouth of Oyster Creek are at a distinct advantage because they are constantly supplied with slightly warmer water with (presumably) higher organic content. It is, therefore, not surprising to find more species in this area. However, there were not increased numbers of individuals. It appears that species number is more responsive to differences in regions than the density of individuals.

Fig. 11.- Volume (liters) of samples (7 ponar grabs) taken at each of 15 stations on 4 sampling dates.



6 July 73

20 August 73

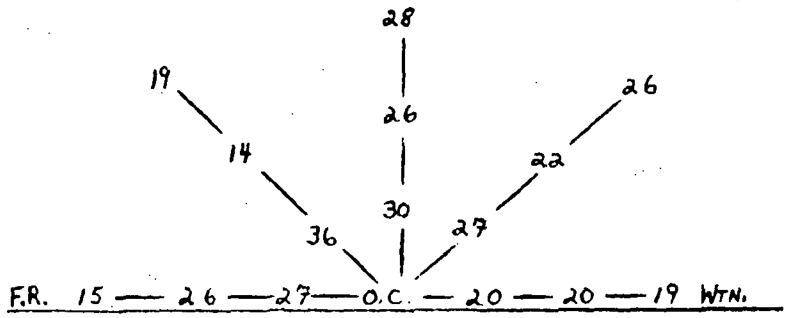
29 September 73

13 November 73

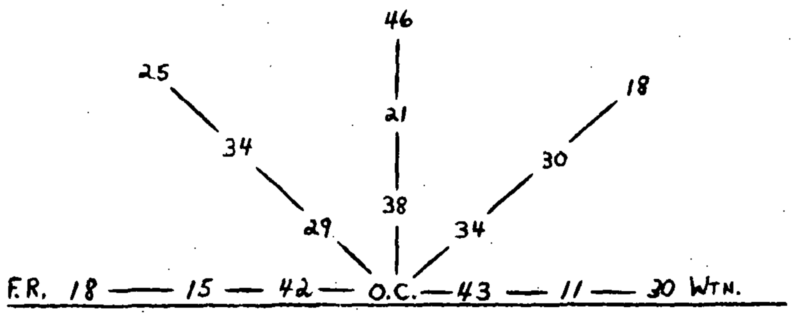
Station means over 4 sampling dates

Fig. 12 - Number of species per sample (7 ponar grabs) at each of 15 stations on 4 sampling dates.

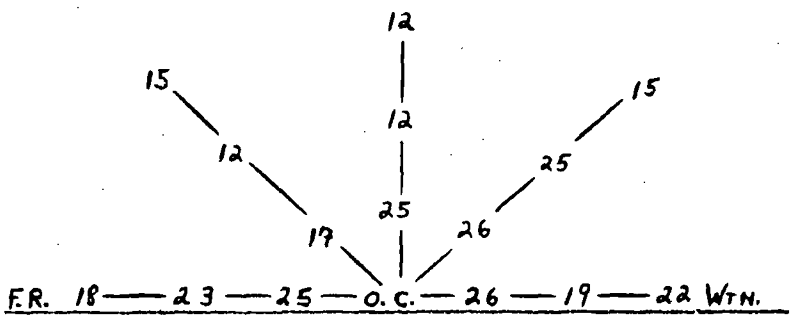
6 July 73



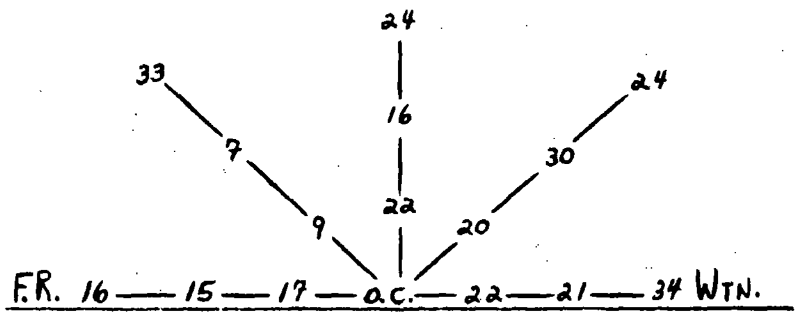
20 August 73



29 September 73



13 November 73



Station means over 4 sampling dates

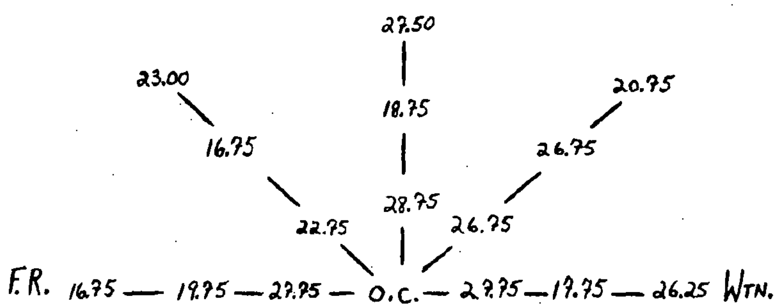


Fig. 13 - Number of individuals per M^2 at each of 15 stations on 4 sampling dates.

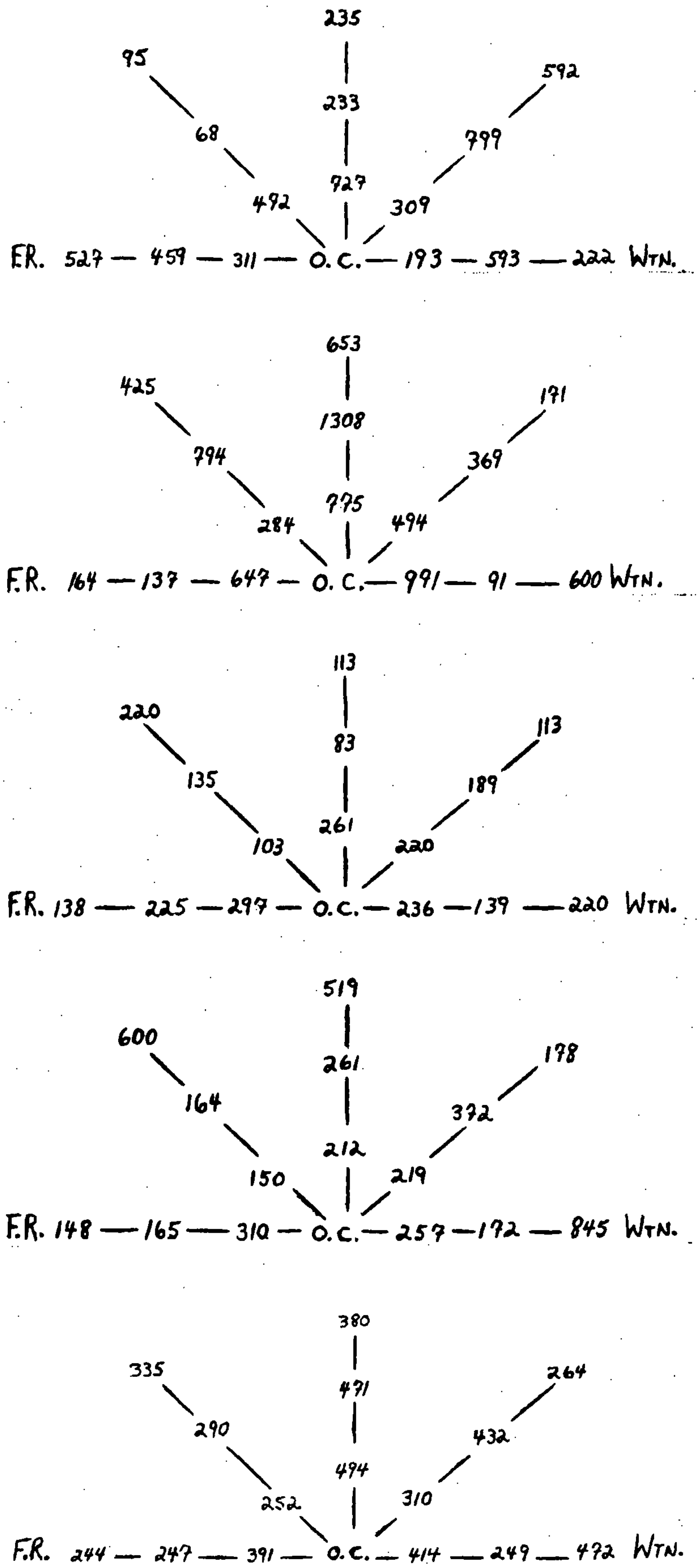
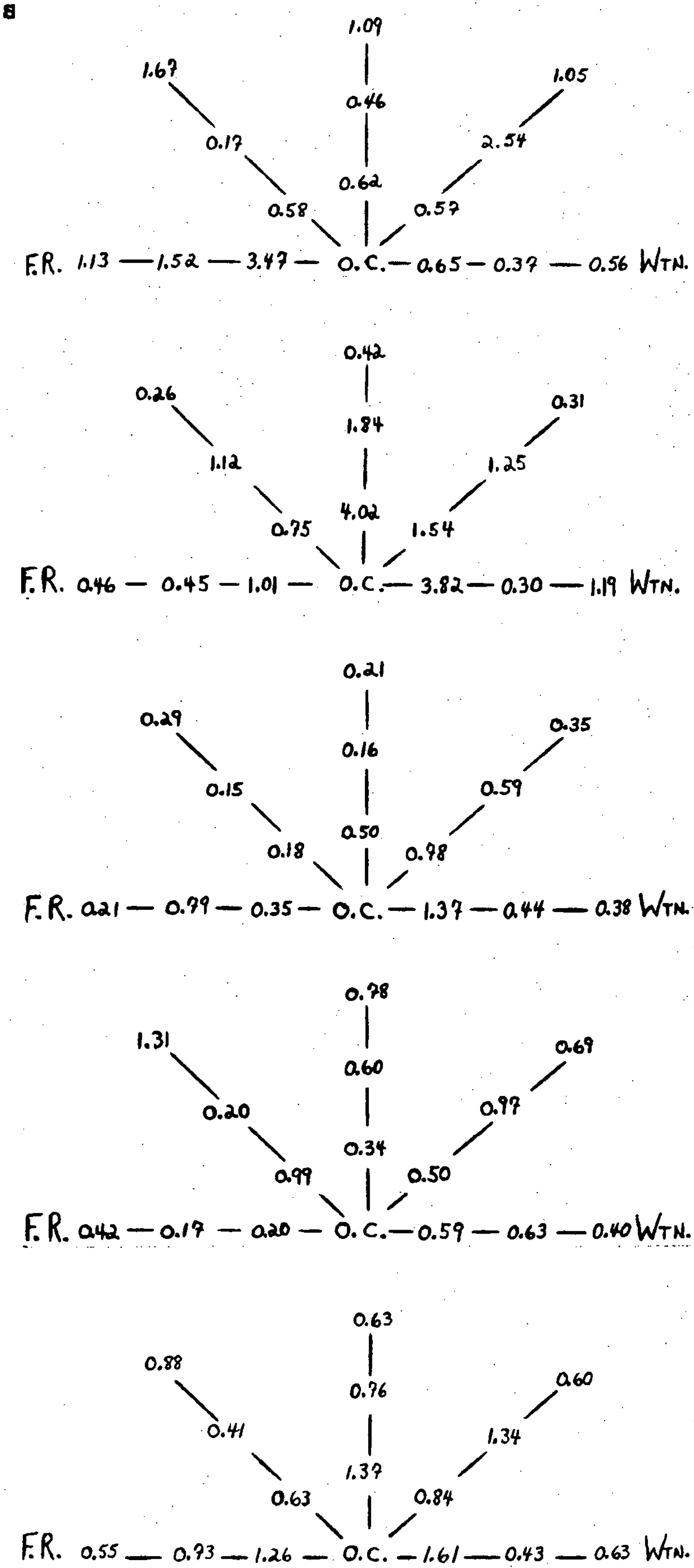


Fig. 14 - Biomass (gms) of benthic invertebrates collected at each of 15 stations on 4 sampling dates.



6 July 73

20 August 73

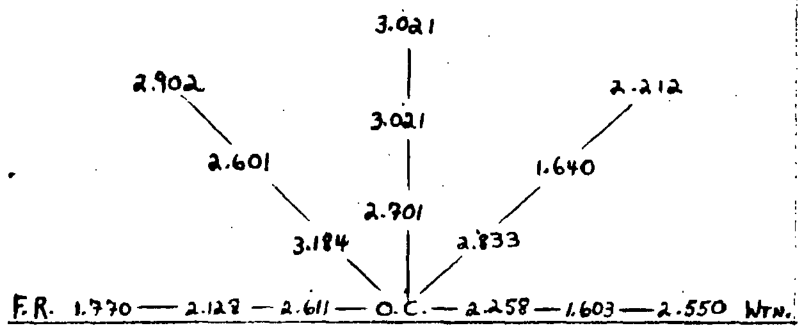
29 September 73

13 November 73

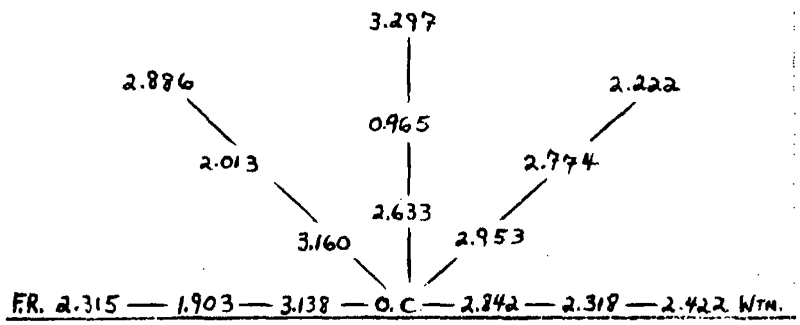
Station means over 4 sampling dates

Fig. 15 - Diversity index ($\bar{H}$) at each of 15 stations on 4 sampling dates.

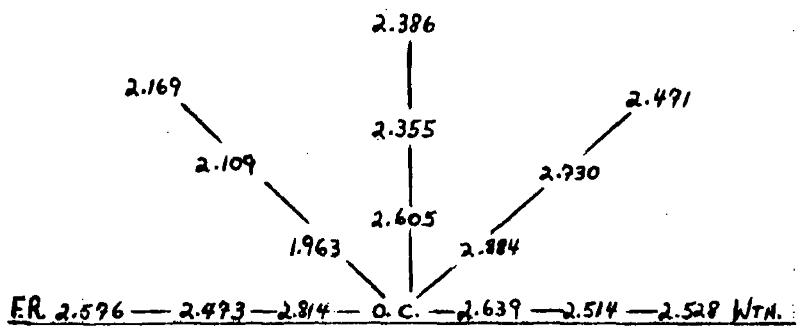
6 July 73



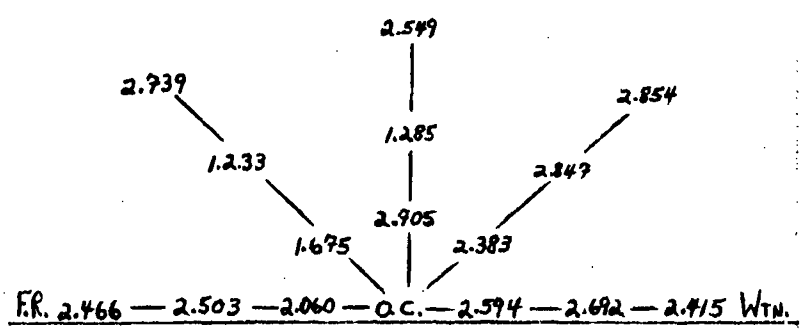
20 August 73



29 September 73



13 November 73



Station means over 4 sampling dates

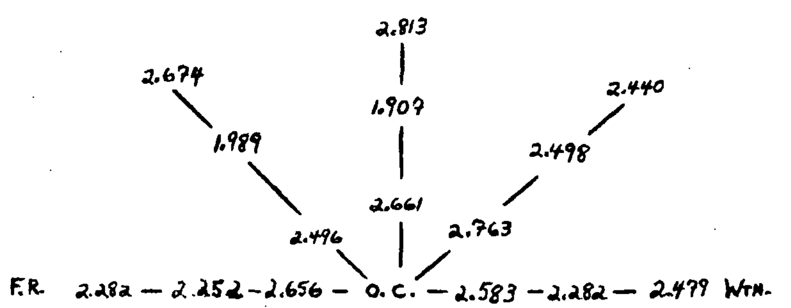


Fig. 16 - Surface water temperature (degrees C) at each of 15 stations on 4 sampling dates.

6 July 73

20 August 73

29 September 73

13 November 73

Station means over 4 sampling dates

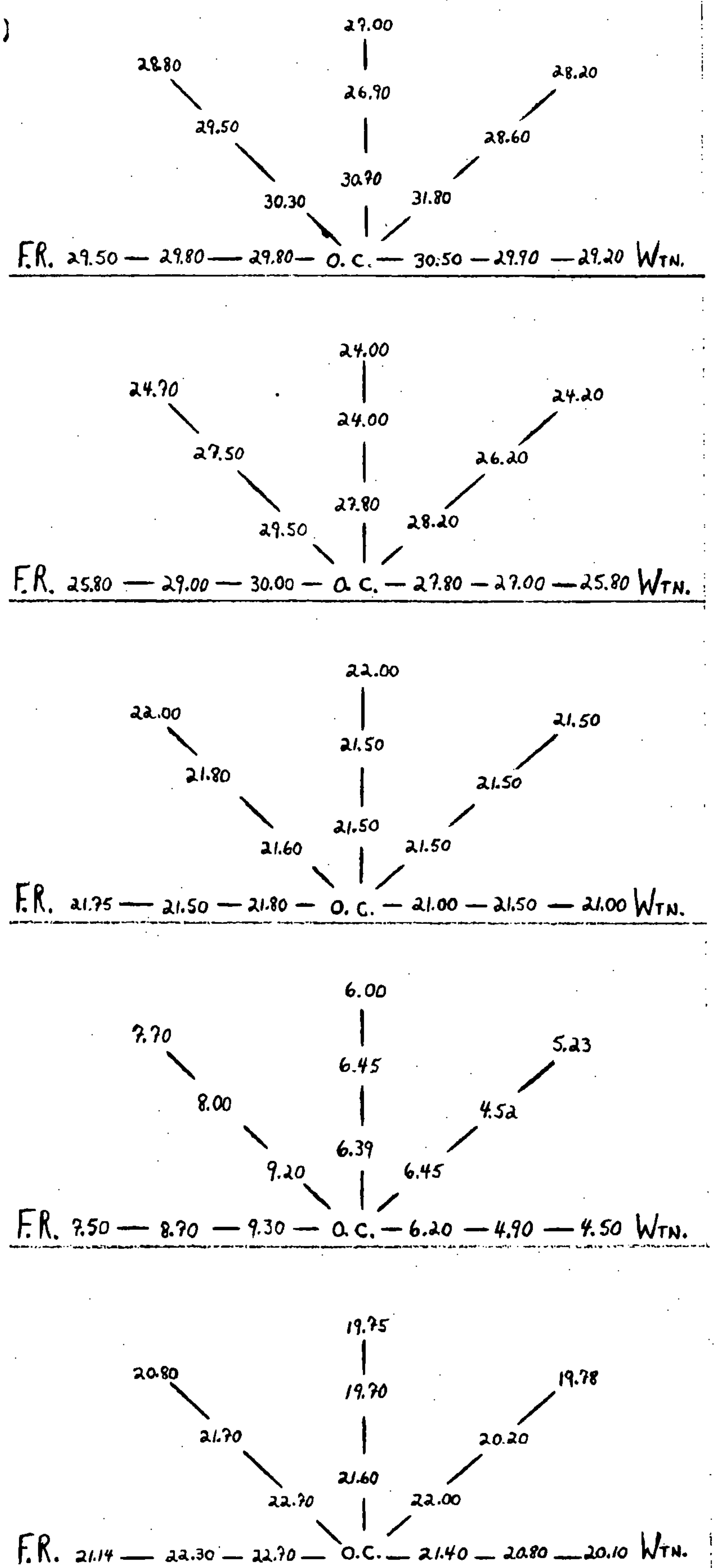
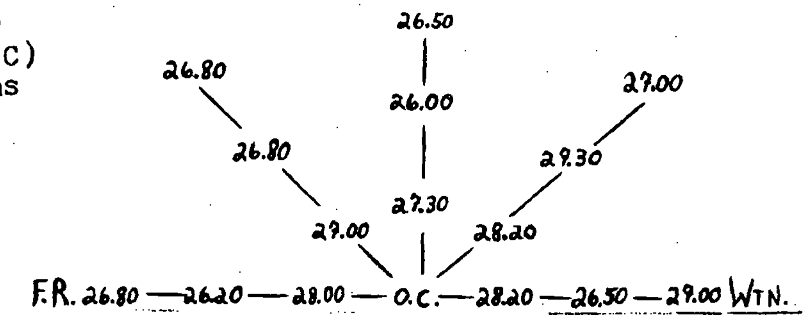
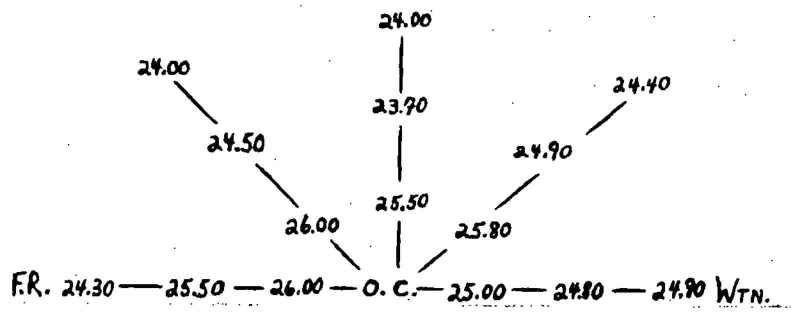


Fig. 17 - Bottom water temperature (degrees C) at each of 15 stations on 4 sampling dates.

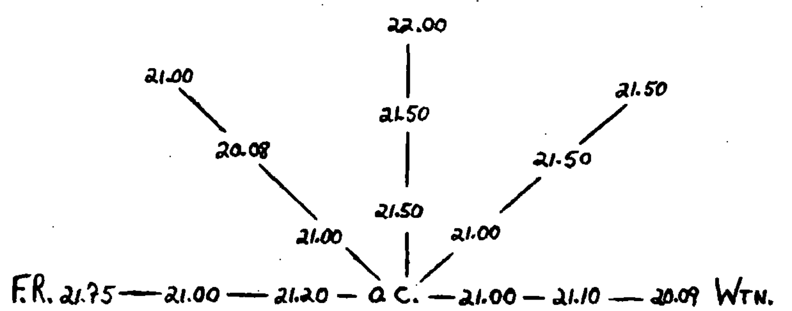
6 July 73



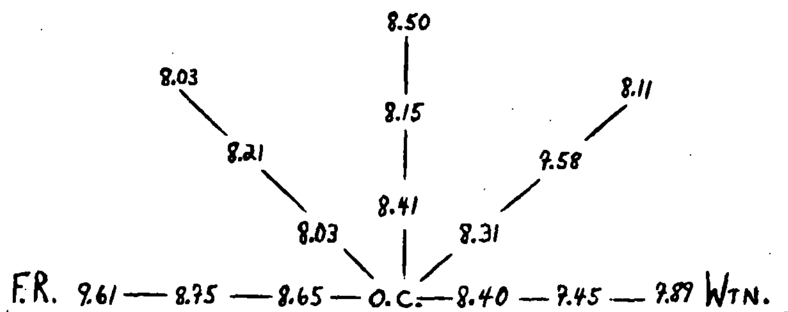
20 August 73



29 September 73



13 November 73



Station means over 4 sampling dates

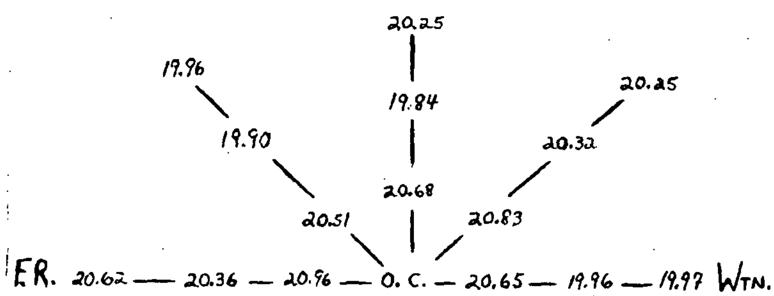
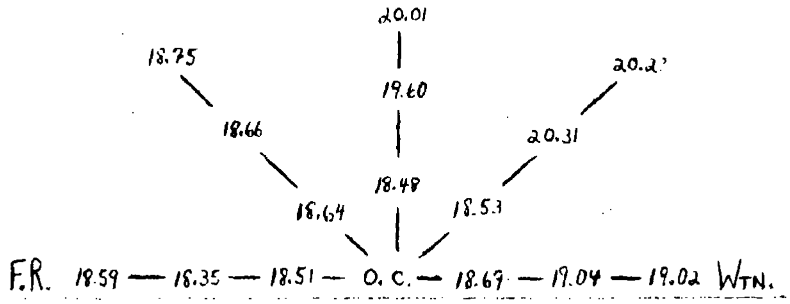
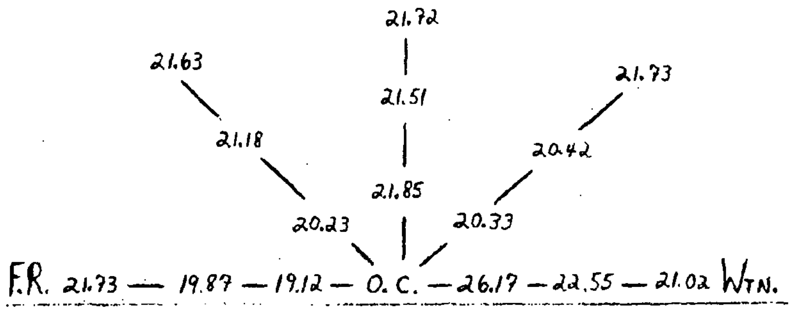


Fig. 18 - Surface salinity (ppt) at each of 15 stations on 4 sampling dates.

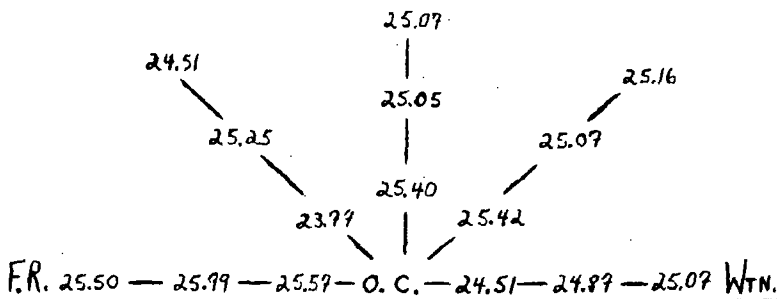
6 July 73



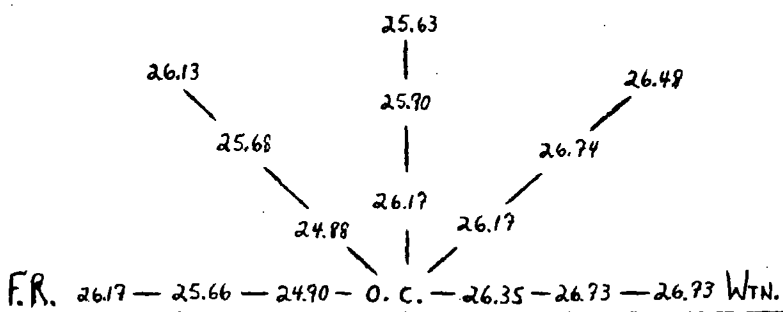
20 August 73



29 September 73



13 November 73



Station means over 4 sampling dates

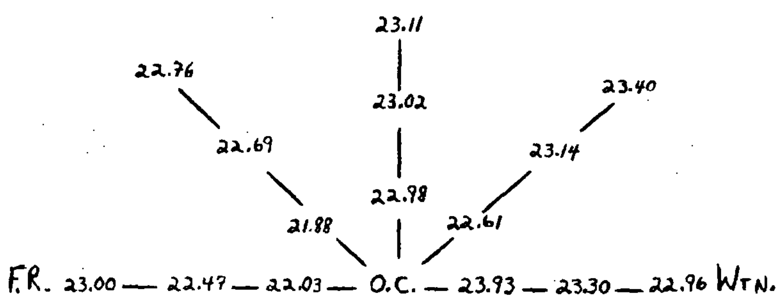


Fig. 19 - Bottom salinity (ppt) at each of 15 stations on 4 sampling dates.

6 July 73

20 August 73

29 September 73

13 November 73

Station means over 4 sampling dates

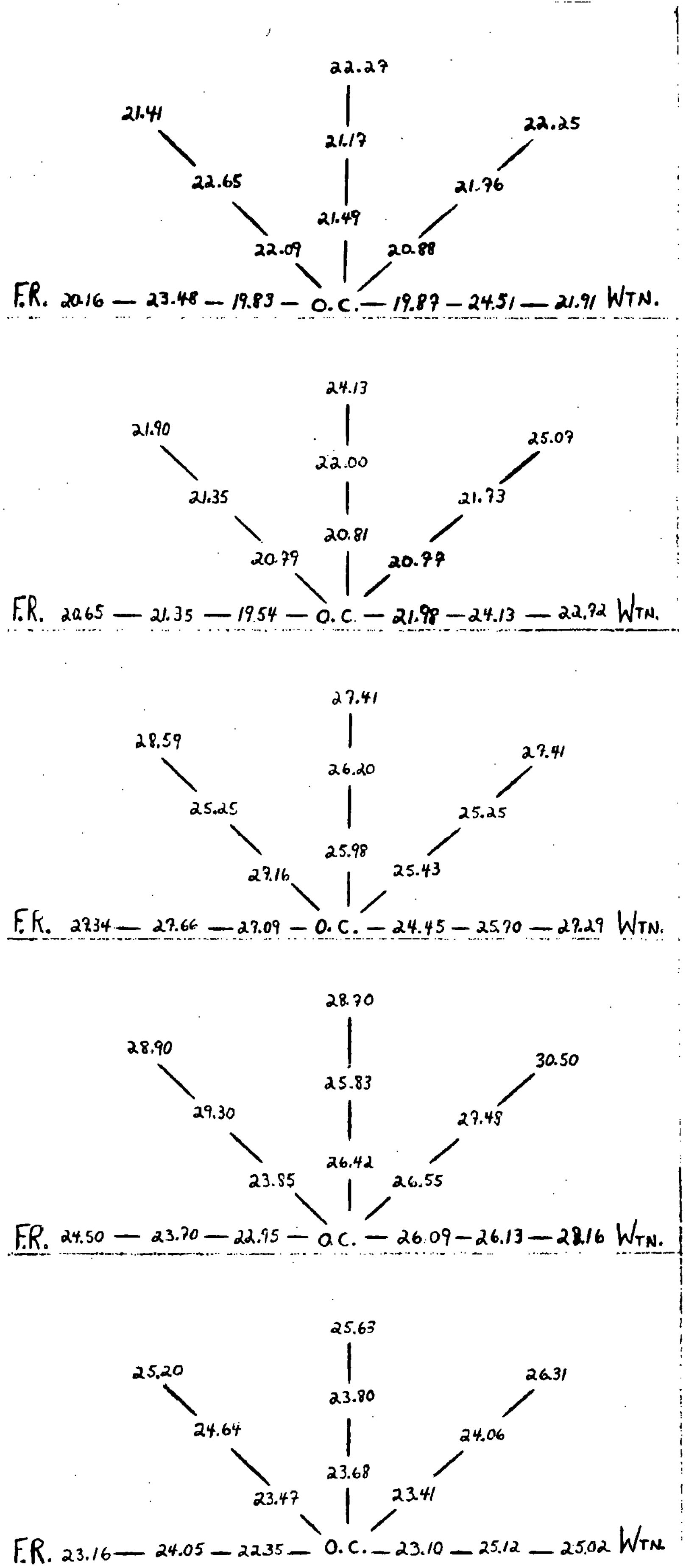
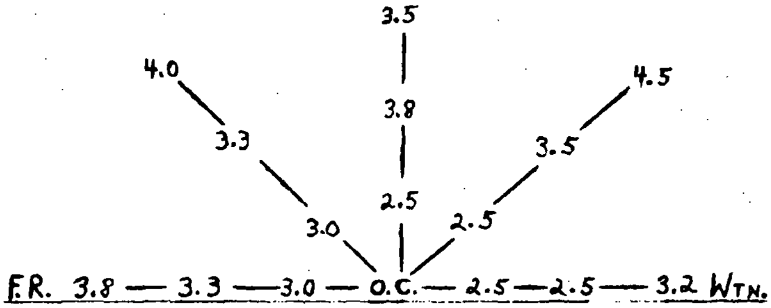
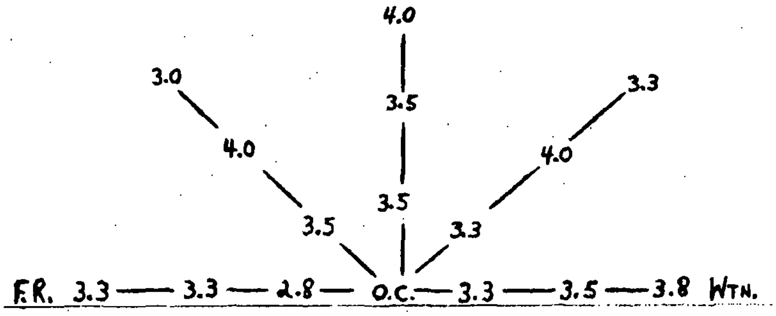


Fig. 20 - Secchi depth (feet) at each of 15 stations on 4 sampling dates.

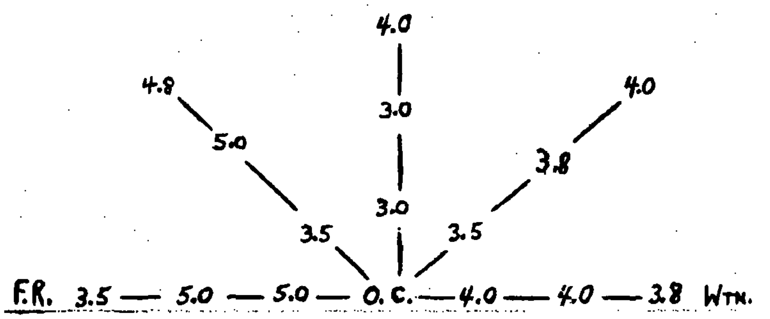
6 July 73



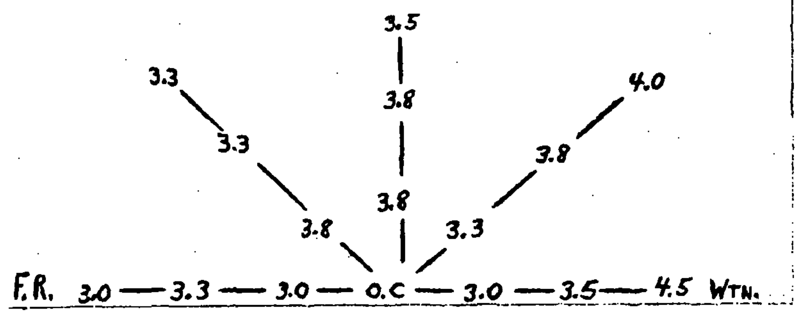
20 August 73



29 September 73



13 November 73



Station means over 4 sampling dates

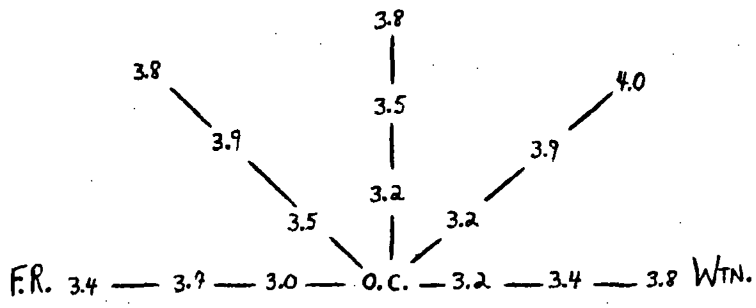


Fig. 21A — Number of Species

Fig. 21C — Bottom Temperature (°C)

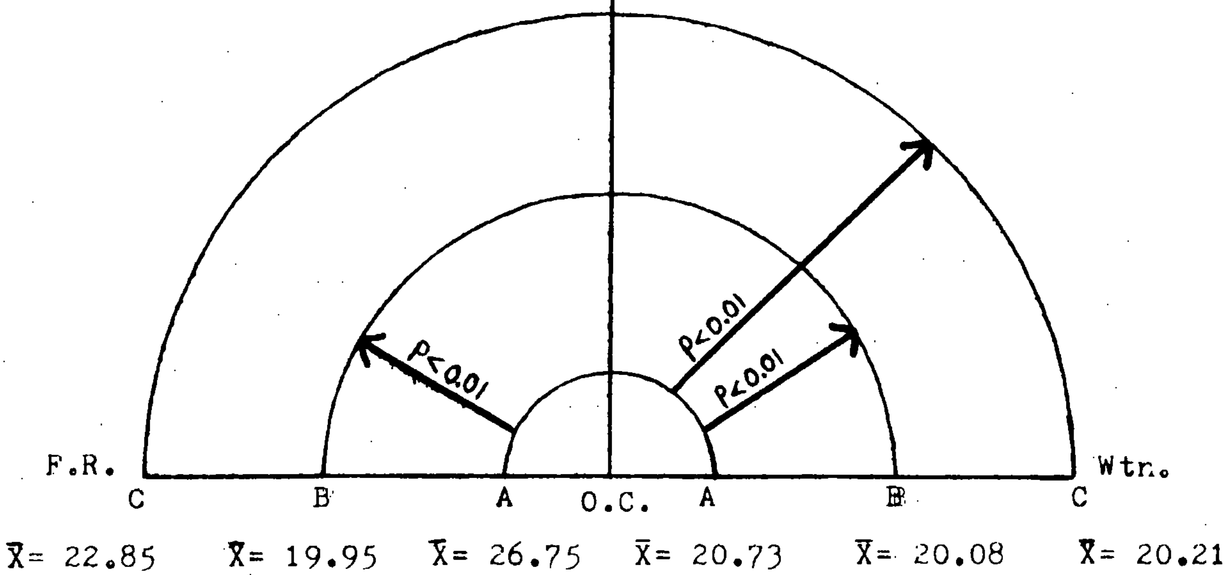
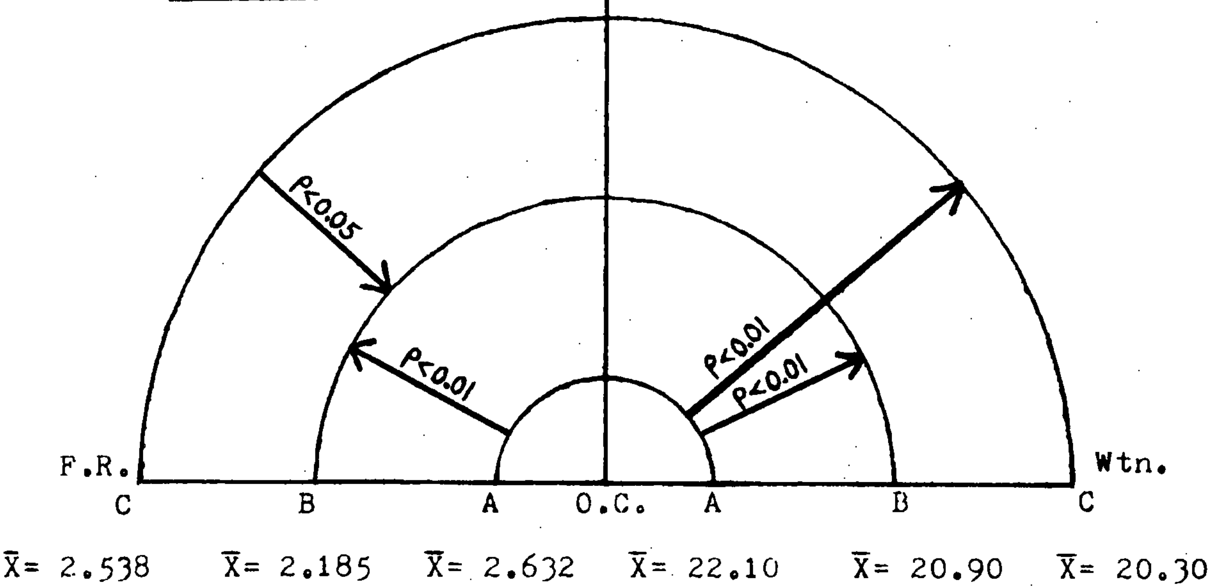


Fig. 21B — Diversity Index

Fig. 21D — Surface Temperature (°C)



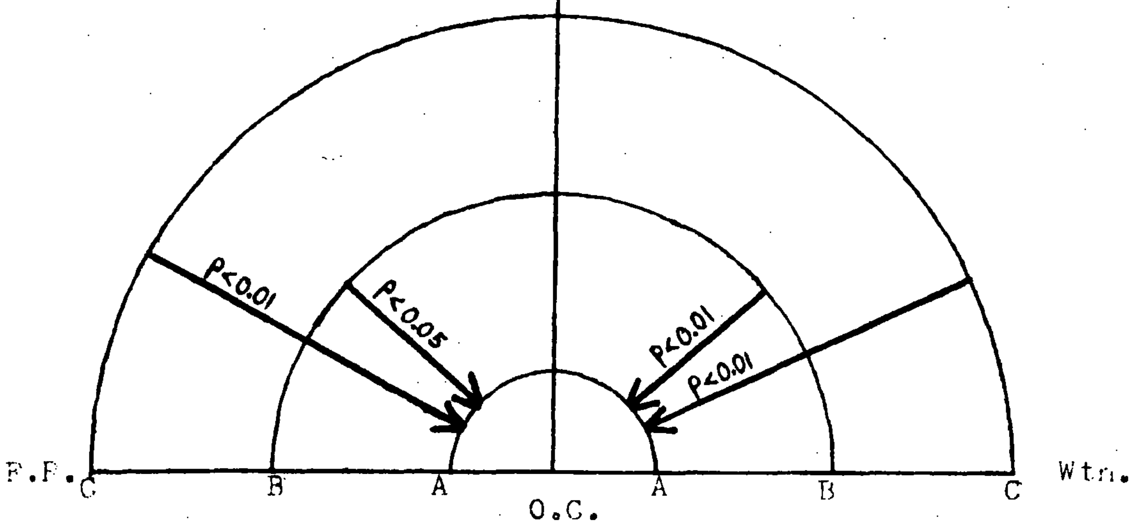
Figs. 21A-F - The results of the Analysis of Variance carried out on radii cruise data. An arrow from one circumfrence to another indicates that the mean value for the circumfrence at the start of the arrow is greater than the mean value for the circumfrence at the end of the arrow. Probability values are the probability that the difference is due to random variation.

Fig. 21E

Bottom Salinity (‰)

Fig. 21F

Secchi Depth (ft.)



$\bar{X}$= 25.06 $\bar{X}$= 24.33 $\bar{X}$= 23.20 $\bar{X}$= 3.19 $\bar{X}$= 3.66 $\bar{X}$= 3.74

Fig. 22A

Surface Temperature (°C)

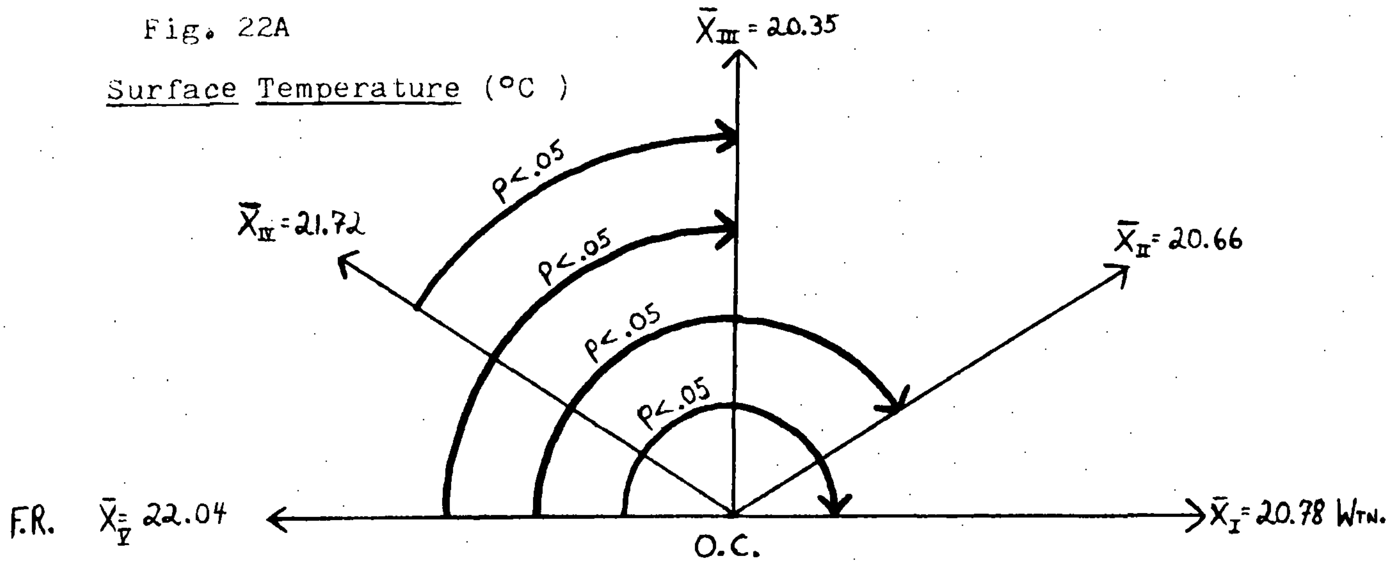
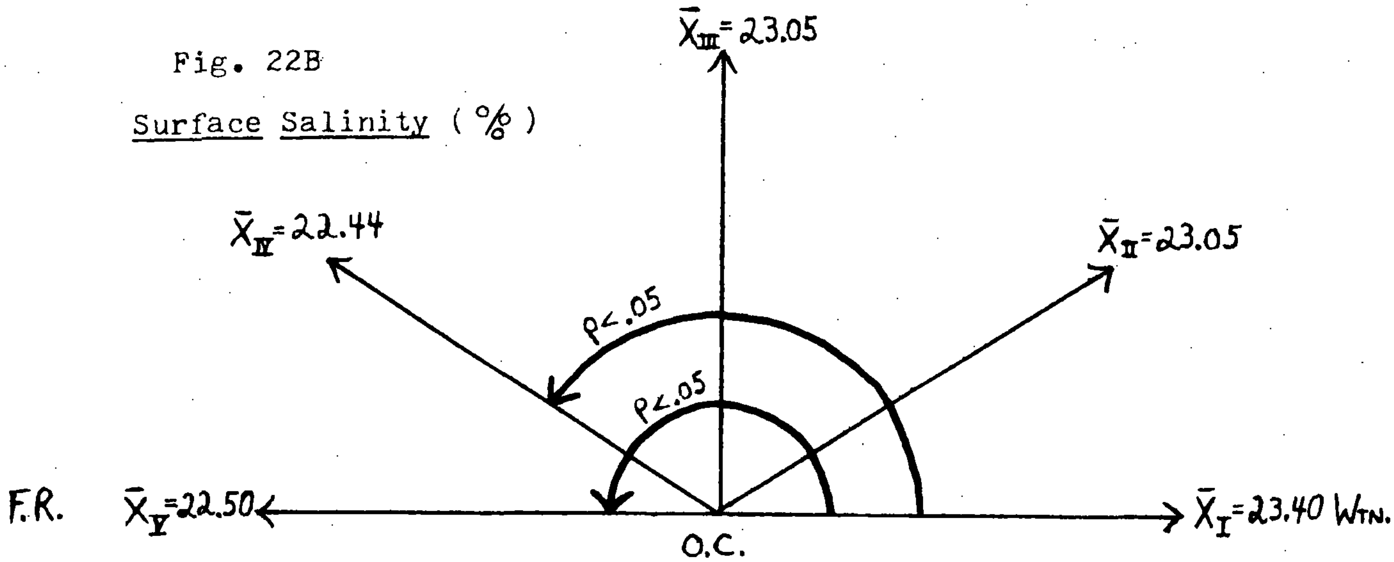


Fig. 22B

Surface Salinity (‰)



Figs. 22A&B - The results of the Analysis of Variance carried out on radii cruise data. An arrow from one radius to another indicates that the mean value for the radius at the start of the arrow is greater than the mean value for the radius at the end of the arrow. Probability values are the probability that the difference is due to random variation.

5) Bankia study. We have continued our monitoring program of the shipworm or boring clam (Bankia gouldi). The technique was simply to place replicate samples of cured Douglas fir blocks (2x3x6") into the water column at six locations (Intake and Outfall canals adjacent to the power plant; Oyster Creek, downstream of the marina areas; Forked River, at Beach Blvd. bridge; Stouts Creek, near the mouth; and Waretown, near the public pier). The boards were hung about two feet apart and the supporting rope was weighted. The top board usually was one to two feet below the low water mark. On several occasions vandals had stolen the weights and the boards were floating at the surface. The samples were brought back to the lab in plastic bags under refrigeration. Examination for Bankia took place within two days. Each board was scraped clean of all encrusting organisms and was them examined under a dissecting microscope for the characteristic holes made by Bankia. All surfaces, except the two ends (where end grain appears), were enumerated. The results of this study are indicated in Figures 23-26.

The earliest boards were set out during the first two weeks of June, when we recorded the highest "catch" of Bankia throughout the six stations. As can be seen from the plots of mean number against date, there were very high densities of Bankia on both the top (Figure 23) and bottom (Figure 24) board. In fact, we found more Bankia in one sample at Waretown during the June-July period then we did for all samples during the previous year. The number of new Bankia dropped very rapidly through the summer-they were almost non-existent by the middle of September. The mean number of all four boards, per station, is indicated in Figure 25.

A plot of mean number of new Bankia by station is indicated in Figure 26. The boring clam seems to be most common at Waretown and Forked River (two very different locations both in terms of wave action and water clarity). The lowest numbers of Bankia occurred adjacent to the power plant, with a slight increase in numbers within Oyster Creek.

The temperature and salinity values for the selected stations are indicated in Figure 27 A and B. It is obvious that all stations behaved in a similar fashion over the time period.

As can be seen from Figures 28 and 29, which are summary records for Bankia in 1972, the overall pattern of distribution of Bankia has not changed much over the two years. What has changed, of course, is that there are many more Bankia recorded from the middle region of Barnegat Bay in 1973 compared to 1972.

6) Oyster Growth Study - Over the period August 1972 - July 1973 over 12,000 individual measurements of oysters (Crassostrea virginica) have been made in order to determine if there is a difference in the growth of oysters cultured inside and outside the influence of the thermal plume.

The stock oysters used in this growth experiment were collected from Delaware Bay in the form of spat laden clam shells. The oyster bearing shells were strung on nylon ropes, 10 shells per rope. A total of 14 of these long lines were suspended in the intake

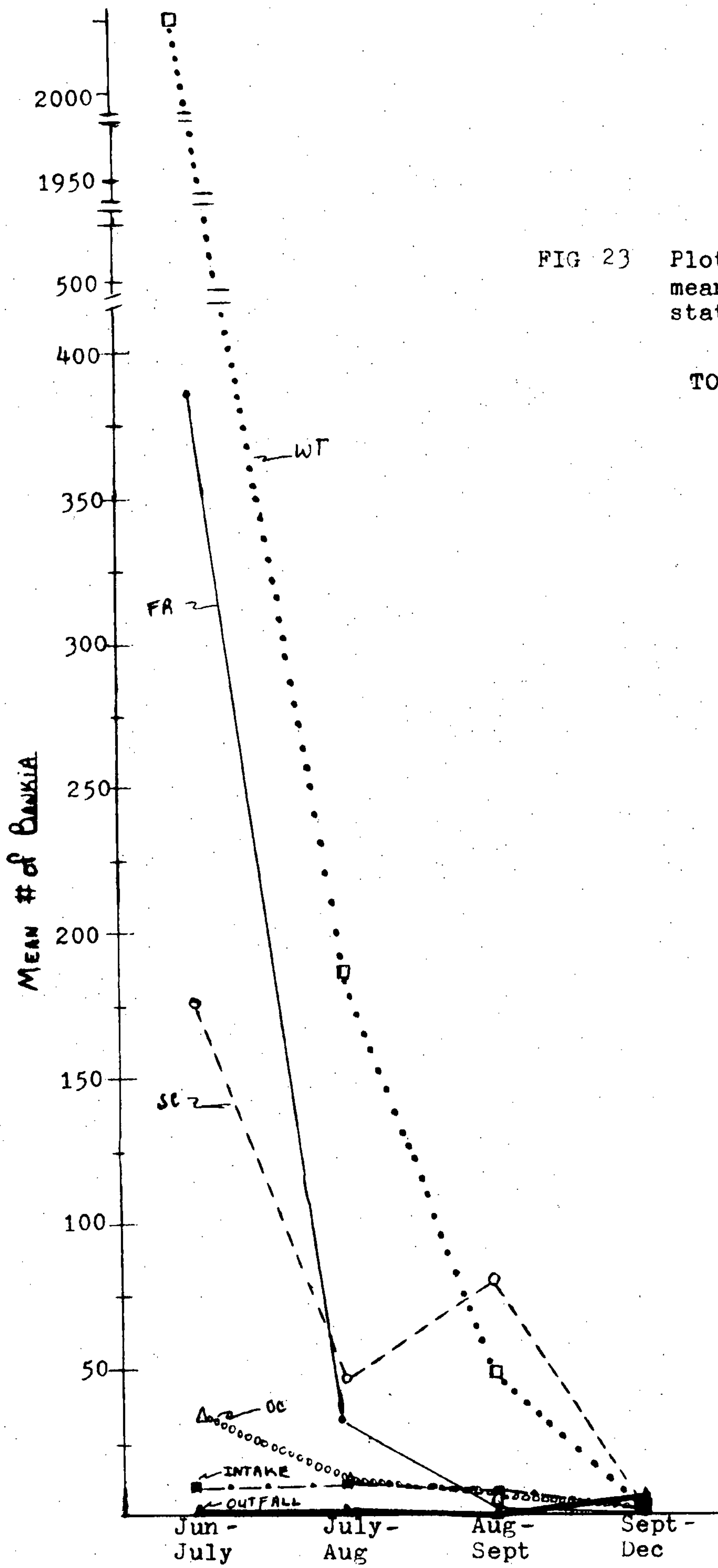


FIG 23 Plot of position means by date and station.

TOP BOARD

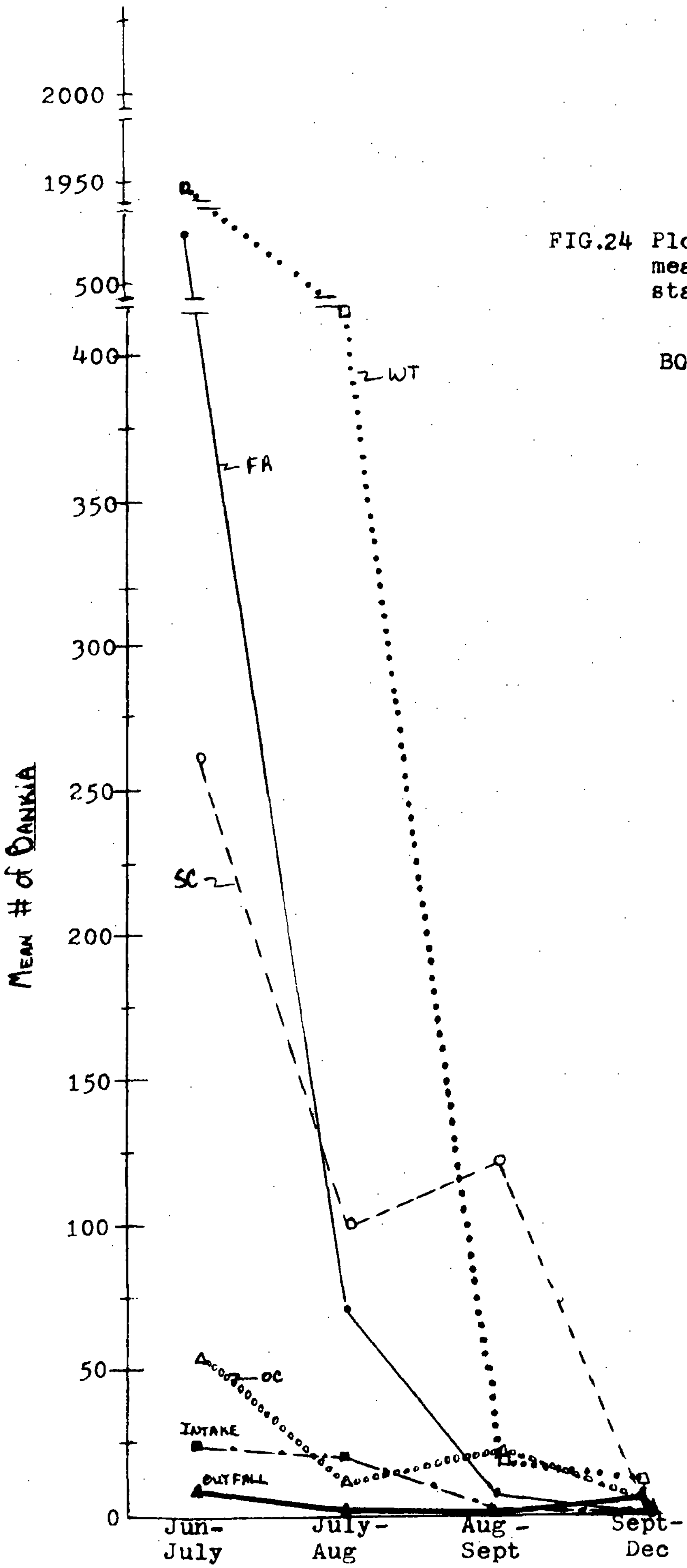


FIG.24 Plots of position means by date and station.

BOTTOM BOARD

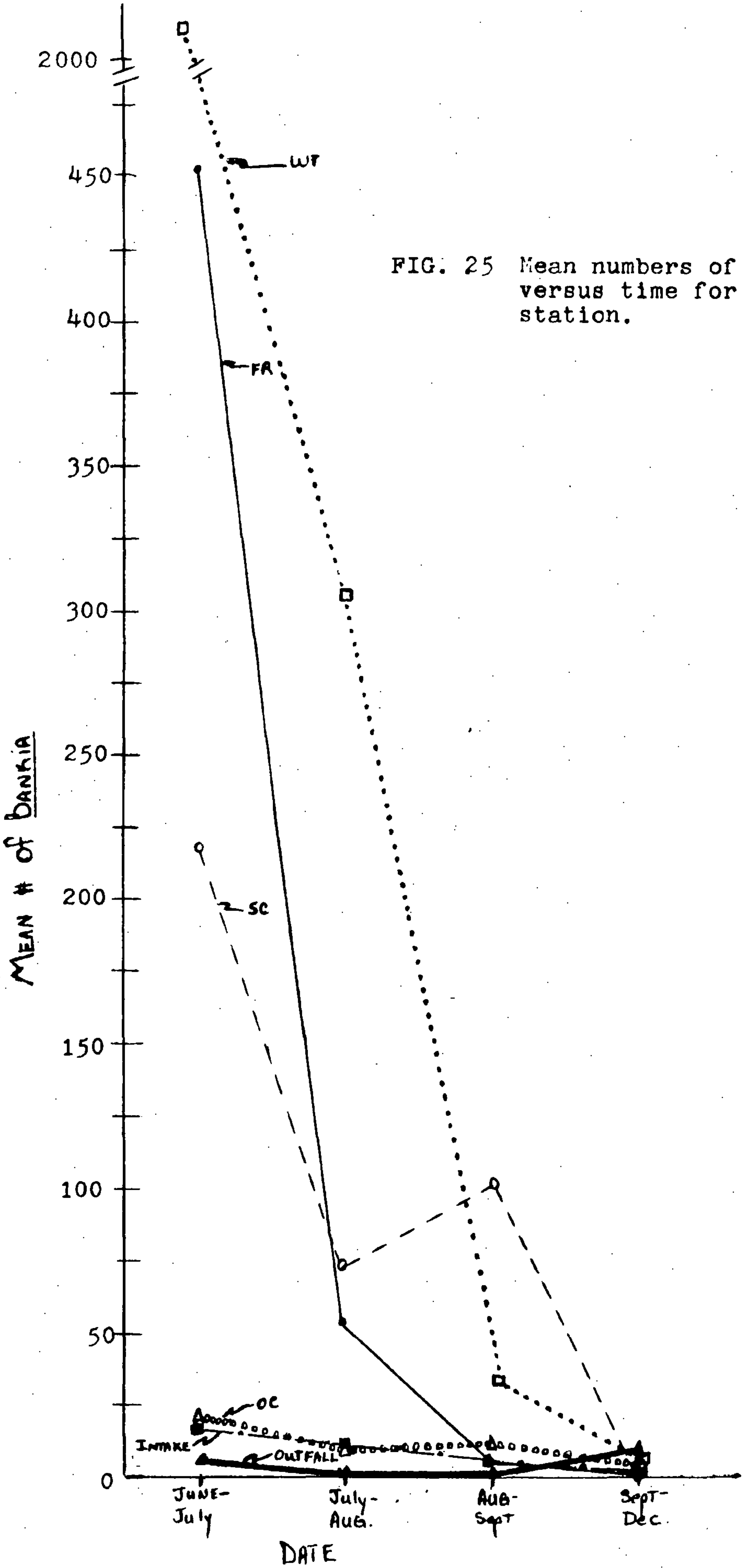
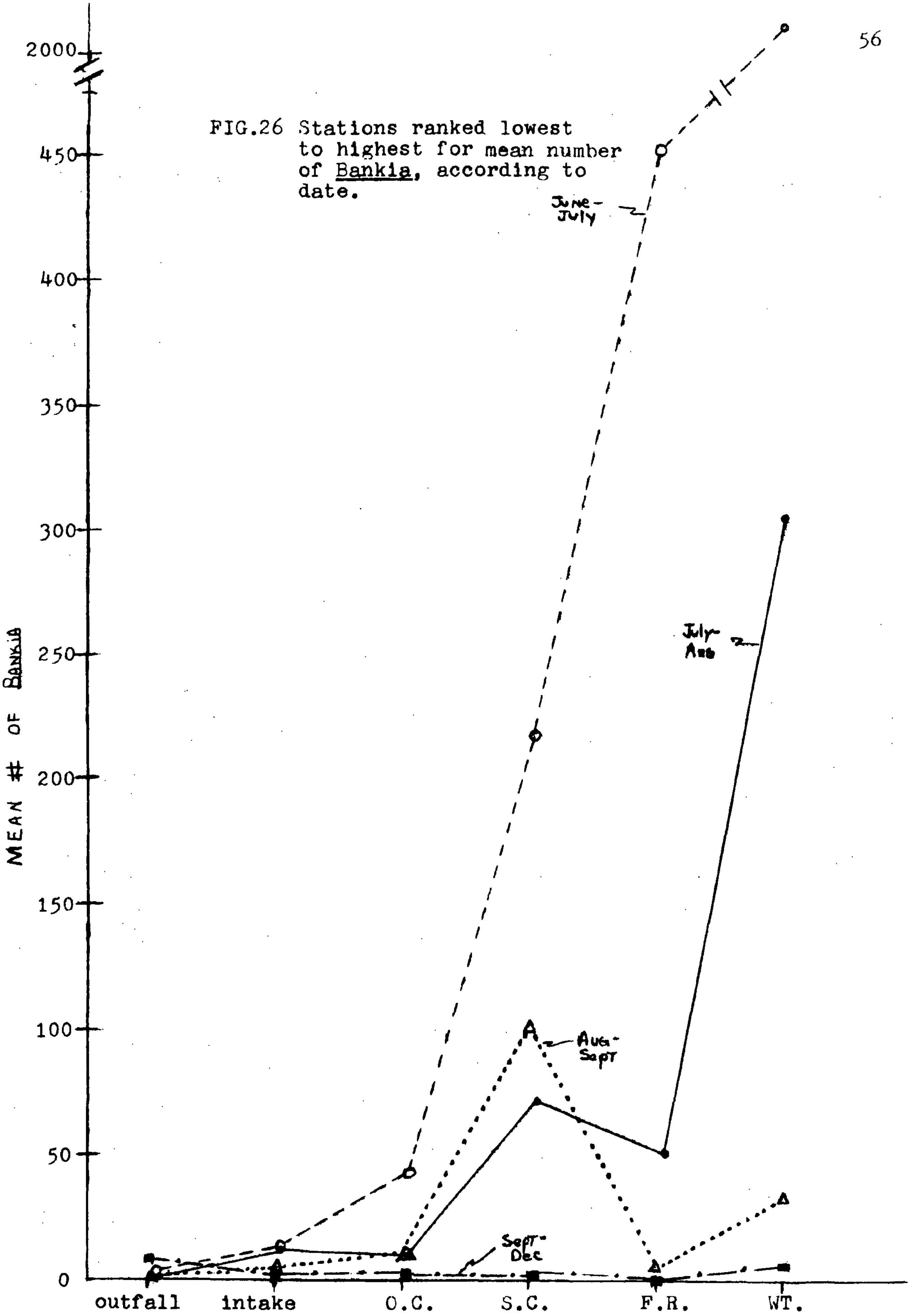


FIG. 25 Mean numbers of Bankia versus time for each station.

FIG.26 Stations ranked lowest to highest for mean number of *Bankia*, according to date.



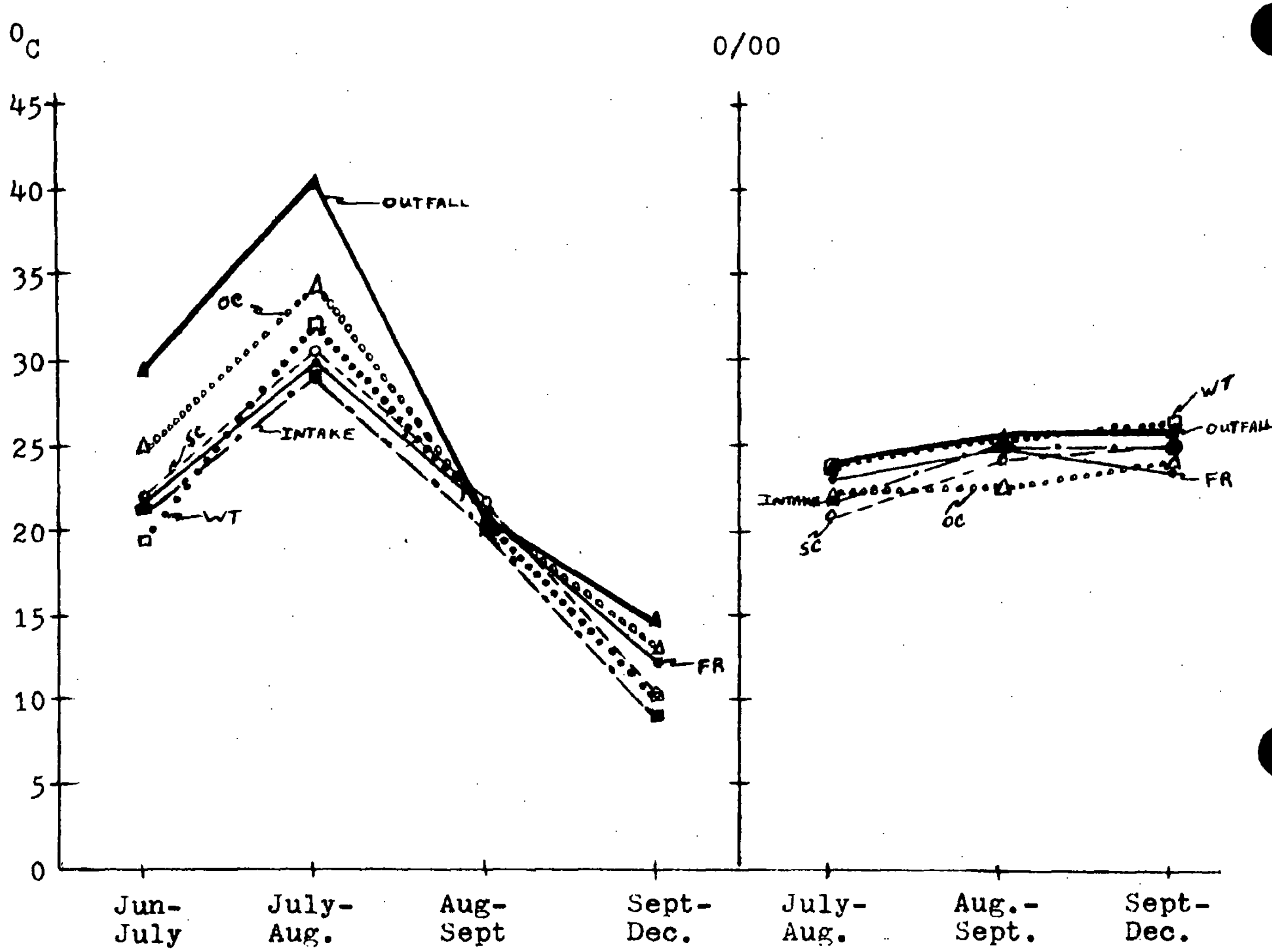


FIG.27 A Temperature data versus time for each *Bankia* station.

B Salinity data versus time for each *Bankia* station.

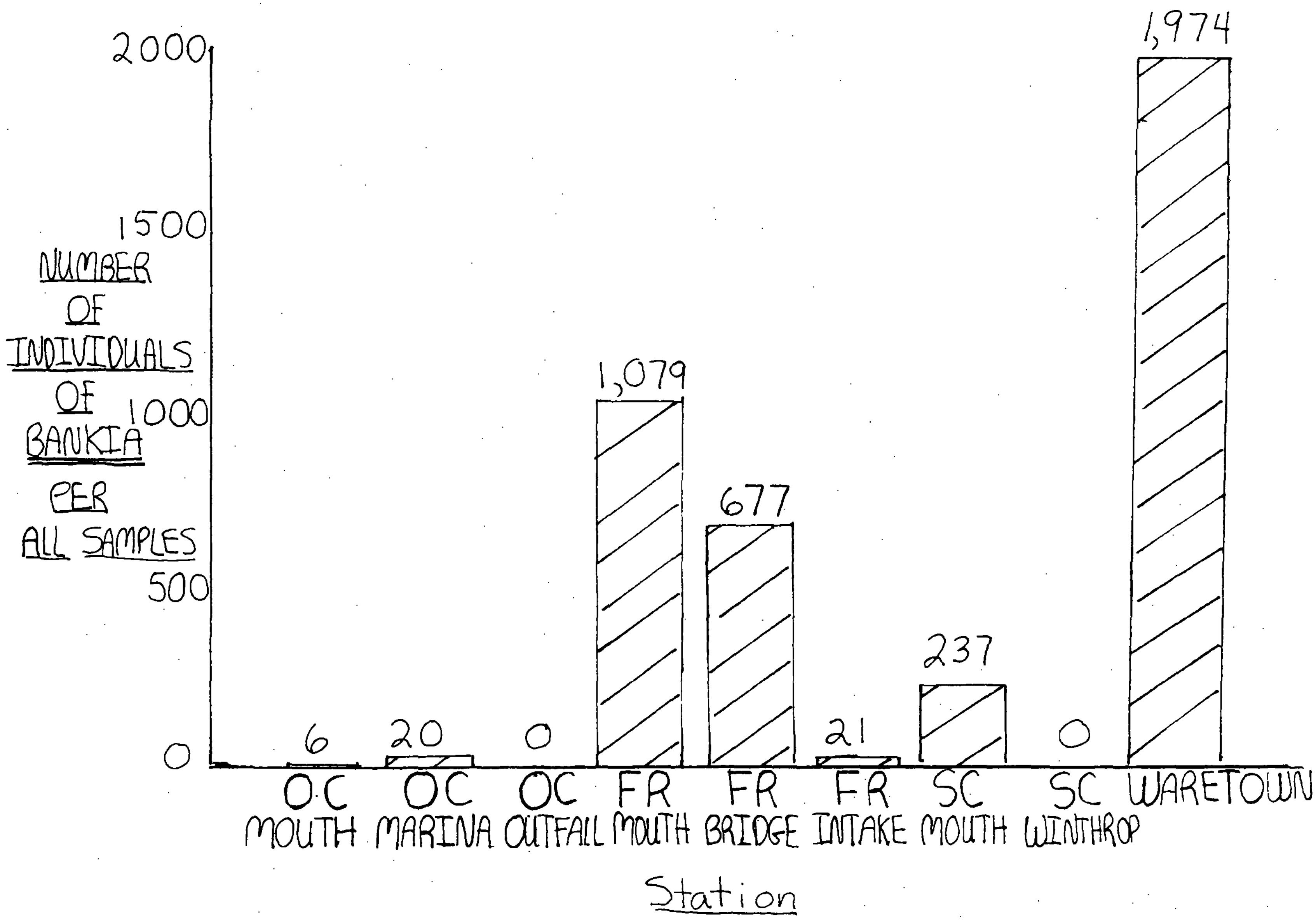
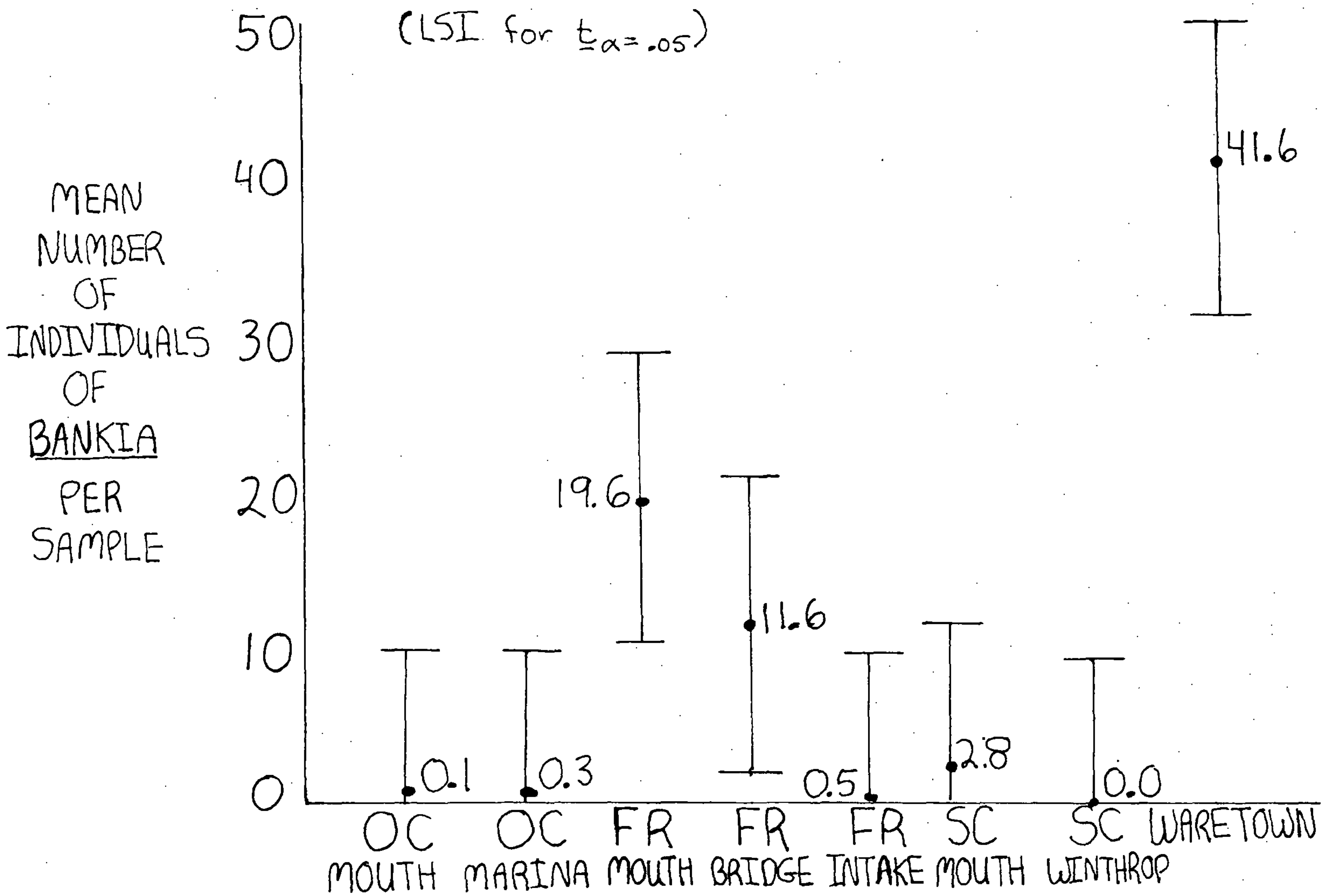


Figure 28 Summary records for *Bankia* in 1972


(LSI for $t_{\alpha=.05}$)
MEAN NUMBER OF INDIVIDUALS OF BANKIA PER SAMPLE
50
40
30
20
10
0
41.6
19.6
11.6
0.1
0.3
0.5
2.8
0.0
OC MOUTH
OC MARINA
FR MOUTH
FR BRIDGE
FR INTAKE
SC MOUTH
SC WINTHROP
WARETOWN

and outfall canals (before dilution) within the confines of the power plant. (Four lines set out on Aug. 18, 4 lines on Oct. 13 and 6 more on Nov. 10, 1972). Shell length measured from umbo to shell edge along the vector of maximum length was used as the indicator of growth. Measurements were taken at monthly intervals using vernier calipers.

In Fig. 30 we have plotted mean shell length against time for the initial 4 lines of oysters set out on Aug. 18, 1972. Over the period Aug.- Dec. we see that except for the first month of growth, outfall growth exceeded intake growth in all cases. The average length of both intake and outfall oysters at the start of the experiment (Aug. 18, 1972) was 1.75mm. On Dec. 8, 1972 intake oysters averaged 22.10mm in length while outfall oysters averaged 43.43mm or very nearly twice as long. In addition we see that while intake oysters seemed to stop growing early in October, outfall oysters continued to grow into late November. Outfall oysters then, grew at a greatly accelerated rate when compared with intake oysters over the period August-December. Intake oysters, on the other hand, seemed to grow at approximately the same rate as Delaware Bay oysters as determined by comparative measurements of stock, Delaware Bay oysters.

Since shell deposition is not necessarily correlated with an increase in the living tissues, a dry weight analysis of 37 experimental oysters was carried out on March 3, 1973, approximately 7 months after the start of the experiment. In Table XI we see that 17 randomly selected intake oysters averaged 0.155% dry weight while 20 outfall oysters averaged 24.64% dry weight. It is apparent then, that tissue growth, as well as shell growth, is greatly accelerated in the heated effluent waters, at least over the period August-December.

After a period of little or no growth extending from late October to late March for intake oysters and from late November to early March for outfall oysters, the pattern of growth described above (ie. outfall oysters growing faster than intake oysters) resumed. At some point between April 28 and May 25, 1973 however, the pattern was reversed as the rate of growth of outfall oysters suddenly dropped to below that of the intake animals. (See Fig. 31- plot of mean increase in shell length vs. time.) After this sudden decrease in growth rate outfall oysters grew very slowly through June and heavy mortality was observed until on July 27, 1973 all outfall oysters were dead. Water temperatures in the outfall canal during this period of decrease in growth rate and finally mortality were in the 22-28 degrees C range. During the previous summer outfall oysters grew quite rapidly at temperatures considerably higher than this (up to 37 degrees C) with no observed mortality. Apparently then, some other factor, acting alone or interacting with water temperature was involved in the death of the outfall oysters. Further studies will be necessary in order to determine the cause of oyster mortality in the outfall canal.

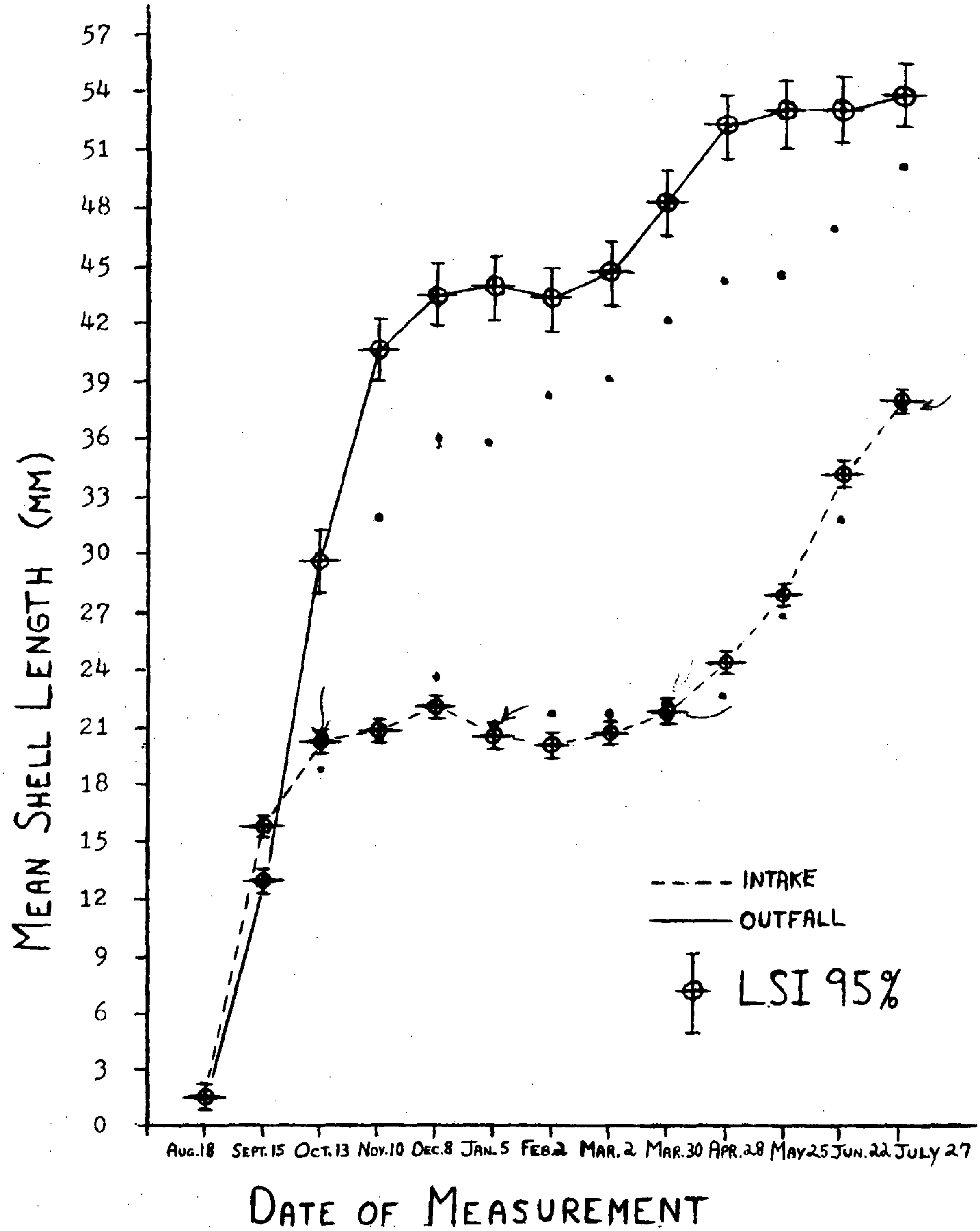


Fig. 30 - Plot of mean shell length vs. time for the initial 4 lines of oysters set out on Aug. 18, 1972.

% Dry Weight	
Intake	Outfall
0.067	24.99
0.200	23.82
0.100	25.00
0.050	26.08
0.100	28.59
0.200	25.02
0.300	28.57
0.067	27.25
0.200	21.75
0.201	21.88
0.300	27.67
0.100	23.51
0.299	26.12
0.200	20.03
0.050	18.75
0.100	29.65
0.100	22.58
	21.75
	22.28
	27.59
X = 0.155%	X = 24.64%

Table XI- Results of the percent dry weight analysis of 17 intake and 20 outfall oysters, March 3, 1973.

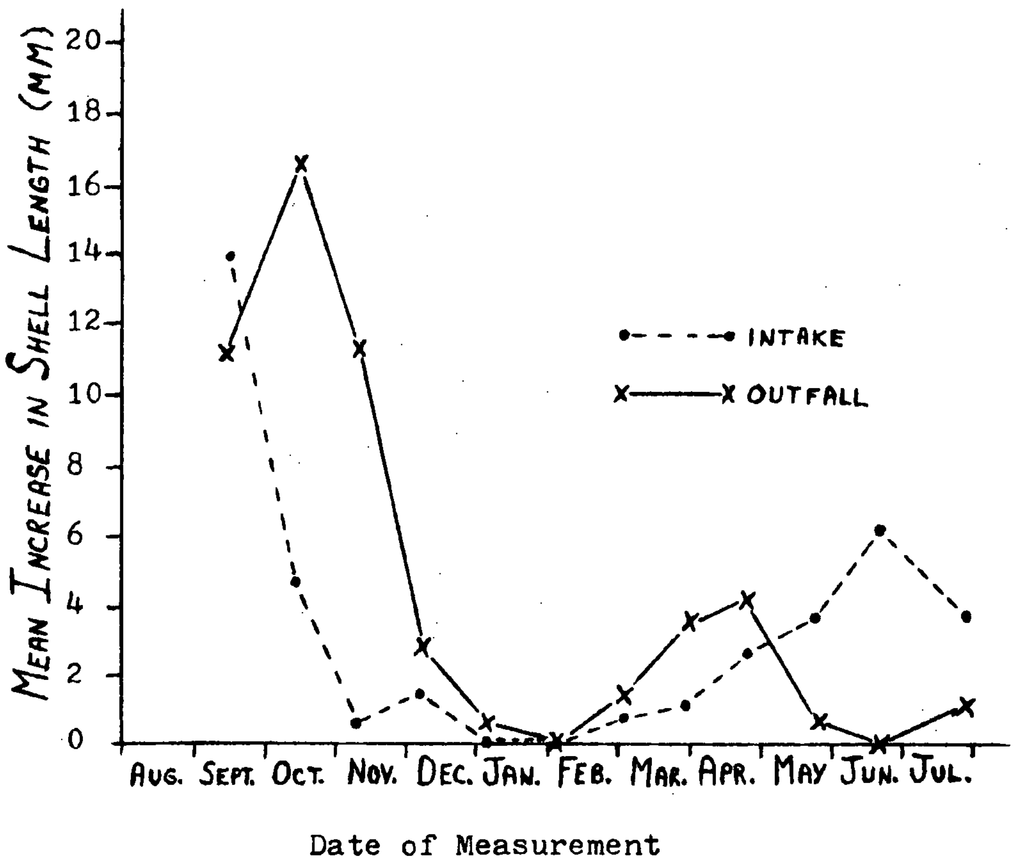


Fig. 31 - Plot of mean increase in shell length vs. time for the initial 4 lines of oysters set out on Aug. 18, 1972.

Discussion and conclusions of invertebrate survey.

Since 1965 our group has been sampling the middle region of Barnegat Bay for benthic invertebrates, meroplanktonic invertebrates and invertebrate menbers of the boring and fouling community. We are constantly finding new species and have assembled a list of invertebrates for the area that will serve as a base line for studies on benthic invertebrate communities. The number of invertebrate species found in Barnegat Bay will undoubtedly exceed 250 when all species (i.e., benthic, fouling and planktonic) are considered. We have observed a continual increase in the number of species through time; however, on the average the number of species per unit area tends to remain constant. We also continue to find no significant difference in the invertebrate community throughout our Barnegat Bay study area during a particular season. Year to year differences are observable, but patterns of distribution during a year are consistent throughout the study area.

We originally selected our sampling areas after completing a cluster analysis which demonstrated that the middle region of Barnegat Bay, on its west banks, was comprised of essentially the same invertebrate community. Recent qualitative studies in the area have reinforced our opinion that our sampling area is basically uniform and therefore amenable to statistical analysis. From a purely qualitative point of view our study area is remarkably uniform from one sampling area to another. We do, however, begin to detect a southern community of invertebrates in the vicinity of Waretown, where salinity and water clarity is higher.

Locally, we found that the region directly off Oyster Creek is actually richer in species number. At a very local level, the sandy mud just to the south of the Oyster Creek channel (entrance to the Creek itself) is very rich in species and fairly high in density of individuals. This pattern is consistent south toward Waretown. On the other hand, the very fine silts and clays just north of the Oyster Creek channel are poor in species number and individuals. Dredging activity increases along the north shore until one reaches Forked River. Approximately one half the distance between Oyster Creek and Forked River, there is a region where bottom sediments are dominated by gravel. In this region, few species of invertebrates are detected. Surprisingly, our field observations indicate a northerly drift of effluent water, which might lead to entrainment. Nevertheless, the bottom invertebrates are not being damaged in the region directly off Oyster Creek, even though some warm water from the surface reaches the bottom during vertical mixing.

Although all the data is still not completely analyzed, we still maintain that we cannot detect any statistically significant effect of the thermal plume on the bottom invertebrate community off Oyster Creek.

Station Locations for Hydrographic Data: 1972

12 July 72-6

1. 110° SE Light 1, 50 yds off mile marker, SC
2. 70° NE and 200 yds off mile marker, SC
3. 220° SW, 20 yds off Light 1, SC
4. Oyster Creek, Rt. 9
5. 280° ,400 yds off Light 3, OC
6. 240° SW, 100 yds off Light 3 OC.
7. 20° N, 200 yds off light 3, OC
8. 220° SW, 300 yds off Light 2, FR
9. 320° NW light 2, 400 yds off light, FR.
10. 280° W Light 2, 180 S Black buoy #7, 50 yds off buoy, FR
11. Forked River, Rt. #9

1 August 72-7

1. 160° SSE Mile Marker, 200 yds from Light 1, SC
2. 40° NE Light 1, 150 yds off Light, SC
3. Oyster Creek, RT. #9
4. 225° SW, 75 yds off Light 3 OC
5. 210° SSW, 100 yds off Light 3, OC
6. 180°S Light2, 300 yds off Light,FR
7. 0° N, 75 yds off Light 2, FR
8. Forked River, Rt. #9

16 August 72-8

1. 140° , 25 yds SE of mile marker, SC
2. 60° , 200 yds NE Light 1, SC
3. Oyster Creek, Rt. #9
4. 250° , 300 yds off Light 3, OC
5. 20° N, 200 yds off Light 3, OC
6. 250° , 350 yds SW Light 2 FR
7. 330° , 200 yds NW of Light 2, FR
8. Forked River, Rt.#9

Station Locations for Hydrographic Data: 1973
6 July 73-1

IA. 36° 31' IBCG Tower-BGLT, 5° 25' BGLT-BG Water tower
IB. 38° 27' IBCG Tower-BGLT, 5° 47' BGLT-BG Water tower
IC. 39° 9' IBCG Tower-BGLT, 6° 12' BGLT-BG Water tower
IIA. 47° 28'IBCG Tower-BGLT, 5° 14' BGLT-BG Water tower compass fix on 280°
IIB. 40° 9', 5° 47' ; Compass fix on 285°
IIC. 42° 9', 6° 2'; compass at 290° on microwave antenna
IIIA. 36° 17', 4° 21'; microwave at 275°
IIIB. 38° 54', 4° 17'; compass on microwave 280°
IIIC. 40° 15', 5° 22'; compass on microwave at 275°
IVA. 37° 55', 5° 16'; 275° off mouth O.C.; 100 yds, 225° off pole marker, OC
IVB. 39° 5', 5° 9'; 27° off OC in line with Buoy and BGLT.
IVC. 39° 29', 4° 56'; 255° off OC
VA. 38° 31', 5° 19'; 30° yds N Buoy 2 at end of OC channel
VB. 37° 7', 5° 3' ; 285° off old dredge

Station Locations for Hydrographic Data: 1973

6 July 73-1 con't

VC. 36° 37', 4° 48'; ¼ mile off lagoon N of dredge; 260° off lagoon, 240° off dredge

11 July 73-2

Algae cruise, see map in text of report

18 July 73-3

1. 300 yds, 120° off Light 1, SC
2. 300 yds, 310° off Light 1, SC
3. 300 yds, 60° NE of Light, OC
4. 300 yds, 240° SW of Light, OC
5. Oyster Creek, Rt. #9
6. 400 yds, 250° SW Light 2, FR
7. 300 yds, 20° NW Light 2,FR
8. Forked River, Rt. #9

28 July 73-4

No hydrographic data

4 August 73-5

1. 500 yds off SC, 300 yds N 'can D', 310° off Light 1, SC
2. 85° , 50 yds off 'can D' SC
3. 250 yds off 'can D' , 190° off Light 1, SC
4. Oyster Creek, Rt. #9
5. 300 yds, 200° off Light3,OC
6. 600 yds, 30° off Light 3, OC
7. 300 yds, 130° off Buoy F, OC
8. 800 yds, 65° off Light 2, FR
9. 100 yds, 100° off Light2, FR
10. 500 yds, 15° off Light 2, FR
11. Forked River, Rt. #9

9 August 73-6

1. 100 yds, 70° off Light 1,SC
2. 300 yds, 60° off Light 1, SC
3. 200 yds off shore, 160° off Light 1, SC
4. 500 yds off shore, 310° off BL, WT
5. 600 yds off shore, 125° off BL, WT
6. 200 yds off shore, 115° off BL, WT
7. 180° , 400 yds off Light3 , OC
8. 280° off microwave antenna, 100 yds off dredge, OC
9. 600 yds from shore, 160° off deedge , OC
10. 400 yds off shore, 300 yds, 220° off Light 2, FR
11. 25 yds, 110° off Light 2, FR
12. 5° , 500 yds off light, 400 yds off shore, FR.

Station Locations for hydrographic Data: 1973

15 August 73-7

Algae Cruise, see map in text of report for station locations

20 August 73-8

IA. 36° 40' left, 5° 30'right ; 8°,250 yds off Light 3, OC
IB. 35° 20' left, 5° 50'right; 70° off Light3, OC
IC. 38° 42' left, 6° 22'right; 310° off microwave antenna 200 yds off shore, WT.
IIA. 37° 00' left, 5° 30'right; 70°,100 yds off Light 3, OC
IIB. 39° 20' left, 10° 1'right; 60° off Light3, OC
IIC. 40° 7' left, 5° 45' right; 310° off microwave antenna, WT
IIIA. 37° 00' left, 4° 55' right; 90° , 100 yds off Light 3, OC
IIIB. 39° 20' left, 4° 45' right; 330° off microwave antenna
IIIC. 40° 8' left, 4° 49' right; 60° , 100 yds off El can
IVA. 40° 19' left, 4° 53' right; 100 yds, 230° off Light 3; 280° off microwave, OC
IVB. 37° 40' left, 4° 40' right; 350 yds off shore; 315° off microwave
IVC. 39° 20' left, 4° 50' right; 290° off microwave
VA. 31° 40' left, 4° 40' right; 290° off microwave
VB. 36° 20' left, 4° 0' right; 310° off microwave antenna
VC. 35° 30' left, 3° 40' right; 320° off microwave

11 September 73-9

1. 200 yds off shore at mouth of SC
2. 400 yds off shore at mouth of SC
3. Inland waterway off SC
4. ½ distance from SC to FR, outermost station at Inland waterway
5. 350 yds off shore, ½ the distance from SC to FR
6. 200 yds off shore, ½ the distance from SC to FR
7. 200 yds off mouth of FR
8. 50 yds off Light 2, FR
9. Inland waterway off FR
10. ½ the distance from FR to OC, outermost point on transect, Inland waterway
11. ½ the distance from FR to OC, 400 yds off shore
12. ½ the distance from FR to OC, 200 yds off shore
13. 200 yds off mouth of OC
14. approximately 350 yds off shore, OC
15. Outer most point on transect, 500 yds off shore

29 September 73-10

IA. OC mouth, 250° off Light 3, 250 yds off shore
IB. 250 yds off shore, 210° off Light 3 at OC
IC. 250 yds off shore, 210° off Loading Derrick
IIA. 170° off Loading Derrick, 250 yds off shore OC
IIB. 190° off Loading Derrick
IIC. 190° off Loading Derrick
IIIA. 200 yds off Light 3 , 270° off microwave antenna
IIIB. 150 yds off Can, 275° off microwave, OC
IIIC. 275° off microwave antenna
IVA. 100° off microwave, inner point of transect, 250 yds off shore
IVB. 90° off microwave, 400 yds off shore

Station Locations for Hydrographic Data: 1973

29 September 73-10 con't

IVC. 90° off microwave, outer station at 500 yds off shore, OC
VA. 100° off microwave, 110° off power plant tower, 200 yds off shore
VB. 200 yds off shore, 60° N of Dredge
VC. 80° off microwave, ½ mile off derrick

9 October 73-11

1. 190°, 50 yds S Light 1, SC
2. 40°, 75 yds NE Light 1, SC
3. 100°, 100 yds off Light 1, SC
4. 20°, 250 yds off Light 3, OC
5. 340°, 100 yds off Light 3, OC
6. 230°, 50 yds off Light 3, OC
7. 120° SE of microwave antenna, 300 yds off shore, WT
8. 140° Se microwave antenna, 400 yds off shore, WT
9. 230°, 100 yds SW Light 2, FR
10. 340°, 50 yds NW of Light 2, FR
11. 310°, 300 yds off Light 2, FR

23 October 73-12

1. 180°, 75 yds off Light 1, SC
2. 120°, 100 yds off Light 1, SC
3. 140° SE of microwave antenna, 100 yds off shore, WT
4. 120° SE of microwave antenna, 300 yds off shore, WT
5. 110° off microwave, 100 yds off shore, OC
6. 90° E of microwave, 120°, 75 yds off Light 3, OC
7. Oyster Creek, RT. #9
8. 240°, 100 yds off Light 2, FR
9. 280°, 150 yds off Light 2 FR
10. FR. Rt. #9

13 November 73-13

IA. 285° off tower
IB. 290° off tower
IC. 295° off tower
IIA. 285° from tower
IIB. 285° off tower
IIC. 295° from tower
IIIA. 245° off tower
IIIB. 250° off microwave
IIIC. 250° off microwave antenna
IVa. 270° off tower
IVB. 275° from Light 3
IVC. 275° off Light 3
VA. 275° from Light 3
VB. 270° from tower
VC. 270° from tower

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972-73

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (0/00)	Secchi (feet)
12 Jul.	72-6	0627	1	0.0	23.62	16.98	3.3
				8.0	24.30	19.27	
		0640	2	0.0	23.96	16.95	2.5
				10.0	24.06	17.72	
		0723	3	0.0	24.03	17.17	2.5
				10.0	24.73	19.02	
		0820	4	0.0	32.21	18.24	2.8
				10.0	31.97	19.00	
		0845	5	0.0	31.04	19.67	2.8
				10.0	25.03	21.71	
		0908	6	0.0	30.67	19.72	2.3
				10.0	24.40	20.76	
		0920	7	0.0	30.21	19.82	3.0
				10.0	23.97	22.14	
		0955	8	0.0	26.78	20.10	2.9
				10.0	24.02	20.16	
		1010	9	0.0	27.13	20.13	2.8
				10.0	25.58	20.17	
		1030	10	0.0	26.95	20.13	3.0
				8.0	26.37	20.00	
		1110	11	0.0	26.77	19.47	2.8
				10.0	26.77	19.64	
1 Aug.	72-7	0700	1	0.0	24.07	19.23	3.0
				7.0	24.20	27.32	
		0721	2	0.0	24.05	18.98	3.0
				7.0	24.43	27.20	
		0803	3	0.0	31.07	19.30	---
				1.0	31.07	19.50	
		0835	4	0.0	28.43	21.05	3.3
				7.0	25.98	25.98	
		0853	5	0.0	28.07	20.40	3.5
				7.0	24.77	26.15	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (0/00)	Secchi (feet)
1 Aug.	72-7	0945	6	0.0	25.55	20.68	3.8
				7.0	24.60	25.83	
		1005	7	0.0	25.64	20.49	4.0
				7.0	24.30	27.97	
		1043	8	0.0	25.44	19.86	—
				2.0	25.41	19.82	
16 Aug.	72-8	0715	1	1.0	20.60	21.17	2.1
				10.0	21.27	16.86	
		0740	2	1.0	20.70	20.98	2.3
				10.0	21.40	24.66	
		0823	3	1.0	25.33	20.78	2.3
				10.0	24.90	21.42	
		0850	4	1.0	23.87	21.70	2.5
				10.0	22.04	23.23	
		0910	5	1.0	23.20	21.63	2.2
				10.0	21.23	23.88	
		0935	6	1.0	21.30	22.87	2.5
				10.0	21.20	25.40	
		1050	7	1.0	22.13	22.30	2.5
				10.0	21.69	25.60	
		1115	8	1.0	21.55	21.13	—
				10.0	21.78	21.18	
6 Jul.	73-1	0955	I-A	0.0	30.50	18.69	2.5
				4.0	28.20	19.87	
		1015	I-B	0.0	29.90	19.04	2.5
				3.5	26.50	24.51	
		1045	I-C	0.0	29.20	19.02	3.3
				6.5	27.00	21.91	
		1435	II-A	0.0	31.80	18.53	2.5
				5.0	28.20	20.88	
		1505	II-B	0.0	28.60	20.31	3.5
				5.1	27.30	21.76	
		1530	II-C	0.0	28.20	20.23	4.5
				6.5	27.00	22.25	
		0925	III-A	0.0	30.70	18.48	2.5
				4.9	27.30	21.49	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (0/00)	Secchi (feet)
6 Jul.	73-1	0900	III-B	0.0	26.90	19.60	3.8
				6.5	26.00	21.17	
		0757	III-C	0.0	27.00	20.01	3.5
				7.5	26.50	22.27	
		1255	IV-A	0.0	30.30	18.64	3.0
				6.0	27.00	22.09	
		1320	IV-B	0.0	29.50	18.66	3.3
				7.0	26.80	22.65	
		1345	IV-C	0.0	28.80	18.75	4.0
				10.0	26.80	—	
		1125	V-A	0.0	29.80	18.51	3.0
				6.5	28.00	19.83	
		1158	V-B	0.0	29.80	18.35	3.3
				5.5	26.20	23.48	
		1325	V-C	0.0	29.50	18.59	3.8
				5.0	26.80	20.16	
11 Jul.	73-2	1325	1	0.0	27.30	18.82	3.0
				9.0	27.00	21.11	
		—	2	0.0	27.30	21.29	3.0
				9.0	27.00	19.31	
		—	3	0.0	27.50	20.19	3.0
				10.0	26.50	21.83	
		—	4	0.0	29.20	19.63	3.0
				9.0	26.90	22.97	
		1220	5	0.0	29.80	19.70	3.0
				10.0	26.00	25.12	
		1158	6	0.0	30.10	19.89	3.0
				9.0	27.30	22.50	
		—	7	0.0	27.50	21.74	4.5
				10.0	26.90	22.97	
		—	8	0.0	27.00	23.04	4.5
				8.0	26.90	23.26	
		—	9	0.0	28.10	—	—
				7.0	26.10	23.39	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (0/00)	Secchi (feet)
18 Jul.	73-3	0835	1	0.0	25.50	18.28	3.3
				bot.	25.00	22.02	
		0905	2	0.0	25.75	20.23	4.0
				bot.	25.00	21.73	
		0930	3	0.0	30.00	18.64	3.0
				bot.	25.50	21.73	
		0955	4	0.0	29.00	19.40	2.8
				bot.	28.00	20.23	
		1035	5	0.0	31.50	18.39	2.0
				bot.	31.50	—	
		1115	6	0.0	25.50	23.15	4.5
				bot.	26.00	20.88	
		1130	7	0.0	26.00	20.32	4.8
				bot.	—	20.88	
		1235	8	0.0	26.00	20.43	2.5
				bot.	25.90	20.43	
4 Aug.	73-5	0615	1	0.0	26.20	22.65	4.0
				10.0	25.80	23.59	
		0655	2	0.0	26.20	22.27	4.5
				10.0	25.20	25.32	
		0720	3	0.0	26.30	22.37	4.0
				10.0	24.60	27.13	
		0810	4	0.0	33.00	19.87	3.0
				10.0	32.50	21.20	
		0945	5	0.0	30.20	22.24	4.0
				5.0	28.00	24.39	
		1015	6	0.0	30.50	21.87	3.8
				5.0	28.50	23.57	
		1040	7	0.0	30.50	21.59	4.0
				7.0	27.00	24.13	
		1100	8	0.0	27.20	22.63	4.0
				4.0	27.50	22.76	
		1135	9	0.0	27.50	22.46	4.8
				5.0	27.00	22.92	

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (°C)	Salinity (0/00)	Secchi (Feet)
4 August	73-5	1205	10	0.0	27.40	22.83	4.8
				11.0	26.80	23.86	
			11	0.0	28.00	22.65	2.8
					28.00	22.83	
9 August	73-6	0635	1	0.0	26.50	20.70	3.0
				7.0	26.00	20.70	
		0700	2	0.0	26.50	20.72	3.3
				8.0	26.00	20.61	
		0715	3	1.0	26.50	20.14	3.0
				8.0	26.00	20.14	
		0745	4	1.0	26.20	23.22	3.8
				8.0	26.20	25.33	
		0800	5	1.0	26.00	22.52	4.3
				7.0	26.50	24.41	
		0820	6	0.0	27.00	26.72	3.8
				8.0	26.80	23.94	
		0840	7	1.0	29.00	22.09	3.8
				6.0	27.00	22.65	
		0905	8	1.0	31.00	20.98	4.0
				5.0	28.00	22.27	
		0925	9	1.0	30.20	21.35	2.3
				4.2	28.00		
		1007	10	0.0	27.00	21.69	3.8
				5.0	26.50	23.21	
		1020	11	1.0	27.00	21.72	4.0
				7.0	26.00	23.11	
		1040	12	1.0	26.50		4.0
				8.0	27.00	21.35	
15 August	73-7	1100	1	0.0	25.80	21.34	3.8
				9.5		28.33	
		1045	2	0.0	25.50	21.72	3.5
				9.5	22.70	28.39	
		1030	3	0.0	25.10	21.90	3.5
				10.0	24,10	25.98	
		1015	4	0.0	25.20	22.50	3.5
				10.0	23.80	27.19	
		1000	5	0.0	25.20	22.61	4.0
				8.5	23.50	28.28	
		0936	6	0.0	25.80	22.09	4.0

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (°C)	Salinity (0/00)	Secchi (Feet)
15 August	73-7	0936	6	8.5	24.20	26.35	4.0
		0915	7	0.0	25.40	23.37	4.0
				8.5	24.00	27.54	
		0855	8	0.0	26.00	23.78	3.0
				8.0	24.70	26.20	
		0840	9	0.0	26.10	23.94	3.5
				8.5	24.30	26.72	
20 August	73-8	0720	IA	0.0	27.80	26.17	3.3
				6.0	25.00	21.98	
		0755	IB	0.0	27.00	22.55	3.5
				7.0	24.80	24.13	
		0820	IC	0.0	25.80	21.01	3.8
				9.0	24.90	22.72	
		0850	IIA	0.0	28.20	20.33	3.3
				6.0	25.80	20.77	
		0708	IIB	0.0	26.20	20.42	4.0
				7.0	24.90	21.73	
		0922	IIC	0.0	24.20	21.73	3.3
				10.0	24.20	25.07	
		0945	IIIA	0.0	27.80	21.85	3.5
				7.0	25.50	20.81	
		1013	IIIB	0.0	24.00	21.51	3.5
				10.0	23.70	22.00	
		1030	IIIC	0.0	24.00	21.72	4.0
				11.0	24.00	24.13	
		1120	IVA	0.0	29.50	20.23	3.5
				7.0	26.00	20.79	
		1142	IVB	0.0	27.50	21.18	4.0
				9.0	24.50	21.35	
		1205	IVC	0.0	24.70	21.63	3.0
				10.0	24.00	21.35	
		1225	VA	0.0	30.00	19.12	2.8
				7.0	26.00	21.51	
		1245	VB	0.0	29.00	19.87	3.3
				7.0	25.50	21.35	
		1320	VC	0.0	25.80	21.73	3.3
				5.0	24.30	20.65	

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (°C)	Salinity (0/00)	Secchi (Feet)
11 September	73-9	1145	1	0.0	23.00	23.57	
		1153	2	0.0	22.00	23.89	
		1202	3	0.0	22.00	24.31	
		1216	4	0.0	22.00	25.34	
		1225	5	0.0	22.00	23.94	
		1234	6	0.0	22.00	23.76	
		1249	7	0.0	22.00	24.13	
		1259	8	0.0	22.50	22.09	
		1310	9	0.0	22.50	24.78	
		1323	10	0.0	22.50	24.09	
		1330	11	0.0	22.50	24.30	
		1337	12	0.0	22.50	25.80	
		1401	13	0.0	23.20	24.13	
		1410	14	0.0	23.50	24.22	
		1420	15	0.0	23.00	24.44	
29 September	73-10	0803	1A	0.0	21.00	24.51	4.0
				5.0	21.00	24.45	
		0855	IB	0.0	21.50	24.87	4.0
				5.0	21.10	25.70	
		0920	IC	0.0	21.00	25.07	3.8
				7.0	20.09	27.29	
			IIA	0.0	21.50	25.43	3.5
				8.5	21.00	25.43	
			IIB	0.0	21,50	25.07	3.8
				11.0	21.50	25.25	
			IIC	0.0	21.50	25.16	4.0
				8.0	21.50	27.41	
			IIIA	0.0	21.50	25.40	
				9.0	21.50	25.98	
			IIIB	0.0	21.50	25.05	3.0
				11.5	21.50	26.20	

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (°C)	Salinity (0/00)	Secchi (Feet)
29 September	73-10		IIIC	0.0	22.00	25.07	4.0
				11.0	22.00	27.41	
			IVA	o.o	21.60	23.77	3.5
					21.00	27.16	
			IVB	0.0	21,80	25.25	5.0
				14.0	20.00	25.25	
			IVC	0.0	22.00	24.51	4.8
				12.0	21.00	28.59	
			VA	0.0	21.80	25.57	5.0
				9.0	21.20	27.09	
			VB	0.0	21.50	25.99	5.0
				7.0	21.00	27.66	
			VC	0.0	21.75	25.50	3.5
				5.0	21.75	25.50	
9 October	73-11	0900	1	1.0	18.50	21.53	5.0
				8.0	19.00	21.92	
		0918	2	1.0	18.80	21.80	5.0
				8.5	19.00	24.13	
		0940	3	1.0	19.00	22.23	5.0
				7.0	19.20	24.81	
		1006	4	1.0	21.00	23,21	5.0
				7.0	20.00	23.21	
		1025	5	1.0	22.00	21.92	4.5
				7.0	20.30	24.92	
		1042	6	1.0	21.40	22.47	4.0
				5.0	20.70	24.52	
		1114	7	1.0	20.00	24.87	4.0
				7.0	19.80	25.57	
		1130	8	1.0	20.00	24.69	3.3
				8.0	19.80	24.69	
		1155	9	1.0	19.40	22.66	4.0
				6.0	19.70	24.13	
		1215	10	1.0	19.80	23.66	5.0
				6.0	19.50	23.78	
		1230	11	1.0	20.00	20.00	4.5
				6.0	20.00	20.00	

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (C)	Salinity (0/00)	Secchi (feet)
23 October	73-12	0745	1	0.0	13.48	25.43	3.3
				6.0	13.70	25.99	
		0815	2	0.0	13.12	25.40	3.0
				6.5	13.21	26.98	
		0915	3	0.0	15.25	26.56	4.5
				4.5	14.63	26.65	
		0935	4	0.0	15.27	26.21	3.3
				5.5	14.90	26.45	
		1000	5	0.0	17.85	26.91	4.0
				4.5	15.58	26.35	
		1026	6	0.0	18.95	25.50	4.0
				8.0	15.10	27.20	
		1110	7	0.0	20.57	24.81	3.5
				15.0	20.10	24.88	
		1150	8	0.0	15.85	25.99	4.5
				6.5	14.62	26.18	
		1210	9	0.0	16.04	25.62	5.5
				7.0	14.51	26.30	
		0100	10	0.0	15.18	25.58	4.0
					15.26	25.78	
13 November	73-13	1320	IA	0.0	8.40	26.35	3.0
					8.40	26.09	
		1300	IB	0.0	7.33	26.73	3.5
					7.45	26.13	
		1240	IC	0.0	7.00	26.73	4.5
					7.89	28.16	
		1125	IIA	0.0	8.65	26.17	3.3
					8.31	26.55	
		1145	IIB	0.0	7.02	26.74	3.8
					7.58	27.48	
		1205	IIC	0.0	7.53	26.48	4.0
					8.11	30.05	
		1105	IIIA	0.0	8.69	26.17	3.8
					8.41	26.42	
		1050	IIIB	0.0	8.75	25.90	3.8
					8.15	25.83	

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (C)	Salinity (0/00)	Secchi (Feet)
13 November	73-13	1030	IIIC	0.0	8.31 8.50	25.63 28.70	3.5
		1335	IVA	0.0	11.00 8.03	24.88 23.85	3.8
		1405	IVB	0.0	10.03 8.21	25.68 29.30	3.3
		1350	VA	0.0	11.10 8.65	24.90 22.95	3.0
		1440	VB	0.0	10.61 8.75	25.66 23.70	3.3
		1455	VC	0.0	9.61 9.61	26.17 24.50	3.0

THE ECOLOGY OF THE BENTHIC MACROINVERTEBRATES OF BARNEGAT BAY, NEW JERSEY

BY

FRANCIS X. PHILLIPS

A thesis submitted to

The Graduate School

of

Rutgers University

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

written under the direction of

Dr. Robert E. Loveland

New Brunswick, New Jersey

June, 1972

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INTRODUCTION

The earliest attempts at quantifying the "productivity" of coastal areas may be traced to Dahl's (1893) investigation in the lower Elbe. Johnstone (1908) contributed some more quantified information, but it was not until Petersen (1911) developed his "Petersen grab" that benthic quantitative studies could be conducted. The usefulness of this tool was quickly realized in Europe, so numerous studies were conducted and published. Among the better known are Blegvad's contributions (1914, 1925, 1928), Davis' work (1923, 1925), Hagmeir (1923, 1926, 1930), Spärck (1929, 1931, 1935), and Stephen (1923, 1928, 1929).

The western shores of the North Atlantic have not been without their benthic investigations. However, quantitative surveying was not initiated until 1944 with Lee's study of Menemsha Bight. Previous to this, the investigations were qualitative and included such classic studies as Verrill (1873); Sumner, Osburn, Cole, and Davis (1913); Allee (1923a,b); and Proctor (1933).

Since Lee's (1944) investigation there have been a few survey type studies conducted in the northeastern states, but the quantity of studies is not overwhelming. Dexter (1944, 1947) studied two areas along the Massachusetts coast. F. E. Smith (1950) sampled the benthos of Block Island Sound. Another benthic study was not conducted until Sanders' (1956) work in Long Island Sound. This investigation apparently initiated some enthusiasm because the frequency of benthic surveys increased after this publication. Stickney and Stringer (1957), Sanders (1958, 1960), Sanders et. al. (1962), Hanks (1964), Sanders et. al. (1965), and Richards and Riley (1967) have all contributed to the knowledge of the distributional pattern of invertebrates in the Northeastern states.

The Middle Atlantic states are noticeably lacking in published information concerning their invertebrate faunas. Richards (1938) listed the common New Jersey coastal forms, Dean and Haskin (1964) surveyed a small portion of the Raritan River, and Phillipe (1967) provided a checklist of estuarine forms from the central portion of New Jersey.

Cory (1967), Cory and Nauman (1969) and Nauman and Cory (1969) reported on epifauna in the Patuxent River estuary (Maryland). Wass (1965) compiled a listing of the marine invertebrates in Virginia waters. Wells (1961) published a register of those invertebrates associated with oyster beds in the Newport River region of North Carolina. Brett (1963) studied the sediment-fauna relationship in Bogue Sound, North Carolina.

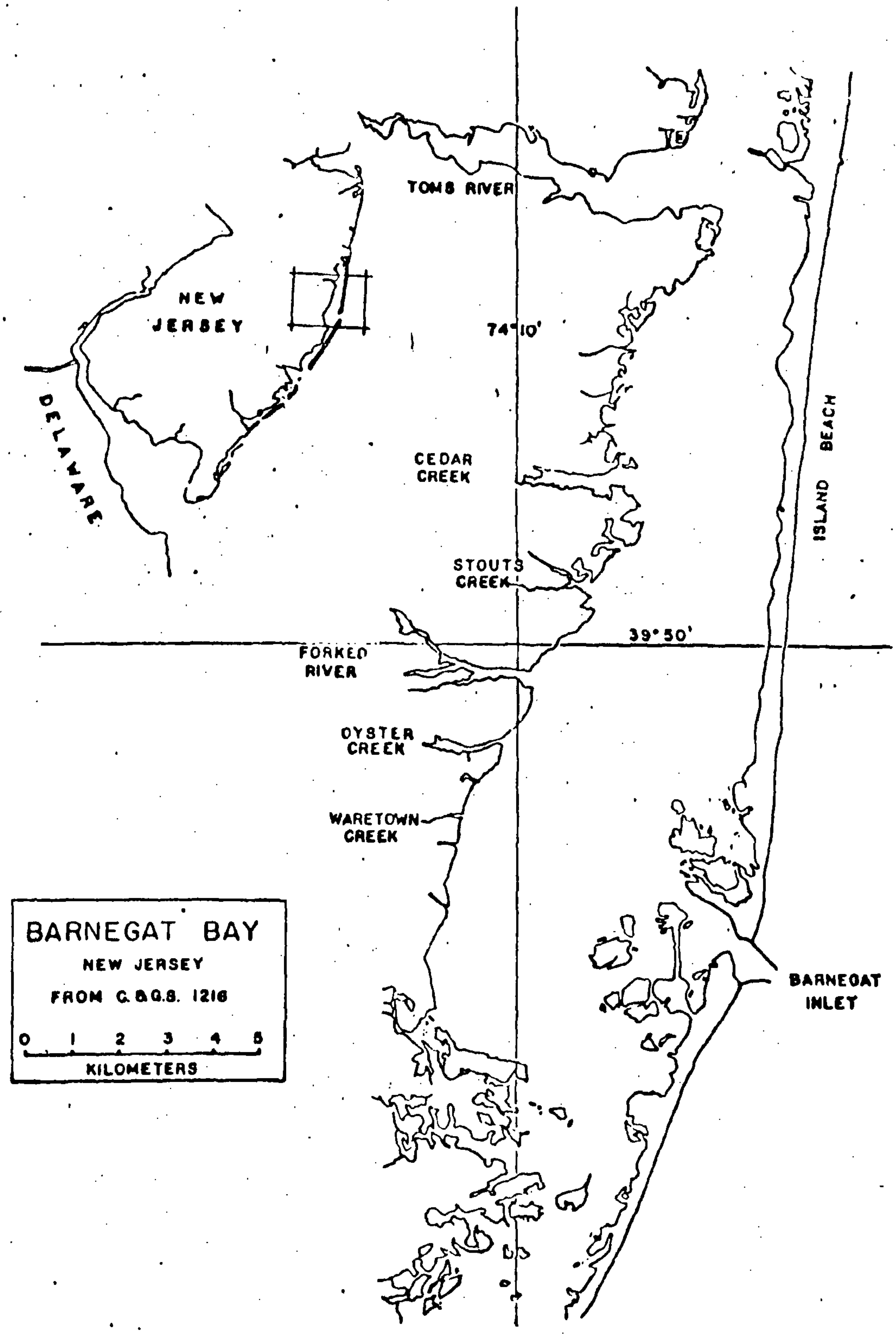
From the above citations it is apparent that most of the benthic studies conducted in the Virginian Province have been limited to the northern aspects. The centralized area of the coastal region is notably lacking in published information concerning the invertebrates.

Barnegat Bay is about centrally positioned (Fig. 1) along the New Jersey coastline. It is a shallow lagoon-type estuary (Emery & Stevenson, 1957) with a small tidal range of about 0.2 meters. The barrier island which forms the eastern boundary of the Bay is a state park which has remained undeveloped. The mainland side of the bay system is moderately developed with domestic housing, boating marinas, and, recently, an electric generating station.

During 1963, the Jersey Central Power & Light Company initiated construction of a 1600 megawatt electric generating station. The plant draws water from Barnegat Bay which acts as the secondary coolant for the thermonuclear reaction. Approximately 0.5 x 10^6 gallons per minute (gpm) will be continuously pumped through the condensers. Even though the passage time is very short, the coolant temperature will be increased by about 10^oC. above ambient. This is an average figure—the actual thermal differential may be higher or lower. As an initial measure to reduce the temperature of the coolant water before it re-enters the system, a bypass water course has been constructed around the plant. This portion of the physical system will dilute the heated effluent by two-thirds, i.e., 1.0 x 10^6 gpm will be pumped through the bypass and added to the coolant as it leaves the generating plant.

All of Barnegat Bay was not sampled in the present study. The Bay is approximately 39 km long (Metedeconk Neck

Figure 1. Barnegat Bay, New Jersey

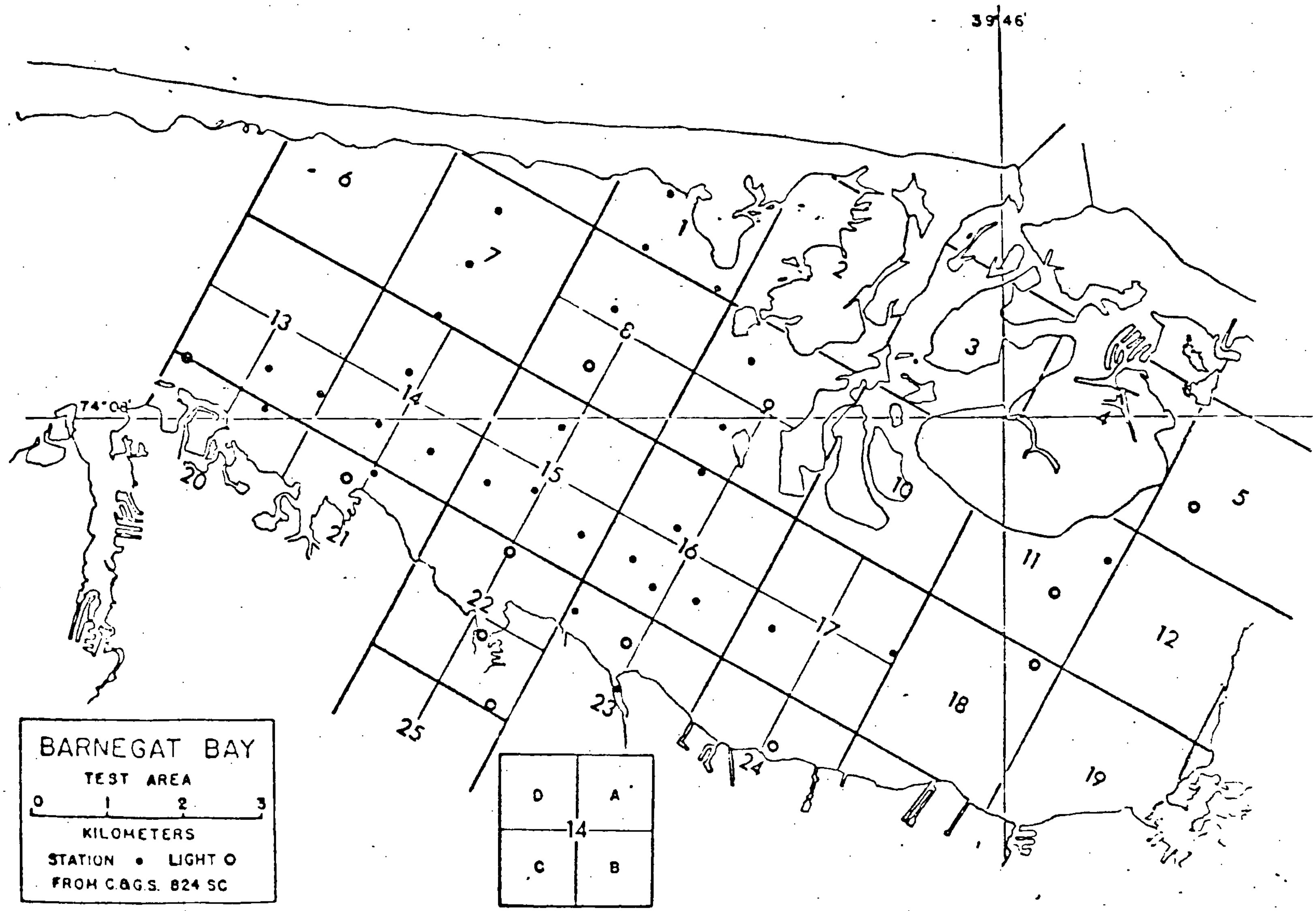

TOMS RIVER
NEW JERSEY
DELAWARE
74°10'
CEDAR CREEK
STOUTS CREEK
39°50'
FORKED RIVER
OYSTER CREEK
WARETOWN CREEK
ISLAND BEACH
BARNEGAT INLET
BARNEGAT BAY
NEW JERSEY
FROM C.&G.S. 1216
0 1 2 3 4 5
KILOMETERS

to Manahawkin Bay, Fig. 1) and varies in width from 2 km to about 6.5 km. Most of the surveys were conducted in the central region around Forked River and Oyster Creek (Fig. 1 & 2). These positions are almost directly north-west from Barnegat Inlet (39°45'N, 74°06'W) in Figure 1.

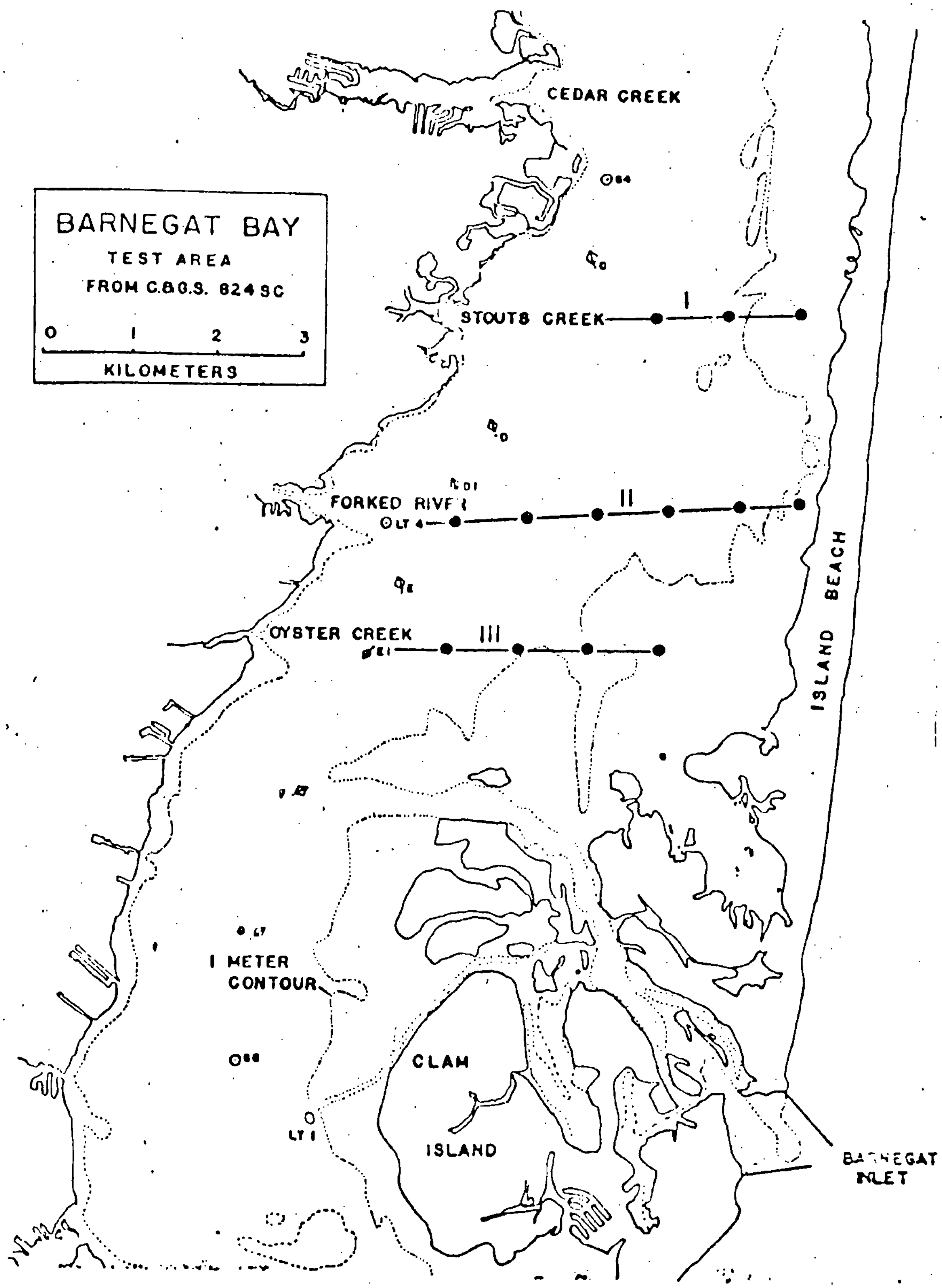
The Jersey Central Power and Light Company provided the funding for this study and others (Taylor, 1970). These investigations were designed to determine the condition of the benthos before and after operation of the station. In addition to the flora and fauna of the area, different environmental parameters were measured to serve as points of reference for pre- and post-operational studies.

The power plant did not begin operation according to the initial schedule. As a result no post-operational data were collected by the author. An earlier publication (Phillips, 1967) presented some preliminary data concerning the benthic invertebrate community prior to thermal addition.

Figure 2. Test site area, Barnegat Bay.



39°46'
74°08'
BARNEGAT BAY
TEST AREA
0 1 2 3
KILOMETERS
STATION • LIGHT O
FROM C.&G.S. 824 SC
D A
14
C B


BARNEGAT BAY
TEST AREA
FROM C.&G.S. 824 SC
0 1 2 3
KILOMETERS
CEDAR CREEK
STOUTS CREEK
I
FORKED RIVER
II
OYSTER CREEK
III
ISLAND BEACH
I METER
CONTOUR
CLAM
ISLAND
LT 1
BARNEGAT
INLET

METHODS

I. Ponar Characterization

Various sites along the New Jersey coast and a recently drained inland lake were sampled to investigate the working characteristics of the Ponar quantitative bottom grab in different bottom types. Areas sampled included two inter-tidal sand flats, a sandy beach (surf zone), subtidal "mud," and the lake environment.

Substrate composition greatly determines the usefulness of the grab in question (Thorson, 1957; Holme, 1964), so knowledge of the grab's performance on different bottom types was imperative. The main parameter investigated was the volume of material collected by the Ponar grab. The most influential variable measured was the composition of the substrate (viz., "hard or sandy" vs. "soft or muddy").

When possible, grab samples were obtained during both high and low tides. For low tide sampling, the Ponar was hand held and released at a constant height (0.9 m) above the substrate. When sampling through the water column, the grab was lowered until it touched bottom and was then raised approximately 1.2 m, at which point it was permitted to fall freely. The increased drop height at high tide was used in simulating penetration under the different tidal circumstances.

The volume of each sample was measured to the nearest 20 ml, using a large graduated cylinder. After measurement, the samples were returned in polyethylene bags to the laboratory for particle size analysis.

II. Sediments

A. Field Procedures

Samples of the substrate were taken at those sites sampled for faunal composition. All of the station locations were continually submerged, so sampling was conducted through the water column from a boat, a 16' 7" Boston Whaler." The open vessel had a shallow draft, sufficient deck area for working, and was equipped with a custom-constructed davit and winch.

A removable wooden culling board was positioned forward of the davit apparatus. One end of the board extended out over the water. Nested sorting screens were fitted into a cut-out at this end. As materials were brought on board via the davit and collecting gear, these could be deposited on the culling board, washed by hand, and sorted.

Substrate samples were taken by two varieties of quantitative bottom grab samplers: 1) the 0.1 m^2 Petersen (Petersen & Jensen, 1911) grab; and 2) the 0.05 m^2 Ponar grab (Wildlife Supply Company, Saginaw, Michigan).

From 1966 to the termination of this study a series (generally four) of bottom grab contents were pooled at each station. This technique was adopted for both samplers. The pooled bottom materials were mixed by hand on the culling board; conspicuous organisms, larger than approximately 20 mm, were removed from the sample prior to packaging. Random substrate samples were then taken, packaged, and returned to the laboratory for analysis. During the first season (1965), the contents of only one Petersen grab were used to characterize the sedimentary composition of the sites studied.

B. Laboratory Procedures

In the laboratory the sediment samples were removed from the carrying packages, individually placed in aluminum pans and dried in a ventilated, electric oven. It was found that drying at 100°-105°C. for 48 hours was sufficient to bring the sample (average wet weight about 800-1000 grams) to a relative constant weight ($\pm$2 grams). When dried, the substrate materials were sorted into diameter size classes in the diameter range 2000μ to 1μ. Analysis of the sands (2000μ-62μ, Wentworth, 1922) was conducted by mechanically agitating the dried sediments through nested standard sieves (A.S.T.M. #422-51 modified) using a conventional sieve shaker. The silt-clay fraction (materials finer than 62μ) was trapped in a retaining pan and analyzed as to particle size by the hydrometer technique of Bouyoucos (1927, 1928). Unless the silt-clay fraction accounted for more than five percent by weight of the sample, the hydrometer determination was not conducted.

After computing the percentage composition of the different diameter classes, cumulative curves for the size distributions were generated. From cumulative curves, certain sedimentary characteristics were derived. These were the median grain diameter (M_2), sorting coefficient (S_o), and skewness (S_k). All three properties were computed using the conventional formulae presented in Sverdrup, Johnson, and Fleming (1942).

During the final summer (1969), available amounts of organic materials in the substrate were determined. Aliquots of the samples used in the size determinations were removed for the organic analysis. Two techniques were used in this portion of the study. The rationale was that the two measurements would be "backups" for each other. A colorimetric analysis (Perrier and Kellogg, 1960) following wet oxidation was conducted using a Beckman Model B spectrophotometer. The percentage transmittance at 540mμ was measured with the spectrophotometer set at the greatest sensitivity. These values were then converted to percentage organic material by the formula developed by Perrier and Kellogg (1960), % organic matter = 10.9375 (log % transmittance) - 5.6321.

In addition to the above technique, duplicate samples of substrate were subjected to ignition analysis. This was an ashing technique wherein a sample was carefully weighed using a Mettler Balance (±0.1mg) before and after a one-hour exposure to 700°C. in a muffle furnace. The recorded weight differential was calculated as the percentage total organic matter of that sample.

RESULTS

I. Ponar Characterization

A. Volumes Collected

Table I presents the data obtained with this grab using different sampling conditions, i.e., substrate and water depth. Series 1 and 2 were taken on the same sandy tidal flat, but at two different positions. Series 3 was taken in the surf zone of a protected bay. Series 4 was taken through a shallow water column on a sand flat. Series 5 and 6 were taken in muddy environments.

As a generality, it appears that the Ponar is more consistent in unit capture in the finer, muddier environments. Greater volumes are consistently recorded in the softer substrates; this may be a function of the light weight (20.4 kg) of the unit.

By filling the Ponar with sand, the total volume was found to be approximately 7.5 liters. In use, the sampler was never completely filled in any of the coastal areas studied. The best volumes recorded for these locations were obtained on a very protected marsh mudflat (Series 5 in Table I). During the draining of a small eutrophic lake (Middlesex County, Lake Nelson), the working characteristics of the Ponar were to be further quantified. The unit was permitted to fall freely from about one meter in height onto the exposed lake substrate. This procedure was conducted

Table I. Comparison of volumes obtained with the Ponar bottom grab on different bottom types. See text for series locations.

SERIES	1a	1b	2a	2b	3	4	5a	5b	6
TYPE *	High	Low	High	Low	Surf	Low+	High	Low	High
Sample Number 1	1.28	2.05	0.88	2.25	1.05	0.95	6.35	7.15	4.05
2	0.89	2.46	0.95	2.40	0.86	1.83	6.80	7.30	3.95
3	1.18	2.30	0.85	2.80	0.78	2.04	6.65	7.35	3.60
4	0.70	2.20	0.76	2.32	1.31	1.64	6.40	7.40	4.95
5	1.27	2.05	0.80	3.25	1.18	2.80	6.35	7.25	3.40
6	0.96	2.18	0.75	2.61	1.09	2.40	6.75	7.10	4.60
7	1.18	1.96	1.16	2.62	1.26	2.30	6.70	7.40	4.00
8	0.50	2.20	0.72	3.12	1.52	1.10	6.65	7.30	4.55
9	0.86	1.96	0.94	2.82	0.86	1.20	6.75	7.25	4.20
10	0.66	2.28	0.78	2.78	0.94	0.78	7.00	7.40	4.45
$\bar{x}$	0.94	2.16	0.86	2.70	1.08	1.70	6.64	7.29	4.17
Std. Dev.	0.27	0.16	0.13	0.33	0.23	0.68	0.02	0.01	0.05
99% C.I.	1.23	2.33	0.99	3.03	1.33	2.41	6.66	7.30	4.22
	0.67	2.00	0.73	2.36	0.84	1.00	6.62	7.28	4.13
M_2(u)	182	202	190	187	103	188	90	90	63
Q_1(u)	125	138	130	130	69	136	44	48	23
Q_3(u)	262	295	272	265	145	272	187	186	117
S_o **	1.44	1.46	1.44	1.42	1.45	1.41	2.06	1.96	2.25

* "High" and "Low" refer to the tidal stage at time of sampling.
\+ through 0.20-0.25 m of water
** S_o is dimensionless

for three free-falls. Each time the sampler, which sank out of view except for the attachment ring, was completely filled with substrate.

Series 4 in Table I was to have been a high/low water study, but the prevailing winds on the sampling date prevented the tide from dropping as it should have. Since the working characteristics of the Ponar could not be studied as originally planned, a direct comparison of the Ponar and Petersen grabs was made. In this sandy situation the Petersen retrieved slightly more material and demonstrated less variability ($\bar{x}$ = 1.87 liters; standard deviation = $\pm$0.14 liter) than the Ponar ($\bar{x}$ = 1.70 liters; standard deviation = $\pm$0.68 liter).

B. Comparison of Samplers

Since two different samplers were used in obtaining the sediments for analysis, some index of their comparability was desirable. Three areas were chosen for the comparisons. One region was "muddy" with large amounts of silts and clay. Another was sandy, and the third area was intermediate in substrate composition.

Both bottom samplers were used on the same day within any particular bottom type; this negated temporal variability. Since sampling was conducted within a limited area, spatial variation was probably minimal within a test site. The sampling pattern used was to take multiple sets of samples using both bottom grabs. Each set sample was an aliquot of a pooled collection of the contents of four consecutive samples. Four sets were taken at each site with each variety of bottom grab, so a total of eight sets were taken at each test site.

The results of the above are presented in Table II. Each value is the average of four figures (from the four sets). These data demonstrate that the samplers provided comparable results in the distribution of sediment size classes at the same general site.

II. Sediments

During the study period (summer 1965 - summer 1969) a total of 94 samples were analyzed to determine the particle size distribution of the substrate in Barnegat Bay. This number represents 35 sites or stations that were sampled. Of these sites, three were sampled only once. Two of these represented peripheral locations that were visited only during the early exploratory phases of the investigation.

Most of the particle size data is presented in the appendix. The average yearly values for the different particle size classes appear for each regularly examined station. Each value is the average of at least two determinations of the particle size composition. If the difference between the two determinations was greater than 5.0 - 5.5%, another analysis was performed to verify the observed results.

The twelve stations in the appendix that were sampled only twice during the study period were chiefly on the

Table II. Comparison of sediment size analysis using Petersen and Ponar Grabs.

Site Location	Bouy C1		FRC*		"Sand Flats"	
Quadrate	13B		22A		9C	
Grab Type	Petersen	Ponar	Petersen	Ponar	Petersen	Ponar
Lower Limit of Particle Size Range μ	% Weight		% Weight		% Weight	
2000	0.55	0.17	0.65	0.15	0.65	0.50
1000	1.05	0.35	1.20	0.65	1.02	1.40
500	5.60	6.90	5.10	5.90	1.60	2.30
250	36.25	33.20	6.75	7.45	25.32	23.50
125	30.35	32.00	8.45	8.40	59.40	54.75
62	10.80	10.45	28.00	27.55	10.00	14.35
-62	16.30	16.77	50.00	49.90	2.05	2.25

*FRC:Forked River Channel, situated between Light 12 and Light 4.

eastern side of the Intracoastal Waterway. Biological sampling was infrequent on the oceanic side of the Bay after the 1965 season. These areas were sampled in 1969 for sediment composition to determine if any noticeable changes had occurred in the time period.

A very condensed version of the appendix is presented in Figure 3. At a point corresponding to a station's position in the Bay, two numbers appear. The upper value is the median grain diameter (M_2); the lower is the sorting coefficient (S_o). The M_2 value represents the empirically derived particle size which has 50 percent larger and 50 percent smaller materials in that sample or average. The larger this value (M_2), the "sandier" or coarser it becomes.

The sorting coefficient gives an index of the particle size uniformity within a soil sample. When water velocities vary slightly about some average value, the substrate will be composed of more uniformly sized particles than a situation involving larger current variations. With more uniform particle size, the S_o value decreases until unity is achieved. An S_o value of 1.0 indicates that the soil particles are all of the same size.

A more amplified graphical index of the sediment distribution in the area studied is presented in the cumulative particle size curves for various positions in the Bay. Rather than present each year's collection of curves, only the most recent (1969) data are presented in Figures 4, 5, 6, and 7. With only minor variations, the cumulative

Figure 3. Median grain diameter (M_2) and sorting coefficient (S_o) values of sampling stations in Barnegat Bay. Values are presented as M_2/S_o.

Figure 4. Cumulative curves of sediment size distribution along northern transect (Transect I) stations, 1969 data.

Transect	I-1	⊙————⊙
	I-2	⊙— — — —⊙
	I-3	⊙·············⊙
	I-5	⊡—··——··—⊡
	I-6	⊡——–——⊡

Figure 5. Cumulative curves of sediment size distribution along middle transect (Transect II) stations, 1969 data.

Transect II-1	⊙———⊙
II-2	⊙— — —⊙
Forked River Channel	⊙·········⊙
Transect II-7	⊡—··—··—⊡
II-9	⊡—— ——⊡

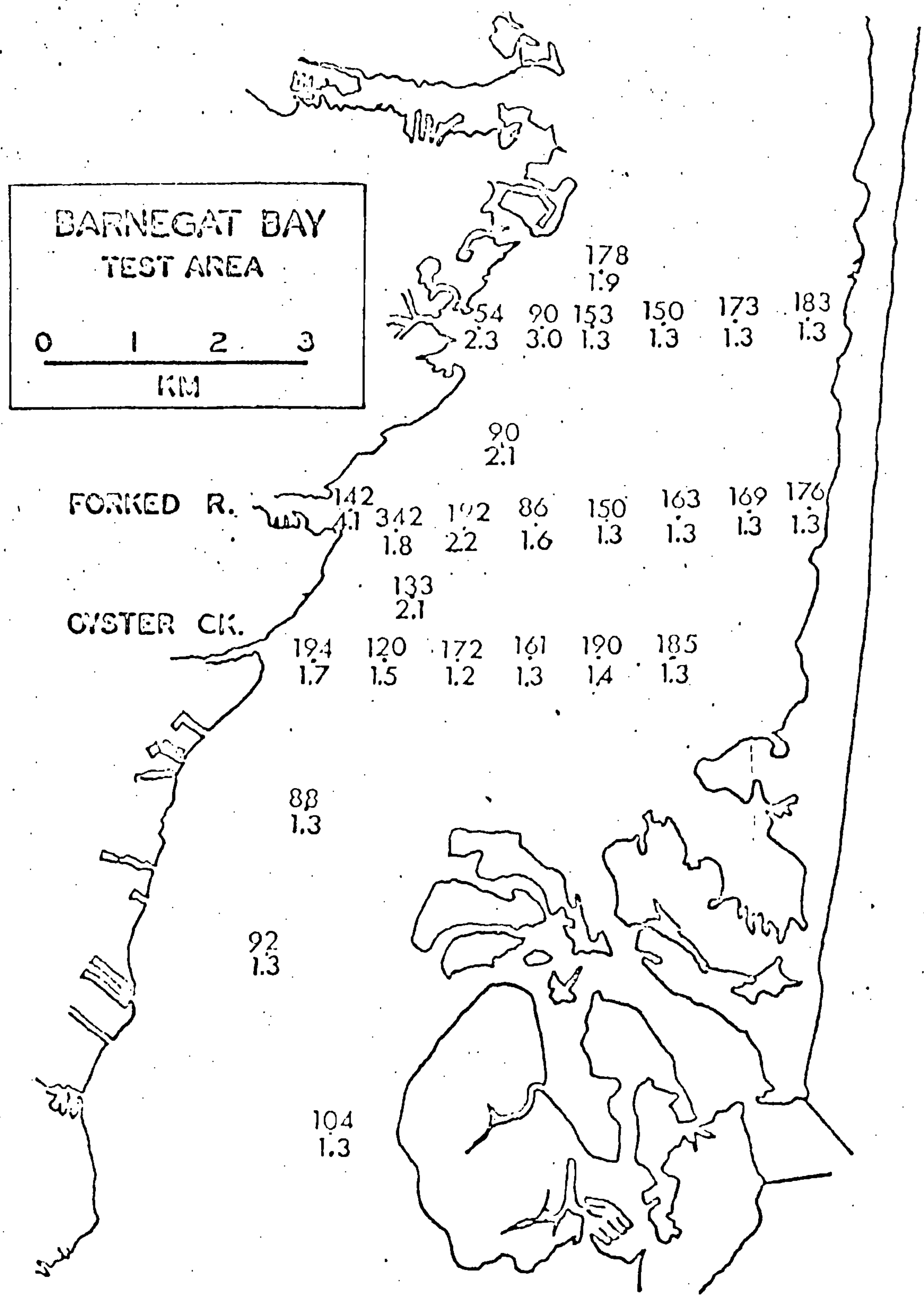

BARNEGAT BAY
TEST AREA
0 1 2 3
KM
FORKED R.
OYSTER CK.
178 1.9
54 2.3
90 3.0
153 1.3
150 1.3
173 1.3
183 1.3
90 2.1
142 4.1
342 1.8
86 1.6
150 1.3
163 1.3
169 1.3
176 1.3
133 2.1
194 1.7
120 1.5
172 1.2
161 1.3
190 1.4
185 1.3
88 1.3
92 1.3
104 1.3

Figure 6. Cumulative curves of sediment size distribution along southern transect (Transect III) stations, 1969 data.

Transect III-1

III-2

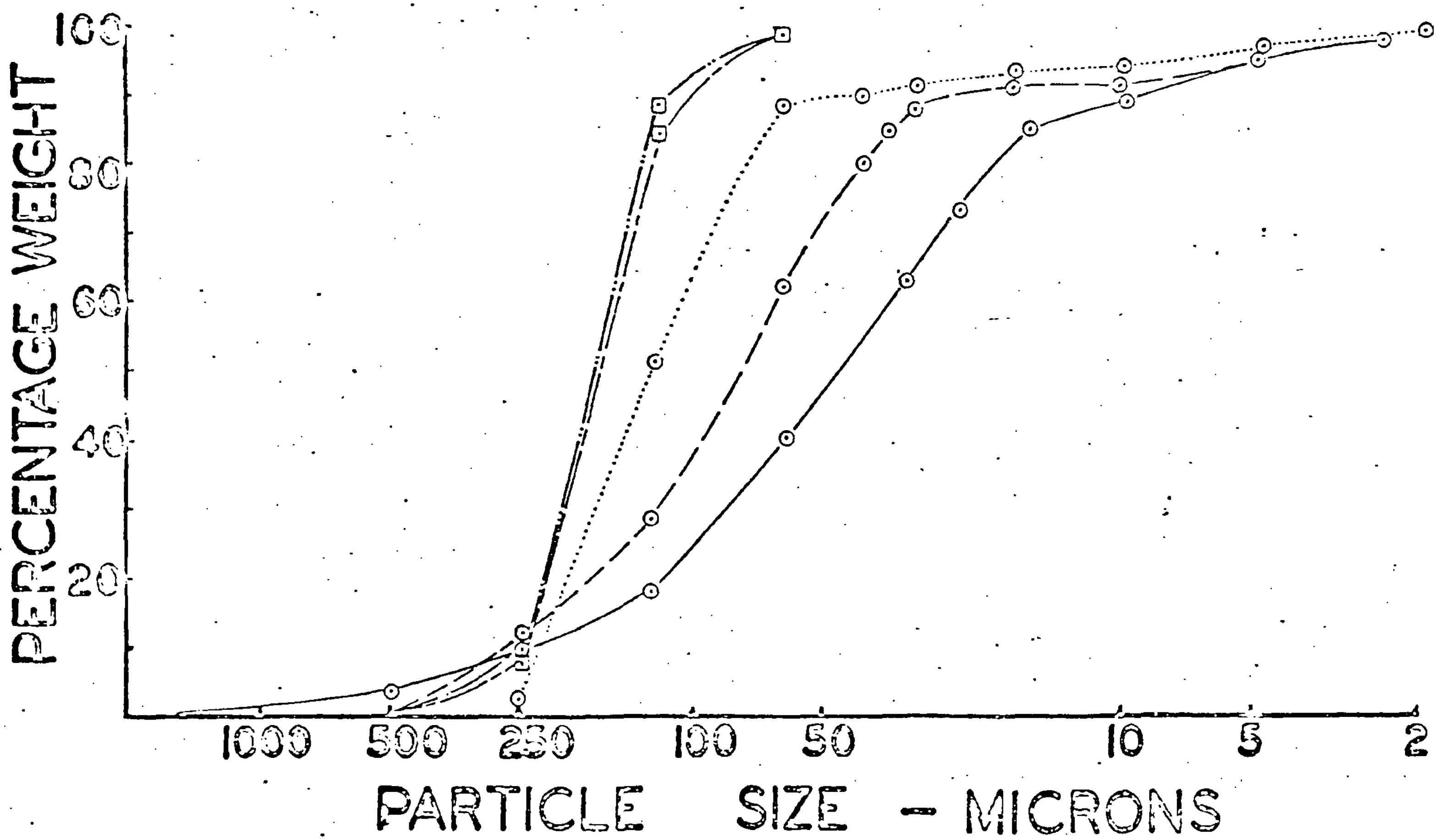
III-3

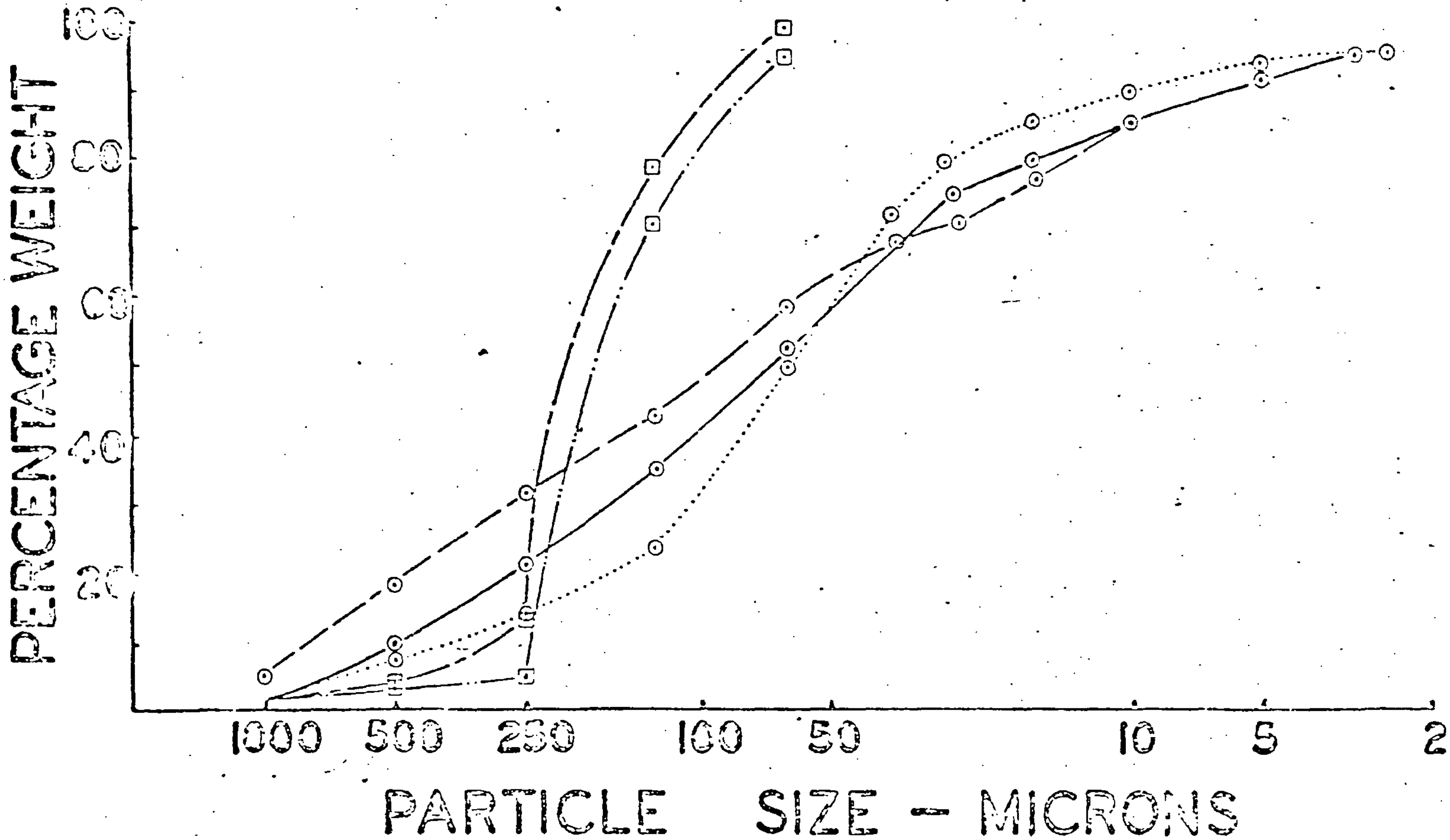
III-5

III-6

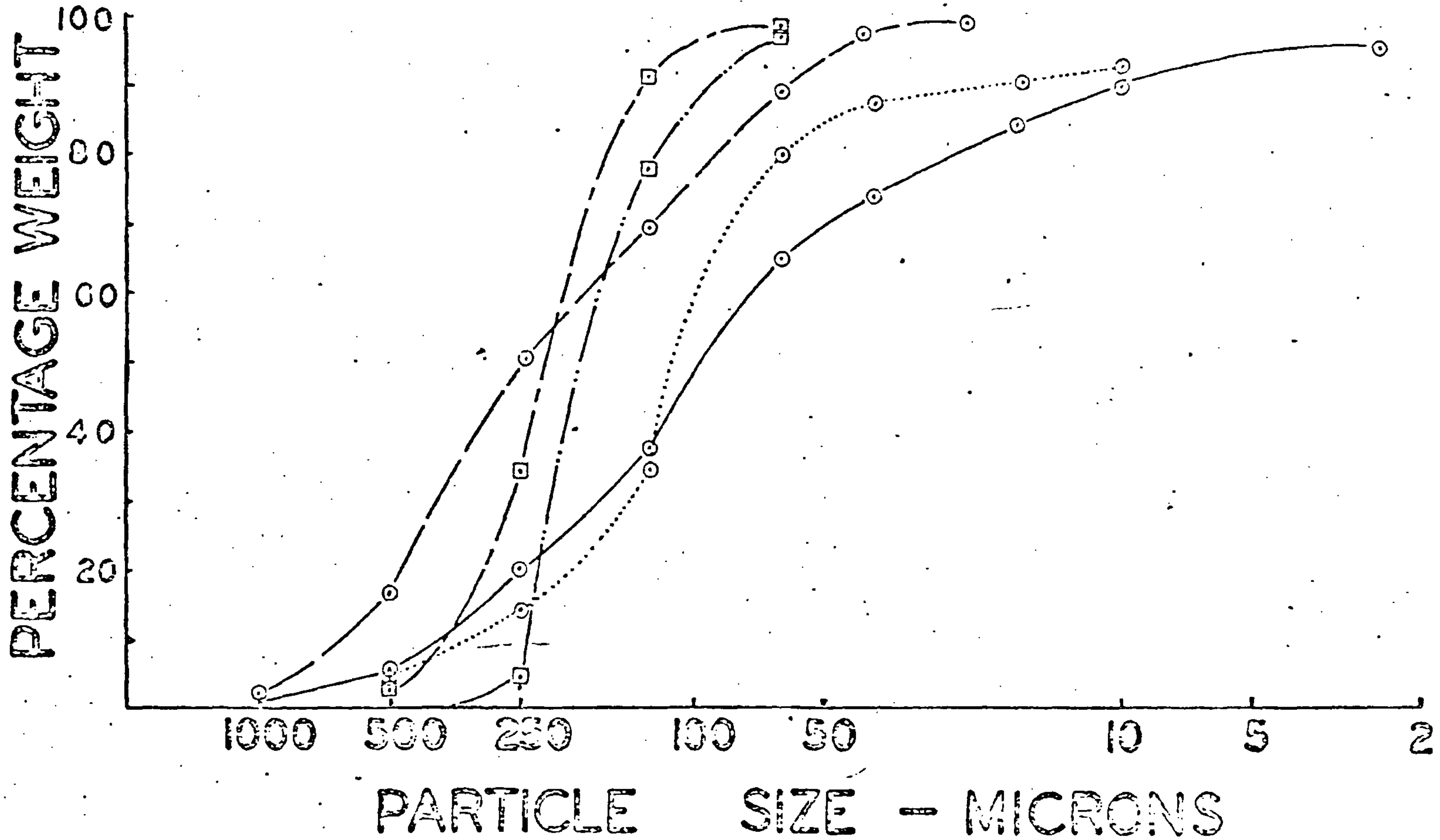
Figure 7. Cumulative curves of sediment size distribution along Intracoastal Waterway.

Bouy C	●————————●
D	⊡————————⊡
D1	■————————■
E	★————————★
E1	☆————————☆
F	⊙————————⊙
G	●- - - - - - - - - -●

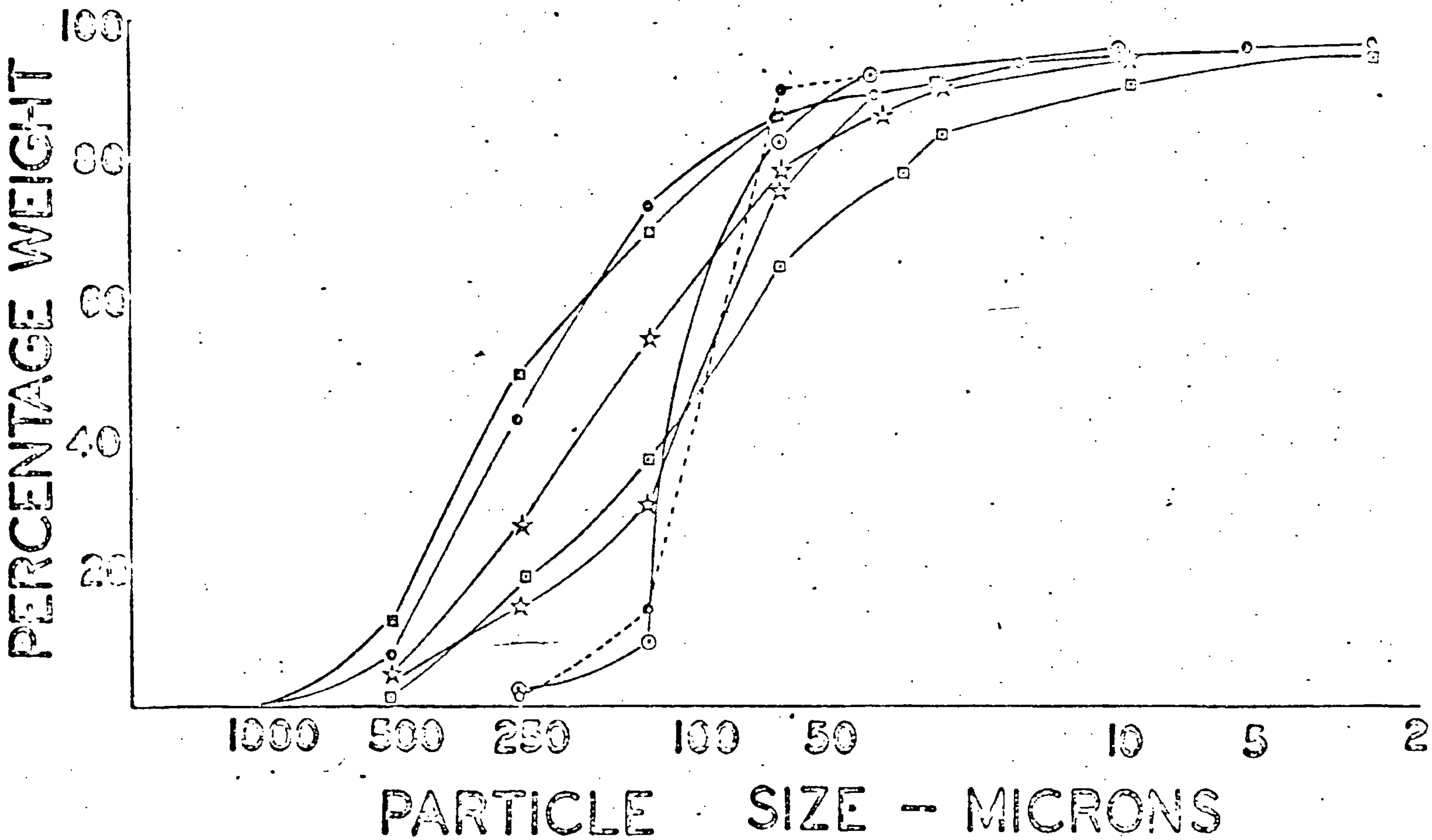

PERCENTAGE WEIGHT
100
80
60
40
20
1000
500
250
100
50
10
5
2
PARTICLE SIZE - MICRONS



100
80
60
40
20
PERCENTAGE WEIGHT
1000 500 250 100 50 10 5 2
PARTICLE SIZE - MICRONS



PERCENTAGE WEIGHT
100
80
60
40
20
1000
500
250
100
50
10
5
2
PARTICLE SIZE — MICRONS


PERCENTAGE WEIGHT
100
80
60
40
20
1000
500
250
100
50
10
5
2
PARTICLE SIZE - MICRONS

curves of the earlier annual data fit the 1969 information excellently.

With a limited number of exceptions, materials retained by the 2000- and 1000-micron screens were not sedimentary in nature. The most commonly encountered components in these size ranges were molluscan shells and fragments (notably the small prosobranchs, Bittium alternatum and Mitrella lunata. Juvenile and small bivalves were occasionally found in the 1000μ and 2000μ sieves. These materials were not observed during the field collecting so they were included in the laboratory workups. Such biological materials were included in the percentage analyses of the sediments. Other non-sedimentary components were fragmented pieces of eel grass (Zostera marina) and sea lettuce (Ulva lactuca).

Based on these data, one would be forced to conclude that among the regions sampled there were no very coarse sands (2000-1000μ, Wentworth, 1922).

From the Appendix and Figures 4 through 7, it may be seen that the coarse sands (1000-500μ) and larger particle classes generally account for less than five percent, by weight, of the substrate. The most notable exception to this occurs in Transect II, Stations 1, 2, and 3. Stations 1 and 2 occur within Forked River, Station 1 being about 0.9 km more inland than Station 2. At both of these sites the bottom is predominatly silt deposited among luxuriant growths of eelgrass. Therefore, plant fragments constitute much of the coarse sand fraction.

Station 2 is situated on what may have been an oyster bed. At least the bottom materials contain comparatively large amounts of old shell. The shell fragments contribute markedly to the overall pattern at this station in addition to the plant materials.

Station 3 is the first open-bay sampling site on this transect. Since artificial maintenance (dredging) of the Forked River Channel starts at about Station 3, it is possible that the sedimentary composition is a direct result of dredging.

The one remaining position on the east-west transects that has considerably more than five percent of the bottom material in the coarse sand fraction is Transect III, Station 2. This site is about 0.6 km from the mouth of Oyster Creek on the ocean side. As with II-3, III-2 marks the beginning of a maintained passage into Oyster Creek. Based on similar locations, the same explanations may hold for III-2 that were proposed for II-3. The more valid explanation for the Oyster Creek site may be the disruption of the bottom by dredging. Numerous bottom samples taken randomly around position III-2 demonstrated marked change in substrate composition within short distances. Several hauls brought up only granules (4000-2000μ) and small pebbles (8000-4000μ).

From about the Intracoastal Waterway to the barrier island, the sediment composition shifts quite rapidly to a predominating fine sand. Most of the stations to the east of the waterway have at least 50 percent of the substrate contained within the 250-125μ class. Inspection of Figures 4, 5, 6, and 7 reveals that there appear to be two generalized families of curves. On the western side of the lagoon, using the Intracoastal Waterway as a north-south axis, the cumulative curves are fairly smooth, i.e., there are no rapid shifts in slope. This condition is contrasted with the eastern stations' curves which demonstrate a rather marked change in slope in the fine sand range.

The fine sands are apparently fairly well compacted. Routinely, more than four bottom grabs were necessary in the sandy areas to collect a large enough volume from which to sample. It was possible to "feel" the hardness (compactness) of the substrate from the surface using the grab.

Gross approximations of water content of the substrate were made in the laboratory prior to size analyses. The sandy areas consistently contained about 20-35 percent water weight as compared with water contents of about 50 percent in the siltier regions. Lower water contents of the sands may have contributed to the greater impenetrability by the dredge of these areas. Much of the eastern portion substrate is protected by extensive Zostera beds (Taylor, 1970). Certainly the dense rhizomes and root systems of this plant contribute to the compactness of the substrate and subsequently to the difficulty in obtaining full grab samples.

III. Organic Content

Since data concerning the organic content of the substrate were collected only during the 1969 season, this parameter will be treated rather briefly. Total organic matter was estimated in both laboratory techniques. Comparison of the results of the two methods and subsequent calculations appear in Table III.

There appears to be a decline in the amount of organic material as one moves from the mainland across the lagoon. The highest values consistently appear on the western margin, and there is a trend toward lower organic content moving toward the Oyster Creek Channel (in communication with Barnegat Inlet) from the most northern transect.

Table III. Total organic matter at specific stations, 1969. Percentage total organic carbon and percentage organic carbon (readily oxidizable) computed from wet oxidation figures. The total organic matter figures are the means of three determinations.

LOCATION	TOTAL ORGANIC MATTER Wet Oxid.	Ignition	% TOTAL ORGANIC C*	% ORGANIC C**
Station				
I-1	5.24	4.80	3.04	2.34
2	6.68	6.43	3.87	2.98
3	2.89	2.57	1.67	1.28
4	3.40	3.63	1.97	1.52
5	2.57	2.71	1.49	1.15
6	5.94	5.83	3.44	2.65
II-1	--	8.56	--	--
2	8.02	8.34	4.65	3.58
FRC+	4.15	4.02	2.41	1.85
FRC	3.83	3.76	2.22	1.71
3	3.25	3.38	1.88	1.45
4	3.45	5.58	3.23	2.49
5	3.73	2.75	2.16	1.66
6	2.68	2.89	1.55	1.19
7	3.13	3.84	1.81	1.39
8	--	--	--	--
9	3.25	1.61	1.88	1.45
III-1	7.45	7.60	4.32	3.32
OCC+	7.06	7.27	4.09	3.15
OCC	4.43	4.29	2.57	1.98
2	2.56	2.75	1.48	1.14
3	3.77	3.12	2.18	1.68
4	2.52	2.84	1.46	1.12
5	3.10	3.38	1.80	1.38
6	3.18	3.27	1.84	1.41
Bouy				
C1	4.98	6.85	2.89	2.22
D	3.83	4.24	2.22	1.71
D1	3.54	3.91	2.05	1.58
E	4.13	4.49	2.39	1.84
N66	3.99	4.21	2.31	1.78
E1	3.43	3.67	1.99	1.53
F	2.63	1.78	1.52	1.17
G	2.57	2.17	1.49	1.15
Light 1 South	2.52	1.40	1.46	1.12

* % total organic matter/1.724

** % organic C readily oxidizable = (% total organic C) · (0.77); Walkley, 1947

\+ these stations are situated between the original II-2 and II-3, and III-1 and III-2, respectively. They are samples from the dredged canals in the two tributaries.

SEDIMENTS - DISCUSSION

I. Particle Size Composition

The substrate of Barnegat Bay is most accurately described as being sandy. This is a fine-grained substrate with the lower three sand classes (Wentworth scale) predominating. Median grain size tends to decrease from the inlet area towards the mainland (Fig. 3). Abrupt changes in bottom composition occur at about the Intracoastal Waterway (Fig. 4, 5, and 6).

West of this transition zone the silt-clay fraction increases until it dominates within the creeks and at the mouths of these tributaries. This is probably a function of the materials being transported by the streams and settling with a decrease in current velocities. Flocculation may also be operating on colloidal materials. Eolian transport of sedimentary particles cannot be disregarded. Thoulet (1908), using quartz particles, found that a wind velocity of 3m $\cdot$ sec^{-1} was sufficient to transport particles with a diameter of 250μ. Silt particles of 40μ diameter were moved by a velocity of only 1m $\cdot$ sec^{-1}.

The deepest portion (3.3 m) of the area studied occurs just to the east of the Intracoastal Waterway. Observable quantities of silt-clay occur within this deep area. Precise characterization of this region is difficult because the substrate composition is variable within the central bay area. Random bottom grabs obtained about 10-15 m apart ranged from a semi-fluid material to a compacted, consolidated state. The latter material, when removed from the grab, retains the shape of the particular grab used. It is difficult to fractionate by hand washing.

The widest section of the Bay (about 5.0 - 5.5 km) encompasses the deep area mentioned above. Transect III almost marks the southern extent of the deep central portion. Cedar Creek, about 3.5 km above Transect I, marks the northern boundary of the deeper section. From these boundary points the Bay narrows, often considerably. Outside of this central area the remainder of the Bay is comparatively shallow. Depths of 1.8 m, or greater, are found only in maintained areas.

The depth in this central portion may be important in maintaining the silt-clay fraction at fair distances from their sources, i.e., the creeks. With the increased depths there is a lesser likelihood of wind-generated currents disturbing and transporting the finer materials. Depth dampening of surface currents may permit settling and expulsion of water from between the grains and consolidation. The result is a more dense substrate requiring greater velocities to transport the composite particles. Laboratory experiments (Postma, 1967) have shown that a 10 percent water decrease (from 90 to 80 percent) increases the erosion velocity from 19 $cm \cdot sec^{-1}$ to 48 $cm \cdot sec^{-1}$. As the substrate expels more water during consolidation, the current velocity necessary to transport it increases. Postma (1967) indicates that water movement from the consolidating sediment is irreversible in sands and clays. Clays (finer than 2μ) are relatively scarce in Barnegat Bay. The contribution of the clays is only about 2.5 to 4.5 percent by weight. The amount of sand, however, is considerable (see Appendix), so consolidation may be occurring in the deeper areas.

Another agency which may be operable in maintenance of the muddy, central depression is the settling lag and scouring lag (Luttmer, 1950) brought about by the asymmetrical distance-velocity characteristics of tides (Van Straaten and Kuenen, 1958).

Even though the central region can qualitatively be labeled as "muddy", the sand fractions are great enough to quantify the substrate as being either silty sand or sandy silt (Shepard, 1954). On the eastern side of the central depression, with decreasing depths, the sands totally dominate the composition of the substrate. It is within this segment of the study area that extensive sand flats and eel grass beds are found. The preponderance of sands in the shallow portions agrees with Emery's (1960) findings concerning depth of the water column and particle size sedimentation. Stickney and Stringer's (1957) description of Greenwich Bay, Rhode Island, seems similar to Barnegat Bay:

> ...central core of the bay is mud composed of principally silt sized particles with some clay and sand.

> Sand bottom occurs near the mouth of the bay where the water is somewhat shallower.

One apparent difference between the two bays is the amount of silt. The amounts of silt-sized material recorded from Barnegat Bay could not be described as the principal substrate component.

Agreement among or between the different years' data for the same station is generally good. As mentioned previously, much of the material greater than 500μ diameter is primarily non-sedimentary. Variation among the larger size (above 500μ) classes is more biological than sedimentary. There is no reason to expect precise agreement among the data since the sedimentary composition is in a dynamic equilibrium with numerous environmental parameters. Samples were always obtained in July and/or August, so this should have reduced seasonal variation (Stephens, Sheldon, and Parsons, 1967). Normal bottom variation from point to point probably accounts for much of the observable within station variation.

Materials with a sorting coefficient (S_o) less than 2.5 indicate well-sorted material (Trask, 1932). This parameter provides an index of how uniform the substrate particles are within the central 50 percent size range. Thus, two samples may have the same median grain diameter, but vastly different sorting coefficients. The sample in which the first and third quartile (Q_1 and Q_3 in the Appendix) values have a narrower range will have the lower S_o. The range of substrate particles will be smaller in a well-sorted area because the currents are relatively uniform and the currents maintain a more uniform family of particles. The more dissimilar the Q_1 and Q_3 values, the greater the S_o will be.

The only areas in the study region that have values greater than 2.5 are those within the creeks and around the mouths of the creeks. Progressing across the Bay from the mainland there is a general decrease in the sorting coefficient. Concomitant with this, there is an increase in the skewness (S_k) indicating larger percentages of the larger sediment particles (sands).

These distributional data are most likely the product of the current phenomena at the particular location and the nature of the substrate from where the dominating currents originate. The eastern region is closer to the Oyster Creek Channel and Barnegat Inlet, so sands introduced on the flood tide should settle out in this area as the currents diminish below transport velocity. Finer materials will be carried more westward until they too are no longer maintained in suspension. Inman (1949) has demonstrated that particles of 180μ (0.18 mm) are the most easily moved. As a result, particles of this size will be the best sorted. Referring to Figure 3, this is seen to be borne out. Hough (1940, 1942) and Sanders' (1958) data agree very well with Inman's findings. Harrison et. al. (1964) in Chesapeake Bay also seem to agree, although their values are computed differently. By converting Krumbein's (1936) phi scale to microns, there are six stations (nos. 18, 22, 26, 28, 42, and 53) in the Chesapeake study that have M_2 of about 180μ, but only one is described as being well sorted. Two others are moderately sorted, while the last three are very poorly sorted (terminology and computational technique for S_o, Folk and Ward, 1957).

On the mainland side, the creeks act as the main channels of deposition. Varying in size and drainage area, they collect a variety of terrigenous materials; and these are transported toward the Bay. Much of the western margin consists of marshland. The muds associated with marsh generally have a wide range in grain size and are more poorly sorted than sub-marine sands (Guilcher, 1963). Marsh runoff undoubtedly contributes to the larger amounts of fine materials (skews the particle composition to the fine particle end). The lower current velocities and sheltered reaches along much of the mainland side do not permit as effective a flushing mechanism as found in the open bay situation. These factors result in a more poorly sorted bottom material along the western side.

II. Organic Material

Increasing amounts of organic material with increasing amounts of silt-clay is expected. Trask (1932) demonstrated a similar condition for coastal situations. In the Thames Estuary (United Kingdom), the finer bottom types contained more organic carbon and nitrogen than the sandier areas

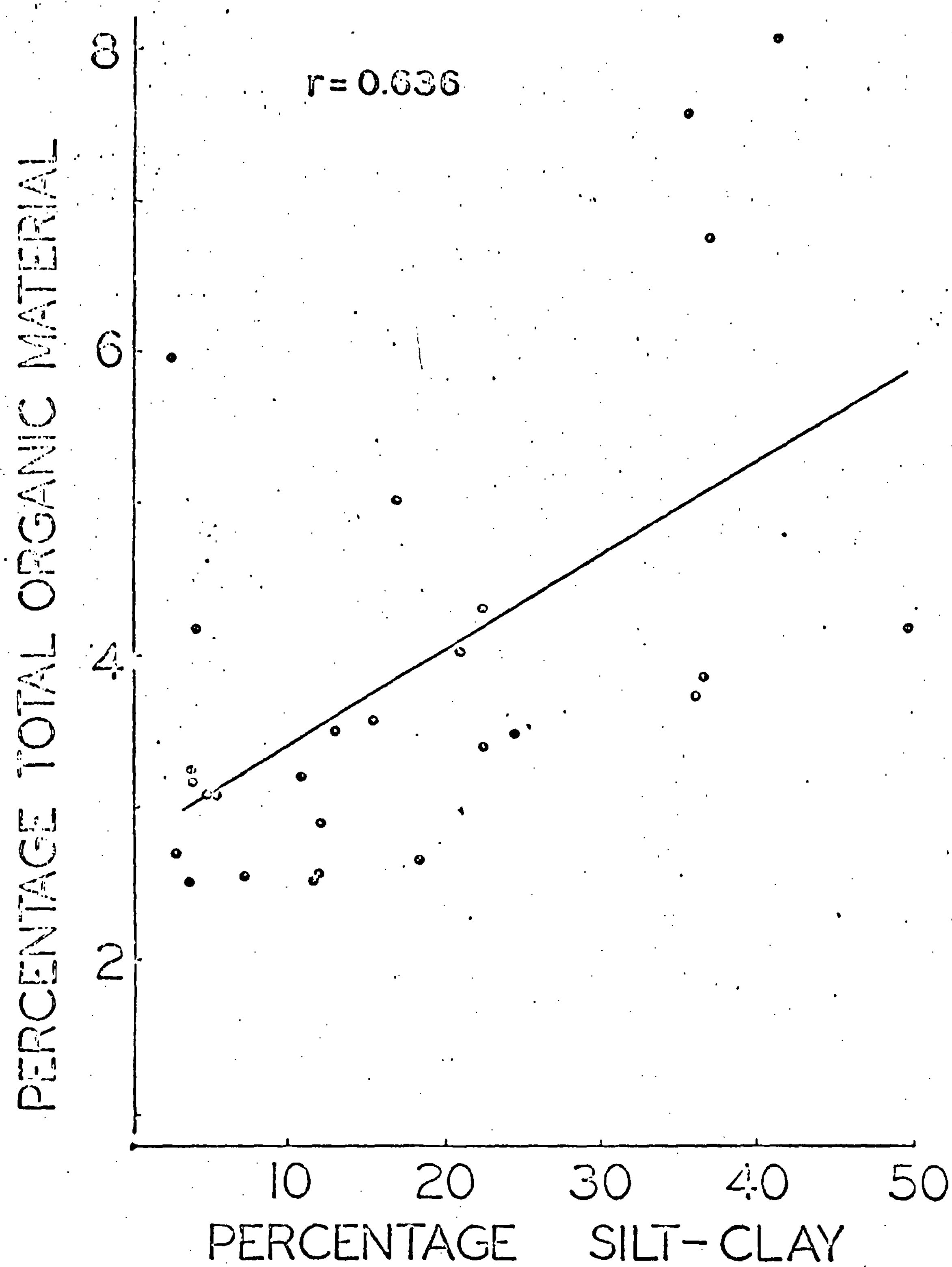
(Newell, 1965). Examination of Stickney and Stringer's data (1957) shows that the stations (nos. 1-7) described as silt or sandy silt have consistently greater organic contents than the sand stations (nos. 8-12). The data of Harrison et. al. (1964) show no consistent pattern between organic carbon content and substrate size composition. Certain sand stations contain as much or more organic carbon than clayey-silt stations.

The amount of organic material recorded in Barnegat Bay is comparable with the results of the studies previously credited. Although the correlation is not very high ($r = 0.636$) between the amount of organics and the percentage silt-clay fraction, the generalized tendency relating these parameters may be seen in Figure 8. The correlation coefficient in this instance is significant at the 0.001 probability level. The equation determined in regressing Y on X in this situation is $y = 2.82 + 0.06x$.

Proximity to the marshes probably plays an important role in organic content of the substrate. Vegetation and decomposition products could be washed into the Bay on the mainland side as a result of storm tide flushing and precipitation runoff. In this way the western margin has a greater immediate contributing source area for organic materials than does the more seaward portion of the Bay.

Other factors enter into the amount of organics present. Although no attempt in assaying bacterial populations was made, it is probable that the finer sediments

Figure 8. Relation between the amount of organic material and the percentage of silt-clay in the substrate.


r = 0.636
8
6
4
2
PERCENTAGE TOTAL ORGANIC MATERIAL
10
20
30
40
50
PERCENTAGE SILT-CLAY

contained greater bacterial concentrations than the sandier substrates (Zobell, 1938). In conjunction with the bacterial flora, availability of oxygen can affect the amount of organic material. Anaerobic situations coupled with inorganic sedimentation can maintain an organic material longer than an aerobic environment. Stations within and adjacent to the creeks generally had bottom materials premeated with the odor of H_2S. Redox potentials were not measured, but it is assumed that the blackened, sulfurous sediments were anaerobic. These stations typically had the highest organic content.

BENTHIC INVERTEBRATES - METHODS

I. Field

Quantitative estimation of the benthic invertebrate population was conducted using the bottom grabs described in the section on sediment methodology of this paper. The Petersen grab was used during 1966 and about halfway through 1967. The first use of the Ponar was 19 July, 1967. After this date the Ponar was the primary grab used. Both samplers were lowered and raised by a hand-operated winch.

The contents of an average of seven samples per station were pooled on board. These materials were then washed by hand through nested sorting screens. Large, immediately identifiable specimens were noted and returned to the Bay. All organisms larger than 1.5 mm (smallest screen aperture) were picked off the screens, preserved, and returned to the laboratory.

Occasionally, qualitative samples were obtained with a Caribbean type dredge (Crowell, Collier, and Macmillan, Inc.). This was towed along the bottom for a period averaging four minutes. Upon retrieval, the organisms were treated the same as in the quantitative section.

II. Laboratory

All organisms were identified to the lowest possible taxon. Various authorities were used. Among the major identification sources were Abbott (1954), Mills (1967), Pettibone (1963), and Smith (1964). Representative individuals of many of the species are stored as verification specimens in the Department of Zoology, Rutgers University.

The density of each species was calculated for the sample area and expressed as numbers of individuals per square meter. In addition to the species' densities, the species' diversities were also calculated for each quantitative sample, Two formulae were used in the diversity calculations: 1) Margalef's (1957) index $d = S-1/\ln N$ where S is the number of species encountered in the sample and N is the number of individuals; and 2) Shannon-Weaver (1949) Information function $H' = -\sum_{i=1}^{N} p_i \cdot \log p_i$ where H' is the information content and p_i is the proportion of the i th species in the community (1,2,3,...i).

BENTHIC INVERTEBRATES - RESULTS

Table IV. lists the invertebrates recorded during this study. This register includes epi- and infauna. All invertebrates captured by qualitative and/or quantitative methods have been listed. Generic and specific nomenclatures are based on the authorities used in initial identification. Table V. presents the organisms in taxonomic ranking.

The faunistic survey was conducted through the year. Frequency of collecting was greatest during the spring-to-fall seasons. This skewed temporal sampling pattern appears to be fairly routine in the middle-to-high temperate latitudes. Temporal distribution of the benthic invertebrates is presented in Table VI. This is a presence/absence listing; a species was or was not recorded from some area in the Bay during that month. No distinction is made as to whether a species was obtained quantitatively or qualitatively.

A condensed monthly register of invertebrates appears in Table VII. This table records the actual appearance of the fauna; no interpolations have been generated.

A concise presentation of the spatial distribution of the benthos can be generated only by reducing the resolution of the individual samples. Since no two of the 300 collected samples were identical, a complete picture of the spatial arrangement and densities of the invertebrates could be given only by a monotonous listing of the individual sample

Table IV. Benthic invertebrates recorded from Barnegat Bay, New Jersey. Collected during the period June 1965 - March 1969.

Aequipecten irradians (Lamarck)
Anathia sp.
Ampelisca macrocephala (Lilljebourg)
Amphitrite ornata (Leidy)
Anachis avara (Say)
Anadara ovalis (Bruguiere)
Asterias forbesi (Desor)
Balanus balanoides (Linnaeus)
Balanus improvisus (Darwin)
Bittium alternatum (Say)
Botryllus schlosseri (Pallas)
Bugula turrita (Desor)
Busycon canaliculatum (Linnaeus)
Callinectes sapidus (Rathbun)
Callipallene brevirostris (Johnson)
Cancer irroratus (Say)
Caprella geometrica (Say)
Caprella linearis (Linnaeus)
Carcinus maenas (Linnaeus)
Cerebratulus lacteus (Leidy)
Cerianthus americanus (Verrill)
Cirratulus grandis (Verrill)
Cliona celata (Grant)
Clymenella torquata (Leidy)
Crangon septemspinosus (Say)
Cratena pilata (Gould)
Crepidula convexa (Say)
Crepidula fornicata (Linnaeus)
Crepidula plana (Say)
Cyathura polita (Stimpson)
Diopatra cuprea (Bosc)
Drilonereis longa (Webster)
Edotea triloba (Say)
Ensis directus (Conrad)
Epitonium rupicola (Kurtz)
Erichsonella attenuata (Harger)
Erichsonella filiformis (Say)
Eupleura caudata (Say)
Eurypanopeus depressus (Smith)
Gammaridae
Gemma gemma (Totten)
Glycera dibranchiata (Ehlers)
Golfingia gouldi (Pourtales)
Grubia compta (Smith)
Halichondria bowerbanki (Burton)
Haloclava producta (Stimpson)
Haminoea solitaria (Say)
Harmothoe imbricata (Linnaeus)
Heteromysis formosa (S. I. Smith)
Hippolyte zostericolor (Smith)
Hydractinia echinata (Fleming)
Hydroides dianthus (Verrill)
Idotea baltica (Pallas)
Laevicardium mortoni (Conrad)
Lepidonotus squamatus (Linnaeus)
Leptosynapta inhaerens (O. F. Müller)
Libinia dubia (Milne Edwards)
Limulus polyphemus (Linnaeus)
Lumbrineris tenuis (Verrill)
Lyonsia hyalina (Conrad)
Macoma balthica (Linnaeus)
Macoma tenta (Say)

(Table IV, continued)

Marphysa sanguinea (Montagu)
Maldanopsis elongata (Verrill)
Membranipora sp.
Mercenaria mercenaria (Linnaeus)
Metridium senile (Linnaeus)
Microciona prolifera (Ellis & Solander)
Mitrella lunata (Say)
Molgula manhattensis (DeKay)
Mulinia lateralis (Say)
Mytilus edulis (Linnaeus)
Nassarius obsoletus (Say)
Nassarius trivittatus (Say)
Nassarius vibex (Say)
Neomysis americana (S. I. Smith)
Neopanope texana (Smith)
Nephtys incisa (Malmgren)
Nereis arenaceodonta (Moore)
Nereis pelagica (Linnaeus)
Nereis succinea (Frey & Leuckart)
Nereis virens (Sars)
Notomastus latericeus (Sars)
Nucula proxima (Say)
Oxyurostylis smithi (Calman)
Pagurus longicarpus (Say)
Palaemonetes vulgaris (Say)
Pectinaria gouldii (Verrill)
Pennaria tiarella (Ayres)
Petricola pholadiformis (Lamarck)
Pista cristata (O. F. Müller)
Pista palmata (Verrill)
Podarke obscura (Verrill)
Polinices duplicatus (Say)
Polycirrus eximius (Leidy)
Retusa canaliculata (Say)
Rhithropanopeus harrissi (Gould)
Sabella microphthalma (Verrill)
Sabellaria vulgaris (Verrill)
Scoloplos armiger (O. F. Müller)
Solemya velum (Say)
Sthenelais boa (Johnston)
Sthenelais limicola (Ehlers)
Tagelus divisus (Spengler)
Tellina agilis (Stimpson)
Tellina versicolor (DeKay)
Tubularia crocea (L. Agassiz)
Turbonilla sp.
Urosalpinx cinerea (Say)
Yoldia limatula (Say)

Table V. Taxonomic register of benthic invertebrates recorded from Barnegat Bay, New Jersey.

PHYLUM PORIFERA (3 spp.)
- Cliona celata
- Halichondria bowerbanki
- Microciona prolifera

PHYLUM CNIDARIA (7 spp.)
- Class Hydrozoa (4 spp.)
  - Amathia sp.
  - Hydractinia echinata
  - Pennaria tiarella
  - Tubularia crocea
- Class Anthozoa (3 spp.)
  - Cerianthus americanus
  - Haloclava producta
  - Metridium senile

PHYLUM NEMERTEA (1 sp.)
- Cerebratulus lacteus

PHYLUM MOLLUSCA (36 spp.)
- Class Gastropoda (18 spp.)
  - Anachis avara
  - Bittium alternatum
  - Busycon canaliculatum
  - Cratena pilata
  - Crepidula convexa
  - Crepidula fornicata
  - Crepidula plana
  - Epitonium rupicola
  - Eupleura caudata
  - Haminoea solitaria
  - Mitrella lunata
  - Nassarius obsoletus
  - Nassarius trivittatus
  - Nassarius vibex
  - Polinices duplicatus
  - Retusa canaliculata
  - Turbonilla sp.
  - Urosalpinx cinerea
- Class Bivalvia (18 spp.)
  - Aequipecten irradians
  - Anadara ovalis
  - Ensis directus
  - Gemma gemma
  - Laevicardium mortoni
  - Lyonsia hyalina
  - Macoma balthica
  - Macoma tenta
  - Mercenaria mercenaria
  - Mulinia lateralis
  - Mytilus edulis
  - Nucula proxima
  - Petricola pholadiformis
  - Solemya velum
  - Tagelus divisus
  - Tellina agilis
  - Tellina versicolor
  - Yoldia limatula

PHYLUM ANNELIDA (28 spp.)
- Class Polycaeta (28 spp.)
  - Amphitrite ornata
  - Cirratulus grandis
  - Clymenella torquata
  - Diopatra cuprea
  - Drilonereis longa
  - Glycera dibranchiata
  - Harmothoe imbricata
  - Hydroides dianthus
  - Lepidonotus squamatus
  - Lumbrineris tenuis
  - Maldanopsis elongata
  - Marphysa sanguinea
  - Nephtys incisa
  - Nereis arenaceodonta
  - Nereic pelagica
  - Nereis succinea
  - Nereis virens
  - Notomastus latericeus

(Table V. continued)

PHYLUM ANNELIDA, Class Polchaeta (continued)

Pectinaria gouldii	Sabella microphthalma
Pista cristata	Sabellaria vulgaris
Pista palmata	Scoloplos armiger
Podarke obscura	Sthenelais boa
Polycirrus eximius	Sthenelais limicola

PHYLUM SIPUNCULIDA (1 sp.)
Golfingia gouldi

PHYLUM ARTHROPODA (28 spp.)
Class Merostomata (1 sp.)
Limulus polyphemus
Class Pycnogonida (1 sp.)
Callipallene brevirostris
Class Crustacea (26 spp.)

Ampelisca macrocephala	Eurypanopeus depressus
Balanus balanoides	Gammaridae
Balanus improvisus	Grubia compta
Callinectes sapidus	Heteromysis formosa
Cancer irroratus	Hippolyte zostericolor
Caprella geometrica	Idotea baltica
Caprella linearis	Libinia dubia
Carcinus maenas	Neopanope texana
Crangon septemspinosus	Neomysis americana
Cyathura polita	Oxyurostylis smithi
Edotea triloba	Pagurus longicarpus
Erichsonella attenuata	Palaemonetes vulgaris
Erichsonella filiformis	Rhithropanopeus harrissi

PHYLUM ECTOPROCTA (2 spp.)

Bugula turrita	Membranipora sp.

PHYLUM ECHINODERMATA (2 spp.)
Class Asteroidea (1 sp.)
Asterias forbesi
Class Holothuroidea (1 sp.)
Leptosynapta inhaerens

PHYLUM CHORDATA
Subphylum Urochordata (2 spp.)

Botryllus schlosseri	Molgula manhattensis

Table VI. Temporal distribution of benthic invertebrates in Barnegat Bay, New Jersey.

SPECIES	1965						1966								1967								1968										1969	
	MAY	JUN	AUG	SEP	OCT	NOV	APR	MAY	JUN	AUG	SEP	OCT	NOV	DEC	FEB	MAR	APR	MAY	JUN	AUG	OCT	DEC	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	DEC	FEB	MAR
Aequipecten irradians		+	+															+			+													
Amathia sp.												+																						
Ampelisca macrocephala		+					+	+										+	+	+	+	+			+	+	+	+	+	+	+	+	+	
Amphitrite ornata									+																			+					+	
Anachis avara	+	+	+			+			+	+	+	+						+		+							+	+						
Anadara ovalis																				+				+		+								
Asterias forbesi	+	+	+			+	+	+	+	+	+	+	+	+			+	+	+	+	+	+		+	+	+	+	+	+	+	+		+	
Balanus balanoides						+																												
Balanus improvisus																					+	+	+	+			+							
Bittium alternatum	+	+	+	+	+	+	+	+	+	+	+	+				+		+	+	+						+	+	+	+			+	+	
Botryllus schlosseri		+						+	+							+	+	+				+	+	+		+	+	+			+	+		
Bugula turrita		+			+			+	+	+	+	+	+	+		+	+	+	+	+	+			+	+		+	+						
Busycon canaliculatum		+																									+							
Callinectes sapidus									+			+							+		+										+	+	+	+
Callipallene brevirostris								+														+					+							
Cancer irroratus																												+						
Caprella geometrica		+							+						+			+			+	+	+				+		+					
Caprella linearis	+	+	+		+																													
Carcinus maenas																						+												
Cerebratulus lacteus									+																		+							
Cerianthus americanus																			+	+	+						+							
Cirratulus grandis		+							+						+			+									+	+			+	+		+
Cliona celata	+							+			+	+	+	+				+	+							+	+	+					+	
Clymenella torquata		+	+	+					+		+	+			+			+	+	+	+	+				+	+	+	+	+	+	+	+	
Crangon septemspinosus	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Cratena pilata																						+					+							
Crepidula convexa		+	+		+		+	+	+			+						+	+	+	+	+			+		+	+	+	+				
Crepidula fornicata	+	+	+				+	+				+						+											+	+	+			

(Table VI. continued)

SPECIES	1965						1966								1967								1968										1969	
	JUN	JUL	AUG	SEP	OCT	NOV	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	FEB	MAR	MAY	JUN	JUL	AUG	OCT	DEC	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	DEC	FEB	MAR
Crepidula plana		+	+					+	+			+					+	+		+	+			+			+	+	+	+				
Cyathura polita	+	+	+	+	+		+	+	+	+	+	+	+		+	+		+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+
Diopatra cuprea	+							+		+		+			+	+		+	+	+	+	+		+		+	+	+	+	+	+	+	+	+
Drilonereis longa																															+			
Edotea triloba																									+		+							
Ensis directus	+	+					+	+	+	+	+	+						+	+	+	+				+	+	+	+	+	+	+	+		
Epitonium rupicola																			+											+	+		+	
Erichsonella attenuata			+					+	+	+		+				+		+				+				+	+		+		+	+	+	
Erichsonella filiformis	+	+	+			+	+	+	+	+	+					+	+	+	+	+	+	+			+	+	+	+	+		+		+	
Eupleura caudata	+	+			+		+	+	+	+	+	+					+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+
Eurypanopeus depressus		+						+			+	+						+	+	+	+			+	+	+	+							
Gammaridae	+	+														+	+	+	+			+	+	+	+		+	+						
Gemma gemma	+	+	+								+					+		+	+	+		+				+		+						
Glycera dibranchiata	+	+	+	+	+			+	+	+	+					+		+	+	+	+	+			+	+	+	+	+	+	+	+	+	+
Golfingia gouldi		+																									+	+			+		+	
Grubia compta									+		+	+				+	+	+	+	+	+	+				+	+	+	+	+	+			
Halichondria bowerbanki	+	+	+		+		+	+	+				+	+		+					+	+				+	+	+	+	+	+	+	+	
Haloclava producta																												+					+	
Haminoea solitaria																													+		+			
Harmothoe imbricata	+	+						+	+				+	+				+	+	+	+	+		+	+	+	+	+	+		+	+		
Heteromysis formosa		+							+		+	+							+	+											+			
Hippolyte zostericola									+		+	+	+	+				+	+	+	+	+	+					+		+				
Hydractinia echinata		+	+					+			+		+	+				+	+		+			+			+	+						
Hydroides dianthus		+	+					+	+	+	+	+							+		+	+		+	+	+	+	+		+	+		+	
Idotea baltica	+	+	+		+	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Laevicardium mortoni		+			+				+	+	+	+						+		+		+	+		+	+		+	+	+	+	+	+	
Lepidonotus squamatus																	+	+	+					+		+	+	+					+	
Leptosynapta inhaerens		+								+	+							+	+		+	+			+	+	+	+			+	+		+

(Table VI. continued)

SPECIES	1965						1966								1967								1968										1969	
	JUN	JUL	AUG	SEP	OCT	NOV	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	FEB	MAR	MAY	JUN	JUL	AUG	OCT	DEC	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	DEC	FEB	MAR
Libinia dubia									+		+							+															+	
Limulus polyphemus																		+																
Lumbrineris tenuis											+				+								+					+	+	+	+		+	
Lyonsia hyalina	+	+	+		+			+	+	+		+						+	+	+	+	+	+		+	+	+	+	+	+	+		+	
Macoma balthica		+																									+	+			+			
Macoma tenta									+			+							+								+						+	
Marphysa sanguinea																															+			
Maldanopsis elongata		+	+	+	+			+	+	+		+	+		+			+	+	+	+	+			+	+	+	+	+	+	+	+	+	+
Membranipora sp.		+	+					+	+			+					+		+	+	+	+		+	+	+	+	+	+				+	
Mercenaria mercenaria		+			+		+	+	+	+	+	+				+		+	+	+	+	+			+	+	+	+	+	+	+	+		
Metridium senile																														+	+			
Microciona prolifera								+				+						+	+							+				+	+		+	
Mitrella lunata	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Molgula manhattensis		+	+																	+	+	+	+	+	+	+	+	+	+	+	+	+		
Mulinia lateralis		+	+	+	+			+	+	+	+	+	+		+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	
Mytilus edulis		+						+	+							+	+	+	+	+	+			+	+	+	+	+						
Nassarius obsoletus	+	+	+		+			+	+			+			+			+			+	+	+	+			+	+			+	+		+
Nassarius trivittatus																																	+	
Nassarius vibex	+	+	+		+			+	+		+	+			+				+		+						+	+			+		+	
Neomysis americana																+						+	+	+	+									
Neopanope texana		+	+		+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+		+	+	+	+	+	+	+	+		+	
Nephtys incisa		+						+	+										+		+	+												
Nereis arenaceodentata	+	+	+					+											+															
Nereis pelagica	+	+	+					+	+	+	+		+					+	+	+	+					+	+	+	+		+			
Nereis succinea																								+			+	+		+	+	+	+	+
Nereis virens																													+	+	+			+
Notomastus latericeus		+				+		+	+		+	+						+	+	+	+	+			+	+	+	+	+		+		+	
Nucula proxima		+							+										+															

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(Table VI. continued)

SPECIES	1965 Jun	Jul	Aug	Sep	Oct	Nov
Oxyurostylis smithi						
Pagurus longicarpus	+	+	+			
Palaemonetes vulgaris	+	+	+			+
Pectinaria gouldii	+	+	+	+	+	+
Pennaria tiarella	+	+	+			+
Petricola pholadiformis		+				
Pista cristata						
Pista palmata						
Podarke obscura						
Polinices duplicatus						
Polycirrus eximius						
Retusa canaliculata	+	+	+		+	
Rhithropanopeus harrissi	+	+	+		+	
Sabella microphthalma			+			
Sabellaria vulgaris						
Scoloplos armiger						
Solemya velum	+	+				
Sthenelais boa						
Sthenelais limicola	+	+	+	+	+	
Tagelus divisus		+		+		
Tellina agilis	+	+	+	+	+	
Tellina versicolor	+	+		+		
Tubularia crocea						
Turbonilla sp.		+			+	
Urosalpinx cinerea	+	+				
Yoldia limatula						

SPECIES	1966 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oxyurostylis smithi								
Pagurus longicarpus	+	+	+	+	+	+	+	+
Palaemonetes vulgaris		+	+	+	+		+	+
Pectinaria gouldii		+	+	+	+	+	+	
Pennaria tiarella		+	+	+	+	+	+	
Petricola pholadiformis	+		+		+			
Pista cristata								
Pista palmata								
Podarke obscura								
Polinices duplicatus			+	+		+	+	+
Polycirrus eximius								
Retusa canaliculata		+	+		+			
Rhithropanopeus harrissi	+	+	+	+		+	+	
Sabella microphthalma			+					
Sabellaria vulgaris								
Scoloplos armiger			+					
Solemya velum			+	+	+	+	+	
Sthenelais boa			+			+		
Sthenelais limicola		+	+	+	+	+	+	
Tagelus divisus			+					
Tellina agilis	+	+	+	+	+	+	+	+
Tellina versicolor			+	+				
Tubularia crocea		+						
Turbonilla sp.		+	+		+	+	+	+
Urosalpinx cinerea		+	+		+	+		
Yoldia limatula								

SPECIES	1967 Feb	Mar	May	Jun	Jul	Aug	Oct	Dec
Oxyurostylis smithi								
Pagurus longicarpus		+		+	+	+		
Palaemonetes vulgaris	+	+	+	+	+	+	+	+
Pectinaria gouldii				+	+	+	+	+
Pennaria tiarella		+		+	+	+		
Petricola pholadiformis		+	+		+		+	
Pista cristata								+
Pista palmata								
Podarke obscura								
Polinices duplicatus						+		
Polycirrus eximius								
Retusa canaliculata		+		+	+	+	+	+
Rhithropanopeus harrissi	+		+	+	+	+	+	
Sabella microphthalma						+	+	
Sabellaria vulgaris								
Scoloplos armiger					+	+		+
Solemya velum		+	+	+	+	+	+	+
Sthenelais boa					+			+
Sthenelais limicola				+	+	+	+	+
Tagelus divisus								
Tellina agilis	+	+		+	+	+	+	+
Tellina versicolor				+				
Tubularia crocea								
Turbonilla sp.				+	+	+	+	
Urosalpinx cinerea		+	+	+	+	+		+
Yoldia limatula								

SPECIES	1968 Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec
Oxyurostylis smithi							+			
Pagurus longicarpus	+	+	+	+	+	+				
Palaemonetes vulgaris	+	+	+	+	+	+	+	+	+	+
Pectinaria gouldii	+	+	+	+	+	+	+	+	+	+
Pennaria tiarella					+					
Petricola pholadiformis						+	+			
Pista cristata					+	+	+	+	+	
Pista palmata								+	+	+
Podarke obscura								+	+	
Polinices duplicatus										
Polycirrus eximius										
Retusa canaliculata			+	+	+	+	+	+	+	+
Rhithropanopeus harrissi		+			+				+	+
Sabella microphthalma								+	+	
Sabellaria vulgaris								+	+	
Scoloplos armiger	+		+	+	+	+	+	+	+	+
Solemya velum		+	+	+	+	+	+	+	+	+
Sthenelais boa		+	+		+	+	+	+	+	
Sthenelais limicola			+	+	+	+	+			
Tagelus divisus										
Tellina agilis			+	+	+	+	+	+	+	+
Tellina versicolor			+	+	+				+	
Tubularia crocea										
Turbonilla sp.		+	+		+	+		+		
Urosalpinx cinerea					+	+	+		+	
Yoldia limatula						+				

SPECIES	1969 Feb	Mar
Oxyurostylis smithi		
Pagurus longicarpus		
Palaemonetes vulgaris	+	
Pectinaria gouldii	+	+
Pennaria tiarella		
Petricola pholadiformis		
Pista cristata		
Pista palmata		
Podarke obscura	+	
Polinices duplicatus		
Polycirrus eximius	+	
Retusa canaliculata	+	
Rhithropanopeus harrissi	+	
Sabella microphthalma	+	
Sabellaria vulgaris	+	
Scoloplos armiger	+	+
Solemya velum		+
Sthenelais boa		
Sthenelais limicola		
Tagelus divisus		
Tellina agilis	+	+
Tellina versicolor		
Tubularia crocea		
Turbonilla sp.	+	
Urosalpinx cinerea	+	
Yoldia limatula		

Table 10. Monthly occurrence of benthic invertebrates. The species are arranged in a decreasing order of number of months found during the calendar year.

Species	J	F	M	A	M	J	J	A	S	O	N	D
appeared during all twelve months												
Crangon septemspinosus	+	+	+	+	+	+	+	+	+	+	+	+
Cyathura polita	+	+	+	+	+	+	+	+	+	+	+	+
Idotea baltica	+	+	+	+	+	+	+	+	+	+	+	+
Mitrella lunata	+	+	+	+	+	+	+	+	+	+	+	+
Palaemonetes vulgaris	+	+	+	+	+	+	+	+	+	+	+	+
Pectinaria gouldii	+	+	+	+	+	+	+	+	+	+	+	+
appeared during eleven of the twelve months												
Asterias forbesi		+	+	+	+	+	+	+	+	+	+	+
Erichsonella filiformis		+	+	+	+	+	+	+	+	+	+	+
Halichondria bowerbanki		+	+	+	+	+	+	+	+	+	+	+
Laevicardium mortoni	+	+		+	+	+	+	+	+	+	+	+
Maldanopsis elongata		+	+	+	+	+	+	+	+	+	+	+
Mulinia lateralis		+	+	+	+	+	+	+	+	+	+	+
Neopanope texana		+	+	+	+	+	+	+	+	+	+	+
Pagurus longicarpus	+		+	+	+	+	+	+	+	+	+	+
Scoloplos armiger	+	+	+	+	+	+	+	+	+	+		+
Tellina agilis		+	+	+	+	+	+	+	+	+	+	+
appeared during ten of the twelve months												
Bugula turrita			+	+	+	+	+	+	+	+	+	+
Eupleura caudata		+	+	+	+	+	+	+	+	+		+
Glycera dibranchiata		+	+	+	+	+	+	+	+	+		+
Hydroides dianthus		+	+	+	+	+	+	+	+	+		+
Lyonsia hyalina	+	+		+	+	+	+	+	+	+		+
Molgula manhattensis	+		+	+	+	+	+	+	+	+		+
Notomastus latericeus		+		+	+	+	+	+	+	+	+	+
Retusa canaliculata		+	+	+	+	+	+	+	+	+		+
Solemya velum			+	+	+	+	+	+	+	+	+	+
Turbonilla sp.		+	+	+		+	+	+	+	+	+	+
appeared during nine of the twelve months												
Ampelisca macrocephala		+		+	+	+	+	+	+	+		+
Diopatra cuprea		+	+		+	+	+	+	+	+		+
Harmothoe imbricata			+	+	+	+	+	+		+	+	+
Leptosynapta inhaerens			+	+	+	+	+	+	+	+		+
Membranipora sp.		+	+	+	+	+	+	+		+		+
Mercenaria mercenaria			+	+	+	+	+	+	+	+		+
Sthenelais limicola				+	+	+	+	+	+	+	+	+
Urosalpinx cinerea		+	+		+	+	+	+	+	+		+

(Table VII. continued)

Species	J	F	M	A	M	J	J	A	S	O	N	D
appeared during eight of the twelve months												
Bittium alternatum		+			+	+	+	+	+	+		+
Cliona celata		+			+	+	+		+	+	+	+
Clymenella torquata		+			+	+	+	+	+	+		+
Crepidula convexa				+	+	+	+	+	+	+		+
Ensis directus				+	+	+	+	+	+	+		+
Eurypanopeus depressus			+	+	+	+	+	+	+	+		
Grubia compta			+		+	+	+	+	+	+		+
Hippolyte zostericolor	+					+	+	+	+	+	+	+
Hydractinia echinata			+			+	+	+	+	+	+	+
Nassarius obsoletus	+	+	+			+	+	+		+		+
Rhithropanopeus harrissi		+	+		+	+	+	+		+	+	
Sthenelais boa			+	+		+	+	+	+	+		+
appeared during seven of the twelve months												
Botryllus schlosseri	+		+		+	+	+			+		+
Caprella geometrica	+	+				+	+	+		+		+
Cirratulus grandis		+	+		+	+	+			+		+
Crepidula plana			+		+	+	+	+	+	+		
Erichsonella attenuata			+		+	+	+	+		+		+
Gammaridae	+		+	+	+	+	+					+
Gemma gemma			+		+	+	+	+	+			+
Mytilus edulis			+	+	+	+	+	+		+		
Nereis pelagica					+	+	+	+	+	+	+	
Nereis succinea		+	+			+	+		+	+		+
Pennaria tiarella			+			+	+	+	+	+	+	
Tellina versicolor				+	+	+	+	+	+	+		
appeared during six of the twelve months												
Anachis avara						+	+	+	+	+	+	
Crepidula fornicata					+	+	+	+	+	+		
Lumbrineris tenuis	+	+					+	+	+	+		
Microciona prolifera		+			+	+	+		+	+		
Nassarius vibex		+				+	+	+	+	+		
Petricola pholadiformis			+		+		+	+	+	+		
Pista cristata						+	+	+	+	+		+
appeared during five of the twelve months												
Balanus improvisus	+		+			+				+		+
Lepidonotus squamatus		+	+		+	+	+					
Polinices duplicatus							+	+		+	+	+
Sabella microphthalma		+					+	+	+	+		

(Table VII. continued)

Species	J	F	M	A	M	J	J	A	S	O	N	D
appeared during four of the twelve months												
Aequipecten irradians						+	+	+		+		
Callinectes sapidus		+	+				+			+		
Caprella linearis						+	+	+		+		
Cerianthus americanus						+	+	+		+		
Epitonium rupicola		+					+		+	+		
Golfingia gouldi		+				+	+			+		
Heteromysis formosa							+	+	+	+		
Libinia dubia		+				+	+		+			
Macoma tenta		+				+	+			+		
Nephtys incisa						+	+			+		+
Nereis virens			+					+	+	+		
appeared during three of the twelve months												
Anadara ovalis			+		+			+				
Callipallene brevirostris					+	+						+
Macoma balthica						+	+			+		
Neomysis americana		+		+	+							
Nereis arenaceodonta						+	+	+				
Pista palmata									+	+		+
Podarke obscura		+							+	+		
Sabellaria vulgaris		+							+	+		
appeared during two of the twelve months												
Amphitrite ornata		+					+					
Busycon canaliculatum						+	+					
Cerebratulus lacteus						+	+					
Cratena pilata						+						+
Edotea triloba				+		+						
Haloclava producta		+					+					
Haminoea solitaria								+		+		
Metridium senile									+	+		
Tagelus divisus							+			+		
appeared during one of the twelve months												
Amathia sp.										+		
Balanus balanoides											+	
Drilonereis longa										+		
Cancer irroratus							+					
Carcinus maenas												+
Limulus polyphemus						+						
Marphysa sanguinea										+		

(Table VII. continued)

Species	J	F	M	A	M	J	J	A	S	O	N	D
(one appearance, continued)												
Nassarius trivittatus		+										
Nucula proxima								+				
Oxyurostylis smithi								+				
Polycirrus eximius		+										
Tubularia crocea							+					
Yoldia limatula							+					

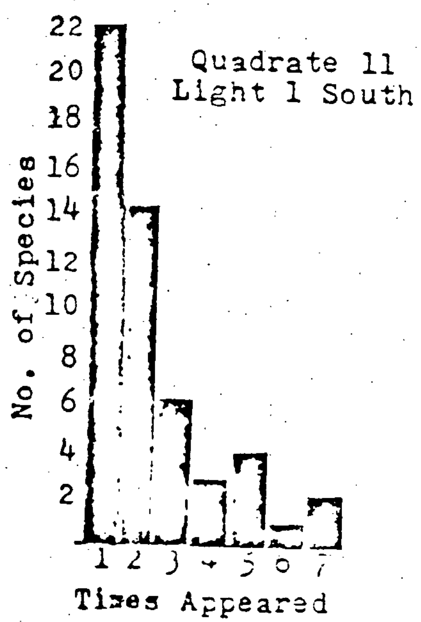
tabulations.

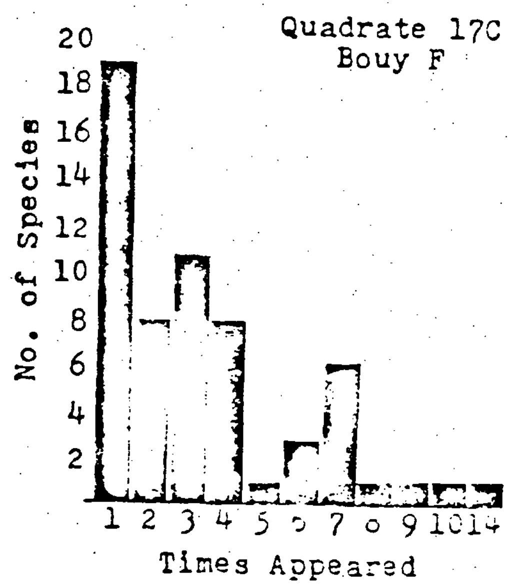
Pooling of all the data, estimation of grand means, standard deviations, L.S.D.'s, etc., would condense the volume of data, but it is the author's feeling that such treatment would be inappropriate in this study. Such statistical manipulations could mask the natural variability among different regions of the Bay and the infrequently encountered, or rare, organisms might be entirely deleted in such a gross treatment.

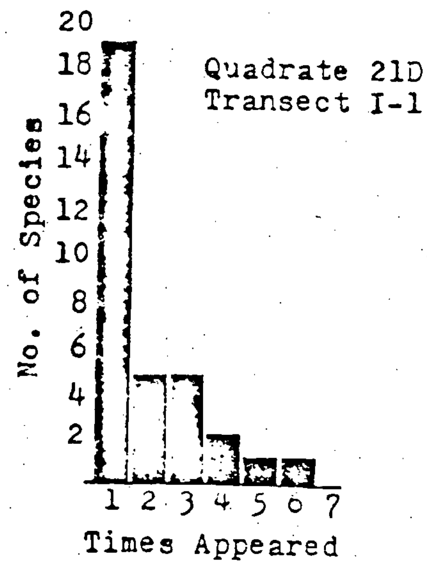
A compromise between a complete listing and a very condensed presentation has been attempted here. Tables VIII. and IX. present the spatial distribution of the benthos in a "patchwork" fashion. The positions listed correspond to the major sampling stations within the Bay. All of the collections made at a particular site have been pooled so the total volume of data is reduced somewhat. At the same time, all of the organisms that appeared at that site are listed, regardless of the frequency of their appearance, so the taxonomic composition is complete. Table VIII. presents total (qualitative and quantitative) appearance at a site, while Table IX. includes only quantitatively derived data. Graphical representation of these data appears in Figures 9 and 10 respectively. As may be seen from the data, there are many species which appeared infrequently. The small number of appearances of such organisms precludes significant statistical treatment of their numbers. For the quantitative samples, the most

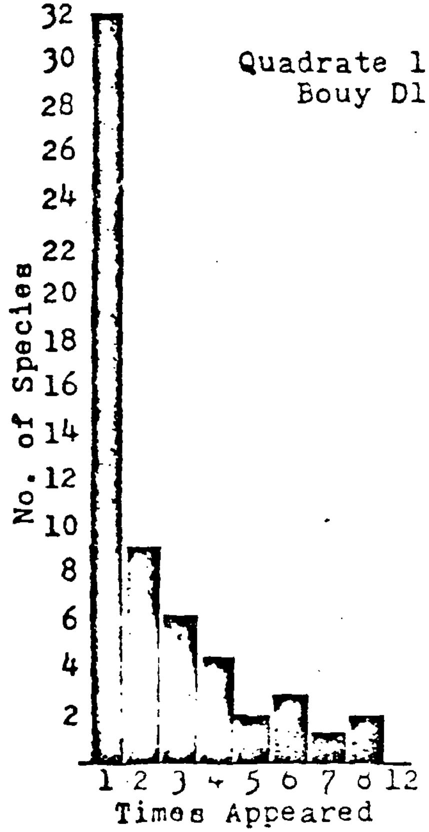
Figure 9. Total (qualitative and quantitative) number of invertebrate species and the frequency of their appearance at major stations in Barnegat Bay.

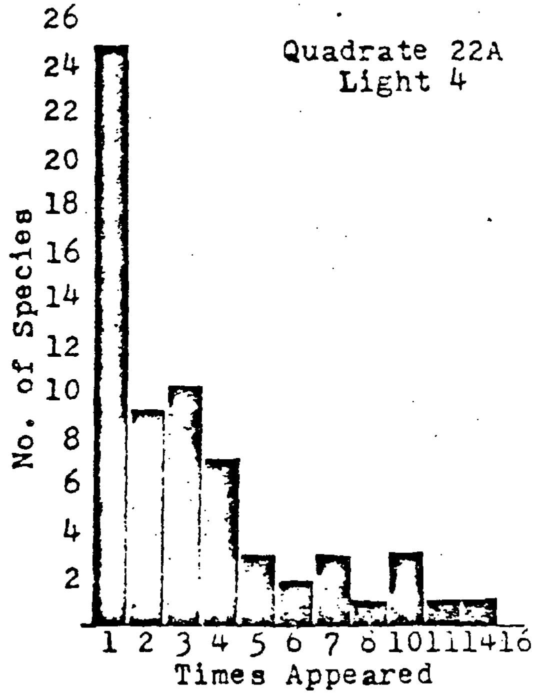
Figure 10. Number of invertebrate species recorded quantitatively and the frequency of their appearance at major stations in Barnegat Bay.

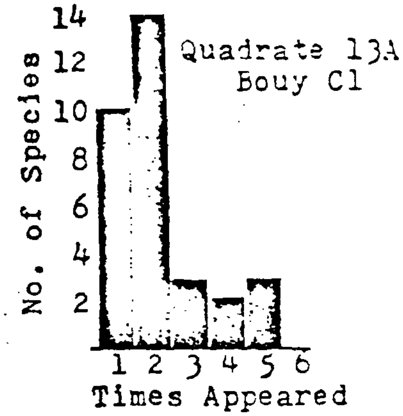

Quadrate 11
Light 1 South
No. of Species
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7
Times Appeared

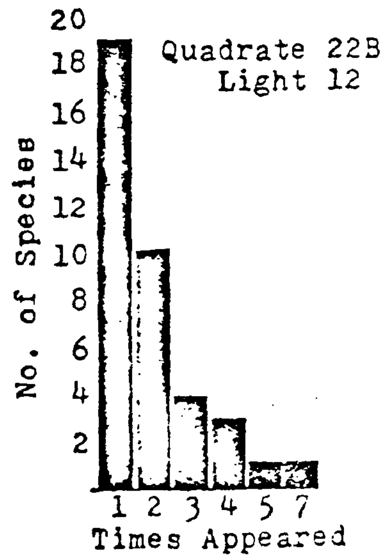

Quadrate 17C
Bouy F
No. of Species
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 9 10 14
Times Appeared

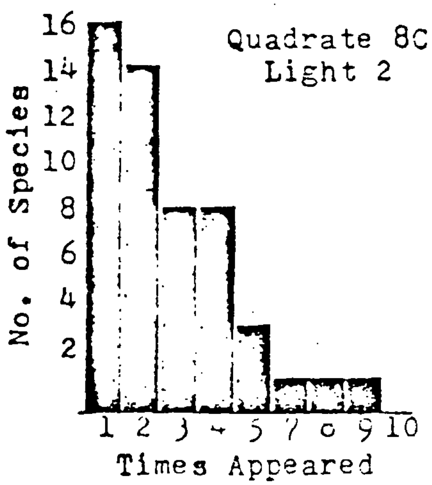

Quadrate 21D
Transect I-1
No. of Species
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7
Times Appeared

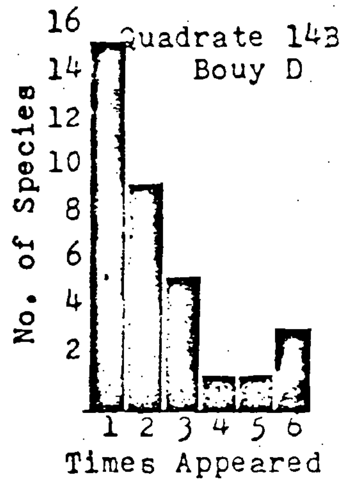

Quadrate 15C
Bouy D1
No. of Species
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 12
Times Appeared

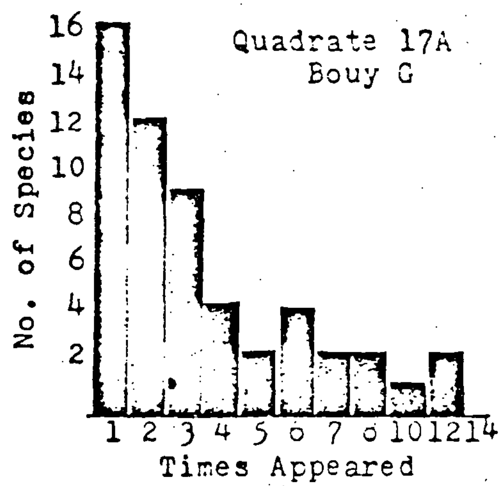

Quadrate 22A
Light 4
No. of Species
26
24
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 10 11 14 16
Times Appeared

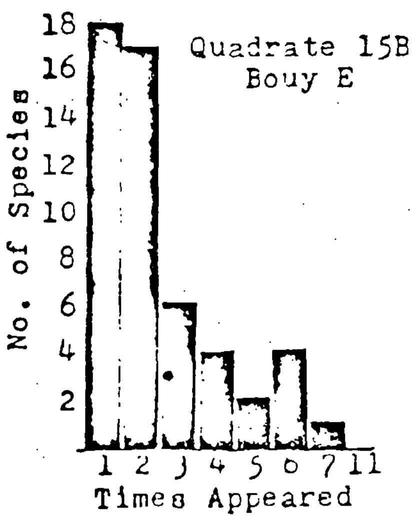

Quadrate 13A
Bouy C1
No. of Species
14
12
10
8
6
4
2
1 2 3 4 5 6
Times Appeared

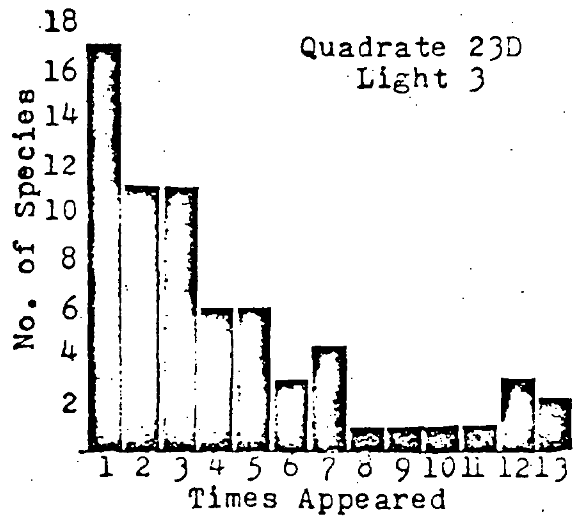

Quadrate 22B
Light 12
No. of Species
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 7
Times Appeared

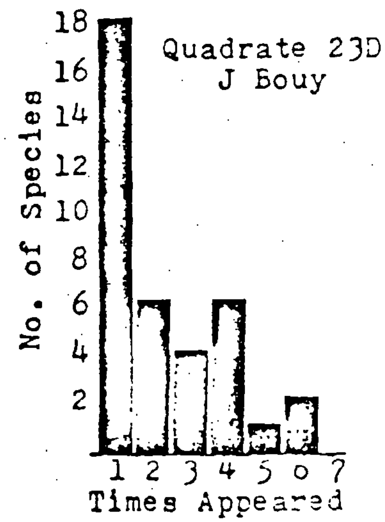

Quadrate 8C
Light 2
No. of Species
Times Appeared

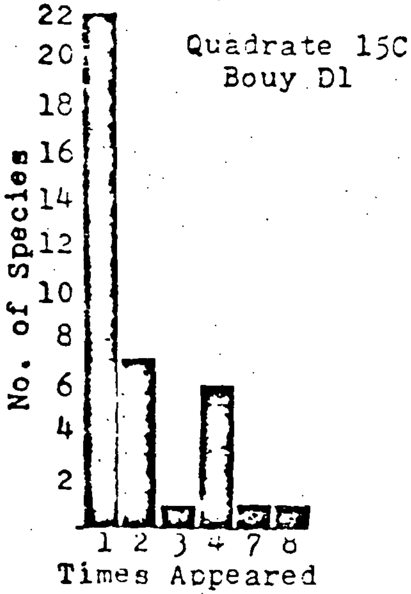

Quadrate 14B
Bouy D
No. of Species
Times Appeared

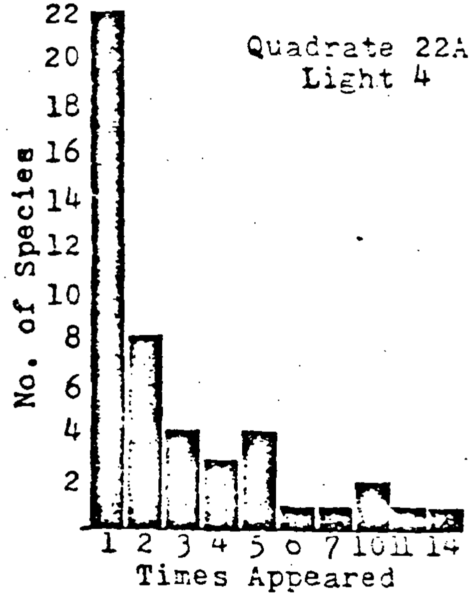

Quadrate 17A
Bouy G
No. of Species
Times Appeared

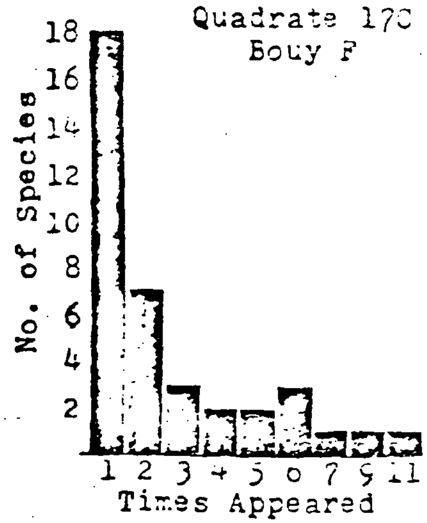

Quadrate 15B
Bouy E
No. of Species
Times Appeared

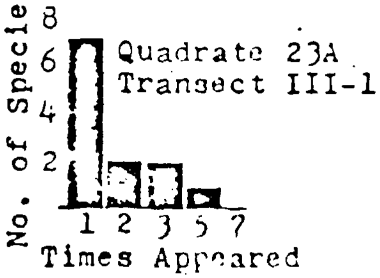

Quadrate 23D
Light 3
No. of Species
Times Appeared

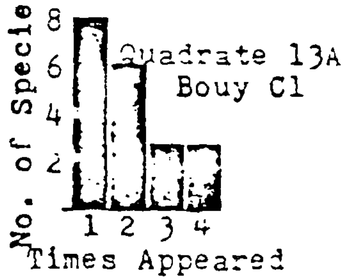

Quadrate 23D
J Bouy
No. of Species
Times Appeared

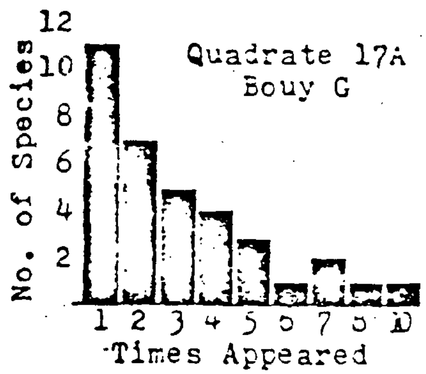

Quadrate 15C
Bouy D1
No. of Species
Times Appeared
1 2 3 4 7 8

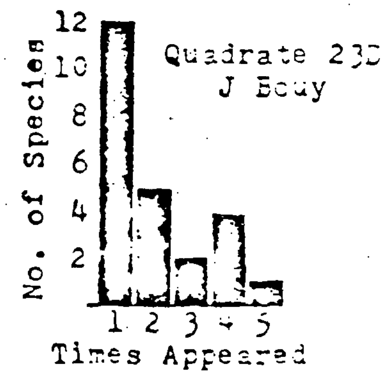

Quadrate 22A
Light 4
No. of Species
Times Appeared
1 2 3 4 5 6 7 10 11 14

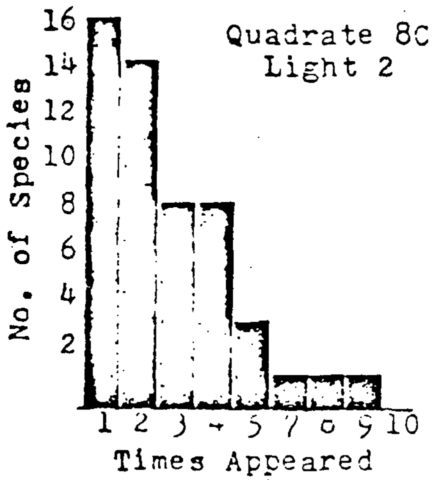

Quadrate 17C
Bouy F
No. of Species
Times Appeared
1 2 3 4 5 6 7 9 11

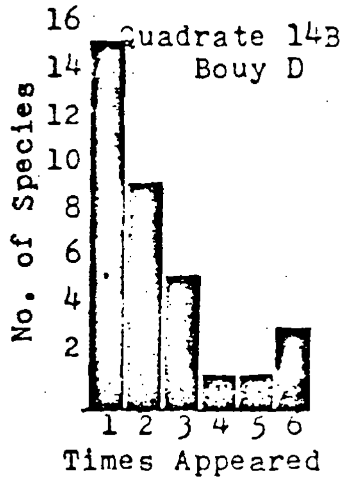

Quadrate 23A
Transect III-1
No. of Species
Times Appeared
1 2 3 5 7

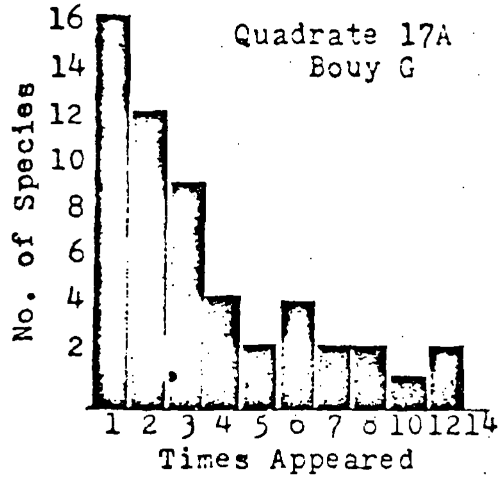

Quadrate 13A
Bouy C1
No. of Species
Times Appeared
1 2 3 4

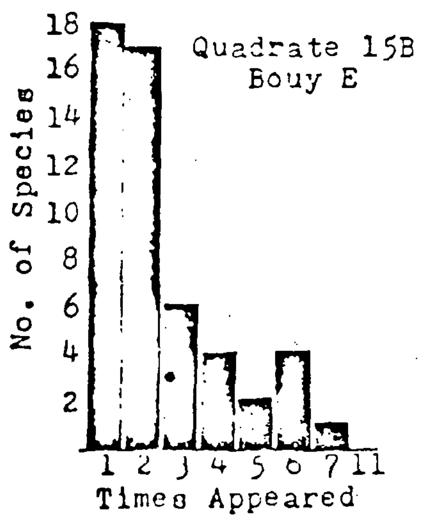

Quadrate 17A
Bouy G
No. of Species
Times Appeared

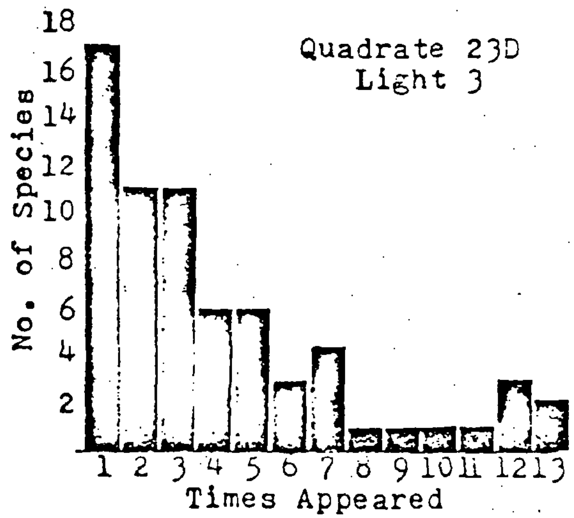

Quadrate 23D
J Bouy
No. of Species
Times Appeared
1 2 3 4 5

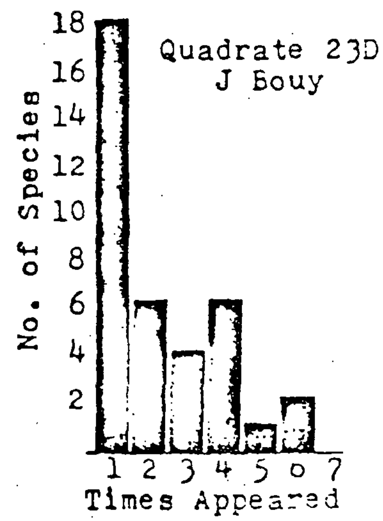

Quadrate 8C
Light 2
No. of Species
16 14 12 10 8 6 4 2
1 2 3 4 5 7 8 9 10
Times Appeared

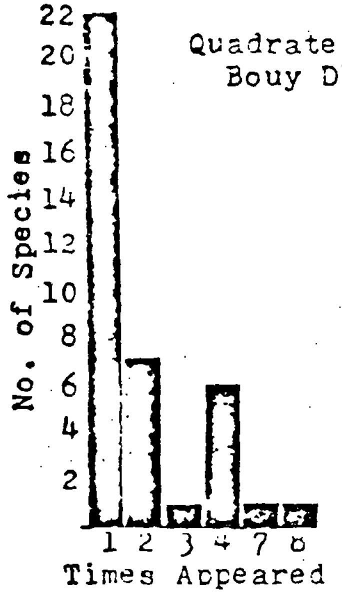

Quadrate 14B
Bouy D
No. of Species
16 14 12 10 8 6 4 2
1 2 3 4 5 6
Times Appeared

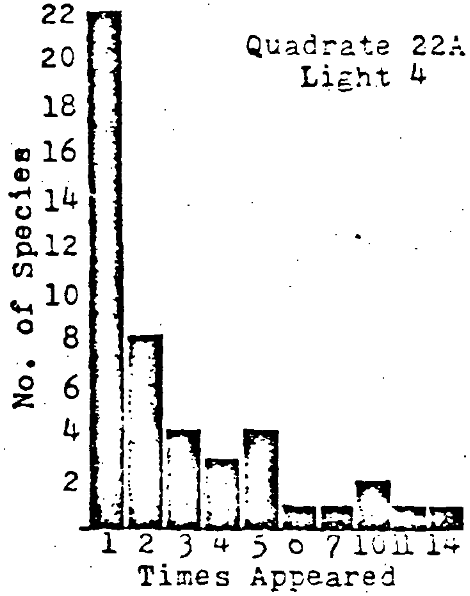

Quadrate 17A
Bouy G
No. of Species
16 14 12 10 8 6 4 2
1 2 3 4 5 6 7 8 10 12 14
Times Appeared

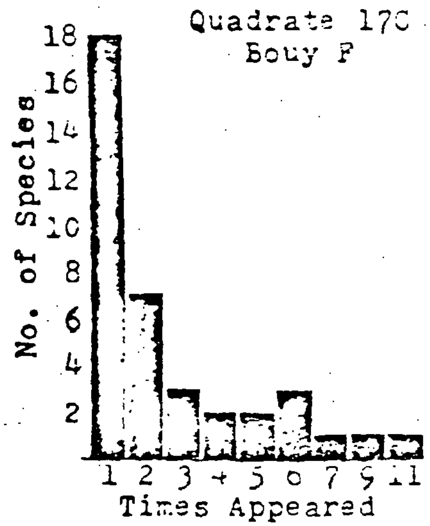

Quadrate 15B
Bouy E
No. of Species
18 16 14 12 10 8 6 4 2
1 2 3 4 5 6 7 11
Times Appeared

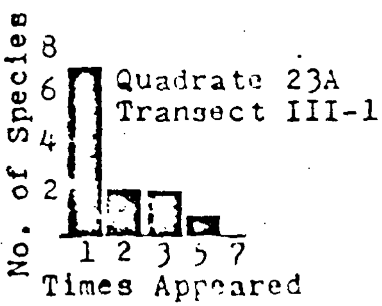

Quadrate 23D
Light 3
No. of Species
18 16 14 12 10 8 6 4 2
1 2 3 4 5 6 7 8 9 10 11 12 13
Times Appeared

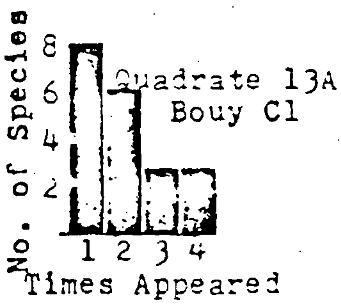

Quadrate 23D
J Bouy
No. of Species
18 16 14 12 10 8 6 4 2
1 2 3 4 5 6 7
Times Appeared

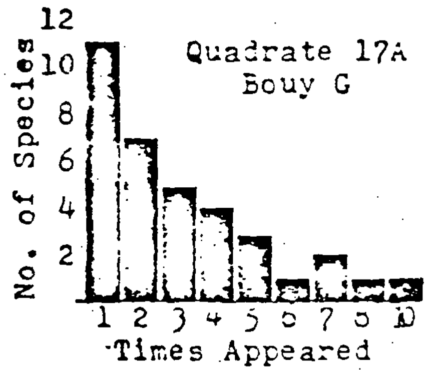

Quadrate 15C
Bouy D1
No. of Species
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 7 8
Times Appeared

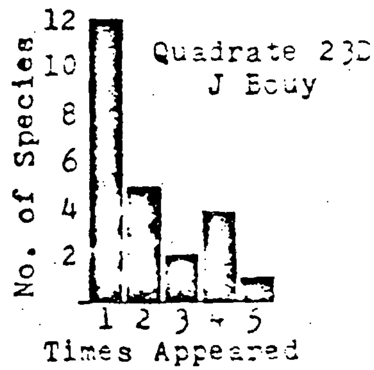

Quadrate 22A
Light 4
No. of Species
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 10 11 14
Times Appeared

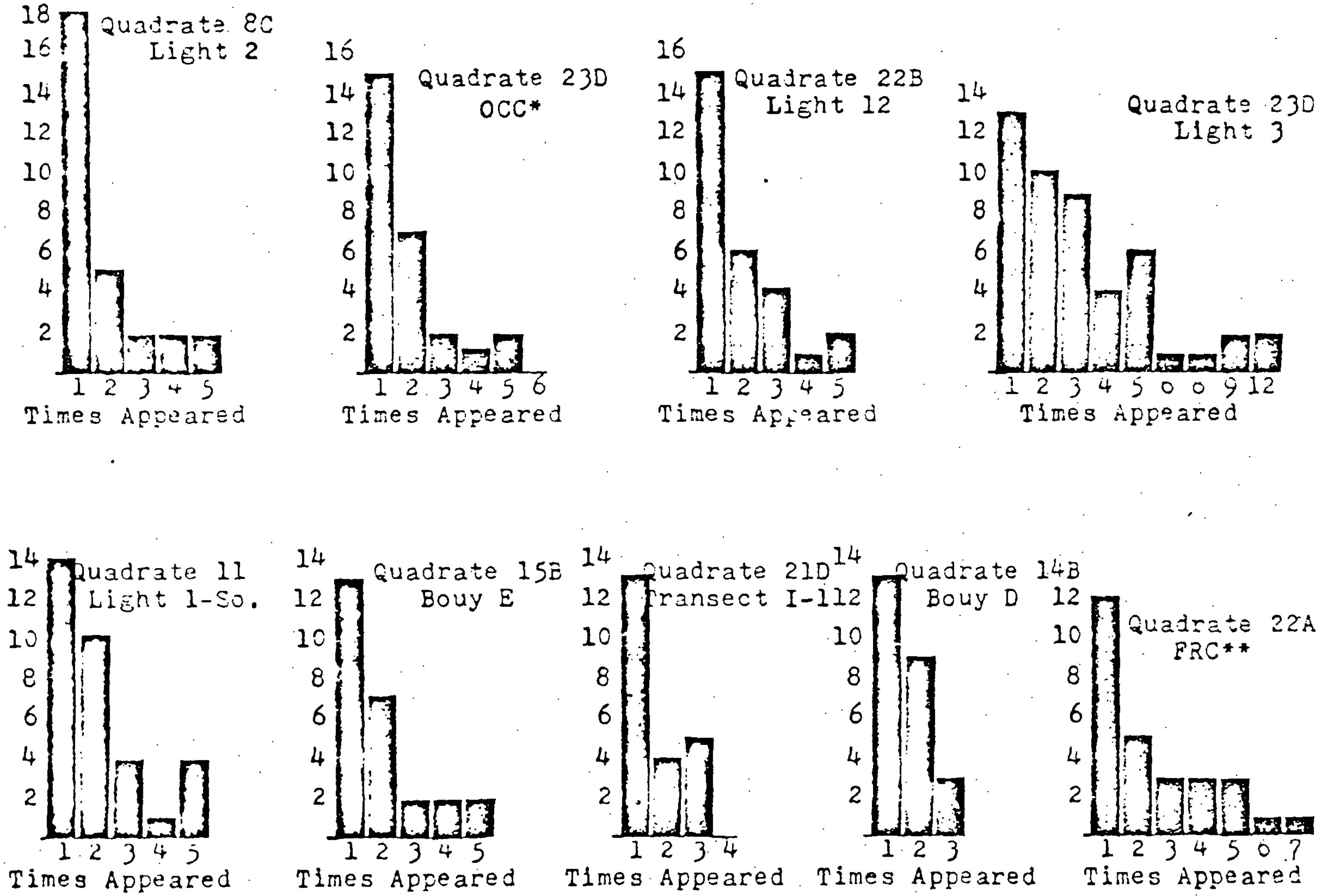

Quadrate 17C
Bouy F
No. of Species
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 9 11
Times Appeared


Quadrate 23A
Transect III-1
No. of Species
8
6
4
2
1 2 3 5 7
Times Appeared


Quadrate 13A
Bouy C1
No. of Species
8
6
4
2
1 2 3 4
Times Appeared


Quadrate 17A
Bouy G
No. of Species
12
10
8
6
4
2
1 2 3 4 5 6 7 8 10
Times Appeared


Quadrate 23D
J Bouy
No. of Species
12
10
8
6
4
2
1 2 3 4 5
Times Appeared



*Oyster Creek Channel
**Forked River Channel

Table VIII. Spatial distribution of benthic invertebrates in Barnegat Bay, New Jersey. Number of appearances are based on both qualitative and quantitative bases.

QUADRATE LOCATION No. SMPL. DATES	5C Lt. 2 10	11 Lt. 1-3. 7	13A Bouy C1 5	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23C J Bouy 7
Species						Number of Appearances							
Ampelisca macrocephala	1	2		1	1		7	10		5		4	4
Amphitrite ornata								1					
Anachis avara	2					1							
Anadara ovalis	1									1			
Asterias forbesi	1	1			4	1	2	6		3		9	
Balanus improvisus	3											1	
Bittium alternatum	2	3	1			2		4	2		1	2	2
Botryllus schlosseri	3				1		2				3	3	
Bugula turrita		1	1		3	3	2	1		3	2	3	3
Busycon canaliculatum				1						1			
Callinectes sapidus		1			2	1				1	1	2	
Callipallene brevirostris					1								
Cancer irroratus								3					

(Table VII. continued)

QUADRATE LOCATION NO. SMPL. DATES	8C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23D J Bouy [illegible]
Species						Number of Appearances							
Caprella geometrica	3											2	
Carcinus maenas	1												
Cerebratulus lacteus												1	
Cerianthus americanus			2		1								
Cirratulus grandis				1					1	1	5		
Cliona celata		3			1	1	1			1	1	1	2
Clymenella torquata	1	3	3	2	5	5	2	6	1	6	1	5	
Crangon septemspinosus	8	7	2	1	6	3	8	9	1	11	2	13	4
Cratena pilata							1					1	
Crepidula convexa	4					1	1	3				3	
Crepidula fornicata							2	1				1	
Crepidula plana	1						1	1				1	
Cyathura polita	2	2	5	6	5	6	8	5	3	10	4	5	4
Diopatra cuprea		1	5	2	7	6	2	3	1	4	1	7	2
Drilonereis longa					1	2				2	1	1	

(Table VIII. continued)

QUADRATE LOCATION NO. SMPL. DATES	8C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23D J Bouy 7
Species						Number of Appearances							
Edotea triloba								2					
Ensis directus	2	3	2	1	2	1	3	2	1	4		3	2
Epitonium rupicola		1				1				1		1	
Erichsonella attenuata	2	2			1	1	2	2		2	1	2	
Erichsonella filiformis	2	4			2		6	2		4	1	5	
Eupleura caudata		1	2	1	2	3	2	7	4	7	3	12	6
Eurypanopeus depressus	1	2	1	2	2	1	1	4		1		2	1
Gammaridae	3	1					1	4				2	
Gemma gemma	1	1								1			
Glycera dibranchiata	2	1	2	5	2	7	5	7	4	7	2	3	
Golfingia gouldi				1	1	1					2		
Grubia compta	1	2			2	1	4	4		3		6	1
Halichondria bowerbanki		1				1	3		1	4		1	1
Haloclava producta		1				1	1						

(Table VIII continued)

QUADRATE LOCATION NO. SMPL. DATES	6C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23D J Bouy 7
Species						Number of Appearances							
Haminoea solitaria		1											
Harmothoe imbricata	2		1	2	2	3	5	2	1	2	2	7	1
Heteromysis formosa		2			1			2		1			
Hippolyte zostericolor	2	3			2	1	3			1		3	1
Hydractinia echinata	1	1					1	3		1			
Hydroides dianthus	3	2			2	2		1		4	2	3	1
Idotea baltica	9	5	1	1	2	3	3	7	1	5	1	10	3
Laevicardium mortoni	3	2				1	1	1		5		3	1
Lepidonotus squamatus	3	1	1			1	1	2				1	
Leptosynapta inhaerens	1					1		1	1	2		2	
Lumbrineris tenuis	4					1				2			
Lyonsia hyalina	5	2	2	4	2	5	4	3	3	1		4	[illegible]

(Table VII. continued)

QUADRATE LOCATION NO. SMPL. DATES	8C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 12	22B Lt. 12 7	23D Lt. 3 7	[illegible] J Bouy [illegible]
Species						Number of Appearances							
Macoma tenta			2	1	1	1							
Marphysa sanguinea						1				1			
Maldanopsis elongata	1		3	3	4	2	2	1	3	3		2	
Membranipora sp.					2	1	3	1	1	3	1	4	1
Mercenaria mercenaria	2	2		2	1	1	6	1	1	7	2	5	5
Metridium senile					1					1		1	1
Microciona prolifera		4			1					1		1	
Mitrella lunata	7	5	2	1	3	4	10	5	1	8	1	13	5
Molgula manhattensis	4					1	3	1		4	1	6	2
Mulinia lateralis	4	1	4	1	4	4	12	8	6	10	1	11	4
Mytilus edulis				1	1	1	2	3		1		7	1
Nassarius obsoletus	4					1		1	3	1	7		
Nassarius trivittatus						1							
Nassarius vibex									2		2		1

(Table VIII. continued)

QUADRATE LOCATION NO. SMPL. DATES	8C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23D J Bouy 7
Species						Number of Appearances							
Neomysis americana	1	1					1			2			
Neopanope texana	5	7	2	3	6	4	6	7	3	6	3	8	4
Nephtys incisa	1											2	
Nereis arenaceodonta		1											
Nereis pelagica	2	4	2	3	1		2	2		3	2	6	1
Nereis succinea	2					1	1			3	3	1	1
Nereis virens								1		1			
Notomastus latericeus		1	2	2	3	6	4	3		3		5	
Nucula proxima								1					
Oxyurostylis smithi						1				1		2	
Pagurus longicarpus	3	2			2	2	1	7		1		1	
Palaemonetes vulgaris	4	2	1		3	2	3	4	1	3	1	7	3
Pectinaria gouldii	4	2	5	6	6	8	7	7	5	10	4	12	4
Pennaria tiarella		1	1	2	2	2	1	3		1	1	3	2

(Table VIII. continued)

QUADRATE LOCATION NO. SMPL. DATES	5C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	15C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 16	22B Lt. 12 7	23D Lt. 3 7	23D J Bouy 7
Species						Number of Appearances							
Petricola pholadiformis		1	1		1			3				1	
Pista cristata								1					
Pista palmata												1	
Polinices duplicatus								1					
Polycirrus eximius				1						1			
Retusa canaliculata	2	2	2	2	2	3	4	4	2	3		3	
Rhithropanopeus harrissi		1	2	3	3		3	1		1	4	4	1
Sabella microphthalma					1	1					1	1	
Scoloplos armiger	2	5			1	1	3	4	1	4	1	3	1
Solemya velum	4	5	1	2	3	2	6	6	1	2		5	
Sthenelais boa			2	1		1			1	2	2	2	
Sthenelais limicola	1	3		1	2	2	2	1	2	1		4	
Tagelus divisus									1				
Tellina agilis	5	6	3	3	4	5	12	1-	2	1-	1	12	6

(Table VIII. continued)

QUADRATE LOCATION NO. SMPL. DATES	8C Lt. 2 10	11 Lt. 1-S. 7	13A Bouy C1 6	14B Bouy D 6	15B Bouy E 11	16C Bouy D1 12	17A Bouy G 14	17C Bouy F 14	21D Trans. I-1 7	22A Lt. 4 10	22B Lt. 12 7	23D Lt. 3 7	25D J Bouy 7
Species						Number of Appearances							
Tellina versicolor		1					1	3	1				
Tubularia crocea										1			
Turbonilla sp.			4	6	6	4	1	1	1	2			1
Urosalpinx cinerea	1							4			1	4	1
Yoldia limatula						1							

Table IX. Spatial distribution of benthic invertebrates in Barnegat Bay, New Jersey. Number of appearances are based on quantitative data.

N.S.D.:Number Sampling Dates L:Light B:Buoy T:Transect FRC:Forked River Channel OCC:Oyster Creek Channel

QUADRATE LOCATION N.S.D.	8C L 2 5	11 L 1-3	13A B 21 4	14B B D	15B B E	15C B D1	17A B G 10	17C B F 11	21D T 1-1 4	22A L 4 14	22A FRC	22B L 12	24A T III-1	25D J B 5	25D L 12	25D OCC
Species							Number of Appearances									
Ampelisca macrocephala	1	1		1			5	[illegible]		5	1			4	4	1
Amphitrite ornata								1					1			
Anadara ovalis										1						
Asterias forbesi										1					[illegible]	
Balanus improvisus															1	
Bittium alternatum	1	1					2								1	
Botryllus schlosseri												3				
Bugula turrita			1			1				1		1			2	
Busycon canaliculatum				1						1						
Callinectes sapidus										1		1			2	1
Cancer irroratus								2								

(Table IX. continued)

QUADRATE LOCATION N.S.D.	8C L 2 5	11 L 1-S 5	13A B C1 4	14B B D 3	15B B E 5	15C B D1 8	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23D J B 5	23D L 3 12	23D OCC 6
Species	Number of Appearances															
Cerebratulus lacteus											1				1	
Ceriantheus americanus			2		1											
Cirratulus grandis									1	1	1	5				
Cliona celata						1										
Clymenella torquata		3	3	2	5	4	2	6		6	5				5	[illegible]
Crangon septemspinosus	1	5		1		1	3	4	1	5	1	2		1	8	1
Crepidula convexa	1															
Crepidula plana							1									
Cyathura polita	1	2	4	3	4	4	7	5	2	10	5	4	2	4	5	4
Diopatra cuprea		1	4	2	5	4	2	1	1	4	3				4	
Drilonereis longa					1	2				2		1			1	1

(Table IX. continued)

QUADRATE LOCATION N.S.D.	5C L 2 5	11 L 1-S 5	13A B C1 7 4	14B B D 3	15B B E 7	15C B D1 8	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23D J B 5	23D L 3 12	23D CCC 6
Species							Number of Appearances									
Ensis directus	2	3	1	1	1	1	2	2	1	4	1			2	3	
Epitonium rupicola		1								1						
Erichsonella attenuata										2		1	1			
Erichsonella filiformis		2					3	1		1						1
Eupleura caudata					1	3		3	3	3		2		4	6	2
Eurypanopeus depressus		1		1			1	1							2	
Gammaridae	1														1	
Gemma gemma		1														
Glycera dibranchiata	1	1	2	3	2	7	5	5	3	7	5	1	3		3	2
Golfingia gouldi				1	1	1					2	2				
Grubia compta							1							1	3	1
Halichondria bowerbanki							1		1	2				1		

(Table X. continued)

QUADRATE LOCATION N.C.D.	[illegible] L [illegible]	11 L 1-3	1?A B ?1	1-? B ?	1?B B ?	1?? B ?1	1?A B ?	1?? B ?	[illegible]	?A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Species																
Halosclava producta		1				1	1									
Haminoea solitaria		1														
Harmothoe imbricata	1			1		2	2	1			2	1			3	1
Heteromysis formosa								1		1						
Hippolyte zostericola		2					1									
Hydroides dianthus	1	1			2	1				1		1				
Idotea baltica	5	3					3	2		1				1	[illegible]	2
Laevicardium mortoni	1	2				1		1		[illegible]				1	2	1
Lepidonotus squamatus											1				1	
Leptosynapta inhaerens	1							1	1	2	[illegible]				2	
Lumbrineris tenuis	2					1				2	2					1

(Table X. continued)

QUADRATE LOCATION N.S.D.	8C L 2 5	11 L 1-S 5	13A B C1 4	14B B D 3	15B B E 5	15C B D1 8	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23C J B 5	23D L 3 12	23D OCC 6
Species							Number of Appearances									
Lyonsia hyalina	2	2	1	2	1	2	3	1	2	1	1			2	3	
Macoma tenta			2	1	1	1							1			
Marphysa sanguinea						1										
Maldanopsis elongata	1		3	2	3	1	2	1	3	3	7					
Membranipora sp.							1								1	
Mercenaria mercenaria	2	2					4	1	1	5		2		3	4	3
Metridium senile					1					1				1	1	
Mitrella lunata	3	2				1	5	1						2	9	1
Molgula manhattensis						1	1					1		1	1	
Mulinia lateralis	4		3	1	2	4	6	7	3	11	4		3	3	9	1
Mytilus edulis				1		1		2						1	4	

(Table X. continued)

QUADRATE LOCATION N.S.D.	8C L 2 5	11 L 1-S 5	13A B C1 4	14B B D 3	15B B E 5	15C B D1 6	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23D J B 5	23D L 3 12	23D OCC 6
Species							Number of Appearances									
Nassarius obsoletus								1	2	1		5	5			5
Nassarius trivittatus						1										
Nassarius vibex									1		1	2				1
Neomysis americana		1					1			1						
Neopanope texana	3	4	1		1		4	2		1		1	1	1	5	
Nephtys incisa															2	
Nereis pelagica	1	2	1	1						1		1		1		1
Nereis succinea	1					1				2	2	3		1	1	2
Nereis virens										1						
Notomastus latericeus		1	2	2	3	4	4	3		3	3				5	1
Nucula proxima								1								
Oxyurostylis smithi						1				1						

(Table IX. continued)

QUADRATE LOCATION N.S.D.	8C L 2 5	11 L 1-S 5	13A B C1 4	14B B D 3	15B B E 5	15C B D1 8	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23D J B 5	23D L 3 12	23D OCC 6
Species								Number of Appearances								
Palaemonetes vulgaris	1							1	1	1				2	2	
Pectinaria gouldii	4	2	4	3	4	4	7	6	3	10	6	3	1	4	12	5
Pennaria tiarella												1				
Petricola pholadiformis		1	1		1			2							1	
Pista cristata								1								
Pista palmata															1	
Polinices duplicatus								1								
Retusa canaliculata	1	2		1	2	2	4	3	2	3	1				3	
Rhithropanopeus harrissi				2								3		1	3	
Sabella micropthalma					1	1						1			1	
Sabellaria vulgaris											1					

(Table X. continued)

QUADRATE LOCATION N.S.D.	5C L 2 5	11 L 1-3 5	13A B C1 4	14B B D 3	15B B E 5	15C B D1 8	17A B G 10	17C B F 11	21D T I-1 4	22A L 4 14	22A FRC 7	22B L 12 5	23A T III-1 7	23D J B 5	23C L 3 12	23D CCC 6
Species								Number of Appearances								
Scoloplos armiger	1	5			1	1	3	4	1	4	4	1	2	2	3	3
Solemya velum	2	5	1	2	2	2	6	6	1	2	1				5	2
Sthenelais boa			2	1		1			1	2	2	2	1		2	
Sthenelais limicola	1	3			1	2	2	1		1					3	1
Tellina agilis	5	5	2	2	2	8	10	11		14	3	1	1	5	12	2
Tellina versicolor		1					1	2								
Tubularia crocea										1						
Turbonilla sp.			1	2	2	2	1		1		1					
Urosalpinx cinerea												1			2	
Yoldia limatula						1										

frequently appearing organisms are listed with their observed density (number/meter^2) ranges and an average density value in the Appendix, Table II.

The results of the quantitative data manipulation in estimating the species diversity using the Margalef (1957) formula and the Information Theory are given in Table X.

Table X. Calculated species diversity indices of locations in Barnegat Bay, New Jersey.

M: Margalef I: Information

LOCATION	QUADRATE	INDEX	RANGE	NO. SAMPLES	MEAN	STD. DEV.
Bouy C1	13B	M	1.18-2.71	9	1.99	0.62
		I	2.20-3.42		2.89	0.51
Bouy D1	15C	M	1.50-2.21	14	1.72	0.26
		I	1.23-2.83		2.23	0.80
Bouy E	15B	M	0.80-2.61	10	1.41	0.78
		I	1.71-2.87		2.28	0.56
Bouy F	17C	M	0.33-2.44	19	1.56	0.55
		I	0.71-2.50		1.58	0.54
Bouy G	17A	M	1.05-2.34	16	1.84	0.43
		I	1.70-3.11		2.57	0.44
Lt. 1-So.	11	M	1.86-2.98	14	2.45	0.52
		I	2.27-3.36		2.68	0.40
I-1	21D	M	1.31-1.91	13	1.65	0.27
		I	2.25-2.93		2.59	0.29
II-2	22B	M	0.92-2.57	11	1.81	0.74
		I	1.05-3.11		2.23	0.94
FRC	22A	M	0.29-1.94	12	1.15	0.58
		I	0.90-2.66		1.63	0.62
II-3	22A	M	0.46-2.65	21	1.73	0.56
		I	1.66-3.28		2.28	0.50
Lt. 2	8C	M	1.57-2.73	13	2.12	0.51
		I	2.11-3.13		2.71	0.43
III-1	23A	M	0.33-2.45	12	0.88	0.76
		I	0.22-2.31		1.13	0.78
OCC	23D	M	0.58-2.47	8	1.43	0.79
		I	0.88-3.01		1.83	0.93
III-2	23D	M	0.47-4.99	25	1.91	1.05
		I	0.76-3.36		1.98	1.09
J	23D	M	0.94-2.17	13	1.85	0.51
		I	1.76-2.74		2.36	0.90

BENTHIC INVERTEBRATES - DISCUSSION

I. Predominant Organisms

Tabulation of the 304 quantitative, benthic samples obtained during the study showed that very few species appeared at most of the sampling stations throughout the investigated area. The probability of encountering a natural community in which the component species are infradispersed (Slobodkin 1966) both intra- and interspecifically, is, most likely, highly remote. Specific components of a community are more commonly found to be distributed in a random or clumped fashion (Slobodkin, 1966). The term "community" is used here in the same sense described by Mills (1969):

> . . . a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable by means of ecological survey from other groups.

Based on the data obtained during the investigation, no species was found to be uniformly distributed within the portion of the Bay studied. Table XI presents the 10 most frequently captured species. Of these 10, only 4 were taken in 50% or more of the samples. An amplified presentation of distributional heterogeneity is presented in Tables IX and X. Ordination of species appearance for total sampling (qualitative and quantitative) is not presented since the accuracy of the qualitative method used in this study is questionable. The qualitative dredge net (p. 37) was not

Table XI. Ten most commonly found benthic invertebrates taken quantitatively.

SPECIES	NUMBER OF QUANTITATIVE APPEARANCES	APPEARANCE PERCENTAGE
Tellina agilis	217	71
Pectinaria gouldii	187	61
Cyathura polita	169	55
Mulinia lateralis	152	50
Glycera dibranchiata	147	48
Clymenella torquata	100	32
Maldanopsis elongata	100	32
Diopatra cuprea	84	27
Eupleura caudata	65	21
Nassarius obsoletus	58	19

utilized dur several sampling dates, its collecting efficiency was not known and field trials to determine repeatability within the same area gave extremely varying results.

The frequency of co-appearance among the 10 most common species is presented in Table XII. Of the 45 possible combinations between any two species, the greatest observed incidence of collecting a specific combination was a 45% co-appearance between Tellina agilis and Pectinaria gouldii. This value is only slightly above (+1.7%) a predicted, independent occurrence of both. Actually, most of the recorded co-appearances agree very well with predicted occurrences. Associations among the species were calculated with a X^2 measure using Yates' correction. The results of these calculations are presented in Table XIII.

Since there is only one degree of freedom, any value in Table XIII. below 3.481 indicates an association that may be due to chance alone (0.05 probability level).

Inspection of Table XIII. shows that there are only six associations that are significant at the 0.05 probability level or greater, indicating that some factor(s) is(are) operating other than random variation. From the physical-chemical viewpoint the significant associations would imply that the species in question are either compatible or incompatible under the existing environmental conditions. Obviously, those organisms which have a greater overlap among their tolerance limits might be expected to co-occur

Table XII. Frequency of co-appearance among the ten most common benthic invertebrates. Values below the dividing line are the number of co-appearances based on a total of 304 samples; values above the line are the respective percentages.

	Clymenella	Cyathura	Diopatra	Eupleura	Glycera	Maldanopsis	Mulinia	Nassarius	Pectinaria	Tellina
Clymenella		23.5	16.6	5.7	21.3	12.6	16.7	2.3	22.9	25.8
Cyathura	72		16.1	9.2	32.7	20.1	27.0	8.0	39.1	40.2
Diopatra	51	49		3.4	18.4	14.4	14.4	1.1	18.9	21.3
Eupleura	17	28	10		7.5	5.7	11.4	4.6	14.9	15.5
Glycera	65	100	56	23		24.7	25.9	6.9	32.7	39.1
Maldanopsis	38	61	44	17	75		17.8	2.9	22.9	19.5
Mulinia	51	82	44	35	79	54		6.9	34.5	40.2
Nassarius	7	24	3	14	21	9	21		8.0	6.3
Pectinaria	70	119	56	45	100	70	105	24		45.4
Tellina	79	122	65	47	119	59	122	19	1[illegible]3	

Table XIII. Computed numerical associations among the ten most common benthic invertebrates in Barnegat Bay, New Jersey. Values obtained by X^2 calculation using Yates' correction. Numerically significant values (0.05 probability level or greater) appear above the diagonal line.

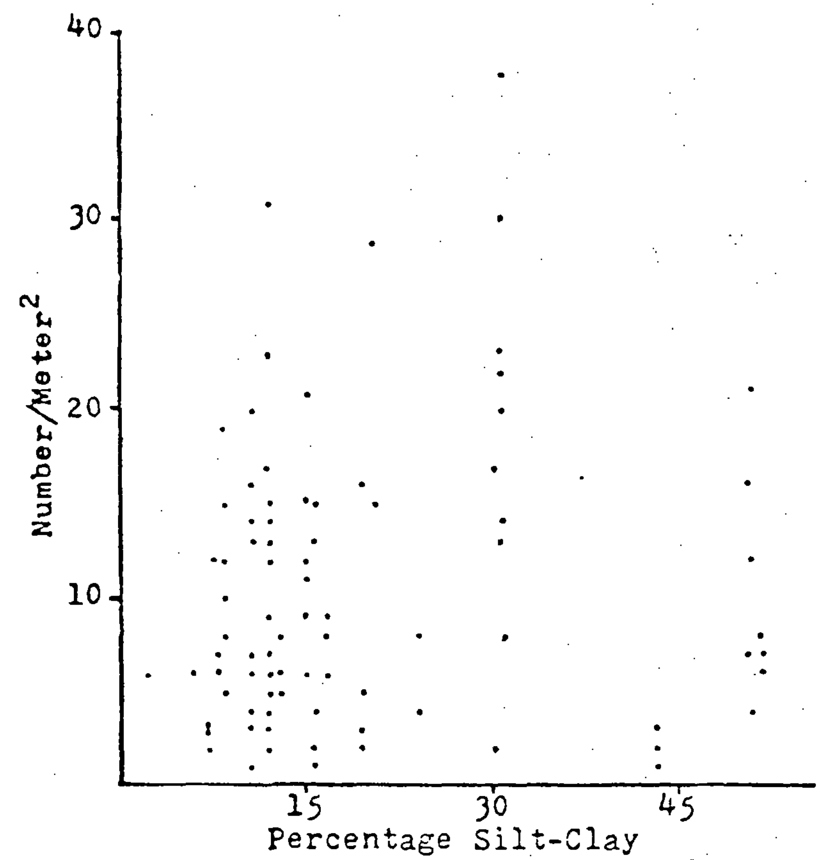
	Clymenella	Cyathura	Diopatra	Eupleura	Glycera	Maldanopsis	Mulinia	Nassarius	Pectinaria	Tellina
Clymenella			+0.005							
Cyathura	2.128									
Diopatra	9.584	0.002				+0.03		-0.03		
Eupleura	0.104	0.637	1.007							
Glycera	2.615	1.797	2.644	0.835		+0.005				
Maldanopsis	0.290	0.156	4.356	0.104	7.622					
Mulinia	0.009	0.005	0.000	0.013	0.095	0.079			+0.03	
Nassarius	3.123	0.627	4.092	0.000	0.539	2.140	0.742			-0.02
Pectinaria	0.445	0.906	0.209	0.222	0.365	0.445	4.491	1.381		
Tellina	0.281	0.000	0.094	0.005	0.851	0.778	0.790	5.640	0.040	

more frequently than entities requiring different environmental parameters. Biologically, those forms which are able to partition the environment and thereby reduce competition between themselves would be expected to co-occur more than severely competing species. Four of these groupings are positive. The two negative associations involve _Nassarius obsoletus_. One is with _Diopatra cuprea_; the other is with _Tellina agilis_.

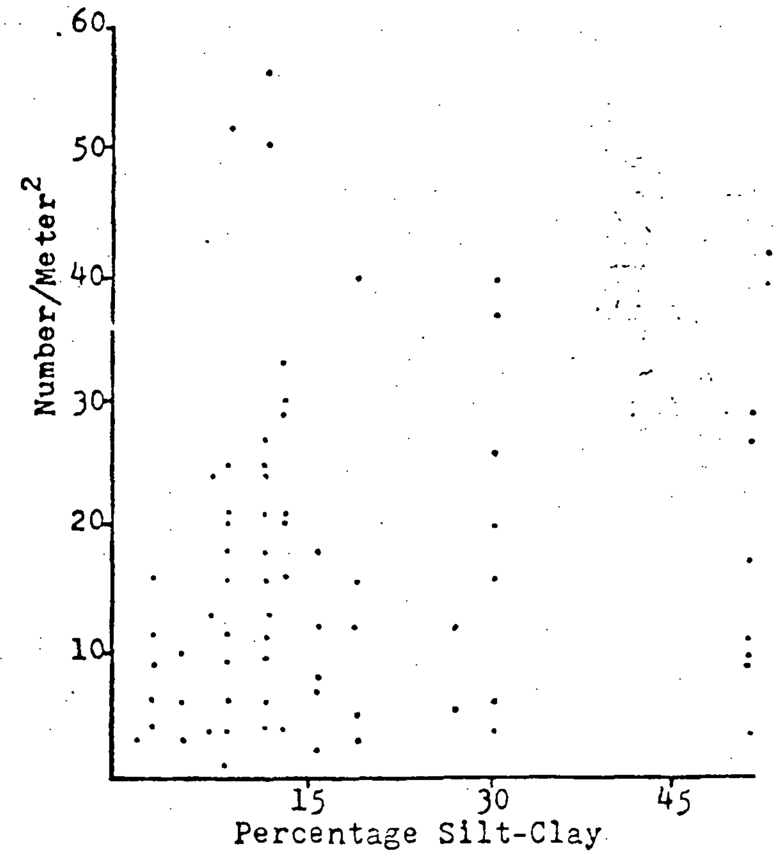
N. obsoletus is a deposit feeding grazer, commonly associated with mud/sand flats. In this study the snail was most commonly found in the silty substrates of the creeks and rivers along the western margin of the Bay. Within these regions the snail achieved its greatest densities (Fig. 11) and frequently was the only organism recorded in the very fine sediments. The high levels of organic materials found in the finer substrates (Table III.) are probably influential in maintaining large populations of _Nassarius_. The paucity of other invertebrates within the creek mouths might be due to the reducing sedimentary conditions associated with the accumulation of decaying material. Possession of a highly flexible siphon is a morphological adaptation which permits _Nassarius_ to exist within reducing substrates while maintaining communication with the overlying water. Another possibility that might help explain the absence of other forms in the creeks is the suitability of the substrate for the metamorphosing larvae. Possibly, the quality of the substrate in these low current

Figure 11. Observed densities (ordinate) among major infaunal invertebrates in relation to the percentage silt-clay (abscissa) composition of the substrate.

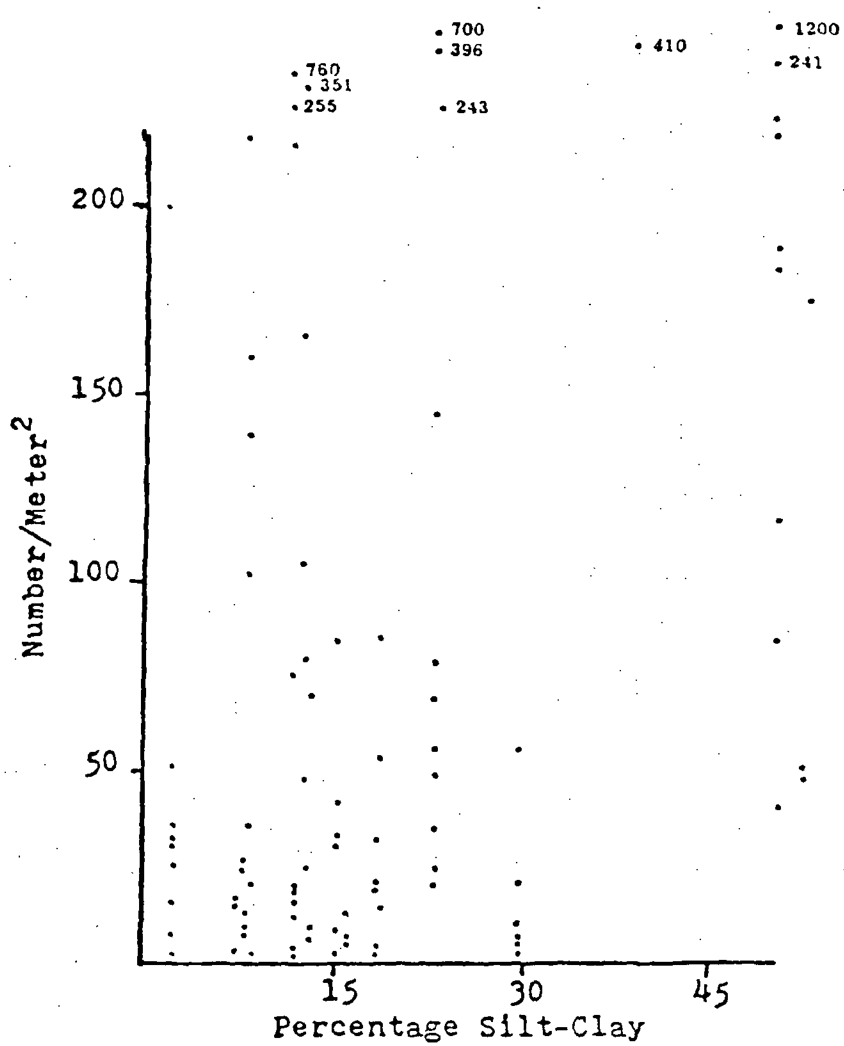
GLYCERA DIBRANCHIATA



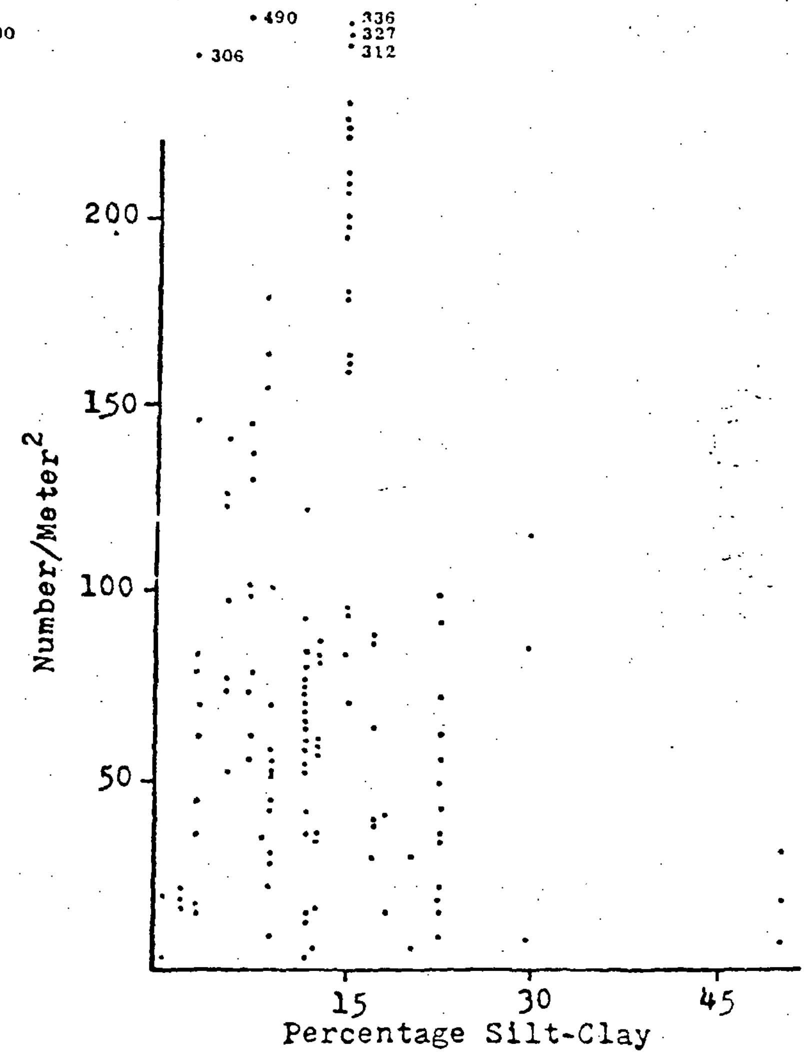
CYATHURA POLITA



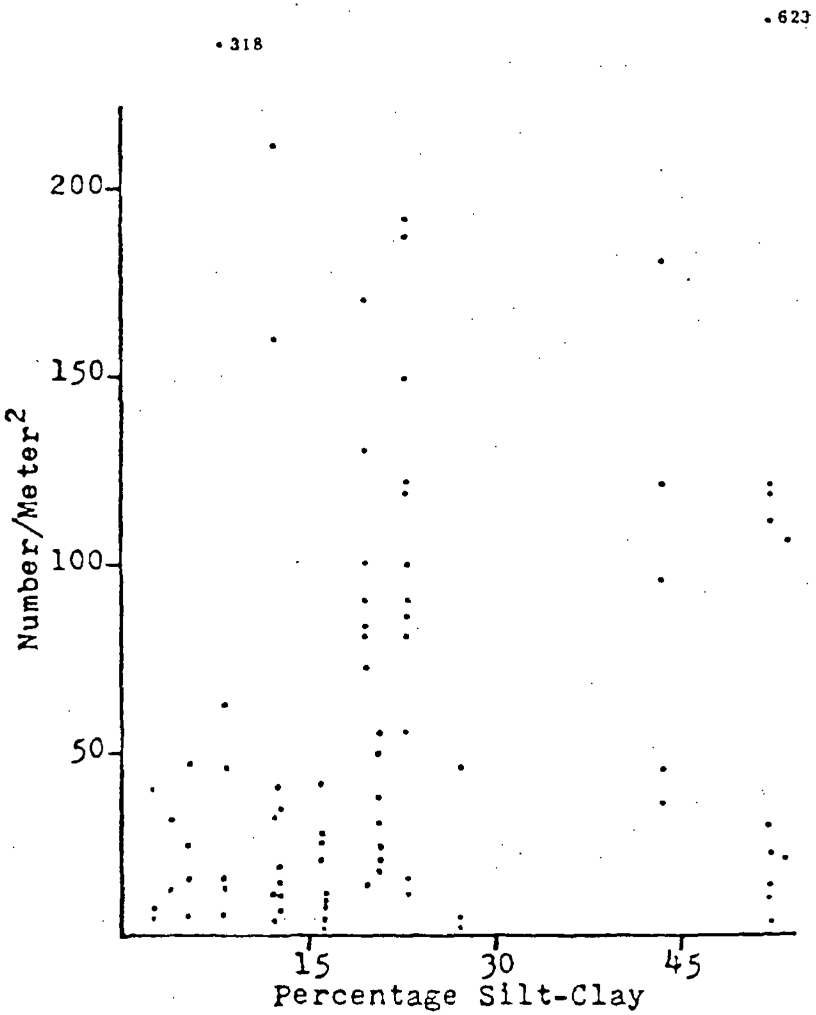
PECTINARIA GOULDII



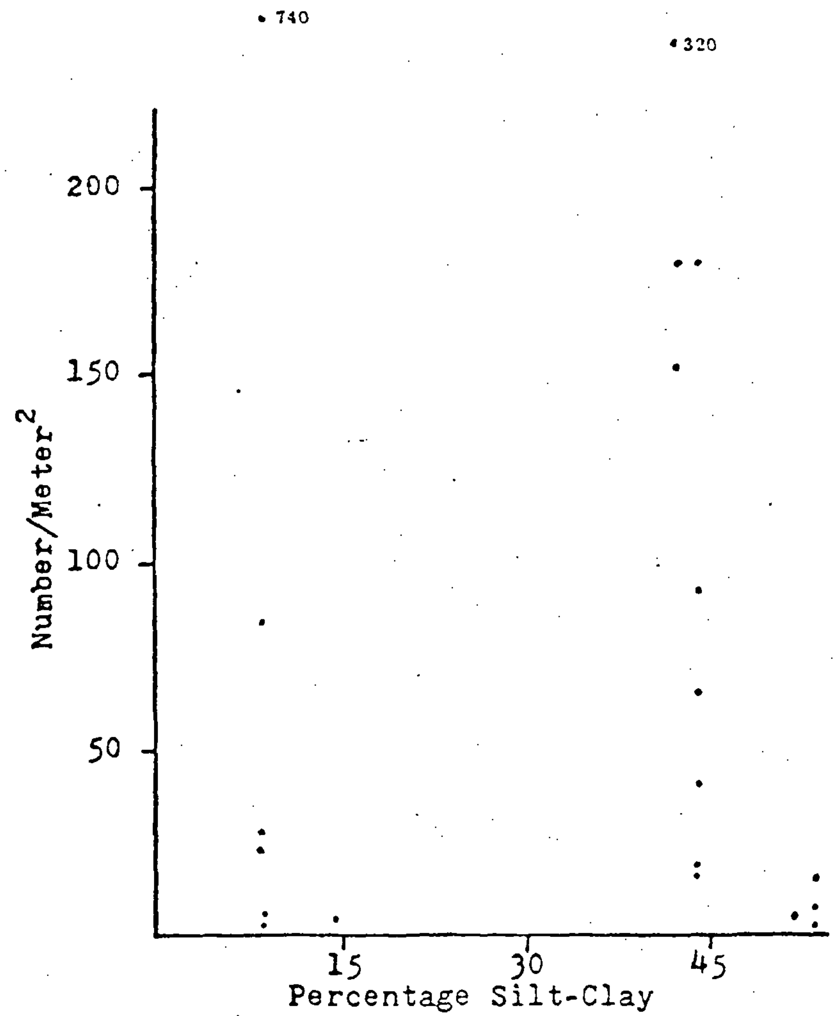
TELLINA AGILIS



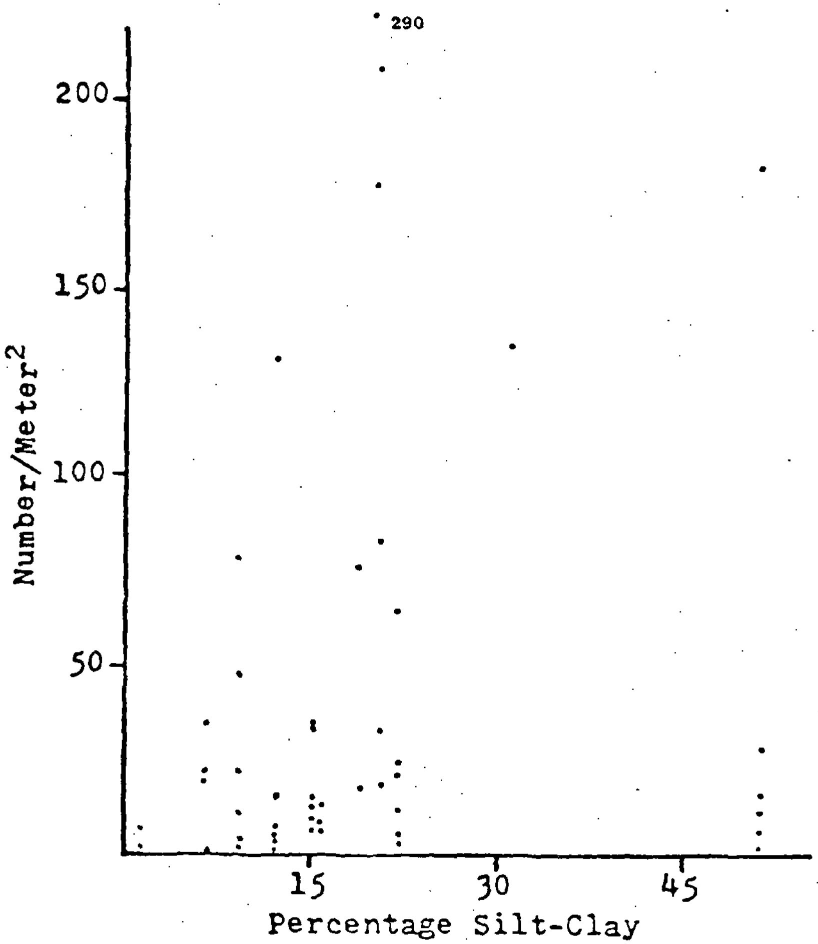
MULINIA LATERALIS



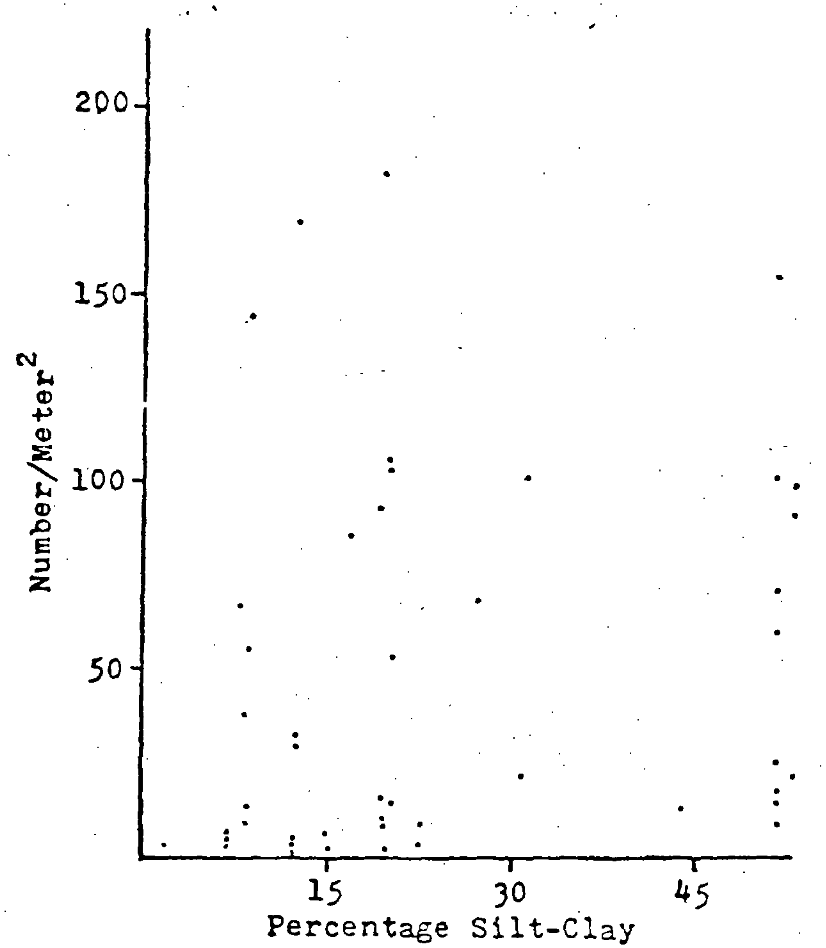
NASSARIUS OBSOLETUS



CLYMENELLA TORQUATA



MALDANOPSIS ELONGATA



areas prevents establishment of larval sets of many other common invertebrates. Even if larval settlement is successful, continuance might be prevented by ingestion of the newly metamorphosed individuals by the dense congregations of *Nassarius* (Scheltema, 1961).

The onuphid, *Diopatra*, has reportedly been dredged on all types of bottom (Pettibone, 1963). However, this polychaete was recorded only once from the very fine substrates of the creeks and their immediate mouths. Being carnivorous (Pettibone, 1963), the worms might not be present in the same areas as *Nassarius* due to lack of sufficient food. *Diopatra* appears more commonly (Tables VIII. and IX.) in regions having greater biological diversity. This could be a function of greater availability of food.

The distribution of *Tellina* in this study agrees with published data. "Fine or muddy sand" is the description of the Systematics-Ecology Program at Woods Hole (Smith, 1964). Lee (1944), in the first quantitative survey on the Western Atlantic coast, lists a *Tellina tenera* (=*agilis*, Abbott, 1954) community from "pure, yellow sand." Of the four *Tellina* communities listed in Thorson (1957), all are variants of "fine" or "pure" sand. Ansell and Trevallion (1967) list *Tellina tenuis* (daCosta) as inhabiting fine sand. This species is not comparable in habitat with *T. agilis*. However, *T. fabula*'s distribution is similar to *T. agilis* (Ansell, personal communication) and it (*T. fabula*) is a fine sand species also. Based on these distributional descriptions, the negative association found between Nassarius and Tellina is not surprising. Tellina did occassionally appear in the Nassarius areas, but the clam's densities were always very low (Figure 11) in these areas.

The positive associations, recorded among the most common infauna, involved primarily those forms taken between 27-50% of the stations sampled (Table XI), with the exception of Pectinaria (61%). On a bay-wide scale, 50% appearance (actually, the capture) of an organism may not be particularly impressive; however, when the appearance and co-appearances are ordinated, an interesting pattern begins to emerge.

Both of the most significant (numerical) associations, Clymenella-Diopatra and Glycera-Maldanopsis, occur much more frequently within the "muddy" sections of the Bay. The slightly less significant (Table XIII) Diopatra-Maldanopsis association also occurs more frequently in mud substrates. The Mulinia-Pectinaria grouping appears on a much wider range of substrates, i.e., this co-appearance extends significantly into the sandy portions as well as within the muddy areas.

Qualitative description of a parameter is generally ambiguous since the aspects of a quality are relative. For brevity, however, Barnegat Bay can be described as a soft-bottomed lagoon. No solid substrates (viz. "rocks") were encountered during the study. A couple of presumed oyster reefs or beds were located, but these have been covered by sedimentation. The soft bottom varies from "sandy" to "muddy." Particle size analysis is presented in the appendix.

Distribution of the major invertebrates follows the sediment type rather well. Table IX has been divided into "sandy" and "muddy" areas. This division and the most commonly encountered animals are presented in Table XIV. In addition to the counts obtained at the station proper, the data from adjacent positions are included within the results. These additions represent samples that were taken at varying distances removed from the station position but still within the general station area.

Initial splitting of sand vs. mud substrates was empirically conducted. Other than generalized locations (western side of Bay), the muddy substrates can be described as having greater amounts of interstitial water and being darker (dark brown to black) in color than the sands.

The sixteen major stations in Table XIV are equally divided between the two gross substrate types. Sandy areas contain 15% or less of the silt-clay fraction, while the muds have a minimum of 20% silt-clay (Appendix, Table I).

Only the quantitatively more common organisms have been used in this comparison of bottom types. All animal occurrences represent at least a 50% encounter, i.e., the species listed were found at least 50% of the times the station was sampled. Most of the benthic forms listed had

Table XIV. Comparison of sand and mud stations and associated infauna.

S A N D

L: Light   B: Bouv

QUADRATE LOCATION NO. SAMPLES	8C L 2 13	11 L 1-S 11	15C B D1 14	17A B G 16	17C B F 19	22A L 4 21	23D B J 13	23D L 3 25
Ampelisca macrocephala					+		+	
Crangon septemspinosus		+						+
Cyathura polita				+		+	+	
Ensis directus								+
Glycera dibranchiata			+			+		
Eupleura caudata							+	
Idotea baltica	+							
Mitrella lunata								+
Mulinia lateralis	+			+	+	+		+
Neopanope texana		+						
Pectinaria gouldii	+			+		+	+	+
Scoloplos armiger		+						
Solemya velum		+						
Tellina agilis	+	+	+	+	+	+	+	+

(Table XIV. continued)

MUD FRC: Forked River Channel OCC: Oyster Creek Channel QUADRATE LOCATION NO. SAMPLES	13A B Cl 9	14B B D 7	15B B E 10	21D L 1-N 13	22A FRC 12	22B II-2 11	23A III-1 12	23D OCC 8
Cirratulus grandis						+		
Clymenella torquata	+		+		+			
Cyathura polita	+	+	+		+	+		+
Diopatra cuprea	+		+					
Eupleura caudata				+				
Glycera dibranchiata		+		+	+		+	
Maldanopsis elongata	+			+	+			
Mulinia lateralis	+			+			+	
Nassarius obsoletus						+	+	+
Pectinaria gouldii	+	+		+	+			+

75-80% encounters. Lower encounters represent stations not sampled very heavily.

A condensation of the animals associated with the different bottom types appears in Table XV. Here the most common species are listed according to their respective frequencies of appearance. Certain species which are included in Table XIV are not listed in Table XV because these were not well represented in several quadrates. Therefore, each species listed in Table XV was quite common in at least two quadrates (sand environment) or three quadrates (mud environment).

Inspection of Table XV shows that only one species is common to all sandy quadrates. This is the lamellibranch, Tellina agilis. In addition to appearing in all sand quadrates, this small clam always has the greatest frequency of appearance. Among the muddy quadrates, Tellina never appears more than 50% of the examinations. Frequently, Tellina is recorded from only one quarter of the quantitative samples or less. At Light 1 North (quadrate 21D) Tellina was captured only once by quantitative means.

Tellina is the most characteristic infaunal organism for the sandy portions of the study area. Numerically, the small clam was relatively abundant with a grand average density of 86 individuals/m^2 in the sandy locations. The greatest recorded average density was 204/m^2 taken at Bouy F. Bouy D had an average density of 40 animals/m^2. Some indication of the overall variability of counts may be seen from

Table XV. Most commonly associated infaunal invertebrates within the two principle substrate types.

ANIMAL	FREQUENCY OF APPEARANCE+							
Sand Environment:								
	Quad. 8C	11	15C	17A	17C	22A	23D[1]	23D[2]
Tellina agilis	10/13	10/11	13/14	16/15	19/19	19/21	21/25	12/13
Mulinia lateralis	8/13	*	*	13/16	14/19	17/21	17/25	*
Pectinaria gouldii	9/13	*	*	11/16	*	16/21	21/25	9/13
Cyathura polita	*	*	*	12/16	*	14/21	*	9/13
Glycera dibranchiata	*	*	12/14	*	*	12/21	*	*
Mud Environment:								
	13A	14B	15B	21D	22A	22B	23A	23D
Cyathura polita	8/9	7/7	7/10	*	9/12	7/11	*	6/8
Pectinaria gouldii	8/9	6/7	*	10/13	10/12	*	*	7/8
Glycera dibranchiata	*	6/7	*	8/13	8/12	*	7/12	*
Clymenella torquata	6/9	*	10/10	*	9/12	*	*	*
Maldanopsis elongata	7/9	*	*	7/13	12/12	*	*	*
Mulinia lateralis	6/9	*	*	9/13	*	*	6/12	*
Nassarius obsoletus	*	*	*	*	*	11/11	12/12	7/8

*Species did not appear at least 50% of the time.
+Number of times recorded/number of samples
1 Light 3; III-2
2 Bouy J

the scatter of points in Figure 11.

Both the lamellibranch Mulinia lateralis and the polychaete Pectinaria gouldii appeared regularly within five of the sandy quadrates (Table XV). The isopod Cyathura polita was taken less frequently in only three quadrates. These three species occur frequently enough within the muddy quadrates so that they are included among the most commonly encountered forms there also. Based on these distributional data, it might be advisable to use only Tellina agilis as an indicator species for sand substrates, at least in this study.

Pectinaria gouldii is widely distributed within the sampling area. This worm appears more than 50% of the time in five sandy and five muddy quadrates (Table XV). With such an apparently wide distribution, Pectinaria would be a poor choice as a substrate-type indicator. The observed densities recorded from the 10 quadrates reveal a greater density of worms in the muddy than in the sandy regions ($107/m^2$ vs. $67/m^2$ respectively). However, there is no significant difference between the two values due to the wide variability among density counts at stations (Fig. 11). When all of the density values are utilized (i.e., all 16 quadrates/stations in Tables XIV and XV) there is significant overlap between the two substrate types—126 animals/m^2 in mud and 88 animals/m^2 in sand. Since this polychaete is widely distributed throughout the sampling area, it would seem logical to suggest its being used as an indicator organism to monitor pollution. Because the animal apparently can exist within a range of sediment types, it could serve as an index of environmental change other than sediment change (possibly caused by scouring or altered sedimentation patterns).

The wide-spread distribution of Pectinaria found in this study is in agreement with Stickney and Stringer (1957). The greatest concentrations were found in sediments intermediate in their silt-clay/sand composition. Sanders (1956) has discussed the distributional pattern of Pectinaria (Cistenoides sic) and the significance of the substrate composition to it.

Since Pectinaria is a deposit feeder, one parameter that might be useful in determining its distribution is the amount of organic matter present in the substrate. Table XVI shows that this is not true, at least from the data obtained in this study. The densities of animals are so variable, within specific bottom types as well as between substrates, that the correlation coefficient (r) derived is only 0.27. Perhaps it is not the quantity of organic material that determines a particular species' spatial distribution. Local variations in organic constituents and the relative availability of these to the organism may exert more influence on the animal's positioning than the amount of organic material *per se*. Sanders (1960), based on some preliminary data, suggested that qualitative organic differences between different levels of substrate might assist in

Table XVI. Relationship between *Pectinaria* distribution and amount of organic matter within substrate.'

Mud Sta.	*	No./m^2	Sand Sta.	*	No./m^2
II-2	8.02	12	Lt. 2	3.73	7
III-1	7.45	410	Bouy D1	3.54	328
OCC	7.06	128	II-3	3.25	97
I-1	5.24	92	Bouy J	3.11	58
Bouy C1	4.98	16	Bouy F	2.63	33
FRC	4.15	279	Bouy G	2.57	11
Bouy E	4.13	52	III-2	2.56	165
Bouy D	3.83	22	Lt. 1-So.	2.52	10
	$\bar{x}$ = 126			$\bar{x}$ = 88	

Major Stations Only

Position	Density	Position	Density
Bouy C1	16	III-2	165
Bouy D	22	II-3	97
I-1	92	Bouy J	58
FRC	279	Bouy G	11
OCC	129	Lt. 2	7
$\bar{x}$ = 107/m^2		$\bar{x}$ = 67/m^2	

$$y = \bar{y} + b(x-\bar{x}) = y = 107.50 + 19.13(x-4.29)$$
$$= 25.43 + 19.13x$$

$r = 0.27$

*Percentage Organic Matter

explaining deposit-feeders' distribution. Unfortunately, there have been no followup articles to this interesting hypothesis, so this aspect of benthic ecology remains to be researched.

The dwarf mactrid Mulinia lateralis is characterized as inhabiting muddy or clayey substrates in shallow water, occasionally being found in surf-stirred sand (Smith, 1964). Sanders (1956) found Mulinia widely distributed within Long Island Sound. From his data the greatest concentration occurred at an area with about 25% silt-clay (Station 5, 2/18/54). The greatest concentration (actually biomass) was found at silt-clay values ranging from 20-40%. If Mulinia was present in the first Buzzards Bay study (Sanders, 1958), it must have accounted for less than 1% of the population since it was not listed. Twelve individuals were recorded from the R station during 1956 and 1957 (Sanders, 1960). These represented 0.08% of the fauna by number. Sanders et. al. (1962) and Hanks (1964) do not include Mulinia among their species lists. In the Mississippi Delta region, Mulinia has been found chiefly in silty sand, sandy silt, and clayey silt (Parker, 1956). Jackson (1968) reported a substantial population (108 individuals/m^2) within an intertidal mudflat in Connecticut, but provided no quantification for the "mudflats" sedimentary composition. This location is interpreted as being toward the mud end of the sediment spectrum since Jackson includes a statement concerning Mulinia's ability to exist in areas of high silt-clay concentration.

Although this mactrid appears to be more widespread in the sandy (five quadrates) areas, it is numerically greater in the muddy stations (three quadrates appearance). Average values for the two substrate types are $74/m^2$ (mud) and $41/m^2$ (sand). Typically, muddy bottoms are associated with reduced current velocities and such conditions characteristically do not support suspension feeders to the same degree as do sandy areas. Perhaps the existing currents can move some of the surface detrital material into suspension, and the suspension feeder (Mulinia in this case) can utilize this food source. According to Hayes (1964) and Sanders (1960), the uppermost layer in very muddy areas is a semi-fluid, flocculent layer. Prior to consolidation such material would be put into suspension by relatively low velocity currents.

Cyathura polita is the most widespread of the infaunal species within muddy areas (six of eight quadrates represented). This isopod also appeared within three of the sandy quadrates at least two-thirds of the times sampled (Table XV), so this is a widely distributed form. Harger (1878) described the distribution of Cyathura as ". . . usually found in eelgrass or mud in shallow waters." The only verification materials found from Harger's work were a few slides labeled "from mud" (Miller & Burbanck, 1961). Within this same work, Miller and Burbanck (1961) indicate that Cyathura can generally be found in areas of demarcation between Spartina and Typha which are characterized as sandy substrates being matted with roots.

Burbanck, in his rather extensive work dealing with the isopod, describes the substrate associated with Cyathura populations as follows:

> mucky clay in Wading River (tributary of Mullica River), N. J. (1959)
>
> substrate contains much or little sand with an admixture of vegetable debris (1959)
>
> most are found around shell (boat) ramps in Ashepoo River, South Carolina (1961)
>
> much or little sand . . . stable substrate . . . sandy mud which contains enough natural coarse material to become firm (1962)

Examination of the above substrate descriptions reveals a consistent pattern concerning the stability of the sediments. Even though the qualitative aspects vary among the described sites, they could all be identified as being relatively stable. Since Cyathura is a burrowing (horizontal more than vertical) form, the stability of the substrate probably is an important aspect of this animal's biology.

Sandier areas are associated with increased current velocities, and these might effectively carry away the isopods. If the animals were not directly eliminated, the continued scouring action might prevent all but short-term colonization of an area. Another aspect which might be operable in preventing Cyathura's inhabiting of sandier areas is the reduced amount of organic matter. Again, the greater currents associated with sand areas do not permit settling of the finer detrital particles. This, theoretically, could stress any _Cyathura_ present since they appear to be detritus-algae feeders (Burbanck, 1959). However, within this study the data do not warrant such a conclusion. While those sandy quadrates at which _Cyathura_ appears do have lower organic matter content (Table III) than the muddy stations, there is no significant difference in the grand averages of _Cyathura_ densities (mud: 24 organisms/m^2 vs. sand: 27/m^2). Such values are far lower than those described by Burbanck (1959) in New England with averages of about 1000/m^2 increasing to 4000/m^2 during breeding. These results are even considerably lower than Spooner and Moore's (1940) findings in the Tamar Estuary. The low values recorded within this study are consistent among the various regions. Based on this, the likelihood of sampling error throughout the study should be reduced.

The third most widespread animal in the muddy quadrates is the bloodworm, _Glycera dibranchiata_. This polychaete also appears in the sandy quadrates, but it is not as spatially widespread in the sand. In their study of the bloodworm, Klawe and Dickie (1957) noted increasing densities of the worm with increasing softness of the substrate. The data of Stickney and Stringer (1957) are in direct contrast with this. In the Greenwich Bay study the greatest densities of _Glycera_ occur in sand bottom stations (Nos. 8-12). Klawe and Dickie noted an absence of the polychaete in the finest substrate (no quantification). This is perhaps corroborated by Stickney and Stringer's findings since the silt, sandy-silt stations harbor the lowest densities of Glycera. One aspect of the Greenwich Bay study which may have greatly influenced the distribution patterns was the presence of sewage and industrial wastes which entered at the western end of the Bay. The presence of these materials probably exerted some influence on the ability of different animals to live in the wastes region. Stickney and Stringer (1957) suggested that the high levels of organic content of the substrate in the western portions of the Bay might be due to the above effluents.

In Long Island Sound (Sanders, 1956), Glycera was most dense (23/m^2) in an area quantified as 89% fine sand. At another sandy area (72% sands) there were eight animals/m^2 recovered.

Sanders (1962) has found G. dibranchiata in concentrations of 20 and 11 animals/m^2 in areas with median grain diameters of 130μ and 160μ (fine sand—Wentworth, 1922) respectively on the flats of Barnstable Harbor. G. americana, a closely related species, was found in the Ampelisca spp. community (less than 35-45% silt-clay) in Buzzard's Bay (Sanders, 1958).

The polychaete is widely distributed within Barnegat Bay; it has been recorded quantitatively from all major quadrates. Bouy J is the only location from which Glycera was not recorded. This is probably a sampling error since it has been recorded from stations surrounding Bouy J.

In agreement with Klawe and Dickie, and in contrast to

Stickney and Stringer's findings, the larger concentrations of Glycera were associated with the finer sediments in this study (Fig. 11). Thus, at the sandier positions at which Glycera appears at least 50% of the time, the average density is only $10/m^2$. In the muddier areas with intermediate silt-clay fractions, the average density was $19/m^2$, and in the areas with a relatively large amount of silt-clay, the average dropped to $4/m^2$.

The reduced densities in the latter category may be a reflection of increased anaerobic conditions. The finest (grain diameters) sediments are generally associated with reduced current velocities, so any organic matter introduced might remain and decompose adding to the B.O.D. of the area. Under reduced conditions, a relatively active form such as Glycera might not be able to continue metabolic activities for long periods of time. However, the importance and scope of anaerobic respiration and energy utilization during low pO_2 are largely unknown (Hoffman and Mangum, 1970). Since these worms appear to be primarily burrowers rather than swimmers (Pettibone, 1963), the oxygen availability within the substrate might be an important factor in their distributional pattern. Apparently Glycera dibranchiata does not frequently crawl on the substrate or swim long distances (Klawe and Dickie, 1957). Continuance within the substrate would then depend, at least partially, on sufficient levels of dissolved oxygen. As long as the animal can maintain communication with the overlying water, it can probably continue normal metabolic activities since the worm ventilates its burrow and thereby offsets the reducing effects of the substrate. This may partially explain the greater observed densities of worms in sediments of intermediate silt-clay composition. With some measure of the finer sediment particles present, construction and maintenance of a burrow would probably be easier than in coarser substrates. Periodic or irregular disruption of the waterflow should not be deleterious to Glycera since the coelomic cell hemoglobin may maintain adequate oxygen levels for almost two hours after ventilation ceases (Hoffman and Mangum, 1970). In the same study Hoffman and Mangum demonstrated that G. dibranchiata can withstand 42 hours exposure to reduced oxygen levels (0.14 ml O_2/l.). During such sustained exposures the metabolic rate probably decreases to comparable or lower rates as those measured during observed ventilation activity. This represents a 90% decrease in oxygen consumption (133 μl O_2/hr. vs. 14 μl O_2/hr. ventilation vs. pause, Hoffman and Mangum, 1970). Even though the animal is capable of strong, rapid muscular movements, the worm does not readily invade new areas (Pettibone, 1963).

Glycera has been described as a detritus feeder (Pettibone, 1963) and, probably more accurately, an omnivore (Sanders et. al., 1962; Phillips, 1967). The amount of organic material in the substrate, in conjunction with other environmental parameters, should influence the density of animals. Sand grains have less available surface area for binding materials than do silt-clay sized particles, so sandy areas may be predicted to harbor fewer glycerids than muddy areas. In areas of greater silt-clay levels there would be greater surface area available for binding organic materials so the number of animals that could be maintined would be greater.

Physical aspects of the substrate per se could exert some influence on distribution of infaunal forms such as Glycera. Sanders et. al. (1962) have demonstrated that the stability of sand will also greatly influence the distribution of Glycera (and other deposit feeders). Unconsolidated mud should be easier to move through than sand because of the higher levels of interstitial water present in mud. Mud would probably be less abrasive on the animal than a sand medium too. Within the more plastic mud substrate a burrowing organism such as Glycera probably would not have to produce as much lubricating mucous for passage through the sediment. If Sander's et. al. (1962) hypothesis that Glycera does not feed in the summer (based on Klawe and Dickie's report that the worm doesn't grow during this period) is correct, then those animals residing in a muddy area could conserve energy expenditure better while moving through mud than could an animal working through the more compacted sand.

The two remaining organisms that were captured regularly in the muddy areas were Clymenella torquata and Maldanopsis elongata, both members of the Family Maldanidae. Both worms construct mucoid tubes to which are attached sediment particles. Clymenella uses fine sand particles (Lee, 1944; Sanders et. al., 1962) in covering its tube, while Maldanopsis' tube is constructed more of silt materials (Phillips, unpublished data). The polychaetes appear together at all of the major sampling stations (Table XVII) even though neither appeared more than 50% of the time in sandy areas (Table XV). Table XVII shows that greater densities of these two forms are routinely associated with finer substrates. The lowest densities are found in the sandy areas—Bouys F and G, and Light 1-South. Lack of suitable sediment for tube construction might be operable in the low densities of Maldanopsis seen in the sandy areas, but this factor would not be likely for Clymenella in the same locations. Some other factor(s) is(are) probably operating in maintaining smaller populations of the maldanids within sand substrates. Perhaps the currents associated with these particular sandy areas effectively flush most newly entering or settling young worms from the area.

Based on the distribution of the invertebrates found in the sampling region of Barnegat Bay, it would be somewhat presumptuous to characterize the Bay by one organism or a pair of organisms as is the more common practice (Sanders, 1956, 1958; Thorson, 1957; and others). There would appear to be at least two broadly definable communities—a sand bottom situation and a softer (mud) bottom community. The generalized pattern of the substrate distribution has already

Table XVII. Comparison of *Clymenella* and *Maldanopsis* densities at selected positions.

POSITION	PERCENTAGE SILT-CLAY	CLYMENELLA No./m²	MALDANOPSIS No./m²
Bouy C1	19.2	47	51
Bouy D	30.5	135	61
Bouy D1	11.8	47	51
Bouy E	20.0	127	104
Bouy F	15.4	16	6
Bouy G	12.0	9	15
I-1	54.5	--	43
FRC	52.7	16	62
II-3	8.4	17	70
Lt. 1-So.	7.0	22	4

been described in the sediment section of this paper (pp. 23-26).

Tellina agilis is the only animal that truly characterized the sand bottom areas. The remaining animals, even though they routinely appear in sand, are also common in the muddy areas.

For the mud substrate, one faces a more difficult choice for (a) characterizing species. No species is found at all locations; those forms which are most widespread in the softer bottom (*Cyathura* and *Pectinaria*) are also found in the sand environments. The animals that are unique to the muds (*Clymenella*, *Maldanopsis*, and *Nassarius*) do not appear widely enough to warrant their being classified as indicator organisms. A compromise characterization could be attempted; specifically, a coappearance of *Cyathura* and *Pectinaria* coupled with a reduced number of *Tellina* would generally indicate a mud substrate. It may be equally as valid, based on the data available, to state that the mud areas do not have a recurrent characterizing faunal composite of only two species. Rather, there are assemblages found in the muddy sectors with greater species numbers.

Comparing the results of this study with similar studies (Table XVIII) indicates that the recorded numbers of species are comparable among the different areas. All of the comparisons are situated in the northern section of the Virginian Province, all of the studies are sublittoral and

Table XVIII. Comparison of Barnegat Bay (New Jersey) invertebrates with other Virginian Province studies.

SITE	Barnegat Bay(NJ)	Long Island Sound(NY)[1]	Buzzards Bay(Mass)[2]	Menemsha Bight(Mass)[3]	Greenwich Bay(RI)[4]	Sheepscot River (Me)[5]
BOTTOM TYPE	mixed	mixed	mixed	sands	mixed	soft mud
SCREEN SIZE	1.5mm	1.0mm	0.5mm	1.8mm	2.0mm	1.5mm
NO. SPECIES FOUND	110	135	68*	40	114	108
NO. SPECIES COMMON IN BARNEGAT BAY AND...		51	25	15	57	12

1 Sanders, 1956

2 Sanders, 1958

3 Lee, 1944

4 Stickney & Stringer, 1957

5 Hanks, 1964

* only species constituting more than 1% of the population were included in the paper.

all are quantitative in design. Wells' (1961) paper is not included because it was not quantitative and it is from the Carolinian Province.

Of the studies sited (Table XVIII), the two most similar (number of species) to Barnegat Bay are Long Island Sound and Greenwich Bay. These are both mixed bottom environments so it is likely that more niches exist than would be found in a single bottom type. Annelids, arthropods and molluscs predominate in the common speciation among the three bays. Greenwich Bay and Long Island Sound each had 49 species among the three above taxa which appeared in Barnegat Bay.

II. Species Diversity

This is a concept that is unique to the description of communities in ecological investigations. Essentially, the parameter of diversity indicates how "rich" or "poor" a region's fauna and/or flora components may be. The numerical diversity value of one sample or area may be compared directly with another situation (assuming collecting techniques are comparable) to determine relative similarities or dissimilarities.

On large scale generalities, it has been noted that tropical regions maintain a more diverse biotic component than do arctic areas (Odum & Odum, 1959). Sanders (1968) mentions that marine habitats normally demonstrate greater diversity than estuarine (brackish) situations. Provided the scale of an investigation is large enough, differences between widely separated points may be of sufficient magnitude so that simple inspection shows obvious differences. It is within narrower range studies that the idea of species diversity can be used more fruitfully.

The principle components of diversity are the number of species within the study area and the number of individuals. The relationship between these two parameters will determine the richness or evenness of a region. Two sites with the same numbers of species and the same total numbers of individuals can have different diversity indices. When the individuals are equally spread among the species the diversity will be lower than in a situation where there is unequal distribution of individuals. The latter condition is the more diverse of the two examples.

Figures 9 and 10 present graphical presentation of the comparative richness of the different areas within the Bay. The two most diverse stations are Lights 3 and 4, located at the entrances of Oyster Creek and Forked River respectively. These were also the most frequently sampled sites. The lowest number of species was found at Transect III-1 located inside Oyster Creek. Distribution of individuals among the areas was such that the actual calculation of diversity resulted in significant overlap of diversity indices among the stations. Many organisms that appeared a small number of times were in very low densities, so their overall contribution was practically insignificant. Conversely, many of those organisms that appeared routinely were in considerably greater densities so this smaller number of species constituted the bulk of the numerical diversity calculations.

Figure 12 presents a graphical comparison of the two techniques used in computing the species diversity indices in this study. These data are the same as in Table X. Based on these data, there were no statistically significant differences among the various areas repeatedly sampled within the Bay. There was considerable overlap among the calculated values between the two methods as well as within the same method. The Information Theory, however, had consistently greater values. The computed grand mean for the Shannon-Weaver method (information) was 2.20 ± 0.49 (std. dev.), while Margalef's index was 1.70 ± 0.38, an average difference of 0.50 between the two methods.

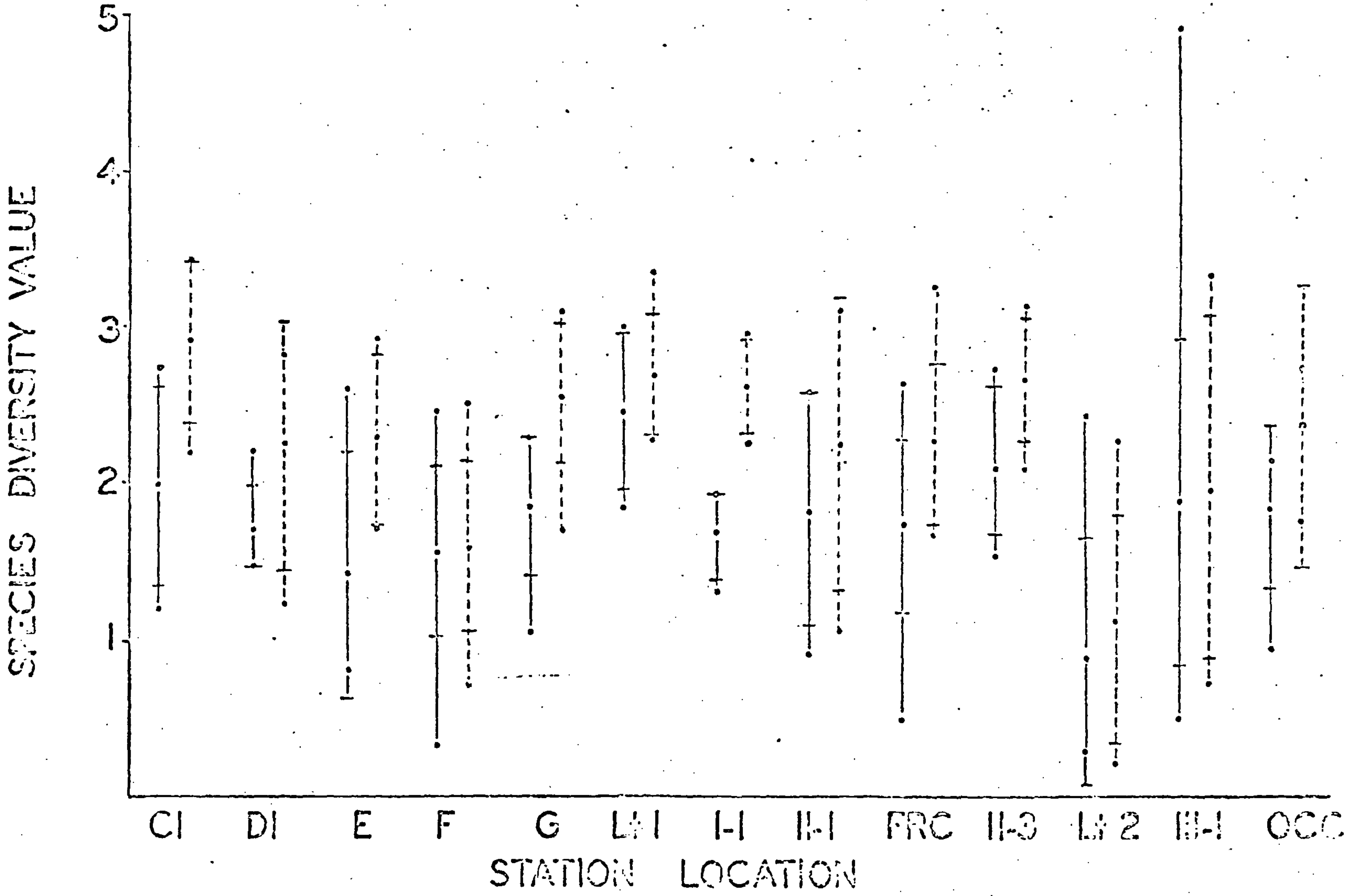
According to the recorded values, the different locations in Barnegat Bay are quantitatively, equally diverse (or non-diverse) over the time span studied. This finding, in conjunction with the noticeable range of values found at most areas, relegates the parameter of species diversity to an academic moot point within this investigation. It may be argued that the data collected will be available for future surveys and this will then permit meaningful comparisons. Within the framework of this study, however, the quantified results generated by the two diversity techniques indicate no differences for comparisons to be made.

It is important at this point to realize that differences do exist within the infaunal assemblages of Barnegat

Figure 12. Comparison of observed ranges and means between the Information Theory (Shannon-Weaver) and Margalef diversity indicies. These data appear in Table X. The middle dot on each line represents the mean value, the terminal dots are the observed ranges, and the cross bars represent the calculated standard deviations.

Margalef Index : •———•

Information Theory : •-------•


5
4
3
2
1
SPECIES DIVERSITY VALUE
CI
DI
E
F
G
I-I
II-I
FRC
II-3
III-I
OCC
STATION LOCATION

Bay even though these are not demonstrable by the diversity indicies. Qualitative differences can be seen in Tables VIII and IX; quantitative differences among the major organisms are presented in the Appendix, Table II.

Again, the comparative richness of the sampled sites is indicated by Figures 9 and 10. Continued sampling of the major sites will permit monitoring of faunistic composition. Changes within the communities' components should be observable in the shifts of richness and/or evenness brought about by pollution. Precise prediction of species' shifts (assuming changes occur) would be difficult, but the general pattern might be simplification; some species might be eradicated (reducing richness), while others increase in numbers of individuals if the new environmental conditions are favorable.

III. Spatial Distribution

This particular parameter is a reflection of the homogeneity or heterogeneity of chemical-physical factors within a study area, as well as the various biological interactions.

Temperature variation is certainly a parameter to be considered in distributional studies; but in the rather limited area of this study, temperature probably can be disregarded as a major local factor. The bay system demonstrates the normal pattern of seasonal warming/cooling seen in temperate latitudes in which this investigation took place. Very similar temperatures were found among several stations throughout the Bay during any daily cruise. Such findings might be explained if the investigators had remained with one water mass throughout the day. Due to the randomized sampling pattern, the probability of remaining with the same water mass is greatly reduced. Table XIX presents randomly selected data on temperatures at different sites on the same day. As may be seen, there are no great differences among the various locations. Complete hydrographic data are included in Loveland and Moul (1966, Table V); Phillips (1967—Appendix, Table III); Moul, et. al. (1968, Table VII); Loveland, et. al. (1969, Fig. H-4).

Those organisms dominating within the community are probably eurythermal. Rapid, short-term changes might be deleterious, but the seasonal shifts are regularly occurring events and so would be expected to be within the tolerance limits of the common forms. Drastic diurnal changes were never noted in the temperature regimes. The possibility of micro-environmental differences is not being denied, but on the scale of this investigation it seems that micro levels would have to be maintained for extended periods to play a directing, distributional role. The evidence indicates that even though certain regions (primarily around the inlet area) tend to be more conservative in thermal (and salinity) regime than other regions, this is not directly governing distribution of the major invertebrates in this study. Any gross meteorological change should affect large portions of the bay system so point-to-point variation would be unlikely.

Table XIX. Randomly selected temperatures from Barnegat Bay.

Date	Position	Temperature (°C)	Date	Position	Temperature (°C)
7-28-65	23B	23.6	11-16-66	23B	10.7
	1	24.2		16C	9.8
	8C	23.0		15B	10.1
8-17-65	23A	25.8		22A	10.1
	16D	25.2	12-17-66	16C	5.2
	8C	25.7		23D	4.5
	22A	25.2		15C	4.2
5-27-66	17A	19.0	3-11-67	1	5.1
	11	20.4		22A	4.9
	19	20.8		24A	4.5
	24A	20.8			

Temperature classically has been used in large scale distributional studies (Hutchins, 1947; Ekman, 1953).

Within the test area, the salinity of the water varies. This variability is a function of the tidal stage, position within the Bay, and meteorological conditions. Average bottom salinities vary between about 23‰ and 29‰, while the ranges are between 18‰ and 30.5‰. Since the salinity regime at any point within the area investigated is variable, and since there is considerable overlap in the salinity among different stations, it is probable that salinity is not a major directing parameter in the distribution of many of the benthic invertebrates in this study. Through the course of evolution, estuarine forms have become physiologically adapted to the variation experienced in certain environmental parameters. As a result of these adaptations, many estuarine forms are euryhaline.

Salinity and temperature do exert important roles in the distribution of organisms. Jones (1950) lists these two parameters as prime factors in determining distribution; however, their influence is best demonstrated where significant gradients exist. In situations involving minor oscillations about some mean value, the likelihood of demonstrating direct effects on organismal distributions within localized areas is probably small.

If salinity and/or temperature are not directing the distribution of organisms within the Bay, then some factor(s) must be operating since the spatial arrangement of animals is not homogoneous. The described distributions could be due purely to chance; but, if so, then one would expect more of a randomized distribution, especially among the most characteristic animals. Tables VIII, IX, XIV, and XV show that a randomized distribution is not apparent. Some factor other than chance must then be operating. The possibilities of directing factors become quite broad: dissolved oxygen, specific chemical in the water/substrate, turbidity, depth (pressure), and others. One aspect of benthic ecology which has received some study is that of the relationship between the organism and its substrate. Jones (1950) considers the substrate as the third directing force for the benthos, along with temperature and salinity.

The preference of different animals for different bottom types has been demonstrated for larval types (Lynch, 1959; Scheltema, 1961; Thorson, 1957; and Wilson, 1952) and adults (Chapman and Newell, 1949). Actual influence of the substrate on metamorphosis of larvae and distribution of mobile benthic forms remains to be demonstrated in many species. An excellent introductory discussion of the "attractiveness" of substrate is presented in Thorson (1957).

The nature of the substrate is a reflection of other parameters such as current velocity, distance from sediment source, and biological activity within the particular area. As a result of these external modifications, the substrate *per se* may not exert direct influence on the biota that may reside within or upon the bottom. Under such circumstances the particle size composition of the substrate may still be used for characterizing the type of associated biota as long as it is realized that the composition is a secondary characterization. The precise governing factor that determines a substrate's suitability for colonization is unknown. In all probability there is no one factor, rather a series of chemical/physical interactions combined to determine what taxa, if any, are capable of adapting to that particular environment.

Sanders (1956, 1958) demonstrated a relationship between sediment type and feeding type in two subtidal areas. In these studies, infaunal suspension feeders were most prominent in fine sands, while deposit feeding forms were more characteristic of sediment rich in silt and clay-sized particles. Harrison et. al. (1964) indicate "slight tendencies" for similar findings in Chesapeake Bay. Hank's (1964) community was dominated by deposit feeders, a finding which further supports Sanders' characterizations since the Sheepscot study site was 90% silt and clay. Inspection of Stickney and Stringer's (1957) data shows additional agreement with Sanders. This relationship, as Sanders et. al. (1962) point out, is based on the availability of food more than the actual particle size composition of the sediment.

In Barnegat Bay, the sandy areas, supposedly dominated by suspension feeders, are characterized by *Tellina agilis*, a deposit feeder. Such findings are in opposition to Sanders' (1956, 1958) generalizations concerning feeding types and associated substrates. The repeated findings of

Tellina in sandy areas of the Bay, and the recurrent densities at any station indicate that the observed results are valid and are not isolated incidents. Actually, Tellina was the second most common bivalve found by Sanders (1958) in the sandy sediments of Buzzards Bay. The recorded densities (Table 3. Sanders, 1958) of the clam are comparable to those of this study, but Tellina's contribution to the sandy assemblages was overshadowed by Cerastoderma (Family Cardidae), a filter feeder. The distribution of Tellina is not anomalous in this study; as mentioned earlier, Tellina is characteristic of sands.

An explanation of the apparent paradox of Tellina's distribution may reside in the stability of the substrate and colonization of the sand particle surfaces by benthic unicellular algae. Assuming a stable substrate, an initial innoculum of algae and favorable light penetrati on, an algal population might be established which could serve as an energy source for the deposit feeders. The faster turnover rates of the algae might be sufficient to maintain the deposit feeders. If such were the case, then the level of organic matter at any time would not be a valid parameter on which to base a prediction concerning feeding type. In such a situation, correlations would be better calculated by chlorophyll concentration (Sanders, et. al., 1962).

The ability of Tellina to burrow rapidly permits successful colonization of sandy areas. Dislodgment by currents associated with sand bottoms could eliminate populations of organisms unable to rapidly relocate within the substrate.

IV. Temporal Distribution

During the course of the investigation samples were taken during 34 months of the study period (46 months). The composite first third of the calendar years has the poorest representation in sampling. Of a possible 15 sample months (Table XX) during the period January through April, only 7 months were actually sampled. January and April were both sampled only in 1968. Ice cover, storm systems, and mechanical malfunction contributed to the rather patchy sampling periodicity during the early part of the years. The time course of May through December has a better record of sampling frequency, with 27 of the possible 31 months investigated.

The period of May through October is the best sampled span during the year. The largest numbers of species are recorded during this interval (Tables XX and XXI) with an observed range of 54 (May) to 87 (July) species. The probability exists that there were additional species which were not captured during May because the sampling frequency was not as great as during the summer months. This is probably also true for August and September during which the sampling intensity was not as great as during June and July.

Dividing the monthly records into epi- and infaunal components (Table XXI) does not contribute greatly to defining any patterns. Both faunistic portions have their

Table XX. Numbers of benthic invertebrate species collected monthly. Figures within parentheses represent total number of different species found during that month for the four-year study. The final column is the average number of species recorded per station.

	1965	1966	1967	1968	1969	$\bar{x}$/station
Jan		--	--	19	--	4.8
Feb (48)		--	16	--	47	5.3
Mar (52)		--	27	32	17	4.7
Apr		--	--	40		13.3
May (54)		22	22	46		6.0
Jun (79)	37	49	59	69		1.4
Jul (87)	65	61	59	64		1.1
Aug (69)	39	33	51	46		2.2
Sep (65)	11	42	--	44		3.4
Oct (85)	24	47	41	60		3.0
Nov (31)	14	25	--	--		3.4
Dec (61)	--	15	49	34		3.4

Table XXI. Epifaunal and infaunal components of benthic invertebrates collected within months.

	1965		1966		1967		1968		1969	
	E*	I*	E	I	E	I	E	I	E	I
JAN	--	--	--	--	--	--	12	7	--	--
FEB	--	--	--	--	8	8	--	--	22	25
MAR	--	--	--	--	16	11	21	11	5	12
APR	--	--	--	--	--	--	19	21	--	--
MAY	--	--	13	7	16	6	20	26	--	--
JUN	22	15	32	17	34	25	36	33	--	--
JUL	36	29	31	30	28	31	28	36	--	--
AUG	26	13	16	17	27	24	20	26	--	--
SEP	1	10	23	19	--	--	17	27	--	--
OCT	15	9	28	19	27	24	23	37	--	--
NOV	11	3	16	9	--	--	--	--	--	--
DEC	--	--	13	2	24	25	14	20	--	--

* E - numbers of epifaunal species
I - numbers of infaunal species

greatest representation during June, July, and August, the most intensely sampled months. Among these 12 sampling months (4-years' data), the number of epifaunal species always surpassed the number of infauna during June, while the two fractions were equally represented in July and August.

As a generality, the number of species recorded decreased during the remainder of the year from September to May. Some of this decrease may be due to emigration, but much would have to be attributed to decreased collecting and efficiency, especially during the colder months. The last column of Table XX presents the number of species recorded during a month on the basis of the number of stations made during that month. This technique, while not solving the problem of skewed sampling, at least approximates average values. Some temporal variation is to be expected since the animals respond to the changing environmental regimes. During the colder periods the more mobile members of the epibenthos may move into oceanic water which normally does not become as cold as the more isolated bay system. Some organisms may form overwintering bodies or stages which are more resistant to cold than the parental form.

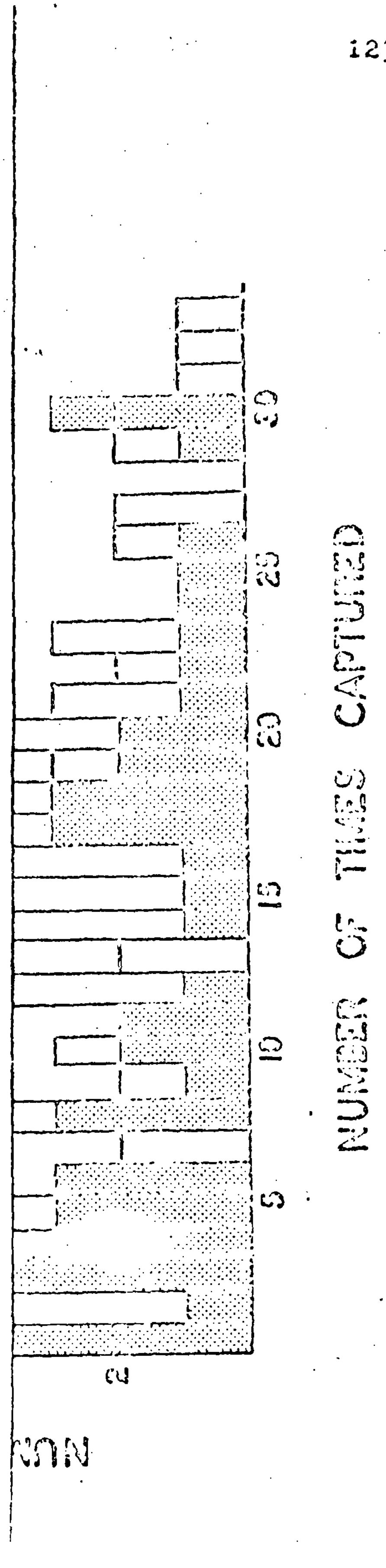
Infaunal organisms by their nature cannot get up and leave their habitats. Burrowing deeper into the substrate is the only escape mechanism available to such animals.

Since the actual number of samples collected within a particular month was variable, a direct monthly comparison of species richness would be somewhat dubious. A greater number of samples might result in an increased number of species—this assumes that the species-area curve (Gleason, 1922) has not peaked out. The areas studied during a particular time period will also influence the number of species found. One station made at a qualitatively rich area (large number of species) might surpass the cumulative number of species collected at a multiple of poorer areas.

A graphical presentation of the repetition in temporal capture pattern is given in Figure 13. The resultant pattern is similar to the general relationship in species-numbers within communities. There were several species which appeared infrequently, while only a few species were encountered regularly. No single species appeared during every collecting trip over the 34 months of the investigation.

Sixty-one species, or 55% of the total number, appeared one-third of the time or less. Only 13 species (1.2%) were taken more than two-thirds of the time. Of the latter group, 7 species were epifaunal. The mobility of these forms may play an important role in the temporal as well as the spatial distribution of these organisms. The most frequently found epifaunal species are _Mitrella lunata_ (recorded during 33 months), _Crangon septemspinosus_ (32 months), _Idotea baltica_ (31 months), _Palaemonetes vulgaris_ (29 months), _Neopanope texana_ (27 months), _Asterias forbesi_ (27 months) and _Eupleura caudata_ (26 months).

Figure 13. The number of species that appeared during a specified number of months (out of 34 months of sampling). Shaded portion of bars represents number of infaunal species; unshaded portion corresponds to number of epifaunal species.



species that appeared during a
er of months (out of 34 months of
aded portion of bars represents
unal species; unshaded portion
number of epifaunal species.

The temporally most commonly encountered infauna included the lamellibranchs Mulinia lateralis and Tellina agilis (both 30 months), Cyathura polita (30 months), Pectinaria gouldii (29 months), Glycera dibranchiata (26 months), and Maldanopsis elongata (25 months).

Table VII presents a monthly appearance register of the benthos. This represents a condensation of the 34 collecting months. Six species appeared every month throughout the year. As might be expected, all of these are included among the most commonly encountered animals. The six are Crangon, Cyathura, Idotea, Mitrella, Palaemonetes, and Pectinaria. Ten other species have been recorded during 11 months of the year. Five of these—Asterias, Maldanopsis, Mulinia, Neopanope, and Tellina—are included among the most commonly taken forms. The other 5 species which appeared during 11 of the 12 months include Erichsonella filiformis, Halichondria bowerbanki, Laevicardium mortoni, Pagurus longicarpus, and Scoloplos armiger. These 5 latter forms appeared between one-third and two-thirds of the total number of months investigated.

It is highly probable that the 10 species which appear during 11 months are present during the entire year. Seven of these 10 were not recorded during January. It is unlikely that all the organisms would migrate to the ocean even though January is the coldest month (average bottom temperature is about 2°C.—Taylor, Fig. 8, 1970). The bay system begins gradual warming so that the average temperature by late

February is above the offshore waters. Three of the genera not recorded in January are infaunal (Maldanopsis, Mulinia, and Tellina) and Halichondria is an attached epi-benthic form so these forms could not leave. Since January is one of the poorest sampled months, it is fairly safe to assume that many, if not most or all, of these organisms were present but simply were not collected in the limited sampling program.

There were 10 species which appeared 10 of the 12 months. Two of these were Eupleura caudata and Glycera dibranchiata which were among the best represented species in total number of months captured. Both of these were not encountered during January and November. Among the other 8 species within this category (10 out of 12 months), 6 were not taken during January; these were Bugula turrita, Hydroides dianthus, Notomastus latericeus, Retusa canaliculata, Solemya velum, and Turbonilla sp. November was not a heavily sampled month so there were a number of missing species; Hydroides and Retusa were missing as well as Lyonsia hyalina and Molgula manhattensis.

As with the species lacking during one month, it is likely that the ones missing during two months are also present year round. Their absence is probably a result of the reduced sampling effort during January and later in November. Since none of the genera within this category was absent for a two-month span, it is likely that the organisms were present throughout the entire year. More sampling, or perhaps sampling different localities, would have filled in the temporal gaps.

The proposed filling-in of temporal appearance gaps could be carried further, but naturally this becomes more tenuous as one attempts to fill in more and more gaps. There are other organisms that could be chosen as reference levels for a complete year study. Mercenaria mercenaria and Nassarius obsoletus, which appeared nine and eight months respectively, would probably serve as reliable species in a temporal distribution study. The gaps in their apparent temporal distribution are probably indices that the areas in which they were commonly found were not sampled, rather than these organisms being absent from the Bay during certain months.

For predictive purposes or establishing base indices for future studies, the most logical choices of species are the 26 that appear during 10 or more months during the year. These are the first 26 species listed in Table VII. The present environmental parameters are such that these organisms can maintain themselves year round. Provided no changes occur within the study area, these species should continue to exist throughout the year. Any subsequent study which reveals other species temporally as widespread as the 26 listed would not be surprising for the reason listed earlier—certain months are not well represented in this study, especially January. If January had been investigated more, there probably would have been several more species registered in the year-round category.

CONCLUSION

1. As a result of 304 quantitative samples taken over a four-year span, 110 species of benthic macroinvertebrates were collected from the central portion of Barnegat Bay.

2. Only four species were recorded from at least 50% of the sampling stations. Temporally, there were only six species that appeared during every calendar month of the year. It is suggested that there were at least an additional 20 species within the year-round category.

3. The organisms found were typical of "soft bottom" environments. The substrate of the Bay was predominantly finer sands east of the Intracoastal Waterway and "mud" west of the Waterway.

4. *Tellina agilis*, a deposit feeding lamellibranch, was the characteristic organism of sandy substrates; this finding is in contrast to the classic description of filter feeders dominating sand areas. No characterizing animal or pair of animals was found for the muddy regions.

5. *Pectinaria gouldii*, a polychaete, was widely distributed within both major substrate types. It is suggested that this species would be a good indicator organism to monitor pollution.

6. The species diversity, measured by two techniques, was similar among the major sampling sites. There was

significant overlap between the two indices among the samples even though there were qualitative and quantitative differences among the samples. The "richest" areas (greatest numbers of species) were located at the mouths of Forked River and Oyster Creek.

7. Although there was considerable variation among the data, a significant correlation (P=0.001 level) was found between the percentage of silt-clay material and the amount of organic material present in the sediments.

8. Comparison of the Petersen and Ponar quantitative bottom dredges indicated that the two tools were not significantly different in the volumes captured in sandy environments.

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Appendix
Table Ia. Yearly sediment size distribution of collecting stations sampled at least three years. The particle size data are the percentage weights of the different size classes. In the column labeled "Particle Size" the figures represent the lower limit of each size class with the exception of the silt-clay fraction (-62). In the tabular presentation of the related sedimentary characteristics the median grain diameter (M_2), the first quartile (Q_1), and the third quartile (Q_3) values are given in microns. The sorting coefficient (S_o) and the skewness (S_k) are dimensionless.

Station I-1, Light 1, Quadrate 21-D
"North" off Stouts Creek.

Particle Size μ	1965	1966	1968	1969
2000	6.50%	0.00%	0.15%	0.10%
1000	3.80	0.50	0.30	0.60
500	4.40	8.80	6.25	2.45
250	5.00	8.00	5.90	6.40
125	7.90	9.60	7.90	8.55
62	24.10	15.40	24.85	23.55
-62	48.10	57.50	54.35	58.30
M_2	64	45	58	49
Q_1	22	18	28	24
Q_3	150	145	105	98
S_o	2.61	2.84	1.94	2.02
S_k	7.18	7.62	7.12	6.93

(Table Ia continued)

Station II-1, Quadrate 22-B, Light 19

Particle Size μ	1965	1968	1969
2000	-- %	0.30%	0.10%
1000	1.90	1.15	1.70
500	21.00	7.65	8.50
250	14.60	8.40	11.40
125	12.80	11.95	12.90
62	13.30	24.85	18.45
-62	36.30	45.35	46.85
M_2	130	72	69
Q_1	28	35	26
Q_3	470	160	208
S_o	4.09	2.14	2.83
S_k	10.07	8.82	8.85

Station II-2, Quadrate 22-B, Light 12

Particle Size μ	1965	1968	1969
2000	4.20%	21.75%	1.95%
1000	6.60	9.70	1.15
500	10.50	9.80	15.00
250	10.60	7.75	13.25
125	12.90	8.45	10.85
62	24.90	14.40	15.90
-62	30.00	28.10	42.05
M_2	108	230	87
Q_1	55	54	18
Q_3	400	1550	345
S_o	2.70	5.36	4.32
S_k	14.27	19.10	8.56

(Table Ia continued)

Station II-3, Quadrate 22-A, Light 4
800 yards east of Light 12

Particle Size μ	1965	1966	1967	1968
2000	0.20%	0.95%	0.20%	0.30%
1000	1.20	1.00	3.10	1.75
500	22.90	16.10	31.55	15.70
250	45.50	41.75	57.65	38.50
125	12.30	14.65	5.15	15.20
62	10.20	10.70	1.70	17.65
-62	7.60	14.70	0.65	10.85
M_2	335	340	415	280
Q_1	195	120	310	105
Q_3	500	455	610	495
S_o	1.60	2.01	1.40	2.17
S_k	17.06	13.08	21.30	13.60

Station II-4

Particle Size μ	1965	1967	1969
2000	2.30%	6.00%	0.30%
1000	1.30	7.20	0.25
500	14.80	9.10	5.00
250	20.40	16.30	39.30
125	24.20	22.00	25.50
62	20.40	19.80	17.00
-62	16.50	19.70	12.65
M_2	180	178	218
Q_1	93	75	106
Q_3	470	430	360
S_o	2.25	2.39	1.84
S_k	15.58	13.47	13.23

(Table Ia continued)

Station II-5

Particle Size μ	1965	1967	1969
2000	0.40%	0.10%	0.10%
1000	3.10	0.40	0.25
500	3.70	1.80	1.60
250	6.10	5.70	2.20
125	24.30	9.00	5.60
62	49.80	48.50	54.50
-62	12.30	34.20	35.90
M_2	105	77	75
Q_1	73	35	47
Q_3	180	112	104
S_o	1.57	1.79	1.49
S_k	11.19	7.14	8.07

Station II-7

Particle Size μ	1965	1967	1969
2000	0.80%	0.30%	0.70%
1000	0.70	0.20	1.00
500	1.40	0.70	1.15
250	6.30	11.70	2.45
125	59.90	80.40	63.35
62	25.30	6.80	25.80
-62	5.10	0.40	4.60
M_2	155	180	155
Q_1	115	145	108
Q_3	207	225	203
S_o	1.34	1.25	1.37
S_k	12.39	13.47	11.89

(Table Ia continued)

Station II-9

Particle Size μ	1965	1967	1969
2000	0.50%	0.60%	0.40%
1000	0.70	0.60	0.80
500	1.40	3.10	1.55
250	11.00	22.70	10.40
125	59.50	57.20	63.95
62	22.60	14.20	21.50
-62	1.80	1.70	1.50
M_2	170	190	168
Q_1	126	148	128
Q_3	227	260	220
S_o	1.34	1.33	1.31
S_k	12.97	14.23	12.95

Station III-1, Quadrate 23-A
150 yards inside mouth of Oyster Creek

Particle Size μ	1965	1967 a	1967 b	1968	1969
4000	0.00%	0.00%	0.00%	0.00%	0.00%
2000	0.00	0.10	0.15	0.00	1.20
1000	0.30	3.40	0.10	0.00	0.50
500	1.10	4.70	1.60	6.30	4.15
250	2.60	5.80	9.85	12.05	13.85
125	4.50	13.40	16.35	16.25	17.55
62	13.00	33.90	33.70	32.90	26.95
-62	76.80	38.70	38.00	32.25	35.75
M_2	24		79	92	88
Q_1	19		37	30	33
Q_3	54		135	175	199
S_o	1.98		1.91	2.42	2.45
S_k	6.54		7.95	7.55	8.64

(Table Ia continued)

Station III-2, Light 3

Particle Size μ	1965	1966	1967 a	1967 b	1968	1969
4000	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%
2000	0.70	0.45	4.90	1.20	0.25	0.90
1000	0.90	1.15	1.10	4.20	0.60	1.35
500	5.40	6.45	4.50	36.10	1.20	13.20
250	18.70	12.65	30.10	33.60	2.50	34.65
125	16.30	8.10	43.30	7.40	4.50	18.70
62	39.40	40.65	8.30	9.70	43.95	20.10
-62	17.90	30.25	8.00	7.70	47.05	11.25
M_2	109	94	215	425	67	252
Q_1	68	62	145	250	38	103
Q_3	268	180	365	690	98	415
S_o	1.98	1.70	1.58	1.66	1.61	2.01
S_k	12.93	10.90	15.70	20.10	7.45	13.02

Bouy C-1

Particle Size μ	1966 a	1966 b	1967	1968	1969
2000	0.25%	0.10%	0.40%	0.80%	0.30%
1000	1.00	0.80	0.65	1.35	0.60
500	12.80	9.70	2.25	9.15	6.45
250	49.50	27.10	12.50	11.65	34.25
125	21.70	18.50	26.85	14.60	31.45
62	6.20	16.10	28.75	43.75	10.55
-62	8.30	27.60	28.30	18.45	16.65
M_2	310	160	110	100	210
Q_1	185	54	46	69	118
Q_3	445	345	198	220	320
S_o	1.55		2.07	1.78	1.65
S_k	16.30		9.09	12.30	13.41

(Table Ia continued)

Bouy D

Particle Size μ	1966	1968	1969
2000	0.30%	0.00%	0.00%
1000	2.90	0.00	0.10
500	8.80	7.70	1.70
250	13.52	12.45	16.45
125	16.32	14.35	15.70
62	21.20	47.75	29.60
-62	37.42	17.80	36.40
M_2	90	100	81
Q_1	42	69	36
Q_3	260	190	176
S_o	2.49	1.66	2.23
S_k	11.01	11.50	8.78

Bouy D1

Particle Size μ	1966	1968	1969
2000	0.00%	0.15%	0.05%
1000	3.80	2.65	0.10
500	8.80	24.70	11.50
250	24.20	47.25	35.80
125	12.85	12.45	21.40
62	21.40	6.55	15.60
-62	13.95	6.05	15.50
M_2	145	360	230
Q_1	66	245	99
Q_3	370	510	380
S_o	2.37	1.44	1.96
S_k	12.98	18.60	12.79

(Table Ia continued)

Bouy E

Particle Size μ	1966	1968	1969
2000	0.20%	0.20%	0.10%
1000	2.35	0.30	0.55
500	13.30	3.70	4.40
250	20.65	25.90	21.05
125	14.90	22.85	25.30
62	24.30	33.90	26.00
-62	24.70	12.95	22.50
M_2	135	135	130
Q_1	66	80	68
Q_3	380	270	258
S_o	2.40	1.84	1.95
S_k	13.63	12.65	11.62

Bouy E-1

Particle Size μ	1966	1967	1968	1969
2000	0.47%	0.30%	0.00%	0.70%
1000	0.97	1.90	0.00	0.85
500	3.77	1.80	2.20	3.35
250	14.12	2.30	15.50	8.75
125	44.92	40.60	16.10	14.45
62	21.30	46.10	48.00	47.40
-62	14.25	7.40	18.35	24.55
M_2	170	120	100	91
Q_1	96	80	69	62
Q_3	245	182	175	140
S_o	1.60	1.51	1.59	1.50
S_k	11.76	11.01	11.00	9.77

(Table Ia continued)

Bouy F, Quadrate 17-C

Particle Size μ	1966	1967	1968	1969
2000	0.15%	0.30%	0.10%	0.15%
1000	0.45	0.20	0.55	0.45
500	0.70	0.70	0.85	0.75
250	1.70	1.90	1.60	0.95
125	9.95	15.40	12.05	6.85
62	71.30	68.30	70.95	72.25
-62	15.60	13.40	14.00	18.60
M_2	86	90	88	86
Q_1	68	70	72	68
Q_3	110	118	110	109
S_o	1.27	1.30	1.24	1.26
S_k	9.32	9.58	9.45	9.28

Bouy G

Particle Size μ	1966	1967	1968	1969
2000	0.00%	0.10%	0.15%	0.35%
1000	0.50	0.10	0.30	0.25
500	0.90	0.60	0.65	0.30
250	1.90	1.30	1.30	0.70
125	17.30	11.70	23.80	12.10
62	66.70	71.40	64.75	74.10
-62	12.30	14.80	8.90	12.10
M_2	92	88	98	90
Q_1	71	69	76	72
Q_3	120	113	125	114
S_o	1.30	1.28	1.28	1.26
S_k	9.62	9.41	9.85	9.55

(Table Ia continued)

Light 1 South

Particle Size μ	1966	1968	1969
2000	0.60%	1.20%	1.35%
1000	0.45	1.30	0.90
500	0.80	1.00	1.30
250	1.60	1.45	2.10
125	26.20	30.35	31.15
62	61.65	57.05	58.25
-62	8.45	7.40	4.85
M_2	96	108	108
Q_1	73	84	80
Q_3	130	133	165
S_o	1.33	1.26	1.44
S_k	9.32	10.15	11.05

Table Ib. Sediment size distribution of collecting stations sampled twice. Explanation is the same as in Table

Particle Size μ	Sta. I-2 Quad. 14C 1965	Sta. I-2 Quad. 14C 1969	Sta. I-2 Quad. 14D 1965	Sta. I-2 Quad. 14D 1969
4000	2.90	0.00	0.00	0.00
2000	2.60	0.00	0.40	0.10
1000	2.70	0.20	0.40	0.25
500	2.40	1.20	0.70	0.45
250	8.80	10.30	4.40	1.35
125	71.00	15.45	84.60	50.75
62	7.60	36.00	8.50	34.90
-62	2.00	37.00	1.00	12.10
M_2	180	75	175	132
Q_1	145	43	140	80
Q_3	235	132	215	184
S_o	1.30	1.75	1.20	1.52
S_k	13.76	8.69	13.11	10.56

Particle Size μ	Sta. I-4 Quad. 7 1965	Sta. I-4 Quad. 7 1969	Sta. I-5 Quad. 7 1965	Sta. I-5 Quad. 7 1969
4000	0.30	0.00	0.00	0.00
2000	0.40	0.05	0.20	0.35
1000	0.40	0.09	0.50	0.70
500	1.00	1.23	2.00	0.90
250	14.50	3.04	24.10	9.00
125	75.30	37.00	64.60	79.10
62	7.10	37.64	7.20	9.25
-62	0.70	20.80	1.30	0.70
M_2	185	115	195	178
Q_1	150	76	150	143
Q_3	230	178	255	222
S_o	1.20	1.53	1.30	1.25
S_k	13.66	10.85	14.00	13.35

(Table Ib continued)

Particle Size μ	Sta. I-6 Quad. 7 1965	1969	Sta. II-6 Quad. 8C 1965	1969
4000	0.00	--	0.60	--
2000	0.10	0.10	0.30	0.05
1000	0.40	0.60	0.70	0.20
500	2.00	0.75	1.00	0.55
250	25.70	6.30	4.40	1.10
125	59.80	78.50	69.90	56.00
62	11.10	11.15	21.80	39.75
-62	1.00	2.45	1.30	2.60
M_2	195	172	163	138
Q_1	145	138	127	93
Q_3	265	215	210	188
S_o	1.35	1.25	1.28	1.42
S_k	14.04	13.13	12.79	11.26

Particle Size μ	Sta. II-7 Quad. 8AD 1965	1969	Sta. II-9 Quad. 1 1965	1969
4000	0.00	--	2.50	--
2000	0.80	0.70	0.50	0.40
1000	0.70	1.00	0.70	0.80
500	1.40	1.15	1.40	1.55
250	6.30	2.45	11.00	10.40
125	59.90	63.35	59.50	63.95
62	25.30	25.80	22.60	21.50
-62	5.10	4.60	1.80	1.50
M_2	155	155	170	168
Q_1	115	108	126	128
Q_3	207	203	227	220
S_o	1.34	1.37	1.34	1.31
S_k	12.39	11.89	12.97	12.95

(Table Ib continued)

Particle Size μ	Sta. III-4 Quad. 16D 1965	Sta. III-4 Quad. 16D 1969	Sta. III-5 Quad. 16D 1965	Sta. III-5 Quad. 16D 1969
4000	0.55	--	0.60	--
2000	0.90	0.15	0.40	0.25
1000	1.60	0.50	0.70	0.55
500	1.75	0.95	1.10	0.40
250	6.00	2.70	5.90	3.10
125	71.85	83.40	61.80	74.50
62	15.00	10.70	22.70	18.15
-62	2.15	1.50	6.50	3.15
M_2	170	174	160	163
Q_1	138	140	118	130
Q_3	218	215	210	205
S_o	1.26	1.24	1.33	1.26
S_k	13.30	13.15	12.44	12.79

Part. Size μ	Station III-6 Quadrate 9C 1965	Station III-6 Quadrate 9C 1969	Station FRC* Quadrate 22A 1968	Station FRC* Quadrate 22A 1969	Station OCC** Quadrate 23D 1968	Station OCC** Quadrate 23D 1969
4000	1.10	--	--	--	--	--
2000	1.40	0.90	0.25	0.15	4.45	1.35
1000	1.90	1.00	0.40	0.65	2.50	7.80
500	3.25	1.30	1.90	5.90	4.75	51.00
250	13.65	32.30	6.95	7.45	6.65	28.80
125	48.80	55.85	8.95	8.40	25.35	2.60
62	23.15	7.00	25.90	27.55	35.60	3.65
-62	6.65	1.65	55.65	49.90	20.85	4.65
M_2	170	210	48	62	112	580
Q_1	117	154	29	31	70	385
Q_3	240	294	98	116	195	770
S_o	1.43	1.38	1.84	1.93	1.67	1.41
S_k	12.85	14.68	7.70	7.62	11.00	22.61

Appendix.
Table II. Mean density (number/meter^2) and observed density ranges of major invertebrates recorded quantitatively from principle sampling stations, Barnegat Bay.

Species	Mean Density	Observed Range
QUADRATE 8C, LIGHT 2		
Idotea baltica	12	6- 27
Mitrella lunata	14	9- 18
Mulinia lateralis	18	5- 40
Neopanope texana	6	1- 10
Pectinaria gouldii	7	1- 14
Tellina agilis	26	15- 46
QUADRATE 11, LIGHT 1-So.		
Clymenella torquata	19	1- 34
Crangon septemspinosus	4	1- 9
Ensis directus	2	2- 3
Idotea baltica	4	1- 6
Neopanope texana	10	4- 23
Scoloplos armiger	14	1- 30
Solemya velum	12	9- 18
Sthenelais limicola	5	4- 7
Tellina agilis	98	55-144
QUADRATE 13A, BOUY C1		
Clymenella torquata	49	17- 76
Cyathura polita	18	5- 40
Diopatra cuprea	49	7-126
Maldanopsis elongata	94	8-182
Mulinia lateralis	63	5-170
Pectinaria gouldii	15	3- 32
QUADRATE 14B, BOUY D		
Cyathura polita	16	6- 37
Glycera dibranchiata	22	8- 38
Pectinaria gouldii	22	2- 57
QUADRATE 15B, BOUY E		
Clymenella torquata	145	13-290
Cyathura polita	33	9- 50
Diopatra cuprea	20	3- 38
Maldanopsis elongata	50	14-105
Notomastus latericeus	22	20- 24
Pectinaria gouldii	83	14-217
QUADRATE 15C, BOUY D1		
Glycera dibranchiata	13	3- 31
Tellina agilis	40	3- 84

(Appendix Table II. continued)

Species	Mean Density	Observed Range
QUADRATE 17A, BOUY G		
Cyathura polita	44	6- 56
Mulinia lateralis	35	4-160
Pectinaria gouldii	11	3- 20
Solemya velum	13	5- 32
Tellina agilis	73	41-122
QUADRATE 17C, BOUY F		
Ampelisca macrocephala	17	3- 60
Clymenella torquata	11	1- 35
Cyathura polita	8	2- 18
Glycera dibranchiata	9	1- 15
Mulinia lateralis	11	2- 41
Pectinaria gouldii	33	3- 84
Solemya velum	11	2- 33
Tellina agilis	204	69-336
QUADRATE 21D, TRANSECT I-1		
Eupleura caudata	5	2- 8
Glycera dibranchiata	8	6- 12
Maldanopsis elongata	58	21- 77
Mulinia lateralis	45	2-105
Pectinaria gouldii	92	49-176
QUADRATE 22A, LIGHT 4		
Clymenella torquata	15	1- 47
Cyathura polita	13	1- 52
Glycera dibranchiata	8	2- 19
Mulinia lateralis	57	7-318
Pectinaria gouldii	100	3-325
Tellina agilis	80	8-306
QUADRATE 22A, FORKED RIVER CHANNEL		
Clymenella torquata	47	3-188
Cyathura polita	17	4- 29
Glycera dibranchiata	15	7- 21
Maldanopsis elongata	63	9-156
Pectinaria gouldii	303	40-1200
QUADRATE 22B, LIGHT 12		
Botryllus schlosseri	--	--
Cirratulus grandis	34	9- 55
Cyathura polita	23	4- 40
Nassarius obsoletus	155	9-156
Nereis succinea	19	17- 20
Pectinaria gouldii	11	4- 20
Rhithropanopeus harrisi	1	1- 2

(Appendix Table II. continued)

Species	Mean Density	Observed Range
QUADRATE 23A, TRANSECT III-1		
Glycera dibranchiata	2	1- 3
Mulinia lateralis	115	45-180
Nassarius obsoletus	32	17- 64
QUADRATE 23D, OYSTER CREEK CHANNEL		
Cyathura polita	18	4- 33
Mercenaria mercenaria	3	3- 4
Nassarius obsoletus	176	5-740
Pectinaria gouldii	150	48-351
Scoloplos armiger	4	2- 7
QUADRATE 23D, LIGHT 3		
Crangon septemspinosus	6	2- 12
Eupleura caudata	6	1- 11
Mitrella lunata	34	2-150
Mulinia lateralis	82	1-192
Pectinaria gouldii	163	2-700
Tellina agilis	40	9- 93
QUADRATE 23D, BOUY J		
Ampelisca macrocephala	19	4- 43
Cyathura polita	8	4- 16
Eupleura caudata	11	1- 23
Mercenaria mercenaria	5	1- 13
Pectinaria gouldii	89	30-200
Tellina agilis	63	14- 82

Francis Xavier Phillips

[redacted]

1959	Graduated from Camden Catholic High School, Camden, New Jersey
1959-1960	Attended Villanova University, Villanova, Pennsylvania
1960-1964	Attended Rutgers College of South Jersey, Camden, New Jersey
1961-1963	Summer research assistant—Dr. J. B. Durand, R.C.S.J.
1964	January: Graduated Rutgers University (C.S.J.) A.B., Natural Sciences
1964-1965	Research technician, Colgate Palmolive Company, Piscataway, New Jersey
1964-1971	Graduate student, Department of Zoology, Rutgers University
1965-1966	Teaching assistant, Rutgers College, Rutgers University
1966-1969	Research assistant, Department of Zoology, Rutgers University
1967	Laboratory instructor, Department of Biology, Drew University, New Jersey
1967	M.S., The Graduate School, Rutgers University
1968	Paper Read: "Organization and Distribution of the Benthic Invertebrates of Barnegat Bay." New Jersey Academy of Science
1969-1971	Instructor, Department of Biology, Jacksonville University, Florida
1970	Paper Read: "Urban Pollution and Its Effects on Invertebrate Animals." Florida Academy of Sciences
1971	Assistant Professor, Department of Biology, Jacksonville University, Florida