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

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Report #7 to N. J. Public Utilities Commission

Rutger's University, New Brunswick, New Jersey

Introduction

The current report attempts to summarize much of the data for the past year and at the same time make comparisons with data of previous years. We have relied heavily on statistical procedures in analyzing the data; however, we have attempted to discuss the results as clearly as possible for the non-technical reader. Wherever possible, we have emphatically stated our conclusions, which, we hope, can be debated in an orderly fashion.

The report is similar to previous reports, with one exception in format; we have not listed the biological data extensively, station by station. This data is available in the Department of Zoology at Rutgers University. Much of our data is now on IBM cards for ease of data processing. The hydrographic, physical and chemical data are listed extensively in this report. Additional hydrographic and physical data are on file in the Department of Zoology.

Budget Statement

For the period 1970-71 we were on shaky financial grounds because of uncertanties in the contract. However, recent confirmation of the contract has permitted us to enter this summer with sufficient funds and personnel to continue the contract at its desired level. Our biggest expense has continued to be salary; however, we are also experiencing increasing equipment problems, some of which will need to be replaced soon. We have not prepared a detailed budget report (although an estimate is available) since the principal investigator (and book-keeper) has not been able to obtain budget printouts from the research contract office (due to difficulties with the contract). As soon as a full budget statement for 1970-71 is available it will be sent out as a supplement to this report.

Personnel

Mr. Kent Mountford completed his Ph.D. dissertation and is now employed at the Benedict Estuarine laboratory. His thesis is a comprehensive review of the phytoplankton species and productivity in the vicinity of the JCPL reactor for the period 1968-71. The conclusions of that thesis are included in this report. The thesis is now on file in the Rutgers University library and in the Department of Zoology.

Mr. Phillip Sandine and Mrs. Donna Busch continue as the research assistants in charge of the benthic invertebrates. Both students are finishing up their masters theses.

Mrs. Sylvia Shafto has joined us to replace Kent Mountford during the summer. She is currently assisting Mrs. Busch in the statistical analysis of all data in this study.

Mr. Andrew Marinucci and Miss Jane McCarty are assisting us in sorting and identifying specimens.

R.E. Loveland is taking a years leave in order to improve his knowledge of mathematics at the University of British Columbia. He will be absent from the project from 1 September '71 'till 1 June '72.

Publications and Professional Activities

1. Two short abstracts will be published on the reports of Mrs. Busch (Sand grain selection for tube building in populations of *Pectinaria gouldii* from Barnegat Bay) and Mr. Sandine (Studies of entrainment of Calanoid copepods by a nuclear power plant on Barnegat Bay) in the Bulletin of the N.J. Academy of Sciences. These papers were delivered at the recent annual spring meetings of this society in Princeton, N.J.

2. Both Kent Mountford and Frank Phillips have completed their Ph.D. dissertations on aspects of this project. It is hoped that publications will soon arise out of these theses.

3. K. Mountford, P. Sandine and R. Loveland spent three days in January at the

Entrainment Workshop at Johns Hopkins University in Baltimore, Maryland. It is our opinion that such professional activity is absolutely essential to a continuing understanding of the environmental effects of thermal addition. We made a very strong appeal for investigators to look more into system effects (i.e., how does a power plant alter the estuarine system?) and pay less attention to local effects, which often are disastrous.

Benthic Algae

Fourteen collecting cruises for benthic algae have been made since June 1969. On each of these cruises 9 stations were collected along a transect from just north of Stouts Creek to Buoy G, which is south of Waretown Creek. On each station, a tow of 5 minutes with the "poaching" dredge was made. The entire sample was placed in a plastic bag, preserved and brought to the laboratory for analysis. This sample was in reality a qualitative sample; however, we were able to perform certain quantitative tests on the data. Each sample was sorted to species (generally by Dr. Moul, algal consultant); the wet and dry weight of each species was then obtained.

1) Ordination. Of a total of 74 samples which had been completely sorted, identified and weighed (i.e., there are still 52 samples backlogged), we computed for each species its frequency (percentage distribution) with the set of samples. We were able to do this for 38 species of benthic algae (includes Zostera, which is not an alga, but appears regularly in the samples). The species with the greatest frequency of appearance was ranked number 1, and this ranking was continued for all species. Next we went back to the progress report of March 1969 (5th progress report) and looked up the rank of these 38 species for the period 1965-68. The results of this comparison is given on the following page (Table 1).

It is interesting to note that the species which showed the highest dominance, and therefore ranked high in 1965-68, continue to remain as the dominants in the period 1969-70. Two exceptions are: a) Polysiphonia nigrescens has not been reported at all for 1969-70, yet it was ranked 8th out of 128 species in 1965-68. b) Acrochaetium sp. has also "fallen out of favor" and now ranks 19th. Ulva lactuca continues to rank as the most dominant species of algae. Although we cannot state that it contributes the most biomass (we are still computing biomass data), Ulva is certainly the most probable species of benthic algae one would encounter in our study area. Another noticeable species change seemed to involve Codium fragile, Champia parvula, Enteromorpha intestinalis and Enteromorpha linza. It is obvious that Codium is becoming more dominant in the bay; however, it appears to be increasing at the expense of Champia and the two Enteromorpha species. Codium is one of the heaviest species in wet weight, and thus, very bulky. It may be competing very successfully for space and therefore, excluding, previously common species. One other interesting observation seems to be that very few epiphytic plants grow on Codium. It is reported that after Codium firmly establishes itself in an estuary, it becomes the substrate for other species of benthic algae. We haven't noticed this phenomenon, perhaps because Codium seems to be drifting along the bottom, as are most of the other algal species.

The number of algal species identified in 1969-70 (total = 38) is considerably less than for the period 1965-68 (total = 128). This is because we have spent more time sorting and estimating biomass of the species and less time observing the microalgal forms, such as epiphytes. The decrease in species encountered in Barnegat Bay is thus to be interpreted as a change in technique—we have found no evidence for a drastic loss of algal species in Barnegat Bay.

2) Correlation. The figure titled "Frequency vs frequency", is interesting because it again indicates how the dominant algal species compared for the two time periods. Those species that are above the $\pi/4$ line have become relatively less frequent since 1968, while those that are below the line are relatively more frequent. Gracilaria verrucosa, for example, has moved from 5th in 1965-68 to 2nd in 1969-70. It should be added that many of the species (non-dominants) show almost no correlation between their frequency of distribution in 1965-68 in comparison to 1969-70. The correlation of the minor algae is even more complicated because of the different emphasis on identification and taxonomy between the two periods.

3) Diversity. Since we had complete benthic algae samples from eight months (or a total of 72 samples), which were analyzed for dry weight and species composition, we attempted an analysis of diversity through time and space for the benthic algae. We defined diversity by biomass (dry weight) rather than the number of individuals. Thus for each sample we computed average diversity, maximum diversity and evenness. We then ran a 2-factor analysis of variance (position in bay vs. month) on the data, the results of which are shown in Table 2 and Figs. 2, 3, 4 .

Table 1.

BARNEGAT MACRO ALGAE RANKED ACCORDING TO FREQUENCY OF APPEARANCE, 1965-68 AND 1969-70

RANK 69-70	RANK 65-68	SPECIES	RANK 69-70	RANK 65-68	SPECIES
1	1	Ulva lactuca	20	19	Ceramium rubrum
2	5	Gracilaria verrucosa	21	13	Enteromorpha intest.
3	–	Ulothrix fucca	22	22	Chaetomorpha linum
4	10	Codium fragile	23	29	Spyridia filament
5	3	Ceramium fastigium	24	129	Striatella unipunc.
6	2	Agardhiella tenera	25	52	Rhizoclonium
7	6	Polysiphonia harveyi	26	63	Ascophyllum nodosum/ scorpiodes
8	9	Gracilaria folifera			
9	14	Callithamnion sp.	27	115	Dasya pedicellata
10	4	Champia parvula	28	116	Lomentaria baileyana
11	135	Biddulphia pulchella	29	121	Spermothamnion sp.
12	20	Cladophora sp.	30	124	Calothrix sp.
13	81	Callithamnion corymbosum	31	131	Ruppia maritima
14	12	Polsyphonia denudata	32	134	Agmenellum quadricatum
15	80	Callithamnion byssoides	33	15	Enteromorpha linza
16	25	Callithamnion roseum	34	32/33	Ectocarpus confervoid./ heimalis
17	27	Sphacelaria cirrosa			
18	130	Schizonema gnerelli	35	49	Antithamnion cruciat.
19	7	Acrochaetium sp.	36	74	Ulothrix implexa
			37	111	Callithamnion baileyi
			38	133	Endophytons sp.

NOTE: 1965-68 rank number is assigned from a total of 136 species.

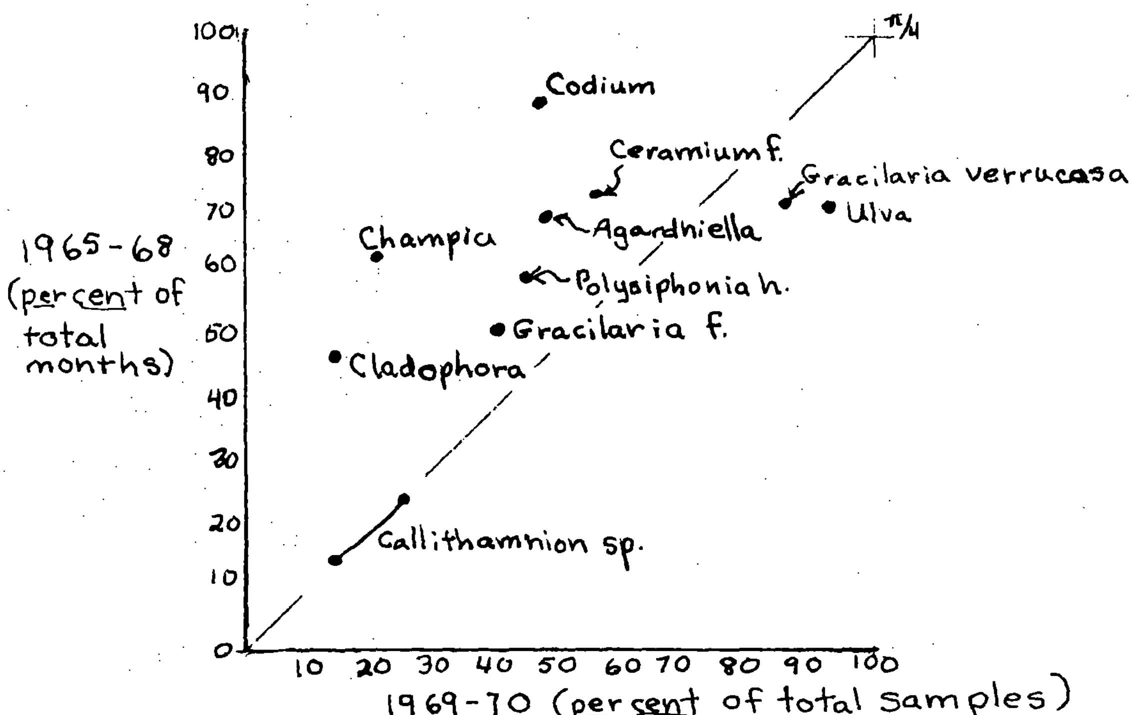
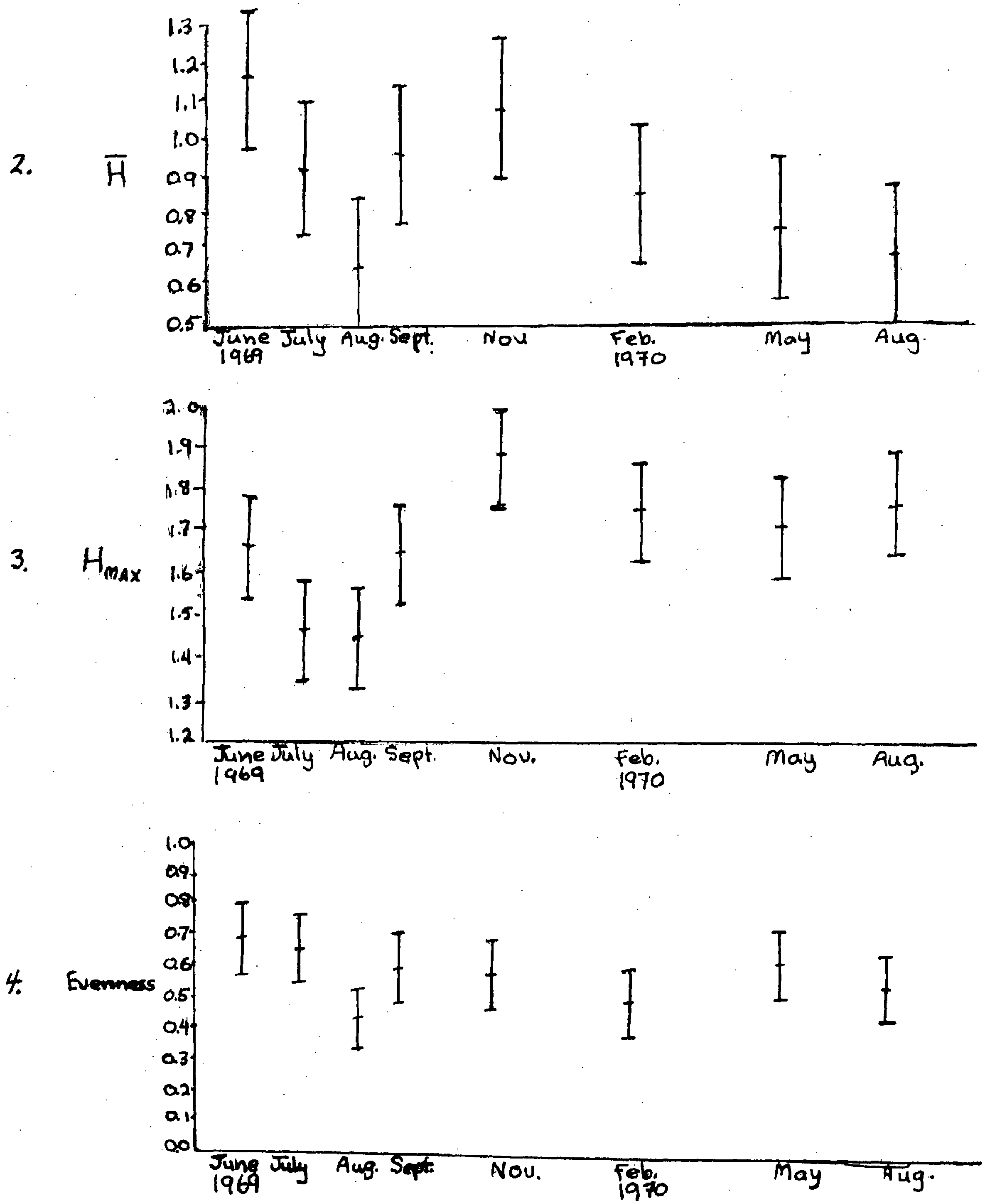


Fig.: 1. Frequency vs. Frequency, for two time periods, of Barnegat Bay most frequent macro algae species.

Table 2.

Position	Diversity	Max. Diver.	Evenness
Stouts Creek	1.0701	1.5291	0.7101
Forked River	0.8673	1.6775	0.5363
Oyster Creek	0.8110	1.6411	0.5106
Waretown Creek	1.0263	1.7345	0.6385
Buoy G.	0.8703	1.7620	0.4878
Month			
June '69	1.1283	1.6547	0.6757
July	0.9068	1.4664	0.6386
Aug.	0.6369	1.4691	0.4389
Sept.	0.9669	1.6292	0.5871
Nov.	1.0822	1.8517	0.5917
Feb. '70	0.8199	1.7372	0.4574
May	0.7537	1.6919	0.4861
Aug.	0.6994	1.7360	0.4023

Grand mean for diversity for all positions for eight months = 0.8743
Grand mean for maximum diversity for all positions and time = 1.6545 (= 5.23 species)
Grand mean for evenness for all positions and time = 0.5360



Figs. 2,3,4 : Mean ± 1si for $\overline{H}$, H_{MAX}, and Evenness, respectively, vs. time (June, 1969 - August, 1970) for macro algae from Barnegat Bay.

As in previous years, we have again found that the number of algal species reaches its lowest value during the warmest months of the year. In fact, no brown algae have ever been recorded from Barnegat Bay during the month of September. The greatest number of species occurs in June and December (Progress Report #5, March 1969); in the current year (1969-70) the same trend appears. From a baywide point of view it appears that there are no significant differences in position (i.e., from one station to another) whether one measures diversity, the number of species, or the contribution of each species to the sample. However, there are significant differences from month to month (as one would expect due to differences in algae abundance with seasons).

It appears that diversity is a good measure of the behavior of benthic algae in Barnegat Bay. Since we cannot quantify algae in any other way, we have some confidence that qualitative collections of benthic algae yield very good estimates of the quantitative behavior of the algae; even though the samples vary in total weight, they don't vary much in relative weight. Maximum diversity (or the number of species) is a poor estimate of the algae behavior, for two reasons: 1) there are a few (~10) dominant species which repeatedly comprise the sample, thus the number of species at any station tends to be small (range: 2 to 8 species); and, 2) the variance in this character is much too large to be dependable. Evenness seems to be the most stable of all the algal characteristics measured; this measure of the contribution of each species to the sample remains very constant over time. We, therefore, conclude that the number of species and the proportion of each species in random samples taken in the study area does not vary significantly from point to point in the bay. Algae in the bay seem to be rather homogeneously distributed. However, communities of algae (i.e., the types of algae comprising the sample) may very well vary. A cluster analysis of species from each station will be attempted soon. With respect to time, the algae populations do vary, as expected, with season--however, they vary equally (i.e., no statistical differences) throughout the bay.

To be perfectly fair in our analysis, we have summarized the month of August both pre-operational (1969) and post-operational (1970) at Oyster Creek (thermally influenced) and Stouts Creek (not thermally influenced) in the following table:

Table 3.

	Oyster Creek		Stouts Creek	
	Aug. '69	Aug., '70	Aug. '69	Aug. '70
Diversity	1.0240	0.8220	0.6880	0.9190
Max. Diversity	1.3860(= 4 spp.)	1.9460(= 7 spp.)	1.3860(=4 spp.)	1.7920(= 6 spp.)
Evenness	0.7390	0.4230	0.4960	0.5130

In this table there is a significant difference (5% level) only in the number of species from August 1969 to August 1970; however, this significance is true for both Oyster Creek and Stouts Creek. Why the number of species increased throughout the bay during the post-operational month of August is not known. We would have predicted that warmer water would have decreased the number of species to a yearly low during July; or, it would have accentuated the normal decrease (see Fig A-2 in Fifth Progress Report, Mrach 1969) during the summer months. Both diversity and evenness remained rather constant at both test areas for August of both years.

Benthic Invertebrates
August 1969 to September 1970:

Although the previous progress report covered the period 15 March 1969 to 1 June 1970, it is important to include the time period August 1969 to September 1970 in this report. During this period the project began a more intensive study of the statistical distribution of benthic invertebrates in Barnegat Bay than in any previous period. Also, the reactor went into operation in December 1969, so the data from this period (Aug. '69 to Sept. '70) represents bay conditions immediately preceding and following operation of the generating facility. It is important to note that the facility was not "on line" continuously during its early operation, however similar analysis of the data for September 1970 to September 1971 will be made for comparison. Mrs. Marsha Moskowitz is responsible for many of the conclusions drawn for benthic invertebrates during this period.

Samples. At least 258 individual samples from Stouts Creek, Forked River and Oyster Creek (bay regions), plus the canals, were taken. Each sample was thoroughly analyzed for species composition (at least 123 species were identified) and number of individuals. The dominant species continued to be *Pectinaria gouldii* and *Mulinia lateralis*, with significant numbers of Ampelisca and Elasmopus appearing at certain times of the year. The parameters that were either measured or computed were: 1) salinity, 2) temperature, 3) depth, 4) sediments (characterized by the sorting coefficient, median grain diameter, and skewness), 5) average diversity ($H' = \sum_{1}^{n} p_i \ln p_i$), 6) maximum diversity ($H_{max} = \ln$ # species, sometimes referred to as "species richness"), and 7) evenness ($J' = H'/H_{max}$).

Analysis: The parameters were then subjected to statistical analysis, or were examined by inspection for trends.

1) Salinity--bottom salinities were generally lower on the bottom in all bay areas. However, in the canals, where thorough mixing occurred, the average salinity was slightly lower than in the bay. In the Oyster Creek region, bottom salinities were similar to other bay areas. In general, the variability in S‰ throughout the study areas in the bay is equal at all points.

2) Temperature--the temperature in the Oyster Creek canal was from 1-8°C. higher (during operation) than in the surrounding bay. However, this warmer water tended to stratify in the bay, with bottom temperatures around Oyster Creek not unlike other regions of the bay. This condition, of course, is sensitive to wind and current and, occasionally, stratification might not be obvious. The variability of bottom temperatures in the study area was about equal during this period.

3) Depth--the mean readings for the study area were: Oyster Creek, 6.4 feet; Forked River, 7.5 feet; Stouts Creek, 7.2 feet; Forked River at Route 9, 10 feet; and Oyster Creek at Route 9, 10.7 feet.

4) Sediments--the variability of the three sediment characteristics (sorting coef., skewness and median grain diameter) was similar at the three bay stations. That is to say, although the median grain diameter can be characterized for any particular region, there is a great amount of variability in sediment type within any one region. However, Forked River and Oyster Creek are more similar to one another with respect to mean median grain diameter (FR = 138 ; O.C. = 131) than either is to Stouts Creek (S.C. = 66). There appears to be no significant difference in the sediments in any of the three areas, and all areas in this study can be considered to be in the silt-clay category.

When the values of median grain diameter of 145 samples were plotted against biological parameters there appeared to be no relationship at all between the two (viz., diversity does not correlate with sediment characteristics). However, further study of the relationship between sediments and biological parameters (especially with respect to single species) is being attempted. (Note: the raw data for salinity, temperature, depth and sediments are recorded under the section called Hydrography.)

5) Diversity and Evenness: Before any statistics were performed on these biological parameters, all of the computed diversity indices were subjected to a chi-square test for normal distribution. H' withstood the normality test for 258 samples. However, although evenness and maximum diversity did not test well for normality, their

distributions were examined by Professor H.P. Andrews (statistical consultant) who judged them to be amenable to statistical analysis. The range in H' values were from 0.00 (only one species present) to 2.8 (many species present). When average diversity was plotted against evenness, it was found that a correlation occurred between these parameters($r = 0.93$, in the bay samples only). That is, as the diversity of a sample increases (viz., an increase in the number of species) the number of individuals in each species tends to be equal to the number of individuals in any other species. However, even though most species are rather equally represented in the sample, there still occur the dominants, which generally far outweigh all other species within any sample. Therefore, many of our analyses were performed both in the presence and absence of the dominants.

For convenience, we have divided the time period into three eras, based primarily on what we think are important reproductive portions of the calendar year. The number of samples within each era or sub-period (see Table 4) was balanced, such that the same number of observations occurred within each sub-period (roughly based on eighty samples per sub-period). The statistical results follow in the form of two tables.

Table 4. Statistical comparisons of the bay stations (comparing O.C. with F.R. and S.C.) sub-periods, and for various biological parameters.

Biol. parameter \ Sub-period	27 Aug - 5 Dec (69) 1st period	9 Feb - 19 Jun (70) 2nd period	30 Jun - 2 Sept (70) 3rd period
1. Diversity (H)	O.C. was sign. lower	No differences	No differences
2. Evenness (J)	"	No differences	No differences
3. # species	No differences	No differences	F.R. was sign. higher
4. # Mulinia (M)	O.C. was sign. higher	No differences	No differences
5. # Pectinaria (P)	No differences	No differences	F.R. had sign. lower #'s
6. Total # indiv. (P+M)	F.R.>S.C.>O.C.	F.R.>S.C., O.C.	F.R.>S.C., O.C.

Discussion of Table 4.

During the period immediately preceding the operation of the nuclear electric-generator, the region around Oyster Creek (in the bay) was characterized by a lower diversity than other regions of the bay. However, the species richness remained constant, as evidenced by a decreased evenness. Therefore, the lower diversity in the O.C. region during pre-operation can be attributed to the presence of the dominant bivalve Mulinia lateralis. Also, during pre-operation, as a general statement, it can be said that the Forked River region had consistently higher numbers of individuals of all species except the dominants than either Stouts Creek or Oyster Creek. This pattern was evident early in this study and has persisted to date.

The second sub-period is characterized by the presence of fewer species and individuals throughout the bay. This is the winter season, with reproductive activity being much lower. Moreover, even though this period includes the early spring months when spawning is prevalent throughout the bay, many of the benthic organisms are too small to be detected. This part of the year is considered by our study group to be the low part of the year with regard to getting meaningful comparative data (viz., the samples are harder to get in freezing weather, and the numbers of individuals and species tends to be lower).

The third period in Table 4 is distinctly post-operational as is evidenced by

the higher surface temperatures in the Oyster Creek region (see Hydrography). However, during this period we were not able to detect any difference in the diversity around Oyster Creek. Forked River, on the other hand, did show significantly higher numbers of species (these were primarily amphipods that settled in large numbers in this area). It must be pointed out, though, that while F.R. increased in species richness, neither Oyster Creek nor Stouts Creek decreased in total number of species. In fact, Forked River actually showed a decrease in one of the dominant species (Pectinaria).

Separate calculations of diversity of the subordinate species (i.e., all members of a sample except Pectinaria and Mulinia) for all samples demonstrated that there were no significant differences for all of these species throughout the bay for this study period. In other words, although the numbers of individuals for all species in Barnegat Bay rise and fall with reproductive systems, there has not been a significant change in the benthic community of invertebrates for the time period August 1969 to September 1970. Evidence of F.X. Phillips (personal communication) indicates that this statement seems also to be true for the years 1965-69.

Table 5. Statistical comparisons of the canal stations (comparing Forked River at Route 9 with Oyster Creek at Route 9) for three sub-periods.

Biol. parameter / Sub-period	27 Aug - 5 Dec (69) 1st period	9 Feb - 19 Jun (70) 2nd period	30 Jun - 2 Sept (70) 3rd period
1. Diversity (H')	O.C.> F.R.	No differences	O.C.> F.R.
2. H' - (P&M)	No differences	----	F.R.> O.C.
3. # P + M	F.R.> O.C.	No differences	F.R.>>> O.C.
4. # species	no diff. (F.R. = 11, O.C. = 9)	No diff. (F.R.= 6, O.C. = 7)	F.R. (=14)> O.C. (=8)

Discussion of Table 5.

During the pre-operational period, both of the canals were relatively similar. Oyster Creek at Route 9 did have a higher diversity; however, this is a product of the index since Forked River at Route 9 actually had more species (not significantly different) and larger numbers of individuals of the dominant species. It was not until the third period that we detected the most significant changes in our entire study. In Forked River canal at Route 9 the number of Pectinaria and Mulinia reached extremely high levels (up to 20,000 individuals/meter^2 of each species). These dominants did not increase in number in the Oyster Creek canal at Route 9, thus accounting for higher diversity in this region (recall that large numbers of dominants depress the index in information theory). Moreover, the number of species in Forked River canal increased, while the number of species in Oyster Creek canal remained rather constant. Generally speaking, Oyster Creek canal at Route 9 (the effluent canal) is exemplified by a rather sparse community of benthic invertebrates with very few individuals. Forked River at Route 9 (the intake canal) is very rich in the dominants and tends to have a greater variety of species present.

This section can best be summarized by quoting Marsha Moskowitz directly: "Thus, the Oyster Creek (bay) area, the only area receiving heated effluents, appears from the information available not substantially different from the Stouts Creek area, a region (of the bay) not so influenced (by warmer water)."

Community composition of Barnegat Bay

In order to better understand the general distribution of communities of benthic invertebrates in the mid-region of Barnegat Bay, we conducted a qualitative survey of twelve points in the bay. These points were selected in order to characterize the western "muddy" portion of the bay and the eastern "sandy" portion. At each point a 5 minute qualitative dredge haul (Carribbean dredge, about 1 meter wide) was taken. All species of invertebrates in the sample were identified to the lowest taxon. In all, about 70 species were collected for the entire 12 samples. The bay was divided arbitrarily into a North region (by combining samples N 1-4 + M 3-4) and a South region (by combining samples M 1-2 + S 1-4). Alternately, we divided the bay into a West region (by combining samples N 1,4, M 1,4, and S 1,2) and an East region (by combining samples N 2,3 M 2,3 and S 3,4). Analyses were then performed on the total number of species from each of these four regions. Surprisingly, there were no significant differences (with respect to the number of species) within any region of the bay. The number of species is as follows:

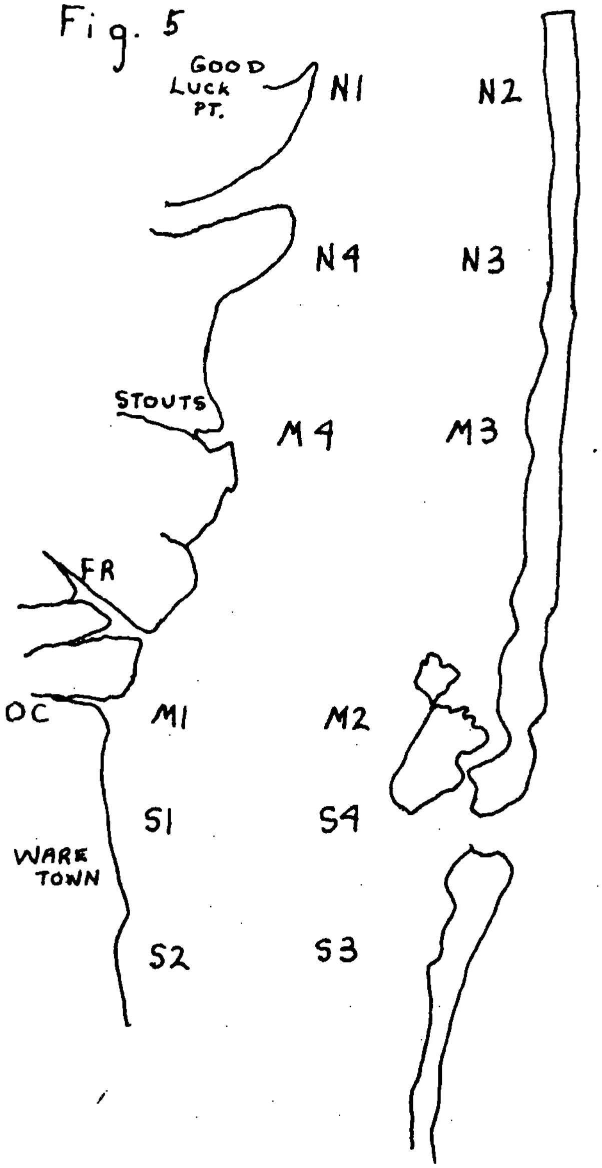
North (N 1-4 + M 3,4)= 18.7 species $\pm$ 3.8 (95%CI)
South (M 1,2 + S 1-4)= 15.2 species $\pm$ 5.8 (95%CI)
East (N 2,3 + M 2,3 + S 3,4) = 16.0 species $\pm$ 6.2 (95%CI)
West (N 1,4 + M 1,4 + S 1,2) = 17.8 species $\pm$ 3.6 (95%CI)

We conclude, therefore, on the basis of this preliminary study (more qualitative excursions are planned for this summer) that the species richness of Barnegat Bay is rather uniform from at least Good Luck Point south to Waretown Creek.

Another analysis of the same data was performed in order to discover whether distinct communities exist in Barnegat Bay. The method of analysis was the technique of cluster analysis (two separate programs were used ; the one described here is that of S. Johnson's as modified by M.G. Shafto). The results of this analysis (Fig. 6) indicate that while the number of species remains rather constant throughout the bay, the kinds of species comprising the community vary considerably. In fact, the most striking feature that emerges from the cluster analysis is that the community to the north of Stouts Creek is decidedly different from that to the south. The greatest degree of clustering occurred between stations S 1 and S 4 (in the vicinity of the main channel from Barnegat Inlet), where 8 species out of 18 were common to both stations (i.e., 44% overlap). The study area for this project also clustered very well, with station M4 (Stouts Creek) having 10 species in common with station M1 (Oyster Creek), out of a total 31 species between them (i.e., 32% overlap).

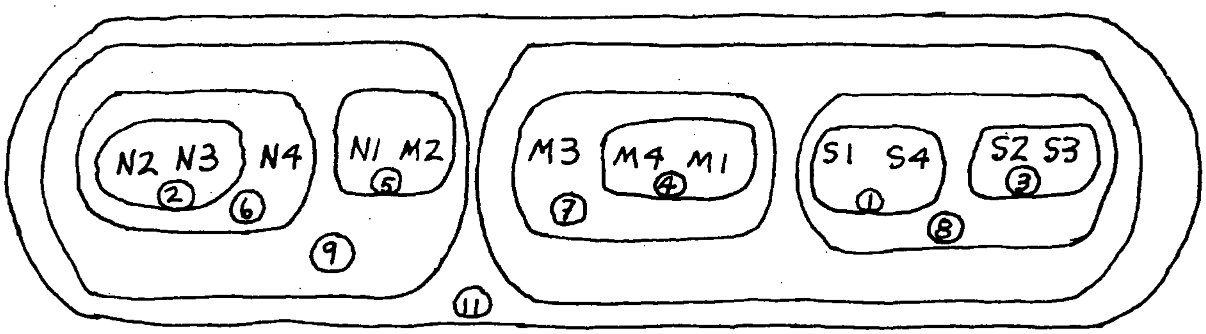
It is interesting to note that in the southern portion of the bay species tend to cluster in an east-west direction; whereas, in the northern portion of the bay species tend to cluster in a north-south direction. Our study area is more characteristic of the latter, thus lending credence to our comparison of Stouts Creek with Oyster Creek. Also, the sediments north of the inlet are distinctly graded in an east-west direction; thus "muddy" communities are characteristic of the west portion of the bay, and "sandy" communities are more characteristic of the east side of the bay.

Fig. 5



Station	Latitude N.	Longitude W.
N 1	39° 54' 30"	74° 07' 15"
N 2	39° 54' 30"	74° 06'
N 4	39° 52' 55"	74° 08'
N 3	39° 52' 15"	74° 06' 25"
M 4	39° 50' 50"	74° 08' 15"
M 3	39° 50' 45"	74° 06' 45"
M 1	39° 48' 20"	74° 10'
M 2	39° 48'	74° 09' 10"
S 1	39° 47' 45"	74° 10' 45"
S 4	39° 47'	74° 09' 30"
S 2	39° 46' 25"	74° 11'
S 3	39° 46'	74° 09' 45"

Fig. 6



Animal-sediment relationships and growth in populations of Pectinaria gouldii from Barnegat Bay

In the present study, Pectinaria gouldii, the golden bristled or mason worm, along with Mulinia lateralis (little mactia) comprise the dominant species in the vicinity of the reactor. Although Pectinaria is a deposit feeder (deposit feeders are positively correlated with the clay fraction of sediments (Sanders, 1958)) it is found in a variety of sediment types; muddy with a high clay fraction to sandy with an extremely low clay fraction. However, the worm inhabits muddy areas in greater numbers than in sandy areas.

Pectinaria, a tubicolous polychaete, utilizes sediment particles in construction of its tube. Its importance in reworking bottom sediments was established by Gordon (1964). Further investigations into Pectinaria-sediment relationships were carried out because of its importance as a dominant animal in Barnegat Bay, its role in sediment reworking, and the limited nature of the literature concerning the worm. Sand grain selection for tube building was studied in the following manner. Four areas in the Bay were sampled, two characterized by having muddy bottoms and two with sandy bottoms. Ten worms per area were randomly collected without disturbing the tubes. The worm tubes were dried, trisected and sonified in order to separate the grains; then the maximum diameter of 20 grains from each one third tube were measured.

Statistical analyses performed indicate that Pectinaria actively selects certain grains as it constructs its tube. Grains in the anterior end of the tube were significantly larger than those in the posterior end. Thus, as the worm grows, it uses progressively larger sand grains. Also, length of worm was positively correlated with anterior sand grain diameter. The longer the worm (from any area), the larger the mean anterior grain size. So, only tubes of equal length may be compared with one another.

Although Pectinaria actively selects grains, populations are limited by the particular sediment they inhabit. Worms in muddy areas use generally smaller grains than worms in sandy areas due to the availability or lack of certain grain sizes in the two types of sediments.

Presently, growth measurements taken in 1970 (length of tube, weight of worm) on worms from muddy and sandy areas are being analyzed for 1) differences in muddy vs sandy-located populations 2) differences between Route 9 (F.R.) muddy-located populations and other muddy-located populations.

Analysis of the dominants: Pectinaria and Mulinia

In order to assess the differences between years for four positions in the bay system, we randomly chose six samples from data covering the period September-December for both 1969 and 1970. This was done for the two dominant infaunal species (Pectinaria and Mulinia), since both of these species can be estimated with high accuracy. The data used were corrected (for each position) to the number of individuals per square meter. During the above time period at least six samples were taken in each of four positions (Forked River at Route 9, Oyster Creek, Forked River and Stouts Creek); these data were available for this time period during both 1969 (considered the immediate pre-operational period) and 1970 (a comparable "season" but about one year post operational). Thus, 48 samples (4 positions x 6 replicates x 2 years) were used to estimate differences in Pectinaria between 1969 and 1970. The following table summarizes the data.

Table 6.

	Pectinaria (no. ind./m^2)			Mulinia (no. ind./m^2)		
	1969	1970	% change	1969	1970	% change
Oyster Creek	216.5	47.8	- 78*	1079.6	47.2	- 96***
Forked River	86.5	171.5	+ 98	1359.2	16.5	- 99***
Stouts Creek	162.3	202.0	+ 25	738.3	29.7	- 96
F.R. Route 9	161.8	2073.6	+ 1179**	672.0	888.2	+ 32

* significant interaction at 5%
** significant at the 1% level
*** significant at the 0.5% level

From the above table certain conclusions can be made.

1) Pectinaria tended to increase from 1969 to 1970; this was especially noticeable in Forked River at the Route #9 bridge, where very favorable growing conditions seem to prevail. On the other hand, this species showed a decrease of 78% at Oyster Creek, where the average temperature was higher during 1970. Such a decrease, although not statistically significant, was opposite in its tendency in comparison to all other bay stations. There was, therefore, a significant interaction at Oyster Creek; in other words, the Pectinaria at Oyster Creek failed to respond to 1970 (and all the variables of that year) in the same way that all other stations responded.

2) The difference in the number of Pectinaria is significantly greater from one position to another than it is from year to year. This is, again, primarily due to such rich areas as Forked River at Route #9 and such poor areas as Oyster Creek at Route #9. The Pectinaria in the bay do not appear to vary significantly from one position to another, at least for the period September through December.

3) Mulinia, a co-dominant of Pectinaria, tended to be in much higher concentration for about a two year period prior to 1970. By the end of 1970 this species underwent a population "crash", especially in the bay stations. We noticed increasing numbers of dead Mulinia by the winter of 1970 (interestingly enough, every dead Mulinia yielded a Spio sp. living within the closed valves!). As the data indicate, Mulinia decreased significantly at both Oyster Creek and Forked River (96% & 99% reduction in number). Even though Stouts Creek diminished by 96% this change was not statistically significant. Only one station showed an increase, and even at F.R. #9 the Mulinia were dying by the end of the 1970 collecting period. The reason for such a "crash" in Mulinia can only be guessed. It is very probable that we have witnessed a "year-class" phenomenon and that Mulinia will now begin to increase in numbers for the next two years.

We conclude from this analysis that whereas both of the dominant species diminished in the region of Oyster Creek during the first post-operational period, their decrease can be explained by reasons other than thermal stress. First the decrease in Pectinaria was not significant because it is offset by a huge increase in the Forked River canal at Route #9. Second, the almost total loss of Mulinia at Oyster Creek was also accompanied by the loss of this species throughout the bay. It is predicted that Mulinia will continue to increase at Oyster Creek as the two year reproductive cycle is phased in.

Sampling program for benthic invertebrates.

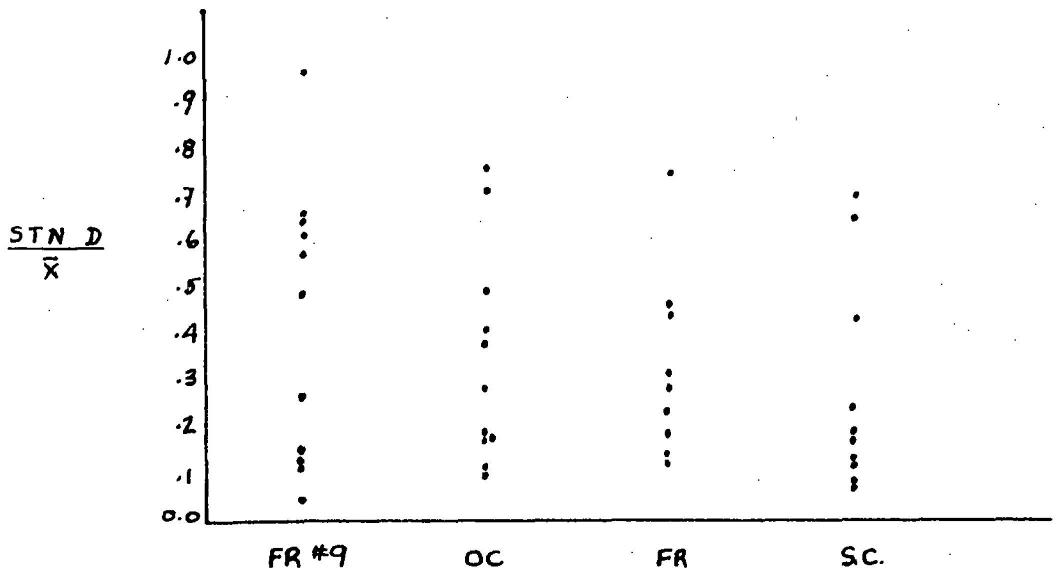
Characterizing the benthic community of marine habitats is relatively difficult from a quantitative point of view. We have attempted to be as rigid and accurate as possible in our study, especially since most of our data analysis is done by statistical techniques. Therefore, in order to answer the question "What constitutes a reasonable sample?", we have performed the following field observations (based on a bay-wide approach): 1) Four areas of the bay, within our study area, were chosen for two types of sampling. 2) At each area we either, a) anchored at a point and proceeded to take ten consecutive samples (this was done at Forked River at Route 9 and in the bay around the mouth of Oyster Creek), or b) anchored at a point, obtained one sample, moved to another point and took a second sample, and continued to move in a random manner until ten samples were obtained (this was done around the mouth of Forked River and, Stouts Creek). Each sample was treated individually, with the parameters listed in Table 7. being measured for each sample. This data was then subjected to a one-way analysis of variance, using the O1V program of IBM/360.

Table 7 : Mean values for eleven parameters measured for ten samples collected at four points in the study area.

	Oyster Creek			Forked River			Stouts Creek			F.R. Route 9		
Character	$\bar{X}$	STN D	STN D / $\bar{X}$	$\bar{X}$	STN D	STN D / $\bar{X}$	$\bar{X}$	STN D	STN D / $\bar{X}$	$\bar{X}$	STN D	STN D / $\bar{X}$
1. Num. Pectinaria	8.400	6.43	.7655	16.2	22.31	1.3772	36.50	25.59	.7011	880.2	556.4	.6231
2. Median grain size	229.1	40.8	.1781	172.4	130.8	.7587	38.0	3.4	.0895	26.9	26.3	.9777
3. Sediment volume	1060	526.4	.4996	1515	434.6	.2869	1720	759.8	.4417	5945	279.3	.047
4. Skewness	11.42	1.23	.1077	10.27	4.56	.4440	5.35	0.685	.1280	2.76	1.792	.6493
5. Sorting Coeff.	2.20	0.245	.1114	1.760	0.212	.1205	1.59	0.185	.1164	5.24	2.596	.4954
6. Num. Mulinia	22.60	16.11	.7128	1.500	1.841	1.227	4.90	3.213	.6557	797.1	485.5	.6091
7. Benthos volume	57.5	21.8	.3791	67.2	30.9	.460	57.0	24.0	.4210	740.2	428.1	.5785
8. Diversity HBAR	1.5607	.4599	.2947	1.7753	.3361	.1893	1.9277	.3837	.1991	.8421	.0954	.1133
9. Max diversity	2.1807	.4339	.1990	2.7616	.3642	.1319	2.774	.2608	.0940	2.5952	.3346	.1289
10. Num. of species	9.80	3.9665	.4047	16.80	5.3707	.3197	16.40	4.0606	.2476	14.0	3.8873	.2777
11. Evenness	.714	.122	.1709	.652	.152	.2331	.670	.126	.1881	.329	.047	.1429

From this table, and from independent analysis of significance, we conclude the following: 1) The relationship between the mean of any parameter and the variability (variance) of points which generate that mean seems to be rather constant throughout the bay. This is reflected by the ratio of the standard deviation to the mean; note that Figure 7., where the ratios are plotted, indicates wide variability. Therefore, we conclude that any area can be adequately characterized by either a) taking 10 consecutive samples at a point within the region, or b) taking 10 different samples from 10 locations within a region.

Fig. 7.



A separate analysis (not shown in this table) of the probability of obtaining 90% of all species present in the region indicates that seven (maximum) consecutive samples (a sample is defined here as the contents of one ponar drop) are necessary. Therefore, in light of the statement in the above paragraph, we are now taking seven consecutive samples (pooled) at three different points (within a region) in order to adequately characterize the region for any date. The sampling periodicity is two weeks for any region.

2) There is an obvious relationship between the amount of sediment brought up by the ponar and the sediment characteristic: the finer the sediment, the more the ponar brings up per drop. In other words, at Oyster Creek, where the sediments are quite variable, but generally characterized by having a median grain diameter of 229μ, we must drop the ponar at least seven times in order to obtain a "full" ponar ($\cong$ 7000 mls). Of course, the area sampled increases with the number of drops; however, we have independently shown that one can characterize any area with seven consecutive samples regardless of the sediment composition or the number of ponar drops in excess of seven.

3) There appears to be good correlation between the number of individuals of the dominant worm (Pectinaria) and the sediment composition: the finer the sediment, the more worms that are found. However, note that whereas the sediment at F.R. #9 is very fine (26.9μ) it is also poorly sorted (S_o = 5.24). It is quite possible that Pectinaria responds more to the presence of fine, poorly sorted sediments than it does to other environmental parameters. It is obviously not responding to increased temperature at Oyster Creek since there is no significant difference between the Pectinaria at Oyster Creek and Stouts Creek. Further, the number of worms at Forked River at Route 9 might be anomalous, since they occur there in huge (>20,000 per square meter) numbers; we feel that this locality is a region of optimum growing conditions for Pectinaria, given the soft bottom and the amount of organic matter presumed to be in the mud.

4) The diversity indices at the three bay stations were not significantly different from one another, while F.R. #9 showed a lowered diversity due to the

dominants (Pectinaria and Mulinia). The number of species at Oyster Creek was significantly lower than the other three areas. However, it must be recalled that the present analysis was the result for one day; it is previously stated in this report that the number of species at Forked River went up during late summer, even though the number of species at Oyster Creek remained the same. Also, whereas Oyster Creek had the lowest number of species in this study, it had the highest number of Mulinia in the bay (excluding F.R. #9), and, the benthos volume was about the same as at other bay stations. Under conditions of stress (viz., thermal at Oyster Creek) it is possible to have lowered diversity, lowered number of species and increased dominance—we do not believe that this trend has occurred at Oyster Creek.

In summary, then, we believe that characterizing the invertebrate community of Barnegat Bay requires at least seven samples per area on any day (we take 21) and that the biological parameters of the samples seem to be related more to the sediment composition than to the hydrographic (except current at F.R. #9) parameters.

Status report on benthic invertebrates.

During the period 1 June 1970 to 15 June 1971 a total of 25 cruises were taken with 242 samples collected and sorted. We did not obtain as many field samples in the early spring, as desired, because of severe engine trouble. However, we have managed to continue to keep abreast of the backlog. The following new species have been added to our checklist during this period:

number	species
134	Sagartia modesta
139	Doridella obscura
140	Cerebratulus sp.
143	Goniadidae
144	Scoloplos fragilis
145	Sthenelais boa
146	Diadumene leucolena
151	Carinogammarus mucronotus
152	Phyllodoce arenae
153	Clymenella sp.
154	Paranaitis speciosa
156	Modiolus demissus
157	Nephtys picta
158	Eumida sanguinea
159	Batea secunda
160	Scoloplos sp.
161	Corophium cylindricum
162	Erichthonium difformis
163	Haliclona sp.
164	Microdeutopus gryllotalpa
166	Melita nitida
167	Elasmopus laevis
168	Spiochaetopterus sp.
169	Amphitrite cirrata
170	Cuthona concinna

Although we have been primarily concerned with invertebrates and algae, it is worth mentioning that several new species of fish have appeared in Barnegat Bay for the first (recorded) time. One of these is somewhat tropical and is called the common butterfly fish (Chaetodon ocellatus). A single specimen of this species was found among shrimp-nets in the eel-grass beds off Sedge Island. It apparently strayed in from the Gulf Stream during an extremely hot spell in early September, 1970.

PROGRESS REPORT: BARNEGAT REACTOR SURVEY, FOR THE PERIOD JUNE, 1970, THROUGH MARCH, 1971.

(Plankton Section)

Prepared by Kent Mountford, Ph.D., May 27, 1971

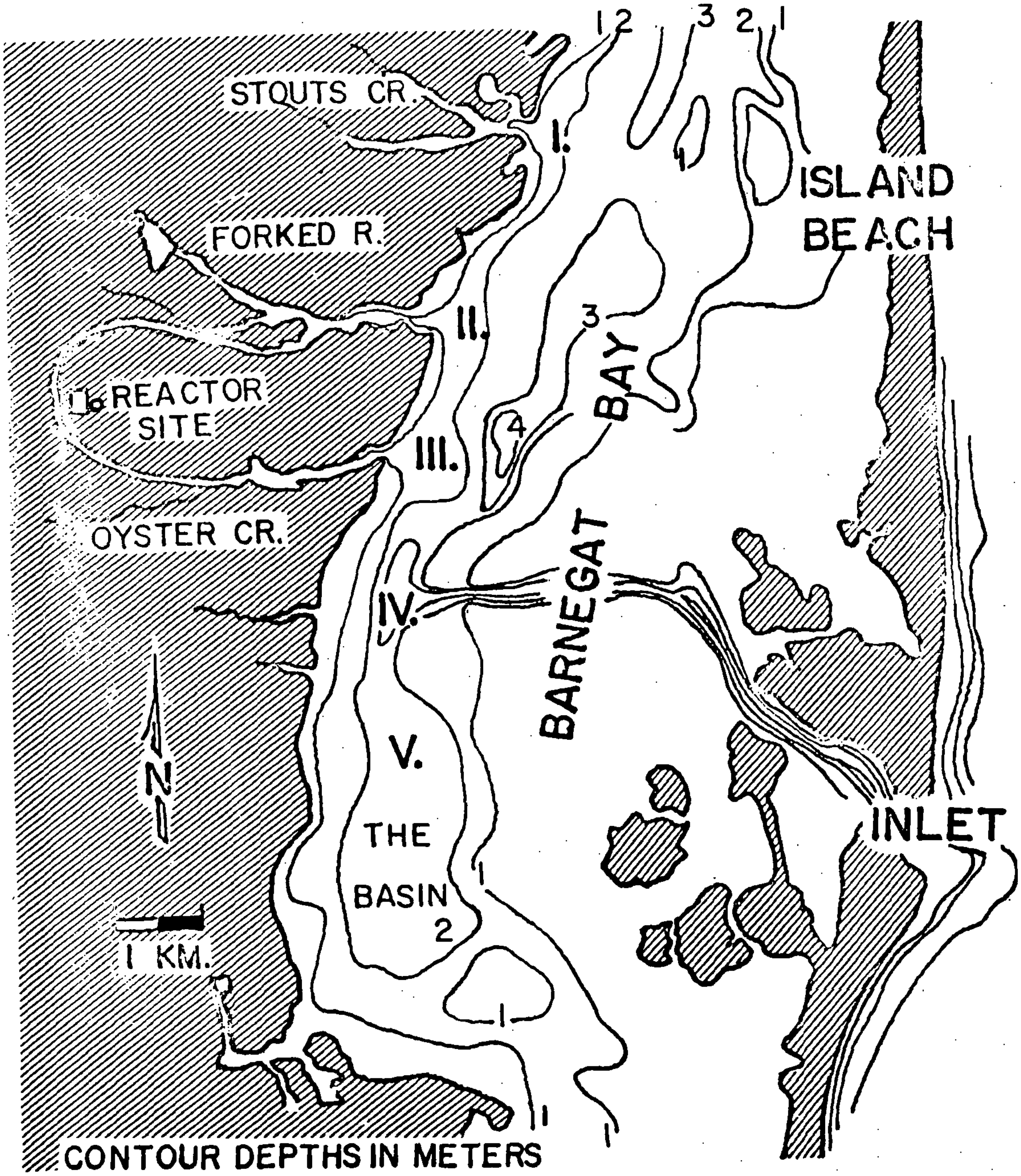


Figure 1. The Barnegat Reactor Survey Area. The five regular transect stations are shown with Roman numerals.

SAMPLING

During the period covered by this report, twelve regular cruises were made at an average interval of 14 days. Eighty-four plankton stations were occupied, and 144 samples analysed. Regular sampling at the five transect stations initiated in February, 1969 was continued into December, 1970 at which time the R/V "Clio" was decommissioned for repairs. At each station (Fig. 1) chlorophyll, cell count and hydrographic data were assembled, and replicate light-dark bottle productivity experiments were daylight tank incubated. A replicate consisted of water drawn in a carboy from the bay from which all parameters were measured. Two such samplings were made at each station at an approximate interval of five minutes. The entire transect, including additional stations at the intake and outfall, was run in slightly over one hour.

PRODUCTIVITY DIFFERENCES

During 1969, gross productivity was used to demonstrate position differences along the transect. The observed differences, particularly between Station III (o = off Oyster Cr.) and Station V (Δ = at Buoy "G" in the mid-basin area of the Bay)-Fig. 2-A - were associated both with chlorophyll differences (Fig. 2-B) and the number of cells per count (Fig. 2-C). A summer peak in cell numbers had also been observed in 1967 off Oyster Creek. During 1968, between mid-June and mid-October,

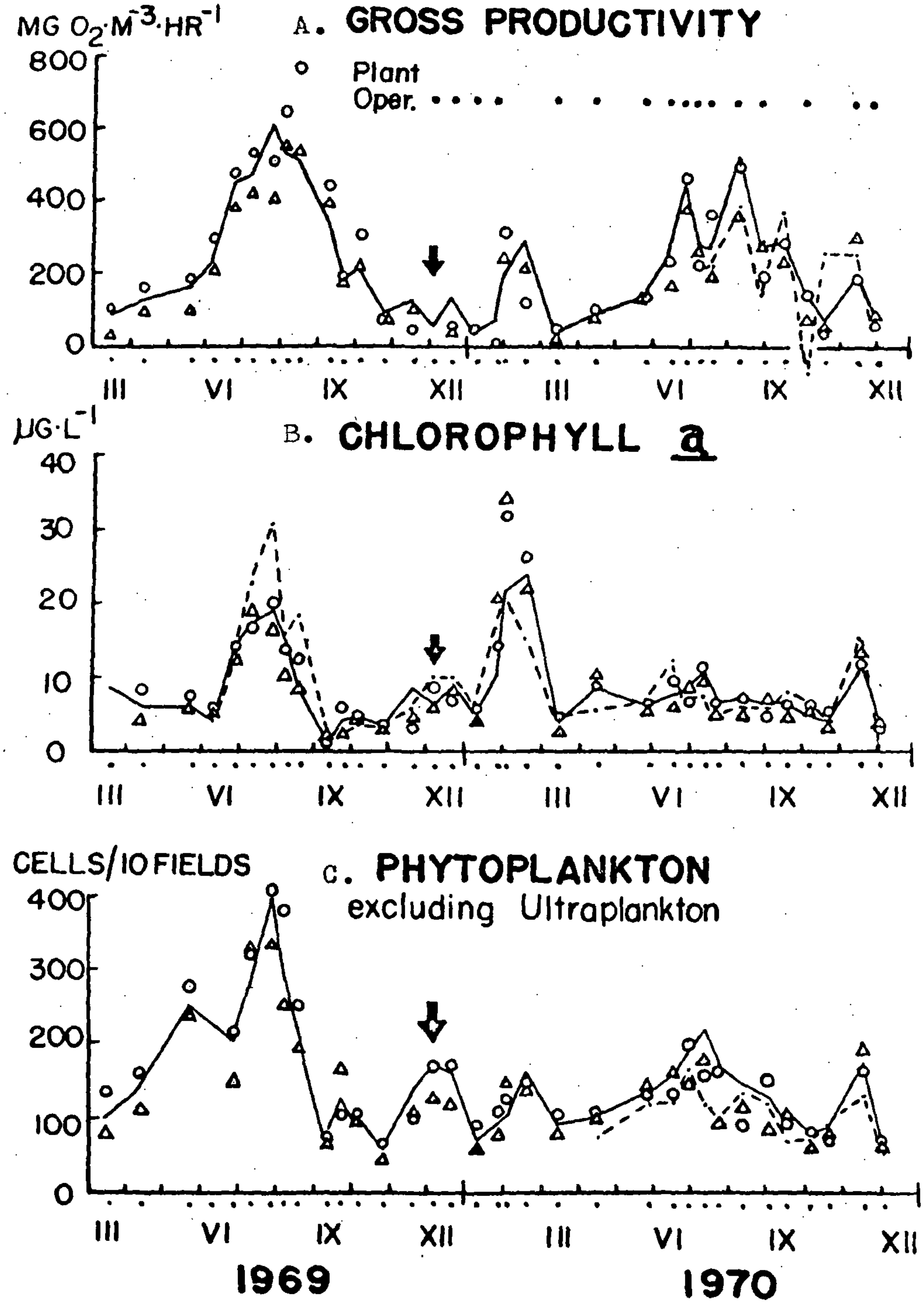


Figure 2. Plankton Parameters, o = Sta.III, Δ = Sta V
↑ = Start of generation. • = dates operating during fieldwork. -•- = data for mouth of discharge canal.

in five of six cases where data for Station III are available, this area had cell counts higher than the mean within-date. This is believed to reflect naturally higher productivity off Oyster Creek. This does not exclude the possibility of eutrophication by stream and residential effluents.

The period mid-June through mid-October was used to compare conditions before and after the onset of generation. It would have been desirable to construct this comparison over an entire annual cycle, but operations during the first winter. December, 1969, through March, 1970, were so erratic that the data are more confusing than enlightening.

The year 1970, in general, was significantly less productive along the entire transect than was 1969. This difference is in no way connected with plant operations. It is probably related to lower values of solar energy income during 1970. This parameter itself is reflected in slightly cooler average water temperatures. During 1970, however, the relationship of Station III to the grand mean, $\bar{\bar{Y}}$. (June through October) changes significantly (Fig. 3-A). This suggests a depression of the expected productivity level off Oyster Cr. There was, in fact, a difference of - 55.4 mg $O_2 \cdot m^{-3} \cdot hr^{-1}$ between Station II (Forked R.) and Station III (Oyster Cr.).

During most of the June through October period additional samples were taken in the mouths of the intake and discharge canals and analyses made for cell count, chlorophyll and productivity. When five available dates are compared for these two positions, productivity at the outfall averages

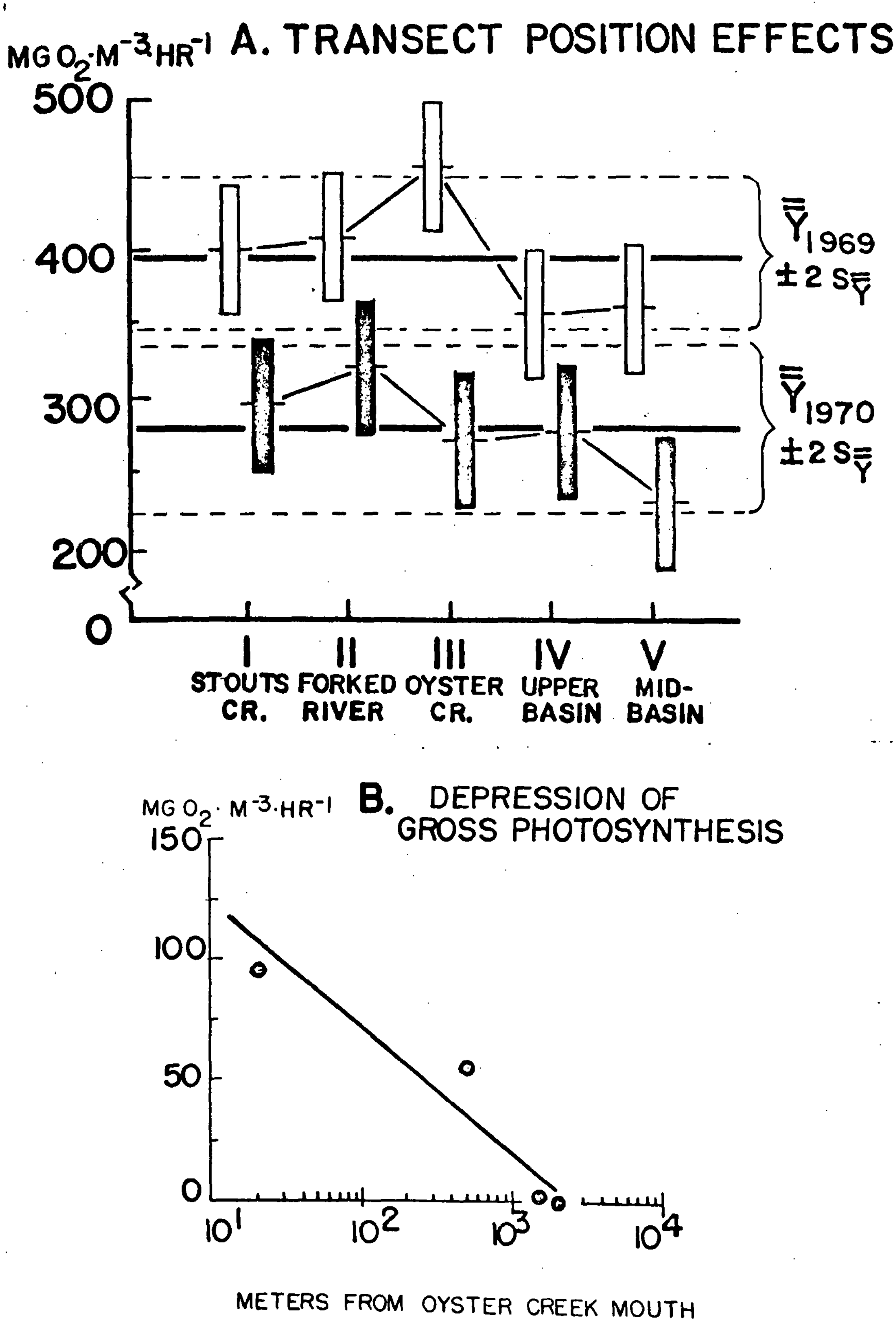


Figure 3. Productivity changes by position, June - October 1969 and June - October, 1970.

92.3 mg $O_2 \cdot m^{-3} \cdot hr^{-1}$ below the intake. Chlorophyll a dropped from a mean of 7.60 µg/liter to 6.93 µg/liter, compared to 10.64 at the intake and 12.87 at the outfall during 1969 (a difference of +2.23 µg/liter.)

Cell counts at the intake averaged 143.3 cells/10 fields and at the outfall 115.6. Most of the observed difference resulted from the disappearance of microflagellates (Intake 127.6; Outfall 98.5 cells/10 fields), but a decrease in dinoflagellates, particularly naked forms, was also detected (mean counts 7.6 Intake, 3.0 Outfall). The absence of species (Fig. 4) present in the intake water after transit slightly depressed phytoplankton diversity between the two stations.

Qualitative changes in the phytoplankton (Fig. 5) from year to year during the survey were primarily seasonal in nature, signalling essentially cold-and warm-water floral shifts. Variability in occurrence dates was sufficient that no general displacements attributable to plant operations could be distinguished in a single year's experience. The average number of species occurring along the transect was also not significantly altered, although a small decline in 1970 may reflect the selective loss of several groups observed at Station II but not at Station III.

It was considered likely that plankton respiration would be elevated by passage through the plant and canal system. Since gross productivity as measured in this investigation is expressed as the differential between light and dark bottle oxygen, values for a given position are sensitive to the magnitude of respiration. To look at effects through the

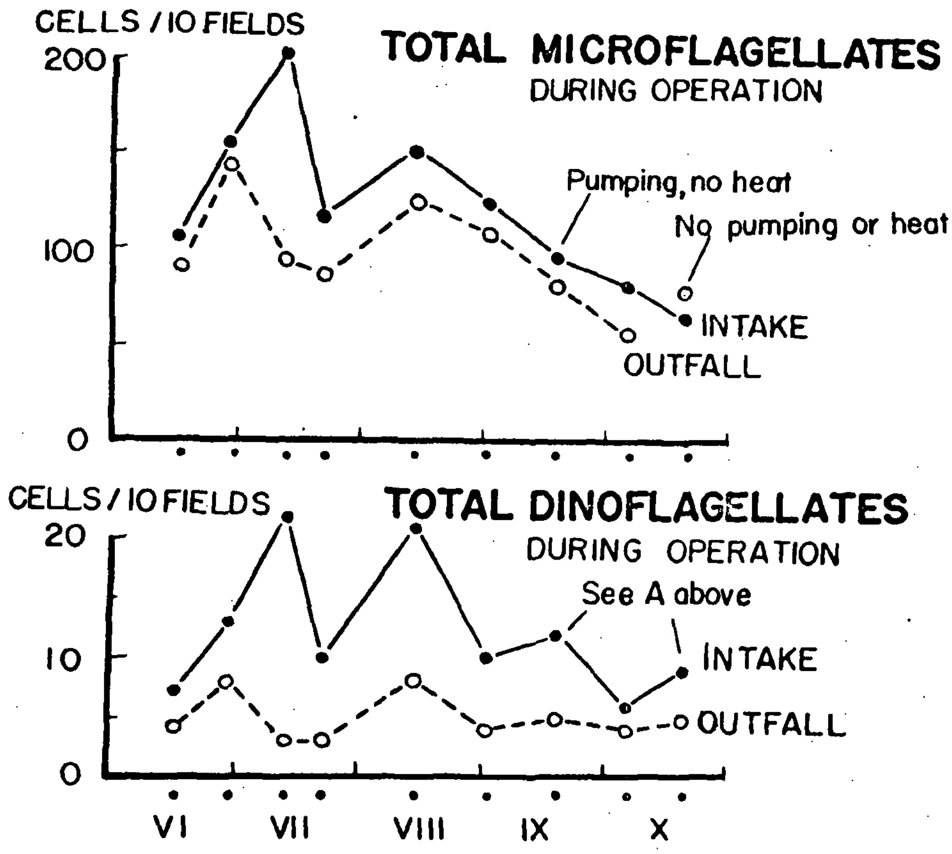


Figure 4. Plankton cell count differences on either side of the Plant-Canal system.

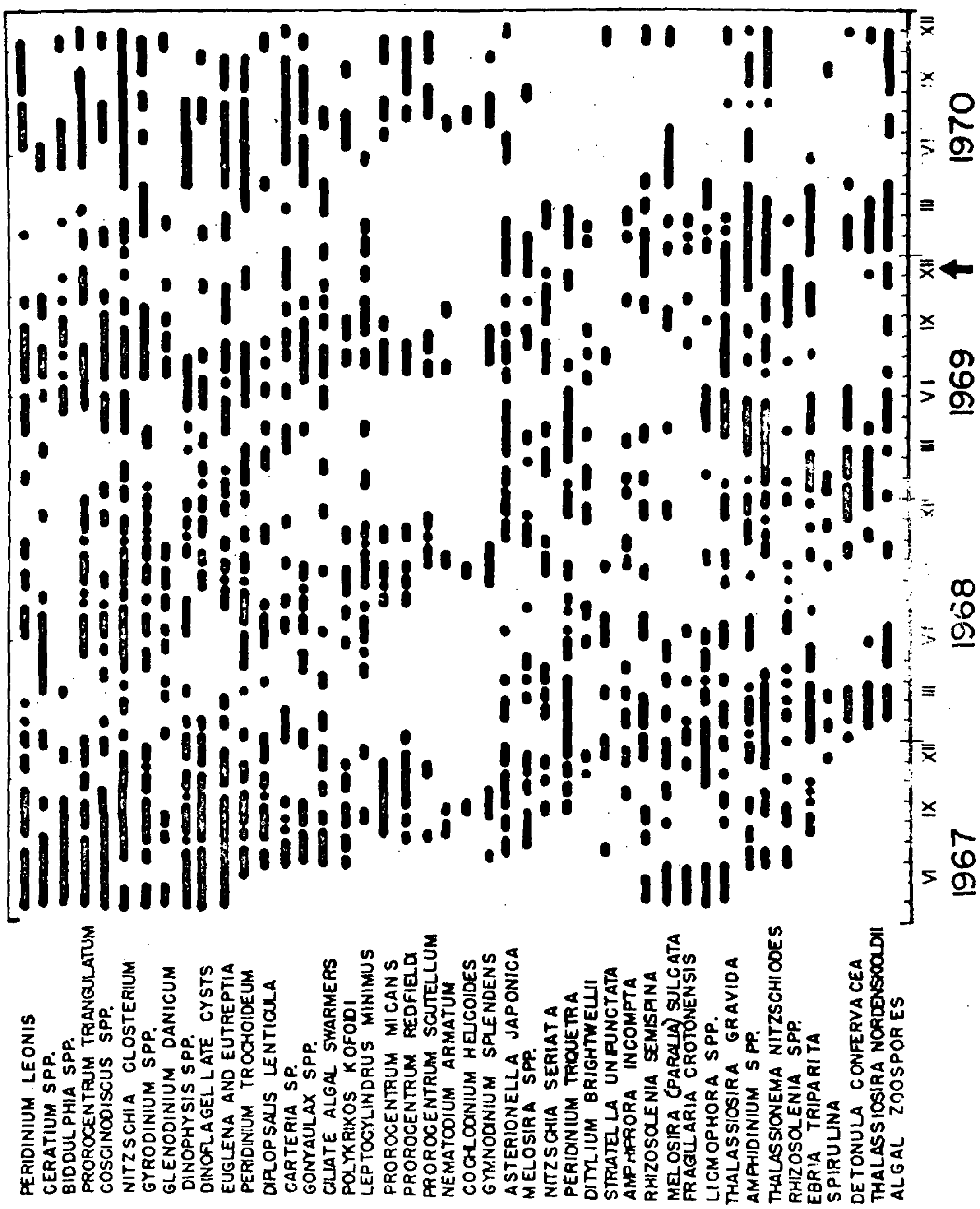


Figure 5. Phytoplankton Composition shifts over a four-year period, 1967 - 1970

canal system on net photosynthesis, a fully replicated series was run using both the dissolved oxygen and ^{14}C radioassay methods. (Fig. 6, open symbols = O_2; solid symbols = ^{14}C). This indicated a highly significant decrease in net productivity between intake and outfall (-121.4 mg $C \cdot m^{-3} \cdot hr^{-1}$). Since respiration (assayed by O_2) was indeed about three-fold greater at the outfall, the measurement of photosynthetic change between these two stations may have consistently underestimated. The two methods of measurement were related to each other by a coefficient of correlation exceeding +.90.

HYDROGRAPHIC DATA

The hydrographic data in Fig. 7 show temperatures and dissolved oxygen at the outfall (-•-) and Station III (o) compared to the five station mean (___). The salinity relationship among stations, particularly between III (o) and V (Δ), was apparently unchanged, although at the outfall itself the additional freshwater entrained from Forked R. is detectable as an average salinity difference of 1.40 o/oo.

With the several years of salinity data now available it is possible to construct an average salinity profile for this portion of the Bay (Fig. 8).

Dissolved oxygen decreases between intake and outfall from a mean of 8.60 mg/liter to 7.41, a drop of 1.19 mg. This must be considered against the background of surface-to-bottom differentials observed during the preoperational period

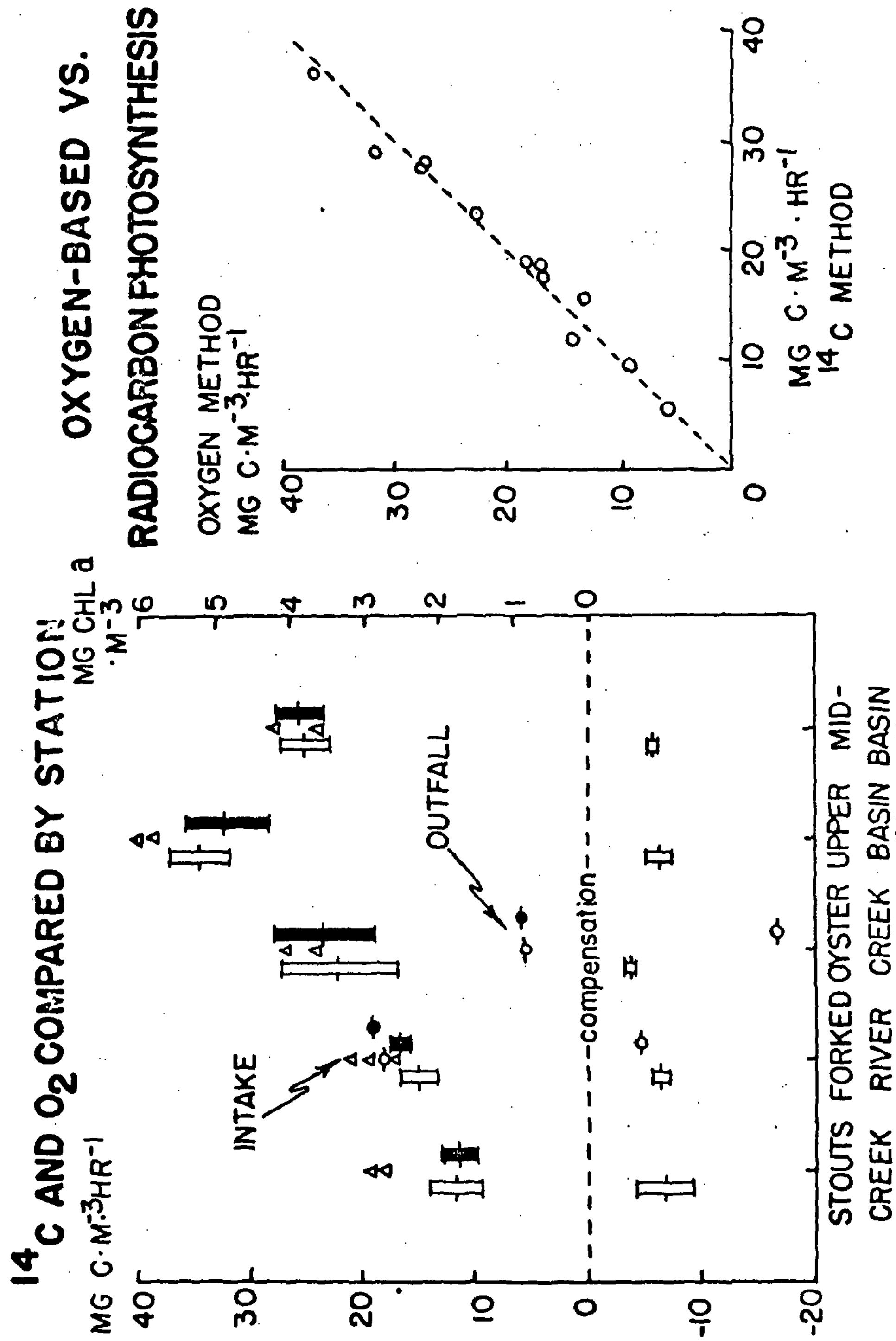


Figure 6. The Dissolved Oxygen and ^{14}Carbon Methods Compared for the entire transect; open symbols = O_2, Solid symbols = ^{14}C., Δ = chlorophyll a at each station.

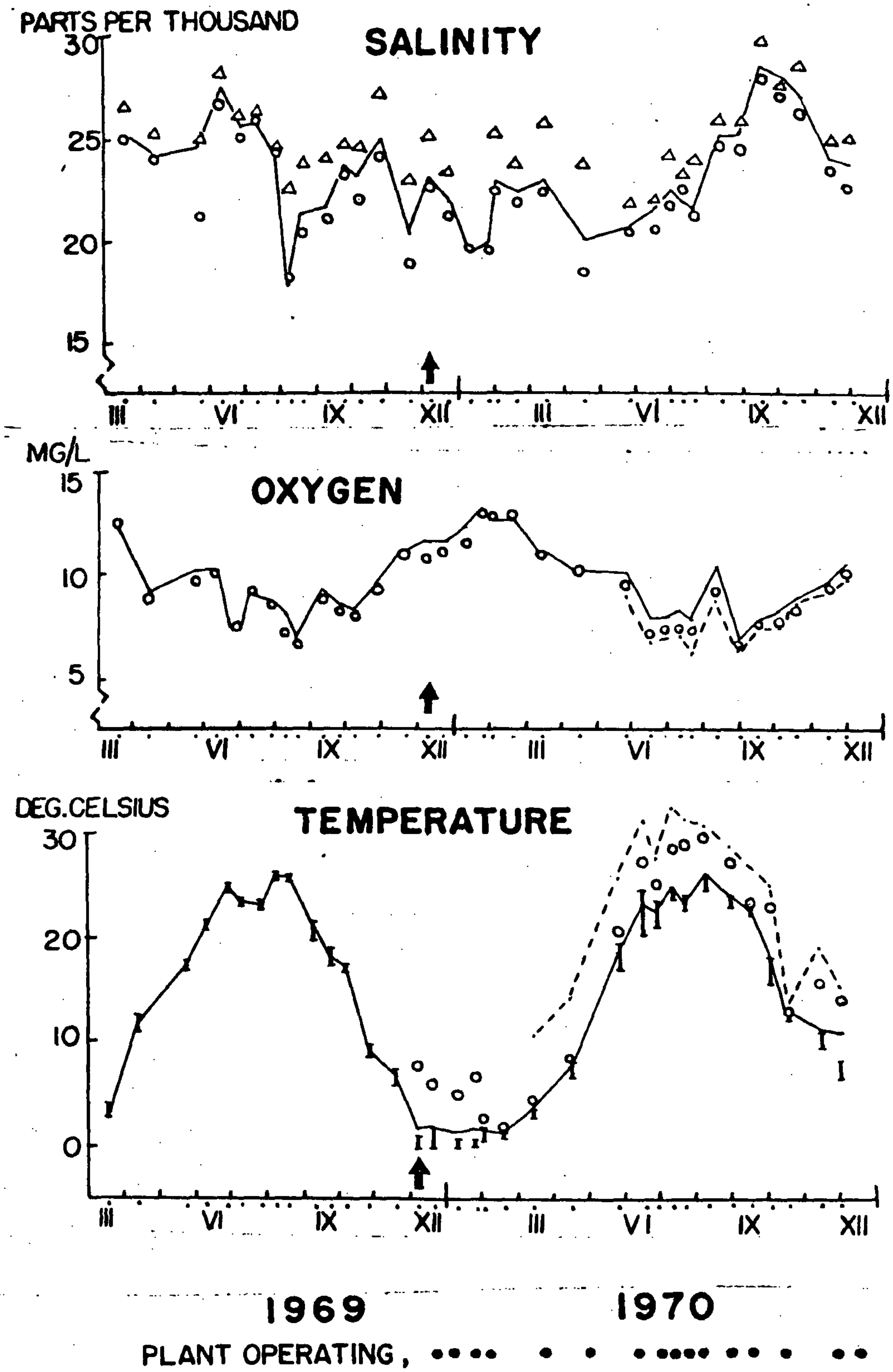


Figure 7. Hydrographic data for the transect, 1 yr. before and 1 yr. during operation. o = Sta III, Δ = Sta V, -·- = outfall, —— = five-sta. mean, ↑ = onset of generation, I range, °C excluding Sta III and outfall.

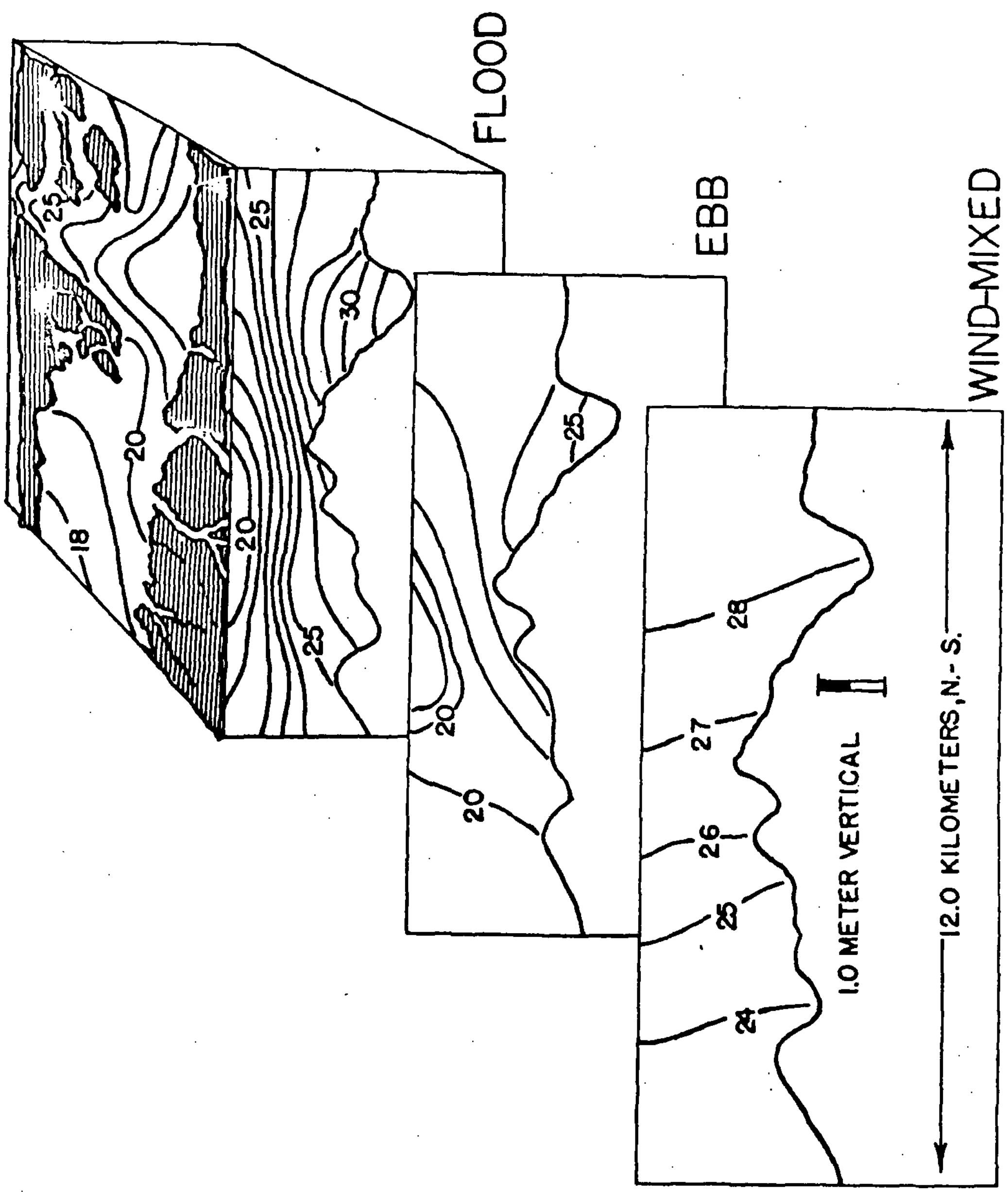


Figure 8. Generalized Salinity Profiles for the Transect, in parts per thousand (o/oo) Note: isohalines indicate the inlet has begun to ebb at high-tide along the transect. Wind in mixed profile had blown SSE at least 5 hr.

(1967 through 1968). The magnitude of differences is no greater but the plant effluent is already at the surface and therefore somewhat aerated by the time it travels three km. to the outfall and the "supply" of water being partially deoxygenated is virtually continuous.

The distribution of plume effects can be partially seen using temperature as a tracer (Fig. 9). In some cases the plume is deflected south, and back against the shore at Waretown (Fig. 9-A) as predicted by Carpenter (1963). In calm weather or with westerly winds, it will often orient straight toward the East (Fig. 9-B), and under the influence of southerly winds, displacement toward the north may occur, making possible recirculation of heated water (Fig. 9-C). The observed plume areas agreed closely with those predicted by North and Adams (1969). The heated layer was rarely more than 1.5 m thick at station III, 500m from the outfall.

COMPUTER ANALYSES

The availability of part-time lab assistance made it possible to keypunch a large portion of the plankton data. Following the suspension of field collections in December, 1970, several months of intensive effort permitted analyses to be run on the IBM-360. Correlation analyses examined the relationship of each variable with every other variable on the data matrix. A multiple stepwise linear regression technique developed equations for several data subsets that can serve as calculative (predictive) models.

The equation for gross productivity built from data taken before operation included values for temperature,

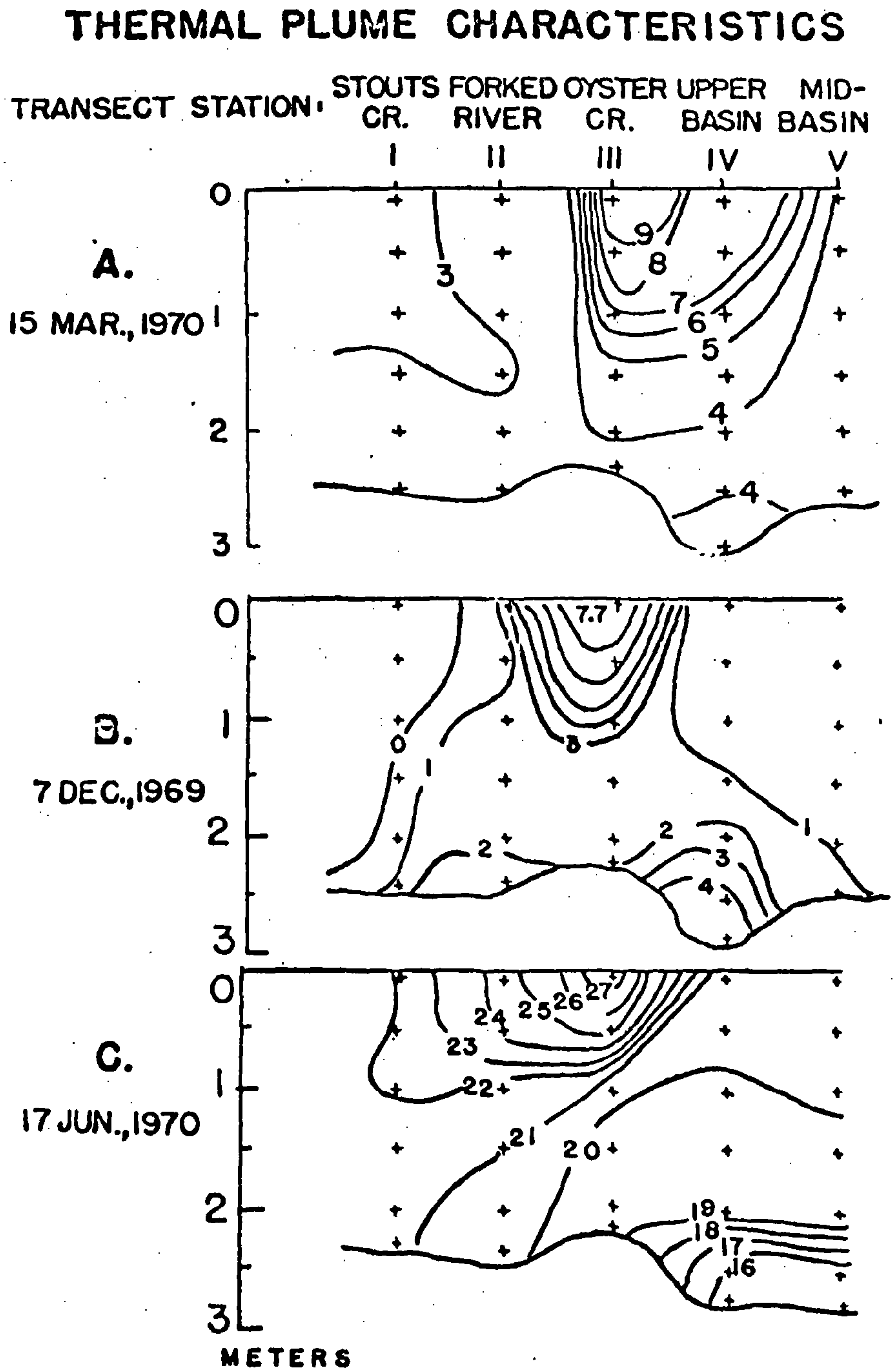


Figure 9. Vertical Temperature Profiles along the transect. Temperatures were taken each 0.5 m surface to bottom at each station.

chlorophyll a, salinity, microflagellate counts, and the stage of tide at sampling. The resulting calculated values for gross productivity correlated with observed data from the field at the level of +.92. This means we were able to account for some 85% of the variability using five parameters.

Temperature was the variable most highly related to gross productivity, with a correlation coefficient of + .803 during the preoperational period. It was also strongly related to gross productivity during operation but the correlation fell to +.681, a value significantly different from 1969 at the 5% level. This seems to reflect the association, particularly at Station III, of high temperatures with reduced photosynthesis. Since a temperature change, in the absense of biocides, pumping and erosion-based turbidities, does not necessarily result in decreased productivity, the relationship is not a simple one. Considerably deeper probing is required before predictive modeling will have much application to the "real" world.

During the preoperational period, the equation for gross photosynthesis, when used to calculate annual curves for each station, clearly "predicted" the observed differences between Station III and Station V. The same equation will now be applied to environmental parameters gathered during operation, as a true predictive model. The possibilities suggested are exciting.

Note: The plankton work has been summarized in a Ph.D. Thesis, Plankton Studies in Barnegat Bay, by Kent Mountford, Rutgers Univ. Library of Science and Medicine, 147 p.

Effect of increased temperature on copepod egg viability

During the copepod bloom of Feb-Apr 1971, experiments were conducted to determine the following: 1) the ability of adult copepods to lay viable eggs within 24 hours of experiencing a temperature increase of 10°C. above ambient (by passage through the cooling system of the plant), 2) the viability of copepod eggs after exposure to temperature elevations of 10°, 15°, 20°, & 25° (above an ambient of 5°C. in the laboratory).

The use of copepods was deemed appropriate on the basis that copepods exceed, in both numbers of individuals and number of species, all the rest of the metazoan plankton combined and are thus, extremely important in food chains. In Barnegat Bay the copepod Acartia is the dominant form in the region of the bay near the power plant and is the form dealt with in these experiments.

To compare the viability of eggs layed by those individuals having passed through the plant with those having not, adults were collected at the intake and the outfall of the plant. Upon return to the lab they were placed in bowls and held overnight at the ambient temperature of the intake. However, individuals collected from the outfall were maintained at the outfall temperature for two hours to simulate passage time down Oyster Creek before being returned to intake temperature. Eggs from both treatments were removed the following day and placed in small bowls for observation of hatching. The results are shown in Table 8.

Table 8 . % eggs hatching from individuals collected at intake and outfall.

	# eggs	% hatching
intake	75	73
outfall	75	78

Thus, (when the ambient was 5°C.) the delta (i.e., increased temperature) experienced by Acartia on passage through the cooling condensers did not seem to affect their ability to lay viable eggs within 24 hours of exposure to the delta.

To determine the effect of a delta upon eggs directly, eggs were obtained from individuals collected at the intake and then subjected in the laboratory to temperature elevations of 10°, 15°, 20°, & 25°C. above ambient for a 2 hour duration. As shown in Fig. eggs subjected to deltas of 10° & 15° had a better hatching success than the controls, while those receiving a delta of 20° were about as successful as the controls. A delta of 25°C. above the temperature at which the eggs were laid was definitely disastrous to the eggs.

Another finding of this experiment was that a synchronization of hatching occurred in those eggs subjected to deltas of 10° and 15°; i.e. they hatched within a shorter time span and also finished hatching sooner than the controls (Fig. 9).

Fig. 8. Ave. % of eggs hatched vs. temperature increase above ambient (5°C.).

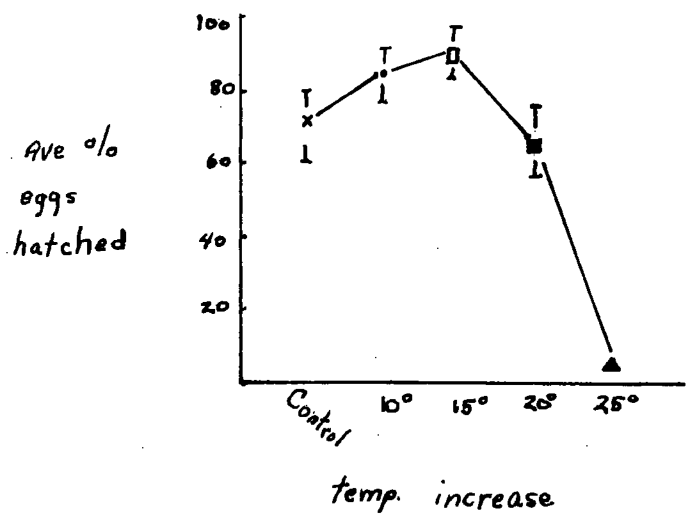
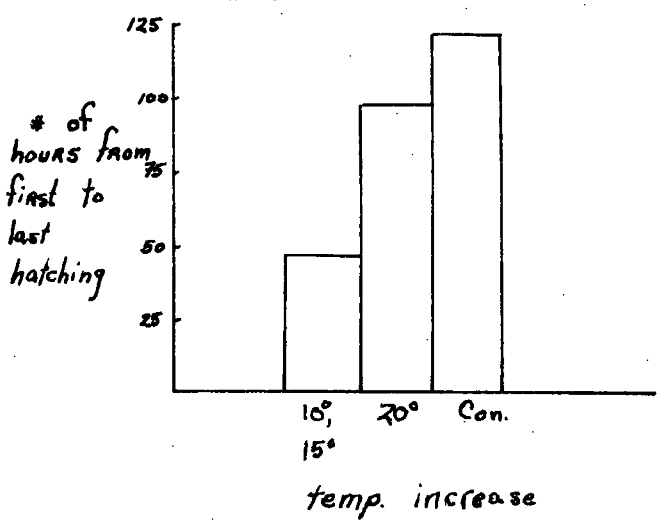


Fig. 9. # of hours from first to last egg hatching vs. temperature increase.



Thus exposure of *Acartia* eggs to a delta of 10° or 15° above ambient (5°) not only results in a significant shortening of the time span needed for a cohort of eggs to hatch, but also eggs so treated show a better % of hatching success than the controls.

In summary, at the winter timperatures of the bay, we have detected no significant effect on the viability of eggs of the dominant copepod *Acartia sp.*. It should be cautioned, however, that these experiments were run for the cold months, so a delta of 15° may, in fact, result in an end point temperature of 15-20° C.

Summary

For the time period covered in this report (through the end of 1970), it is our opinion that severe, radical, extreme or disastrous environmental changes have not occurred in Barnegat Bay. Unfortunately, there are those who are stating that there is "boiling water" in Barnegat Bay—this is nonsense. We have, indeed, measured decreases in the number of some biological parameters in the vicinity of the Oyster Creek generating station. However, in all cases but one, a decrease in number of species (or any other biological parameter) at Oyster Creek has not been statistically significant (in comparison to other regions of the bay) or such decreases have occurred simultaneously throughout the bay. The one exception involves the productivity of phytoplankton in the vicinity of Oyster Creek. There was a statistically significant decrease in the level of productivity in this area of the bay which seems to be correlated to the post-operational time period. Such a change is discussed fully in this report.

We are of the opinion that the period December 1969 to December 1970 represents the first post-operational year, which, unfortunately, was marked by frequent "ups" and "downs" in generator activity. There is some probability that the organisms that might be affected by the activities of the generating plant are adults that may have been spawned in the summer of 1969. Thus, the summer of 1970 was the first summer that the offspring of the bay populations could have been affected by plant activities. We are, therefore, very much interested in the data of the present summer (1971) since presumably we will now measure affects on the first generation. We feel that the significant year for detecting effects will be 1971-72, and, therefore, are submitting a proposal to continue this study for yet another year. The latest proposal will accompany this report.

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

Eighth Progress Report

August 18, 1972

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Report #8 to N. J. Public Utilitites Commission

Rutger's University, New Brunswick, New Jersey

Introduction

The present progress report will use data drawn from previous progress reports. However, this report is not an attempt to summarize our work of the past six years. We expect to offer summary reports on each topic (viz, benthic algae; primary productivity; benthic invertebrates; zooplanton; phytoplankton; hydrography; sediments; and encrusting organisms) as the data of six years is condensed into a coherent "story" with the help of a computer. What follows, however, is an attempt to give a preliminary summation of our work in the respective areas. Notable among all of our work is the failure of any single parameter to respond differently from one position in the bay to another. We have witness huge variability over time and space--but the causes of specific variability seem to operate over the entire study area. There are two cases where the generating station may be having an effect on bay populations: 1) It is becoming more apparent that the biomass and number of organisms is lower around Oyster Creek, perhaps as a result of thermal mortality of the meroplankton which then fail to re-populate the area off the outfall canal; 2) The primary productivity over four years has been lowest in the area of Oyster Creek. Although these conclusions are based on an extremely complex situation and do not appear to be statistically significant, we should be aware of the general trend which is taking place. Should the generating plant remain functional for the next ten years, we would strongly recommend that a brief survey of the benthic invertebrates and primary production in the study area be continued at a low level (e.g., one trip per quarter year). We do not recommend that the study which is now in its sixth year be continued at its present intensity.

In some places in the composition of this report a single writer offers an opinion which may or may not be agreed upon by all of the writers. Dr. R.E. Loveland is primarily responsible for the editing of the information contained in this report. We apologize for the hand-drawn graphs, but time and costs prohibit a more professional approach.

Budget. At the beginning of the current grant period (i.e., 1 September 1971) we estimate that we had a carry-over balance from the previous period of approximately $3889.00. On 19 July 1972 we were credited for the amount of #23,199.42 in the office of the Bureau of Biological Research. During the year, we lost funds due to the manner in which Rutgers University calculates salary. It is apparent from the budget table that nearly $3140.00 was paid to our research assistants over and above the amount committed in the grant. Although we feel it reasonable and just for Rutgers to maintain competitive salaries, this difference of over $3000.00 effectively wiped out our carry-over balance. Also, because our greatest demand on this project is for skilled labor, we also had to over-spend in the area of part-time labor by nearly $1000.00. Fortunately, we experienced little major mechanical problems with our research vessel, so some of our loss is made up in this area, plus some balance in supplies. Due to the loss of a Ponar Dredge and the breakdown of our salinometer, we experienced losses in the area of equipment. Finally we had some difficulties with the University contract office regarding the vehicle--in the end, we were allowed only direct reinbursement for mileage. We were not permitted any reimbursements for insurance, depreciation and maintenance.

The consulting algologist, Dr. E.T. Moul, did not work as long as we had expected because the bulk of the sorting was done by part-time labor. Also, because Dr. R.E. Loveland returned rather late to the project, he requested a decreased salary for the summer.

One area which has been preserved is in the last budget item, publication and computing. We will need every amount available at the end of this grant period for computing time (at 500.00/hour). However, any funds now remaining will have priority towards labor since we anticipate finishing this tenure with no backlog (with three trips to go, we can meet this deadline). Any funds which are left will be used for computer time in 1972.

Budget Statement, 15 August 1972

		Alloted	Committed	Balance
I	Salary			
	a) Principal Investigator	1000.00	600.00	400.00
	b) Full-time research assistant	8079.21	10,048	-1968.79
	2 Half-time research assistants	8079.21	9,250	-1170.79
	c) Part-time labor	1500.00	2,399.80	- 899.80
	d) Consulting algologist's fee	630.00	200.00	430.00
			I Sub-balance =	-3209.38
II	Equipment	300.00	534.40	
			II Sub-balance =	-234.40
III	Supplies	500.00	266.97	
			III Sub-balance =	233.03
IV	Operations			
	a) Vessel upkeep and maintenance	1080.00	420.43	659.57
	b) Vehicle (same as mileage)	1431.00	735.52	695.48
			IV Sub-balance =	1355.05
V	Publications and computer time	600.00	63.20	
			V Sub-balance =	536.80
			Grand balance =	-1318.90

Note: Since we entered the grant period on 1 September '71 with a balance of $3889 (estimate), we actually have a balance of approximately 3889-1318 = $2571.00 on 15 August 1971.

We do not expect to continue this project further. We feel that we have adequate post-operational data for valid comparisons and do not wish to continue the intensity of sampling we have experienced over the past three years. However, we would like to discuss with the granting agency the possibility of getting additional funding for two aspects of this research which we feel should be continued. The first is with respect to the work of Sylvia Shafto on encrusting and boring organisms. As her data indicates, the species of boring clam Bankia gouldi seems to show a significant "preference" for particular stations in our study area. We would like to continue her year-long study into at least two years, and we would anticipate, therefore, requesting additional funding for a half-time research assistant for 1972-73. Also, we would like to place all of the data since August 1969 on computer cards. We have been developing some mathematical models of Barnegat Bay, especially with respect to thermal addition. This study, supported by Jersey Central Power and Light, has been one of the most intensive studies of pre-operational and post-operational effects that we are aware of. The data for phyto-plankton especially are suitable for modelling. We are, therefore, considering additional support in the area of computer simulation modelling of Barnegat Bay.

Personnel. We were fortunate to have Andy Marinucci continue on the project through the school year. He is now a graduate student at the University of Delaware. Kent Mountford now is heading up the phytoplankton andproductivity studies at the Benedict Laboratory, in association with Dr. Ruth Patrick. Nancy Mountford was hired by the University of Maryland to head up the benthic invertebrate sampling program at Dr. Joe Mihurski's laboratory. Miss Dale Palumbo has been a part-time employee with us, primarily involved in sorting specimens—she has been invaluable in the invertebrate area. Mrs. Donna Busch will soon be working with Dr. Diana Ward on pesticide studies on the salt marsh; we will miss her dedicated spirit and devotion to this project. Mr. Phil Sandine has been most helpful in administering this grant and in carrying on with the zooplankton studies. He will soon be working for Ichthyological Associates in Absecon, New Jersey. Miss Jane McCarty will continue on through next year with her physiological study of Codium fragile; she has also helped us extensively on the analysis of the benthic algae material. Mrs. Sylvia Shafto will continue with her work on the boring clam, Bankia gouldi, and encrusting organisms in the Oyster Creek area. Her study already covers a time span of one year, and we anticipate continuing for at least another year, with continuous monitoring through the winter period as well. Dr. E.T. Moul is still thinking about retiring, but seems to be more active than ever—his help in identifications of species of algae is quite welcome. Dr. R. E. Loveland has returned from a year at the University of British Columbia and is all fired up about mathematical modelling. We also appreciate the help received by two former students, Dr. Frank Phillips, now at Jacksonville College in Florida; and Dr. Jon Taylor, who continues his work on benthic algae at the University of Delaware. Thanks also to all those "part-time" students, many of whom are continuing their education in the area of marine ecology. Finally, we wish to thank the continued support of Prof. Harold H. Haskin, Dr. Charles B. Wurtz, Dr. James Carpenter, and other members of the committee responsible for reviewing this work.

Benthic Algae

During the period covered by this progress report (May 1971 through June 1972), we collected 99 samples of benthic algae from Barnegat Bay. These samples were collected at nine stations: Station I, off Stouts Creek at "Nun" can #C1; Station II, between "Nun" can #D and #D1; Station III, off Forked River at "Nun" can #D1; Station IV, at Buoy #E; Station V, off Oyster Creek at "Nun" can #E1; Station VI, at "Nun" can #66, Station VII, off Waretown Creek, at "Nun" can #F; Station VIII, at ½ the distance between "Nun" cans #F and #G; and, finally our southern-most Station IX, at "Nun" can #G. Unfortunately, two of the samples were either lost or not properly preserved, so this discussion is based on 97 samples. Each sample was obtained using a small hand dredge, which was dragged at a slow speed for 5 minutes. The entire sample was placed in a plastic bag and returned to the lab for sorting. Professor E.T. Moul made all final identifications to species. After sorting and identification, each species was weighed (both wet and dry weight), then the diversity index and evenness index were calculated for the sample.

1. Ordination. Table 1 gives a list of the species of algae (note the presence of micro-algae and vascular plants as well) collected during the above period. A total of forty species of algae and other benthic plants were identified during this period. We have stated previously the reason for fewer species being identified since June 1969: we continue to place more emphasis on the quantitative aspects of our algae sampling program, and, therefore, do not identify the micro-algal species unless they are very abundant. We counted the number of times that a particular species appears in the 97 samples, and constructed a list of the frequency of occurrence for all species. The species with the greatest frequency is ranked #1 (in the case of equal frequency, we rank the two species 1a and 1b). Such a ranking of those species which appeared at least 5% of the time, or greater, is given in Table 2. Table 2 also includes the rank of a particular species for the time period December 1965-October 1968 (when John Taylor was emphasizing qualitative aspects of the algae), and the time period June 1969-December 1969 (immediately pre-operational, when we began to emphasize the quantitative aspects of the algae). From this table, we have constructed a frequency plot in Figure 1 of the period 1965-1968 (on the X-axis) against the same species' rank in 1970-1972 (on the Y-axis).

From Table 2 and Figure 1, it is clear that at least eight dominant species of algae have not changed much in their frequency since 1965. Only Codium fragile has moved from a relatively rare species to a dominant species. Recent evidence suggests that even this species is diminishing from its once dominant position, although it is still abundant locally. Otherwise, Ulva lactuca, Agardhiella tenera, Ceramium fastigiatum, Champia parvula, Gracilaria (both G. foliifera and G. verrucosa), Enteromorpha intestinalis, Polysiphonia (both P. harveyi and P. denudata), and Ceramium rubrum continue to be the dominant forms of benthic algae in Barnegat Bay. The species listed in Table 2 are for only those species which were represented in at least 5% of the samples collected in the period 1970-72 (i.e., we collected 119 samples of benthic algae during this period, so any species on this list was present in at least 6 of these samples). We see that some species which were present at the 5% frequency level in 1965-1968 are no longer as common in 1970-72 (viz., Acrochaetium sp., Polysiphonia nigrescens, Entocladia viridens, Enteromorpha linza and Cladophora sp.). However, three species which were not as common in 1965-68 are now being found at the 5% frequency level (viz., Sphacelaria cirrosa, Chaetomorpha linum and Polysiphonia nigra). In addition, we are now including the vascular plants Zostera marina and Ruppia maritima in our survey. Zostera, of course, ranks very high in our list because of its abundance in the bay. Finally, some species of diatoms now appear on the list because of their

Table 1 - List of algae collected from Barnegat Bay during the period May 1971-June 1972.

Green Algae (Chlorophyta)

Codium fragile
Ulva lactuca
Enteromorpha intestinalis
Chaetomorpha aerea
Chaetomorpha linum
Cladophora sp.
Enteromorpha plumosa
Enteromorpha prolifera
Entocladia viridis
Enteromorpha linza

Brown algae (Phaeophyta)

Sphacelaria cirrosa
Desmotrichium undulatum
Ectocarpus sp.
Fucus vesiculosis

Miscellaneous

Biddulphia pulchella
Grammatophora marina
Licmorphora abbreviata
Navicula grevelli
Nitschia grevelli
Vaucheria sp.
Rhabdonema adriaticum

Red algae (Rhodophyta)

Gracilaria foliifera
Gracilaria verrucosa
Agardhiella tenera
Champia parvula
Ceramium fastigiatum
Polysiphonia harveyi
Ceramium rubrum
Polysiphonia nigra
Spyridia filamentosa
Callithamnion sp.
Polysiphonia denudata
Polysiphonia urceolata
Acrochaetium sp.
Antithamnion plumule
Bangia fuscopurpurea
Ceramium diaphanum
Ceramium strictum
Porphyra sp.

Vascular plants

Zostera marina
Ruppia maritima

Table 2. Relative rank-order checklist of major algal species in Barnegat Bay, 1965-72.

Species	Rank in Dec.'65-Oct'68	Rank in June-Dec.'69	Rank in Jan'70-May'72
Codium fragile	10	3	1a
Gracilaria verrucosa Gracilaria foliifera	5b	4(comb.)	1b (comb.)
Ulva lactuca	1	2	2
Zostera marina *	37	1	3
Agardhiella tenera	2	6a	4
Ceramium fastigiatum	3	5	5a
Champia parvula	4	9a	5b
Enteromorpha intestinalis	9	—	6
Biddulphia pulchella	39	9b	7
Polysiphonia harveyi Polysiphonia denudata	6(comb.)	6b(comb.)	8(comb.)
Ceramium rubrum	13	—	9a
Sphacelaria cirrosa	16	10	9b
Chaetomorpha linum	15	10(comb.)	10a(comb.)
Ruppia maritima *	—	—	10b
Callithamnion sp.	14b(comb.)	7(comb.)	11a(comb.)
Grammatophora marina	—	—	11b
Polysiphonia nigra	21	—	12
Desmotrichium	12a	—	13a
Rhabdonema adriaticum	—	—	13b

* non-algal species

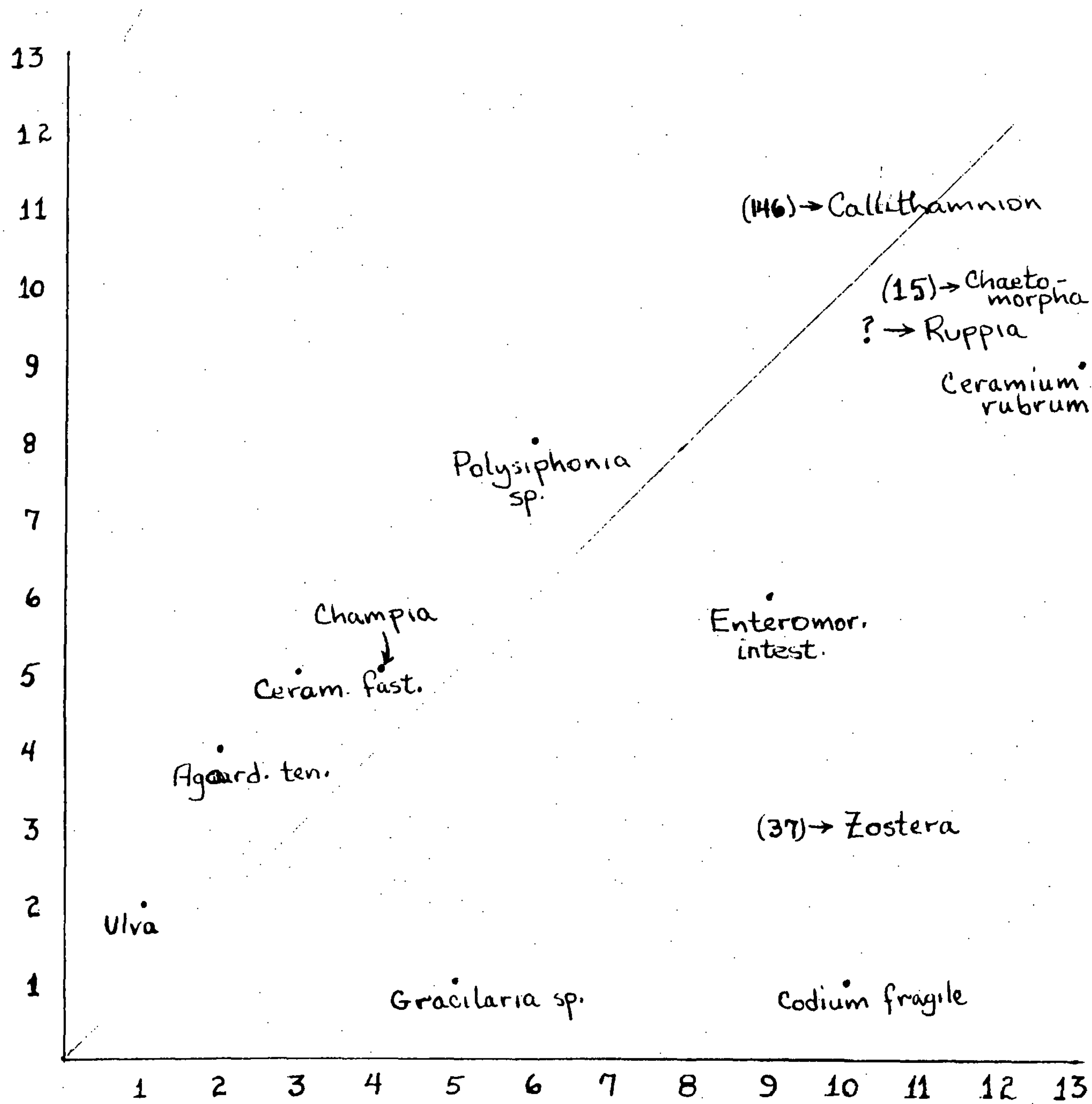


Fig. 1. Frequency vs. frequency, for two time periods, of Barnegat Bay most frequent macroalgal species.

frequent association with the benthic algae (viz., Biddulphia and Rhabdonema). We are unable to explain the decrease in frequency of a particular species of benthic algae. The increase in Codium is probably attributable to a recent introduction of the species into New Jersey waters. To our knowledge, no species of benthic algae has become more or less common as a function of its position (i.e., station) within the bay. To be sure, some species such as Codium are more common locally, especially in the region around Buoy G.

We are, therefore, interested in the question: "Have the populations of benthic algae in the area sampled changed significantly as a function of time or position?" In the past we have found the fewest number of algal species in the late summer. In particular, the three year average of 1965-68 showed about 10 species present in September. During 1971-72 we found an average of 8 species of algae in September. Unfortunately, this kind of comparison is not too meaningful because of gross differences in sampling technique during the above periods. If we examine, however, the dominant forms of algae (i.e., those that occur with enough biomass to be accurately weighed) in the bay, we find that the number of species in the bay remains rather constant through time (see Fig. 2b). An average of 7.74 dominant species can be found in a sample of benthic algae at any particular time(with a range of 5.3 in October to 10.7 in April). We have not observed any large changes in the number of species through time (except due to changes in technique). Furthermore, the total biomass of algae doesn't seem to change significantly with time, although some species are more abundant in biomass at certain times of the year. The dry weight of the total sample for all stations in 1971 is plotted in Figure 2e from data in Table 4. Although extremely variable (note November, 1971, where biomass ranged from 7 gms to over 550 gms. dry wt), there seems to be no statistical difference in the quantity of all species sampled through time. Perhaps one of the reasons for such variation in the amount of algae at a particular station (in dry weight) is due to the floating nature of the algae. Most of the algae on the western side of Barnegat Bay seems to be moving along the bottom. Finally, when one looks at the average dry weight of algae for 1971 collected at each station (Table 3), we find that both Oyster Creek and Stouts Creek have the lowest overall concentration of algae. These two stations are very similar in their bottom sediment composition, with Oyster Creek having a higher surface temperature. Surprisingly, we find large amounts of algae off Forked River, but the sediments tend to be more sandy and there is an abundance of old oyster shell in this area that may serve as substrate for the algae. The large amount of algae at Buoy G is generally due to the increased proportion of Codium which we find at this station.

Diversity and Evenness: We have stated in the past that the technique which we employ for collecting benthic algae is not precisely quantitative. We do not know exactly how much area has been sampled, nor do we know the collecting efficiency of the dredge. However, each five minute tow collects a representative sample of the algae, which allows us to measure the relative proportions of each species of algae collected. This relative quantity can be best expressed by the diversity and evenness indices. The Shannon-Weaver diversity index is simply a number which gives us an idea of the species composition and their relative dominance; while the evenness index gives us an idea of how nearly equally (in quantity) the species contribute to the sample. For example, a low diversity index suggests few species (or extreme dominance by one species); an evenness value of 1.0 means that each species in the sample contributed the same amount of biomass. We are presently

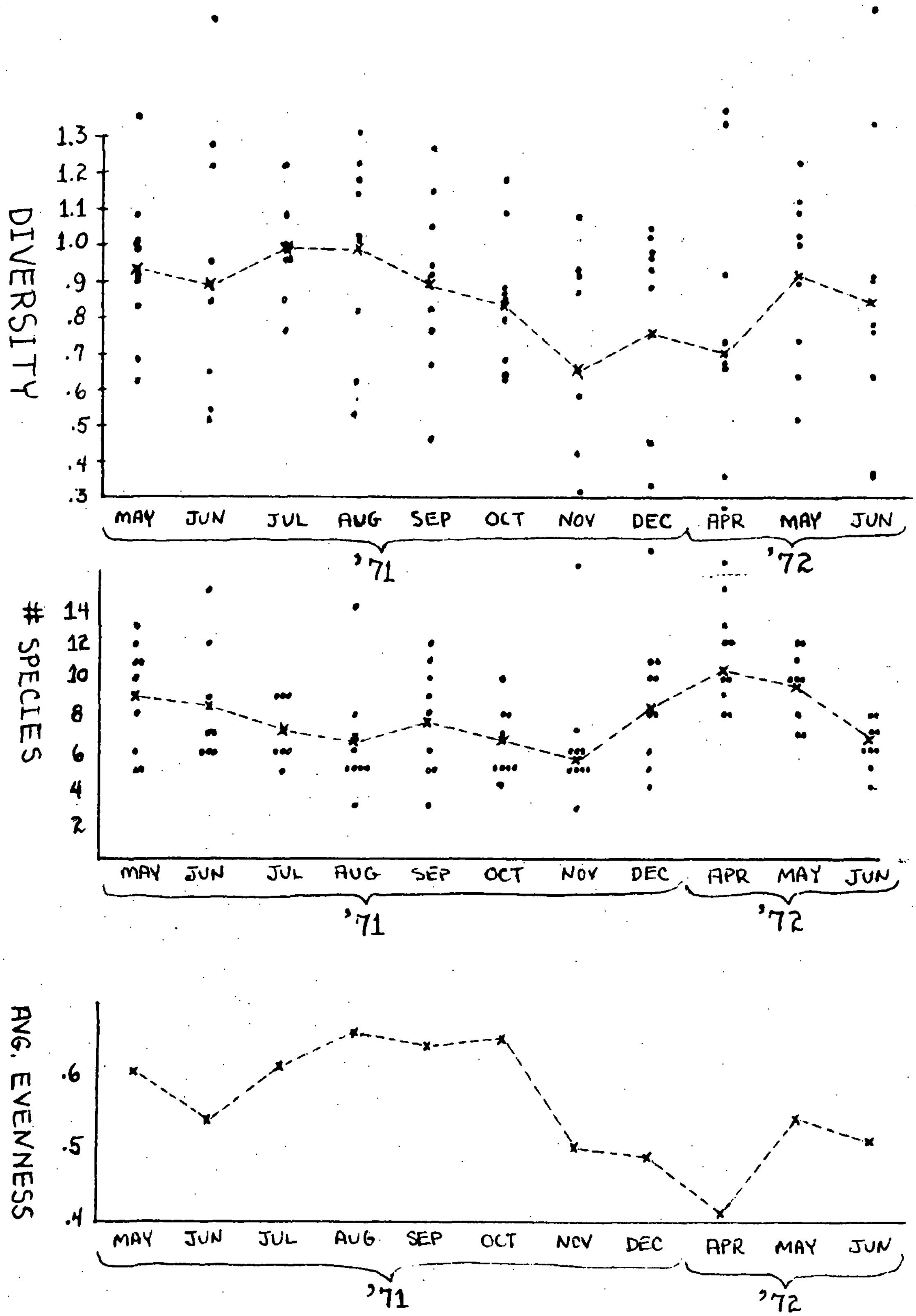
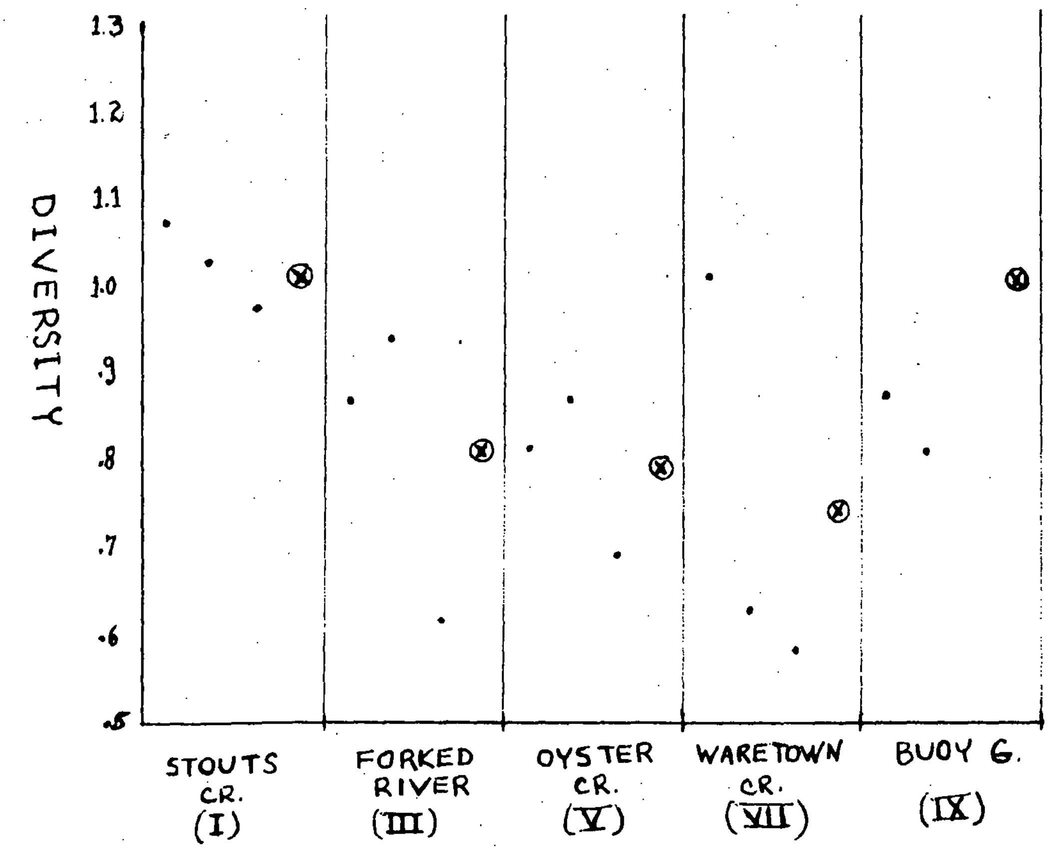


Fig. 2a Diversity vs. time for macroalgal species in the bay sampling area.
2b # species of macroalgae vs. time in the bay sampling area.
2c Average evenness vs. time for macroalgal species in the bay sampling area.



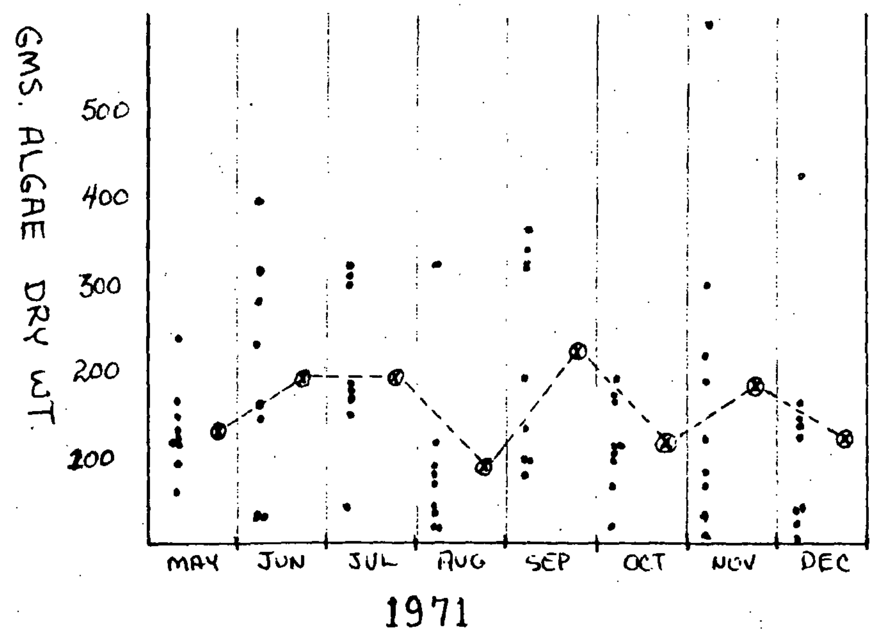


Fig. 2d Diversity vs. position of macroalgae.
2e Dry weight of algae (GMS) vs. [illegible]

Table 3. Average dry weight of algae for 1971, diversity and evenness indices for 1969-72, as a function of position.

Position in Bay	(Station)	Average Dry Wt. of Algae in 1971
Stouts Creek	(I)	107.63 gm.
Forked River	(III)	209.48
Oyster Creek	(V)	108.20
Waretown Creek	(VII)	171.80
Buoy G.	(IX)	191.73
		Ave = 157.77

	Diversity for the period June'69-Aug.'70	May'71-Dec.'71	April'72-June'72	Overall Diversity since June 1969	
I	1.070	1.028	.907	1.002	
III	.867	.940	.618	.808	Grand
V	.81[illegible]	.866	.699	.792	Ave.
VII	1.026	.625	.577	.743	
IX	.870	.806	1.352	1.009	0.871
	Ave = .929	Ave = .853	Ave = .831		

	Evenness for the period June'69-Aug.'70	May'71-Dec.'71	April'72-June'72	Overall Evenness since June 1969	
I	.710	.716	.564	.663	
III	.536	.605	.379	.507	Grand
V	.511	.581	.386	.193	Ave.
VII	.639	.406	.333	.459	
IX	.488	.587	.710	.543	0.543
	Ave = .577	Ave = .579	Ave = .474		

Table 4. Average dry weight of algae in 1971, diversity and evenness indices for 1969-72, as a function of time.

Month	Average Dry Weights	Average No. of Species	Diversity (for all positions)	Evenness (for all positions)
June 1969	—	—	1.1283	.6757
July 1969	—	—	.9068	.6386
August 1969	—	—	.6369	.4389
September 1969	—	—	.9669	.5871
November 1969	—	—	1.0822	.5917
February 1970	—	—	.8199	.4574
May 1970	—	—	.7537	.4861
August 1970	—	—	.6994	.4023
May 1971	131.15 gm.	9.0	.9287	.6026
June 1971	197.85	8.5	.8955	.5498
July 1971	193.95	7.1	.9739	.6137
August 1971	86.43	6.4	.9808	.6689
September 1971	210.98	7.7	.8916	.6418
October 1971	112.40	6.3	.8466	.6504
November 1971	176.96	5.3	.6499	.5002
December 1971	120.98	8.1	.7518	.4896
April 1972	—	—	.7031	.4126
May 1972	—	—	.9194	.5406
June 1972	—	—	.8536	.5127
		Grand mean =	0.8626	.5505

doing a study of the rank of each species per sample, but the results of this analysis are not yet available. Therefore, we have listed in Table 3 the diversity and evenness indices by position in the bay for three time periods. These time periods reflect differences in personnel sorting algae (although Dr. E.T.Moul identified all algae throughout the course of this study, dating back to 1965). In Table 4, we have listed the monthly average diversity and evenness indices for all positions. Although we have not completed the analysis of variance for the data of Tables 3 and 4, we have plotted these data in Figures 2a, 2c, and 2d. It is evident that the diversity index exhibits wide variation from station to station and from month to month. However, the pattern developed on a baywide basis (from Stouts Creek to Buoy G) seems to indicate that there have been no significant changes through time in the diversity index for benthic algae in Barnegat Bay. If one examines Table 2 and Figure 2 from Progress Report #7 (dated 25 June 1971), it is apparent that the diversity indices for samples of May 1971 through June 1972 have had little effect on the grand mean for diversity for all positions. That is, the grand mean for diversity for all positions in the period June 1969 through August 1970 was 0.874; and the grand mean for diversity (all positions) for the period May 1971 through June 1972 was 0.854. The grand mean for the period June 1969 through June 1972 was 0.863. It is doubtful that the slight drop in the diversity index is significant on a bay-wide basis. Similarly, if one examines Table 2 and Figure 4 of Progress Report #7, one finds that the evenness index has not changed significantly (from 0.5347 in the period June 1969 through August 1970 to 0.562 in the period May 1971 through June 1972). Furthermore, direct comparison of Figure 2a of this report, with Figure 2 of Report #7 shows that the diversity index has been rather stable over time. This conclusion is also reached for the evenness index if one compares Figure 4 of Report #7 with Figure 2c of this report.

In summary, we conclude that with respect to the benthic algae of Barnegat Bay:

1) the dominant species seem to remain constant in composition from year to year, both in number of species and amount of biomass.

2) only one species, Codium fragile, has become more numerous in the past five years.

3) both the diversity index and evenness index remain highly variable from sample to sample, but the pattern of these indices, over time, has not changed significantly.

4) there has been no sudden "crash" or "explosion" in the benthic algae populations in the past three years; if anything, the algae seem to be more stable than the benthic invertebrates in Barnegat Bay.

Primary Productivity

In the previous progress report, the topic of phytoplankton and primary productivity was covered extensively by Kent Mountford. Dr. Mountford was employed on this project specifically to work on benthic algae and phytoplankton, particularly the latter because of his expertise in this subject. Since his resignation (he is now directing a marine laboratory in Maryland) we have had to de-emphasize the intensity of his study. This is, in part, due to the lack of another qualified person to fill his position and, also, to the shift of emphasis towards encrusting and boring organisms (which is being done by Sylvia Shafto, Kent's immediate replacement). However, we have attempted, on a monthly basis, to continue a survey of primary productivity in the region around Oyster Creek. The technique used has been that of Kent Mountford, with a few logistic changes described below.

Methods

Area sampled. We continued to sample essentially the same regions that Dr. Mountford selected. They are: Stouts Creek, near the "Mile Mark"; Forked River, off Light #2; Oyster Creek, off Light #3; Waretown, about ½ mile off the northern area of the town; the Intake Canal, near Light #12, and the Outfall Canal, in the cove just inside the mouth of Oyster Creek.

Field Technique. Whereas Kent Mountford collected his water sample and set up the experimental bottles at each station, we felt it was important to gather all of the water samples as quick as possible and then begin the experiment. The rationale was simply that the shift in light quality from the beginning of setting up an experiment might prove significant if the logistics of the experiment took too long. Therefore, we have decided to collect all samples in rapid sequence, beginning at Stouts Creek for one run, and at Waretown for the next run. Collecting samples took about 20-30 minutes. Each sample was gathered by dipping a gallon, plastic, wide-mouth bottle beneath the surface and after a minute or so for equilibration, we capped the bottle underwater. The samples were stored at ambient temperature until the setting up of the bottles began. All bottles were incubated at ambient bay temperature for at least four hours in available daylight, beneath 10-15 cm. of sea water. All bottles received exactly the same treatment—there were no temperature differences between bottles for any one run.

Design and procedure. At each of the four bay stations, two one-gallon samples were taken. From each gallon bottle we filled six B.O.D. glass-stoppered bottles. Of the six bottles filled by siphoning, two acted as initial oxygen samples, two acted as light bottles and two acted as dark bottles. Thus for each bay station we had two duplicate samples (i.e., two different samples of bay water) from which two replicate experiments were run. This gives a total of four experiments per station, or 16 experiments in the bay for a days run. The canals were also replicated, however only one gallon was collected, so the canal experiments were not duplicated on a run.

The bottles were incubated in the field for four or more hours, beneath 10-15 cm. of sea water, at ambient bay temperature. They were then fixed with the appropriate Winkler reagents, returned to the lab and titrated the following morning. In the titration procedure, two independent titrations were run on each bottle in order to obtain an average titration value. The values reported in this section of the report are for uncorrected, average titration values. Since all of the thiosulfate reagent was prepared from commercially available "Acculutes", reagent corrections were generally negligible. Also, we are primarily interested in differences between bottles, rather than absolute values for oxygen.

Discussion

There is one unfortunate omission in the data collected for 1971-72: we failed to sample on all dates a station which Kent Mountford felt to be important in the comparison of positions within the bay; viz. Buoy "G". However, we have sufficient data for all other stations to make some general statements regarding primary productivity in Barnegat Bay.

1. Comparison of years. Figure 3 indicates the average values for gross productivity for four years and five bay stations. The plotted point is for all samples taken within the period from June through October. No table of data is offered since the comparison is not yet complete for 1972 (i.e. only June and July are available in 1972; also, only August, September and October are available for 1971). In addition, a plot is given for the four-year average gross productivity at each station, and for the entire area of the bay sampled. It will be seen immediately that 1969 was quite different within the four year period—with the exception of Stouts Creek in 1971, all stations in the bay were higher in 1969 (for gross productivity) than at any other time sampled. Although we have not performed the appropriate statistical tests, it appears that gross productivity is lower in Barnegat Bay during the post-operational period (as evidenced by having only two points out of 13 falling above the four-year average). However, it must be pointed out that the general lowering of primary productivity has occurred throughout all stations. There appears to be little difference in the four-year average for the three lower bay stations (viz., Oyster Creek, Waretown and Buoy G). If we exclude the data from 1969 and Buoy "G", then we see that Oyster Creek does have the lowest rate of gross productivity (see Table 5). Since Stouts Creek and Waretown are considered to be outside the influence of thermal addition, we conclude, tentatively, that over the past four years, Oyster Creek is not unlike the other bay positions with respect to gross productivity. A more accurate statistical statement will be offered in our last report.

It will be recalled that Kent Mountford argued that Oyster Creek showed that there was a significant decrease in gross productivity at Oyster Creek between 1969 (pre-operational) and 1970 (post-operational). However, we are now confronted with the realization that 1969 was exceptionally high in productivity. Also, on the average, Waretown had the lowest productivity in 1969; Buoy "G" had the lowest in 1970; Oyster Creek in 1971; and Stouts Creek in 1972. Oyster Creek, is therefore, not consistently lowest through time. Since the distribution of plankton in Barnegat Bay is "patchy", it is likely that some areas of the bay will have higher (or lower) productivity values, but the exact position of sampling will be characterized by variability. We will attempt through analysis of this variability, to sort out effects of position in the last report.

Dr. Mountford also found that Forked River was consistently higher in productivity when compared to Oyster Creek. He found this difference to be 55 mg $O_2/M^3/hr$. Conversely, we have found for all samples of 1971 and 1972 that only three out of eight samples at Forked River (bay station), were higher than Oyster Creek. Yet, the average for Forked River was 21 mg $O_2/M^3/hr$. higher than Oyster Creek for all samples (see Table 5). Furthermore, only three out of eight samples taken within the intake canal had higher gross productivity values than comparable samples taken from the outfall canal. Yet, the average productivity in the intake canal was 8mg $O_2/M^3/hr$. higher than the outfall canal. In addition both the intake canal and the outfall canal were lower in gross production than the average bay values.

While Kent Mountford found the dissolved oxygen to decrease between the intake and outfall canal, we found that in eleven samples, taken at the same times, there was no difference in the average dissolved oxygen in the two canals (both had mean values of 7.47 mg O_2/liter). Mountford also found that because of increased respiration in the outfall, the net productivity of the outfall was 121 mg $O_2/M^3/hr$. less than the intake canal. In 1971-72, we also found a reduction in net productivity (37 mg $O_2/M^3/hr$.) across the two canals, probably due to increased respiration (114 mg $O_2/M^3/hr$. in the outfall canal, vs. 99 mg $O_2/M^3/hr$. in the intake canal).

Fig. 3. Gross productivity for four years and five bay stations.

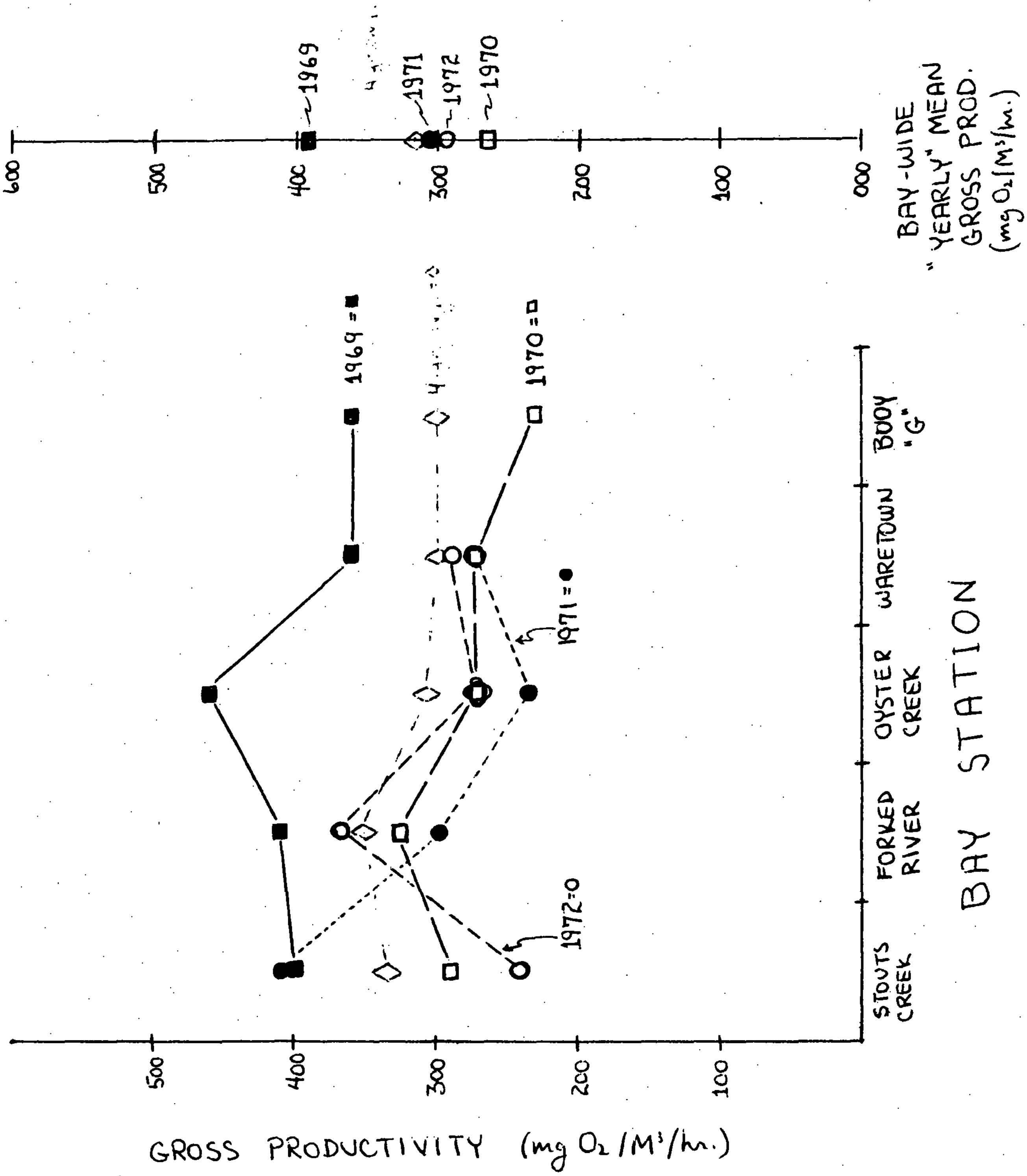


Table 5. Primary productivity data, from four bay stations and the intake-outfall canals, from 4 August 1971 to 27 July 1972.

		Net Productivity mg O_2/M^3/hr.	Respiration mg O_2/M^3/hr.	Gross Productivity mg O_2/M^3/hr.
Stouts Creek	* 1.	256	277	533
	2.	396	124	520
	3.	23	143	166
	4.	-82	360	278
	5.	-6	76	70
	6.	131	32	163
	7.	38	86	124
	8.	280	76	356
Forked River	1.	264	173	437
	2.	157	156	313
	3.	7	135	142
	4.	-135	144	9
	5.	60	-4	56
	6.	76	57	133
	7.	78	82	160
	8.	489	89	578
Oyster Creek	1.	168	161	329
	2.	60	169	229
	3.	26	120	146
	4.	28	162	190
	5.	43	41	84
	6.	101	35	136
	7.	4	157	161
	8.	296	89	385
Waretown	1.	183	231	414
	2.	218	49	267
	3.	56	77	133
	4.	55	84	139
	5.	28	35	63
	6.	78	37	115
	7.	133	72	205
	8.	234	96	330
Intake Canal	1.	410	-38	372
	2.	52	148	200
	3.	10	[illegible]	136
	4.	-32	295	262
	5.	12	40	52
	6.	98	[illegible]	142
	7.	42	72	114
	8.	252	[illegible]	234

Table 5 con't.

Outfall Canal	1.	46	370	416
	2.	2	92	90
	3.	16	148	130
	4.	-138	72	66
	5.	40	34	74
	6.	140	52	190
	7.	182	72	252
	8.	254	72	326

* Time periods are as follows: 1. 4 August 1971; 2. 9 September 1971; 3. 11 October1971; 4. 11 November 1971; 5. 18 April 1972; 6. 11 May 1972; 7. 28 June 1972; 8. 27 July 1972.

Table of Mean Values (4 Aug. '71-27 July '72)

		Mean Net Productivity $mgO_2/M^3/hr.$	Mean Respiration $mgO_2/M^3/hr.$	Mean Gross Productivity $mgO_2/M^3/hr.$
Stouts Creek		129	147	276
Forked River		124	104	228
Oyster Creek		91	117	207
Waretown		131	85	215
Intake Canal		104	99	201
Outfall Canal		67	114	193
Overall Bay Average (excludes canals)		119	113	232
By Date (for Bay Stations only)	1.	220	211	428
	2.	208	125	332
	3.	28	119	147
	4.	-34	188	154
	5.	31	37	68
	6.	97	40	137
	7.	63	99	163
	8.	337	88	425

1971-72 Productivity Data. In Table 5 we have given the net and gross productivity rates, plus respiration, for eight dates at each of six stations. A table of mean values both by station (for all dates) and by date (for all stations) is also given. These data are plotted in Figures 4 and 5. For net productivity the pattern for all stations is consistent; i.e., the peak productivity occurs in the warmer months of the year in Barnegat Bay. It is interesting to note that both Stouts Creek and Oyster Creek show a depression in net productivity during June 1972, a time when productivity should be rapidly increasing. On the other hand, both Forked River and Waretown show slight increases in net productivity in June. This supports our view that Forked River and Waretown are less influenced by fresh water runoff than is either Stouts Creek or Oyster Creek. We need to perform more detailed analyses of hydrographic data during the post-operational period to see if this assumption is correct. At any rate, it is seen that net productivity eventually dips to zero (or negative) in most of the bay during the colder months of the year.

Figure 5 gives a plot of gross productivity, by date and station for 1971-72. It is seen that the same pattern of productivity holds. In Fig. 5b we have plotted the average for all bay stations (lazy B character). It is seen that most of the data clump around the average curve of the bay. One interesting exception is the very wide difference between Forked River bay water and Intake canal water on 11 Nov. 1971. We fail to see how the water quality could be so affected within a distance of several thousand yards—perhaps this is a reflection of either patchiness or very high respiration values at both stations.

We have plotted Kent Mountfords data for 1969 in Fig. 5a. Recalling that 1969 was an exceptionally high year for gross productivity during June through October it is remarkable to see how well the data which Mountford gives for all months of 1969 fits the data of all months sampled in 1971-72! The only notable exception is for June 1972. Mountford found in his studies a definite sharp increase in gross productivity during June. The increase in 1972 did not occur until July, possibly due to the very wet month of June 1972.

In summary, it appears that until we can perform more accurate statistical analyses of our data, only the following tentative conclusions can be made:

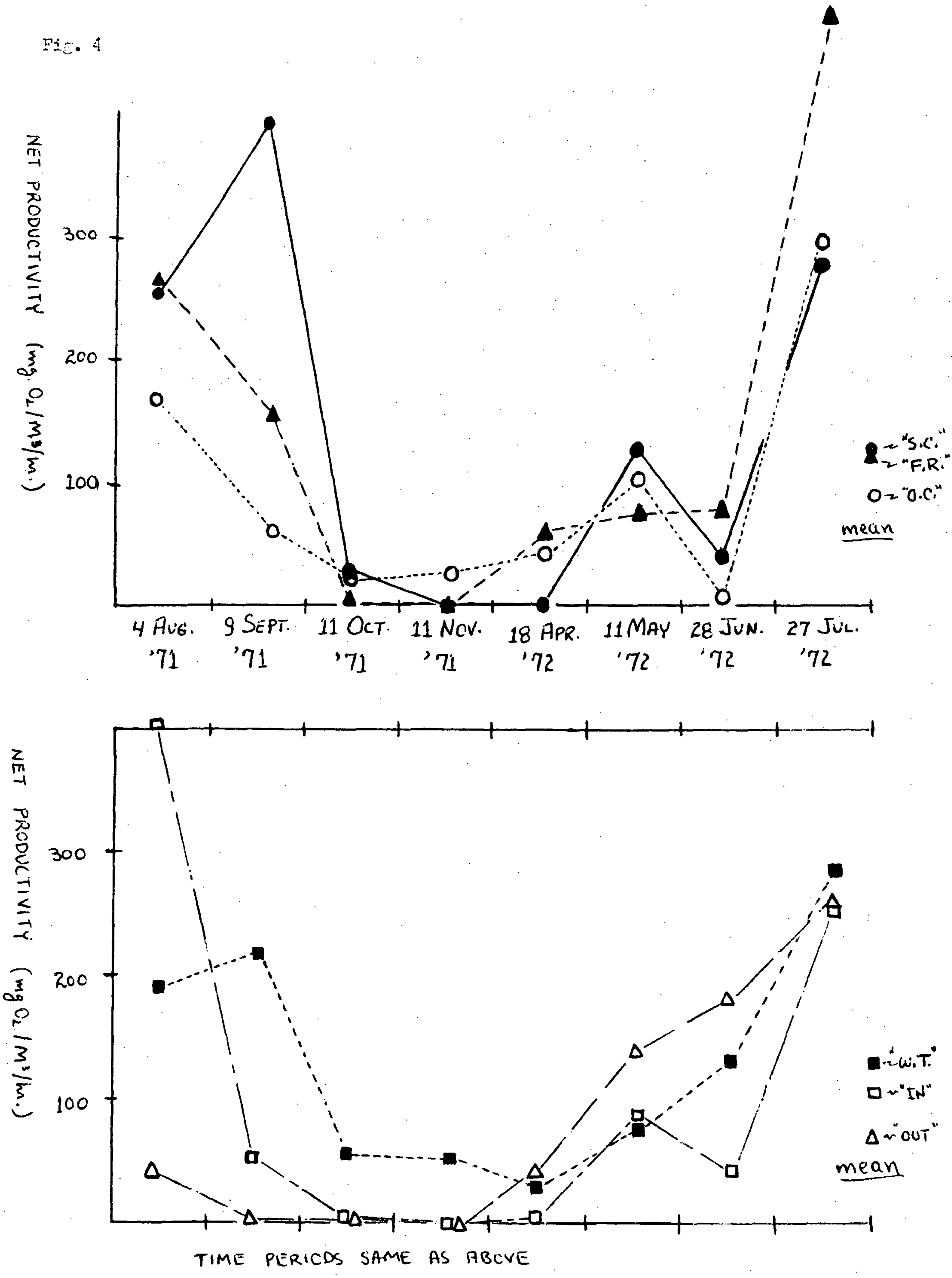
1. During the test period June through October, the primary productivity in Barnegat Bay is lower for 1970-72 than for 1969. That is, the average gross production at all stations is lower for the three-year period 1970-72 than for the four year period 1969-72.

2. The intake and outfall canals generally exhibit lower productivity values than the bay, with net productivity being lower and respiration being higher in the outfall canal.

3. Dissolved oxygen never fell below 6ppm (=6 mg O_2/liter) in any part of the bay samples; initial dissolved oxygen went as high as 12.00 ppm in the area off Forked River during November 1971. In the canals oxygen levels have fallen as low as 5.5ppm, although we have observed no difference in mean value of dissolved oxygen between the canals in 1971-72 at the stations sampled.

4. The area of the bay off Oyster Creek had the lowest average value for both net and gross productivity in 1971-72. However, we do not know if the difference between the average for this period is statistically different from the 3-year (post-operational) baywide average, or different from all other stations in the bay.

Fig. 4



NET PRODUCTIVITY (mg. O2/M3/hr.)
300
200
100
4 AUG. '71
9 SEPT. '71
11 OCT. '71
11 NOV. '71
18 APR. '72
11 MAY '72
28 JUN. '72
27 JUL. '72
"S.C."
"F.R."
"O.C."
mean
NET PRODUCTIVITY (mg O2/M3/hr.)
300
200
100
"W.T."
"IN"
"OUT"
mean
TIME PERIODS SAME AS ABOVE

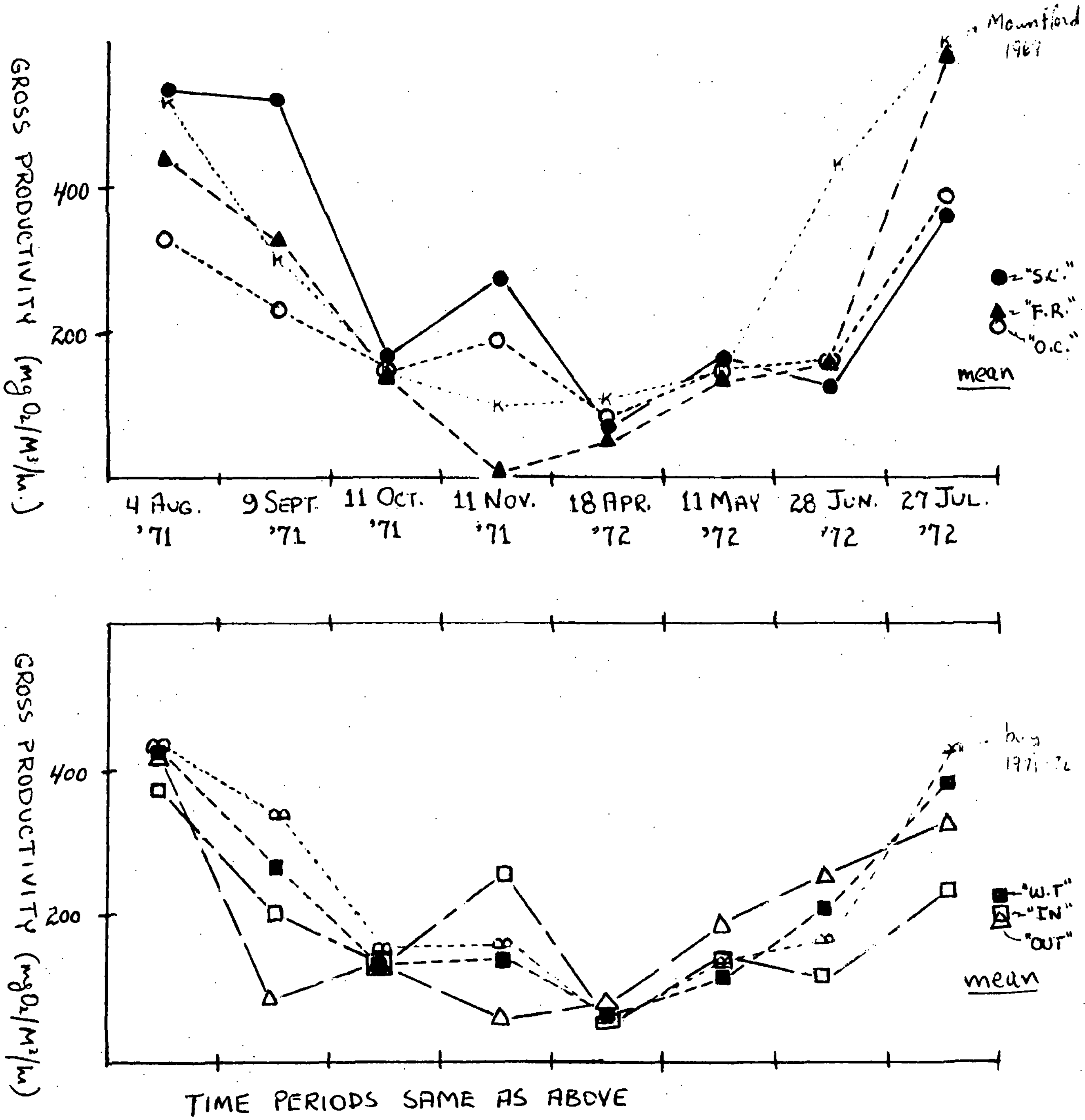

Mountford 1969
GROSS PRODUCTIVITY (mg O2/M3/hr.)
400
200
4 Aug. '71
9 Sept. '71
11 Oct. '71
11 Nov. '71
18 Apr. '72
11 May '72
28 Jun. '72
27 Jul. '72
"S.C."
"F.R."
"O.C."
mean
GROSS PRODUCTIVITY (mg O2/M3/hr)
400
200
"W.T"
"IN"
"OUT"
mean
TIME PERIODS SAME AS ABOVE

Fig. 5a and b.

Invertebrates

We are again including data taken from two previous progress reports (Sixth Progress Report, dated 1 June 1970; Seventh Progress Report, dated 25 June 1971) in order to facilitate comparisons between time of sampling. The data in the present progress report will be discussed for six individual time periods, beginning 27 August 1969 and ending 26 June 1972. It will be recalled that in August of 1969, the project shifted from a more general survey of "middle" Barnegat Bay (i.e., from North at Stouts Creek to South at Buoy G) to more specific locations. We made a major change in our technique of sampling at that time (see Methods, below) and feel that our most accurate quantitative data begins in August 1969.

Methods:

Location of stations. In August, 1969, we made the decision to concentrate our efforts on benthic invertebrates at five specific localities: Stouts Creek, out of the influence of thermal addition; Forked River, in the area supplying water to the generating plant; Oyster Creek, an area receiving heated effluents (these three stations are all in the bay); Forked River at Route #9, the intake canal; and, Oyster Creek at Route #9, the outfall canal. These stations were chosen because they are adjacent to one another, yet hydrographically distinct. Stouts Creek serves as our "control" area because it is quite similar to Oyster Creek in its sediment composition, but it receives no heated effluents. Forked River is a region where bay water is pulled into the intake canal, and may, therefore, be less exposed to fresh water run-off from the land. The region off Oyster Creek is generally warmer than either of the other two bay stations, although thermal stratification is the rule. We are thus interested in a statistical design which will allow us to detect differences in the benthic invertebrate community, due to 1) the geographical position of the community in the bay and 2) the effect of normal seasonal variation (time) on the three positions.

Samples. We found earlier that at least seven Ponar "grabs" had to be made at a fixed point in the bay in order to characterize 95% of the potential species at that point. Therefore, whenever a sample is taken at an anchor station (within one of the three localities in the bay) we drop the Ponar seven consecutive times; each volume of mud collected, per drop, is recorded. In the past we have characterized the sediments of the sample, but after hundreds of such analyses of our three bay locations we feel we have an adequate description of each study area with respect to sediements (see Progress Report #7). The sample is pooled and washed through screens. While we have always "fixed" the sample in formalin, we now keep the animals alive and do all sorting and identification on living specimens. This slight change in sorting technique may introduce some error (with respect to time) but it more accurately characterizes species composition of the sample. A total of 431 samples (of seven Ponar grabs each) were analyzed from August 1969 to June 1972. These samples were collected in all but the coldest months of the year, when it is impossible to sample the bay.

Statistics. The data through September 1970 were analyzed statistically, using the procedure of analysis of variance. However, because of time limitations the data from October 1970 to date are still being compiled for computer analysis, so we will restrict our discussion to the simple calculation of averages. Plots of the variability from one station to another indicate that any bay station is as variable as any other; however, confirmation of this conclusion awaits our summary analysis.

Diversity and Evenness. Each sample is sorted for the number of individuals of each species. Biomass of the sample is also estimated; and, in some instances, we have made measurements of the size-frequency of a particular species. With this

information we have calculated an index of diversity (Shannon-Weaver) which allows us to characterize each sample by a number which incorporates both number of individuals and number of species in a sample. Marsha Moskowitz has shown previously that the number representing diversity is amenable to normal statistical analysis. We have continued to use the concept of diversity even though there is serious debate over its utility in the ecological literature.

Hydrography

Whenever a sample is taken we note 1) the position, estimated in yards and degrees from a fixed buoy marker, nearness to a dredged channel, etc.; 2) time on station (for tidal reference); 3) weather; 4) water clarity; 5) salinity and temperature (usually a profile, but always top and bottom); and 6) sediment characteristics. Such data are listed in the appendix to this report.

Time periods. We have divided the data into two time periods, based on a Winter-Spring reproductive period and a Summer-Fall growth period. The reproductive period begins with our earliest sample of the calendar year and ends around the end of June. The growth period starts around the beginning of July and ends with our last sample of the calendar year. Obviously our best time for collecting samples is in the growth period because of weather, so the greatest number of samples will be for this period. Three growth periods and three reproductive periods will be discussed.

Discussion

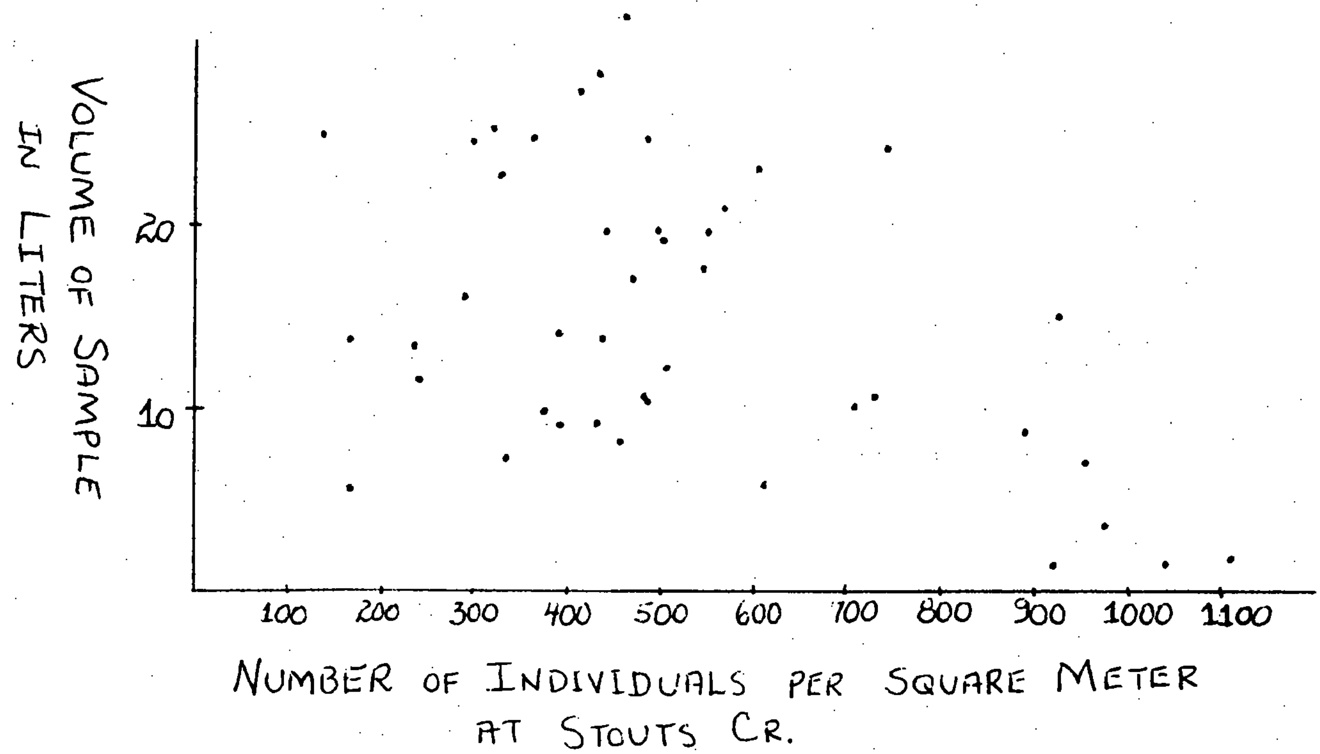
New species. In the last year (June 1971-June 1972) we have identified 31 new invertebrate species for Barnegat Bay, bringing the total number of benthic species to 197 collected in the bay since 1965. These new species are given in Table 6.

Number of individuals and species as a function of sample size.

One concern in our sampling procedure has been accuracy. How well does a single sample (consisting of seven Ponar grabs) characterize a point in the bay? Unfortunately, the variability of organisms on the bottom of Barnegat Bay is very large, both in time and space. Two stations within 100 yards of one another will give very different results. For example, at Forked River it is possible to sample sediments which are either very silty (north of the dredged channel), very sandy (south of the marker) or composed of almost pure *Spartina* debris (south of the dredged channel). Two samples within yards of one another will yield very different numbers of a single species (viz, a few *Mulinia*, per square meter, to tens of thousands). We, therefore, are faced with the problem of estimating whether the patterns of variability differ from one region of the bay to another. Figure 6 demonstrates the kind of variability we obtain when we consider the number of individuals per square meter as a function of the volume of the sample taken. Recalling that the volume of the sample increases with decreasing grain size, we still see that there is no relationship between the volume of the sample and the number of individuals present. This is as true for Stouts Creek as it is for Oyster Creek. However, if we examine the data carefully, we find that Stouts Creek has more samples which are larger than 20 liters (Fig. 6 a vs. 6 b). Also, of 67 samples from Stouts Creek, 35.82% (or 24 samples) are characterized by having more than 1100 individuals/M^2; while at Oyster Creek, only 11 samples, out of 61 analyzed, had more than 1100 individuals/M^2. Unfortunately, it is most difficult to estimate the actual area sampled by the Ponar. Therefore, while one may conclude that there are fewer numbers of individuals at Oyster Creek (average = 724/M^2 for 61 samples) than at Stouts Creek (average = 1079/M^2 for 67 samples), we are more interested to see if the pattern of change through time is similar. Furthermore, we must examine the species present at both places as a function of sample size. In Figure 7, we see that, again, there is no distinct relationship between the volume of the sample and the number of species in that sample (compare Fig. 7a with 7b) even though Stouts

Table 6 . New species recorded from July, 1971 through July, 1972.

Goniadella gracilis	Corambella sp.
Glycinde solitaria	Spisula solidissima
Polycirrus eximius	Lembos smithi
Eteone lactea	Unciola irrorata
Etone heteropoda	Leptosynapta roseola
Polydora ligni	Gammarus locusta
Scololelpis squamata	Polycirrus sp.
Harmothoe extenuata	Phyllodoce maculata
Scoloplos robustus	Onuphis quadricuspis
Jassa mamorata	Hypaniola grayi
Calliopius laeviusculus	Spio filicornis
Talorchestia longicornis	Leptochilia savignyi
Arbacia punctulata	Bowerbankia gracilis
Scolecolepides viridis	Electra hastingsae
Orbinia norvegica	Euplana gracilis
Tharyx acutus	



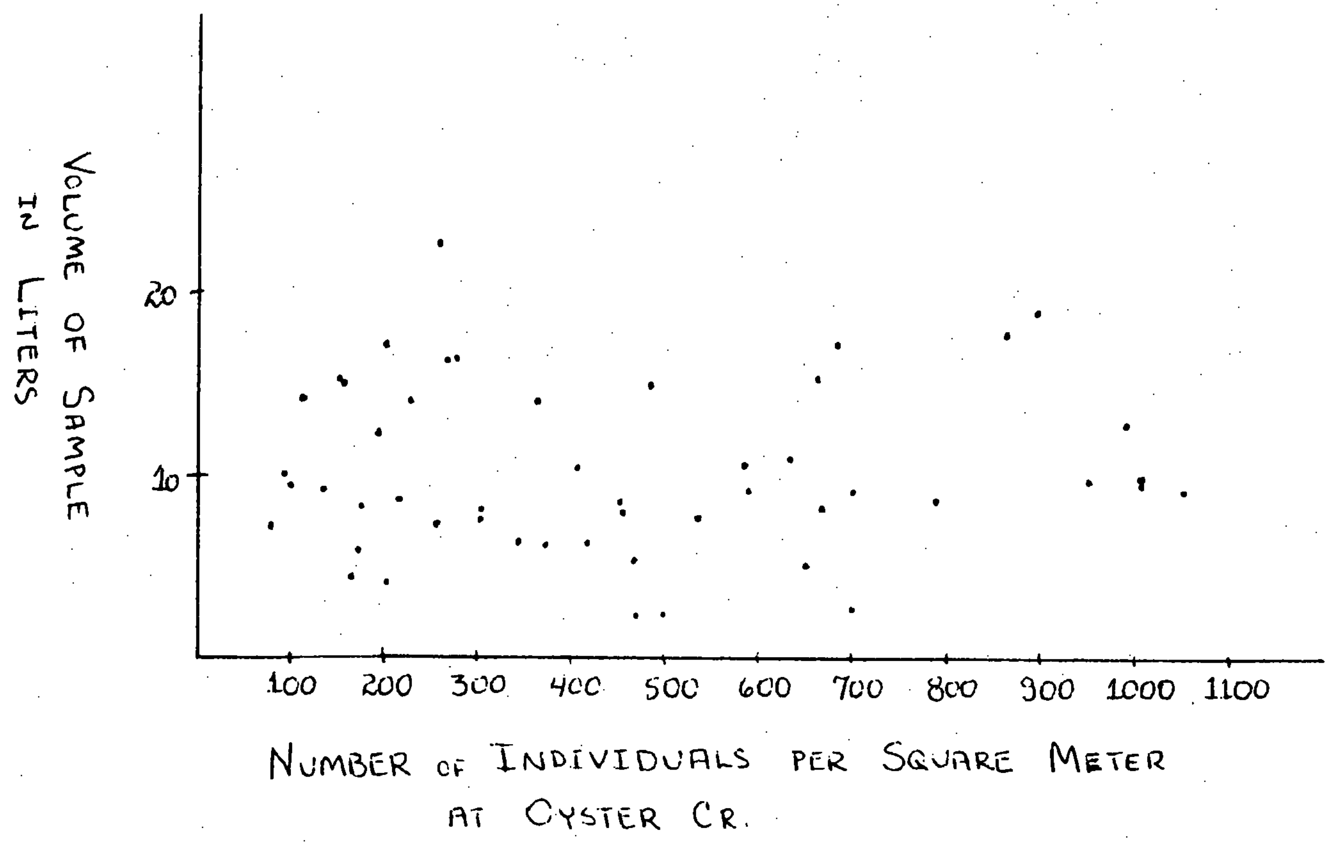
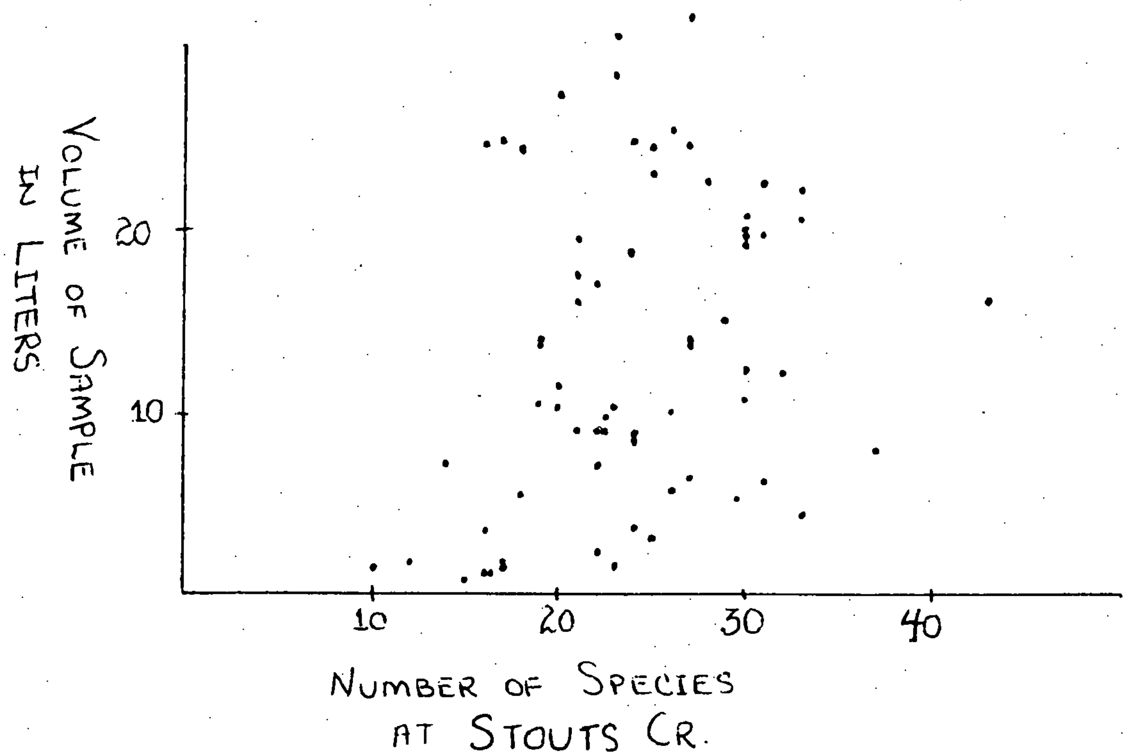


Fig. 6a, b. From 25 April 1970—26 June 1972.


Volume of Sample in Liters
20
10
10
20
30
40
Number of Species at Stouts Cr.

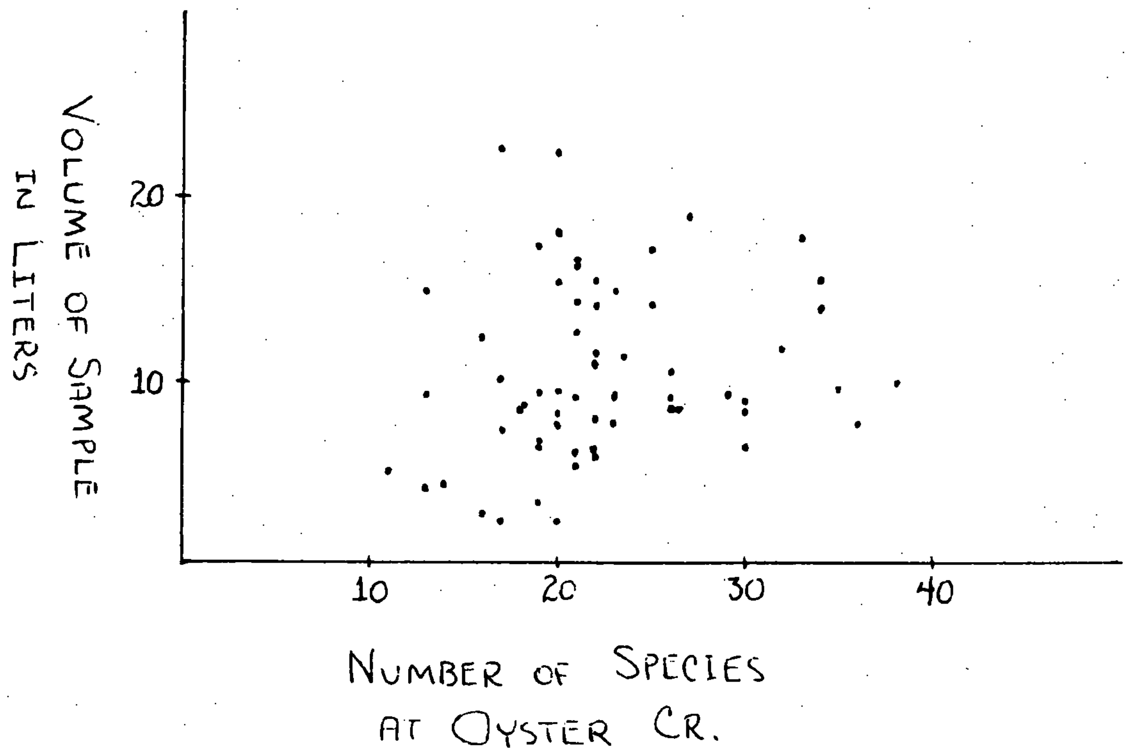
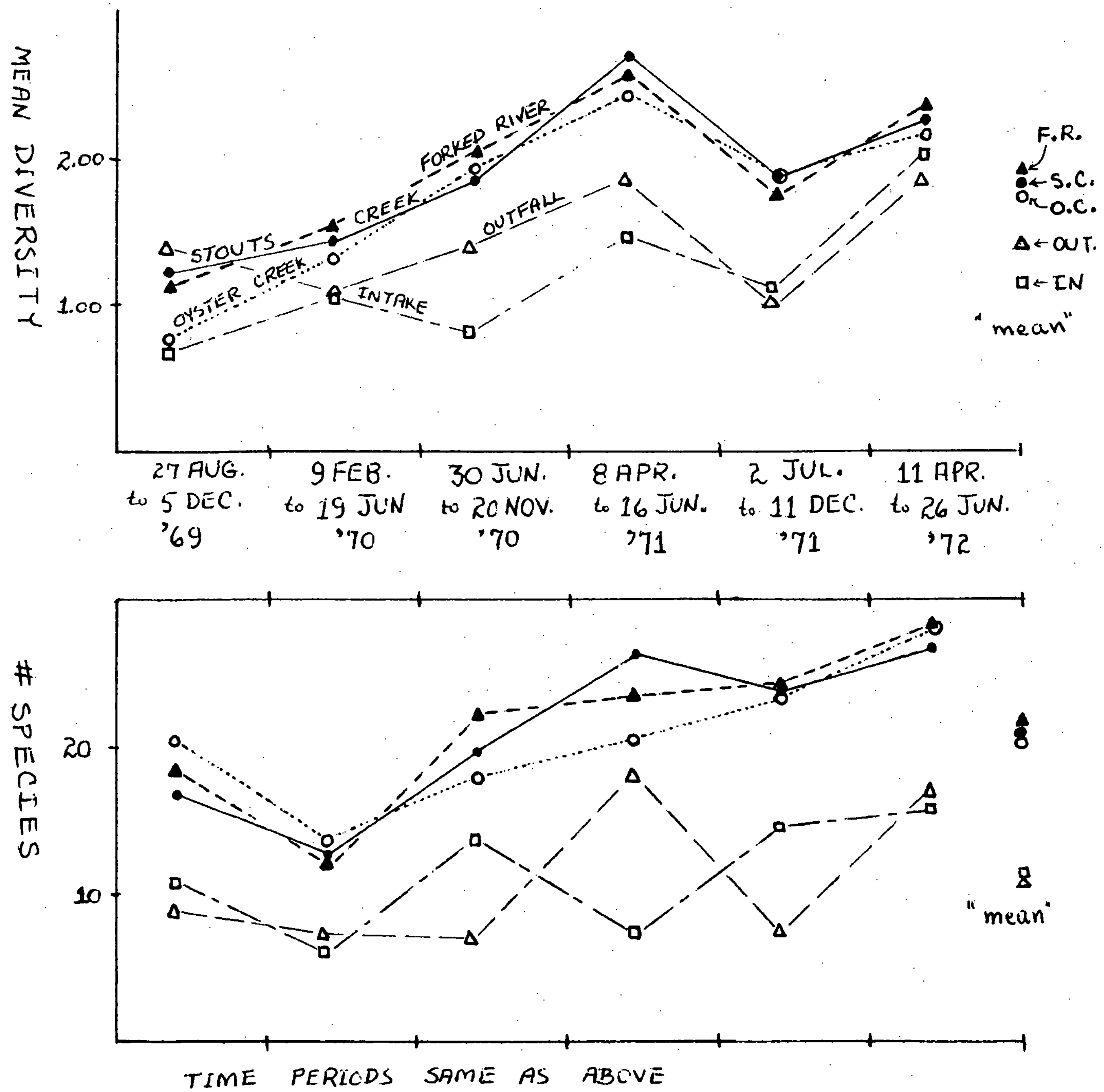

Volume of Sample in Liters
20
10
10
20
30
40
Number of Species at Oyster Cr.

Fig. 7a, b.

Creek seems to have more samples of larger size than Oyster Creek. However, if we compute the average number of species over two years, we find that Stouts Creek has less than one species more than Oyster Creek (21.01 for 67 samples, vs. 20.61 for 61 samples, respectively). It is also interesting to note that we rarely find fewer than 10 species or more than 40 species in any one sample from the bay. We conclude, therefore, that whereas there is variability between samples from one point to another, this variability seems to be the same throughout the study area. Furthermore, this variability does not seem to be related to our sampling procedure, but rather to patchiness in the distribution of the benthic invertebrates. This patchiness of organisms may be secondarily due to the nature of the sediments in the study area.

Variability through time. A critical question to be eventually answered is with respect to how each region of the bay changes through time. Clearly the three regions are decidedly under different environmental influences: Oyster Creek is warmer, at the surface, at all times of the year; Forked River rarely receives fresh water run-off because the current is generally upstream due to the pumping activity at the generating plant; and Stouts Creek is more exemplary of a control or "normal" area of the bay. Yet, if we compare the diversity of organisms that are found in these three regions, we find that all three regions are similar. In Table 7, we have divided time into six periods, alternating between reproductive and growth periods. In this table we list for each period, the pooled or mean diversity index for all samples taken for the period. The data, when plotted in Figure 8a, indicate that, for the three bay stations, there is practically no difference in the diversity of organisms as a function of time. While diversity may differ from one time period to another, it appears that all three bay stations behave in the same way. In other words, the pattern of diversity is consistent in the study area, with each region showing the same kind of variability. Because diversity is yet an ill-defined biological concept, we have also plotted the number of species through time for each station. Figure 8b shows a distinct similarity in the number of species taken from each region. While we would have expected the number of species to decrease during the colder months (and therefore influence the so-called "reproductive" period), we have found that there has been a general increase in the number of species in the study area through time. We attribute this increase, tentatively, to better sorting and identification techniques, and also to increased experience of the working staff. However, the pattern is the same for all three regions. Only a thorough statistical analysis will indicate whether there are real differences in diversity and species composition from one region to another through time.

The most unstable regions of the study area are the canals. Both the intake and outfall canal have fewer species and less diversity than the bays probably due to more restricted and stressful environmental conditions. For example, the outfall canal (Oyster Creek at Route #9) shows a pattern of lower diversity and species number in the warmer months of the year, when the temperature may exceed 30°C. So there are decided differences in both canals as a function of both time and position. While the generating plant has a strong influence on the canals, it would be most difficult to say that the variability in these canals is due only to the water currents and thermal load. We have observed a distinct increase in the amount of "people pollution" in the canals. It is not uncommon to retrieve garbage in our samples, probably thrown there by careless people who use the banks of the canal for recreation. Also, the increased bulk-heading and boat traffic could also be influencing the canals. These are factors which are as difficult to assess as is the simple increase in temperature. Even so, the canals continue to have about one-half the number of species as the bay. Some of these species, such as Mulinia and Ampelisca reach very high densities on the bottom. Although we have not done any controlled collections, we have also noticed an increase in the crab Callinectes sapidus populations in these canals. We are currently doing experiments on the encrusting and boring organisms in these canals (see later section of this progress report).



MEAN DIVERSITY
2.00
1.00
STOUTS
CREEK
FORKED RIVER
OYSTER CREEK
OUTFALL
INTAKE
F.R.
S.C.
O.C.
OUT.
IN
"mean"
27 AUG. to 5 DEC. '69
9 FEB. to 19 JUN '70
30 JUN. to 20 NOV. '70
8 APR. to 16 JUN. '71
2 JUL. to 11 DEC. '71
11 APR. to 26 JUN. '72
SPECIES
20
10
"mean"
TIME PERIODS SAME AS ABOVE

Fig. 5a, b.

Table 7. Number of invertebrate species and diversity indices for six time periods from 27 August 1969 through 26 June 1972.

Position	27 Aug. - 5 Dec. '69 #samples	Diversity	#species	9 Feb. - 19 June '70 #samples	Diversity	#species
1. Stouts Creek	19	1.2104	16.68	14	1.4165	12.71
2. Forked River	17	1.1543	18.59	12	1.5228	12.58
3. Oyster Creek	22	0.7960	20.27	29	1.3137	13.59
4. Intake Canal*	4	0.7330	10.75	9	1.0188	6.00
5. Outfall Canal**	3	1.4011	9.00	11	1.0185	7.36

	30 June - 20 Nov. '70 #samples	Diversity	#species	8 Apr. - 16 June '71 #samples	Diversity	#species	2 July - 11 Dec. '71 #samples	Diversity	#species
1.	31	1.8455	19.81	14	2.6877	26.21	24	1.8682	23.83
2.	29	2.0138	22.41	13	2.5629	23.85	23	1.7714	24.43
3.	31	1.9307	17.84	15	2.4198	20.33	22	1.8529	23.55
4.	13	0.8310	13.77	5	1.4922	7.20	8	1.1131	14.63
5.	12	1.3916	7.00	5	1.8618	18.00	6	1.0798	7.50

	11 Apr - 26 June '72 #samples	Diversity	#species	Grand Mean for diversity 27 Aug. '69 — 26 June '72	Grand Mean for #species 27 Aug. '69 — 26 June '72	Total Samples Taken on Station
1.	11	2.2482	26.82	1.8794	21.01	113
2.	11	2.3315	28.45	1.8928	21.72	105
3.	11	2.1847	28.09	1.7496	20.61	130
4.	3	2.0020	15.67	1.1984	11.34	42
5.	4	1.8463	17.25	1.4332	11.02	41

* Forked River at Rt. #9 ** Oyster Creek at Rt. #9

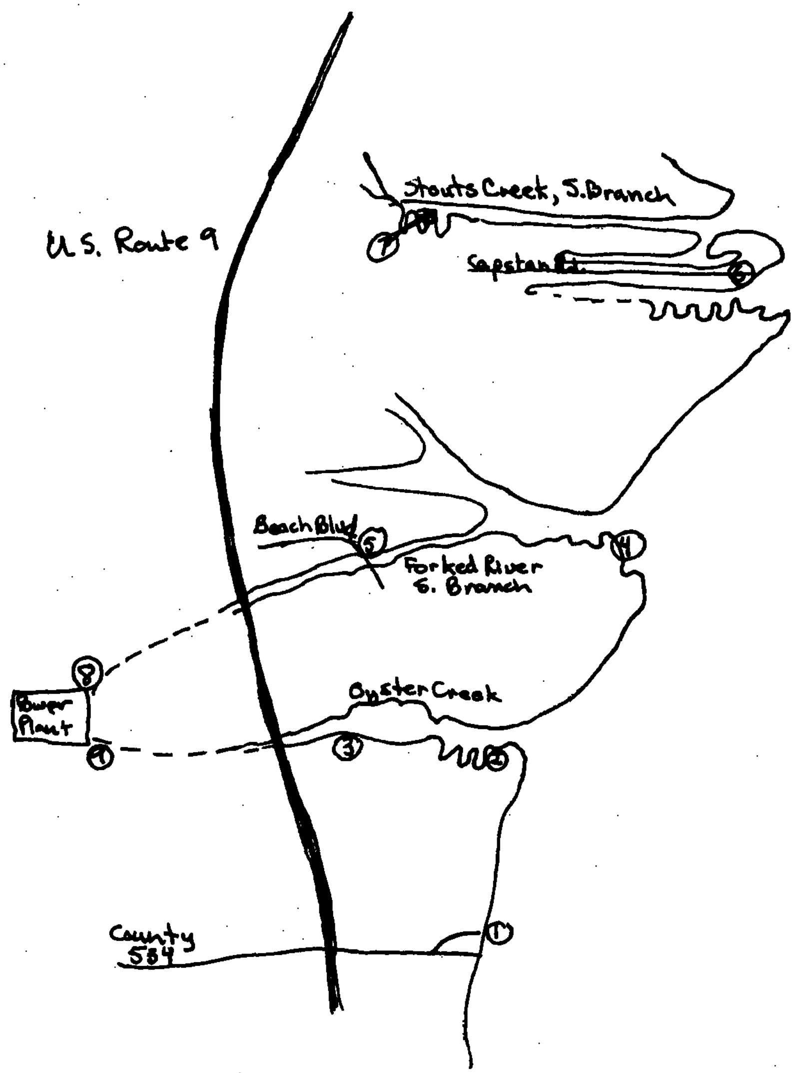
In conclusion, it appears to us that in the two and one-half years since the beginning of thermal addition in Barnegat Bay in the region around Oyster Creek, we have observed no large differences in the benthic populations of invertebrates. Particularly, any variability which can be called "background" or "natural" variability seems to be operating uniformly at all three bay stations. While we have observed one population "explosion" of algae (see Codium in the benthic algae section) which started prior to the operation of the generating station, we have also witnessed one population "crash" of Mulinia. Still, this species of bivalve disappeared in all regions of the bay and is just now beginning to appear in significant numbers in our samples.

BORING CLAM STUDY IN BARNEGAT BAY

The purpose of this study is to investigate the effect the boring clam, Bankia gouldi is having on wood in Barnegat Bay particularly in the Oyster Creek area. The total impact of this species on an area could depend on any or all of the following factors: 1) larval distribution, 2) the rate of larval settlement and wood penetration, and 3) survival and growth rate of adults. This study has been designed to find the effect temperature and salinity have on the second factor in the field, although the first and third factors are also being examined.

A second purpose of the study is to characterize the general settling population of invertebrates. This includes finding organisms that occur together and seeing if salinity or temperature influence the community present.

Fig. 9



MATERIALS & METHODS

Recruitment of settling organisms is being studied by placing boards in the water at the nine sampling stations shown in Fig. 9. Six stations were selected so as to observe the recruitment before and after water travels through the power plant (stations no. 2, 3, 4, 5, 8 and 9), with three additional comparison stations removed from immediate effects of thermal addition to Barnegat Bay (1, 6 and 7). The stations were selected to give the widest range in salinity and temperature without becoming too distant from the power plant. Station 1 at Waretown and station 7 at Stouts Creek represent high and low extremes in salinity. Stations 3, 5 and 7 were placed so as to be comparable distances from the bay; all three are on stream-fed, dredged canals. Stations 8 and 9 are at the power plant; boards are placed within 50 feet on either side of the pumps, with station 9 boards sampling outflow water before it is diluted.

Boards used for sampling are knot-free Douglas fir 2"x3"'s cut into six inch lengths. Two of these lengths are used for each sample. Boards are suspended on a rope and weighted by a brick, with one board above the mudline and the other just under low tide line. Boards are tied off docks or bulwarks where the water is generally 2.5 - 4 feet deep. No samples including those of stations 8 and 9 are taken any deeper than four feet.

Boards were set out for a month at a time for the months of October, 1971, and January, February, March and April, 1972. Since May, 1972, samples have been made for a month each so that they overlap in time periods by two weeks. In addition, since the second half of May, boards have been set out for consecutive two week intervals. Thus, every two weeks at each station, one sample is picked up for the previous two weeks and one for the previous month.

From July through September, sample boards are being placed at each station that will be left for two months. Nine sample sets are presently being kept at the mouth of Forked River for a month. Each board will be examined for exact number of boring <u>Bankia</u> and then the samples will be distributed over the nine stations and left until December. Similar sets will be left until March and June, 1973. These will be examined for remaining live organisms.

All boards are examined under a dissecting scope for any invertebrates larger than 250μ. All organisms are speciated and counted, and dry weight of barnacles and other organisms as a whole are taken. Ectoprocts, however are not weighed; estimates of <u>per cent.</u> surface covered are made instead. Boards from samples for the first half of July and the four weeks of June-July overlap were tallied surface by surface. In general, though, counts are made for a whole board. In this discussion, estimates for number of organisms for each sample are made by averaging top and bottom board counts and then expressed in number/meter-squared values.

Salinity, temperature and qualitative plankton samples have been taken every two weeks at stations 1-6 since Jan. 27, and since March 21 at stations 1-9.

When possible, natural wood from the area near all stations has been collected. In particular in August, 1971, stakes and posts attached to the bottom were collected in Forked River and Oyster Creek.

RESULTS AND DISCUSSION

A list of all species found attached or living on the boards with the per cent. of stations at which they occurred each month is given in Table ? . Species dominance by number of individuals or per cent. coverages varies over the year and from station to station. In general, Balanus and Membranipora are almost always present; during early spring especially (April and May) Corophium is a dominant; during May and June Polydora ligni is a dominant; and during June-July Hydroides dianthus can be dominant. These last three are all tube-dwelling and can take up large areas of the board with masses of tubes.

Total number of species found each month at each station is summarized in Figure ?? . Salinity and temperature data are summarized in Figure 11 . There appears to be a retarded increase of species occurring in Oyster Creek as compared to Forked River after the second half of June. As seen in temperature data, this coincides with a sharp increase in Oyster Creek temperature as the power plant resumed production after a six week operations halt.

Bankia and Balanus data for two sample periods, 1) second half of June through first half of July, and 2) first half of July, is summarized in Table 9 . Values per meter squared are given for two depths, Top (T) boards and mudline (B) boards; these are broken into three board surfaces values Upper, Lower, and Side. A four-way analysis of variance was made of this data using the board as the unit of analysis with time, depth and stations as "between" factors of boards and three surfaces as "within" factors. (The July sample for station 9 was lost so that no data from 9 was used in analysis). Transformed raw data was used for analysis. Since the analysis of variance assumes a normal distribution of data size frequency, data frequency that is extremely skewed must be transformed. This data is similar to a Poisson distribution so that the Tukey-Freeman Transformation ($\sqrt{x} + \sqrt{x+1}$) was used (Natrella, 1966). Analysis results are summarized in Table 9a. Essentially, the lower the P value, the lower the probability that the variance occurred by chance.

Table

maximum probability = P = 1.00

	Time	Depth	Station	Surface
Balanus	0.048	1.00	0.010	0.001
Bankia	0.022	0.049	0.001	0.326

"Station" is a very significant factor in the distribution of both Balanus and Bankia. According to Table ? , this significance for Bankia is due at least to the differences in the number of organisms found at stations 4 and 5 (Forked River) as compared to all other stations. The significance of station differences in Balanus distribution at least is due to differences between station 8 compared to stations 2, 3, 4, 5 and 6. Since a station could be defined as its salinity and temperature values, the distribution of these two organisms may correlate with the hydrographic data. However, a correlation analysis failed to show any significant correlation of the number of organisms appearing in all July with either salinity or temperature or salinity x temperature. This could easily be due to as of yet insufficient data (again, too many zeroes).

TABLE 8

Per cent of stations species occurred during a given time period

	species	Oct.	Nov.	Jan.	Feb.	Mch.	Apr.	May	May-June	June	June-July
1.	Ampelisca spinipes	0%	0%	0%	0%	0%	22%	0%	11%	11%	22%
2.	Balanus balanoides	100	100	100	33	66	12	89	78	89	78
3.	Bankia gouldi	0	0	0	0	0	0	0	0	22	66
4.	Bittium alternatum	0	0	0	0	0	11	0	0	11	22
5.	Botryllus schlosseri	66	0	0	0	0	11	0	22	0	0
6.	Bowerbankia sp.	0	0	0	0	0	0	0	0	0	33
7.	Caprella geometrica	0	0	0	0	0	0	0	0	11	0
8.	Cirolana concharum	0	0	0	0	0	0	0	0	0	11
9.	Corophium sp.	0	0	0	0	0	55	33	77	33	44
10.	Crepidula fornicata	11	0	0	0	0	0	0	0	11	22
11.	Cyathura polita	0	0	0	0	0	0	0	0	0	11
12.	Diopatra cuprea	0	0	0	0	0	0	0	0	0	11
13.	Electra hastingsae	0	0	0	0	0	0	0	11	11	66
14.	Erichsonella filiformis	0	0	0	0	0	0	0	0	11	0
15.	Euplana gracilis	0	0	0	0	0	0	0	0	0	22
16.	Gammarus sp.	0	22	0	0	0	0	0	0	11	33
17.	Hydroides dianthus	11	0	0	0	0	0	11	33	88	88
18.	Leptochelia savignyi	0	0	0	0	0	0	0	0	11	22
19.	Membranipora sp.	100	100	100	0	0	0	77	89	89	100
20.	Mitrella lunata	0	0	0	0	0	11	0	0	0	11
21.	Molgula manhattensis	11	0	0	0	0	0	0	22	22	33
22.	Mytilus edulis	0	0	11	0	0	22	0	0	0	0
23.	Nassarius obsoletus	0	0	0	0	0	0	0	0	33	0
24.	Nereis succinea	100	100	0	0	0	11	11	33	44	88
25.	Polydora ligni	11	0	0	0	0	0	11	33	88	77
26.	Sabellaria vulgaris	11	0	0	0	0	0	0	0	0	22
27.	Styllochus ellipticus		22	0	0	0	11	0	44	33	55

Number of species

(slashed bars represent 2-week sampling periods; non-slashed bars are one-month; time periods can overlap)

Fig. 10

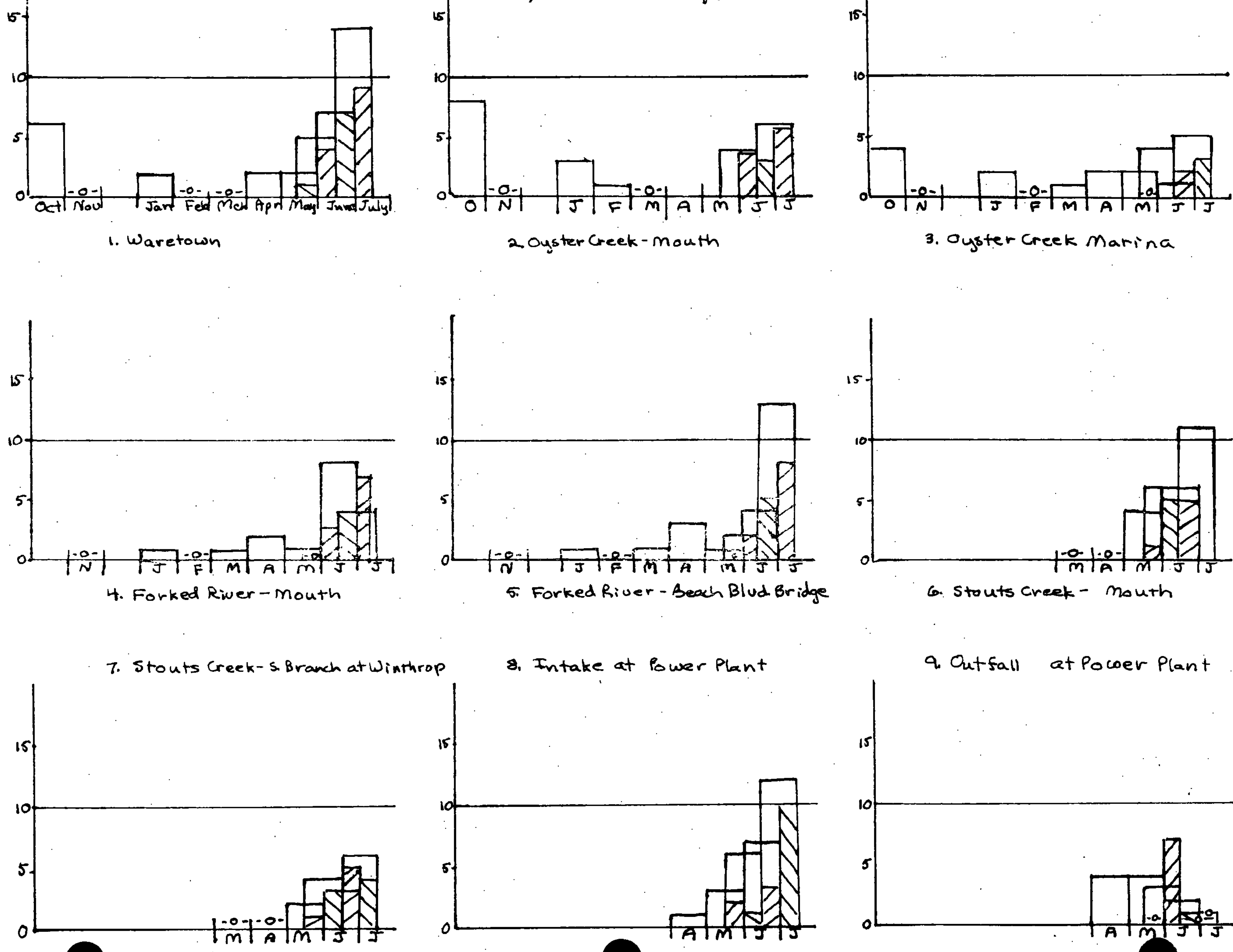
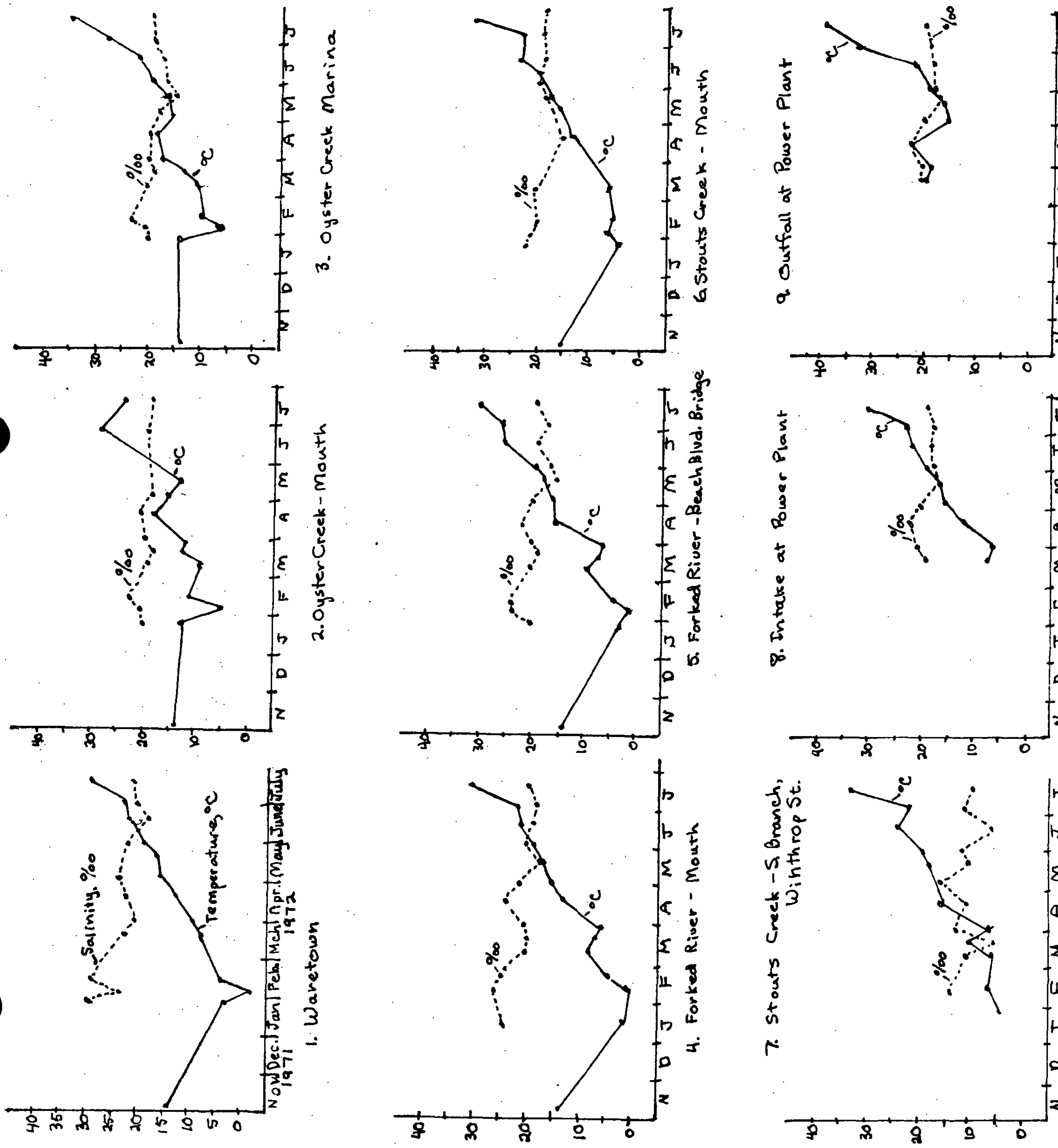


Fig. 11 Salinity and Temperature data for each sampling period



1972

TABLE 9

Number of organisms/meter squared for station, time depth and surface.

	Station number 1	2	3	4	5	6	7	8	9
I. Bankia									
A. 1/2 July-T-U	0	0	0	0	0	0	0	0	0
L	0	0	0	2560	384	0	0	128	0
S	0	0	0	256	512	0	0	0	0
average:	0	0	0	939	299	0	0	0	0
-B-U	0	0	0	128	128	0	0	0	0
L	0	0	0	1405	384	384	0	0	0
S	128	128	0	2176	128	640	0	0	0
average:	43	43	0	1236	213	341	0	0	0
B. June/July-T-U	0	0	128	0	256	128	0	0	
L	512	0	0	1024	896	1280	0	0	
S	256	0	128	256	256	256	128	0	0
average:	256	0	85	427	469	512	0	0	
-B-U	128	0	128	512	512	0	0	0	
L	0	0	0	5760	344	1664	0	0	
S	384	256	128	1405	896	256	0	0	
average:	171	95	85	2139	584	640	0	0	
II. Balanus									
A. 1/2 July-T-U	0	0	0	0	768	0	2560	0	
L	0	0	1920	512	9600	128	2816	14336	
S	128	0	768	0	1280	128	3840	2176	
average:	43	0	896	171	1003	85	3072	5504	
B-U	0	0	0	0	128	0	0	384	
L	256	256	0	384	3712	0	256	19072	
S	128	0	0	0	0	0	128	3072	
average:	112	85	0	128	1280	0	128	7509	
B. June/July-T-U	5888	128	0	0	0	640	768	3456	
L	12032	1536	1792	0	768	10752	768	14051	
S	11520	384	640	0	0	1536	896	7956	
average:	9813	683	811	0	256	4309	811	8488	
B-U	0	512	768	0	128	1280	1405	3840	
L	128	0	5760	0	0	6400	7540	9984	
S	0	256	3080	0	384	768	6104	11392	
average:	43	256	3203	0	171	2816	5016	8405	

"Depth" is significant for distribution of Bankia, as other studies have found for Teredinids (see Clapp and Kenk, 1963, under Teredinids-Ecology). The conclusion is that as depth increases, so does amount of settling. This probably relates to an apparent negative phototropism of larvae (Quayle,a1959). Interestingly, it is of no significance for Balanus.

Board surfaces differences are significant for both species. Apparently settling numbers decrease for both in order of lower, side and upper surfaces. In the case of Bankia this could be due to light again. Balanus needs another explanation, though; perhaps there is a negative geotropism of larvae.

The significance of "Time" as a variable emphasizes that maximum settling does not occur within two weeks time. It will be worthwhile to further study time-dependent data to determine if and when maximum density of organisms occurs and whether there are interaction effects of species inhibiting each other's further settling.

Plankton samples have been preserved but not examined yet. They will be examined qualitatively primarily for presence or absence of Bankia larvae. Plankton samples taken by Phil Sandine at the power plant outfall (before dilution) found what are probably Bankia larvae appearing in the water on August 30, October 11, October 20, 1971, and June 8, June 28, July 12, 1972.

Natural wood collected in Oyster Creek and Forked River in August, 1971, showed six out of 8 pieces of wood in Oyster Creek and one out of seven in Forked River as containing evidence of adult Bankia. Only one board, which was found in Oyster Creek had live Bankia; the others showing evidence had empty calcium-line tunnels.

Narrow wooden slats placed in Forked River, Oyster Creek and Stouts Creek last August by Chris Evans have shown adult Bankia appearing in all three areas near the bay. As of November, boards at the mouth of Forked River were being broken and lost because they were so weakened by tunnels.

Wood collected in July at the Waretown station had several large empty tunnels measuring 5 mm. in diameter traveling the length of the wood; the number of clams that had entered the wood equalled approximately 230/meter squared.

PROJECTED STUDIES

Throughout the following winter these problems will be studied:

1) Determine the growth rate of adult Bankia under different salinity and temperature conditions. Pallet length gives some indication of growth (Quayle, b 1959). There is some difficulty in extracting the pallets from wood, but this analysis will be done as well as possible. Growth rate will also be studied in the laboratory using combinations of temperature and salinity extremes. Adults will be obtained from Bay samples.
2) Determine survival ability of adults during winter months. Boards with adults will be left at all stations in the fall and retrieved at three times during the winter.
3) Estimate a depth constant for the rate of settling of Bankia and other dominant organisms.
4) Estimate variance in sampling size.
5) Analyze variance for all dominant species in terms of station, depth time and surface. Continue to test for correlations of numbers with salinity, temperature and interactions. Look for changes in settling rate with changes in exposure time in order to discern inhibition effects of species on itself or on other species.

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Natrella, Mary Gibbons. 1966. Experimental Statistics, National Bureau of Standards, Washington, D.C. (Revised edition.)

Zooplankton: General Survey and Evaluation of Thermal Shock on Pumped Zooplankton.

Methods:

Survey--Since January 1971, a biweekly survey of zooplankton of Barnegat Bay has been conducted. Samples were taken at the outfall pipes and consisted of two, 50 liter samples which were concentrated by passing them through a #20 plankton net. Passage of Bay water through the plant results in a thoroughly mixed water column which allows for a realistic estimate of the populations present, the small sample size notwithstanding.

Thermal Study--Experiments to determine the effect of 10°C. temperature shocks above ambient on zooplankton components were conducted. A difference of 10°C. is about the normal delta between intake and discharge water. However, when one of the circulating pumps was down, this difference increased to 13°C. The attempt to separate the total effect of the plant from that of temperature alone was done by laboratory experiments run within 8 hours of collection on samples, obtained from the intake. These laboratory experiments simulated the temperature regime produced by the plant on date of collection.

1. Holoplankton

Field experiments consisted of replicated samples of from 5 to 50 liters taken from the intake (= control) and the discharge (= treatment). The samples were concentrated to 100 to 1,000 mls and maintained at their respective ambient temperatures for 2 hours. This was the maximum time we would expect organisms to be exposed to the elevated temperatures in their passage down Oyster Creek. When dilution pumps were running, discharge samples were held for 2 hours at the temperature of the "diluted" water, which was approximately 3°C. below discharge temperature. At the end of two hours, discharge samples were returned to the control temperature. Determination of live and dead organisms in the controls and treatments was initiated 2-4 hours after return of discharge samples to the control temperature. Enumeration of "dead" organisms was carried out under the scanning lens of a compound microscope. In this study, organisms not showing normal swimming behavior or that did not show an escape response when disturbed by a probe were also classified as dead. To express number dead as a percent, samples were "fixed" by the addition of formalin and a total count was made of the zooplankters under evaluation.

2. Meroplankton

A. Mulinia

In order to determine the effect of temperature on meroplankton forms, the larvae of which do not usually occur in the plankton in sufficient number for field experimentation, it was necessary for the adults to be spawned in the lab. An organism suited for lab spawning is Mulinia lateralis, a small clam. Adults of this species were collected from the Bay when ambient temperatures were between 8° and 15°C.. They were held in the lab at 15°C. until needed. Spawning was induced by placing adults at temperatures of 22-24.5°C.. From a spawn, approximately equal subsamples of fertilized eggs were placed in culture tubes containing filtered Bay water. At intervals of 15 minutes, 4 hours and 8 hours after spawning, replicate tubes with developing larvae were placed in controlled temperature baths of 27.5°, 30°, 32.5° and 35°C.. Controls were maintained at 22-24.5°C.. Exposure to the elevated temperatures was for either 15 minutes or 2 hours, after which larvae were returned to the control temperature. When larvae were 25 or 36 hours old they were killed by the addition of formalin, the contents of the samples concentrated and total count of larvae per sample made. All larvae in the 15 minute exposures were obtained from the same spawn; those in the two hour exposures were from separate spawnings.

To determine the effect of temperature on Mulinia larvae which had already reached the straight hinge stage, that is 24 hour old individuals, the following procedure was used: Twenty-four hour old larvae were subjected to the test temperatures for one hour, then returned to the control temperature for 2 hours, after which time enumeration of live and dead was as previously explained for zooplankton in general.

Results:

<u>Copepods</u>--A comparison of laboratory experiments simulating the temperature regime created by the plant with those conducted in the field on the same day showed no significant differences in percent mortality of copepods. Thus, it is felt that the results from laboratory simulation experiments conducted when the plant was not on-line are indicative of what would have occurred had the plant been on-line.

The average percent mortality of copepods resulting from passage through the plant's condensers or laboratory simulation there of for 14 dates is shown in Fig. 12. A discernable pattern that emerges from this figure is the occurrence of peaks in early June of both years. Furthermore, these peaks coincide with the beginning of the replacement of <u>Acartia clausi</u> by <u>Acartia tonsa</u>. The large values obtained at this time are most likely a function of the lethal temperature of <u>A. clausi</u> having been exceeded during the two hour exposure. If the exposure time is lessened to 15 or 30 minutes, as was done on June 8, 1972, the percent mortality is substantially lowered (Table 10), indicating the importance of time-temperature relationships. It should be noted however that, if the contents of the 15 and 30 minute exposed samples had been examined immediately after return to ambient temperature, a mortality of about 90% would have been noted. This was caused by a temporary loss of the copepods' swimming ability. This phenomenon has been observed by others when copepods have been exposed to a sublethal time-temperature regime.

Table 10. Average percent mortality of copepods exposed to a 10° C. elevated temperature above ambient for 15 minutes, 30 minutes and 2 hours. Date of experiment June 8, 1972, intake temperature 19.8° C..

Exposure	Nauplier	Copepodites	Adults
Control	0.0	0.4	0.7
15 Minutes	3.3	4.8	5.9
30 Minutes	48.0	36.8	27.4
2 hours	85.0	99.0	100.0

The large percent mortality of July 17, 1972 (Fig. 12) was due to an unusually high ambient temperature. The high temperature of the discharge (40.4°C.) was a result of the hot spell occurring at the time, complicated by the possibility of the entrainment of discharge water. The latter phenomenon has been observed by us. The need for lowering the delta created by the power plant during such extreme temperature conditions is stressed by the results presented in Table 11.

The effect of exposure to 10°C. above ambient for 2 hours on egg laying by <u>A. clausi</u> is shown in Table 12. The results are that when the experimental egg laying interval includes the exposure period there is a temporary stimulation of egg laying (note experiments of 18 and 26 April). But if the exposure period is not included during egg laying, then there is an apparent drop in eggs produced (note experiments of 15 and 21 March). Whether this temporary stimulation of egg laying produces some non-viable eggs was not determined.

It should also be noted that in Progress Report #7 (June 1971) it was stated that the production of viable eggs was comparable between individuals collected from the intake and discharge. However, in that experiment the egg laying interval did not include the two hour exposure to the elevated temperature and thus, its results are presently questionable.

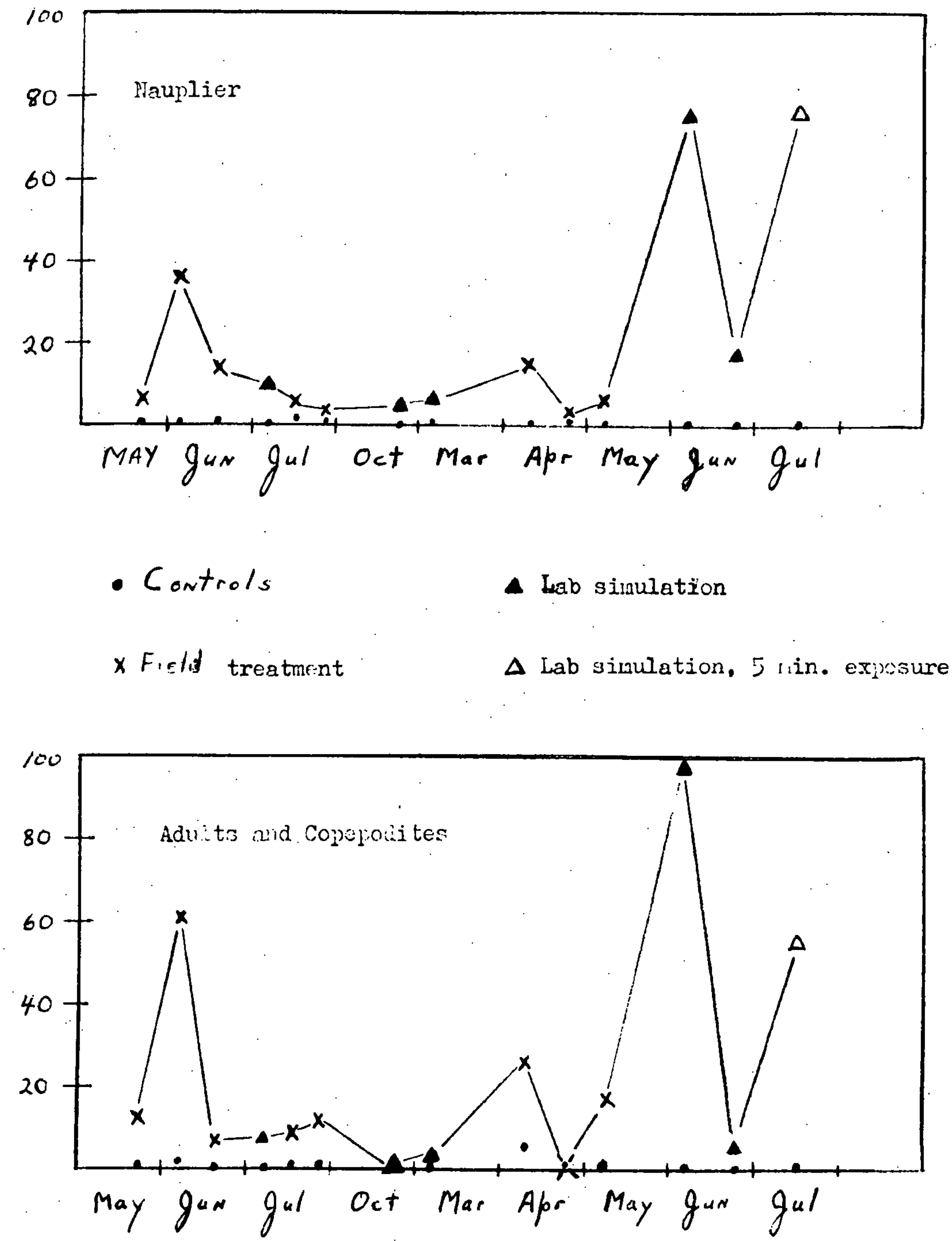


Fig.12. Average percent mortality of copepods exposed to the elevated temperatures generated by the power plant or laboratory simulation thereof.

Table 11. Average percent mortality of zooplankters exposed for 5 or 15 minutes to 40°or 37.5°C.. The 40°C. exposure represents the abnormally high discharge temperature recorded on July 17, 1972.

		Copepods		Other Zooplankters		
Temperature	Length of Exposure	Nauplier	Copepodites	Barnacle Larvae	Gastropod Larvae	Unidentified Trocophores
40°	15 min.	81.4	78.6	13.2	50	71.5
40°	5 min.	77.8	61.8	0.0	100	23.4
37.5°	15 min.	9.5	14.2	0.0	90	5.8
37.5°	5 min.	1.0	0.0	0.0	16.6	0.0
Controls (25°)		0.2	0.0	0.0	0.0	0.0

Table 12. Comparison of egg laying rates of *Acartia clausi* females collected at the discharge (treatment) and the intake (controls).

		Control		Treatment	
Date	Duration of egg laying (hrs)	# females	# eggs/female	# females	# eggs/female
15 III '72	24*	78	9.2	25	4.6
		28	11.0	18	6.9
21 III	12*	59	5.3	48	3.9
		54	5.5	80	3.8
	24*	72	9.3	50	3.4
		107	8.6	100	4.9
31 III	4**	18	2.6	78	3.7
		27	2.5	45	4.2
	12**	56	2.7	70	5.8
		56	6.0	33	6.7
	24**	49	8.6	66	13.7
		27	10.5	19	10.1
18 IV	5**	80	0.8	61	1.9
26 IV	5**	103	2.8	186	5.8
		37	2.3	156	5.6

* Experiment not started until 4-5 hours after collection and does not include the two hour interval of exposure to elevated temperature.

** Experiment started immediately after collection and includes two hour exposure to elevated temperatures above ambient.

Bivalve larvae

The results of exposing different age pre-straight hinge Mulinia larvae to a set of 4 different temperatures for either 15 minutes or 2 hours is shown in Fig. 13. Conclusions that can be made from these experiments are: 1) Two hour exposures are significantly more devastating than a 15 minute exposure at the same temperature (except for 15 minute old larvae exposed to 35° C.) 2) The younger the larvae, the more sensitive they are to temperature 3) Exposure to the higher test temperatures results in a decrease in the number of larvae present at the termination of the experiment, except for 8 hour old individuals exposed for 15 minutes. This decrease in number was the result of fragmentation of the developing embryo at the higher temperatures 4) Of the larvae which have reached the straight-hinge stage at the end of the experiment, the percent appearing morphologically normal is decreased at the higher test temperatures, regardless of age at time of exposure.

The results from exposing Mulinia larvae already at the straight hinge stage (i.e. 24 hours old individuals) to the test temperatures for 1 hour are given in Table 13. It is obvious that at this age, only 35° C. is high enough to exert a significant lethal effect over a 1 hour exposure.

Factors not examined by the preceding series of experiments were the long term effects the higher temperatures, specifically 32.5° and 35° C., may have on the surviving larvae in their ability to feed, grow and metamorphose into adults.

Table 13. Results of a 1 hour exposure to various temperatures on 24 hour old *Mulinia lateralis* larvae.

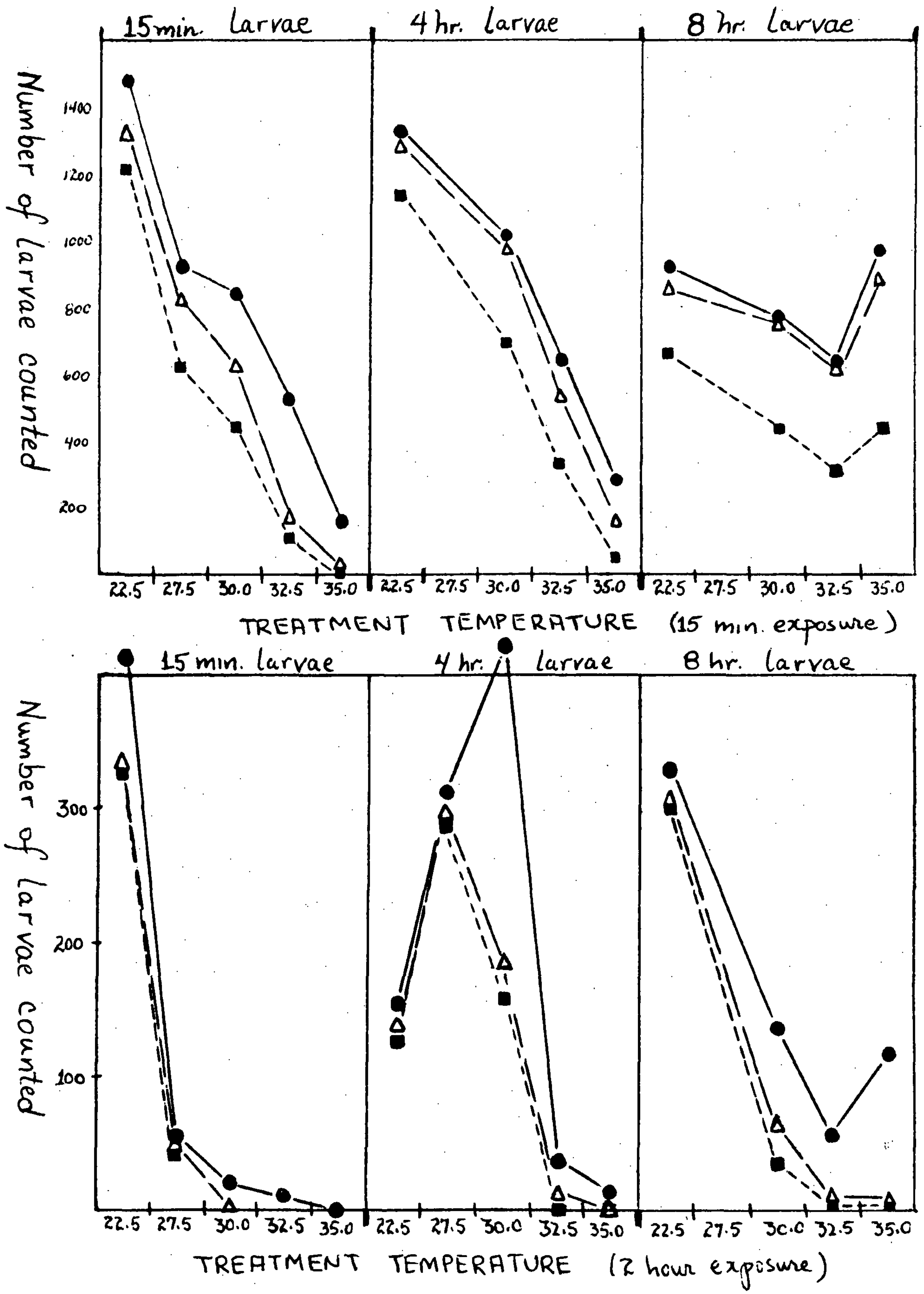
	Temp. (°C.)	Ave. # of larvae	Ave. % of straight hinge larvae appearing morphologically abnormal.	Ave. % of straight hinge larvae considered dead.
(control)	22.5	290	2	1.7
	27.5	200	8.3	5.5
	30.0	328	7.6	8.0
	32.5	424	12.7	5.9
	35.0	179	23.8	34.8

Other Zooplankters

Three additional benthic forms which produce planktonic larvae in relatively large numbers are the polychaete worms, barnacles, and gastropods (= snails). Of these three, the polychaetes and the barnacles have their peak spawning periods at water temperatures below 20° C.. The gastropods though, have the bulk of their larvae present at temperatures above 20° C. (Fig. 14).

At ambient temperatures of 20° C. or less, polychaete larvae survive a 10° C. delta for 2 hours. However, at higher ambient temperatures results are inconclusive due to insufficient numbers of polychaete larvae in the experiments. Testing of gastropod larvae at higher temperatures has also been hindered by small numbers present in the test samples. Thus, it is recommended that some of the common species from the Bay of these 2 groups be spawned in the lab in order to test their survival when exposed to 10° C. deltas at ambient temperatures above 20° C..

Fig. 13


15 min. larvae
4 hr. larvae
8 hr. larvae
Number of larvae counted
1400
1200
1000
800
600
400
200
22.5
27.5
30.0
32.5
35.0
TREATMENT TEMPERATURE (15 min. exposure)
15 min. larvae
4 hr. larvae
8 hr. larvae
Number of larvae counted
300
200
100
22.5
27.5
30.0
32.5
35.0
TREATMENT TEMPERATURE (2 hour exposure)

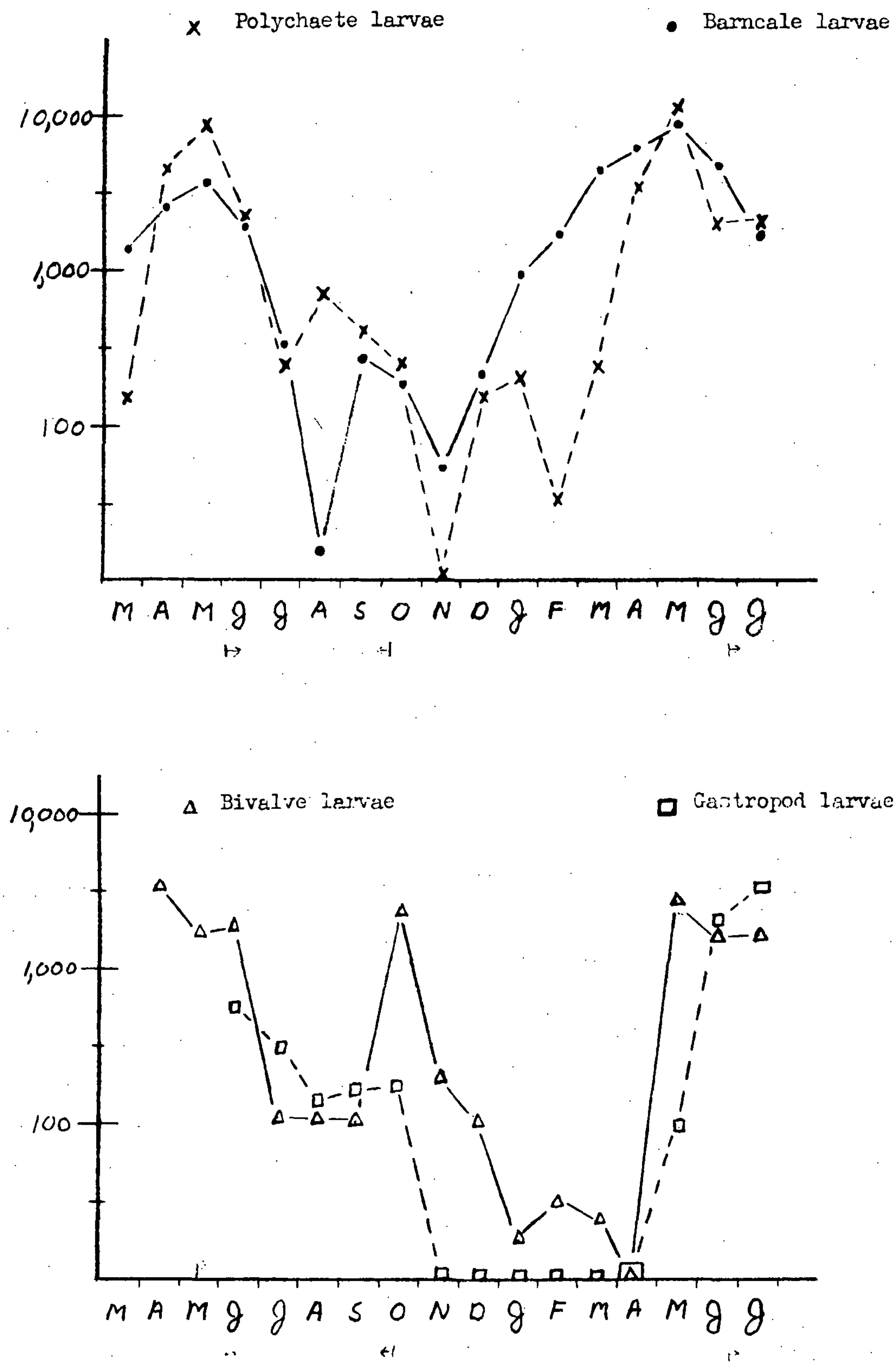


Fig. 14. Average monthly concentration/M^3
of four meroplankton larval forms.

A gastropod species common in our Bay sampling area in 1970 was Nassarius obsoletus, the common mud snail. The life history of this species includes a planktonic larval stage which does not hatch until water temperatures reach 20°C. or above (Scheltema*). In 1971 and 1972 the number of individuals of this species taken in our benthic samples are well below the values of 1970 (Table 14). Though not included in Table 14, the qualitative data from the latter half of 1969 shows that N. obsoletus was present that year in numbers similar to those of 1970.

Barnacles, though also occurring in relatively low numbers when temperatures exceed 20°C., did occur in sufficient numbers on July 17, 1972 for testing. The results of the short time exposures conducted on that date indicate the hardiness of barnacle larvae relative to the other groups present (Table 11). Other workers have also found the larvae of barnacles to survive exposure to relatively high temperatures. They felt that it was a result of their being brooded by a parent which, living in the in the intertidal, exposes both the parent and the developing young to high summer air temperatures.

Table 14. Average number of Nassarius obsoletus per 100 drops of the Ponar at our 3 Bay sampling areas.

	Stouts Creek	Forked River	Oyster Creek
1970	82	24	2
1971	18	0	0
1972*	22	1	1

* to the end of June.

Another benthic group producing planktonic larvae, but in relatively small numbers, are the crabs and shrimp. The need for fewer larvae in this group is due to the following adaptations which aid in the survival of their larvae: 1) the larvae hatch from eggs which are carried by the adults 2) the larvae are usually strong swimmers 3) some forms, like the crab zoea, with its long spines, have a body structure which gives protection against predation. Because of these adaptations fewer young need to be produced to insure replacement of the adults. But it is just this low level of reproduction that makes this group sensitive to any plant produced mortality. Thus, it is imperative that members of this group be spawned in the laboratory and their larvae subjected to the temperature regime produced by the plant.

A group of organisms which have not been examined in this study are the microzooplankters. This is primarily due to the fact that they are not conveniently dealt with in the manner that experiments were conducted for this study. Two forms of microzooplankters that can occur in large numbers in Barnegat Bay are rotifers and tintinneds. In July 1972, the latter group was present in numbers exceeding 160,000 per M^3, and this estimate is conservative since the width of these organisms is about one half of the mesh opening in the plankton net used.

Among the macrozooplankton are such large forms as the arrow worm Sagitta, the hydromedusae Sarsia mirabilis, the Ctenophores Mnemiopsis leidy and Beroe ovata and the coelenterate Cyanea capillata. In addition to a temperature shock, these forms encounter physical damage upon passage through the cooling condensers. For example, of 16 Sagitta collected from the discharge only one did not have its body distorted. It was also the only one that attempted to escape if a probe was placed near it. Nine Sagitta collected from the intake in the same manner showed no body distortion or lack

* Scheltema, R.S., 1962a

of an escape reaction.

Discussion

It is the opinion of some that a loss of some fraction of the rapidly reproducing zooplankters, such as copepods or tintinnids, will not have much influence on the estuarine community as a whole (especially if their predators are also proportionally decreased by the plant). However, the loss of meroplankton larvae could influence the ability of the local adult populations to maintain normal population levels (prevalent prior to plant operation). Especially important would be the influence of the power plant on important (ecologically or economically) species who have larvae occurring in small numbers. But such losses could go undetected due to recruitment of larvae from other areas of the bay, or from other bays by transport along the coast (or by other environmental changes) as long as the loss did not exceed a critical threshold for the entire interacting system.

Tied in with the preceding problem is the additional problem of being able to differentiate the direct and indirect effects of the Oyster Creek Plant on the biota of Barnegat Bay. To illustrate this point the following discussion, which will pivot primarily around the small clam Mulinia lateralis, is given. In the first half of 1970 Mulinia was occurring at densities of up to and greater than $1,000/M^2$ in the Bay areas sampled. In July of 1970 the Mulinia population experienced a "crash", with densities of over $100/M^2$ becoming the exception. This low density level has held throughout 1971 and is continuing into 1972. Since Mulinia has a maximum life span of about 18 months the "crash" was mainly a function of the 1969 population dying off. Yet at the same time there appeared to be little recruitment of young Mulinia from the spring spawn of 1970. When analysis of the Mulinia data from 1970 is completed we will be able to determine what percent of the population consisted of 1970 Mulinia when the "crash" occurred.

But what effects might this drop in Mulinia have on other components of the community that use this organism as a food source? Known predators on small bivalves are crabs and gastropod drills. A relative density of these predators in our Bay sampling area is given in Table 15. That a drop in the number of these forms has occurred is obvious. The crabs, which have a planktonic larval stage, could also have their population levels directly influenced by passage through the condensers, but the gastropod drill, Eupleura caudata would not be as it does not have a planktonic larval stage.

Table 15. Average number of some bivalve predators, crabs and Eupleura caudata per 100 drops of the Ponar. Values are for our bay sampling areas combined.

year	Neopanope and Rhithropanopeus	Callinectes sapidus	Eupleura caudada
1970	12	8	35
1971	2	3	10
1972*	1	4	6

* to the end of June

Again it should be stressed that, though we have documented a drop in the numbers of some organisms that have a planktonic larval stage, we cannot unequivocally state that the plant was the prime factor in causing the decline. The reason for this is we do not have information on the population dynamics of these organisms from areas

totally outside the influence of the power plant (i.e., from adjacent bays).

Recommendations for possible regulation of thermal addition by the Oyster Creek Power Plant.

At present the laws governing the addition of heat to a body of water are in a state of flux, with the debate being over the size of the mixing zone. However, it is our feeling that the main criteria for regulation of thermal addition to the environment should include the temperature elevation of the cooling water upon passage through the condensers. Before discussing this opinion, we want to stress the fact that our evidence is based not only on the mortality of pumped zooplankton, but also on the notable decrease which has occurred in the bay in the numbers of some benthic invertebrate species that possess a planktonic larval stage.

The basis for our above recommendation is as follows:

1) The significant mortality of an ecologically important meroplankton form, i.e. Mulinia lateralis, can occur at intake temperatures as low as 20°C., even when exposure time to the elevated temperature is for 15 minutes.

2) The number of Mulinia and other larvae passing through the condensers can indeed be large. For example, the average number of straight hinge Mulinia larvae pumped through the condensers during the 16 week interval in 1971 when intake temperatures exceeded 20°C., was 9 x 109/week! Note that this value does not includes the pre-straight hinge stage.

3) The inability of Mulinia to return to its population level of 1969/70, notwithstanding the fact that it has since undergone 3 seasonal spawns. It should be noted, however, that there has been an increase in the Mulinia population this year. But then the plant was not on-line this spring when Mulinia began their spawn.

4) The drop in other benthic invertebrate species which are at least partially dependent upon Mulinia as a food source and which may or may not have a planktonic larval stage.

5) When intake temperatures exceed the normal maximum of the Bay, i.e. 27°-28°C., a lowering of the elevated temperature above ambient produced by the plant is needed because even a 5 minute exposure to such high temperatures is lethal to most organisms present (Fig. 10).

At the expense of being repetitious, we again state that our data still does not allow for uniquivocal statements concerning the influence of the Oyster Creek Power Plant on the benthic biota of Barnegat Bay. However, the above listed factors, upon which our recommendations rest, are not without need of consideration.

A procedure which we recommend to be implemented immediately is that two dilution pumps be run when intake temperatures exceed 20°C. and all three at intake temperatures above 24°C. This simple procedure would lessen the significance of the time-temperature interaction.

Recommendations for future student concerned with evaluating the effect of the Oyster Creek plant on the biota of Barnegat Bay.

The present investigation has produced ideas which we feel should be incorporated into any future study. In attempting to determine the plant's effect on the biota of the Bay, our efforts have been complicated by the random shutting down of the plant over the last two years. In addition, the application of a biocide (chlorine gas) and the use of the dilution pumps has also varied. Thus, we recommend that scheduling of plant shut-downs, use of biocide and dilution pumps be at least in concert with the investigators of the study. Two examples to help illustrate the point.

1) To evaluate the plant's effect on primary productivity it would be advisable for tests to be conducted on consecutive days with the following plant procedure.

- a) day 1: circulating pumps on, no heat, no Cl_2
- b) day 2: circulating pumps on, heat, no Cl_2, no dilution
- c) day 3: circulating pumps on, heat, Cl_2, no dilution
- d) day 4: circulating pumps on, heat, no Cl_2, dilution
- e) day 5: circulating pumps on, heat, Cl_2, dilution

2) To evaluate the plant's effect on benthic invertebrates which possess a planktonic larval stage the following idea is offered. The plant would run for a calendar year with no dilution pumps in operation (the State would need to approve this) and at maximum generating capacity. The following year it would run with all dilution pumps in operation. Chlorination levels and time of plant shut-downs would be comparable for both years. It may be necessary to repeat the cycle once again or change some of the parameters, but at least it could then be stated with more assurance whether the plant had the ability of influence the population levels of the previously described benthic invertebrates.

In brief, we are recommending that the plant be used in designed experiments in order that more precise information may be obtained. This in turn would decrease the amount of conjecture which presently surrounds the influence of the Oyster Creek Power Plant on the biota of Barnegat Bay.

Lit. Cited

Scheltema, R.S., 1962a, Pelagic larvae of New England intertidal gastropods, I. Nassarius obsoletus Say and Nassarius vibex Say. Trans. Amer. microsc. Soc., 81:1-11.

Station Locations for Hydrographic Data: 1971

8 April 71-1

1. O.C. off derrick
2. Route 9 O.C.
3. Route 9 F.R.

13 April 71-2

1. Just SE Light 1 S.C.
2. Due north of pos. 1
   By the two inlets
3. 320° NNW Lgt. 2 F.R.
4. 240° WSW Lgt. 2 F.R.
5. 270° W Lgt. 3 O.C,
6. Due north of nun 2
   320° NW O.C. Lgt 3
7. O.C. Route 9
8. F.R. Route 9

29 April 71-3

1. 170° SE Mile marker 50 yds
2. 25° NE Lgt 1 75 yds.
3. 320° NW Lgt 2 150 yds from
   light. N of black can
4. 240° WSW Lgt 2. S of black
   can 200 yds from light
5. 0° N Lgt 3 O.C. 100 yds
6. 240° WSW Lgt 3 O.C. 100 yds

6 May 71-4

1. 40° NE Mile marker 100 ft
2. Due north previous station
   400 yds
3. 340° NNW O.C. Lgt 3. 300 yds
4. 240° WSW O.C. 3 300 yds
5. Route 9 Oyster Creek
6. 230° WSW F.R. Lgt 2 200 yds
7. 340° NNW F.R. Lgt 2 150 yds
8. Route 9 Forked River

18 May 71-5

1. Next to Mile marker. 120° ESE
   S.C. Lgt 1 75-100 yds
2. Due E of Lgt 1 100-125 yds
3. 120° ESE F.R. Lgt 2 50 yds
4. 220° SW F.R. Lgt 2 125 yds
5. 340° NNW O.C. Lgt 3 100 ft
   from nun buoy.
6. 220° SW O.C. Lgt 3 75-100 yds
   from Lgt. So. of nun buoy.
7. Route 9 Oyster Creek
8. Route 9 Forked River

3 June 71-6

1. StsCrk; N. of Mile Mrkr 200 yds
2. StsCrk; 50 yds. N. of Mi.Mrkr
3. StsCrk; 75 ft. E. of Mi.Mrkr.
4. Light 2; N. 75yds.
5. Light 2; 248° WSW 100 yds.
6. 1/3 way from Can 5 to BlackCan
7. 340° NNW Lt. 3; off Load. Der.
8. 20° NNE Lt. 3 180 yds.
9. 240° WSW Lt. 3, 150 yds.
10. O.C., Rt. 9
11. F.R., Rt. 9

16 June 71-7

1. S.C., 220° SW Light, 200 yds.
2. S.C., 220° SW Light, 25 Yds.
3. S.C., 80° E Light, 50 yds.
4. F.R., 70° E Light, 50 yds.
5. F.R., 260° W Light, 150 yds.
6. F.R., 240° SW Can 5, 50 yds.
7. O.C., Between Derrick and
   light; 100 yds. off
   Derrick
8. O.C., due N Light, 50 yds
9. O.C., 290° W Light, 50 yds.
10. O.C., Rt. 9
11. F.R., Rt. 9

2 July 71-8

1. S.C., 60° NE Light, 300 yds.
2. S.C., 60° NE Light, 100 yds.
3. S.C., 150° SE Light, 300 yds.
4. O.C., 55° NE Light, 122° SE Der.
5. O.C., 175° SE Light, 100 yds.
6. O.C., 260° NW Light , 200 yds.
7. O.C., 70° NE Light, 140° Derrick
8. O.C., Rt. 9
9. F.R., 200° SW Light, 250 yds.
10. F.R., 40° NE Light, 100 yds.
11. F.R., 315° NW Light, 350 yds.
12. F.R., Rt. 9

Station Locations for Hydrographic Data: 1971

15 July 71-9

1. F.R., 240°W Light, 150 yds.
2. F.R., 200°SW Light, 200 yds.
3. F.R., 320° Light, 75 yds.
4. S.C., 220°SW Pole, 100 yds.
5. S.C., 40°NE Pole, 50 yds.
6. S.C., 160°SES Pole, 100 yds.
7. O.C., NE Light, 100 yds.
8. O.C., 330°NW Light, 50 yds.
9. O.C., 5° N Light, 140 yds.
10. O.C., Rt. 9
11. F.R., Rt. 9

29 July 71-10

1. Stouts Creek, 110°ESE 50 yds from mile marker.
2. Oyster Creek, 210°SSE 300 yds from Light 3.
3. Oyster Creek Route 9.
4. Forked River, Route #9.

6 Aug 71-11

1. Stouts Creek, 100°ESE Light 1, 200 yds.
2. Stouts Creek, 120°ESE Light 1, midway between mile marker and Light 1.
3. Stouts Creek, 130° SE Light 1, 40 yds from mile marker.
4. Oyster Creek, Route #9.
5. Oyster Creek, 290° WNW 150 yds off Light 3.
6. Oyster Creek, 0° N Light 3, 150 yds
7. Oyster Creek, 20° NNE Light 3, 100 yds.
8. Forked River, 240° WSW Light 2, 250 yds.
9. Forked River, 270 W Light 2, 150 yds. from first can in from Light.
10. Forked River, 335° off Light 2, 300 yds.
11. Route #9, Forked River.

18 Aug 71-12

1. Oyster Creek Route 9
2. Oyster Creek, 280°WNW Light 3, So. of can 5, 150 yds
3. Oyster Creek, 20°NNE Light 3, 75 yds
4. Oyster Creek, ½ way between derrick and creek.
5. Stouts Creek south of Light, 100 yds
6. Stouts Creek 50° NNE of Light 1, 50 yds

18 Aug 71-12

7. Stouts Creek 105°ESE Light 1, 250 yds
8. Forked River 60° NE Light 2
9. Forked River 180° S. Light 2
10. Forked River 270° W. Light 2
11. Forked River Route 9

2 Sept 71-13

1. Oyster Creek Route 9
2. Oyster Creek due west Light 3, 100 yds
3. Oyster Creek 340° NNW Light 3 ½ way between loading derrick and light
4. Oyster Creek 20° NNE Light 3 25 yds
5. Stouts Creek due south of the mile marker 50 yds.
6. Stouts Creek 40° NNE mile marker
7. Stouts Creek 140° SE mile marker 50 yds
8. Forked River 40° NE Light 2 50 yds
9. Forked River due south Light 2 100 yds
10. Forked River 260° W Light 2, 100 yds
11. Forked River, Route 9.

22 Sept 71-14

1. Stouts Creek 200° SSW mile marker 25 yds
2. Stouts Creek due east of mile marker 25 yds
3. Forked River due north of Light 2, 100 ft.
4. Forked River 200° SSW of Light 2 75 yds
5. Oyster Creek 60° ENE Light 3 50 yds.
6. Oyster Creek 220° SW Light 3 50 yds
7. Oyster Creek Route #9.
8. Forked River Route #9.

4 October 71 -15

1. Forked River 240° WSW Light 2
2. Forked River 140° SSE Light 2
3. Oyster Creek 120° SE Light 3
4. Oyster Creek 180° S. Light 3
5. Stouts Creek 120° ESE Light 1
6. Stouts Creek 180° S. mile marker

26 October 1971

1. Stouts Creek 340° NNW Mile marker. 150 yds from light
2. Stouts Creek 120° ESE mile marker 75 yds from marker
3. Forked River 60° NE Light 2 50 ft. from light.
4. Forked River 240° WSW Light 2, 75 to 100 yds.
5. Oyster Creek, Route #9
6. Oyster Creek 200° SSW Light 3, 30 yds.

Station Locations for Hydrographic Data: 1971

26 October 1971

7. Oyster Creek 60° NE Light 3, 60 yds.
8. Forked River Route #9.

9 December 1971

1. Stouts Creek, 150° SE Light 1, 300 yds.
2. Stouts Creek, 300° NW Light 1, 75 yds from mile marker.
3. Forked River, 80° E Light 2, 200 yds.
4. Forked River, 180° S Light 2, 100 yds.
5. Oyster Creek, Route 9.
6. Oyster Creek, 140° SE Light 3, 100 yds.

Station Locations for Hydrographic Data: 1972

11 April 1972 72-1

1. 20° N. Light, Oyster Creek, 100 yds.
2. 270° W. Light 3, Oyster Creek, 75 yds.
3. 140° SE Light 1, Stouts Creek, 75 yds. from mile marker.
4. 100° E. Light 1, Stouts Creek, 200 yds.
5. 40° NE Light 2, Forked River, 100 yds.
6. 180° S. Light 2, Forked River, 200 yds.

26 April 1972 72-2

1. 190° SSW mile marker, 200 yds.
2. 170° SE of mile marker, Stouts Creek, 75yds.
3. 70° E Light 2, Forked River, 100 yds.
4. 200° SSW Light 2, Forked River, 100 yds.
5. Route #9, Oyster Creek
6. 220° SW Light 3, Oyster Creek
7. 100° ESE Light 3, Oyster Creek, 75 yds.
8. Route #9, Forked River

16 May 1972 72-3

1. 140° SE Light 1, Stouts Creek, 30 yds from mile marker
2. 160° SE Light 1, Stouts Creek, 75 yds from mile marker
3. 220° SW Light 3, Oyster Creek, 75 yds.
4. 20° N. Light 3, Oyster Creek
5. Route #9, Oyster Creek
6. 240° WSW Light 2, Forked River, 75 yds. from light
7. 80° NE Light 2, Forked River, 75 yds.
8. Route #9, Forked River

2 June 1972 72-4

1. 40° NE, 100 yds off Light 1, Stouts Creek
2. 115° ESE , 100 yds off Light 1. Stouts Creek
3. 60° E, 150 yds off Light 3 Oyster Creek
4. 140° SE, 50 yds off Light 3, Oyster Creek
5. 220° SW, 25 yds off Light 2, Forked River
6. 45° N, 75 yds off Light 2 Forked River

26 June 1972 72-5

1. 200° SSW, 200 yds off Light 1, Stouts Creek
2. 130° SE, 50 yds off Light 1, Stouts Creek
3. 90° NE, 150 yds off Light 1 Stouts Creek
4. 250° SW, 50 yds off Light 3, Oyster Creek
5. 55° NE, 200 yds off Light 3, Oyster Creek
6. 110° ESE, 25 yds off Light 3, Oyster Creek
7. 190° S, 75 yds off Light 2, Forked River
8. 40° N, 200 yds off Light 2, Forked River
9. 70° E, 75 yds off Light 2, Forked River

12 July 1972 72-6

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

1 August 1972 72-7

1. 160° SSE Mile marker, 200 yds from Light 1
2. 40° NE Light 1, 150 yds from Light.
3. Oyster Creek, Route 9.
4. 225° SW Oyster Creek, Light 3, 75 yds.
5. 210° SSW. Oyster Creek Light 3, 100 yds.
6. 180° South Light 2, 300 yds.
7. 0° N. Light 2, 75 yds, Forked River.
8. Forked River, Route #9.

16 August 1972 72-8

1. 140° SE of Mile Marker, Stouts Creek, 25 yds.
2. 60° NE Light 1, Stouts Creek, 200 yds.
3. Oyster Creek, Route #9.
4. 250° WSW Light 3, Oyster Creek, 300 yds.
5. 20° N Light 3, Oyster Creek, 200 yds.
6. 250° WSW Light 2, Forked River, 350 yds.
7. 330° NNW Light 2, Forked River 200 yds.
8. Forked River, Route #9.

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1971

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
8 Apr.	71-1	0910	1	0.0	6.3		2.5
				6.56	6.0		
		1010	2.	0.0	13.5		
				20.0	16.0		
		--	3.	0.0	6.7		
				21.0	6.6		
13 Apr.	71-2	0845	1	0.0	10.9	20.18	4.5
				3.28	10.9		
				6.56	10.4		
				7.38	10.1	21.68	
		0930	2.	0.0	10.5	20.52	4.0
				3.28	10.3		
				6.56	10.2		
				7.38	9.9	20.54	
			3	0.0	13.2	21.24	4.0
				3.28	11.9		
				6.56	13.0		
				8.2	10.4	21.19	
		1125	4	0.0	13.2	21.17	4.5
				3.28	13.7		
				6.56	12.9		
				7.38	11.2	21.44	
		1205	5	0.00	13.7	22.36	2.0
				1.64	13.5		
				3.28	13.4		
				4.92	13.4		
				6.56	13.9	22.13	
		1240	6	0.00	13.6	22.47	2.5
				1.64	13.4		
				3.28	13.3		
				4.92	13.2		
				6.56	12.6	22.25	
			7	0.0	21.1	17.43	
				3.28	21.9		
				6.56	21.9		
				9.84	21.9		
			8	0.0	13.2	21.09	
				1.64	13.2		
				3.28	12.8		
				6.56	13.0		
				8.2	12.6		

Date	Cruise	Time	Station	Depth	Temperature	Salinity	Secchi
29 Apr	71-3	0930	1	0.0	11.2	22.39	5.0
				1.0	11.1		
				2.0	11.0		
				3.0	11.0		
				4.0	11.0		
				5.0	11.1		
				6.0	11.0		
				7.0	11.0		
				7.75	10.9	25.46	
		1000	2	0.0	11.0	22.25	5.0
				1.0	11.0		
				2.0	11.1		
				3.0	11.2		
				4.0	11.1		
				5.0	11.1		
				6.0	11.1		
				7.0	11.1		
				8.0	11.1	24.52	
		1030	3	0.0	10.7	23.60	5.0
				1.0	10.9		
				2.0	10.9		
				3.0	10.9		
				4.0	10.9		
				5.0	10.9		
				6.0	10.9		
				7.0	10.9		
				8.0	11.7		
				8.5	10.7	25.41	
		1100	4	0.0	10.7	23.58	6.5
				1.0	10.8		
				2.0	10.9		
				3.0	10.9		
				4.0	10.9		
				5.0	10.9		
				6.0	10.9		
				7.0	10.9		
				8.0	10.9	25.06	
		1200	5 Left--	0.0	11.6	22.92	6.0
				1.0	12.7		
				2.0	12.7		
				3.0	12.7		
				4.0	12.7		
				5.0	12.2		
				6.0	12.0		
				7.0	11.7		
				7.5	11.4	24.33	
			Right--	0.0	18.7		
				1.0	17.0		
				2.0	14.7		
				3.0	13.7		
				4.0	12.5		
				5.0	12.0		
				6.0	12.0		
				7.0	11.7		
				8.0	11.7		

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
29 Apr	71-3	1230	6	0.0	19.1	22.53	6.0
				1.0	19.5		
				2.0	19.0		
				3.0	16.3		
				4.0	14.6		
				5.0	12.5		
				6.0	12.0		
				7.0	11.8	24.43	
6 May	71-4	0820	1	0.0	13.5	22.16	5.0
				1.0	13.5		
				2.0	13.5		
				3.0	13.5		
				4.0	13.5		
				5.0	13.5		
				6.0	13.7		
				7.0	13.7		
				7.75	13.7	23.33	
		0900	2	0.0	13.4	22.37	
				1.0	13.4		
				2.0	13.4		
				3.0	13.4		
				4.0	13.4		
				5.0	13.4		
				6.0	13.4		
				7.0	13.7		
				7.5	13.7	23.39	
		0945	3	0.0	20.6	22.86	5.0
				1.0	20.6		
				2.0	19.9		
				3.0	14.7		
				4.0	14.6		
				5.0	14.7		
				6.0	14.7		
				6.75	14.7	23.51	
		1020	4	0.0	22.7	22.70	5.0
				1.0	20.5		
				2.0	14.9		
				3.0	14.0		
				4.0	14.2		
				5.0	14.4		
				5.75	14.2	23.06	
		1100	5	0.0	24.4	21.33	
				1.0	24.7		
				2.0	24.7		
				3.0	25.0		
				4.0	25.6		
				5.0	25.6		
				6.0	25.7		
				7.0	25.8		
				8.0	25.8		
				12.0	26.0	22.55	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity	Secchi (feet)
6 May	71-4	1137	6	0.0	10.4	22.88	5.25
				1.0	10.2		
				2.0	10.0		
				3.0	9.6		
				4.0	14.7		
				5.0	14.7		
				6.0	14.6		
				7.0	14.6	23.98	
		1205	7	0.0	14.9	22.95	
				1.0	15.0		
				2.0	14.7		
				3.0	14.7		
				4.0	14.8		
				5.0	15.1		
				6.0	15.2		
				7.0	15.0		
				7.75	14.7	24.16	
		1240	8	0.0	16.0	23.46	
				1.0	16.0		
				2.0	16.0		
				3.0	16.0		
				4.0	16.0		
				5.0	16.0		
				6.0	16.0	23.39	
18 May	71-5	0805	1	0.0	16.6	—	5.0
				1.0	15.9		
				2.0	15.7		
				3.0	15.7		
				4.0	15.7		
				5.0	15.7		
				6.0	15.8		
				7.0	16.1		
				8.0	16.0		
		0840	2	0.0	16.9	—	5.0
				1.0	16.2		
				2.0	16.0		
				3.0	15.9		
				4.0	15.7		
				5.0	15.9		
				6.0	16.0		
				7.0	16.0		
				8.0	16.0		
		0920	3	0.0	16.7		
				1.0	16.2		
				2.0	16.0	—	
				3.0	15.9		
				4.0	15.9		
				5.0	15.7		
				6.0	15.5		
				7.0	15.3		
				8.0	15.5		

Date	Cruise	Time (EST)	Station	Depth (Feet)	Temperature (°C)	Salinity	Secchi (feet)
18 May	71-5	0950	4	0.0	16.9	—	5.0
				1.0	16.5		
				2.0	16.2		
				3.0	16.0		
				4.0	16.0		
				5.0	15.7		
				6.0	15.7		
				7.0	15.6		
				7.5	15.5		
		1035	5	0.0	23.7	—	5.0
				1.0	19.0		
				2.0	18.9		
				3.0	17.3		
				4.0	17.1		
				5.0	17.0		
				6.0	16.7		
				7.0	16.6		
		1125	6	0.0	24.0	—	5.0
				1.0	24.0		
				2.0	21.7		
				3.0	22.7		
				4.0	17.0		
				5.0	16.7		
				6.0	16.5		
				7.0	16.9		
		1215	7	0.0	24.2	—	
				1.0	25.2		
				2.0	26.0		
				3.0	26.2		
				4.0	26.4		
				5.0	26.4		
				6.0	26.4		
				8.0	26.7		
				10.0	26.7		
		1300	8	0.0	18.0	—	4.5
				1.0	17.7		
				2.0	17.6		
				3.0	17.6		
				4.0	17.5		
				5.0	17.4		
				6.0	17.4		
				8.0	17.4		
				10.0	17.4		
3 June	71-6	0820	1	0.0	20.0	21.47	3.25
				1.0	19.7		
				2.0	19.7		
				3.0	19.6		
				4.0	19.6		
				5.0	19.5		
				6.0	19.5		
				7.0	19.2		
				8.0	18.7	21.80	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature	Salinity (o/oo)	Secchi (feet)
3 June	71-6	0850	2	0.0	19.6	—	3.75
				1.0	19.5		
				2.0	19.45		
				3.0	19.45		
				4.0	19.45		
				5.0	19.45		
				6.0	19.2		
				7.0	18.9		
				8.0	18.7		
		0913	3	0.0	19.7	—	4.0
				1.0	19.6		
				2.0	19.45		
				3.0	19.2		
				4.0	19.2		
				5.0	19.2		
				6.0	19.2		
				7.0	19.2		
		0940	4	0.0	20.6	21.56	3.25
				1.0	20.2		
				2.0	20.2		
				3.0	20.2		
				4.0	19.95		
				5.0	19.95		
				6.0	18.7		
				7.0	18.2		
				8.0	17.7	22.01	
		1005	5	0.0	21.7	—	4.25
				1.0	21.2		
				2.0	21.2		
				3.0	21.0		
				4.0	21.0		
				5.0	20.7		
				6.0	19.2		
				7.0	18.7		
				7.5	18.2		
		1028	6	0.0	21.7	—	3.75
				1.0	21.7		
				2.0	21.7		
				3.0	21.7		
				4.0	21.7		
				5.0	20.6		
				6.0	18.7		
				7.0	18.4		
		1115	7	0.0	22.2	21.15	3.0
				1.0	22.2		
				2.0	22.0		
				3.0	21.2		
				4.0	19.2		
				5.0	18.5		
				6.0	18.3		
				6.5	18.2	22.36	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (^{o}C)	Salinity (o/oo)	Secchi (feet)
3 June	71-6	1135	8	0.0	23.7	—	3.25
				1.0	23.7		
				2.0	23.2		
				3.0	22.2		
				4.0	19.0		
				5.0	18.7		
				6.0	18.2		
				6.5	18.1		
		1155	9	0.0	2[illegible].7	—	3.0
				1.0	21.7		
				2.0	20.6		
				3.0	20.2		
				4.0	19.5		
				5.0	18.3		
				6.0	18.2		
				6.5	18.2		
		1230	10	0.0	29.2	17.61	
				1.0	28.7		
				2.0	28.7		
				3.0	28.7		
				4.0	30.2		
				5.0	30.2		
				6.0	30.2		
				7.0	30.2		
				8.0	30.6		
				8.5	30.6	18.86	
		1300	11	0.0	22.7	18.01	
				1.0	22.7		
				2.0	22.7		
				3.0	22.7		
				4.0	22.5		
				5.0	22.0		
				6.0	21.7		
				7.0	21.7		
				8.0	21.7		
				9.0	21.7		
				10.0	21.7	18.17	
16 June	71-7	0820	1	0.0	19.3	22.63	4.5
				1.0	19.3		
				2.0	19.3		
				3.0	19.3		
				4.0	19.3		
				5.0	19.3		
				6.0	19.3		
				7.0	19.3		
				7.5	19.5	24.45	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
16 June	71-7	0855	2	0.0	18.7	22.45	4.5
				1.0	19.1		
				2.0	19.3		
				3.0	19.3		
				4.0	19.3		
				5.0	19.3		
				6.0	19.3		
				7.0	19.3		
				8.0	19.3	24.87	
		0930	3	0.0	19.1		4.25
				1.0	19.3		
				2.0	19.3		
				3.0	19.3		
				4.0	19.3		
				5.0	19.3		
				6.0	19.3		
				7.0	19.1		
				8.0	19.1		
		1020	4	0.0	19.3	22.92	4.0
				1.0	19.5		
				2.0	19.5		
				3.0	19,6		
				4.0	19.6		
				5.0	19.6		
				6.0	19.6		
				7.0	19.7		
				8.0	19.6		
				8.5	19.7	23.13	
		1055	5	0.0	19.2	22.52	4.5
				1.0	19.5		
				2.0	19.5		
				3.0	19.5		
				4.0	19.5		
				5.0	19.6		
				6.0	19.6		
				7.0	19.6		
				8.0	19.7	22.54	
		1120	6	0.0	19.3	—	3.5
				1.0	19.6		
				2.0	19.7		
				3.0	19.7		
				4.0	19.7		
				5.0	19.7		
				6.0	19.7		
				7.0	19.7		
				8.0	19.7		

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (oC)	Salinity (o/oo)	Secchi (feet)
16 June	71-7	1150	7	0.0	20.0	22.99	2.5
				1.0	20.2		
				2.0	20.1		
				3.0	20.2		
				4.0	20.2		
				5.0	20.2		
				6.0	20.2		
				7.0	20.2	23.01	
		1220	8	0.0	22.7	20.84	2.5
				1.0	21.2		
				2.0	20.2		
				3.0	20.1		
				4.0	19.4		
				5.0	19.5		
				6.0	19.4		
				7.0	19.3	22.79	
		1250	9	0.0	25.7		3.5
				1.0	24.7		
				2.0	22.7		
				3.0	20.7		
				4.0	20.7		
				5.0	20.3		
				6.0	20.3		
				7.0	19.3		
		1330	10	0.0	28.9	18.19	3.0
				1.0	29.1		
				2.0	29.6		
				3.0	29.7		
				4.0	29.9		
				5.0	29.9		
				6.0	31.1		
				7.0	31.1		
				8.0	31.1		
				9.0	31.1		
				9.5	31.1	20.05	
		1410	11	0.0	20.7	21.35	2.5
				1.0	20.7		
				2.0	20.7		
				3.0	20.7		
				4.0	20.9		
				5.0	20.9		
				6.0	20.9		
				7.0	20.9		
				8.0	20.9		
				12.5	20.9	21.60	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
2 July	71-8	0655	1	0.0	26.4	23.10	2.5
				1.0	26.4		
				2.0	26.4		
				3.0	26.4		
				4.0	26.4		
				5.0	26.4		
				6.0	26.1		
				7.0	26.0		
				7.5	25.95	23.30	
		0720	2	0.0	26.0	23.17	2.5
				1.0	26.0		
				2.0	26.0		
				3.0	26.0		
				4.0	26.0		
				5.0	26.0		
				6.0	26.2		
				7.0	26.2		
				7.75	26.2	23.48	
		0745	3	0.0	25.6	23.44	2.75
				1.0	25.7		
				2.0	25.8		
				3.0	25.7		
				4.0	25.8		
				5.0	25.8		
				6.0	25.8		
				7.0	25.9		
				8.0	25.9	23.44	
		0815	4	0.0	28.7	22.81	2.5
				1.0	29.5		
				2.0	28.7		
				3.0	26.8		
				4.0	26.7		
				5.0	26.7		
				6.0	26.7		
				7.0	26.7	23.50	
		0835	5	0.0	28.7	23.51	2.75
				1.0	29.2		
				2.0	29.2		
				3.0	28.7		
				4.0	27.8		
				5.0	27.2		
				6.0	26.7		
				6.25	26.7	24.38	
		0855	6	0.0	29.7	—	2.5
				1.0	29.9		
				2.0	29.8		
				3.0	29.3		
				4.0	26.8		
				4.5	26.8		
		0930	7	0.0	29.2	—	
				7.5	26.6		

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
2 July	71-8	1010	8	0.0	31.7	21.93	3.0
				1.0	32.2		
				2.0	32.2		
				3.0	32.2		
				4.0	32.2		
				5.0	32.2		
				6.0	32.2		
				7.0	32.2		
				12.0	32.2		
		1100	9	0.0	29.8	22.67	2.5
				1.0	29.7		
				2.0	29.6		
				3.0	29.7		
				4.0	29.7		
				5.0	26.1		
				6.0	26.0		
				6.5	26.0	23.46	
		1130	10	0.0	26.4	23.61	2.5
				1.0	26.4		
				2.0	26.4		
				3.0	26.4		
				4.0	26.2		
				5.0	26.2		
				6.0	26.2		
				7.0	26.1		
				8.0	26.0	23.90	
		1150	11	0.0	26.8	23.57	2.5
				1.0	26.9		
				2.0	26.95		
				3.0	26.95		
				4.0	26.95		
				5.0	26.7		
				6.0	26.5		
				7.0	26.45	23.70	
		1220	12	0.0	27.2	23.93	
				12.0	27.2		
15 July	71-9	0635	1	0.0	23.5	25.92	3.0
				1.0	23.7		
				2.0	23.9		
				3.0	23.9		
				4.0	23.9		
				5.0	23.9		
				6.0	24.1		
				7.0	24.1		
				7.5	24.1	26.18	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
15 July	71-9	0700	2	0.0	23.7	25.61	3.5
				1.0	23.7		
				2.0	23.8		
				3.0	23.8		
				4.0	24.0		
				5.0	24.0		
				6.0	24.1		
				7.0	24.1		
				8.0	24.1	26.29	
		---	3	0.0	23.7	26.00	--
				1.0	23.8		
				2.0	23.8		
				3.0	24.0		
				4.0	24.0		
				5.0	24.0		
				6.0	24.0		
				7.0	24.0		
				7.5	24.0	26.19	
		0820	4	0.0	23.9	24.92	2.5
				1.0	23.9		
				2.0	23.9		
				3.0	23.9		
				4.0	22.8		
				5.0	22.8		
				6.0	22.8		
				7.0	22.9	25.08	
		0850	5	0.0	23.9	24.94	--
				1.0	24.0		
				2.0	24.0		
				3.0	23.9		
				4.0	23.8		
				5.0	23.8		
				6.0	23.8		
				7.0	23.9	25.14	
		0920	6	0.0	24.2	24.92	2.75
				1.0	24.2		
				2.0	24.2		
				3.0	24.2		
				4.0	24.0		
				5.0	23.8		
				6.0	23.7		
				7.0	23.7		
				8.0	23.9	25.23	
		1015	7	0.0	28.4	25.10	3.0
				1.0	27.8		
				2.0	26.3		
				3.0	25.3		
				4.0	24.5		
				5.0	24.2		
				6.0	24.7		
				7.0	24.7	26.22	

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
15 July	71-9	1100	8	0.0	[illegible]	25.70	[illegible]
				1.0	[illegible]		
				2.0	25.8		
				3.0	25.7		
				4.0	25.6		
				5.0	25.6		
				6.0	25.6	25.92	
		1130	9	0.0	25.5	25.95	3.5
				1.0	25.3		
				2.0	25.3		
				3.0	25.0		
				4.0	24.9		
				5.0	24.7		
				6.0	24.6		
				7.0	24.6	26.13	
		1230	10	0.0	30.4	24.94	2.0
		1325	11	0.0	25.6	25.68	2.0
29 July	71-10	0855	1	0.0	26.3	25.71	2.5
				7.0	26.2	25.53	
		0945	2	0.0	29.5	25.59	2.0
				6.0	25.9	26.46	
		1035	3	0.0	32.6	24.49	2.0
				10.0	32.6	24.36	
		1400	4	0.0	28.4	25.97	2.5
				15.0	28.5	25.99	
6 August	71-11	0726	1	0.0	24.0	25.86	2.25
				0.5	24.4		
				1.0	24.3		
				2.0	24.4		
				3.0	24.5		
				4.0	24.6		
				5.0	24.6		
				6.0	24.6		
				7.0	24.6		
				8.0	24.8	25.99	
		0755	2	0.0	24.0	26.00	2.50
				0.5	24.6		
				1.0	24.6		
				2.0	24.6		
				3.0	24.6		
				4.0	24.6		
				5.0	25.2		
				6.0	25.2		
				7.0	25.4		
				7.5	25.4	26.13	
		0819	3	0.0	24.7	—	2.25
				0.5	24.8		
				1.0	24.9		
				2.0	25.1		
				3.0	25.1		

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (°C.)	Salinity (o/oo)	Secchi (feet)
		0819	3	4.0	25.1		
				5.0	25.1		
				6.0	25.0		
				7.0	24.9		
				8.0	24.9		
		0855	4	0.0	30.2	24.29	1.75
				3.0	30.4		
				6.0	30.5		
				9.0	30.5		
				12.0	30.5	24.52	
		0920	5	0.0	28.0	24.98	2.50
				1.0	27.8		
				2.0	27.6		
				3.0	26.7		
				4.0	26.1		
				5.0	24.5		
				6.0	24.3	26.08	
		0950	6	0.0	29.7	24.42	2.50
				1.0	28.8		
				2.0	28.6		
				3.0	26.8		
				4.0	24.9		
				5.0	24.6		
				6.0	24.4		
				6.5	24.4	27.03	
		1012	7	0.0	29.6	—	2.25
				1.0	29.6		
				2.0	28.4		
				3.0	27.9		
				4.0	26.6		
				5.0	24.9		
				6.0	24.5		
				6.5	24.4		
		1040	8	0.0	25.3	26.33	2.50
				1.0	25.6		
				2.0	25.6		
				3.0	25.6		
				4.0	25.3		
				5.0	25.2		
				5.5	25.2	26.29	
		1055	9	0.0	25.6	26.27	2.75
				1.0	25.6		
				2.0	25.7		
				3.0	25.4		
				4.0	25.4		
				5.0	25.2		
				6.0	25.1		
				7.0	25.0		
				7.25	25.0	26.67	

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (°C.)	Salinity (o/oo)	Secchi (feet)
Aug	71-11	1130	10	0.0	25.3	—	2.50
				1.0	25.4		
				2.0	25.5		
				3.0	25.5		
				4.0	25.3		
				5.0	25.1		
				6.0	24.9		
				7.0	24.9		
				8.0	25.0		
		1200	11	0.0	25.7	25.43	2.50
						25.52	
3 Aug	71-12	0730	1	0.0	23.5	24.79	3.50
				1.0	31.0		
				3.0	30.9		
			?	12.0	30.9	25.23	
		0804	2	0.0	28.2	26.94	3.50
				1.0	28.7		
				2.0	28.7		
				3.0	27.0		
				4.0	26.4		
				5.0	25.7		
				5.75	25.6	25.77	
		0821	3	0.0	29.2	25.62	3.75
				1.0	29.2		
				2.0	28.8		
				3.0	27.0		
				4.0	25.6		
				5.0	25.3		
				6.0	25.0		
				7.0	25.1	25.60	
		0850	4	0.0	29.8	—	3.0
				1.0	29.2		
				2.0	25.7		
				3.0	25.2		
				4.0	25.2		
				5.0	25.2		
				6.0	25.2		
				6.5	25.2		
		0955	5	0.0	25.6	25.66	3.5
				1.0	25.3		
				2.0	25.0		
				3.0	24.9		
				4.0	24.9		
				5.0	24.8		
				6.0	24.8		
				7.0	24.8	25.53	
		1020	6	0.0	25.3	—	3.5
				1.0	26.0		
				2.0	25.8		
				3.0	25.6		
				4.0	25.2		
				5.0	24.9		
				6.0	24.9		
				7.0	24.9		

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (°C)	Salinity (o/oo)	Secchi (feet)
18 Aug	71-12	1050	7	0.0	26.5	25.48	3.25
				1.0	26.2		
				2.0	26.2		
				3.0	25.8		
				4.0	25.2		
				5.0	25.1		
				6.0	25.0		
				7.0	25.0		
				7.5	24.9	25.55	
		1115	8	0.0	26.5	26.38	3.50
				1.0	26.4		
				2.0	26.4		
				3.0	26.4		
				4.0	26.4		
				5.0	25.8		
				6.0	25.5		
				7.0	25.3		
				7.5	25.3	26.36	
		1135	9	0.0	25.7	26.38	3.25
				1.0	26.7		
				2.0	26.7		
				3.0	26.7		
				4.0	26.7		
				5.0	25.9		
				6.0	25.7		
				7.0	25.5	26.51	
		1215	10	0.0	26.3	—	3.0
				1.0	26.0		
				2.0	26.5		
				3.0	26.5		
				4.0	26.5		
				5.0	26.1		
				6.0	25.4		
		1230	11	0.0	26.4	25.93	2.25
				10.0	26.4	25.84	
2 Sept	71-13	0700	1	0.0	30.7	19.00	2.25
				1.0	30.9		
				3.0	31.4		
				4.0	32.1		
				5.0	32.3		
				6.0	32.4		
				10.0	32.6	20.05	
		0720	2	0.0	27.9	22.32	2.50
				1.0	28.2		
				2.0	28.1		
				3.0	26.6		
				4.0	24.3		
				5.0	24.0		
				6.0	23.9		
				7.0	23.9	24.49	

Date	Cruise	Time EST	Station	Depth (Feet)	Temperature (° C.)	Salinity (o/oo)	Secchi (feet)
2 Sept	71-13	0740	3	0.0	27.9	22.05	2.75
				1.0	27.9		
				2.0	25.8		
				3.0	24.2		
				4.0	24.0		
				5.0	23.7		
				6.0	23.7		
				6.5	23.9	24.22	
		0803	4	0.0	27.8	—	3.00
				1.0	27.6		
				2.0	27.4		
				3.0	25.3		
				4.0	24.6		
				5.0	24.1		
				6.0	23.9		
				6.5	23.9		
		0835	5	0.0	21.6	20.12	2.00
				1.0	21.8		
				2.0	21.8		
				3.0	21.8		
				4.0	22.2		
				5.0	22.3		
				6.0	22.7		
				7.0	23.3	23.22	
		0855	6	0.0	21.7	20.17	2.00
				1.0	22.0		
				2.0	22.0		
				3.0	22.1		
				4.0	22.1		
				5.0	22.3		
				6.0	22.3		
				7.0	22.8		
				8.0	23.5	22.23	
		0920	7	0.0	22.0	—	2.00
				1.0	22.2		
				2.0	22.2		
				3.0	22.2		
				4.0	22.1		
				5.0	22.3		
				6.0	22.4		
				7.5	23.0		
		0945	8	0.0	22.0	22.03	1.75
				1.0	22.4		
				2.0	22.4		
				3.0	22.4		
				4.0	22.5		
				5.0	22.5		
				6.0	22.8		
				7.0	23.4		
				8.0	23.5	25.32	

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (° C.)	Salinity (o/oo)	Secchi (feet)
2 Sept	71-13	1017	9	0.0	22.0	22.00	2.00
				1.0	22.3		
				2.0	22.4		
				3.0	22.4		
				4.0	23.0		
				5.0	23.0		
				6.0	23.1		
				7.0	23.4		
				7.75	23.5	24.07	
		1025	10	0.0	22.4	—	2.00
				1.0	22.5		
				2.0	22.5		
				3.0	22.6		
				4.0	22.5		
				5.0	22.7		
				6.0	23.0		
				7.0	23.4		
				7.5	23.4		
		1100	11	0.0	22.8	20.99	3.00
				1.0	22.9		
				2.0	23.0		
				3.0	23.0		
				4.0	23.0		
				5.0	23.0		
				10.0	23.0	21.22	
22 Sept	71-14	1205	1	0.0	21.8	19.72	2.50
				1.0	21.8		
				2.0	21.8		
				3.0	21.8		
				4.0	21.8		
				5.0	21.8		
				6.0	21.8		
				7.0	21.8		
				7.5	21.8	20.16	
		1228	2	0.0	21.7	19.45	2.50
				1.0	21.7		
				2.0	21.7		
				3.0	21.7		
				4.0	21.7		
				5.0	21.7		
				6.0	21.8	20.16	
		1300	3	0.0	21.7	19.34	2.50
				1.0	21.7		
				2.0	21.7		
				3.0	21.7		
				4.0	21.7		
				5.0	21.7		
				6.0	21.7		
				7.0	21.7		
				7.5	21.7	19.90	

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (° C.)	Salinity (o/oo)	Secchi (feet)
22 Sept	71-14	1327	4	0.0	21.8	19.31	2.50
				1.0	21.8		
				2.0	22.0		
				3.0	22.0		
				4.0	22.0		
				5.0	21.8		
				6.0	21.8		
				7.0	21.8		
				8.0	21.8	19.54	
		1353	5	0.0	20.8	19.00	2.50
				1.0	20.8		
				2.0	20.8		
				3.0	20.9		
				4.0	21.0		
				5.0	21.1		
				6.0	21.1		
				7.0	21.1		
				7.5	21.1	19.99	
		1415	6	0.0	21.8	19.13	2.50
				1.0	21.8		
				2.0	21.8		
				3.0	22.0		
				4.0	22.0		
				5.0	22.0		
				6.0	22.2		
				7.0	22.3	19.36	
		1447	7	0.0	21.7	18.64	3
				1.0	21.7		
				5.0	21.7		
				10.0	21.7		
				12.0	21.7	19.54	
		1521	8	0.0	21.7	20.28	3
				1.0	21.7		
				5.0	21.7		
				10.0	22.0		
				12.0	22.2	20.30	
4 Oct	71-15	1045	1	0.0	20.1	20.10	2.00
				1.0	19.9		
				2.0	19.9		
				3.0	19.9		
				4.0	19.9		
				5.0	19.9		
				6.0	19.9		
				7.0	19.9		
				8.0	19.9		
				9.0	19.9	22.74	
		1100	2	0.0	19.9	20.43	2.50
				1.0	19.9		
				2.0	19.9		
				3.0	19.9		
				4.0	19.9		
				5.0	19.9		

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (° C.)	Salinity (o/oo)	Secchi (feet)
4 Oct	71-15	1100	2	6.0	19.9		
				7.0	19.9		
				8.0	19.9		
				9.0	19.9		
				9.5	19.9	22.70	
		1120	3	0.0	19.9	18.30	2.00
				1.0	19.9		
				3.0	19.9		
				4.0	19.9		
				5.0	19.9		
				6.0	19.9		
				7.0	19.9		
				8.0	19.9		
				8.5	19.9	22.34	
		1140	4	0.0	19.6	18.30	2.25
				1.0	19.9		
				2.0	19.9		
				3.0	19.9		
				4.0	19.9		
				5.0	19.9		
				6.0	19.9		
				7.0	19.9		
				8.0	19.9	21.15	
		1345	5	0.0	20.1	19.85	2.25
				1.0	20.1		
				2.0	20.1		
				3.0	20.1		
				4.0	20.1		
				5.0	20.1		
				6.0	20.1		
				7.0	20.1		
				8.0	20.1	22.92	
		1404	6	0.0	21.1	19.89	2.25
				1.0	21.1		
				2.0	21.1		
				3.0	21.1		
				4.0	21.1		
				5.0	21.1		
				6.0	21.1		
				7.0	21.1		
				8.0	21.1		
				9.0	21.1	23.64	
26 Oct	71-16	1020	1	0.0	17.8	19.79	3.0
				7.0	17.8	19.89	
		1045	2	0.0	17.8	20.05	3.0
				8.0	17.8	20.10	
		1110	3	0.0	16.6	22.21	3.5
				7.5	16.6	22.21	

Date	Cruise	Time EST	Station	Depth (feet)	Temperature (°C.)	Salinity (o/oo)	Secchi (feet)
26 Oct	71-16	1133	4	0.0	14.8	22.20	3.25
				7.5	14.8	22.38	
		1210	5	0.0	14.4	15.91	2.50
				10.0	14.4	17.50	
		1230	6	0.0	15.2	17.85	2.50
				7.5	15.0	20.79	
		1255	7	0.0	17.7	17.61	2.50
				7.5	17.4	21.83	
		1340	8	0.0	15.5	17.16	3.0
				10.0	16.0	18.60	
9 Dec	71-17	0915	1	0.0	8.0	18.80	3.5
				7.0	8.35	19.73	
		0934	2	0.0	7.69	18.77	4.25
				7.0	6.60	25.30	
		0955	3.	0.0	8.88	21.62	3.25
					6.76	26.77	
		1012	4	0.0	8.58	24.45	4.25
					7.42	26.70	
		1040	5	0.0	16.53	18.27	3.50
					15.98	18.37	
		1100	6				3.00

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C.)	Salinity (o/oo)	Secchi (feet)
11 Apr	72-1	1000	1	0.0	10.25	20.35	4.0
				1.0	10.50		
				2.0	10.54		
				3.0	10.54		
				4.0	9.70		
				5.0	5.80		
				6.0	5.00		
				7.0	5.80	23.72	
			2	0.0	10.00	20.72	3.75
				1.0	10.10		
				2.0	9.65		
				3.0	9.65		
				4.0	7.25		
				5.0			
				6.0	6.20		
				7.0	6.50		
				7.5	6.50	23.47	
			3	0.0	3.25	18.94	3.5
				1.0	3.24		
				2.0	3.14		
				3.0	3.14		
				4.0	3.14		
				5.0	3.14		
				6.0	3.22	19.14	
			4	0.0	3.23	18.85	3.75
				1.0	3.23		
				2.0	3.23		
				3.0	3.00		
				4.0	3.00		
				5.0	3.23	19.01	
			5	0.0	3.83	20.00	4.0
				1.0	3.70		
				2.0	3.70		
				3.0	3.28		
				4.0	3.69		
				5.0	4.10		
				6.0	4.20	21.03	3.75
			6	0.0	4.12	20.21	
				1.0	4.12		
				2.0	5.88		
				3.0	5.20		
				4.0	4.80		
				5.0	4.50		
				6.0	4.53	22.60	
26 Apr	72-2	1010	1	0.0	9.60	20.94	4.5
				1.0	9.64		
				2.0	9.68		
				3.0	9.65		
				4.0	9.66		
				5.0	9.66		
				6.0	9.66	21.25	

...OGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C.)	Salinity (o/OO)	Secchi (feet)
		1035	2	not taken			
		1110	3	0.0		21.58	3.5
				1.0	9.95		
				2.0	9.95		
				3.0	9.95		
				4.0	9.95		
				5.0	9.84		
				6.0	9.84	21.90	
		1130	4				
		1230	5				
		1255	6	0.0	15.60	19.37	3.25
				1.0	15.34		
				2.0	13.74		
				3.0	11.20		
				4.0	11.13		
				5.0	11.09		
			7				
		0150	8			21.29	3.75
16 May	7-3	0835	1	0.0			
				1.0	15.45	17.80	3.25
				2.0	15.45	17.87	
				3.0	15.42	18.14	
				4.0	15.32	18.84	
				5.0	15.00	19.91	
				6.0	14.78	19.46	
				7.0	14.36	19.85	
		0902	2	0.0			
				1.0	15.44	17.96	3.50
				2.0	15.42	18.12	
				3.0	16.35	18.28	
				4.0	15.22	19.11	
				5.0	14.92	19.17	
				6.0	14.84	19.40	
				7.0	14.44	19.79	
		0930	3	0.0	15.51	19.53	
				1.0	15.27	19.78	3.25
				2.0	14.90	20.24	
				3.0	14.70	20.42	
				4.0	14.67	20.58	
				5.0	14.10	20.83	
				6.0	14.17	22.41	
				7.0	13.90	23.30	
		0953	4	0.0	15.46	19.32	
				1.0	15.40	19.41	3.50
				2.0	15.46	19.77	
				3.0	14.92	19.90	
				4.0	14.95	20.25	
				5.0	14.75	20.31	

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time	Station	Depth	Temperature	Salinity	Secchi
				6.0	14.26	21.72	
				7.0	14.01	23.56	
		1033	5	0.0	15.65	17.55	
				1.0	15.54	17.60	~4
				5.0	15.55	18.40	
				10.0	15.59	18.70	
		1110	6	0.0	15.63	19.53	
				1.0	16.00	19.63	3.5
				2.0	15.98	19.69	
				3.0	15.91	19.71	
				4.0	15.63	19.80	
				5.0	15.44	19.83	
				6.0	15.40	19.90	
				7.0	15.29	20.20	
		1125	7	0.0	15.45	19.86	3.5
				1.0	15.96	19.80	
				2.0	15.44	19.97	
				3.0	15.42	19.85	
				4.0	15.30	19.87	
				5.0	15.42	19.88	
				6.0	15.28	19.94	
				7.0	15.37	19.90	
		1155	8	0.0	16.16	19.72	
				1.0	16.24	19.77	4.25
				5.0	16.22	19.82	
				10.0	16.09	19.97	
2 June	72-4	0808	1	0.0	17.42	21.00	
				1.0	17.42		
				2.0	17.42		
				3.0	17.30		
				4.0	17.30		
				5.0	17.30		
				6.0	17.30		
				7.0	17.52		
				8.0	17.52	21.37	
		0840	2	1.0	17.35	20.87	
				2.0	17.35		
				3.0	17.35		
				4.0	17.35		
				5.0	17.35		
				6.0	17.35		
				7.0	17.10		
				8.0	17.61		
				9.0	17.61	21.24	
		0930	3	0.0	18.06	20.30	
				1.0	18.06		
				2.0	18.06		
				3.0	18.06		
				4.0	18.06		

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (°C.)	Salinity (o/oo)	Secchi (feet)
				5.0	18.06		
				6.0	18.06		2.5
				7.0	17.60	23.23	
		0952	4	0.0	18.25	20.55	2.75
				1.0	18.25		
				2.0	18.25		
				3.0	18.25		
				4.0	18.25		
				5.0	18.15		
				6.0	17.85	21.15	
		1055	5	0.0			
				1.0			
				2.0	18.63	21.21	
				3.0	18.63		
				4.0	18.63		
				5.0	18.63		
				6.0	18.55		
				7.0	18.55		
				8.0	18.65		
				9.0	18.65		
				10.0	18.70		
26 June	72-5	0830	1	0.0	18.38	20.19	3.75
				1.0	18.38		
				2.0	18.38		
				3.0	18.38		
				4.0	18.38		
				5.0	18.38		
				6.0	18.18		
				7.0	18.18		
				8.0	18.18		
				9.0	18.18	21.40	
		0900	2	0.0	18.33	20.39	3.5
				1.0	18.33		
				2.0	18.33		
				3.0	18.33		
				4.0	18.33		
				5.0	18.33		
				6.0	18.33		
				7.0	18.13	21.35	
		0920	3	0.0	18.26	20.36	3.75
				1.0	18.26		
				2.0	18.26		
				3.0	18.26		
				4.0	18.26		
				5.0	18.26		
				6.0	18.26		
				7.0	18.26	20.95	
		0950	4	0.0	22.78	19.83	3.5
				1.0	21.93		
				2.0	21.11		
				3.0	19.20		
				4.0	18.21		

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C)	Salinity	Secchi
				5.0	17.58		
				6.0	17.58		
				7.0	17.58	23.85	
		1005	5	0.0	21.43	20.70	3.75
				1.0	21.43		
				2.0	19.85		
				3.0	19.38		
				4.0	18.80		
				5.0	18.23		
				6.0	17.74		
				7.0	17.50		
				8.0	17.50	24.25	
		1025	6	0.0			
				1.0	22.70	20.00	3.0
				2.0	21.30		
				3.0	19.10		
				4.0	18.89		
				5.0	17.84		
				6.0	17.60		
				7.0	17.60		
				8.0	17.60		
				9.0	17.60		
				10.0	17.60	24.40	
		1105	7	1.0	20.62	21.39	
				2.0	20.62		
				3.0	20.62		
				4.0	20.62		
				5.0	19.51		
				6.0	19.51		
				7.0	19.06		
				8.0	17.69		
				9.0	17.69		
				10.0	17.69	23.89	
		1120	8	1.0	20.42	21.41	
				2.0	20.42		
				3.0	20,42		
				4.0	20.42		
				5.0	20.13		
				6.0	19.34		
				7.0	18.73		
				8.0	17.73		
				9.0	17.73		
				10.0	17.73	24.42	
		1140	9	1.0	21.06	21.37	
				2.0	21.06		
				3.0	20.90		
				4.0	20.90		
				5.0	20.55		
				6.0	19.98		
				7.0	17.84		
				8.0	17.79		
				9.0	17.63		
				10.0	17.60	24.17	

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C.)	Salinity (o/oo)	Secchi (feet)
12 Jul	72-6	0627	1	0	23.62	16.98	3.25
				1	23.70		
				2	23.76		
				3	23.78		
				4	23.85		
				5	24.22		
				6	24.30		
				7	24.30		
				8	24.30	19.27	
		0640	2	0	23.96	16.95	2.50
				1	23.96		
				2	23.96		
				3	23.96		
				4	23.88		
				5	23.88		
				6	23.88		
				7	23.88		
				8	24.10	17.72	
		0723	3	0	24.03	17.17	2.50
				1	24.03		
				2	24.03		
				3	23.87		
				4	23.87		
				5	24.26		
				6	24.73		
				7	24.73		
				8	24.73	19.02	
		0820	4	0		18.24	2.75
				1			
				2			
				3			
				4			
				5			
				6			
				7			
				8		19.00	
				9			
				10			
		0845	5	0		19.67	2.75
				1			
				2	30.91		
				3	29.66		
				4	27.09		
				5	26.17		
				6	25.43		
				7	25.43		
				8	25.43	21.71	
		0908	6	0	31.28	19.72	2.25
				1	31.28		
				2	31.28		
				3	28.65		

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C.)	Salinity (o/oo)	Secchi (feet)
12 Jul	72-6	0908	6	4	28.11		
				5	27.65		
				6	25.64		
				7	24.55		
				8	24.55	20.76	
		0920	7	0	30.81	19.82	3.00
				1	30.44		
				2	30.50		
				3	27.42		
				4	26.46		
				5	25.23		
				6	24.30		
				7	23.97		
				8	23.97	22.14	
		0955	8	0	26.90	20.10	2.90
				1	26.90		
				2	26.90		
				3	26.90		
				4	26.71		
				5	26.38		
				6	26.09		
				7	26.09		
				8	24.02	20.16	
		1010	9	0	27.43	20.13	2.75
				1	27.43		
				2	27.43		
				3	27.43		
				4	27.16		
				5	26.94		
				6	26.94		
				7	26.24		
				8	25.78	20.17	
		1030	10	0	27.15	20.13	3.0
				1	27.15		
				2	27.15		
				3	27.15		
				4	26.94		
				5	26.94		
				6	26.57		
				7	26.57		
				8	26.57	20.00	
		1110	11	0	26.97	19.47	
				1	26.97		
				2	26.97		
				10	26.97	19.64	

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C.)	Salinity (o/oo)	Secchi (feet)
1 Aug	72-7	0700	1	0	24.07	19.23	—
				1	24.07	19.20	
				2	24.42	19.47	
				3	24.92	21.65	
				4	25.14	22.82	
				5	24.42	27.27	
				6	24.24	27.29	
				7	24.24	27.32	
		0721	2	0	24.05	18.98	3.00
				1	24.05	19.11	
				2	24.27	19.11	
				3	25.69	21.57	
				4	24.83	25.88	
				5	24.56	26.85	
				6	24.48	27.38	
				7	24.48	27.20	
		0803	3	0	31.67	19.30	—
				1	31.67	19.50	
		0835	4	0	28.81	21.05	3.25
				1	28.81	21.00	
				2	29.44	21.00	
				3	29.43	21.05	
				4	26.22	22.19	
				5	25.23	24.13	
				6	26.18	25.98	
				7	26.18	25.98	
		0853	5	0	28.37	21.05	3.50
				1	28.25	21.00	
				2	27.85	21.00	
				3	26.54	21.05	
				4	25.40	22.19	
				5	24.96	24.13	
				6	24.87	25.98	
				7	24.91	25.98	
		0945	6	0	25.75	20.68	3.75
				1	25.75	20.75	
				2	25.50	20.75	
				3	25.50	20.75	
				4	25.20	23.57	
				5	25.20	23.70	
				6	24.95	24.79	
				7	24.72	25.83	
		1005	7	0	25.84	20.49	4.00
				1	25.68	20.67	
				2	25.60	20.67	
				3	25.60	20.63	
				4	25.20	23.52	
				5	25.32	23.63	
				6	24.87	23.68	
				7	24.36	27.97	

HYDROGRAPHIC DATA FOR STUDY AREA IN BARNEGAT BAY: 1972

Date	Cruise	Time (EST)	Station	Depth (feet)	Temperature (C.)	Salinity (o/oo)	Secchi (feet)
1 Aug	72-7	1043	8	0	25.64	19.86	—
				1	25.61	18.82	
16 Aug	72-8	0715	1	0	20.40	21.17	2.1
				1	20.40		
				2	20.40		
				3	20.77		
				4	20.77		
				5	20.77		
				6	21.06		
				7	21.06	16.86	
		0740	2	1	20.50	20.98	2.25
				2	20.50		
				3	21.15		
				4	21.15		
				5	21.15		
				6	21.15		
				7	21.20	24.66	
		0823	3	1	25.53	20.98	2.25
				2	25.30		
				10	24.90	21.42	
		0850	4	1	23.87	21.90	2.5
				2	23.13		
				3	22.25		
				4	21.35		
				5	21.20		
				6	21.20		
				7	21.76	23.23	
		0910	5	1	23.20	21.63	2.2
				2	21.45		
				3	20.92		
				4	20.92		
				5	20.92		
				6	20.92		
				7	20.92	23.88	
		0935	6	1	21.20	22.87	2.5
				2	21.20		
				3	21.20		
				4	21.20		
				5	21.15		
				6	20.90		
				7	20.77	25.40	
		1050	7	1	22.03	22.30	2.5
				2	21.99		
				3	21.99		
				4	21.99		
				5	21.85		
				6	21.56		
				7	21.45	25.60	
		1115	8	1	21.45	21.13	2.5
				10	21.68	21.18	

Addendum:

Captions as they appear in the text.

p. 2. Table 1. AS IS
p. 3. Table 2. AS IS
p. 4. Figure 1. Frequency vs. frequency for two time periods, of Barnegat Bay's most frequent macroalgal species. On the X-axis we have plotted the rank of a particular species of algae during the period 1965-68 (pre-operational). Similarly, on the Y-axis we have plotted the rank of the same species during the period 1970-72 (post-operational). For example, Codium fragile ranked 10th among all species in '65-'68, but it ranked 1st (along with Gracilaria sp.) in frequency in '70-'72.

p. 6,7. In Figs. 2a,b, and e, we have plotted the actual values for computed diversity, absolute number of species, and grams (dry weight) of algae in each sample taken during the indicated time period. In Fig.2c, we have plotted only the average value of eveness for each time period. The line drawn for Figs. 2a, b, c and e connect the average values. In Fig. 2d we have plotted the diversity indices, for each station, over the three time periods: for example, at Oyster Creek (V) the first point is for June '69-Aug'70, the second point for May'71-Dec'71 and the third point is for April '72-June'72. The X in Fig. 2d is the average value of diversity for the period June '69-June'72. NOTE: the third point for Stouts Creek was plotted wrong, it should be closer to the 0.9 mark.

p. 8. Table 3. AS IS
p. 9. Table 4. AS IS

p. 13. Figure 3. Here we have plotted the calculated average values of gross productivity for four years and for each station. For consistency, we have only plotted data available for the period June through October for each year. Where stations have been plotted, we also give a 4-yr. average (June-Oct.) for all years, by station. On the right side of the Figure, we have given the "bay-wide" average for each year (i.e., the average gross productivity, June-Oct., for all bay stations), and, also, the "grand mean", which is a reflection of gross production of all samples taken in the June-Oct. period for four consecutive years. In a recent re-calculation of data available from 1968, Kent Mountford (personal communication) estimates that the yearly average (all stations) for 1968 was 505 mg. O_2/ M3/ hr. (gross productivity).

p. 14. Table 5. AS IS

p. 17. Figure 4. In bothe the top and bottom diagram, we have plotted the value of net productivity (mg. O_2/ M3/ hr) for each station and for each of the months indicated. On the right side of each diagram, we have given the appropriate symbol for the stations (SC, Stouts Cr.; FR, Forked River; OC, Oyster Cr.; WT, Waretown; IN, is the intake canal at Light #12; and OUT is the outfall canal in the first cove of Oyster Creek). Note that the symbols are also plotted at the right side for the overall

average value of net productivity for 4 Aug.'71 through 27 July '72.

p. 18. Figure 5. Here we have plotted, in both the top and bottom diagram, the value of gross productivity (mg 02/ M3/ hr) for each station, by the date indicated. In the top diagram (Fig. 5a) we have plotted the values which Kent Mountford found in his study for each comparable time period (thses points are indicated by the symbol "K"). In the bottom diagram (Fig. 5b) we have plotted the overall bay avergge for the time period 4 Aug'71-27 July '72 (these points are indicatdd by a lazy "B", or ~)

p. 21. Table 6. This, of course, is a list of new species of benthic invertebrates which we have added to our voucher collection since the last progress report.

p. 22. Figure 6. Here we have plotted the number of individuals of all species of benthic invertebrates in a single sample (consisting of 7 Ponar grabs) against the volume (wet) of the sample. The upper figure (6a) is for samples only from the Stouts Creek region; while the lower figure (6b) is for Oyster Creek samples only.

p. 23. Figure 7. Here we have plotted the total number of benthic invertebrate species in a sample (consisting of 7 Ponar grabs) against the volume of the sample.

p. 25. Figure 8. In the top diagram (Fig. 8a) we have plotted the mean diversity index for all samples, collected at a particular station, for each time period . On the right, we have indicated the appropriate symbols for each station, and have arranged the stations in their diversity rank with respect to the mean diversity over the period 27 Aug.'69 through 26 June '72. In the bottom diagram (Fig. 8b) we have plotted the average number of species for each station and during the indicated time period. The points on the right are for the average number of species at each locality during the period 27 Aug.'69 through 26 June '72.

p. 26. Table 7. AS IS

p. 28. Figure 9. Location of 9 sampling regions where wooden panels are being held under natural conditions in an effort to elucidate the boring and encrusting species of organisms in Barnegat Bay.

p, 30. Table 8. In this table we have listed the occurrence, based on the number of stations at which the species occurred relative to the number of stations sampled of various boring and encrusting species of invertebrates in the vicinity of Oyster Cr.

p. 32. Figure 10. This is a histogram showing the number of species found on or in the test boards at each station over the period October 1971 through July 1972. The slashed bars represent samples taken for a two week interval, while the open bars represent a sample which was in the water for one month.

p. 33. Figure 11. This is a plot of the temperature (°C., solid line) and the salinity (‰, dashed line) at each station for the period November 1971 through July 1972.

p. 30. Table 9a. This table unfortunately was not labled; it appears the middle of p, 30 with a heading "maximum probability". The purpose of Table 9a is to list the probability levels at which differences, in the number of either species, at any station was due to chance. For example, the probablity that the difference in number of barnacles between the two depths is due to chance is 1.00 (i.e., barnacles don't seem to care at which depth they settle).

p. 34. Table 9b. This table should be called 9b. It is a listing of the number of individuals (for I Bankia and II Balanus) on each board surface for boards at the top and bottom at each station, for the time periods indicated. For example, the value 5760 appears in the column marked Station Number 4 - this means that at station 4, in the period 2cd half June through 1st half July of 1972, there were 5760 Bankia, per square meter, on the lower surface of the bottom board.

p. 38. AS IS (Table 10)

p. 39. Fig. 12 AS IS
p. 40. Table 11 AS IS
p. 40. Table 12 AS IS
p. 41 Table 13 AS IS
p. 42. Figure 13. In the top diagram all larval stages (i.e., 15 min old larvae, 4 hr old larvae, and 8 hr. old larvae) were exposed for 15 minutes at the indicated treatment temperature. In the bottom diagram, all larval stages were exposed for 2 hours at the indicated temperature. On the ordinate we have plotted in all cases the number of recognizable living larvae in the sample at the end of 24-36 hours (solid circle). We have also plotted the number of straight hinge larvae for each temperature treatment (open triangle); and, also, the number of straight hinge larvae that appeared to be morphologically normal (solid square).

p. 43. Fig. 14. AS IS
p. 45. Table 15. AS IS

p. 46. Under 2) the number of larvae pumped should read 9×10^{9} (i.e., nine billion)