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Synthesis of Information on the Distribution of Benthic Invertebrates in the Hudson/Raritan System.

Final Report

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INTRODUCTION

Since colonial times the Hudson - Raritan estuary system has been a center of marine based activities such as commerce, recreation, and fisheries. It is an area of high biological productivity and a nursery for many species of fish and invertebrates. This system has also served as a depository for effluents from the sewers and industries from one of the largest cities in the world. Many chemicals, both organic and inorganic bind to particles and, in so doing, accumulate in the sediments on the bottom of estuaries and become repositories and potential sources of contamination to the benthic fauna.

The macrobenthos are often selected in order to study the effects of chemical contamination because they are often sedentary, attached to the substrate, or imbedded in the sediments. In addition, benthic invertebrates are very important to the trophic structure of the estuary (they transfer energy from the producers to the higher level consumers) as well as being commercially important themselves (crabs, clams,oysters). They are also large enough to be collected, enumerated, and identified easily. Changes in the quality of the water and sediments of estuaries have the potential to affect the biota at different levels of biological organization. Figure 1 taken from Sastry and Miller (1981) illustrates a possible time sequence of the effects of pollution on biological systems. The earliest responses to toxic chemicals are on the organism's biochemical and physiological systems, then on growth and reproduction, followed by community and ecosystem responses in the years to decades following the degradation. The Hudson-Raritan system has been subjected to many decades of degraded water quality, therefore, changes at all levels including the structure and function of the ecosystem can be expected.

Carriker et.al. (1982) have reported that the distribution and abundance of the benthos of the New York Bight area are, of course, controlled by natural as well as human factors. Salinity and sediment composition are the most important natural factors. In the lower estuary (Lower Bay, Upper Bay, Raritan Bay, Arthur Kill, Kill Van Kull, Newark Bay, lower Hudson, and East River) the salinity of the bottom waters remains high and relatively constant; here the benthic community assemblages are very dependent on the composition of the sediments. Movement up toward the fresh waters of the Hudson, Hackensack, Passiac or Raritan rivers results in a change in the benthic community from those associated with a particular sediment type to those species that are tolerant to greatly reduced salinities.

BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES TO WATER QUALITY

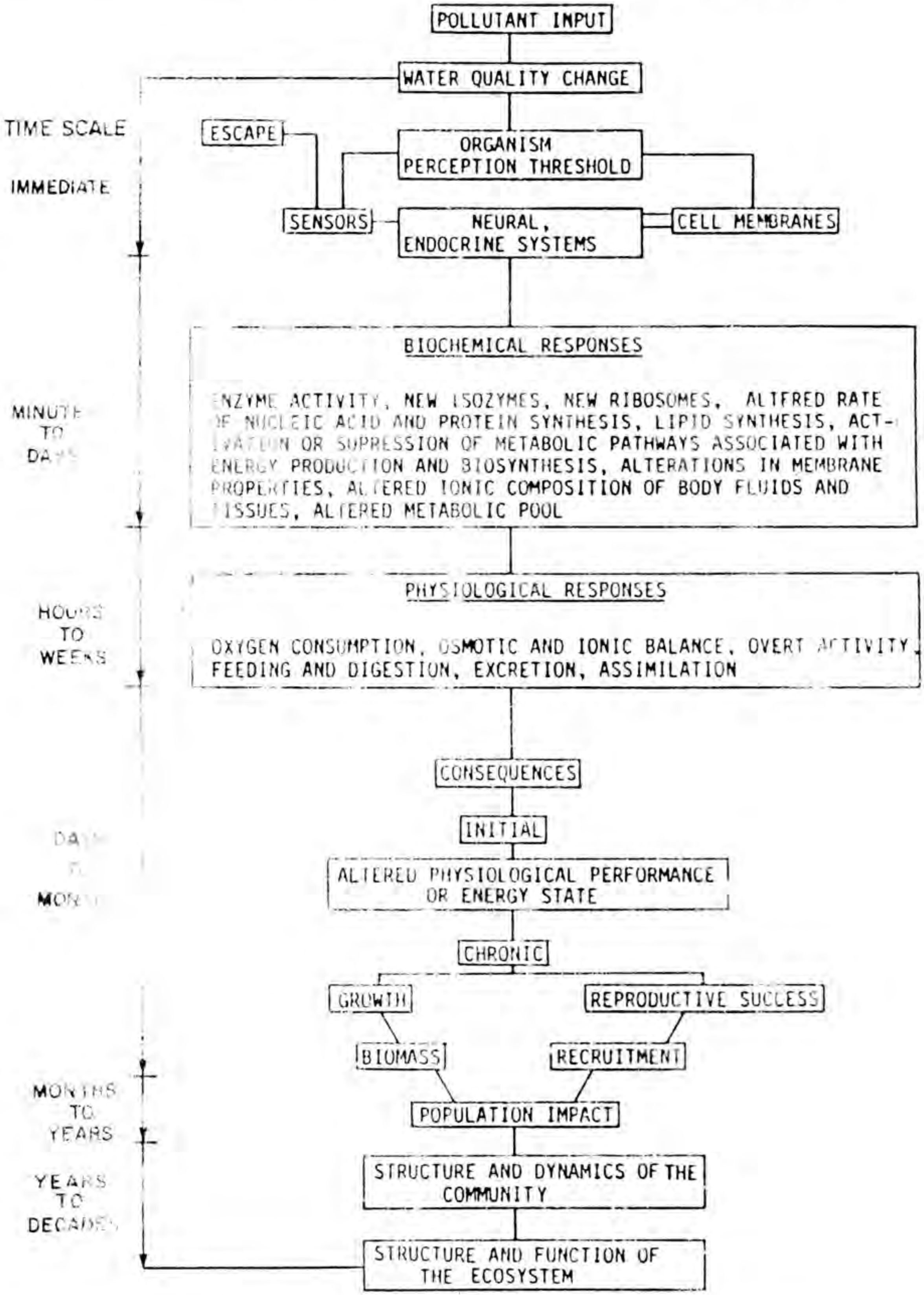

FIGURE 1. A hypothetical time related sequence of ssible biological effects of reduced water quality for rious levels of biological organization.

From Sastry and Miller 1981. 4

The deposition of fine grained sediments is a natural occurrence in an estuary. However, the fine grained sediments of the Hudson-Raritan system contain carbon enriched particles, heavy metals, and organic chemicals that are the result of human activities (Segar and Berberian, 1976; Greig and McGrath, 1977; Anderson, 1982; Michael, 1982; O'Connor, et.al., 1982). Carriker et.al. (1982) state that the most probable effect of increase organic loading on the benthos is the alterations in community structure due to low dissolved oxygen values in the bottom waters. In addition, the levels of toxicants in these sediments affect biochemical and physiological processes in benthic invertebrates as well as the structure of the community.

One of the goals of the Hudson Harbor Estuary Program is to develop a management plan for this ecosystem. Part of this plan should include an environmental monitoring program. A section of the monitoring program should be developed that would provide data that would reflect positive and negative changes in the benthos. However, before such a program can be developed for the Hudson-Raritan system, the extant data on benthic community structure and on the effects of toxic chemicals to the benthic invertebrates must be summarized. This report will focus on these two summaries and make recommendations concerning a possible monitoring strategy.

This report is one in a group of "characterization studies" supported by the EPA for the first year of the Hudson Harbor Estuaries Program. These studies included work on water quality modeling; pollutant loadings; distribution of dissolved oxygen, nutrients and organic carbon; toxicants in sediments and biota; hydrologic modifications; fish distribution and toxicant effects on birds. After all the first year studies are finalized I think it will be an important task to superimpose the data on the benthic communities on the water quality and sediment data sets. These results will provide important information for the development of the monitoring program and the management of the system.

METHODS

Figure 2 is a map of the primary core area, the numbers on the map refer to the 15 data sets that have been collected and computerized by my research group. Table I is a list of the studies examined in the course of the present study. The data sets were obtained as the result of letters of inquiry and phone calls to municipal, state and federal government agencies, the New York/New Jersey Port Authority, the Hackensack Meadowlands Development Commission, and various private consulting companies known to have done work in this ecosystem. In all but three cases the data was available only as hard copy in tabular format; this format was not amenable to any of the "scanners" available at Ramapo College or Rutgers University. Therefore, hundreds of people-hours were expended to enter the data by hand, in tabular form, using IBM word prefect 5.1 on to 3" by 5" computer disks. The complete data sets are included on the disks that accompany this report. Appendix A contains summaries of the available data sets. We were unable to locate data on the distribution of benthic invertebrates from the lower portions of the Passaic and Raritan rivers.

In order to attempt some comparison of the available data on the distribution of benthic invertebrates for the entire system we wished to use some type of measure of the benthic community, and hopefully, use that measure in combination with other measurements as an indicator of the environmental conditions in the system under study. There are several methods used to characterize and compare benthic communities which will be described below. All are based on a numerical analyses, therefore, a constant amount of bottom should be sampled with an appropriate number of replicates taken at each station. There are studies that have been done to evaluate the statistical designs to accurately characterize the amount of organisms within a given area (Eliott, 1971; Andrew and Mapstone 1987). A standard size mesh sieve should also be used to process the samples. Mare (1942) defines macrobenthos as those metazoans retained by a sieve with 1x1 mm mesh openings. Standard Methods

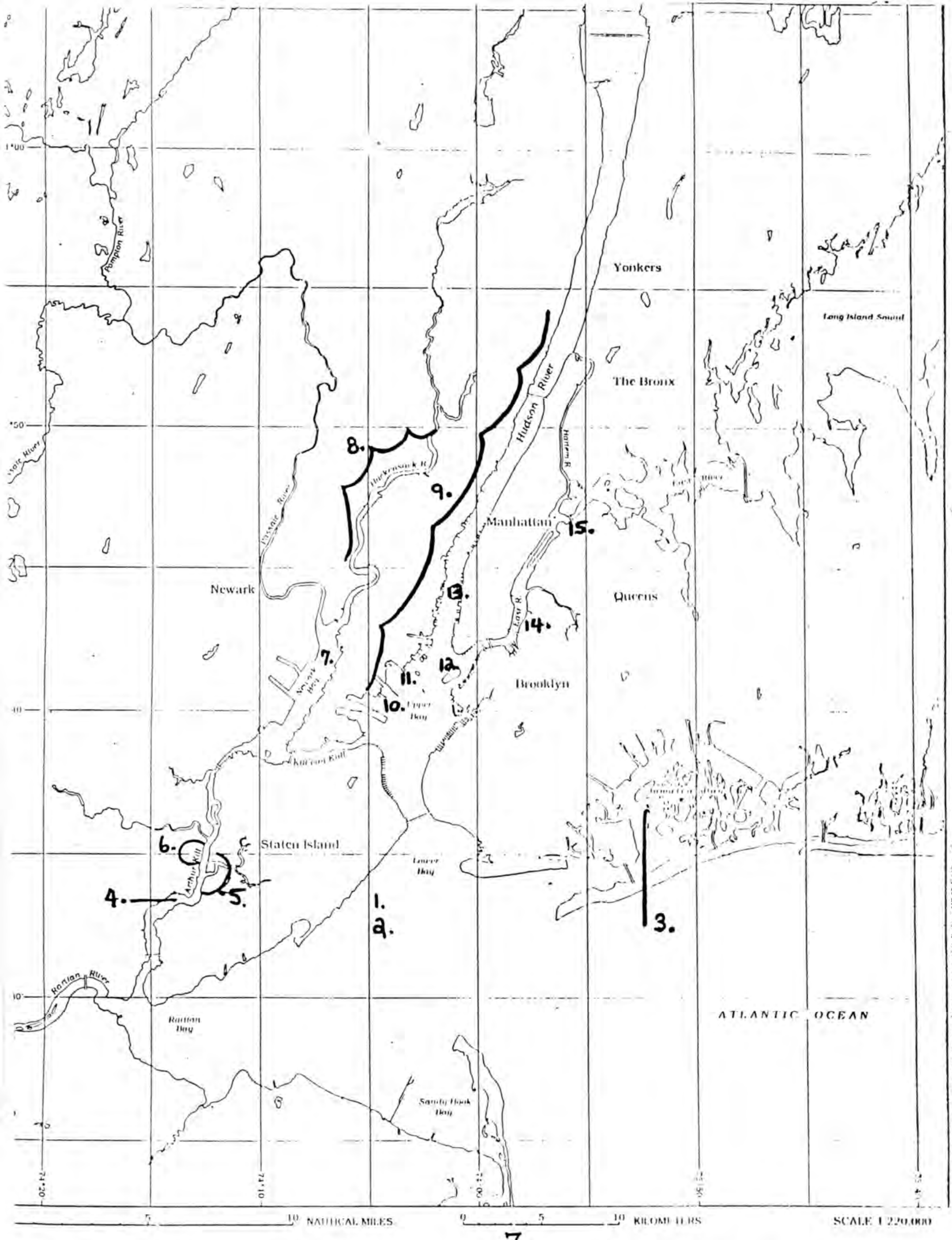

Fig. 2. Locations of the data sets included in this report.

TABLE 1
AVAILABLE BENTHIC DATA

AREA	DATE	MESH SIZE	#SAMPLES STATION	SOURCE/SPONSOR
RARITAN BAY	'73-'74	1mm	2	NMFS/Sandy Hook
	'86-'87	1 mm	2	US Army Corps of Engineers
JAMAICA BAY	'81-'82	1mm	5	Dr. Franz Brooklyn College of NY
ARTHUR KILL	'88-'89	0.5mm	3 or 6	NY-NJ Port Authority
STATEN I. [illegible].P.	'85	0.5mm	2	NYC Public Development Corp.
MORSES CREEK	'89	0.5mm	2	Exxon Corp.
NEWARK BAY	'87-'88	1mm	1	US Army Corps of Engineers
HACKENSACK RIVER	'87-'88	1mm	3	HMDC
HUDSON RIVER	'82-'83	1mm	3	NJDEP
JERSEY CHANNEL	'82-'83	0.5mm	1	NY/NJ Port Authority
LIBERTY PARK	'76	1mm	1	NY/NJ Port Authority
HARBORSIDE	'87-'88	1mm	3	Beyer, Blinder, and Belle
HUDSON RIVER CENTER	'86-'87	0.5mm	1	NYC Public Development Corp.
NORTH RIVER	'82	419 microns	1	NYC-DEP
EAST RIVER	'80-'82	419 microns	1	NYC-DEP

states that the standard opening for marine benthic fauna is 1.0 mm U.S. Standard No. 18 Sieve. However, a recent study by Bachelet (1990) shows that the sieving efficiency of this screen varied between 20 and 70% when compared with 0.5 mm mesh screens for macrobenthos in intertidal samples, and 25-65% of specimens passed through the 0.5 mm mesh screens. In addition, his data indicate that species richness, the diversity index and evenness were affected by the mesh size. The results of this study clearly suggest that the comparison of data from studies using different mesh sizes could be misleading.

In addition, there are many factors besides pollution that could affect the diversity of benthic communities (temperature, salinity, food availability, sediment type, predation and disease), therefore, seasonal sampling over a period of a few years is usual for complete characterization studies. Ferraro and Cole (1990) report that in order to accurately characterize the impact of pollution on the benthic communities of the Southern California Bight the number of taxa at the family level was sufficient using constant sampling conditions and 4 years of seasonal collections. Work in the Gulf of Mexico (Giammona and Darnel, 1990; Phillips et.al., 1990) also suggest that the design of benthic surveys should include more seasonal sampling. Bachelet (1990) observed considerable variation with season in the sieving efficiency due to settlement pulses of the larvae of the benthic invertebrates. Once the benthic community of a given ares is properly characterized, sampling once per year may provide enough information to monitor the state of the benthic community, however, long term trends could be best predicted by knowing something about seasonal variations. The results of these studies also suggest the problems associated with making spatial comparisons of benthic community structure using data that was collected in different seasons in different years.

Examination of the data set summaries in Appendix A indicate that the data generated by many of the benthic surveys have widely variant study designs. The gear used for benthic sampling was different for most studies as was the amount of sediment that was collected (0.01 - 0.1 square meter). The number of replicate samples varied greatly from study to study (1-5) as did the size of the mesh in the sieve (419 microns - 1.0mm). Some studies present only a pooled list of the benthic invertebrates collected using a variety of different gear (grab samplers, seine nets, benthic trawls and traps) within the same study. In addition, most of the studies were not carried out in the same year and did not have a seasonal component. In light of the background information and the methods used in the collection of the 15 existing data sets: I reexamined the methods used to characterize benthic communities in order to choose the best measure for the system as a whole. A summary of these methods is presented below.

Diversity Indices

The most commonly used measure of environmental impact has been the diversity index in one or more of its forms. These indices relate the numbers the number of species (richness) and importance values (dominance). Classical studies have shown that diversity will most often decrease with severe pollution stress. However, there are other factors that can decrease diversity, particularly in the estuarine environment. Diversity indices also do not provide answers to many questions that arise concerning the effects of toxic substances on benthic community structure. In addition, these indices are best applied to data collected using the same methods and sample size. All of these reasons suggest that comparing diversity indices will not be the best approach to meaningful synthesis of the divergent benthic data in the entire Hudson Harbor estuary.

Similarity in Species Composition

Another method of comparison that has been used is similarity in species composition. Many of the indices that have been developed to examine this parameter are very dependent on sample size; there are some indices that have been developed the take sample size dependence into account. However, the difference in the size of the mesh of the sieves in the different studies present a serious problem. In addition, the data that is reported in many of the studies in the Hudson-Raritan system are a compilation of all of the benthic invertebrates collected using all of the gear: for many of the studies a combination of benthic grabs, seine hauls, trawls and traps. The data sets do not separate out the fauna by gear so it is impossible to be sure which invertebrates were collected in the grabs, the seine hauls, the trawls, or the traps, yet only the benthic grab samples are replicated and quantified.

Change in Abundance or Biomass

Community ecologists have also suggested that changes in abundance or biomass can be used with multiple regression and ANOVA's to correlate changes in community structure with environmental variation. However, use of these measures requires that the natural variability in the system as well as seasonality be considered in the initial sampling design. These measures are very good for isolated studies such as the ones done in Jamaica Bay and Raritan Bay because the investigators who designed these studies sampled in different seasons as well as along known sediment and pollutant gradients. Because of the time span of the available data sets, the different gears, the different sample sizes, and the lack of seasonal sampling, this approach will not yield a meaningful measure of community structure as it relates to gradients in environmental conditions or toxicants of concern for consideration of the whole system.

The best data sets are those that were collected for Raritan Bay in 1973 by McGrath and in 1987 by Cerrato. Dr. Cerrato occupied most of the same stations in the 1973 study, used the same gear and sampled seasonally. He designed this study in order to get some idea of seasonal effects, changes over time and to calculate similarity indices. Dr. Ceratto has received a grant from the Hudson River Foundation to do at least the following in Raritan Bay:
1. Assign feeding guilds to fauna in order to interpret community structure
2. Use "surfer" software to contour plot abundance, species richness and environmental data.
3. Use multi-variate statistical techniques to examine community structure.

The report of their work will be available at around the same time that the report for the present study will be available. I have no intention of duplicating their work, rather, I wanted to attempt to concentrate on the whole Hudson Harbor Estuary System. Because of the problems with the methods described above, another, perhaps more generalized, method to measure the benthic community would be more appropriate.

Appendix B contains the literature search on the effects of pollutants on physiological and biochemical processes in different invertebrate species. Many of these studies have examined the toxicity of sediments to different species of amphipods (DeWitt, et.al., 1989; DeLisle and Roberts, 1988; Swartz, et.al., 1985; Swartz, et.al., 1989; Reichert, et.al., 1985; Oakden, et.al. 1984). [illegible], et.al. (1990) use the amphipod mortality test on Rhepoxynius abronius as part of their sediment bioassay system to compare with the alteration of benthic community structure in Puget Sound. Amphipod crustaceans are an important group in the benthic community, some benthic ecologists have suggested that the distribution of crustaceans, particularly the amphipods, could lead to meaningful comparisons of the effects of environmental [illegible]tions, including pollution. Amphipods are known to be sensitive to toxicants, particularly heavy metals, and their distribution is also related to sediment characteristics. Fine grain sediments are indicative of depositional areas where heavy metals, PAH's and other pollutants would be most likely to accumulate.

In order to establish a starting point to begin to examine the changes in benthic communities related to gradients in the ecosystem, the present report will focus on the distribution of the amphipods. The simple reporting of the occurrence of amphipods (numbers per square meter) will provide a general indication of the benthic community in different areas of the Hudson/Raritan system. [illegible] when this measurement is used in conjunction with the other [illegible] of environmental conditions compiled in the other characterization studies" a clearer indication of the relationship [illegible] environmental quality and the benthic community will [illegible].

We selected 4 genera of amphipods that are found in the Hudson/Raritan system. Examination of the data indicated that greater than 90% of the amphipods collected in any of the surveys were from these four genera. (1) Ampelisca - a tube dwelling amphipod found in muddy/sandy bottoms; this genus is often a dominant member of healthy inshore and estuarine benthic communities (2) Unicola also a tube dwelling genus found in sandier bottoms than Ampelisca (3) Corophium - another tube dwelling genus with wider bottom preference (from sand to mud) (4) Melita - this genus is tolerant to low salinities. The data sets were searched, and the information (station #, genus, date, number) were retrieved into a separate file and included on the disk containing the data for the entire survey available at with this report. In order to attempt to reduce seasonal effects; the spatial distribution of the number of amphipods from the available data sets will be compared for samples taken during the Summer months. The next section will contain a description of each segment of the core study area with emphasis on the distribution of the 4 genera of amphipods, followed by the composite distribution for the Summer studies.

DATA SETS

Raritan Bay

Three major benthic studies were done in Raritan Bay since 1973. The study performed by Stainken et.al.(1984) in 1979 - 1980 used a sieve mesh size that was 10 times larger than any of the other studies in the entire study area. It is doubtful that the benthic distributions that were observed in this study will be comparable to any of the other data sets. Therefore, these data were not included in the present report.

The second major study in Raritan Bay was conducted in 1973-74 by McGrath (1974), the data from this survey was reassessed by Steimle and Caracciolo-Ward (1989). Table II is a list of the genera, numbers of amphipods collected, and the station number. These data clearly show that 1973-74 study found very few amphipods present. Except for the occurrence of 8 Melita at station 56 on one cruse in 1973, amphipods of these four genera were absent from the stations sampled in most of the Bay. The only stations where Ampelisca and Unciola occurred were in the sediments of Sandy Hook Bay. Steimle and Caracciolo-Ward (1998) state that amphipods as a whole did not comprise the majority of the biomass of the Bay. They suggest that the limited distribution of amphipods in their study compared to the distributions found in other studies could be attributed to (1) seasonal differences in the collections (2) higher concentrations of heavy metals and organic contaminants in the sediments in portions of Raritan Bay (3) a response to natural environmental factors such as salinity shifts because of Tropical Storm Agnes.

Table II Amphipod distribution for 1973-1974 Raritan Bay Study McGrath (1974).

Cruise 1, 1973

STATION	SPECIES	NUMBER
73	AMPELISCA ABDITA	1
85	UNCIOLA SP	1
86	MELITA NITIDA	1
88	MELITA NITIDA	1
88	UNCIOLA SERRATA	1

Cruise 2, 1973

STATION	SPECIES	NUMBER
73	AMPELISCA ABDITA	1
85	UNCIOLA SP	1
86	MELITA NITIDA	1
88	MELITA NITIDA	1
88	UNCIOLA SERRATA	1

Cruise 3, 1973

STATION	SPECIES	NUMBER
13	UNCIOLA IRRORATA	1
56	MELITA NITIDA	8

Cruise 4, 1973

STATION	SPECIES	NUMBER
88	UNCIOLA IRRORATA	1

The third major study in Raritan Bay was conducted in 1986-87 by Cerrato. Table 3 is a list of the genera, numbers of amphipods collected, and the station number. These data clearly show a remarkable increase in the area of distribution and the numbers of amphipods from the 1973-74 survey. In 1986-87 Ampelisca abdita was the most abundant species and Corophium and Unicola were among the 20 most abundant genera. Clearly these substantial differences in the distribution of the four genera of amphipods suggest that a change has taken place in the benthic environment; these data could suggest a positive trend in the conditions in sections of Raritan Bay. These are the only studies done in the entire system that have sampled the same stations after a period of time using the same study design. Hopefully, the comparison study supported by the Hudson River Foundation will clarify these observed changes in the community structure of the benthos over time.

Jamaica Bay

A survey of the benthic communities in Jamaica Bay was done by Franz and Harris in 1981-1982. The details of the survey are presented in Appendix A. This study used different gear than the Raritan studies although the total sediment volume that was sampled was the same. They sampled seasonally in the Bay along known pollutant gradients and determined sediment grain size and heavy metal concentration in the sediments at these stations. In addition, the heavy metal concentrations were also measured in the tissues of selected benthic organisms at some of these stations.

Franz and Harris found high numbers of Ampelisca, Unicola, and Corophium at many station in the bay. The authors believe that amphipods constitute a major group of primary consumers in the food web and support juvenile fish, adult flat fish and shore bird populations that inhabit Jamaica Bay. They are also concerned that station 9 which is heavily contaminated with heavy metals and PAH's does not support an amphipod community (Appendix A). In addition, stations 25 and 26 seem to be vulnerable; because of the accumulation of heavy metals and organic contaminants these stations do not contain the type of amphipod communities that would be expected in this sediment type. These data serve as an example of how the measurement of the distribution of amphipods in combination with other measures of environmental conditions can be used as an indicator of the effects of pollution on the benthic community.

Table III Amphipod distribution for 1986-1987 Raritan Bay Study
Cruise 1, 1985 (Cerrato)

Page No. 1

STATION	SPECIES	NUMBER
1	Ampelisca abdita	589
1	Corophium tuberculatum	4
1	Unciola dissimilis	1
1	Unciola serrata	8
1	Unciola sp.	1
100	Ampelisca abdita	1
103	Ampelisca abdita	483
103	Corophium tuberculatum	6
103	Melita nitida	1
103	Unciola dissimilis	1
103	Unciola serrata	18
104	Ampelisca abdita	62
104	Corophium tuberculatum	16
104	Melita nitida	1
104	Unciola dissimilis	2
104	Unciola serrata	6
105	Ampelisca abdita	5
12	Unciola serrata	4
13	Ampelisca abdita	5
13	Ampelisca vadorum	3
13	Corophium tuberculatum	2
13	Melita nitida	1
13	Unciola irrorata	4
13	Unciola serrata	3
14	Ampelisca abdita	570
14	Corophium tuberculatum	7
14	Unciola serrata	1
15	Ampelisca abdita	537
15	Corophium tuberculatum	6
15	Unciola dissimilis	4
16	Ampelisca abdita	648
16	Corophium tuberculatum	6
16	Melita nitida	1
16	Unciola dissimilis	2
17	Ampelisca abdita	310
17	Unciola dissimilis	3
18	Ampelisca abdita	1937
18	Corophium tuberculatum	16
18	Unciola dissimilis	4
18	Unciola serrata	25
19	Ampelisca abdita	1
19	Unciola dissimilis	1
2	Ampelisca abdita	2951
2	Ampelisca vadorum	1
2	Corophium tuberculatum	46
2	Unciola dissimilis	6
2	Unciola serrata	7
21	Corophium tuberculatum	1
21	Unciola dissimilis	2
21	Unciola serrata	1
24	Ampelisca abdita	478

Cruise 1, 1985

Page No. 2

STATION	SPECIES	NUMBER
24	Corophium tuberculatum	11
25	Ampelisca abdita	452
25	Corophium tuberculatum	16
26	Ampelisca abdita	2230
26	Corophium tuberculatum	31
26	Unciola dissimilis	3
26	Unciola serrata	4
27	Ampelisca abdita	968
27	Corophium tuberculatum	3
28	Ampelisca abdita	1356
28	Corophium tuberculatum	44
28	Melita nitida	1
28	Unciola serrata	3
29	Corophium tuberculatum	1
30	Ampelisca abdita	767
30	Corophium tuberculatum	3
31	Corophium tuberculatum	1
32	Ampelisca abdita	1
36	Ampelisca abdita	883
36	Corophium tuberculatum	4
37	Ampelisca abdita	2
37	Corophium tuberculatum	1
38	Ampelisca abdita	38
38	Melitid sp.	1
38	Unciola irrorata	1
4	Ampelisca abdita	1672
4	Corophium tuberculatum	25
4	Unciola dissimilis	11
4	Unciola serrata	3
40	Ampelisca abdita	1
40	Corophium tuberculatum	4
40	Unciola serrata	5
41	Ampelisca abdita	8
41	Corophium tuberculatum	3
41	Melita nitida	1
41	Unciola serrata	14
42	Ampelisca abdita	32
42	Corophium tuberculatum	9
42	Unciola serrata	9
43	Ampelisca abdita	1487
43	Corophium tuberculatum	2
46	Ampelisca abdita	1
46	Unciola serrata	1
47	Ampelisca abdita	1
48	Ampelisca abdita	883
48	Corophium tuberculatum	7
48	Unciola dissimilis	1
48	Unciola serrata	1
49	Ampelisca abdita	51
49	Corophium tuberculatum	2
5	Ampelisca abdita	1

Cruise 1, 1985

Page No. 3

STATION	SPECIES	NUMBER
5	Unciola dissimilis	2
50	Ampelisca abdita	396
50	Corophium tuberculatum	4
51	Unciola dissimilis	1
51	Unciola serrata	1
52	Unciola serrata	1
53	Ampelisca abdita	4
54	Corophium tuberculatum	1
54	Unciola serrata	1
55	Ampelisca abdita	22
55	Corophium tuberculatum	2
55	Melita nitida	1
55	Unciola dissimilis	1
56	Ampelisca abdita	444
56	Corophium tuberculatum	3
58	Ampelisca abdita	1
60	Ampelisca abdita	1
68	Ampelisca abdita	4
68	Corophium tuberculatum	5
68	Unciola dissimilis	1
68	Unciola serrata	58
69	Ampelisca abdita	7
69	Corophium tuberculatum	4
69	Unciola irrorata	1
69	Unciola serrata	2
7	Ampelisca abdita	1
70	Ampelisca abdita	1
70	Corophium tuberculatum	2
70	Unciola serrata	19
71	Ampelisca abdita	1
71	Ampelisca vadorum	1
71	Unciola irrorata	1
71	Unciola serrata	1
73	Ampelisca abdita	966
73	Corophium tuberculatum	19
73	Unciola dissimilis	1
73	Unciola serrata	3
8	Unciola serrata	1
80	Ampelisca abdita	7
81	Ampelisca abdita	1
83	Ampelisca abdita	1
83	Corophium tuberculatum	7
83	Melita nitida	4
83	Unciola serrata	6
84	Corophium tuberculatum	1
85	Ampelisca abdita	13
86	Ampelisca abdita	1593
86	Corophium tuberculatum	28
86	Melita nitida	1
86	Unciola dissimilis	2
86	Unciola serrata	1

Cruise 1, 1985

Page No. 4

STATION	SPECIES	NUMBER
87	Ampelisca abdita	157
87	Melita nitida	1
88	Ampelisca abdita	1
89	Unciola serrata	1
95	Unciola serrata	1
98	Melita nitida	2
98	Unciola serrata	3
99	Ampelisca abdita	3
99	Unciola serrata	1
A1	Ampelisca abdita	29
A1	Corophium tuberculatum	1
A1	Melita nitida	1
A1	Unciola dissimilis	1
A1	Unciola serrata	1
A10	Ampelisca abdita	788
A10	Corophium tuberculatum	8
A10	Unciola dissimilis	1
A10	Unciola serrata	1
A2	Ampelisca abdita	1
A2	Unciola serrata	1
A3	Ampelisca abdita	1
A3	Corophium tuberculatum	2
A3	Unciola serrata	3
A4	Ampelisca abdita	435
A4	Corophium tuberculatum	2
A5	Ampelisca abdita	1166
A5	Corophium tuberculatum	6
A6	Ampelisca abdita	1069
A6	Corophium tuberculatum	2
A7	Ampelisca abdita	77
A8	Ampelisca abdita	335
A8	Corophium tuberculatum	1
A9	Ampelisca abdita	438
A9	Corophium tuberculatum	15
A9	Melita nitida	5
A9	Unciola dissimilis	1
A9	Unciola serrata	9
B10	Ampelisca abdita	9
B10	Unciola serrata	1
B3	Ampelisca abdita	1
B4	Ampelisca abdita	3075
B4	Corophium tuberculatum	32
B4	Unciola serrata	1
B5	Ampelisca abdita	2231
B5	Corophium tuberculatum	34
B5	Unciola dissimilis	1
B5	Unciola serrata	2
B6	Ampelisca abdita	1203
B6	Corophium tuberculatum	43
B6	Unciola dissimilis	1
B6	Unciola serrata	1

Table III cont.

Cruise 1, 1985

Page No. 5

STATION	SPECIES	NUMBER
B7	Ampelisca abdita	970
B7	Corophium tuberculatum	26
B7	Unciola dissimilis	1
B7	Unciola serrata	1
B8	Ampelisca abdita	3263
B8	Corophium tuberculatum	22
B8	Unciola serrata	3
B9	Ampelisca abdita	1843
B9	Corophium tuberculatum	7
C1	Ampelisca abdita	2
C1	Corophium tuberculatum	1
C1	Unciola serrata	1
C10	Ampelisca abdita	1
C10	Corophium tuberculatum	2
C10	Unciola irrorata	5
C10	Unciola serrata	4
C2	Ampelisca abdita	1
C2	Corophium tuberculatum	1
C2	Unciola serrata	1
C3	Ampelisca abdita	123
C3	Corophium tuberculatum	1
C3	Unciola serrata	10
C5	Ampelisca abdita	7
C5	Unciola serrata	1
C6	Corophium tuberculatum	1
C6	Unciola serrata	3
C7	Ampelisca abdita	1
C7	Unciola serrata	5
C8	Ampelisca abdita	1
C8	Unciola serrata	8
C9	Ampelisca abdita	1
C9	Unciola serrata	18

Table III cont.
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STATION	SPECIES	NUMBER
1	Ampelisca abdita	112
1	Corophium tuberculatum	3
103	Ampelisca abdita	68
103	Corophium tuberculatum	6
103	Unciola serrata	16
104	Ampelisca abdita	39
104	Corophium tuberculatum	5
104	Unciola serrata	8
105	Ampelisca abdita	4
105	Unciola serrata	2
11	Unciola dissimilis	1
12	Corophium tuberculatum	1
12	Unciola irrorata	2
13	Ampelisca abdita	3
13	Unciola serrata	3
14	Ampelisca abdita	202
14	Corophium tuberculatum	82
14	Unciola dissimilis	2
14	Unciola serrata	1
15	Ampelisca abdita	96
15	Corophium tuberculatum	2
15	Unciola dissimilis	5
16	Ampelisca abdita	988
16	Corophium tuberculatum	47
16	Unciola dissimilis	2
16	Unciola serrata	4
17	Ampelisca abdita	134
17	Corophium tuberculatum	27
17	Unciola dissimilis	1
17	Unciola serrata	1
18	Ampelisca abdita	105
18	Corophium tuberculatum	70
18	Unciola dissimilis	1
18	Unciola serrata	1
2	Ampelisca abdita	1012
2	Corophium tuberculatum	83
2	Unciola dissimilis	1
2	Unciola serrata	1
24	Ampelisca abdita	156
24	Corophium tuberculatum	64
24	Unciola dissimilis	2
25	Ampelisca abdita	98
25	Corophium tuberculatum	2
25	Unciola serrata	3
26	Ampelisca abdita	1295
26	Corophium tuberculatum	482
26	Unciola dissimilis	2
26	Unciola serrata	11
27	Ampelisca abdita	57
27	Corophium tuberculatum	4
27	Unciola dissimilis	1

Table III cont.

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STATION	SPECIES	NUMBER
28	Ampelisca abdita	1123
28	Corophium tuberculatum	351
28	Unciola serrata	1
29	Ampelisca abdita	1
3	Ampelisca abdita	503
3	Corophium tuberculatum	142
3	Unciola serrata	9
30	Ampelisca abdita	128
30	Corophium tuberculatum	11
31	Ampelisca abdita	231
31	Corophium tuberculatum	10
31	Unciola dissimilis	1
[illegible]	Unciola serrata	5
32	Ampelisca abdita	4
32	Corophium tuberculatum	3
32	Melita nitida	5
32	Unciola serrata	4
34	Ampelisca abdita	16
34	Corophium tuberculatum	1
34	Unciola serrata	2
36	Ampelisca abdita	5
36	Corophium tuberculatum	14
38	Ampelisca abdita	7
38	Corophium tuberculatum	8
38	Unciola irrorata	16
38	Unciola serrata	5
4	Ampelisca abdita	1204
[illegible]	Corophium tuberculatum	135
[illegible]	Unciola dissimilis	1
40	Ampelisca abdita	3
40	Corophium tuberculatum	7
40	Unciola dissimilis	1
40	Unciola serrata	3
41	Ampelisca abdita	6
41	Corophium tuberculatum	10
42	Ampelisca abdita	1769
42	Corophium tuberculatum	750
42	Unciola dissimilis	1
42	Unciola irrorata	1
42	Unciola serrata	5
43	Ampelisca abdita	3053
43	Corophium tuberculatum	3316
43	Melita nitida	3
43	Unciola dissimilis	42
46	Ampelisca abdita	761
46	Corophium tuberculatum	74
46	Unciola dissimilis	5
46	Unciola serrata	5
47	Ampelisca abdita	14
47	Corophium tuberculatum	28
47	Unciola dissimilis	1

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STATION	SPECIES	NUMBER
47	Unciola serrata	1
48	Ampelisca abdita	635
48	Corophium tuberculatum	24
48	Unciola sp.	1
49	Ampelisca abdita	1518
49	Corophium tuberculatum	341
49	Unciola serrata	1
5	Ampelisca vadorum	1
50	Ampelisca abdita	457
50	Corophium tuberculatum	148
50	Unciola serrata	5
51	Ampelisca abdita	4
51	Corophium tuberculatum	93
51	Unciola serrata	6
52	Ampelisca abdita	561
52	Corophium tuberculatum	375
52	Melita nitida	1
52	Unciola serrata	10
53	Ampelisca abdita	436
53	Corophium tuberculatum	122
53	Unciola dissimilis	1
53	Unciola serrata	6
54	Ampelisca abdita	516
54	Corophium tuberculatum	173
54	Melita nitida	3
54	Unciola dissimilis	2
54	Unciola serrata	20
55	Ampelisca abdita	266
55	Corophium tuberculatum	1
56	Ampelisca abdita	399
56	Corophium tuberculatum	58
56	Melita nitida	2
57	Ampelisca abdita	214
57	Corophium tuberculatum	8
57	Melita nitida	1
57	Unciola serrata	3
58	Ampelisca abdita	46
58	Melita nitida	10
58	Unciola serrata	1
59	Ampelisca abdita	2
59	Corophium tuberculatum	1
6	Ampelisca abdita	1
60	Ampelisca abdita	6
62	Ampelisca abdita	1
68	Ampelisca abdita	4
68	Corophium tuberculatum	1
69	Ampelisca abdita	1
69	Unciola irrorata	1
7	Ampelisca abdita	1
7	Unciola irrorata	5
7	Unciola serrata	1

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STATION	SPECIES	NUMBER
70	Unciola dissimilis	1
70	Unciola irrorata	1
70	Unciola serrata	3
71	Unciola irrorata	1
73	Ampelisca abdita	231
73	Corophium tuberculatum	4
73	Unciola dissimilis	4
73	Unciola irrorata	1
8	Ampelisca abdita	2
80	Ampelisca abdita	264
80	Corophium tuberculatum	99
80	Melita nitida	2
80	Unciola irrorata	3
80	Unciola serrata	4
81	Ampelisca abdita	12
81	Corophium tuberculatum	72
81	Unciola dissimilis	1
81	Unciola serrata	2
82	Ampelisca abdita	1
83	Ampelisca abdita	5
83	Corophium tuberculatum	7
83	Unciola irrorata	1
83	Unciola serrata	3
84	Ampelisca abdita	6
84	Corophium tuberculatum	2
84	Unciola serrata	1
85	Ampelisca abdita	552
85	Corophium tuberculatum	13
85	Unciola dissimilis	1
85	Unciola irrorata	1
85	Unciola serrata	1
86	Ampelisca abdita	512
86	Corophium tuberculatum	8
86	Melita nitida	1
86	Unciola serrata	3
87	Ampelisca abdita	683
87	Corophium tuberculatum	15
87	Melita nitida	1
87	Unciola dissimilis	1
87	Unciola serrata	1
88	Ampelisca abdita	119
88	Corophium tuberculatum	369
88	Melita nitida	2
88	Unciola dissimilis	1
88	Unciola serrata	38
89	Ampelisca abdita	2
89	Corophium tuberculatum	10
9	Unciola irrorata	1
9	Unciola serrata	2
90	Ampelisca abdita	1
90	Corophium tuberculatum	1

STATION	SPECIES	NUMBER
91	Ampelisca abdita	1
92	Ampelisca abdita	1
92	Unciola dissimilis	2
92	Unciola serrata	2
96	Ampelisca abdita	1
98	Ampelisca abdita	1
99	Ampelisca abdita	2
A1	Ampelisca abdita	64
A1	Corophium tuberculatum	10
A1	Melita nitida	9
A1	Unciola serrata	12
A10	Ampelisca abdita	241
A10	Corophium tuberculatum	75
A2	Ampelisca abdita	324
A2	Corophium tuberculatum	7
A2	Melita nitida	5
A2	Unciola dissimilis	1
A2	Unciola serrata	4
A3	Ampelisca abdita	3
A3	Corophium tuberculatum	6
A3	Unciola serrata	3
A4	Ampelisca abdita	270
A4	Corophium tuberculatum	114
A4	Unciola serrata	1
A5	Ampelisca abdita	554
A5	Corophium tuberculatum	238
A5	Melita nitida	2
A5	Unciola serrata	1
A6	Ampelisca abdita	224
A6	Corophium tuberculatum	45
A6	Melita nitida	1
A7	Ampelisca abdita	200
A7	Corophium tuberculatum	11
A8	Ampelisca abdita	332
A8	Corophium tuberculatum	135
A8	Melita nitida	1
A8	Unciola serrata	2
A9	Ampelisca abdita	185
A9	Corophium tuberculatum	36
A9	Melita nitida	1
A9	Unciola serrata	2
B2	Unciola dissimilis	1
B3	Ampelisca abdita	1
B4	Ampelisca abdita	328
B4	Corophium tuberculatum	20
B4	Unciola irrorata	1
B4	Unciola serrata	1
B5	Ampelisca abdita	1103
B5	Corophium tuberculatum	607
B5	Unciola serrata	13
B6	Ampelisca abdita	174

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STATION	SPECIES	NUMBER
B6	Corophium tuberculatum	16
B6	Unciola dissimilis	1
B7	Ampelisca abdita	292
B7	Corophium tuberculatum	27
B8	Ampelisca abdita	449
B8	Corophium tuberculatum	307
B8	Unciola irrorata	1
B8	Unciola serrata	3
B9	Ampelisca abdita	1058
B9	Corophium tuberculatum	238
B9	Unciola dissimilis	1
B9	Unciola serrata	2
C10	Unciola serrata	3
C2	Ampelisca abdita	1
C3	Unciola irrorata	1
C4	Corophium tuberculatum	1
C4	Unciola dissimilis	1
C5	Ampelisca abdita	1
C6	Unciola serrata	1
C7	Ampelisca abdita	1
C7	Unciola irrorata	1
C7	Unciola serrata	5
C8	Ampelisca abdita	1
C8	Unciola dissimilis	1
C9	Ampelisca abdita	3
C9	Unciola dissimilis	1
C9	Unciola serrata	4

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STATION	SPECIES	NUMBER
1	Ampelisca abdita	589
1	Corophium tuberculatum	4
1	Unciola dissimilis	1
1	Unciola serrata	8
1	Unciola sp.	1
100	Ampelisca abdita	1
103	Ampelisca abdita	483
103	Corophium tuberculatum	6
103	Melita nitida	1
103	Unciola dissimilis	1
103	Unciola serrata	18
104	Ampelisca abdita	62
104	Corophium tuberculatum	16
104	Melita nitida	1
104	Unciola dissimilis	2
104	Unciola serrata	6
105	Ampelisca abdita	5
12	Unciola serrata	4
13	Ampelisca abdita	5
13	Ampelisca vadorum	3
13	Corophium tuberculatum	2
13	Melita nitida	1
13	Unciola irrorata	4
13	Unciola serrata	3
14	Ampelisca abdita	570
14	Corophium tuberculatum	7
14	Unciola serrata	1
15	Ampelisca abdita	537
15	Corophium tuberculatum	6
15	Unciola dissimilis	4
16	Ampelisca abdita	648
16	Corophium tuberculatum	6
16	Melita nitida	1
16	Unciola dissimilis	2
17	Ampelisca abdita	310
17	Unciola dissimilis	3
18	Ampelisca abdita	1937
18	Corophium tuberculatum	16
18	Unciola dissimilis	4
18	Unciola serrata	25
19	Ampelisca abdita	1
19	Unciola dissimilis	1
2	Ampelisca abdita	2951
2	Ampelisca vadorum	1
2	Corophium tuberculatum	46
2	Unciola dissimilis	6
2	Unciola serrata	7
21	Corophium tuberculatum	1
21	Unciola dissimilis	2
21	Unciola serrata	1
24	Ampelisca abdita	478

STATION	SPECIES	NUMBER
24	Corophium tuberculatum	11
25	Ampelisca abdita	452
25	Corophium tuberculatum	16
26	Ampelisca abdita	2230
26	Corophium tuberculatum	31
26	Unciola dissimilis	3
26	Unciola serrata	4
27	Ampelisca abdita	968
27	Corophium tuberculatum	3
28	Ampelisca abdita	1356
28	Corophium tuberculatum	44
28	Melita nitida	1
28	Unciola serrata	3
29	Corophium tuberculatum	1
30	Ampelisca abdita	767
30	Corophium tuberculatum	3
31	Corophium tuberculatum	1
32	Ampelisca abdita	1
36	Ampelisca abdita	883
36	Corophium tuberculatum	4
37	Ampelisca abdita	2
37	Corophium tuberculatum	1
38	Ampelisca abdita	38
38	Melitid sp.	1
38	Unciola irrorata	1
4	Ampelisca abdita	1672
4	Corophium tuberculatum	25
4	Unciola dissimilis	11
4	Unciola serrata	3
40	Ampelisca abdita	1
40	Corophium tuberculatum	4
40	Unciola serrata	5
41	Ampelisca abdita	8
41	Corophium tuberculatum	3
41	Melita nitida	1
41	Unciola serrata	14
42	Ampelisca abdita	32
42	Corophium tuberculatum	9
42	Unciola serrata	9
43	Ampelisca abdita	1487
43	Corophium tuberculatum	2
46	Ampelisca abdita	1
46	Unciola serrata	1
47	Ampelisca abdita	1
48	Ampelisca abdita	883
48	Corophium tuberculatum	7
48	Unciola dissimilis	1
48	Unciola serrata	1
49	Ampelisca abdita	51
49	Corophium tuberculatum	2
5	Ampelisca abdita	1

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STATION	SPECIES	NUMBER
5	Unciola dissimilis	2
50	Ampelisca abdita	396
50	Corophium tuberculatum	4
51	Unciola dissimilis	1
51	Unciola serrata	1
52	Unciola serrata	1
53	Ampelisca abdita	4
54	Corophium tuberculatum	1
54	Unciola serrata	1
55	Ampelisca abdita	22
55	Corophium tuberculatum	2
55	Melita nitida	1
55	Unciola dissimilis	1
56	Ampelisca abdita	444
56	Corophium tuberculatum	3
58	Ampelisca abdita	1
60	Ampelisca abdita	1
68	Ampelisca abdita	4
68	Corophium tuberculatum	5
68	Unciola dissimilis	1
68	Unciola serrata	58
69	Ampelisca abdita	7
69	Corophium tuberculatum	4
69	Unciola irrorata	1
69	Unciola serrata	2
7	Ampelisca abdita	1
70	Ampelisca abdita	1
70	Corophium tuberculatum	2
70	Unciola serrata	19
71	Ampelisca abdita	1
71	Ampelisca vadorum	1
71	Unciola irrorata	1
71	Unciola serrata	1
73	Ampelisca abdita	966
73	Corophium tuberculatum	19
73	Unciola dissimilis	1
73	Unciola serrata	3
8	Unciola serrata	1
80	Ampelisca abdita	7
81	Ampelisca abdita	1
83	Ampelisca abdita	1
83	Corophium tuberculatum	7
83	Melita nitida	4
83	Unciola serrata	6
84	Corophium tuberculatum	1
85	Ampelisca abdita	13
86	Ampelisca abdita	1593
86	Corophium tuberculatum	28
86	Melita nitida	1
86	Unciola dissimilis	2
86	Unciola serrata	1

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STATION	SPECIES	NUMBER
87	Ampelisca abdita	157
87	Melita nitida	1
88	Ampelisca abdita	1
89	Unciola serrata	1
95	Unciola serrata	1
98	Melita nitida	2
98	Unciola serrata	3
99	Ampelisca abdita	3
99	Unciola serrata	1
A1	Ampelisca abdita	29
A1	Corophium tuberculatum	1
A1	Melita nitida	1
A1	Unciola dissimilis	1
A1	Unciola serrata	1
A10	Ampelisca abdita	788
A10	Corophium tuberculatum	8
A10	Unciola dissimilis	1
A10	Unciola serrata	1
A2	Ampelisca abdita	1
A2	Unciola serrata	1
A3	Ampelisca abdita	1
A3	Corophium tuberculatum	2
A3	Unciola serrata	3
A4	Ampelisca abdita	435
A4	Corophium tuberculatum	2
A5	Ampelisca abdita	1166
A5	Corophium tuberculatum	6
A6	Ampelisca abdita	1069
A6	Corophium tuberculatum	2
A7	Ampelisca abdita	77
A8	Ampelisca abdita	335
A8	Corophium tuberculatum	1
A9	Ampelisca abdita	438
A9	Corophium tuberculatum	15
A9	Melita nitida	5
A9	Unciola dissimilis	1
A9	Unciola serrata	9
B10	Ampelisca abdita	9
B10	Unciola serrata	1
B3	Ampelisca abdita	1
B4	Ampelisca abdita	3075
B4	Corophium tuberculatum	32
B4	Unciola serrata	1
B5	Ampelisca abdita	2231
B5	Corophium tuberculatum	34
B5	Unciola dissimilis	1
B5	Unciola serrata	2
B6	Ampelisca abdita	1203
B6	Corophium tuberculatum	43
B6	Unciola dissimilis	1
B6	Unciola serrata	1

STATION	SPECIES	NUMBER
B7	Ampelisca abdita	970
B7	Corophium tuberculatum	26
B7	Unciola dissimilis	1
B7	Unciola serrata	1
B8	Ampelisca abdita	3263
B8	Corophium tuberculatum	22
B8	Unciola serrata	3
B9	Ampelisca abdita	1843
B9	Corophium tuberculatum	7
C1	Ampelisca abdita	2
C1	Corophium tuberculatum	1
C1	Unciola serrata	1
C10	Ampelisca abdita	1
C10	Corophium tuberculatum	2
C10	Unciola irrorata	5
C10	Unciola serrata	4
C2	Ampelisca abdita	1
C2	Corophium tuberculatum	1
C2	Unciola serrata	1
C3	Ampelisca abdita	123
C3	Corophium tuberculatum	1
C3	Unciola serrata	10
C5	Ampelisca abdita	7
C5	Unciola serrata	1
C6	Corophium tuberculatum	1
C6	Unciola serrata	3
C7	Ampelisca abdita	1
C7	Unciola serrata	5
C8	Ampelisca abdita	1
C8	Unciola serrata	8
C9	Ampelisca abdita	1
C9	Unciola serrata	18

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STATION	SPECIES	NUMBER
1	Ampelisca abdita	2
10	Ampelisca abdita	2
103	Ampelisca abdita	8
103	Corophium tuberculatum	39
103	Unciola serrata	8
104	Ampelisca abdita	13
104	Unciola serrata	10
105	Ampelisca abdita	54
13	Unciola serrata	1
14	Ampelisca abdita	157
14	Unciola serrata	4
15	Ampelisca abdita	53
15	Unciola dissimilis	1
16	Ampelisca abdita	189
17	Ampelisca abdita	60
17	Corophium tuberculatum	1
17	Unciola dissimilis	1
18	Ampelisca abdita	105
18	Unciola serrata	2
19	Ampelisca abdita	1
2	Ampelisca abdita	48
2	Corophium tuberculatum	13
2	Melita nitida	10
2	Unciola serrata	9
24	Ampelisca abdita	587
24	Corophium tuberculatum	3
24	Unciola dissimilis	1
24	Unciola serrata	1
25	Ampelisca abdita	92
25	Unciola dissimilis	1
26	Ampelisca abdita	555
26	Corophium tuberculatum	7
26	Unciola dissimilis	1
26	Unciola serrata	4
27	Ampelisca abdita	147
27	Corophium tuberculatum	25
27	Melita nitida	1
27	Unciola dissimilis	2
27	Unciola serrata	4
28	Ampelisca abdita	662
28	Corophium tuberculatum	8
28	Melita nitida	1
29	Ampelisca abdita	10
3	Unciola serrata	1
30	Ampelisca abdita	1668
30	Corophium tuberculatum	18
30	Melita nitida	1
30	Unciola dissimilis	1
30	Unciola serrata	2
31	Ampelisca abdita	1603
31	Corophium tuberculatum	11

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STATION	SPECIES	NUMBER
31	Melita nitida	1
31	Unciola dissimilis	1
31	Unciola serrata	2
32	Ampelisca abdita	2
36	Ampelisca abdita	3
36	Corophium tuberculatum	1
36	Unciola serrata	1
37	Ampelisca abdita	1
38	Ampelisca abdita	14
4	Ampelisca abdita	4515
4	Corophium tuberculatum	129
4	Unciola dissimilis	14
4	Unciola serrata	7
40	Corophium tuberculatum	6
40	Unciola serrata	2
41	Ampelisca abdita	10
41	Corophium tuberculatum	14
41	Melita nitida	5
41	Unciola irrorata	3
41	Unciola serrata	20
42	Ampelisca abdita	1
42	Unciola dissimilis	1
43	Ampelisca abdita	4579
43	Corophium tuberculatum	32
43	Melita nitida	1
46	Ampelisca abdita	674
46	Corophium tuberculatum	3
46	Unciola serrata	2
47	Ampelisca abdita	5
48	Ampelisca abdita	2891
48	Corophium tuberculatum	17
48	Unciola serrata	1
49	Ampelisca abdita	1610
49	Corophium tuberculatum	28
49	Unciola dissimilis	1
49	Unciola serrata	5
5	Corophium tuberculatum	1
5	Unciola serrata	1
50	Ampelisca abdita	347
50	Unciola serrata	2
51	Ampelisca abdita	2
51	Unciola dissimilis	1
51	Unciola serrata	1
52	Unciola serrata	1
53	Ampelisca abdita	138
53	Corophium tuberculatum	1
53	Unciola serrata	3
54	Ampelisca abdita	1049
54	Corophium tuberculatum	102
54	Unciola serrata	8
55	Ampelisca abdita	63

Table III cont.
Cruise 4, 1985

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STATION	SPECIES	NUMBER
56	Ampelisca abdita	127
57	Ampelisca abdita	2
57	Corophium tuberculatum	1
57	Unciola dissimilis	1
57	Unciola serrata	1
58	Ampelisca abdita	40
59	Ampelisca abdita	290
59	Corophium tuberculatum	1
59	Unciola serrata	1
6	Ampelisca abdita	1
6	Corophium tuberculatum	1
6	Melita nitida	1
60	Ampelisca abdita	125
60	Unciola serrata	1
62	Ampelisca abdita	1
68	Ampelisca abdita	2
68	Unciola dissimilis	1
68	Unciola serrata	1
69	Ampelisca abdita	14
69	Corophium tuberculatum	1
69	Unciola serrata	2
7	Ampelisca abdita	23
7	Unciola irrorata	2
70	Ampelisca abdita	2
70	Unciola serrata	24
73	Ampelisca abdita	1166
73	Corophium tuberculatum	1
73	Unciola dissimilis	1
73	Unciola serrata	3
80	Ampelisca abdita	599
80	Corophium tuberculatum	8
80	Unciola serrata	4
81	Ampelisca abdita	3
81	Corophium tuberculatum	43
81	Melita nitida	1
81	Unciola serrata	1
82	Ampelisca abdita	1
82	Corophium tuberculatum	1
82	Unciola serrata	1
83	Ampelisca abdita	1245
83	Corophium tuberculatum	90
83	Unciola dissimilis	1
83	Unciola serrata	44
84	Ampelisca abdita	3
86	Ampelisca abdita	76
86	Unciola serrata	3
87	Ampelisca abdita	157
87	Unciola serrata	1
88	Ampelisca abdita	2422
88	Corophium tuberculatum	10
88	Melita nitida	1

Table III cont.
Cruise 4, 1985

Page No. 4

STATION	SPECIES	NUMBER
88	Unciola dissimilis	4
88	Unciola serrata	31
89	Ampelisca abdita	1
89	Unciola dissimilis	1
9	Unciola serrata	2
9	Unciola sp.	1
92	Unciola irrorata	1
93	Ampelisca abdita	1
95	Ampelisca abdita	1
98	Corophium tuberculatum	1
A1	Ampelisca abdita	1280
A1	Unciola serrata	7
A10	Ampelisca abdita	77
A2	Unciola serrata	6
A3	Ampelisca abdita	3
A3	Unciola serrata	10
A4	Ampelisca abdita	145
A4	Unciola serrata	1
A5	Ampelisca abdita	817
A5	Corophium tuberculatum	3
A5	Unciola serrata	3
A6	Ampelisca abdita	341
A6	Corophium tuberculatum	1
A7	Ampelisca abdita	588
A7	Corophium tuberculatum	1
A7	Unciola serrata	1
A8	Ampelisca abdita	179
A9	Ampelisca abdita	752
A9	Corophium tuberculatum	12
A9	Unciola irrorata	1
A9	Unciola serrata	4
B10	Ampelisca abdita	1
B10	Unciola serrata	1
B3	Ampelisca abdita	1
B4	Ampelisca abdita	1248
B4	Corophium tuberculatum	3
B5	Ampelisca abdita	59
B5	Unciola serrata	2
B6	Ampelisca abdita	326
B7	Ampelisca abdita	95
B7	Corophium tuberculatum	1
B7	Unciola dissimilis	1
B7	Unciola serrata	2
B8	Ampelisca abdita	260
B8	Corophium tuberculatum	3
B8	Unciola serrata	2
B9	Ampelisca abdita	1151
B9	Unciola serrata	4
C10	Corophium tuberculatum	6
C10	Unciola serrata	3
C2	Unciola serrata	1

Table III cont.

Cruise 4, 1985

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STATION	SPECIES	NUMBER
C4	Unciola irrorata	1
C5	Ampelisca abdita	3
C5	Unciola irrorata	1
C6	Ampelisca abdita	3
C6	Unciola serrata	3
C7	Ampelisca abdita	1
C7	Unciola serrata	4
C8	Unciola serrata	6

Arthur Kill

There have been three recent studies in the Arthur Kill and its tributaries (Table I), the details are presented in Appendix A. The study conducted for the NY/NJ Port Authority by Louis Berger and Assoc. (LBA) is the only work to actually sample the Kill itself. The studies for the development of Staten Island Corporate Park and Morses Creek concentrate on two tributaries of the Kill. The Staten Island Corporate Park survey is a detailed, study of a small area which includes sediment chemistry and water quality analysis. The Morses Creek study seems to be a qualitative survey of the benthic organisms that were collected over a two day sampling effort in 1989. Both of these studies use different gear and a sieve with a smaller mesh size that the Raritan and Jamaica Bay surveys (0.5mm vs 1.0mm).

The data from the three studies indicate that the sampling stations at the northern end of the Arthur Kill do not contain amphipods. Stations at the Goethals Bridge, Saw Mill Creek and Morris Creek have sediments that are devoid of amphipods. The sampling station at Outer Bridge Crossing, at the southern end of the Kill, contains very low numbers (<100 / square meter) of Melita and Unicola. These data suggest that the water and/or sediment quality (high heavy metal and organic pollutant concentrations) is to degraded to support the populations of amphipods that would be expected in this type of environment.

Because of the oil spill in January 1990 there was a great effort to collect biological information from the Arthur Kill. These data will not be available before the completion of the present grant, however, an effort should be made in FY'91 to include these data into the data set for the Hudson Harbor Estuary Program.

Newark Bay

The main data set for Newark Bay in the past ten years was generated by Normandeau Assoc. for the Army Corps of Engineers. The details are presented in Appendix A. Once again a different sampling gear was used from all of the other surveys in the system, however, the somewhat standard 1mm mesh sieve was used.

The data reveled very low numbers of amphipods (6 - 20/square meter) throughout this seasonal study at a few of the sampling stations. The data indicates that of the four genera examined only 1 Corophium and 2 Ampelisca were reported present at 2 of the 29 stations sampled in this study. There were seasonal differences in the distribution; the northern most station contained 1 Unicola collected in the February sampling, during the sampling in the other seasons this station was devoid of amphipods. The southern most area of the Bay appears to contain a small year round population of Melita and Unicola. The data from this study also suggest that the benthic environment in much of Newark Bay is to degraded to support the populations of amphipods that would be expected in this type of habitat.

Hackensack River

A survey of the benthos of the Hackensack River was conducted by the Hackensack Meadowlands Development Commission in 1987-1988. The details of the survey are presented in Appendix A. Like the Jamaica Bay study, the survey on the Hackensack is a complete accounting of the fauna of a sub-system in the study area, the gear is different but the sieve mesh size is the same (1mm) as Jamaica Bay and Raritan Bay. Unfortunately, the benthic data are presented by station as a single list that includes all of the benthos collected by a variety of gear (Ponar, dredge, seine, and traps). This method of presentation makes it very difficult to compare these benthic species composition lists with the lists generated by other studies.

There were no Ampelisca or Unicola reported at the 23 stations sampled in this study. The numbers were very low (7 - 71/square meter) for both Corophium and Melita during the entire study period; and no amphipods were collected during the Summer sampling. In addition, there seemed to be some changes in distribution that are related to salinity gradients in the system. Melita has a much wider distribution in the Hackensack and is found further upstream in much lower salinities than Corophium. As in the Arthur Kill and Newark Bay, the degraded conditions in the benthic environment of the lower Hackensack River do not allow for the survival of the communities of amphipods that would be expected. The salinity gradient in the river also seem to exert some controls on the distribution of populations of amphipods.

Hudson River

There are two studies that contain information on the benthos for the entire section of the Hudson that is in the area under consideration for this study. The earlier study was done by Ristich, Crandall and Fortier in 1973, however, the original data were not available to me and are not included in this report. The most recent study was performed by the NJDEP in 1982 - 1983. It includes water quality information and sediment grain size taken at 36 stations from Bayone to Piermont. The gear was different from the surveys in the Raritan and Jamaica Bays but the mesh size of the sieve was the same (1mm). The sampling of the benthic community was done in November which is unusual for such a survey. The details of this study are presented in Appendix A. There are five studies of small areas of the Hudson performed for proposed projects on sections of the river (Table 1). The details of these studies are presented in Appendix A. The studies used different gear and either a 419 micron, 1mm, or a 0.5mm mesh sieve. The results of these studies are interesting because they indicate sub-systems that exist along the river.

The data indicate that stations in Upper Bay had low numbers of Ampelisca and Corophium (4 - 8/square meter) and higher numbers of Melita and Unicola (300 - 500/square meter). The data from the sampling stations further upriver indicate that Ampelisca and Corophium drop out of the collections; at the George Washington Bridge there are small numbers of Melita and Unicola in the samples (4 -65/square meter); the stations above the George Washington Bridge have very small numbers of Melita only (4 -6/square meter). The combination of conditions in the benthic environment; heavy metals, organic contaminants, dissolved oxygen, and the salinity gradients control the distribution of amphipods in this section of the system.

East River

There are two data sets available for the East River done by Hazen and Sawyer for the New York City Department of Environmental Protection 301H reports. One covers the lower East River in the area of the Newtown Creek and Red Hook STPs, the other covers the upper East River in the area of the Wards Island and Hunts Point STPs. The details are presented in Appendix A. Both of these studies used a 419 micron sieve which make comparisons to other benthic surveys difficult.

There are no Ampelisca reported in any of the samples taken in these studies. The lower East River has a steady population of Corophium, Unicola, and Melita throughout the seasons sampled. Unicola is the dominant genus, the numbers are usually between 100 - 300/square meter, but at certain times the numbers are reported as high as 11,000/square meter. The data from the stations in the upper East River show lower numbers of amphipods (4 -500/square meter), and there are no amphipods reported from the station at the Throgs Neck Bridge.

Summer Composite

Figure 5 is a composite of all data on the distribution of the four genera of amphipods from all the surveys that sampled during the Summer months (June - September). The data are presented as numbers of amphipods/square meter of bottom at the stations sampled in all of the studies. Because of the large differences in the numbers of amphipods collected in the two surveys of Raritan Bay, the numbers from the latest survey were used for this figure. Unfortunately, the survey of the Hudson River conducted by the NJDEP and the study of Morses Creek conducted for Exxon Corp. collected benthic invertebrates only on the Fall (November) sampling trip. Therefore, these data can not be included in the Summer composite.

The composite figure shows that the numbers of amphipods from the four genera under consideration vary greatly in different sections of the Hudson Harbor Estuary. The pattern seems to correspond with the historical pattern of water quality for this system, i.e. the numbers decrease radically as known areas of reduced environmental conditions are approached. The numbers of amphipods drop to below 100/square meter at the Western end of Raritan Bay, the sediments of most of the Arthur Kill, Newark Bay, and the Hackensack River are devoid of Amphipods. Upper Bay and the Hudson River have sediments that are not capable of supporting high numbers of amphipods (<100/square meter) or contain no amphipods during the Summer. The East River does contain areas of sediments that support higher numbers of amphipods from the less tolerant genera but the numbers decrease in areas of the river bottom near known sources of pollution. Jamaica Bay, sections of Raritan Bay and Sandy Hook Bay do contain sediments that support much higher numbers of amphipods (1,000 - > 20,000/square meter). These numbers are much more characteristic of coastal environments that are not severely impacted by pollutants. The data presented in this figure suggests that the distribution of amphipods may be a simple measure of the benthic community structure: and, when used in combination with appropriate water quality parameters, could become a valuable indicator of the environmental quality of the benthic system.

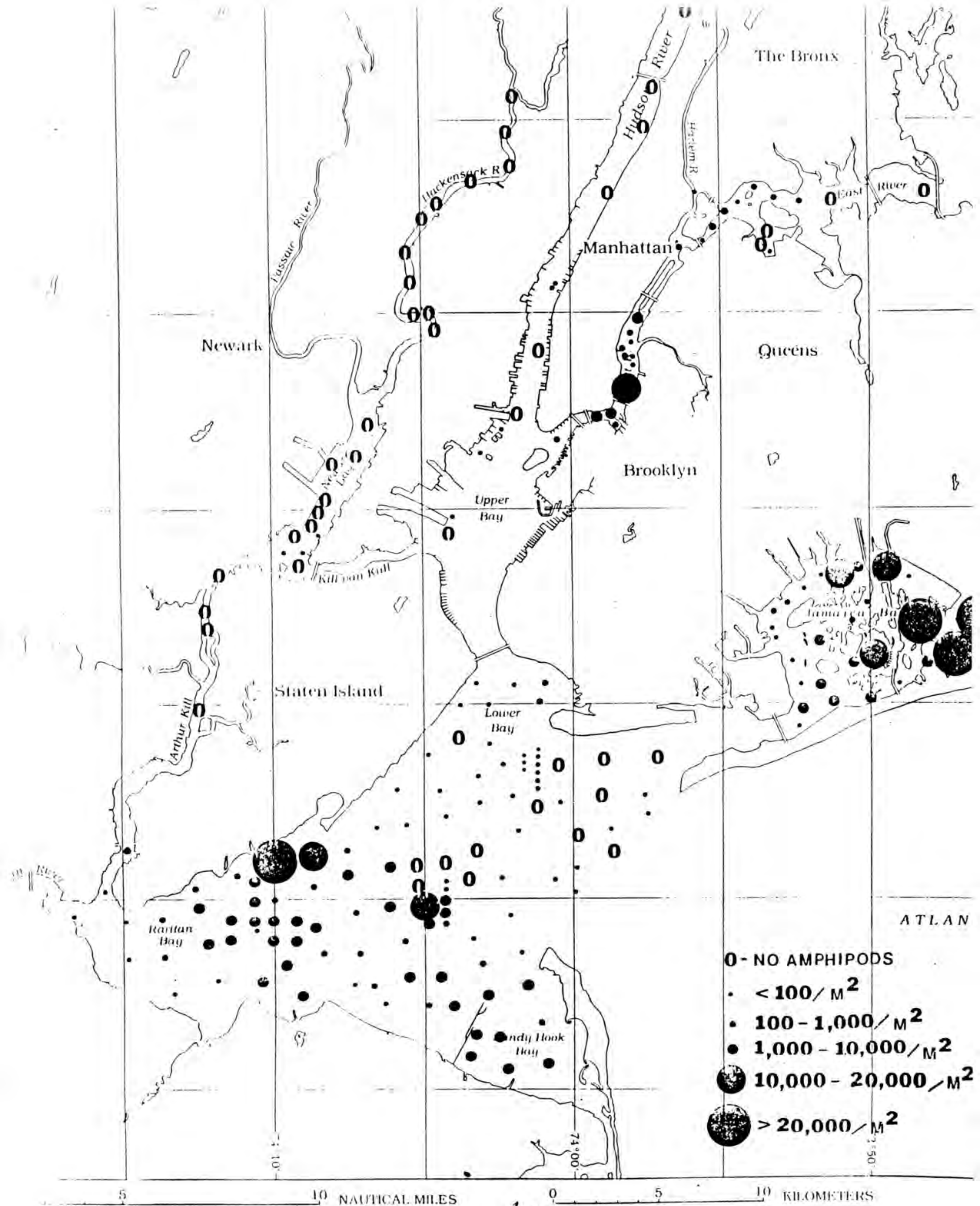

Figure 3 Summer Composite of Amphipod Distribution

CONCLUSIONS/RECOMMENDATIONS

I am pleased to have been able to accumulate the data sets on the distribution of benthic invertebrates in the Hudson Raritan system and put them all on one data base. In the future, investigators from government, academia, and private consulting firms will be able to access and search these data prior to initiating benthic surveys in this ecosystem. I would like to recommend the following with regard to the data sets:

1. The data sets be kept in libraries at EPA, NYDEC, NJDEP, NYC DEP, Hudson River Foundation, and at the NOAA Laboratory at Sandy Hook,

2. The existence of these data sets be publicized to potential users i.e. academic institutions, consulting firms, State Government Agencies, environmental groups.

3. Some small amount of monies should be set aside for the yearly update of the data bases. Unless this is done data will continue to be lost in file cabinets.

In addition, I would like to recommend that there be a call for the standardization of the gear and mesh size of the sieves that are used in future benthic surveys. Standardization of the amount of bottom sampled and the use of two sieves (1.0mm and 0.5mm) would allow for much greater comparison between data sets.

This report is one in a group of "characterization studies" funded by the EPA for the first year of the Hudson Harbor Estuaries Program. These studies included work on water quality modeling; pollutant loadings; distribution of dissolved oxygen, nutrients and organic carbon; toxicants in sediments and biota; hydrologic modifications; fish distribution and toxicant effects on birds. Ideally the data on the structure of the benthic communities should be correlated to the levels of toxicants in the sediments and to other water quality parameters. However, all of the "characterization studies" were going on at the same time; although the chemical characterizations do not depend on the biological information, tight linkage between patterns of the distribution of organisms with the chemical composition of the sediments and water do depend on these data.

Dr. K. Squibb (New York University Medical School) was responsible for the characterization of the levels of toxicants in ambient sediments and organisms. Dr. Squibb made every effort to keep me informed of her progress, we communicated on a regular basis and shared data sets when possible. However, at the time of the preparation of this final report I do not have access to her maps and written conclusions or those of the sections on water quality. Some summaries of chemical data do exist (Segar and Berberian, 1976; Greig and McGrath, 1977; Anderson, 1982; Michael, 1982; O'Connor, et.al.,1982) and some of the data sets I examined contain information on water quality. However, without these latest and most complete data sets from the "characterization studies" I am hesitant to make any conclusions or construct maps that link the distribution of any benthic species to specific levels of pollutants. After all the first year studies are finalized I think it will be a relatively easy and important task to superimpose the data on the distribution of any group of benthic invertebrates, particularly the amphipods, on the water quality and sediment data sets. These results will provide important information for the development of the monitoring program and the management of the system.

The data on the distribution of the four genera of amphipods in the entire system; the information on the sensitivity of amphipods to chemical pollutants; and the data on the distribution of pollutants from the available literature suggest that the distribution of amphipods may be adversely effected by chemicals present in the sediments. These data also indicate that the distribution of this sensitive group of organisms can be used as an indicator of the conditions in the benthic environment in order to help set up the monitoring program in the Hudson/Raritan Estuary. Ideally, such a program would include measurements of the major "toxicants of concern" in the sediments of the estuary and in the tissues of important benthic species; indications of the toxicity of the sediments themselves; and the relationship between sediment toxicity and benthic community structure.

Although there are different approaches used to develop a monitoring strategy my background in physiology and aquatic toxicology leads me to highlight a strategy that I believe would be useful in the Hudson-Raritan system. The sediment quality triad has been proposed by Long and Chapman (1985) and measured in Puget Sound and San Francisco Bay (Long and Chapman, 1985; Chapman, et. al., 1987; Becker, et. al., 1990). There is some controversy about the use of the triad in regulatory decision making (Spies, 1989), however, I think that the work of Long, Chapman and others (Chapman, et.al. 1991) indicate that this approach is ecologically meaningful and when used with other predictive indices would provide an excellent monitoring program for this system. The data on the distribution of amphipods would become a factor to help direct the placement of the stations to be monitored. The available data on the effects of toxic chemicals, reveled through the attached literature search, indicate the amphipods are some of the most sensitive species. The results of studies using the "triad" would augment the available data on the distribution of amphipods in the system, provide a stronger basis for using this group as an indicator as well as, providing the needed link between sediment toxicity and the population structure of benthic organisms.

In fact, a benthic survey has been planned by NOAA and EPA in the Hudson/Raritan system (SAIC program) that will accumulate data on the legs of the sediment quality triad. The proposal, submitted November 16, 1990, states that the following tasks will be performed:

1. Collect sediments from 39 sites in the Hudson/Raritan system.

2. Conduct chemical analysis on the sediments.

3. Conduct toxicity tests.
   A. Microtox bioassays on extracts from the sediments.
   B. Bioassays on bivalve embryos using sediment elutriates.
   C. 10 day bioassays on Ampelisca using sediments.

4. Archive benthic samples for community analysis at a future time

This proposed benthic survey presents a unique opportunity for the Harbor/Estuary program to get a head start on its monitoring program. The Hudson Harbor/Estuary program should consider the following recommendations in order to extract the most usable information from the proposed SAIC study:

1. Ask that a 1mm sieve be used in addition to the 0.5mm sieve in the proposal; this would allow for easier comparison to existing data sets.

2. Move 2 - 3 SAIC stations in Raritan Bay so that they replicate stations that had distributions of amphipods in the 1987 survey.

3. Add sampling stations in Jamaica Bay. The location of these stations should correspond to stations sampled by Franz and Harris in 1982.

4. Add sampling stations in the Hackensack and Passiac rivers. Existing data suggest that these two rivers have heavy loads of toxic chemicals, therefore, information on sediment toxicity would be very important.

5. Fund the study to analyze the benthic community structure of the samples collected in the SAIC study, with particular attention to the distribution of the amphipods. (The SAIC proposal does not give any indication that the community analysis will be done at any time in the near future.)

If the above recommendations are followed the synthesis of the existing data and the SAIC data will allow the managers of the Harbor/Estuary Program to select a number of critical stations to continue to monitor. Thus, the monitoring program will be based on the best available information and could continue to track the condition of the benthos in this system.

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