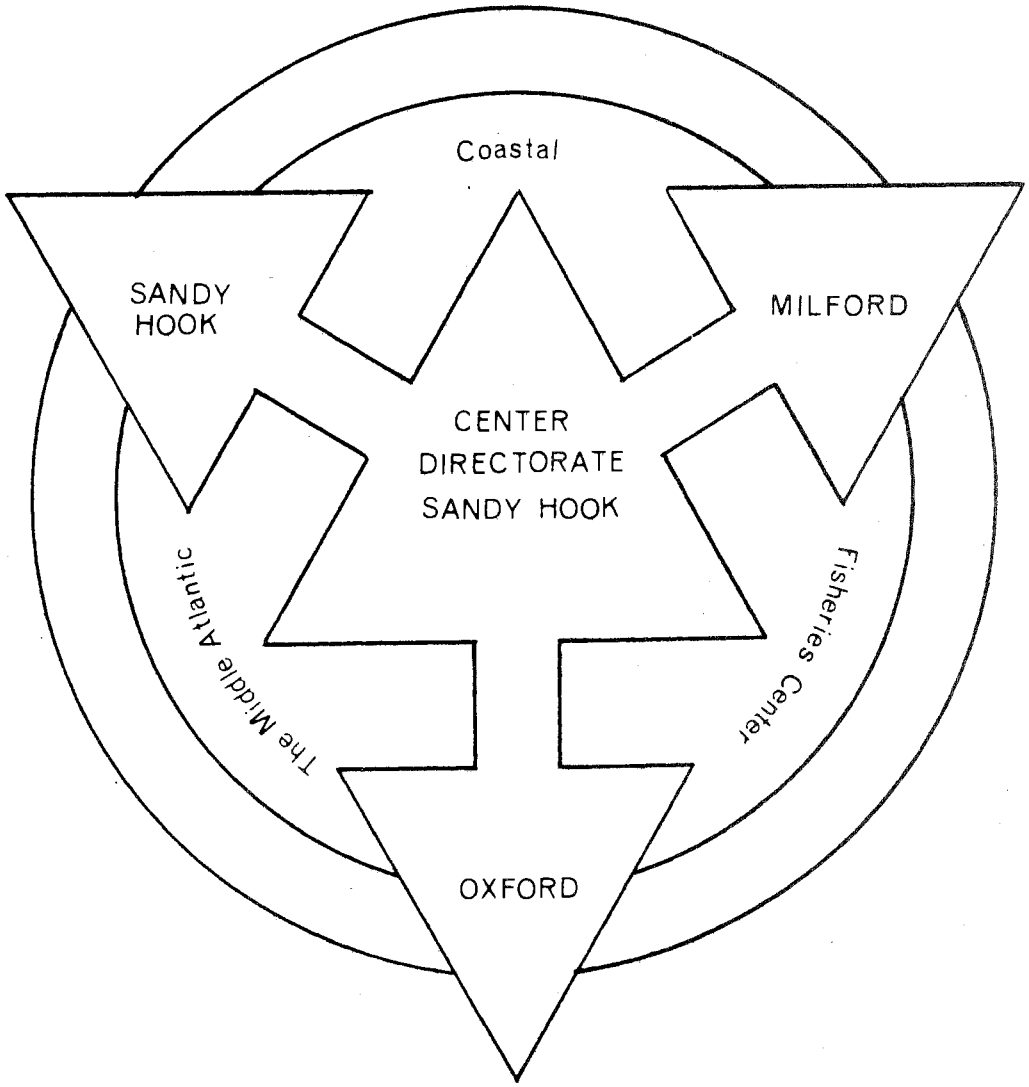
COOPERATIVE STUDY OF CONTAMINANTS IN THE COASTAL ENVIRONMENT AND THEIR EFFECTS ON LIVING MARINE RESOURCES: SUMMARY REPORT, 1971-1972.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region

MIDDLE ATLANTIC COASTAL FISHERIES CENTER



Informal Report No. 5

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MIDDLE ATLANTIC COASTAL FISHERIES
CENTER

NOAA--NMFS

A MULTILABORATORY COOPERATIVE STUDY OF CONTAMINANTS IN THE COASTAL ENVIRONMENT AND THEIR EFFECTS ON LIVING MARINE RESOURCES

SUMMARY REPORT OF OPERATIONS FROM

MARCH 1, 1971 to APRIL 30, 1972

INFORMAL REPORT NO. 5

October, 1972

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NOTE:

The analytical findings reported herein are administratively restricted and are not to be published in any form.

INTRODUCTION

A cooperative venture involving all NMFS Biological Laboratories of the Middle Atlantic Coastal Fisheries Center to study contaminants in marine ecosystems of the northeast and middle Atlantic coasts was initiated in the spring of 1971 with the following objectives:

1. Delineate the contaminant levels (with particular emphasis on mercury) in living marine resources and their environment.
2. Determine the specific effects of waste disposal areas (i.e., ocean dump sites) in concentrating harmful contaminant materials.
3. Determine the pathological and physiological effects of contaminants on selected, typical marine organisms.
4. Develop a multilaboratory cooperative approach to the study of these problems and the essential methodology to conduct a long-range contaminant program.

The ultimate goal of the long-range study was to identify the impact of contaminants in relation to the abundance and distribution of living marine resources, to provide essential baselines for regulatory enforcement, and to provide specific information to balance waste disposal and economically valuable resources.

This report describes the efforts of the MACFC contaminant study from March 1971 through April 1972; the accomplishments, the problems encountered and recommendations for future studies in FY 1973.

The cooperating laboratories and their areas of specific responsibility and more general interest are listed below:

Milford (Laboratory for Environmental Chemistry & Microbiology): Major responsibility for chemical analyses and for microbiological studies of the environment.

Oxford: Responsibility for all pathological studies and for microbiological studies on or in the living organism, and for collecting target species at Chincoteague.

Sandy Hook: Major responsibility for ecological studies of dump sites and control sites along the New York and New Jersey shore.

Milford (Laboratory for Experimental Biology): Responsibility for collecting target species at sites in Long Island Sound, and for laboratory experiments in physiological stress for selected marine species.

Beaufort: Radionuclide analyses--possible pesticides and similar materials in future.

NORTH ATLANTIC GROUNDFISH CONTAMINANT SURVEY

A general survey for pathological examination and mercury analysis of organisms collected on the MARMAP groundfish survey, termed the "piggyback project" in this report, was made. Twice each year (spring and fall), the Woods Hole Biological Laboratory undertakes a comprehensive survey of the groundfish resources over the Continental Shelf from Nova Scotia to Cape Hatteras. Each survey is conducted from the RV ALBATROSS IV and requires about 45 days of ship operations, divided into three legs or cruises: (1) up to 18 days in the Gulf of Maine, (2) up to 18 days on Georges Bank south to Nantucket and Long Island, and (3) up to 11 days from Long Island south to Cape Hatteras.

Personnel from each cooperating laboratory were placed aboard the ALBATROSS, on a rotating schedule, to obtain tissue for pathological examination and mercury analysis. Fish, crustacean and molluscan samples were collected and processed from each cruise, following the sampling protocol outlined in Appendix I.

The purpose of this program is to assess the levels of mercury and pathological changes in the tissues collected. Such analyses have been completed on samples collected from each leg of the spring and fall (1971) cruises. All strata numbers in this report are taken from the strata listing used by the Woods Hole Laboratory. Samples collected on the spring (1972) cruise are being examined at the present time.

A list of scientific and common names of all fish included in this study is attached as Appendix II.

GROUNDFISH SURVEY - CHEMICAL ANALYSES
MILFORD LABORATORY

Finfish, the primary target animals collected in this survey, and a limited number of invertebrate, plankton and sediment samples were collected and analyzed for mercury. A summary of the mercury concentrations found in these finfish is presented in Table 1. Generally, muscle and liver tissues were analyzed; however, for some of the smaller fish the analyses were performed on the whole animal. The methodologies employed for these analyses are described in Appendix III. About 60% of the samples were collected from the mid-Atlantic (extending from waters off North Carolina to waters off Massachusetts), 20% from the Gulf of Maine and 10% each from the southwestern part of the Scotian Shelf and Georges Bank. There were not enough data to critically evaluate differences in mercury concentrations related to geographic area. The fish listed in Table 1 are grouped according to their feeding habits, but these categories are not all inclusive since some fish change feeding habits depending on age. The categories of feeding habits listed in this table are:

Pelagic Feeders - feed mainly on small fish

Bottom Feeders - feed on molluscs, crustaceans and worms

Plankton Feeders - feed on planktonic organisms

Miscellaneous

Table 1. Summary of Finfish Collections From North Atlantic Groundfish Survey. Fish Are Grouped According to Their Feeding Habits.

Fish	N[1]	No. Collections	MERCURY CONTENT (ppm wet wt.) Muscle Range	Muscle Average	Liver Range	Liver Average	Whole Average
Pelagic Feeders							
Pollock	10	2	0.08- 0.10	0.09	<0.05- 0.06	<0.05	-
Spot	10	1	<0.05	<0.05	<0.05	<0.05	-
Silver hake	10	2	0.09	0.09	0.10	0.10	0.09
Butterfish	20	2	-	-	-	-	<0.05
Redfish	15	2	0.10- 0.20	0.15	0.15	0.15	-
Plankton Feeders							
Sand lance	5	1	-	-	-	-	0.05
Shad	10	1	0.05	0.05	0.67	0.67	-
Sea herring	15	2	<0.05- 0.09	0.06	0.26- 0.28	0.27	-
Blueback herring	10	1	-	-	-	-	0.17
Round herring	10	1	-	-	-	-	<0.05
Mackerel	5	1	0.08	0.08	-	-	-

[1] N = Total number of animals analyzed.

Table 1. (cont.) - 2 -

Fish	N	No. Collections	MERCURY CONTENT (ppm wet wt.) Muscle Range	Muscle Average	Liver Range	Liver Average	Whole Average
Bottom Feeders							
Cusk	12	4	0.15-0.49	0.31	0.14- 0.83	0.42	-
Cod	9	2	0.14-0.25	0.20	0.11- 0.20	0.16	-
American dab	10	2	0.06-0.08	0.07	0.11- 0.14	0.13	-
Fourspot flounder	10	2	0.16	0.16	0.23- 0.27	0.25	-
Grey sole	20	2	0.07-0.10	0.09	0.13- 0.16	0.15	-
Gulfstream flounder	20	2	0.05	0.05	-	-	0.10
Windowpane flounder	5	1	0.10	0.10	0.12	0.12	-
Winter flounder	19	3	0.06-0.14	0.09	0.07- 0.18	0.11	-
Yellowtail flounder	15	2	0.10-0.24	0.17	0.17- 0.25	0.21	-
Haddock	15	2	<0.05-0.09	0.06	<0.05	<0.05	-
Ocean pout	20	2	<0.05-0.11	0.07	<0.05- 0.09	0.06	-
Longhorn sculpin	20	2	0.08-0.09	0.09	0.09- 0.16	0.13	-
Mailed sculpin	20	2	-	-	-	-	<0.05
Scup	15	2	-	-	-	-	0.15
Common searobin	21	2	0.35	0.35	0.56	0.56	0.07
Striped searobin	10	1	0.35	0.35	0.38	0.38	-
Shanny	21	2	-	-	-	-	<0.05
Big skate	10	1	0.15	0.15	0.18	0.18	-
Little skate	15	2	0.13-0.16	0.15	0.10- 0.23	0.17	-
Thorny skate	10	2	0.21-0.26	0.24	0.09- 0.15	0.12	-
Wolffish	9	4	<0.05-0.15	0.08	<0.05- 0.06	<0.05	-
White hake	10	2	0.10-0.12	0.11	0.12- 0.16	0.14	-
Spotted hake	15	2	-	-	-	-	<0.05
Red hake	15	2	<0.05-0.05	<0.05	<0.05- 0.08	0.06	-
Black sea bass	10	1	0.08	0.08	0.18	0.18	-

Table 1. (cont.) - 3 -

Fish	N	No. Collections	MERCURY CONTENT (ppm wet wt.) Muscle Range	Muscle Average	Liver Range	Liver Average	Whole Average
Bottom Feeders							
Blackbellied redfish	10	2	0.22	0.22	0.40	0.40	0.11

Table 1. (cont.) - 4 -

Fish	N	No. Collections	MERCURY CONTENT (ppm wet wt.) Muscle Range	Muscle Average	Liver Range	Liver Average	Whole Average
Miscellaneous							
Angel shark	5	1	0.08	0.08	<0.05	<0.05	-
Beardfish	10	1	-	-	-	-	0.06
Cusk eel	10	1	0.11	0.11	0.19	0.19	-
Lantern fish	10	1	-	-	-	-	<0.05
Spiny dogfish	49	8	0.07-0.53	0.32	<0.05- 0.19	0.10	-

The results reveal no substantial differences in mercury concentrations related to feeding habits.

The highest levels of mercury found 0.40-0.83 ppm were present in the livers of the blackbellied redfish, shad, common searobin and cusk. The spiny dogfish, common searobin and striped searobin had elevated levels of mercury in their muscle tissue (range of 0.31-0.35 ppm). Thirty six other species of fish were collected in this survey and all were found to have mercury concentrations less than 0.30 ppm in both muscle and liver. The average and standard deviations were calculated for the mercury concentrations of muscle and liver samples for all the fish collected in this survey. The average concentration of mercury in muscle tissue was 0.154 ppm and the standard deviation 0.124, while in liver tissue the average concentration was 0.164 ppm and the standard deviation 0.157. These data suggest that these fish were not exposed to high levels of mercury such as those which occurred in the Great Lakes, Sweden and Japan where fish of similar feeding habits were found to contain mercury levels of 0.5-10.0 ppm in both muscle and liver tissues.

A very limited number of plankton and sediment samples were collected from each of four broad geographical locations - Scotian Shelf, Gulf of Maine, Georges Bank and the mid-Atlantic. One sample was collected from each of the first 3 locations and 4-5 from the last location. All of these samples contained less than 0.05 ppm mercury

(Table 2), which is the reliable detection limit of the method employed. Sediment samples from the Great Lakes have been found to contain mercury in the thousands of parts per million near the outfalls of chlor-alkali plants.

A limited number of invertebrate samples were collected in this survey in addition to the above mentioned samples. One Pandallid shrimp sample was collected from each of the locations listed above except the mid-Atlantic. One sample contained 0.09 ppm mercury and the others <0.05 ppm mercury (Table 2). Four collections of squid were obtained and all contained less than 0.06 ppm mercury. One lobster sample was obtained and it contained 0.31 ppm in the muscle and 0.60 ppm in the "liver" (tomally).

Mercury concentrations in spiny dogfish muscle tissue generally exceeded that of other animals sampled. These fish were the most extensively collected fish in this survey. The results of analyses of individual animals are presented in Figure 1. A number of investigators have reported that mercury concentrations vary in proportion to length and/or age of a given species of fish. The collections of spiny dogfish from strata 9 and 29 did not have length data collected, thus, evaluation of these samples was difficult. Spiny dogfish were fairly uniform in size from strata 1, 31, 35, 61 and 71, while those collected at stratum 6 were about half as large. The smaller fish had a substantially lower mercury concentration than the larger ones. For the collections from strata

Table 2. Mercury Content of Fish, Plankton and Sediment Collected From the North Atlantic

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
			SCOTIAN SHELF Spring Groundfish Survey - 1971				
Fish							
Pollock	31	April	5	51	0.08	<0.05	-
Sand lance	31	April	10*	23-30	-	-	0.05
Spiny dogfish	31	April	4	68-75	0.23	0.07	-
Wolffish	32	April	5	78-93	0.15	<0.05	-
Thorny skate	32	April	6	60-93	0.21	0.09	-
Plankton[1]							
	47	April	-	-	-	-	<0.05
Sediments[1]							
	47	April	-	-	-	-	<0.05

Table 2. (cont.) -2-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Fall Groundfish Survey - 1971							
Fish							
Cusk	31	Nov.	4	61-67	0.49	0.83	-
Shanny	41	Nov.	1	-	-	-	<0.05
Wolffish	41	Nov.	1	43	0.07	<0.05	-
Wolffish	45	Nov.	2*	20-21	<0.05	<0.05	-
Wolffish	47	Nov.	1	74	0.07	0.06	-
GULF OF MAINE							
Spring Groundfish Survey - 1971							
Fish							
Redfish	24	March	10*	38	0.20	0.15	-
Cusk	27	April	6	44-68	0.27	0.23	-
White hake	28	April	5	57-68	0.12	0.12	-
Spiny dogfish	29	March	10*	-	0.32	0.06	-
Mailed sculpin	34	April	10*	8-13	-	-	<0.05
Winter flounder	39	April	9	22-48	0.07	0.08	-
American dab	40	April	5	32-36	0.08	0.14	-
Shanny	40	April	20*	8-12	-	-	0.05

Table 2. (cont.) -3-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Invertebrates							
Pandallid shrimp	24	April	10*	-	-	-	0.09
Pandallid shrimp	40	April	10*	-	-	-	<0.05
Plankton [1]							
	38	April	-	-	-	-	<0.05
Sediments [1]							
	38	April	-	-	-	-	<0.05
	Fall Groundfish Survey - 1971						
Fish							
American dab	23	Oct.	5	-	0.06	0.11	-
Sea herring	23	Oct.	10	-	0.09	0.28	-
Cod	24	Oct.	5	-	0.25	0.20	-
Redfish	24	Oct.	5	-	0.10	0.15	-
Mailed sculpin	24	Oct.	10	-	-	-	0.06

Table 2. (cont.) -4-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Pollock	24	Oct.	5	-	0.10	0.06	-
Haddock	25	Oct.	5	-	0.09	<0.05	-
Cod	26	Nov.	4	54-61	0.14	0.11	-
White hake	26	Nov.	5	27-72	0.10	0.16	-
Thorny skate	33	Nov.	4	60-81	0.26	0.15	-
Cusk	34	Nov.	1	68	0.32	0.48	-
Spiny dogfish	35	Nov.	5	81-84	0.34	0.09	-
Cusk	36	Nov.	1	58	0.15	0.14	-
Plankton[1]							
	27	Nov.	-	-	-	-	<0.05
	37	Nov.	-	-	-	-	<0.05
Sediments[1]							
	27	Nov.	-	-	-	-	<0.05
	37	Nov.	-	-	-	-	<0.05
	37	Nov.	-	-	-	-	<0.05

Table 2. (cont.) -5-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
		GEORGES BANK					
	Spring Groundfish Survey - 1971						
Fish							
Haddock	13	March	10*	46-68	<0.05	<0.05	-
Invertebrates							
Pandallid shrimp	20	March	50*	-	-	-	<0.05
	Fall Groundfish Survey - 1971						
Fish							
Little skate	13	Oct.	10*	-	0.16	0.23	-
Lantern fish	18	Oct.	10*	-	-	-	<0.05
Big skate	19	Oct.	10*	-	0.15	0.18	-
Longhorn sculpin	19	Oct.	10*	-	0.09	0.16	-
Plankton [1]							
	16	Oct.	-	-	-	-	<0.05

Table 2. (cont.) - 6 -

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
MID-ATLANTIC Spring Groundfish Survey - 1971							
Fish							
Ocean pout	1	March	10*	45-55	0.11	0.09	-
Yellowtail flounder	1	March	10*	28-32	0.24	0.17	-
Longhorn sculpin	5	March	10*	25	0.08	0.09	-
Little skate	5	March	5	45-50	0.13	0.10	-
Fourspot flounder	6	March	5*	16-19	-	0.27	-
Mackerel	6	March	5	30-35	0.08	-	-
Sea herring	6	March	5	20	<0.05	0.26	-
Red hake	6	March	10*	25-30	<0.05	<0.05	-
Silver hake	6	March	5	20	-	-	0.09
Spiny dogfish	6	March	10*	37	0.07	<0.05	-
Ocean pout	9	March	10*	46	<0.05	<0.05	-
Spiny dogfish	61	April	5	80-92	0.53	0.19	-
Common searobin	62	April	11*	17	-	-	0.07
Striped searobin	62	April	10*	28-37	0.35	0.38	-
Scup	62	April	10*	17	-	-	0.14
Angel shark	63	April	5*	43-58	0.08	<0.05	-

Table 2. (cont.) -7-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Blackbellied redfish	64	April	10*	9-21	-	-	0.11
Butterfish	65	April	10*	10	-	-	0.06
Spotted hake	65	April	10*	15-21	-	-	<0.05
Black sea bass	66	April	10*	22-24	0.08	0.18	-
Beardfish	67	April	10*	13-14	-	-	0.06
Blueback herring	69	April	10*	10-12	-	-	0.17
Spiny dogfish	71	April	5	82-95	0.47	0.07	-
Grey sole	72	April	10*	31-36	0.07	0.16	-
Gulfstream flounder	75	April	10*	10-11	-	-	0.10
Invertebrates							
Lobster	4	April	10	6-19	0.31	0.60	-
Squid	7	March	5*	-	-	-	<0.05
Squid flex sp.	64	April	10*	-	-	-	0.06
Plankton [1]							
	62	April	-	-	-	-	<0.05
	65	April	-	-	-	-	<0.05
	73	April	-	-	-	-	<0.05

Table 2. (cont.) -8-

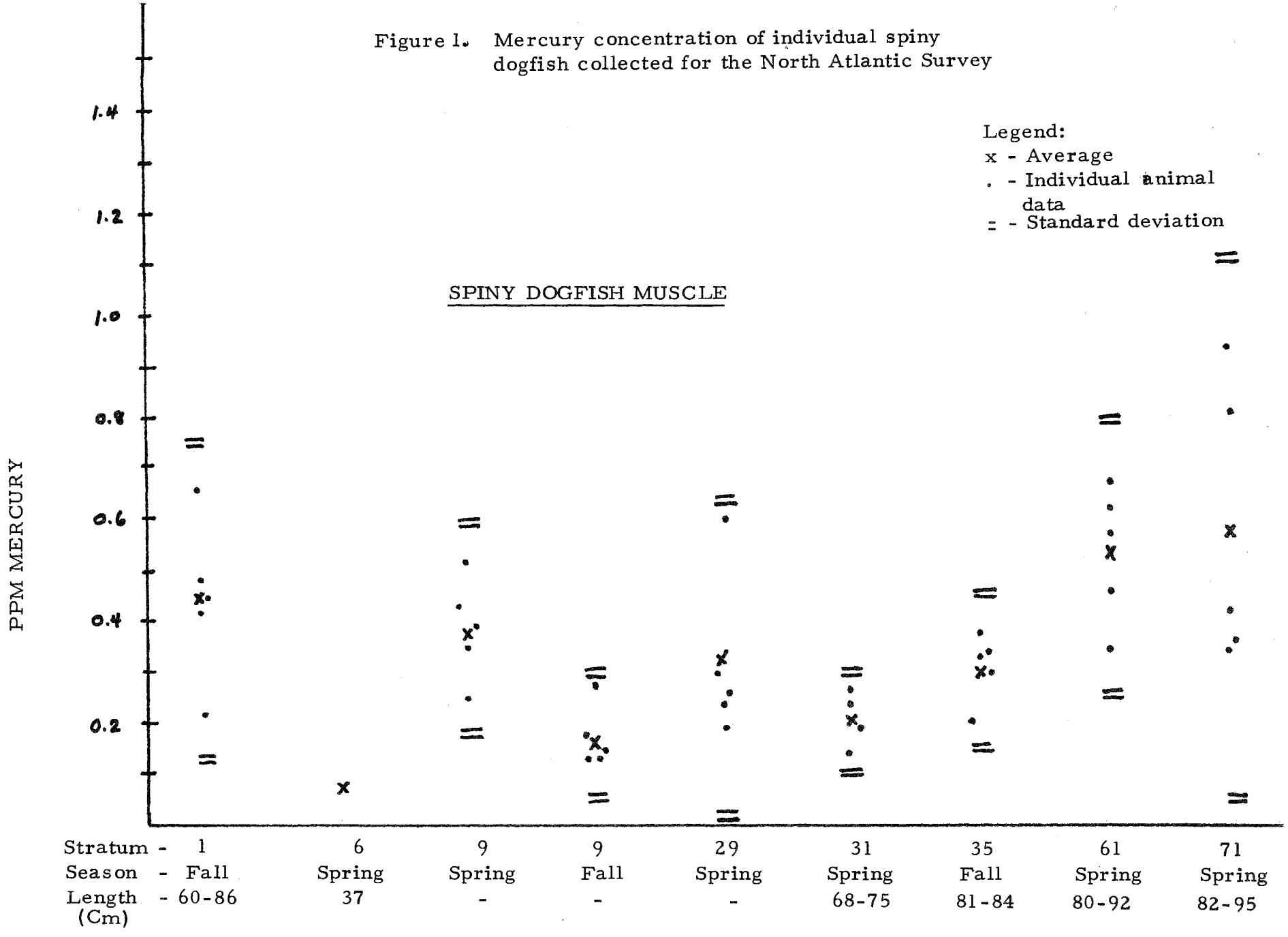
Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Sediments[1]							
	62	April	-	-	-	-	<0.05
	65	April	-	-	-	-	<0.05
	73	April	-	-	-	-	<0.05
	Fall Groundfish Survey - 1971						
Fish							
Round herring	1	Oct.	10*	15-16	-	-	<0.05
Spiny dogfish	1	Oct.	5	60-86	0.44	0.15	-
Winter flounder	1	Oct.	10*	28-35	0.14	0.18	-
Silver hake	2	Oct.	5	28-31	0.09	0.10	-
Blackbellied redfish	4	Oct.	5	16-34	0.22	0.40	-
Butterfish	5	Sept.	10*	10-11	-	-	<0.05
Scup	5	Sept.	5	15-21	-	-	0.16
Grey sole	6	Oct.	5	42-50	0.10	0.13	-
Red hake	6	Sept.	5	27-34	0.05	0.08	-
Yellowtail flounder	6	Sept.	5	33-38	0.10	0.25	-
Cusk eel	7	Oct.	10*	25-29	0.11	0.19	-
Windowpane flounder	9	Sept.	5	22-31	0.10	0.12	-
Spiny dogfish	9	Oct.	5	-	0.18	0.12	-
Shad	10	Oct.	10*	-	0.05	0.67	-

Species	Stratum	Catch Date	No. of Animals	Fork Length (cm)	Mercury Concentration ppm - wet weight Muscle	Liver	Whole
Spot	65	Oct.	10*	27-29	<0.05	<0.05	-
Northern searobin	69	Oct.	10*	24-27	0.35	0.56	-
Gulfstream flounder	70	Oct.	10*	6-12	0.05	-	-
Spotted hake	71	Oct.	5	19-23	-	-	0.06
Fourspot flounder	74	Oct.	5	21-34	0.16	0.23	-
Invertebrates							
Squid	2	Oct.	10*	-	-	-	<0.05
Squid	8	Oct.	5	18-22	-	-	<0.05
Scallop	70	Oct.	10*	5-7	<0.05	-	-
Plankton[1]							
	65	Oct.	-	-	-	-	<0.05
Sediments[1]							
	10	Oct.	-	-	-	-	<0.05
	65	Oct.	-	-	-	-	<0.05

* - All samples with an * were composites of the number of animals listed - the values are averages of 2-3 determinations. For all other samples, individual animals were analyzed and the value is an average of those determinations.

1] - One sample of plankton and sediment was collected from each stratum.

Figure 1. Mercury concentration of individual spiny dogfish collected for the North Atlantic Survey



1, 31, 35, 61 and 71, the data indicate differences related to geographic area of catch i.e., assuming the differences in fork lengths for these collections were not great enough to account for the differences in mercury concentrations. Fork lengths were not collected on individual animals in all cases, thus, a thorough evaluation of the correlation of fork length vs. mercury concentration was not possible for these samples. The samples of spiny dogfish that had the highest mercury concentrations were from strata 1, 61 and 71. These collections were from the New York Bight Area, off the North Carolina Shore and off Delaware Bay, respectively. Spiny dogfish of a similar size to these samples were collected from strata 31 and 35, which were in the Scotian Shelf (north of Gulf of Maine) and in the Gulf of Maine, respectively, and these samples contained mercury levels half that found in samples above. The implication being, therefore, that spiny dogfish from the mid-Atlantic have higher mercury concentrations than spiny dogfish from the North Atlantic. These data suggest that spiny dogfish should be sampled more intensely in order to confirm these results and to obtain statistically valid data that will allow comparison of dogfish of various lengths and from various geographic locations.

SUGGESTIONS AND RECOMMENDATIONS

Based on the experience gained the past 15 months, the following suggestions and recommendations can be made to further carry out cooperative program objectives:

1. Sampling

In order to minimize confusion each group or investigation obtaining environmental samples should be directly responsible for the designation of samples in reference to type, packaging, transportation, etc. The group should work through the Scientist in Charge for the particular cruise rather than through an intermediate coordinator.

In those situations where large numbers of samples are needed for any one investigation, it may be well that a person (or persons) from the investigation be involved in that particular cruise. Announcements of the cruise date should be made in advance so that information in regards to sample and equipment needs, as well as orientation of participating personnel can be adequately made. Cruise dates should be set several months in advance and specific details for participating personnel, a month in advance.

2. Samples to be Collected:

The results of the North Atlantic Survey (piggyback study) has been concerned only with total mercury in the animals tested. Based on the results to date, elevated levels of mercury have been observed

in the following animals: spiny dogfish, cusk and shad. Increased sampling of these species is warranted.

Other animal species were not sampled adequately enough to reach any conclusions regarding mercury levels. If possible, an effort should be made to obtain sufficient animals for analysis in order that the results reported are significant. Preliminary data indicate that plankton may be concentrating metals, thus samples of plankton should be obtained from further survey cruises.

Limited data is available on metal concentrations in sediments. An attempt should be made to obtain sediment samples from several locations for multi-element analyses. These data can then be compared with data from in-shore areas, thus, be another control or baseline for the in-shore work. The sampling of sediments for chemical analyses can be coordinated with that for microbiology.

Heavy metal analyses of samples from the North Atlantic groundfish survey have been concerned, to date, with mercury content only. Fish of a few selected species, which are available in large enough quantities in any one catch, should be analyzed for other heavy metals for which capability exists. This also applies to select samples of sediment and plankton.

GROUNDFISH SURVEY - PATHOLOGY STUDIES
OXFORD LABORATORY

It was the responsibility of the Pathology Investigations to characterize normal or "baseline" histology and determine the prevalence of histopathology and cytopathology in selected tissues of the fish and invertebrates collected on the North Atlantic groundfish survey. It was not intended to conduct histopathological examinations on all liver and muscle tissues collected for mercury analysis from this survey. Since the number of tissues that could be prepared for microscopic examination was limited, animals containing elevated amounts of mercury received first priority. Since suitably fixed duplicate tissues of most species were collected, tissues containing elevated amounts of mercury can be examined for histopathology at any time. To date, with rare exception, mercury levels in tissues sampled are not sufficiently high to warrant further extensive histopathological examination.

Fish species examined included windowpane flounder, sea herring, longhorn sculpin, blackbellied redfish, cod, yellowtail flounder, fourspot flounder and silver hake. Altogether, 36 species of fish were examined and 1,805 slides prepared. With rare exception, no aberrant histology was noted in any of the species examined.

Kidney cysts of unknown etiology were noted in 6 of 10 northern searobins. The fungus, *Ichthyophonus hoferi*, was detected in cod,

yellowtail flounder and longhorn sculpin, and apparently for the first time in American cod and longhorn sculpin. Several tumors or tumor-like lesions were noted; however, further study is required before definitive histological identifications can be made. It appears that the histopathological examination of randomly sampled fish is not worth the effort it requires. On the basis of the mercury analyses completed to date, several species of fish should be sampled more intensively and separate organs analyzed for mercury as well as other metallic ions. It should be recognized that there are no convenient definitions for "normal" levels of metallic ions; the most acceptable "normal" value can be defined only by statistical analysis of sufficient data. Adopting 0.5 ppm as an empirical cut-off for definition of elevated mercury in fish and shellfish is not practical since this standard was established for the well being of the consumer and not the resource. Fish found to concentrate particular ions should be used in laboratory studies in which histopathology is an integral part.

COOPERATIVE DUMP SITE STUDY

A multi-laboratory cooperative dump site study was undertaken in March 1971 to measure the levels of contaminants in waste disposal areas; the concentration of these contaminants in marine organisms; the pathological and physiological responses to contaminant stress; and the effects of contaminants as a limiting factor for living marine resources.

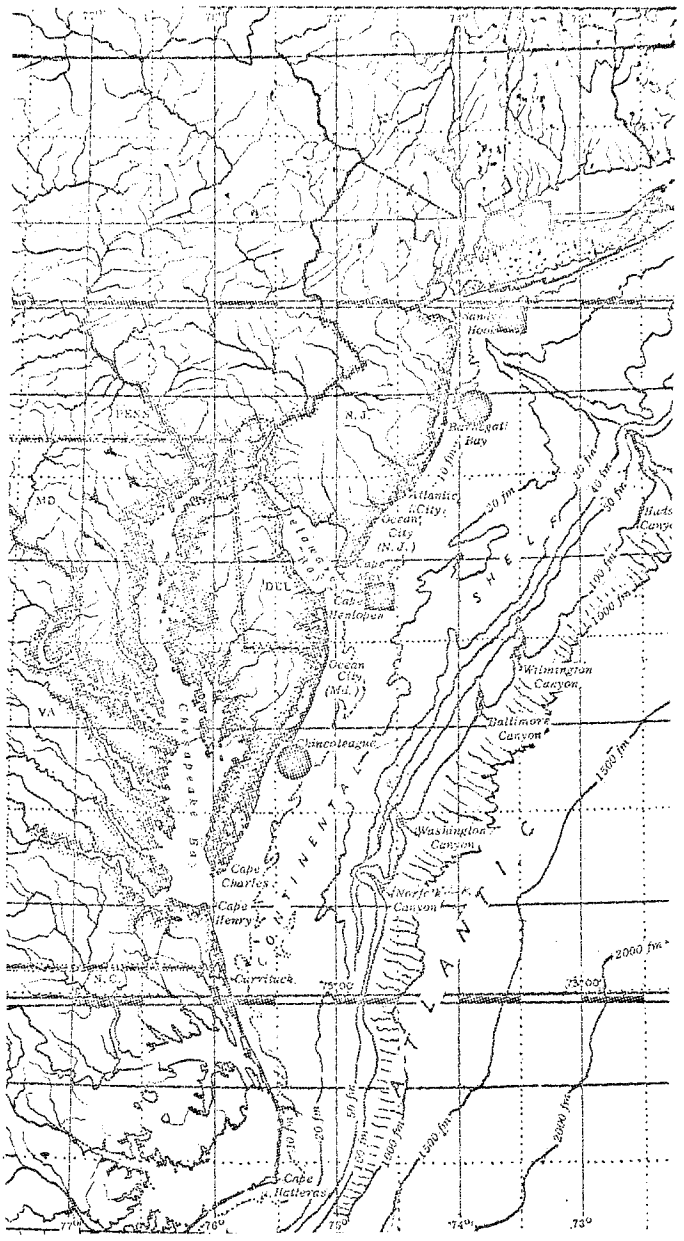
Six sites, three control sites and three waste disposal sites, were selected for intensive study (see Fig. 2). These sites are:

1. A dredge spoil disposal site near New Haven Harbor in Long Island Sound.
2. An adjacent uncontaminated control site.
3. The sewage disposal site, near the entrance to New York Harbor, which has been the subject of investigation by Sandy Hook Laboratory for the past two years.
4. An uncontaminated control site near the center of the surf clam fishery at Barnegat Light.
5. A sewage disposal site near the mouth of Delaware Bay.
6. A control site near Chincoteague, Virginia.

Figure 2

COOPERATIVE CONTAMINANT STUDY

DUMP SITE STATIONS



Waste disposal site

Uncontaminated control site

The purpose of this study was to critically examine the effects of ocean dumping on increasing contaminant levels in the environment and the potential limitations on abundance and distribution of living marine resources. This study was to initially examine 3 target species for levels of contaminants and pathology. After initial sampling, the three target species were selected: a fish, the windowpane flounder, Scophthalmus aquosus; a crustacean, the rock crab, Cancer irroratus; and a mollusk, the surf clam, Spisula solidissima. In no way was the selection of target species intended to be limiting and it was anticipated that each facility involved in this study would conduct more intensive studies relating to their specific interests.

Initially it was planned that the following samples would be obtained each month:

a) Ten (10) specimens for contaminant and pathology studies of each of 3 target species for each site (10 x 3 x 6 = 180 specimens each month). At one dump site (Delaware) additional samples of animals and sediments would be obtained at the center, near the edge and at a selected distance outside the dump site.

b) Any additional organisms showing gross pathology would be obtained for Oxford pathologists.

c) A bottom sample or samples would be obtained at each site for sediment analyses and faunal composition.

d) Special, separate, samples would be obtained of the target species

for radionuclide assay. A minimum of 3 pounds of meat was necessary for each species from each site.

The analytical examination of samples was delegated as follows:

a) Tissues of each specimen were to be analyzed for mercury by staff of the Laboratory for Environmental Chemistry and Microbiology at Milford. Prime tissues were muscle and liver to parallel results of other contaminant studies. These and other organs were to be preserved for future analyses of a much broader range of heavy metals (e.g., lead, arsenic, cadmium, chromium) up to as many as 12 ions. Similarly, these tissues obtained for (a) would also be analyzed by staff for pesticides later.

b) Sections of the same tissues obtained for (a) would be examined at Oxford for pathology and correlation with any concentrations of contaminants found in heavy metal analyses.

c) Sediments and water samples were to be analyzed by Milford staff for mercury concentrations, and portions of these samples were to be reserved for future broad analyses as proposed for tissues.

d) Sediment and water samples were prepared aboard ship and examined by Milford microbiologists for a base-line survey of microflora and for possible indicative modifications species composition in contaminant areas.

e) Oxford laboratory was responsible for microbiological studies of the organisms, particularly with emphasis on potential pathogenic

bacteria on or within the organism.

f) The special radionuclide samples were to be processed at the Atlantic Estuarine Fisheries Center, Beaufort, N. C. Monthly samples were not required for this work, and the sampling schedule was based on preliminary analyses of early samples.

g) The Milford laboratory conducted controlled laboratory experiments on the physiological responses of known levels of contaminants on the life history stages of selected organisms. These studies involved mollusks and crustaceans initially.

h) The Sandy Hook laboratory was responsible for ecological studies on the New York and Delaware dump sites and the Barnegat control site.

COOPERATIVE DUMP SITE STUDY
SANDY HOOK LABORATORY

The Sandy Hook laboratory conducted ecological studies of the New York, Barnegat Bay and Delaware Bay sites and collected faunal samples for chemical, pathological and laboratory analyses and sediment samples for chemical analyses. The Marine Contaminants Program of the Middle Atlantic Coastal Fisheries Center is a natural extension of the New York Bight waste disposal site studies begun in 1968 at the Sandy Hook laboratory under contract from the U. S. Army Corps of Engineers. As a result, some data which were used in the Army Corps report was collected under the Marine Contaminants Program and, likewise, much of the base data from the New York Bight site were collected before the Center-wide Marine Contaminants Program existed. It is felt, therefore, that the Army Corps report should be considered as the initial ecological study.

The Sandy Hook laboratory conducted nine cruises to the study sites between March 1971 and March 1972. Because of ship scheduling and weather difficulty, not all sites were visited on each cruise. These cruises resulted in over 700 samples of sediment, zooplankton, crab parts, and fish muscle and liver being prepared and sent to the Milford laboratory for chemical analyses. Approximately 60 benthic samples, mainly from the Delaware Bay site, were collected, screened and laboratory processed. Otter trawl collections were made on eight sampling dates at the New York site and six sampling

dates at the Barnegat Bay and Delaware Bay sites. A summary table of organisms collected from these trawl stations is given in Appendix IV.

Fish

A total of twenty-nine otter trawl sets were made at the three study areas. Almost half (13) of these sets were at the New York dump site. Ten sets were made at the Delaware Bay dump site and the remaining six at the Barnegat Bay control site. The large differences in number of trawl collections made and seasonal distribution of the collection makes quantitative comparisons impossible. However, there is enough data to make qualitative comparisons and plan future work with knowledge of the seasonal distribution and availability of each species.

The target species (windowpane flounder, *Scophthalmus aquosus*) was present during all sampling months except June. It has, however, been collected from the New York dump site during June in previous years (SHL, 1972). The numbers collected per tow were occasionally low, but increased sampling effort could produce enough fish for the various program objectives. It was the most abundant and frequently taken flatfish. It is also the least migratory and the adults show no tendency for seasonal movements. They may, however, wander for considerable distances and the young generally move from shallow water to deeper water as they mature (Bigelow and Schroeder, 1953).

The windowpane has little commercial or sport importance. It was taken in the New York area commercially during World War II but has been neglected since. It is ecologically important because it feeds on all types of benthic and epibenthic organisms and is found on both sand and mud bottoms, thereby being exposed to all types of contaminants.

Other than its small size and thin body, it is the best potential target species for monitoring levels of pollutants in flatfish. It is non-migratory, feeds on infauna and epifauna, is found on mud and sand bottoms and can be taken readily with an otter trawl.

Yellowtail flounder, Limanda ferruginea, and winter flounder, Pseudopleuronectes americanus, were the other abundant and most frequently taken flatfish. Both species tended to become scarce seasonally in the study areas. The winter flounder's general seasonal pattern is to inhabit the estuaries in the cooler months and migrate to the relatively cooler water of the dump areas in the summer and early fall. The yellowtail flounder inhabits deeper offshore waters in the summer and migrates into shallower waters in winter. Both species, however, may be found in limited numbers on the New York dump site year round. Both species feed on similar organisms, such as small crustaceans, worms, bivalves and, occasionally, small fish. The winter flounder's diet, however, shifts somewhat to bivalves as it grows larger (Bigelow and Schroeder, 1953).

These tow species should be considered in any future studies of marine contaminants for several reasons. They are both commercially important and the winter flounder is also an important sport fish. Both are large and can be readily obtained by otter trawl. The winter flounder is a species that migrates between the dump site areas and the polluted estuaries while the yellowtail flounder migrates from clean waters to the polluted dump areas. Young specimens of both species can be obtained for laboratory experimentation.

Of the other twenty-nine species collected, the silver hake, *Merluccius bilinearis*, red hake, *Urophycis chuss*, and skates, *Raja* spp., were the most abundant and frequently caught. The skates were generally found in low numbers, except in early summer at the New York and Barnegat Bay sites. Red hake were abundant throughout the year at the New York site and scarce at the other study areas.

The red hake and silver hake are potential additional or alternative species to work with in marine contaminants studies. Both are commercially and recreationally important species in the New York area and can be collected throughout most of the year, if not from the dump site, from areas within the zone affected by waste disposal. The red hake is basically a bottom feeder while the silver hake feeds on pelagic organisms. Thus, movement of contaminants through the tow communities of prey species could be compared.

The three areas appear to be quite similar in species composition. Sixteen species occurred at all three sites, eight at two of three sites and four at only one site. Total numbers collected at each site on a particular date were about equal when unusually large numbers of seasonal species were removed.

BENTHOS

At the Delaware Bay site benthic collections were made at 31 stations located on a half-mile grid pattern centered on the designated disposal site (Fig. 3). Also, seasonal collections were made at the center of the dump site, Station D-5 and at three sites located several miles from Station D-5.

The number of organisms per square meter at the Delaware Bay stations ranged from 30 to 4,570. Species per grab ranged from 2 at Buoy "CM" to 25 at E-4. There was no pattern to the distribution of numbers and diversity of organisms found. The data indicate that the disposal of wastes at the Delaware site has no discernable effect on the benthos as far as distribution and abundance are concerned. Station D-5, BWFA, BSFB and FLR, which were sampled periodically, showed no significant differences in numbers or types of animals found. The Barnegat Bay control site station varied greatly in abundance and number of taxa per grab sample; therefore, it is very difficult to assess this station as a control site.

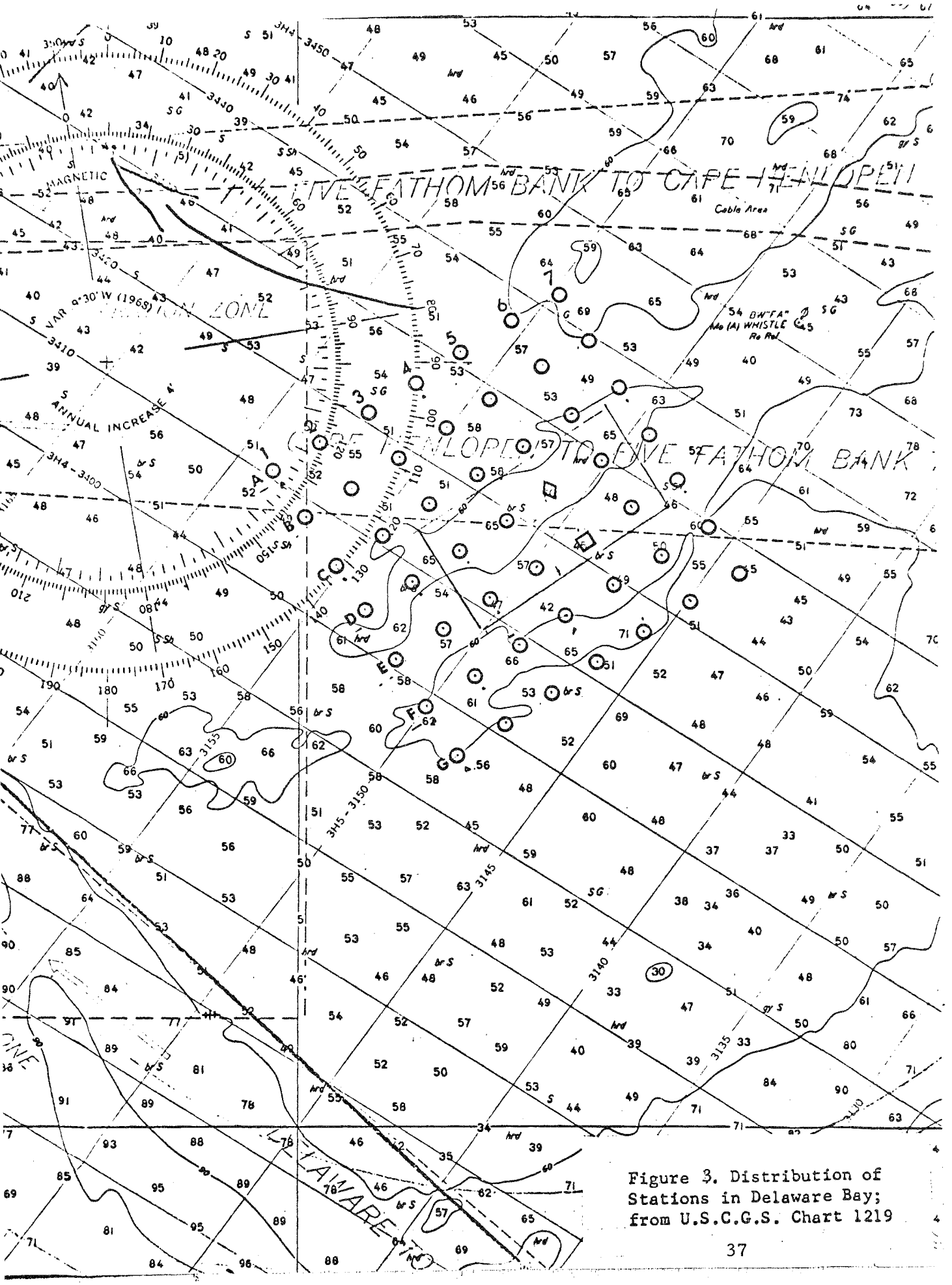


Figure 3. Distribution of Stations in Delaware Bay; from U.S.C.G.S. Chart 1219

The New York Bight waste disposal site studies have demonstrated that sewage sludge and dredge spoils have high levels of heavy metals associated with them. The heavy metals serve as an excellent tag to trace the fate of this waste material in the sediments. As part of the Marine Contaminants Program, sediment cores were collected from the three study sites and sent to the Milford laboratory for heavy metal analyses.

HUDSON SHELF VALLEY STUDIES

The objective of this study is to define the role of the Shelf Valley, which runs from the entrance of New York Harbor to the Hudson Canyon at the slope break, in the ecology of the New York Bight.

As part of this study, samples of sediments, benthos, bacteria, malacostracans and fish are being collected for the marine contaminants study. From these samples it will be possible to delineate the spread of various contaminants seaward from the disposal sites and the river mouths, determine the levels of metals in animals from all levels of the food chain and correlate levels of contaminants found in animals and sediments with distance from the source.

Three cruises were completed, thus far, in this study. Fish, crustacean and sediment samples from selected areas along the Shelf Valley were collected and frozen for heavy metal analyses. To date, only the sediment samples from the January cruise have been analyzed. The results indicate that heavy metals in above normal levels are

found as far as 30 miles from the New York dump sites. Normal levels are taken as those found in a series of six samples collected from depths between 50 and 175 fathoms on the continental slope. On later cruises samples were collected at five mile intervals between the dump sites and edge of the elevated metals zone to more sharply define the extent of the metal dispersion.

Preliminary analysis of faunal distribution and abundance data indicate that the richest areas were those close to the region affected by heavy metals. Fish and malacostracans were concentrated in the deeper waters of the Shelf Valley within 40 miles of the disposal sites. The benthic infauna also appeared to be extremely rich in this area. The number of animals per square meter increased from essentially 0 in the disposal area to 16,000 just beyond the zone of elevated heavy metals and then decreased with increasing distance from shore. The reason for the peak of abundance about 50 miles down the Shelf Valley is not yet understood, but could possibly be caused by a depression of the shoreward population or an increased population due to enrichment by disposal practices.

COOPERATIVE DUMP SITE STUDY
OXFORD LABORATORY

The Oxford laboratory collected target species of marine animals from a relatively clean coastal environment offshore from Chincoteague, Virginia as a basis for comparison of contaminant levels with similar species from known contaminated coastal areas. This was also done to gather data on the biology, seasonal distribution and relative abundance of fish and invertebrates from a relatively clean coastal area as a baseline for indicating any future changes which may occur.

Following four 1-day cruises to the study area in March 1971, target species and trawling stations were chosen. The target species chosen were, as previously mentioned, the windowpane flounder, rock crab and surf clam. These species were chosen on the basis of their availability during most of the year. Surf clams, however, could not be obtained by gear used on the chartered vessel and samples were obtainable from surf clam vessels only on a haphazard basis. Rock crabs were not abundant during the summer months and those present were too small for dissection. Windowpane flounder were the only target species available year-round.

The three trawl stations (S-1, S-2, S-3) selected were at depths of 25, 50, and 65 feet located 1.5, 3, and 5.5 miles, respectively, ESE from the SE tip of Assateague Island. The approximate latitude and longitude for stations S-1, S-2, and S-3 are N 38° 50.1' by W 75° 20.1',

N 38°50.1' by W 75°10.8', and N 38°50.0' by W 75°10.6', respectively. Trawling time was standardized in June to 1/2 hour at each station. The net used was built by the owner of the charter boat and, thus, is not comparable to any other nets being used.

Trawling was conducted monthly at the three stations beginning in April 1971 and continuing to the present. The target species were collected when present, processed, and forwarded for analysis. In addition to the target species, other species were collected as targets of opportunity. A list of the species collected and forwarded for contaminant analysis is presented in Table I (see Appendix V). Beginning in June 1971, samples of all fish caught in the trawl were measured in fork length to the nearest cm. Tables II through XII (Appendix V) present data on the numbers and lengths of finfish collected during all the cruises conducted through March 1972.

COOPERATIVE DUMP SITE STUDY
MILFORD LABORATORY

The Milford laboratory selected a dump site approximately 5 miles offshore from New Haven, Connecticut and a control site offshore from Milford, Connecticut 3 miles west of the dump site in Long Island Sound as part of the MACFC cooperative dump site study. Following preliminary cruises to test sampling gear, three stations were selected on the New Haven dump site and one on the Milford control site for biological studies. Faunal samples were collected for chemical and pathological analyses on a monthly basis beginning in May 1971 and continuing to present.

In May and June 1971 otter trawl sets were made to collect the windowpane flounder. In July 1971 lobster pots were placed on both sites to collect rock crabs and otter trawl sets were made to collect fish. An attempt was made in August 1971 to collect surf clams or any other species of bivalve. Two different size rocker dredges were used, but with no success. The channeled whelk, Busycon canaliculatum, was collected in lobster pots at all stations on both the dump site and control area and it was decided to use this animal as a target species rather than a bivalve.

Table 3 shows that windowpane flounder were not available from August through November at both sites; rock crabs were not present on the dump site at any time, while present at the control site

Table 3. Seasonal distribution of target species of marine organisms on dump site and control areas in Long Island Sound (X indicates presence of organism on sampling station).

Month	Dump Site			Control Area		
	Windowpane Flounder	Channeled Whelk	Rock Crab	Windowpane Flounder	Channeled Whelk	Rock Crab
May 1971	X					
June 1971	X			X		
July 1971	X			X		X
August 1971		X			X	X
September 1971		X			X	X
October 1971		X			X	X
November 1971		X				X
December 1971	X	X		X		X
January 1972	X			X		X
February 1972	X			X		X
March 1972	X			X		X
April 1972	X			X		X

all months that lobster pots were fished; and the channeled whelk was available at least from August to December.

COOPERATIVE DUMP SITE STUDY
CHEMICAL ANALYSES - MILFORD LABORATORY

METAL ANALYSES OF MARINE ORGANISMS

Mercury

Various species of marine organisms were collected from three dump site and three control study areas (see next page for list of geographical locations) for metal analyses. The methodologies, precision and accuracy for these analyses are presented in Appendix III.

The primary emphasis for the first few months of this study was to determine levels of mercury in the three target species selected for this study - the windowpane flounder, rock crab (known as *Cancer*) and surf clam. Mercury levels from samples of windowpane flounder and *Cancer* collected from March - December 1971 were averaged for each of the five major geographical locations and are summarized in Table 4. Two samples of surf clams were collected from Delaware Bay, three from Chincoteague and one from Barnegat Bay. All surf clam samples contained less than 0.08 ppm mercury in the muscle and less than 0.10 ppm mercury in the liver (digestive diverticulum).

Mercury levels in muscle and liver of windowpane flounder and *Cancer* from the New York and Delaware dump sites were similar to those from Chincoteague, Barnegat Bay and Long Island Sound. The Long Island Sound samples were limited, thus, the data were

List of Geographical Locations Referred to in Tables

73BB	Barnegat Bay control site
Chinc.	Chincoteague control site
69D5	Delaware Bay dump site
1-70	Center of New York sewage sludge dump site
1-82	Center of New York dredge spoils dump site
Lg. Is. Sd.	Long Island Sound
1	Northwest corner of New Haven dump site
2	Center of New Haven dump site
3	Southeast corner of New Haven dump site
4	3 miles west of New Haven dump site
1-47	Near Long Beach, New York, about 8 miles from 1-70
1-106	Between the mouth of Hudson River and station 1-70 (7 miles from 1-70)
2 cm	Entrance to Cape May
Wb	5.3 miles at 340° from Delaware Bay dump site
1-X2	1/2 mile southwest of 1-82
1-3	2.8 miles southeast of 1-70

Table 4. Average Mercury Concentrations in Windowpane Flounder and *Cancer* Crab for March-December, 1971 for Five Geographical Locations Sampled in the Dump Site Study

Geographical Location	Species	N[1]	Mercury Concentration (ppm, wet wt.) Range	Average	Standard Deviation
	Windowpane flounder Muscle				
New York Dump Site		4	0.09-0.27	0.15	0.077
Delaware Dump Site		5	0.13-0.16	0.15	0.015
Barnegat Bay Control Site		4	0.17-0.32	0.25	0.081
Chincoteague Control Site		8	0.08-0.32	0.17	0.074
Long Island Sound (all locations sampled)		10	0.09-0.23	0.13	0.070
	Windowpane flounder Liver				
New York Dump Site		2	0.10-0.48	0.29	-
Delaware Dump Site		4	0.10-0.23	0.17	0.051
Barnegat Bay Control Site		4	0.15-0.35	0.24	0.089
Chincoteague Control Site		6	0.08-0.40	0.23	0.120
Long Island Sound (all locations sampled)		10	0.10-0.52	0.22	0.132

Table 4. (cont.) -2-

Geographical Location	Species	N[1]	Mercury Concentration (ppm, wet wt.) Range	Average	Standard Deviation
	Cancer Crab Muscle				
New York Dump Site		7	0.05-0.31	0.19	0.079
Delaware Dump Site		3	0.06-0.28	0.15	-
Barnegat Bay Control Site		2	0.06-0.19	0.13	-
Chincoteague Control Site		3	0.09-0.31	0.20	-
Long Island Sound (all locations sampled)		5	0.13-0.26	0.18	0.054
	Cancer Crab Liver				
New York Dump Site		6	0.05-0.12	0.09	0.024
Delaware Dump Site		3	0.05-0.09	0.07	-
Barnegat Bay Control Site		2	0.15-0.16	0.15	-
Chincoteague Control Site		1	0.24	0.24	-
Long Island Sound (all locations sampled)		5	0.05-0.13	0.09	0.027

1]- The number of collections obtained from March-December, 1971 for the various geographical locations indicated. Each collection consisted of 6-10 animals.

treated as one collection.

A summary of mercury concentrations in the most frequently collected organisms, other than windowpane flounder and *Cancer*, is presented in Table 5. Mercury concentrations found in yellowtail flounder and winter flounder were in the range of 0.06-0.17 ppm for muscle tissue and 0.06-0.35 ppm in the liver, which are quite similar to those levels found in windowpane flounder. The levels of mercury in muscle tissue of fish from the New York and Delaware dump sites were not substantially different from muscle tissue of fish from the Barnegat Bay control site. The level of mercury in the liver of fish from Barnegat Bay was about twice that of fish from both the New York and Delaware dump sites; the number of collections was too few to determine whether this was a significant difference or not.

Busycon were collected from Long Island Sound only. Mercury levels averaged 0.18 ppm in the foot or muscle tissue of animals collected from the center of the dump site (station 2) and 0.08-0.11 ppm in animals from the periphery of the dump site (stations 2 and 3) and the control site (station 4). There was no substantial difference in the average mercury concentration found in the soft parts of *Busycon* from the 4 stations. The ranges of mercury concentrations found in *Busycon* indicate substantial variations in mercury levels for various sample collections, indicating that this variation may be correlated with seasonal time of catch. The data were too few for a critical

Table 5. Average Mercury Concentrations in Yellowtail Flounder, Winter Flounder, and Busycon For March-December, 1971 for Collections in Dump Site Study

Geographical Location	Species	N[1]	Mercury Concentration (ppm, wet wt.) Muscle		Liver	
			range	average	range	average
New York Dump Site	Yellowtail flounder	3	0.07-0.10	0.09	0.10-0.12	0.11
Delaware Dump Site		2	0.14-0.15	0.15	0.13-0.18	0.15
Barnegat Bay		2	0.13-0.15	0.14	0.22-0.30	0.26
New York Dump Site	Winter flounder	4	0.08-0.17	0.11	0.06-0.21	0.12
Delaware Dump Site		3	0.08-0.13	0.10	0.07-0.15	0.11
Barnegat Bay		2	0.12-0.15	0.13	0.13-0.35	0.24
Chincoteague			-	0.10	-	-
Wb			-	0.06	-	0.25
Long Island Sound	Busycon		Muscle		Soft Parts	
Area 1		4	0.09-0.14	0.11	0.12-0.46	0.28
Area 2		4	0.12-0.27	0.18	0.28-0.52	0.37
Area 3		3	0.09-0.12	0.10	0.25-0.41	0.31
Area 4		3	0.06-0.11	0.08	0.20-0.41	0.27

N - The number of collections obtained from March-December, 1971 for the geographic locations indicated. Each collection consisted of 6-10 animals

Table 6. Mercury Content of Key Organisms Collected in Dump Site Study

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH[1]									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		SPECIES - WINDOWPANE FLOUNDER[2]									
1-70	Muscle	-	0.09	0.13	-	-	-	0.12	-	0.27	-
	Liver	-	-	-	-	-	-	0.10	-	0.48	-
69D5	Muscle	0.16	0.14	0.13	0.14	-	-	0.16	-	-	-
	Liver	0.23	0.10	0.19	-	-	-	0.16	-	-	-
73BB	Muscle	0.32	0.32	0.17	0.22	-	-	-	-	-	-
	Liver	0.15	0.35	0.18	0.28	-	-	-	-	-	-
Chinc.	Muscle	0.32	0.15	0.22	-	0.16	0.08	0.12	-	0.10	0.19
	Liver	-	0.28	-	-	0.40	0.29	0.08	-	0.10	0.22
Lg. Is. Sd.											
1	Muscle	-	-	0.09	0.16	0.23	-	-	-	-	-
	Liver	-	-	0.11	0.35	0.52	-	-	-	-	-
2	Muscle	-	-	0.12	0.22	0.12	-	-	-	-	-
	Liver	-	-	0.14	0.21	0.24	-	-	-	-	-

1] each value is the average for a collection of 6-10 animals
2] the length of the windowpane flounder ranged from 200-300mm

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SPECIES - WINDOWPANE FLOUNDER											
Lg. Is. Sd.											
3	Muscle	-	-	0.10	0.14	-	-	-	-	-	-
	Liver	-	-	0.11	0.28	-	-	-	-	-	-
4	Muscle	-	-	-	0.13	0.11	-	-	-	-	-
	Liver	-	-	-	0.10	0.14	-	-	-	-	-
2CM	Muscle	0.20	-	-	-	-	-	-	-	-	-
	Liver	0.17	-	-	-	-	-	-	-	-	-
Wb	Muscle	0.14	-	-	-	-	-	-	-	-	-
	Liver	0.19	-	-	-	-	-	-	-	-	-

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					SPECIES - YELLOWTAIL FLOUNDER[3]						
1-70	Muscle	-	0.07	0.09	-	-	-	-	-	0.10	-
	Liver	-	0.10	0.12	-	-	-	-	-	-	-
69D5	Muscle	0.15	0.14	-	-	-	-	-	-	-	-
	Liver	0.13	0.18	-	-	-	-	-	-	-	-
73BB	Muscle	0.15	0.13	-	-	-	-	-	-	-	-
	Liver	0.22	0.30	-	-	-	-	-	-	-	-
					SPECIES - WINTER FLOUNDER[4]						
1-70	Muscle	-	0.17	0.08	0.11	-	-	0.10	-	-	-
	Liver	-	0.21	0.08	0.14	-	-	0.06	-	-	-
69D5	Muscle	0.09	0.13	0.08	-	-	-	-	-	-	-
	Liver	0.10	0.15	0.07	-	-	-	-	-	-	-
73BB	Muscle	-	0.15	0.12	-	-	-	-	-	-	-
	Liver	-	0.35	0.13	-	-	-	-	-	-	-

3] The length of the yellowtail flounder ranged from 200-350mm
4] The length of the winter flounder ranged from 200-350 mm

Table 6. (cont.) -4-

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					SPECIES - WINTER FLOUNDER						
Chinc.	Muscle	0.10	-	-	-	-	-	-	-	-	-
	Liver	-	-	-	-	-	-	-	-	-	-
Wb	Muscle	0.06	-	-	-	-	-	-	-	-	-
	Liver	0.25	-	-	-	-	-	-	-	-	-
					SPECIES - CANCER CRAB						
73BB	Muscle	-	0.06	0.19	-	-	-	-	-	-	-
	*Liver	-	0.16	0.15	-	-	-	-	-	-	-
	Gill	-	0.07	0.12	-	-	-	-	-	-	-
Chinc.	Muscle	-	0.09	0.19	-	-	-	0.31	-	-	-
	Liver	-	-	-	-	-	-	0.24			
	Gill	-	-	0.05	-	-	-	<0.05	-	-	-
69D5	Muscle	0.10	0.06	0.28	-	-	-	-	-	-	-
	Liver	0.09	0.05	0.07	-	-	-	-	-	-	-
	Gill	<0.05	<0.05	0.08	-	-	-	-	-	-	-

* The liver of the Cancer crab is the digestive diverticulum

Table 6.(cont.) -5-

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					SPECIES - CANCER CRAB						
1-70	Muscle	-	0.23	0.13	0.23	-	-	0.21	-	-	-
	Liver	-	0.05	0.12	0.07	-	-	0.12	-	-	-
	Gill	-	0.12	0.05	0.05	-	-	<0.05	-	-	-
1-X2	Muscle	-	-	-	-	-	-	-	0.16	-	-
	Liver	-	-	-	-	-	-	-	0.09	-	-
1-3	Muscle	-	-	-	-	-	-	-	0.31	-	-
	Liver	-	-	-	-	-	-	-	0.10	-	-
1-82	Muscle	-	0.05	-	-	-	-	-	-	-	-
	Gill	-	0.08	-	-	-	-	-	-	-	-
Lg. Is. Sd.											
4	Muscle	-	-	-	-	0.26	0.15	0.13	0.13	0.23	-
	Liver	-	-	-	-	0.11	0.13	0.09	0.05	0.09	-
	Gill	-	-	-	-	<0.05	<0.05	<0.05	-	-	-
2CM	Muscle	0.15	-	-	-	-	-	-	-	-	-
	Liver	0.08	-	-	-	-	-	-	-	-	-
	Gill	<0.05	-	-	-	-	-	-	-	-	-

Table 6. (cont.) -6-

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		SPECIES - CANCER CRAB									
Wb.	Muscle	0.27	-	-	-	-	-	-	-	-	-
	Liver	0.24	-	-	-	-	-	-	-	-	-
	Gill	0.08	-	-	-	-	-	-	-	-	-
		SPECIES - BUSYCON									
Lg. Is. Sd.											
1	Muscle	-	-	-	-	-	0.09	0.09	0.14	0.14	-
	Soft parts	-	-	-	-	-	0.12	0.19	0.46	0.35	-
2	Muscle	-	-	-	-	-	0.12	0.15	0.17	0.27	-
	Soft parts	-	-	-	-	-	0.33	0.28	0.36	0.52	-
3	Muscle	-	-	-	-	-	0.12	0.09	-	0.10	-
	Soft parts	-	-	-	-	-	0.28	0.25	-	0.41	-
4	Muscle	-	-	-	-	-	0.11	0.07	0.06	-	-
	Soft parts	-	-	-	-	-	0.21	0.20	0.41	-	-

Table 6.(cont.) -7-

Geographical Location	Tissue	MERCURY (ppm wet wt.) BY MONTH									
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					SPECIES - SURF CLAM						
69D5	Muscle	<0.05	<0.05	-	-	-	-	-	-	-	-
Chinc.	Muscle	-	0.05	<0.05	-	0.07	-	-	-	-	-
	Liver	-	0.08	<0.05	-	0.09	-	-	-	-	-
73BB	Whole	-	-	-	-	-	-	<0.05	-	-	-
					SPECIES - PLANKTON						
1-70	Whole	-	-	-	<0.05	-	-	-	-	-	-
1-82	Whole	-	-	-	<0.05	-	-	-	-	-	-
69D5	Whole	<0.05	-	-	<0.05	-	-	-	-	-	-
73BB	Whole	-	-	-	<0.05	-	-	-	-	-	-

Table 7. Mercury Concentrations in Miscellaneous Finfish and Shellfish Collected for the Dump Site Study

Animal Species	Date of Catch 1971	Mean Length cm	Animals per Composite	Mercury Concentration[1] (ppm wet wt.) Muscle	Liver	Gill
NEW YORK WASTE DISPOSAL SITE						
Fish						
Longhorn sculpin	May	26.1	3	0.32	-	-
Spotted flounder	Sept.	-	3	0.08	-	-
Blackback	Nov.	-	4	0.06	0.23	-
Ling		35.1	12	0.10	-	-
Invertebrates						
Lobster	April	-	7	0.36	0.38	0.05
Lobster	May	-	3	0.42	0.11	0.08
Lobster	June	-	8	0.72	0.25	0.05
Cyprina	Sept.	-	1	0.03	(whole)	

Table 7. (cont.) -2-

Animal Species	Date of Catch 1971	Mean Length cm	Animals per Composite	Mercury Concentration (ppm wet wt.) Muscle	Liver	Gill
BARNEGAT BAY CONTROL SITE						
Fish						
Sea herring	March	-	10	0.12	0.15	-
Scup	May	13.0	10	0.06	-	-
Butterfish		13.9	10	0.07	-	-
Searobin		21.2	2	0.18	0.17	-
Ling	Sept.	-	10	0.09	0.02	-
Invertebrates						
Snails	May	7.3	6	0.17	(whole)	
DELAWARE BAY WASTE DISPOSAL SITE						
Fish						
Longhorn sculpin	March	-	10	0.29	0.27	-
Ocean pout		-	10	0.10	-	-
Whiting		-	10	0.19	0.07	-
Sea herring		-	10	0.20	0.21	-
Fluke	May	35.0	4	0.08	0.06	-
Butterfish		12.5	4	0.02	-	-
Searobin		24.4	10	0.26	-	-
Scup		12.0	10	0.02	-	-
Ling	Sept.	-	10	0.05	0.03	-
Fluke		-	9	0.18	0.05	-

Table 7.(cont.) -3-

Animal Species	Date of Catch 1971	Mean Length cm	Animals per Composite	Mercury Concentration (ppm wet wt.) Muscle	Liver	Gill
CHINCOTEAGUE CONTROL SITE						
Fish						
Mackerel	March	-	10	0.10	-	-
Flat herring		-	10	0.12	0.10	-
Round herring		-	10	0.14	-	-
Dogfish		-	10	0.49	0.24	-
Blueback herring		-	5	0.09	(whole)	
Rockfish		-	9	0.43	0.43	-
Whiting	April	-	10	0.15	0.09	-
Spotted ling		-	10	0.10	0.14	-
Weakfish		-	10	0.31	0.11	-
Sand tiger	May	-	10	0.03	-	-
Butterfish		-	10	0.04	(whole)	-
Searobin		-	10	0.15	-	-

Table 7. (cont.) -4-

Animal Species	Date of Catch 1971	Average Length	Animals per Composite	Mercury Tissue	Concentration ppm (wet wt.)
CHINCOTEAGUE CONTROL SITE					
Fish					
Bull shark	June	-	1	Muscle	1.9
" "		-	1	Liver	1.0
" "		-	1	Brain	0.53
" "		-	1	Ovary	0.46
" "		-	1	Pancreas	0.34
" "		-	1	Gill	0.68
" "		-	1	Spleen	0.39
" "		-	1	Rectal Gland	1.0
" "		-	1	Heart	1.4
Fluke	July	-	10	Muscle	0.17
Atlantic sturgeon	Oct.	-	1	Muscle	0.33
" "		-	1	Liver	0.78
" "		-	1	Brain	0.12
" "		-	1	Pancreas	0.14
" "		-	1	Gill	0.08
" "		-	1	Kidney	0.15
" "		-	1	Spleen	0.13
" "		-	1	Heart	0.18
" "		-	1	Gonad	<0.05

1] - Results are on average of 2 or more replicate determinations for a composite of the number of animals indicated

evaluation. The data for the monthly collections of Busycon and other key organisms are presented in Table 6.

Presented in Table 7 are the results of mercury analyses obtained from animals collected occasionally in this survey. Although the same species were not consistently collected from each location, the results indicate that the mercury content of samples from the dump site areas were not substantially different from the control areas. All samples, except the lobster and bull shark, had mercury concentrations less than 0.5 ppm. A sample of lobsters collected from the New York dump site had relatively high mercury concentrations (0.7 ppm) in the muscle tissue. Lobster samples were not obtained from the other locations, but levels of this magnitude have been found in lobsters from Maine and Massachusetts. The sample of bull shark collected from the Chincoteague station contained relatively high levels of mercury. Mercury levels of this magnitude have been found in other large carnivorous fish, such as bluefin tuna, swordfish, hammerhead shark and striped marlin.

Other Metals

Analyses of lead, cadmium and arsenic were to be included in this report, but in-house capabilities to do these analyses were not established at the time of this study and the work was contracted out. The results of these analyses are not yet available.

Table 8. Results of Neutron Activation Analyses on Organisms Collected for Dump Site Study

Month: Location	COBALT Mus.[2]	COBALT Liv.	CHROMIUM Mus.	CHROMIUM Liv.	SELENIUM Mus.	SELENIUM Liv.	SILVER Mus.	SILVER Liv.	RUBIDIUM Mus.	RUBIDIUM Liv.	ZINC Mus.	ZINC Liv.
	METAL CONCENTRATION (ppm, wet wt.)[1]											
	SPECIES - WINDOWPANE FLOUNDER											
1971												
April:												
73BB	*	0.13	*	*	0.73	2.4	*	1.4	*	*	5.5	34.3
69D5	*	0.15	*	*	0.50	1.1	*	*	*	*	10.0	35.0
1-70	*	0.13	*	*	0.60	2.1	*	1.3	*	*	4.0	37.0
Chinc.	*	0.20	*	*	0.55	2.5	*	*	*	*	8.5	46.0
June:												
73BB	*	0.14	*	0.4	0.75	5.1	*	0.5	0.7	1.5	4.3	54.2
69D5	*	0.14	*	*	0.58	1.2	*	*	0.7	*	3.7	23.7
Long Is. Sound 1	*	0.16	0.8	*	0.50	2.0	0.1	*	0.7	*	8.2	37.7
Long Is. Sound 2	*	0.14	1.8	1.3	*	2.0	3.4	*	*	*	7.7	40.6
Long Is. Sound 3	*	0.11	0.3	0.7	0.40	1.7	*	0.2	*	*	5.3	35.0
Long Is. Sound 4	*	0.04	*	0.3	*	1.1	*	*	0.6	*	5.5	36.3
September:												
69-D5	0.04	0.04	0.5	0.8	0.62	1.1	*	*	0.8	*	5.4	30.9

* - Not detected - see discussion for detection limits

1 - All values are an average for 10 animals per month: location

2 - Mus. = muscle, liv. = liver

Table 8. (cont.) -2-

Month: Location	METAL CONCENTRATION (ppm, wet wt.) COBALT Mus.	COBALT Liv.	CHROMIUM Mus.	CHROMIUM Liv.	SELENIUM Mus.	SELENIUM Liv.	SILVER Mus.	SILVER Liv.	RUBIDIUM Mus.	RUBIDIUM Liv.	ZINC Mus.	ZINC Liv.
SPECIES - YELLOWTAIL FLOUNDER												
1971												
April: 73BB	*	-	*	-	0.7	-	*	-	*	-	9.0	-
SPECIES - WEAKFISH												
June: unknown	*	-	0.20	-	0.5	-	*	-	0.7	-	3.0	-
SPECIES - WINTER FLOUNDER												
September: 1-70	*	0.05	*	0.4	0.4	2.8	*	0.1	0.5	5.2		42.0

Month: Location	COBALT Mus.	COBALT Liv.	CHROMIUM Mus.	CHROMIUM Liv.	SELENIUM Mus.	SELENIUM Liv.	SILVER Mus.	SILVER Liv.	RUBIDIUM Mus.	RUBIDIUM Liv.	ZINC Mus.	ZINC Liv.
	METAL CONCENTRATION (ppm, wet wt.)											
SPECIES - LING												
1971												
September:												
73-BB	*	*	*	0.6	0.4	0.8	*	0.2	0.9	0.5	3.8	1.0
SPECIES - FLUKE												
September:												
69-D5	*	-	0.7	-	0.7	-	*	-	*	-	4.0	-
SPECIES - LOBSTER												
June:												
1-70	*	0.11	*	*	2.0	2.9	0.5	*	1.0	*	30.4	39.1

* - Not detected-see discussion for detection limits

Table 8. (cont.) -4-

Month: Location	COBALT Mus.	COBALT Liv.	CHROMIUM Mus.	CHROMIUM Liv.	SELENIUM Mus.	SELENIUM Liv.	SILVER Mus.	SILVER Liv.	RUBIDIUM Mus.	RUBIDIUM Liv.	ZINC Mus.	ZINC Liv.
	METAL CONCENTRATION (ppm, wet wt.)											
SPECIES - CANCER CRAB [3]												
1971												
April:												
73BB	0.20	0.20	*	*	1.0	3.7	1.9	29.5	*	*	35.0	25.0
69-D5	0.10	*	*	*	0.8	2.0	0.9	10.5	*	*	28.0	15.0
1-82	*	*	*	*	0.9	1.5	2.2	16.5	*	*	38.5	16.0
1-70	*	*	*	*	-	1.7	*	10.0	*	*	-	13.0
Chinc.	0.10	-	*	*	0.9	-	0.70	-	*	*	29.5	-
June:												
1-70	*	0.10	*	0.8	1.0	1.3	0.2	2.0	0.6	1.1	24.7	17.1
September:												
1-70	*	0.11	*	0.4	0.7	1.7	0.2	2.8	*	1.5	25.5	24.5
Lg. Is. Sd.-4	0.10	0.13	*	1.0	2.8	2.4	0.1	4.3	*	*	71.8	36.8

3 - Cancer Crab & Surf Clam "Liver" is the digestive diverticulum
* - Not detected - see discussion for detection limits

Table 8.(cont.) -5-

Month: Location	COBALT Mus.	COBALT Liv.	CHROMIUM Mus.	CHROMIUM Liv.	SELENIUM Mus.	SELENIUM Liv.	SILVER Mus.	SILVER Liv.	RUBIDIUM Mus.	RUBIDIUM Liv.	ZINC Mus.	ZINC Liv.
	METAL CONCENTRATION (ppm, wet wt.)											
SPECIES - SURF CLAM[3]												
1971												
April:												
Chinc.	0.20	0.40	*	*	0.7	1.1	*	3.7	*	*	22.5	17.0
69-D5	0.40	-	1.5	-	0.7	-	1.0	-	*	*	16.5	-
June:												
69-D5	0.21	-	1.1	-	0.7	-	0.4	-	1.5	-	14	-
1-47	0.16	-	0.7	-	0.8	-	1.3	-	1.2	-	15	-
1-106	0.35	-	2.7	-	0.8	-	1.0	-	2.3	-	-	-
SPECIES - BUSYCON[4]												
1971												
September:												
Long Is. Sound 1	*	0.09	0.7	*	*	*	*	21.0	*	*	23.5	3,684
Long Is. Sound 2	*	0.10	<0.5	1.3	0.4	1.6	0.3	14.6	1.3	*	35.3	1,373
Long Is. Sound 3	*	0.09	*	*	*	1.7	0.2	8.1	*	1.1	27.2	1,104
Long Is. Sound 4	*	0.06	*	*	*	0.9	*	6.5	*	*	25.0	772

4]- The Busycon "liv." was the material left after removal of the foot (muscle) and shell

Month: Location	COBALT	CHROMIUM	SELENIUM	SILVER	RUBIDIUM	ZINC
	METAL CONCENTRATION (ppm, wet wt.)					
	SAMPLE - PLANKTON[5]					
1971						
April:						
73-BB	0.09	*	0.6	*	*	53
69-D5	0.11	*	0.3	*	*	33
1-70	0.17	2.4	1.3	*	*	57
June:						
73-BB	*	0.30	0.7	0.13	*	37.3
69-D5	*	0.67	0.3	0.04	0.4	12.3
1-82	0.10	6.7	0.9	0.18	0.9	43.4

5] - Entire sample was analyzed, all values on plankton are ppm, dry wt.

Analyses of antimony, cobalt, chromium, nickel, selenium, silver, rubidium and zinc were made by non-destructive neutron activation on these samples and the results are presented in Table 8. Nickel and antimony were not detected in any of the samples analyzed (the detection limit for nickel was about 2-4 ppm and for antimony about 0.04-0.08 ppm).

The fish samples that were examined had similar concentrations of the metals detected. Thus, the data do not reveal any substantial differences in metal concentrations that could be attributed to differences in catch location. A possible exception to this general statement is that chromium and silver at levels of 1-2 ppm and 3.4 ppm, respectively, were found in windowpane flounder from Station #2 in Long Island Sound (June collection). This may be significant, but further sampling is required to determine if this area is different from the other areas sampled in Long Island Sound.

Generally, the shellfish examined (lobster, Cancer or rock crab, surf clam, and Busycon) had metal concentrations that were quite similar to the fish samples. There were, however, two important exceptions. Liver of Cancer collected in April had substantially greater silver concentrations than fish or other shellfish except Busycon. The level of silver was 10-30 ppm as compared to a high of 3.4 ppm in fish. The June and September collections of Cancer liver, however, had silver concentrations of only 2-4 ppm. Unfortunately, the size sample

collected from this crab was too small to allow repetition of the analyses. Thus, any verification of these data must await more analyses of these animals from the same location at various times of the year to determine if the high levels are seasonal. Busycon soft parts contained high levels of zinc (772-3,684 ppm) and silver (6.5-21.0 ppm). Specific organs of Busycon must be examined in future collections to determine where these metals are concentrated.

Analyses of plankton samples in this survey were limited, but the data suggest that differences in chromium levels of the various samples may be attributed to differences in catch location. New York dump site stations 1-82 and 1-59 have elevated levels of chromium as compared to the stations from Delaware Bay (69D5) and Barnegat Bay (73BB). Additional sampling is required to confirm these data and to statistically determine if there are differences related to geographic location.

Examination of the literature concerning metal concentrations in marine organisms revealed that most studies have been conducted on shellfish, since they are effective concentrators of trace elements. Of the metals examined by neutron activation in this study, data were found from other sources on cobalt, chromium, nickel and zinc. Pringle et al., (J. San. Eng. Div., Proc. Am. Soc. Civil Eng., June 1968) reported values for oysters, soft shell clam and quahaug. Meranger and Somers (Bull. Env. Contam. and Tox. 3 (6): 1968) reported values

for salmon, tuna, sardines, oysters, clams and crabs. While these two reports were far from inclusive in terms of available data, they did indicate fairly typical levels that are found in certain marine organisms. The ranges of "average" metal concentrations (in ppm) found in marine organisms by these investigators were as follows:

Species	Cobalt	Chromium	Nickel	Zinc
Fish	0.4-1.0	0.4-0.7	0.6-2.0	18-46
Shellfish				
Oysters	0.1-0.2	0.4-0.5	0.1-2.0	1,400
Clams	0.1-1.0	0.3-0.5	0.2-2.5	17-600

The samples of marine animals examined by these investigators came from both the East and West Coasts. The levels of these same metals that were found in animals collected from the various dump sites and control areas in this study were of the same magnitude as reported by the investigators listed. Thus, the metal concentrations found in animals of this study do not appear to be greater than levels found in marine organisms from other locations. References to antimony, silver and selenium concentrations in marine animals could not be located.

METAL ANALYSES OF SEDIMENT SAMPLES

Core samples of about 2-4 inches in depth were taken from Smith-McIntyre grabs from the New York dump site and Delaware Bay dump site to compare the level of metals in the sediments from these two areas. At the New York dump site the samples were taken from two areas - the dredge spoil dumping site and the sewage sludge dumping site. Sediment samples were also taken at Barnegat Bay and Stations BWFA, BWFB, and FLR for comparison with the dump site stations. Sediment samples were not collected from Long Island Sound.

The results (Table 9) showed that the concentration of metals, other than manganese, was about the same for the dredge spoil and sewage sludge samples collected at the New York dump site. The manganese content of sediments from the dredge spoil area was about 3 times as great as that from the sewage sludge area.

The concentrations for all metals examined, except mercury, were considerably higher for the sediment samples collected from the New York dump site area as compared to the Delaware Bay dump site and the Barnegat Bay, BWFA, BWFB, and FLR stations. The mercury content of sediments from all areas sampled was quite low (highest level was 0.4 ppm from the New York dredge spoil site) and there did not appear to be any measurable difference in concentrations for the various areas sampled.

Table 9. Metal Concentrations in Sediments Collected for Dump Site Study

Number of Samples[1]		METAL CONCENTRATION (ppm, dry wt.)[2]							
		Co	Cr	Cu	Hg	Mn	Ni	Pb	Zn
				DELAWARE BAY DUMP SITE					
19	range	1-6	< 1-2	< 1-4	<0.05-0.23	8-35	< 1-26	2-10	< 4-17
	average	1.3	< 2	< 4	<0.23	13.3	2.6	3.6	5.6
				NEW YORK DUMP SITE					
	Dredge Spoils								
6	range	6-13	40-69	48-101	0.1-0.4	92-170	17-31	70-122	97-189
	average	8.3	58	85	0.2	129	18	97	154
	Sewage Sludge								
8	range	5-11	17-81	28-136	0.03-0.1	22-65	7-35	55-137	78-264
	average	7.3	49	72	0.07	48	17	92	150

1 - Samples were collected in April, June, and September, 1971
2 - Analyses were conducted by atomic absorption employing a strong acid extraction of the metals

Number of Samples		METAL CONCENTRATION (ppm, dry wt.)							
		Co	Cr	Cu	Hg	Mn	Ni	Pb	Zn
				BARNEGAT BAY					
3	range	<2-4	1-2	<4-<4	<0.05	13-39	2-5	2-6	<4-7
	average	<4	1.7	<4	<0.05	22.6	3.3	3.6	5.6
				BWFA[3]					
4	range	1-2	<1-2	1-<4	<0.05	13-30	2-4	1-3	<2-4
	average	1.8	<2	<4	<0.05	23.0	2.5	2.0	<4
				BWFB[3]					
3	range	1-3	<1-2	<1-4	<0.05	16-33	2-3	3-4	<3-4
	average	2	<2	<4	<0.05	26.3	2.5	3.6	<4
				FLR[3]					
3	range	1-8	1-3	2-4	<0.05	17-24	1-28	3-16	<4-7
	average	7.5	2.0	3.0	<0.05	19.7	11.0	8.7	<7

[3] BWFB=6.7 miles at 290° from Delaware Bay Dump Site
BWFA=2.7 miles northeast of Delaware Bay Dump Site
FLR=5.3 miles at 340° from Delaware Bay Dump Site

SUMMARY AND RECOMMENDATIONS

The mercury data for windowpane flounder appear to be adequate and do not warrant further sampling. High levels of silver were observed in the rock crab in the spring samples and additional sampling for this species should be continued in order to determine if these variations do exist. High levels of silver and cadmium were observed in Busycon and increased sampling from different geographical locations is recommended.

In the past, discussions and suggestions were made that surf clams be analyzed; an effort should be made to obtain these animals for analysis. Lobsters, although limited in quantity, should also be included for heavy metal analyses.

Sediment analysis of samples from the New York Bight compare favorably with those obtained by D. Carmody from Columbia University. Further analyses should be limited to comparative studies in this area. Initial analyses of sediments from the Long Island Sound dump site area show values comparable to values obtained in the New York Bight. There seems to be no variation with sampling sites. Increased sampling of Long Island Sound sediments is being given some priority to determine if preliminary results can be substantiated.

Plankton should also be sampled from the dump site areas.

COOPERATIVE DUMP SITE STUDY
RADIONUCLIDE ANALYSES - BEAUFORT LABORATORY

The Atlantic Estuarine Fisheries Center at Beaufort, N.C., agreed to examine tissue samples from selected aquatic organisms collected from dump site studies for radionuclides. Some samples were collected during the trial period of this cooperative study and analyzed for radionuclides in FY 1972. Table 10 shows that the levels of ^{40}K and ^{137}Cs found in these samples were comparable to those found in naturally occuring levels of ^{40}K and long-lived fallout levels of ^{137}Cs. The windowpane flounder sample was interesting in that it contained several isotopes not found in fallout. These probably originated from naturally occuring ^{232}Th and its daughter products, but several additional analyses would have to be made to demonstrate this conclusively.

Table 10. Radionuclide analyses of several species of fish collected from dump site study

Location	Sample	Weights	Results
Delaware Bay	6 windowpane flounder less heads and viscera	782 g wet 171 g dry 30.7 g ash	2295 pCi ^{40}K probably some ^{65}Zn and ^{137}Cs, plus unidentified
Barnegat Bay	inadvertently combined 18 winter flounder less heads and viscera	3048 g wet 700 g dry 80.8 g ash	8540 pCi ^{40}K 36.8 pCi ^{137}Cs trace of ^{65}Zn?
New York Dump Site	9 ling (Urophycis sp) less heads and viscera	2998 g wet 648 g dry 79.6 g ash	7140 pCi ^{40}K 46.8 pCi ^{137}Cs trace of ^{65}Zn?
New York Dump Site	6 skates (Raja sp) whole animals	3043 g wet 611 g dry 85.9 g ash	4970 pCi ^{40}K 64.3 pCi ^{137}Cs nothing more definable

COOPERATIVE DUMP SITE STUDY
PATHOLOGY STUDIES - OXFORD LABORATORY

The dump site target species of fish, the windowpane flounder, Scophthalmus aquosus, and other selected species of fish collected in this study were examined for aberrant histology but none was observed.

Although the rock crab, Cancer irroratus, was collected in this study, it was not available throughout the year in the coastal areas sampled. In all, 128 crabs were examined histopathologically, 90 from the New York Bight and 38 from Chincoteague. The examination of haemolymph, muscle, hepatopancreas and gill failed to reveal any significant pathology. Gill fouling was apparent in numerous crabs but was not confined to crabs from one particular area. It was not possible to link pronounced gill fouling to environmental stress.

It may prove difficult to employ histopathology as a determinant of past or present environmental stress in crustaceans. In general, molting and the absence of discrete organs make histological evaluation difficult. Studies of pathology in crabs have focused more on parasite occurrence (and host response) than histology. Further studies with the rock crab in the New York Bight should be made; however, better sampling gear should be used (trawls, traps) and more effort should be directed toward obtaining crabs on a regular basis. Laboratory studies could readily be performed with specific pollutants or sludge and sludge extract.

Forty surf clams, Spisula solidissima, were examined for histopathology. Most of these were obtained from Chincoteague and not the New York Bight. No obvious pathology was determinable by light microscopy. The surf clam was a difficult animal to examine histologically. In spite of vigorous washing residual sand made sectioning difficult. Because of its large size two sections per animal frequently were necessary for adequate histopathological examination. As yet, the MACFC is not directly capable of sampling surf clams on a routine basis. Because of its availability and the ease with which it can be processed, Astarte may be a worthwhile mollusk to examine. It is recognized that Astarte is not of commercial importance, however, this should not be a limiting factor.

Unusually high concentrations of zinc have been found in both muscle and liver of the channeled whelk, Busycon canaliculatum, collected from Long Island Sound. Unfortunately fixation was inadequate and the tissues could not be examined microscopically. Whelks collected offshore at Chincoteague, Va., were dissected and tissues frozen for mercury analysis and fixed for histopathology. It is anticipated that whelks will also be obtained from Long Island Sound to substantiate the original findings.

On the basis of information obtained during the past year, it is obvious that the histopathological examination of randomly collected

fish, crustaceans and mollusks cannot be justified. The Pathology Investigations of the Oxford Laboratory can participate in MACFC Contaminant Studies based on the following:

1. Histopathological examination of samples of opportunity
2. Histopathological, microbiological and immunological studies of fish and crustaceans exposed to environmental stresses via artificial reefs.
3. Histopathological studies of fish, crustaceans and mollusks deliberately exposed to contaminants in the laboratory.
4. Ultrastructure studies of cytopathology in fish, crustaceans and mollusks deliberately exposed to contaminants in the laboratory.
5. Ultrastructure studies of micropathogens unique to fish, crustaceans and mollusks inhabiting stressed environments.
6. Histopathological studies of fish exhibiting the fin rot syndrome.

COOPERATIVE DUMP SITE STUDY
MICROBIOLOGICAL STUDIES - MILFORD LABORATORY

A concern with the ocean dumping of domestic sewage is the degree and persistence of fecal contamination of the sediments surrounding a disposal site. Studies were initiated to assess the degree of fecal contamination of waste disposal areas in the New York Bight and Delaware Bay, and several New Jersey coastal sewage outfalls. To date, 79 sediment samples collected in June and December (1971) and March and April (1972), have been analyzed for total and fecal coliforms. Except for the length of sample storage before initiating the analyses, all tests were by standard methods. The results of the analyses from individual cruises are listed in Tables 11, 12, 13 and 14. The distribution of fecal coliforms found in sediments collected from the New York Bight is shown in Figure 4.

The fecal coliform counts for 5 stations (4, 14, 59, 70 and 82) which were repeatively sampled, varied substantially between sampling dates as illustrated in Figure 4. These results would indicate that a constant gradient of fecal pollution would not occur within the disposal areas because there is not a constant center of sewage inflow. The counts would fluxuate according to the proximity and time of the latest dump and the persistence of the coliform bacteria in the sediment.

Table 11. Analyses Of Sediments For Coliform Bacteria
Cruise D-71-9 June 22-24, 1971

Station No.	Station Location	MPN/100 gm Total Coliform	MPN/100 gm Fecal Coliform
	NEW YORK BIGHT		
59	East-West transect in the sewage	172	33
4	sludge disposal area	240	79
70		49,000	13,000
39	East-West transect across the	49	23
82	dredge spoils dump. Station 36	27,000	2,700
64	is not in dump area, just off	2,100	22
36	New Jersey Coast	5	0
B2	North-South transect on western	348	13
59	edge of sewage sludge dump	172	33
G2		172	13
	BARNEGAT BAY		
88	Control site	33	0
	DELAWARE BAY		
FLR	Disposal Area	33	17
D5		0	0
BWFA		2	2
BWFB		0	0

Table 12. Analysis Of Sediments For Coliform Bacteria
Cruise 1DE2, November 29-December 1, 1971

Station No.	Station Location	MPN/100 gm Total Coliform	Fecal Coliform
	NEW YORK BIGHT		
59	East-West transect in the sewage	2,200	790
4	sludge dump area	49,000	7,000
70		27,000	2,700
A9	North-South transect on eastern edge	109,000	24,000
D9	of sewage sludge dump	542,000	46,000
G9		4,900	2,200
14	Between both disposal areas	9,400	9,400
82	North-South transect to the center of	130	13
Y00	dredge spoils dumping area at	1,700	220
Y0000	station 82	790	94
V00	North-South transect-Northeast of	790	109
V0000	station 82	790	130
558	Hudson Gorge - location unknown	170	14
556		1,700	490
	DELAWARE BAY		
FLR	Disposal area	2	0
D5		6	0
BWFA		0	0
BWFB		0	0
	N.Y. BIGHT OUTFALLS		
BELMAR	Off New Jersey Coast	17	5
ASBURY		49	5
DEAL		3,300	1,090

Table 13. Analysis Of Sediments For Coliform Bacteria
Cruise D-72-7 March 13-16, 1972

Station No.	Station Location	MPN/100 gm Total Coliform	Fecal Coliform
	NEW YORK BIGHT		
103	North South transect - 4 to 7 miles	130	11
62	north east of the center of the	49,000	1,300
65	sewage sludge dump area	2,400	130
(9)	North South transect between sewage	240	33
14	sludge and dredge spoils dump areas	130	23
(11)		790	46
90	5.5 miles north-west of sewage sludge dump center	790	22
70	Center of sewage sludge dump	2,400	490
101	8 miles north of sewage sludge dump center	110	2
(12)	East-West transect of beginning of Hudson	490	79
BA BUOY	Gorge 5 miles south of station 70	22,100	2,200
(14)		130	17
561	East-West transect each side of Hudson	49	13
562	Gorge 10 miles south of station 70	330	240
1383	Hudson Gorge 15 miles south of station 70	240	79
(21)	Hudson Gorge - station 21 is 20 miles south of station 70, other station's location unknown	1,700	790
(23)		7	4
(25)	These stations are located south of	0	0
(26)	station 21 (see Fig. 4)	2	0
(28)		0	0

Table 14. Analysis of Sediments For Coliform Bacteria
Cruise D-72-11 April 4-6, 1972

Station No.	Station Location	MPN/100 gm Total Coliform	MPN/100 gm Fecal Coliform
	NEW YORK BIGHT		
400		0	0
401		0	0
402		0	0
403		0	0
404		0	0
405		0	0
406		2	0
407		0	0
408		0	0
409	A proposed alternative disposal site,	0	0
410	sampling area is 4 square miles	0	0
411	centered on station 412, located at BW	0	0
412	buoy "NB"	0	0
413		0	0
414	40° 25.6'N 73° 11.4'W	0	0
415		0	0
417		0	0
418		0	0
419		0	0
420		0	0
421		0	0
422		0	0
423		0	0
424		0	0

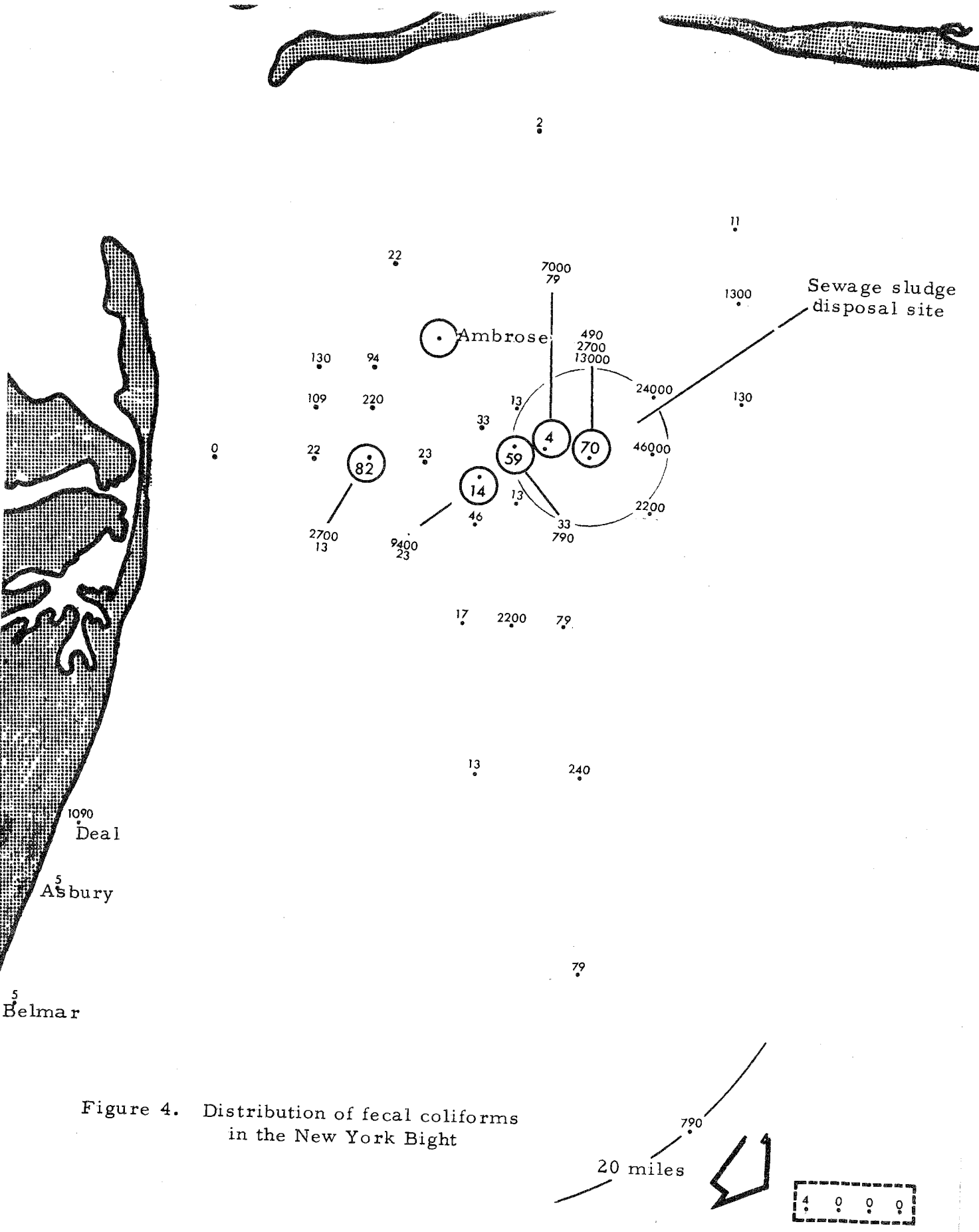


Figure 4. Distribution of fecal coliforms in the New York Bight

The limited number of stations presently sampled and shown in Figure 4 would indicate an area 6 to 7 miles in circumference around station 59 has been affected by fecal contamination. There is also an indication that fecal contamination occurred down the Hudson gorge to a point (station 21) 20 miles south of station 59. Transects across the gorge also showed the highest counts at the gorge center.

A proposed alternative site for the disposal of sewage sludge at Whistle Buoy "NB" was sampled before dumping initiated. Sediments collected from 24 stations in a 4 square mile area centered on BW buoy "NB" showed no significant coliform counts as seen in Table 14. Coliform counts from the Delaware Bay disposal site were also negligible (Tables 11 and 12) and only high from 1 of the 3 sewage outfalls sampled, as shown in Table 12.

OTHER MICROBIOLOGICAL STUDIES ON NEW YORK BIGHT AND LONG ISLAND DUMP SITES

Although the primary emphasis was placed on the fecal contamination in sediments from this area, additional studies on the presence of toxin producing anaerobes were also initiated. To date, 164 primary enrichment cultures from 58 sediments, 60 fish and 20 crabs have been produced in our cooked meat media and tested for toxicity. Of these cultures, supernatants from 13 were toxic to mice, that is, all mice injected died and 11 were questionable in that not all mice died on each test. Time has not permitted the identification of the toxic factor. Some of the mice observed had characteristic symptoms associated with botulism. However, many had symptoms that were non-specific and non-definitive.

Nine sediment samples from the Long Island dump site produced 1 culture toxic for mice and 1 of questionable toxicity.

SUMMARY AND RECOMMENDATIONS

The results obtained from the analyses of 79 sediment samples taken from various stations in the sewage dump site and control area of the New York Bight indicate variable distribution and relative numbers of total and fecal coliforms. Numbers obtained from this study show virtually negligible or no coliforms in sediments from control areas to a high of 542,000 total and 46,000 fecal coliforms per 100 grams of sediment from station D-9.

The variable ratio of total fecal coliforms indicates the periodic addition of sewage into the dump site area. The results obtained from three sampling dates between June and December 1971 support this observation. The finding of a relatively high coliform count some 20 miles distance from the center of the dumping area indicates the persistence of the organisms and possible migration of the bottom sediments. Areas somewhat peripheral from the center of the dump site would, therefore, be subject to fecal contamination.

The results of this study indicate that additional analyses of sediments from the center of the dump site would only give additional numbers. Other on-going studies by other groups and government agencies are sufficient and do not warrant the expenditure of additional time and effort for extensive sampling of this coliform bacteria.

In order to round off our study, we propose, in reference to distribution, to determine relative numbers of coliforms in peripheral areas, especially those areas in which previous results show that concentrations may occur.

Of more importance to our program objectives would be to determine the effect that waste disposal has on enhancing, suppressing or selectively changing the indigenous bacterial flora (this includes both aerobic and anaerobic organisms - with emphasis on the latter since data is lacking) of the water, sediments and marine organisms, and to determine whether these bacteria can act as obligate or facultative pathogens of fish, shellfish or food chain organisms. Primary attention, by use of enrichment and selective media, will be placed on the demonstration of the Clostridium, Vibro and Pseudomonas groups of organisms, since evidence indicates their possible involvement. In addition, isolation and identification of major group types will follow. Areas to be sampled and compared are the New York Bight, Long Island Sound, Chesapeake Bay and North Atlantic areas. These areas have been selected not only because of accessibility through the Center's facilities, but they pose unique features in regard to environmental characteristics. In addition, previous studies show that they do have unique microbiological problems in reference to those microorganisms in which we have an interest.

In addition to the problems related to the microbial hazard on the living marine resources program, planning in regards to microbial ecology, especially as related to microbiological conversion mechanisms, is under consideration. Experimental evaluation of techniques is needed, especially the relationship of in-situ and mock-up laboratory studies. In part, this study will be integrated with the environmental chemistry group, since chemical analyses will be required for the determination of chemical activities of the microorganisms.

For the above, recommendations in reference to techniques and problem approaches have not been considered, since they will be covered in other planning documents for microbiology.

Table 15. Water Quality Analysis - Choptank River

	Phenol mg/l	Grease, Oil, Petroleum mg/l	Total Chromium mg/l Cr	Zinc mg/l Zn	Lead mg/l Pb	Mercury mg/l Hg	Copper mg/l Cu	Cadmium mg/l Cd	Total Kjeldahl Nitrogen mg/l N	Orthophosphate mg/l PO_4	Nitrite mg/l NO_2	Nitrate mg/l NO_3	Total Organic Carbon mg/l C
Denton (surface)	<0.05	1.2	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.03	0.65	0.031	1.62	11
Denton (bottom)	<0.05	1.2	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.68	0.51	0.029	1.59	12
Fowling Cr. (surface)	<0.05	1.6	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.79	0.39	0.034	2.46	10
Fowling Cr. (bottom)	<0.05	1.6	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.40	0.36	0.035	2.45	9
Tuckahoe Cr. (surface)	<0.05	7.8	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.78	0.39	0.031	2.39	9
Tuckahoe Cr. (bottom)	<0.05	1.2	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.31	0.36	0.034	2.46	11
Hunting Cr. (surface)	<0.05	6.8	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.68	0.40	0.034	1.86	9
Hunting Cr. (bottom)	<0.05	1.2	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.79	0.39	0.031	1.65	13
Warwick R. (surface)	<0.05	2.0	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	0.56	0.23	0.027	1.21	8
Warwick R. (bottom)	<0.05	2.8	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	0.05	0.20	0.024	1.09	9
Cambridge (surface)	<0.05	6.4	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.21	0.20	0.024	0.95	10
Cambridge (bottom)	<0.05	3.2	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	0.93	0.16	0.024	0.73	8
Howell Pt. (surface)	<0.05	5.6	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.59	0.16	0.024	0.76	10
Howell Pt. (bottom)	<0.05	4.8	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.90	0.13	0.023	0.75	9
Benoni Pt. (surface)	<0.05	4.0	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.49	0.13	0.027	0.56	16
Benoni Pt. (bottom)	<0.05	4.8	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.01	0.08	0.024	0.39	9
Cook Pt. (surface)	<0.05	7.6	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.59	0.07	0.027	0.43	7
Cook Pt. (bottom)	<0.05	34.0	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.21	0.13	0.024	0.45	6
Double Mills (surface)	<0.05	28.0	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.03	0.10	0.027	0.20	9
Double Mills (bottom)	<0.05	28.0	<0.05	<0.05	<0.25	<0.0001	<0.05	<0.05	1.03	0.12	0.026	0.19	7

salinity, secchi disc visibility, and apparent color. Turbidity and pH analyses were conducted in the laboratory. Measurements such as these allow us to determine the salt-fresh water interface. Precipitation at this point entraps organic material and silt which are carried to the bottom and form a sink for pesticides, heavy metals, and nutrients.

Finfish collections were obtained from both rivers on a monthly basis utilizing a 25-foot semiballoon trawl with a 1/2-inch stretch mesh liner. Monthly trawl surveys revealed that the Choptank and Wicomico Rivers are utilized as nursery or spawning grounds for several important commercial fish species. The Choptank and Wicomico Rivers support large numbers of juvenile weakfish, *Cynoscion regalis*, during the summer months; no adults were taken in the rivers. Concurrent sampling in near offshore waters of Maryland and Virginia disclosed large numbers of adult weakfish. In addition, shad, herring, white perch, striped bass, and spot were taken in considerable numbers and at various stages of their life cycle.

A general survey of benthic fauna was conducted on the Wicomico with a more intensive study implemented on the Choptank. A Ponar dredge was employed on a quarterly sampling regime along a series of transects in the Choptank River and the benthic fauna was preserved, sorted and identified.

Grab samples with a Ponar dredge were taken to determine the distribution of sediments in the Choptank River. Sediment samples are being analyzed for sand-silt-clay ratios and grain size. The distribution of the sediment patterns will be mapped for a 40-mile reach of the Choptank. It will then be necessary to correlate the distribution of benthic organisms with substrate type.

STUDIES OF PHYSIOLOGICAL STRESS - WATER QUALITY
MILFORD LABORATORY

Water quality problems have plagued seawater supply systems in marine laboratories and aquaria. These facilities require large quantities of organic-free water for the culture and rearing of marine animals and plants. During certain seasons seawater utilized by these facilities may become contaminated by toxic phytoplankton by-products, such as "red tide" metabolites. Also, the presence of pathogenic marine microorganisms can cause disease and mortality to marine organisms held in recirculated seawater. Open circuit seawater systems are subject to fouling within the piping by marine invertebrates. In response to such a problem at the Milford Laboratory, an investigation was undertaken to determine the feasibility of ozone gas oxidation of undesirable marine microorganisms and the inactivation of toxic phytoplankton by-products from the seawater supply system.

A lab-scale prototype ozonation system was built to determine the efficiency of microorganism kill and possible injurious effects of previously ozonated water on oyster larvae. In this dual stage system the first stage consisted of an 8-liter oxidation chamber where flowing seawater passed through a direct current ozone air-stripping device. The second 20-liter stage allowed the residual ozone to bubble out, while the seawater effluent drained from the bottom of the container.

A 220-liter continuous flow prototype ozone reacter to test laboratory results on a larger scale was then implemented and found to be successful. Since this system proved to be effective, it was decided that the laboratory as a whole should be equipped with an ozonation treatment

system. Using seawater tank facilities already available in the laboratory, an ozonation treatment system producing 10,000 gallons of ozonated seawater per day was assembled. A sketch of the completed treatment system is shown in Figure 5. The ozone treatment of seawater produces the following:

1. Removal of dissolved organics.
2. Oxidation of complex organics including some herbicides and pesticides.
3. Reduction in silt and suspended solids.
4. Reduced maintenance by eliminating periodic treatment of plumbing system for fouling organisms.
5. Production of constant quality seawater essentially free of organic compounds. (99% removal).
6. A significantly reduced bacterial load (99.9% removal).
7. Elimination of toxic metabolites from phytoplankton blooms.

Development of an ozonation treatment system lead to two further studies: (1) The effect of ozone-treated seawater on the spawned, fertilized, meiotic and cleaving embryos of the American Oyster, Crassostrea virginica and (2) Ozone inactivation of a marine dinoflagellate, Gymnodinium breve, toxin.

In studies on the effect of ozone-treated seawater on oyster embryos, the same male and female oysters were first spawned in non-ozonated and then in ozone-treated seawater. The ozone treated water was not carbon filtered and contained active chemical radicals. Eggs were fertilized in the ozone-treated and control water and some of them were then fixed in Carnoy's solution at intervals up to 2 hours after fertilization.

Unfertilized eggs spawned in the control and ozone-treated water showed no cytological differences. Fertilization occurred less readily in the treated water, as evidenced by a lower incidence of polyspermy and

Figure 5. Sketch of completed seawater ozonation treatment system for improving water quality at the Milford Laboratory.

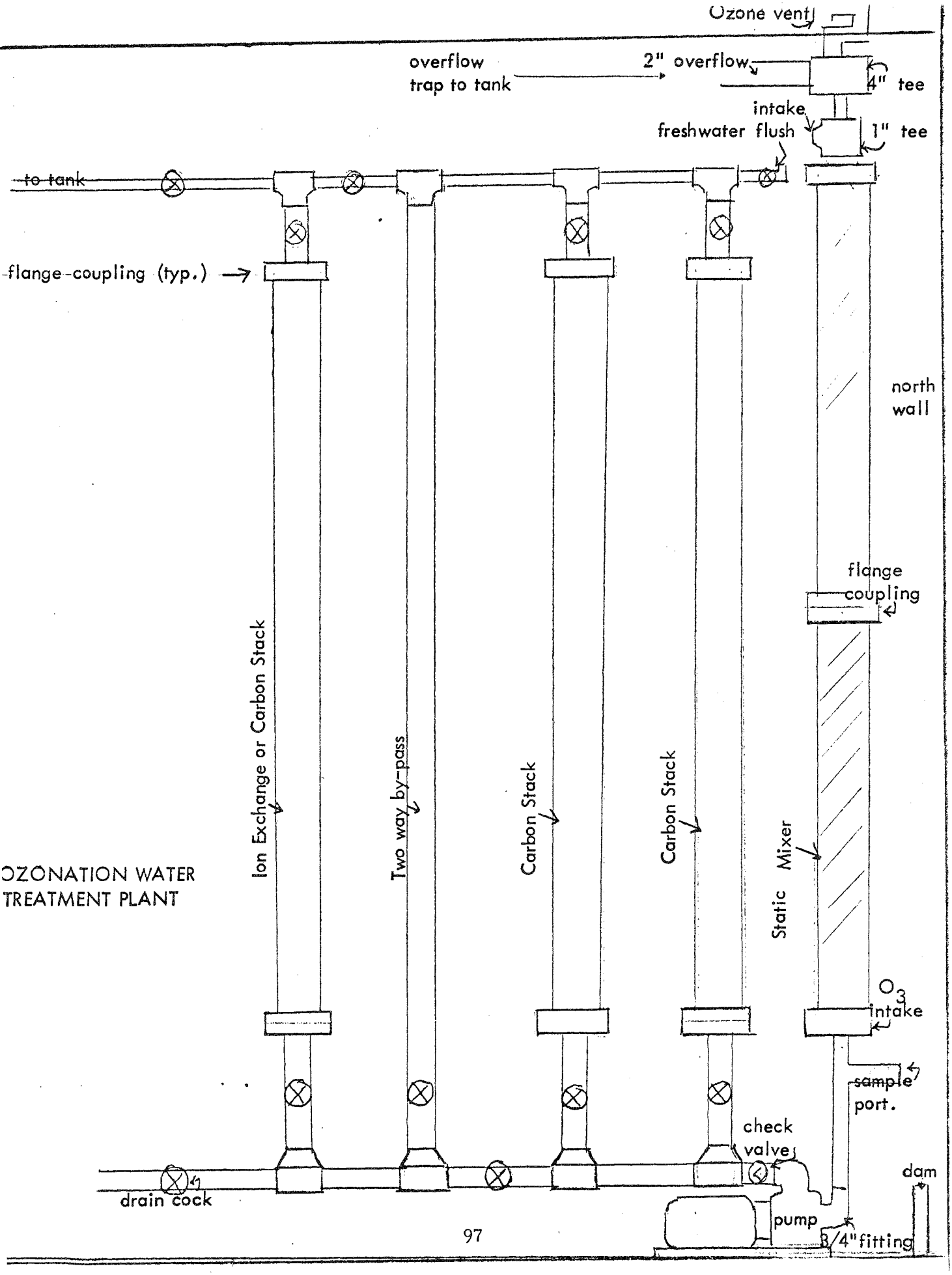

Ozone vent
overflow
trap to tank
2" overflow
4" tee
intake
freshwater flush
1" tee
to tank
flange-coupling (typ.)
north
wall
flange
coupling
Ion Exchange or Carbon Stack
Two way by-pass
Carbon Stack
Carbon Stack
Static Mixer
OZONATION WATER
TREATMENT PLANT
O_3
intake
sample
port.
check
valve
dam
drain cock
pump
3/4" fitting

Table 16. Effect of ozone-treated seawater on the spawned, fertilized, meiotic and cleaving eggs of the commercial American oyster.

Condition or effect scored	Eggs spawned, fertilized and held in control seawater		Eggs spawned, fertilized and held in ozone-treated seawater	
	Percent Eggs scored	Total number eggs scored	Percent eggs scored	Total number eggs scored
Polyspermy	9.0	400	1.75	400
Parthenogenesis	9.0	200	18.0	200
Retarded meiosis and cleavage	12.5	200	28.0	200
Irregularity of polar bodies	5.0	400	16.0	400
Abnormal cleavage nuclei	19.5	200	41.5	200

increased incidence of parthenogenesis. This was also indicated by the larger numbers of eggs retarded in their completion of meiosis. There was a much increased incidence of abnormal polar bodies in the ozonated water. Most prominent in the ozone-treated water were the large numbers of cleaving eggs with abnormal nuclei. These nuclei showed signs of metabolic difficulties or of degeneration, and were pyknotic, pale, diffuse or even fragmented. Results are summarized in Table 16.

The background incidence of abnormalities in the control sample was partly accounted for by the out-of-season spawning of these oysters. The oyster, however, almost invariably shows a comparatively high incidence of early development problems. While some of its extreme zygotic wastefulness must be inherent in a species as the oyster, which produces such a superabundance of eggs, another part of it must certainly derive from impurities in the seawater.

Just how much of the ozone and the products of its decomposition remained in the seawater by the time the oyster eggs were spawned in it was uncertain. Some part of the measured differences between the eggs from the control and treated water may have been due, not to the ozone, but rather to the by-products of its oxidation of impurities in the water. To a great extent these active radicals can be removed by running the ozonated water through an activated charcoal column.

Experience at Milford with ozone-treated seawater indicates that ozonation does improve survival and growth of the oyster larvae that do develop normally from the egg. Work reported here indicates that the probable mutagenic effects of water purification processes on critical stages of meiosis, fertilization and cleavage though should not be overlooked in designing and using water purification systems for marine

contaminant studies.

In studies on the inactivation of the toxin of the dinoflagellate, Gymnodinium breve, the toxic material extracted from this species was obtained as a powder and suspended in mammalian saline (Ringer-Locke's solution) and injected intraperitoneally into white mice. A similar preparation was suspended in seawater and injected intraperitoneally into killifish, Fundulus heteroclitus. After data were obtained on the toxicity of the sample, the material was subjected to ozonation.

The results of ozonation of Gymnodinium breve toxin, as tested by mouse and fish injection, are shown in Table 17. The toxin (6.0 mg/ injection) had an initial toxicity sufficient to kill all the mice in 7-9 minutes. A series of ozone doses (20,40,65,110 ml/min) produced a progressive inactivation of toxic properties with a concomitant loss of the solution's yellow-green color. The final dose of 110 ml/min was sufficient to render the material non-toxic to mice.

Twenty-five fish were injected with untreated toxin and all died within 15-30 minutes. A second group of 25 fish was injected with ozonated (110 ml/min) toxin. The results were 2 deaths after 4-6 hours, and 23 fish still alive when the experiment was terminated a week later.

Red tides, widespread or local, occur in marine waters throughout the world. Toxic metabolites produced by some red tide organisms present potential water quality problems to those facilities which depend on raw seawater for maintenance of marine organisms. Such problems are of particular concern to facilities which rear larval marine forms as they are especially sensitive to changes in water quality. This study has demonstrated the potential use of ozone water treatment as a method of detoxifying red tide water. Studies with other dinoflagellate toxins

Table 17. Reduction of *Gymnodinium breve* toxicity with ozone

	ml O_3/min	No. animals	Death time (min)	No. alive (48 hr)
Mice (*Mus musculus*)	110	10	--	10
	65	10	146-178	8
	40	5	96-166	2
	20	5	18-40	0
	0	10	7-10	0
Killifish (*Fundulus heteroclitus*)	110	25	240-360	23
	0	25	15-30	0

are indicated, as well as large-scale studies during actual red tide blooms.

The importance of an ozonation treatment system at the Milford Laboratory and any other marine laboratory having problems with seawater quality is quite obvious. By having such a system, we have greatly increased our holding capacity for maintaining fish and invertebrates in the laboratory under controlled conditions and have also improved our capabilities for rearing invertebrate embryos and larvae.

STUDIES OF PHYSIOLOGICAL STRESS - LIFE HISTORY
MILFORD LABORATORY

For conducting bioassay studies on the embryonic and larval stages of shellfish, it is necessary that these life forms be available on a continual basis during all seasons of the year so as to provide the researcher the necessary material for such studies.

The techniques for rearing embryos and larvae of the American oyster, Crassostrea virginica, and the hard shell clam, Mercenaria mercenaria, have been well worked out over the years at the Milford Laboratory. These organisms and their various life stages are now routinely used in studies to determine the effect of marine contaminants on marine resources (see Bioassay Section).

During the last year some data were obtained on the reproductive cycle, spawning and early development of the surf clam, Spisula solidissimma, the sea scallop, Placopecten magellanicus and the mahogany clam, Arctica islandica, three species of shellfish inhabiting the New York Bight. Surf clams were conditioned and spawned during several months of the year and the larvae reared to metamorphosis. Some preliminary observations were made on the effects of temperature on development of the eggs and larvae, and it was apparent that the eggs were adversely affected by temperature much over 15°C.

Sea scallops were also conditioned and spawned in the laboratory and the embryonic stage of development studied. Development and survival of the eggs appeared to be best at temperatures between 10°C - 15°C, but the larvae survived best at 10°C or lower. One of the puzzling aspects of larval development of the sea scallop has been their failure to grow on

the foods which have been offered them. These foods are the standard algal species which have produced growth of the larvae of over two dozen species of bivalves reared at the Milford Laboratory. Part of the reason for their failure to grow on these foods may be the fact that they do not ingest the algae readily.

Mahogany clams have ripened in the laboratory facilities, but, so far, have resisted attempts to induce them to spawn. It has been possible to strip the eggs from ripe females and, after chemical treatment, bring about fertilization with stripped sperm. Using this technique, the embryonic and larval stages of development of this species were studied. It was found that the eggs will not develop well at temperatures much over 15°C. Development was good at temperatures as low as 10°C but proceeded at a slower rate than at 15°C. The larvae grew normally at both 10°C and 15°C and at these temperatures, metamorphosis was reached in about 60 days.

A problem of general concern in the culture of all three of these species is the effects of changes in the quality of the natural seawater in which they have been reared. These effects are usually adverse and frequently prevent the development of the eggs or growth of the larvae. Because of this, comparative studies will be made of development and growth in natural seawater treated in various ways with such techniques as ozonation (see Water Quality section), ultra-violet irradiation and activated charcoal filtration. Development and growth will also be observed in artificial seawater, a medium being used increasingly by researchers in experimental marine biology.

STUDIES OF PHYSIOLOGICAL STRESS - BIOASSAY
MILFORD LABORATORY

Laboratory experiments at Milford were directed toward the evaluation of physiological stress induced by contaminants in the environment. The acute toxicity of eleven heavy metals to embryos of the American oyster, Crassostrea virginica, was studied and the concentrations at which 100, 50 and 0 percent of the embryos did not develop were determined.

The effect of heavy metals on the development of oyster embryos into normal straight-hinge larvae was determined by placing a known number of fertilized eggs (usually 15,000 to 17,000) into each of a series of 1-liter polypropylene beakers containing synthetic seawater (salinity $25^{o}/oo$) at $26 \pm 1^{o}C$. The synthetic seawater was used as a standard testing medium in place of natural seawater the composition of which varies, especially in regard to the presence of trace metals, dissolved organics and particulate matter.

The metals, tested as metallic salts, were as follows: aluminum chloride [$AlCl_3.6H_2O$]; cadmium chloride [$CdCl_2.2\text{-}1/2\ H_2O$]; chromium chloride [$CrCl_3.6H_2O$]; cupric chloride [$CuCl_2.2H_2O$]; lead nitrate [$Pb(NO_3)_2$]; manganese chloride [$MnCl_2.4H_2O$]; mercuric chloride [$HgCl_2$]; nickel chloride [$NiCl_2.6H_2O$]; silver nitrate [$AgNO_3$]; sodium arsenite [$NaAsO_2$]; and zinc chloride [$ZnCl_2$]. These metallic salts were chosen because of their solubility factor. A minimum of seven and a maximum of twelve concentrations were used for each metal tested. In preliminary tests several ranges of concentrations were used for each metal to arrive at a range of concentrations to be used in final tests.

Static tests were conducted throughout this study and all tests were initiated within one hour after the eggs were fertilized. Tests were terminated after 42 to 48 hours because known embryonic development, under normal conditions, is completed by this time. To determine the effect of metal toxicity on embryonic development, the larvae from each culture were collected on a 36-micron nylon screen. The larvae were resuspended in a 250-ml graduated cylinder and, after thorough stirring to insure uniform distribution of the larvae, a 4-ml quantitative sample was removed and preserved in 5% neutral formalin. The samples were examined under a compound microscope and the number of larvae that had developed normally was counted. The counts of samples from duplicate cultures were averaged and the results expressed as a percentage of the average number developing in control cultures. This method for determining the number of bivalve embryos developing into normal straight-hinge larvae is considered accurate to about ± 10%. The results of successive tests were then averaged and the LC_{50} value was determined by straight line graphical interpolation using logarithmic probablility paper: percent survival vs log concentration of metal. Under normal conditions in the laboratory, development of oyster embryos in repetitive tests is somewhat variable, thus it was not unexpected to find that only three of the metals tested satisfied tests of linearity. It was not feasible, therefore, to use the probit method of analysis for determining confidence limits of the LC_{50} values. The ranges of the LC_{50} values arising from the individual experiments for ten of the eleven metals tested were then determined using the same procedures as with the LC_{50} values. The LC_0 and 100 values were derived from actual observation.

The results are based on 4 tests conducted with aluminum, 6 with copper, manganese, mercury, nickel, lead, silver and zinc, 7 with arsenic, 8 with cadmium and 11 with chromium.

The acute toxicity of heavy metals to developing embryos of the American oyster is shown in Table 18. Of the metals tested, mercury and silver were toxic at extremely low levels, i.e., mercury was 100% lethal at 0.008 ppm and silver at 0.01 ppm, while the estimated LC_{50} value was 0.0056 ppm for mercury and 0.0058 ppm for silver. Copper and zinc, although not as toxic as mercury and silver, were 100% lethal to oyster embryos at 0.13 and 0.50 ppm, respectively. The LC_{50} value for copper was 0.103 ppm and for zinc, 0.31 ppm.

Although the estimated LC_{50} values derived from this study were 3.80 ppm for cadmium and 10.3 ppm for chromium, these metals were extremely difficult to work with. There was a great deal of variability in toxicity at the same concentrations in eight tests with cadmium and eleven tests with chromium, with no apparent evidence for the cause. Although there was a visible precipitate at all concentrations of chromium tested, this may not have been the reason for the variability between tests. Even at 13.0 ppm, the highest concentration tested, an average of 22.6% of the embryos were able to develop normally in the presence of a substantial amount of precipitate. It was not possible to test concentrations of chromium greater than 13.0 ppm because of the low pH level (6.5) reached at such high concentrations, a pH level which inhibits normal development of oyster embryos.

Nickel and lead were relatively toxic, while arsenic, manganese and aluminum were relatively non-toxic. The estimated LC_{50} value for

Table 18. Toxicity of heavy metals to oyster embryos within 48 hours at 26°C in synthetic seawater (25°/oo salinity). The values are in parts per million added to medium at start, producing mortality of 0, 50 and 100 percent (LC_0 and LC_{100} are actual values and LC_{50} is estimated).

Metal	LC_0	LC_{50}	Range of Mean LC_{50}	LC_{100}
Mercury	0.001	0.0056	0.0042 - 0.0068	0.008
Silver	0.003	0.0058	0.0046 - 0.0064	0.01
Copper	0.08	0.103	0.098 - 0.110	0.13
Zinc	0.075	0.31	0.22 - 0.37	0.5
Nickel	0.1	1.18	0.74 - 1.50	3.0
Lead*	0.5	2.45	2.20 - 3.60	---
Cadmium	1.0	3.80	2.85 - 4.48	6.0
Arsenic	3.0	7.50	5.42 - 9.10	12.0
Chromium*	---	10.3	5.3 - 12.8	---
Manganese	5.0	16.0	14.2 - 19.1	25.0
Aluminum*	7.5	---	--- ---	---

* These metals formed a visable precipitate

nickel was 1.18 ppm and for lead, 2.45 ppm. The LC_{100} value for arsenic was established as 12.0 ppm, while the LC_{50} value was 7.50 ppm. The LC_{50} value for manganese was 16.0 ppm and the LC_{100} value, 25.0 ppm. Aluminum, on the other hand, did not inhibit embryonic development of oysters at a concentration of 7.5 ppm. At concentrations of aluminum greater than 7.5 ppm problems with precipitate and low pH were encountered so it was not possible to determine toxicity at higher levels.

Using methods similar to those with studies of the oyster, experiments were conducted to determine the effect of five heavy metals, namely mercury, silver, zinc, nickel and lead, on development of embryos of the hard shell clam, Mercenaria mercenaria. The acute toxicity of silver, zinc, nickel and lead has been determined, but further studies must be conducted with mercury to obtain definite conclusions.

Of the metals tested, mercury (preliminary data) and silver were the most toxic. Mercury was 100% lethal at 0.008 ppm and silver at 0.045 ppm (Table 19). The estimated LC_{50} value for silver was 0.021 ppm. Zinc and nickel, although not as toxic as mercury and silver, were 100% lethal to clam embryos at 0.25 and 0.60 ppm, respectively, while the estimated LC_{50} values were 0.166 and 0.31 ppm. Lead was the least toxic of the metals tested, although the toxicity of this metal is still great in that it was 100% lethal at 1.2 ppm.

These data indicate that clam embryos are more sensitive than oyster embryos to zinc, nickel and lead, less sensitive to silver, and as sensitive to mercury (Table 20).

Table 19. Toxicity of heavy metals to hard clam embryos at 26°C in synthetic seawater (25°/oo salinity). The values are in parts per million added to medium at start, producing mortality of 0, 50 and 100 percent (LC_0 and LC_{100} are actual values and LC_{50} is estimated)

Metal	LC_0	LC_{50}	Range of LC_{50}	LC_{100}
Mercury	0.002			0.008
Silver	0.010	0.021	0.019-0.025	0.045
Zinc	0.095	0.166	0.138-0.175	0.25
Nickel	0.10	0.31	0.28 -0.33	0.60
Lead	0.40	0.78	0.72 -0.80	1.20

Table 20. Toxicity of heavy metals to oyster and hard clam embryos at 26°C in synthetic seawater (25°/oo salinity). The values are in parts per million added to medium at start, producing mortality of 0, 50 and 100 percent (LC_0 and LC_{100} are actual values and LC_{50} is estimated)

Metal	LC_0		LC_{50}		LC_{100}	
	Clams	Oysters	Clams	Oysters	Clams	Oysters
Mercury	0.002	0.001		0.0056	0.008	0.008
Silver	0.010	0.003	0.021	0.0058	0.045	0.01
Zinc	0.095	0.075	0.166	0.31	0.25	0.5
Nickel	0.10	0.10	0.31	1.18	0.60	3.0
Lead	0.40	0.50	0.78	2.45	1.20	>6.0

It would now be necessary to study the effect of these same heavy metals on larvae of the American oyster and hard shell clam and also the combined effects of these metals on these life stages. A distinction is made between developing embryos and the fully formed larvae because quite often the tolerance of these two pelagic stages to a given toxicant is markedly different.

Moreover, growth of the fully developed larvae may be drastically retarded at concentrations of toxicant too low to cause direct mortality of either embryonic or larval stages. Such a retardation of growth would serve to prolong the pelagic life of the larvae and, thus, increase their chance of loss through predation, disease and dispersion. From the information given one can deduce that with some metals it would require such high concentrations to affect recruitment of this species in large bays and estuaries that metal ion pollution may not be a serious problem. This may be misleading, however, because, depending on the hydrography of a particular body of water, these pollutants may remain localized and, therefore, concentrated. A problem that would also have to be considered is the effect of a combination of pollutants in an area; the interaction of a combination of metals may enhance the toxicity of any one particular metal to bivalves.

STUDIES IN PHYSIOLOGICAL STRESS - PHYSIOLOGY
MILFORD LABORATORY

Many estuarine animals are able to regulate their blood serum solute levels over a broad range of salinities which allows such animals to utilize broad areas of estuarine environments. Any alteration in this regulatory pattern might indicate an inability of such organisms to utilize the full range of their normal habitat.

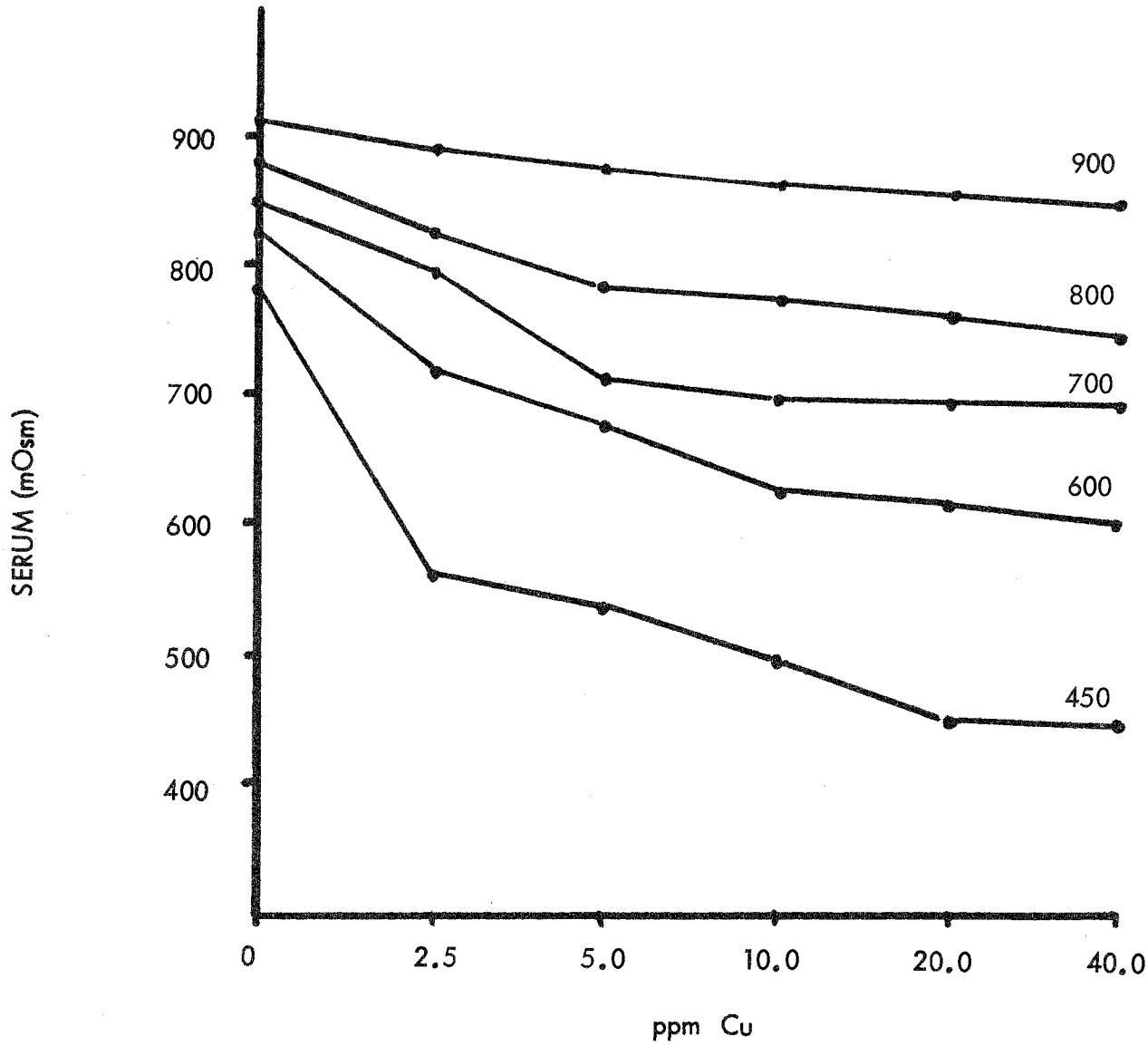
Laboratory experiments were initiated at the Milford Laboratory to evaluate the effects of copper and cadmium on osmoregulation and respiration of two estuarine crabs. Green crabs, *Carcinus maenas*, and rock crabs, *Cancer irroratus*, were exposed to controlled amounts of copper and cadmium at various salinities.

Green crabs were exposed to copper concentrations of 2.5, 5.0, 10.0, 20.0 and 40.0 ppm and cadmium concentrations of 0.5, 1.0, 2.0, 4.0 and 8.0 ppm. Rock crabs were exposed to copper concentrations of 0.34, 0.67, 1.25, 2.5 and 5.0 ppm. Tests of each metal concentration were conducted at salinities of 450, 600, 700, 800 and 900 milliosmoles (mOsm) or equivalent to 15 to 34 parts per thousand salinity.

Six green crabs were exposed to each metal concentration at each salinity and a control series was maintained. After a 48-hour exposure, each crab was removed, a blood sample drawn, and gill tissue removed for oxygen consumption studies.

The osmoregulatory changes induced by copper are summarized in Figure 6. Green crab serum is normally hyperosmotic to the surrounding medium at the salinities tested. Copper reduced the normal osmolality of green crab serum markedly. A concentration of 2.5 ppm reduced the

Figure 6. Effects of copper on osmoregulation of Carcinus maenas. Each point is the average serum osmolality, in milliosmoles (mOsm) of six crabs. Each line is an experiment conducted at a different salinity expressed in milliosmoles.



normal osmotic value of 780 mOsm value to less than 500 mOsm. At all salinities tested the serum became isosmotic with the surrounding seawater after exposure to 10-20 ppm copper. This indicated a complete loss of regulatory ability so that the serum was passively conforming to the salinity of the surrounding medium. When gill tissue was placed in a Gilson Respirometer to measure oxygen consumption, no effects due to copper were noted. These findings are summarized in Figure 7.

The serum osmolality of green crabs exposed to cadmium were elevated after a 48-hour exposure. The results obtained from this experiment are summarized in Figure 8. Cadmium reduced the level of oxygen consumption and these data are presented in Figure 9.

Rock crabs exposed to copper exhibited a decrease in serum osmolality. This species is about 10 times more sensitive to copper than the green crab. The normal osmoregulatory pattern of the rock crab approaches osmoconformity as salinity is increased; one would expect the greatest copper induced changes in osmotic regulation to occur at lower salinities; Figure 10 shows this to be the case. The changes in rate of oxygen consumption for rock crabs exposed to copper are being evaluated at this time.

A study of the effects of local red tide metabolites on shellfish embryos has led to a water quality project on ozone inactivation of dinoflagellate toxins. The poison from Gymnodinium breve, the Florida red tide dinoflagellate, has been successfully inactivated by ozone treatment as tested by mouse and fish injection. A more detailed summary of this cooperative study is presented in the Water Quality section.

Figure 7. Effects of copper on oxygen consumption of Carcinus maenas. Each point is the average oxygen consumption value (μlO_2/mg dry wt/hr) of six crabs. Each line is an experiment conducted at a different salinity expressed in milliosmoles (mOsm).

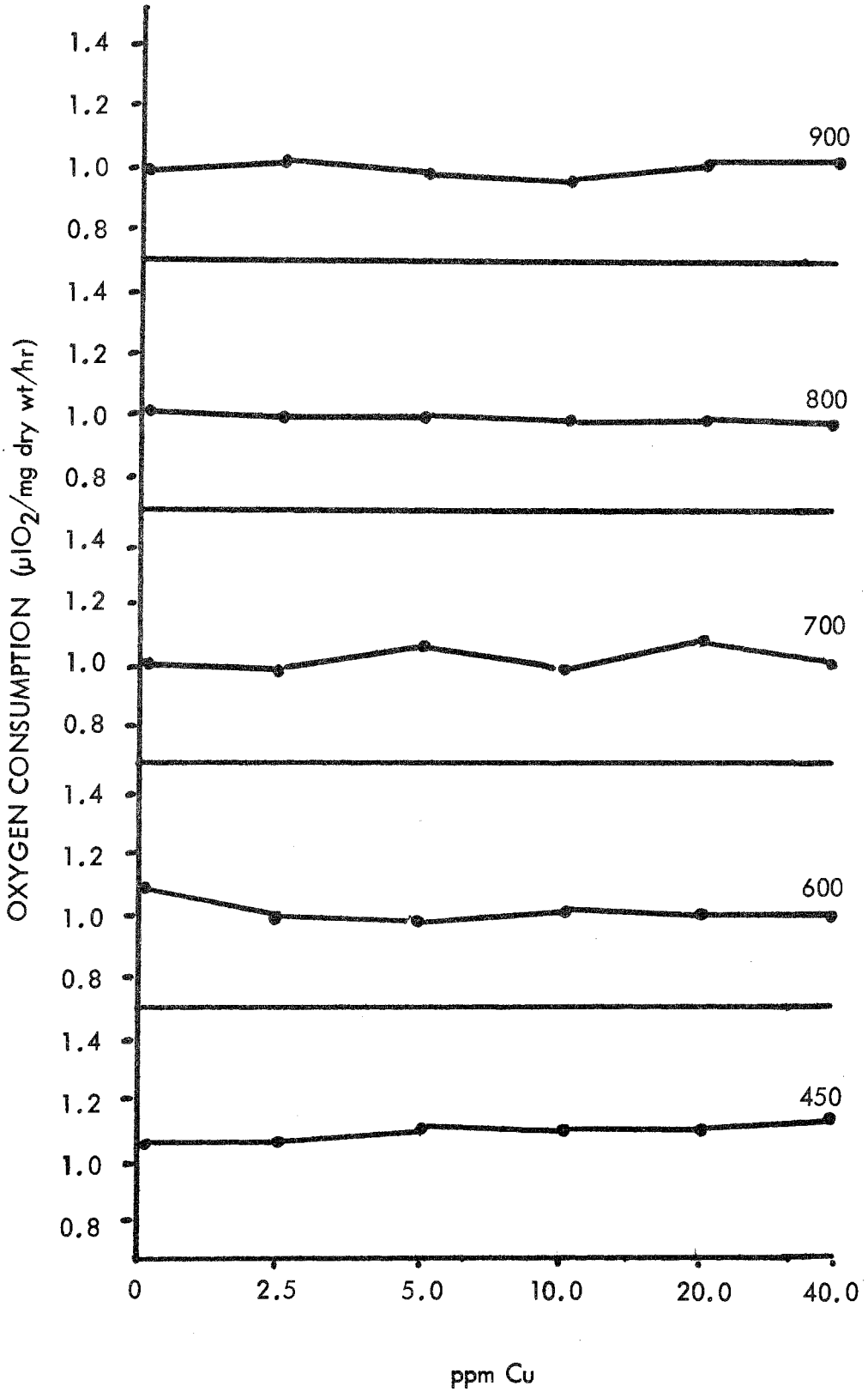


Figure 8. Effects of cadmium on osmoregulation of Carcinus maenas. Each point is the average serum osmolality, in milliosmoles (mOsm) of six crabs. Each line is an experiment conducted at a different salinity expressed in milliosmoles.

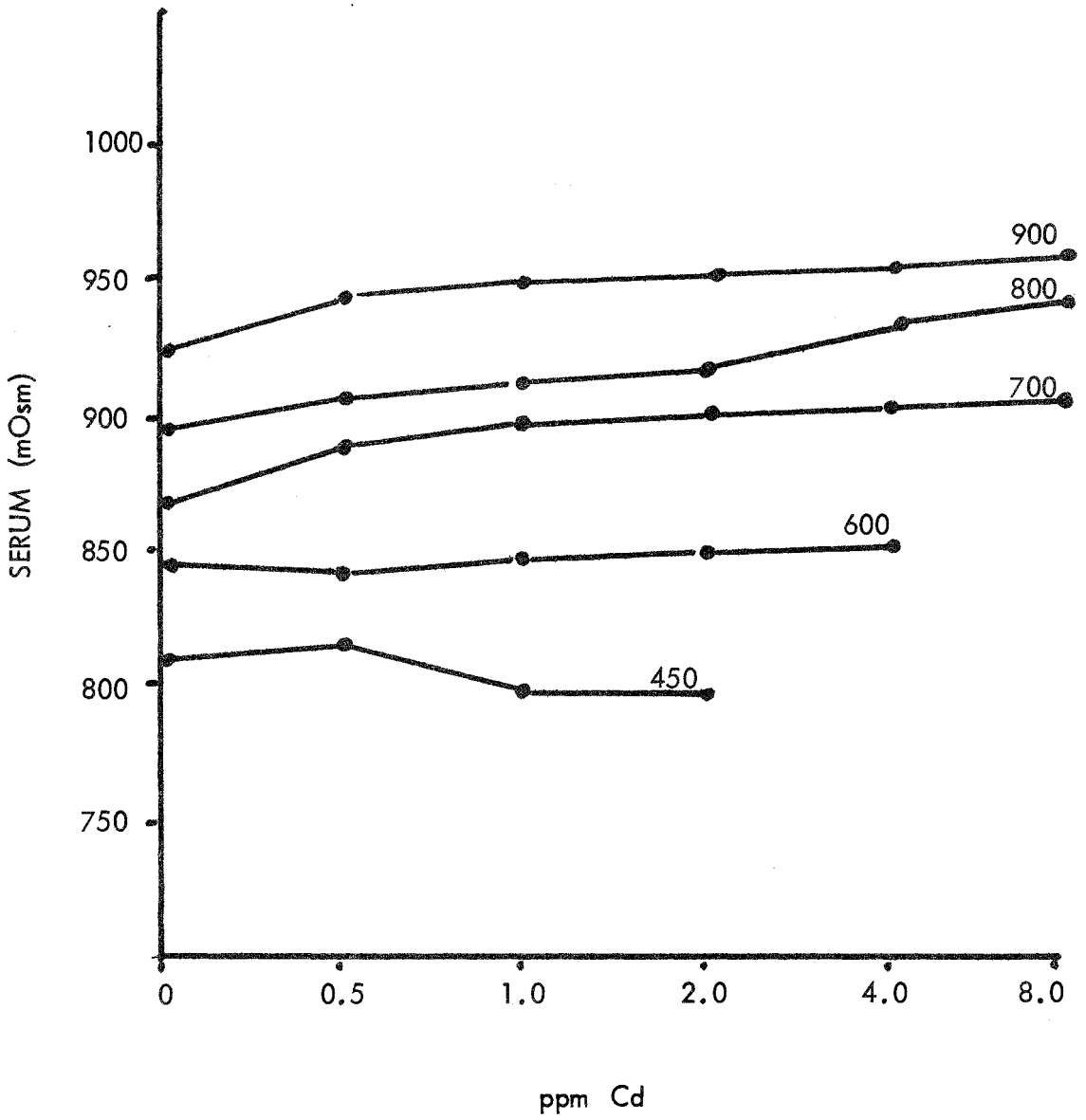


Figure 9. Effects of cadmium on oxygen consumption of Carcinus maenas. Each point is the average oxygen consumption value ($\mu l O_2$/mg dry wt/hr) of six crabs. Each line is an experiment conducted at a different salinity expressed in milliosmoles (mOsm).

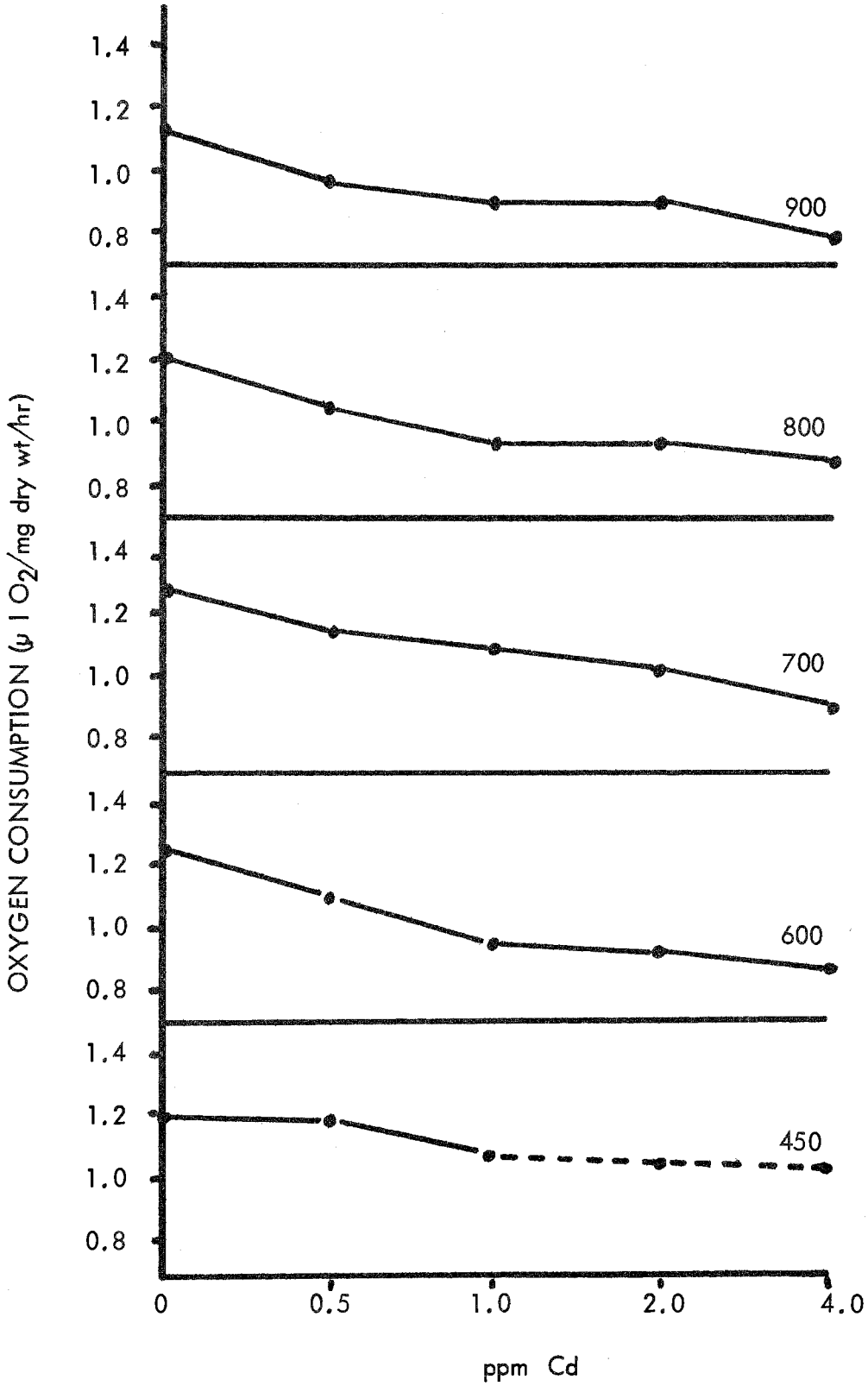
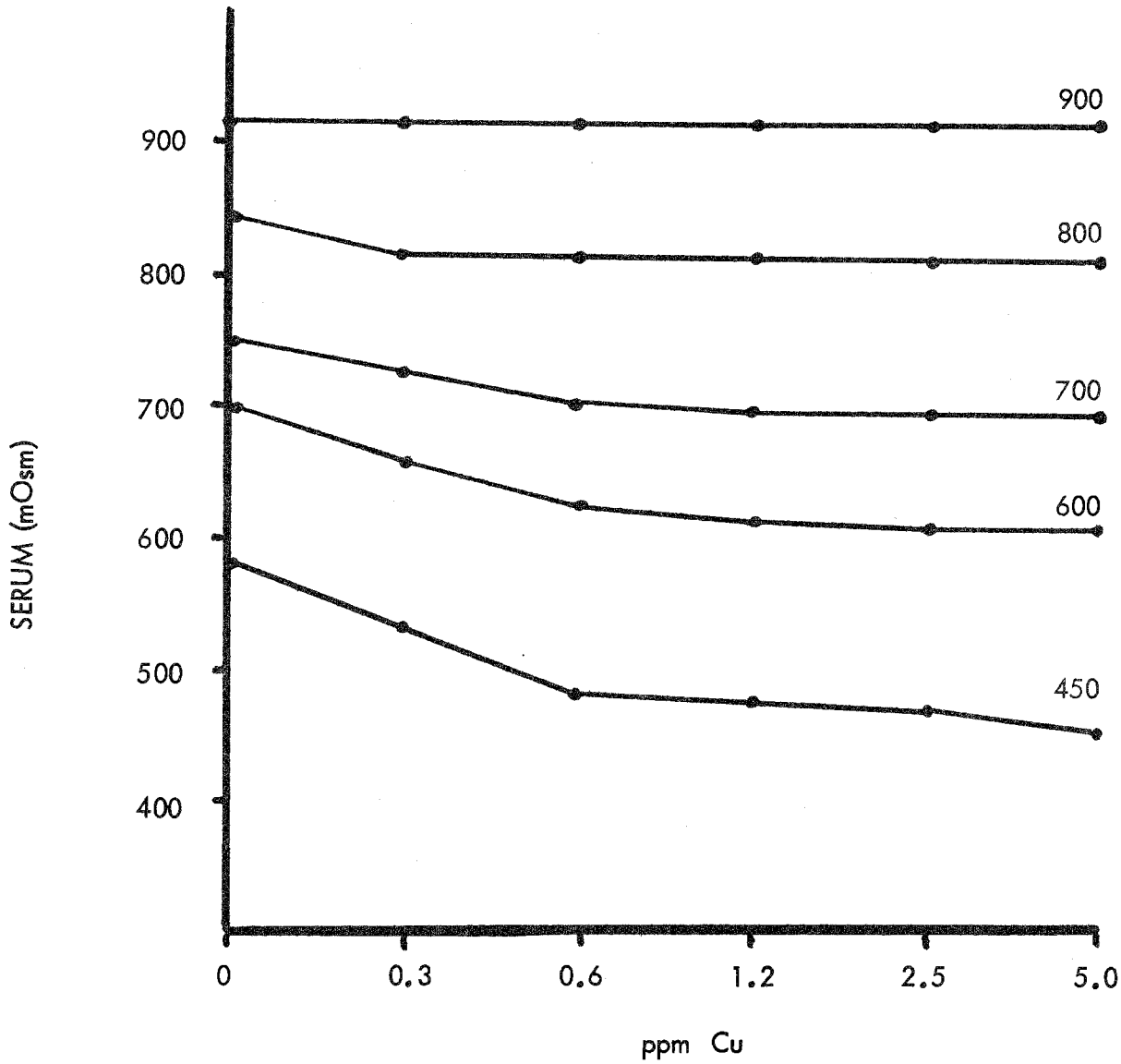


Figure 10. Effects of copper on osmoregulation of Cancer irroratus. Each point is the average serum osmolality, in milliosmoles (mOsm) of six crabs. Each line is an experiment conducted at a different salinity expressed in milliosmoles.



STUDIES OF PHYSIOLOGICAL STRESS - BIOCHEMISTRY/ENZYMOLOGY
MILFORD LABORATORY

On January 10, 1972 a biochemistry project was initiated at the Milford Laboratory, as part of a broad-spectrum study of the effects of pollutants upon representative marine organisms. Its purpose is to discover significant enzymological changes in the tissues of target animals during their exposure to known amounts of selected heavy metals, and to interpret any such changes from the standpoint of biochemical adaptation or malfunction in response to the pollutant. The findings will be coordinated with concurrent studies in bioassay, physiology and histopathology.

Time thus far was spent in acquiring, ordering, and requesting the chemicals, supplies, and instrumentation necessary to a biochemical laboratory. Some exploratory work was carried out on adapting several histochemical media for use in the enzymography of rock crab, *Cancer irroratus*, blood and cunner, *Tautogolabrus adspersus*, liver. The malic enzyme protocol can be used without change, both for enzymography and spectrokinetics; other protocols will require further testing before use in a pollutant study.

PUBLICATIONS DERIVED FROM STUDIES OF PHYSIOLOGICAL STRESS

In Preparation

Blogoslawski, W. J., C. Brown, E. W. Rhodes, Jr. and M. Broadhurst. Use of ozone gas as a disinfectant in a seawater supply system.

Blogoslawski, W. J., F. P. Thurberg and M. A. Dawson. Ozone inactivation of *Gymnodinium breve* toxin.

Calabrese, A., R. S. Collier, D. A. Nelson and J. R. MacInnes. The toxicity of heavy metals to embryos of the American oyster, *Crassostrea virginica*.

Landers, W. S. Early development in the ocean quahog, *Arctica islandica*.

MacInnes, J. R., E. W. Rhodes, Jr. and A. Calabrese. A new method for obtaining measurements of bivalve larvae.

MacLean, S. A., W. J. Blogoslawski and A. Crosby Longwell, Effect of ozone-treated seawater on the spawned, fertilized, meiotic and cleaving eggs of the commercial American oyster.

Thurberg, F. P., M. A. Dawson and R. S. Collier. Effects of heavy metals on the osmoregulation and oxygen consumption of two estuarine crabs.

SUMMARY RECOMMENDATIONS OF THE TASK FORCE

1. Microbiological sampling and sediment chemistry should be continued in the New York Bight and should be expanded in Long Island Sound.
2. Laboratory studies of physiological stress imposed by marine contaminants should continue under the present format.
3. A more comprehensive and selective sampling of groundfish should be carried out on future ALBATROSS IV cruises. Such sampling should include species in which elevated mercury levels were detected. Wide spread general sampling is no longer desirable, since NMFS and other agencies are now involved in similar heavy metal surveys of fish tissue and continuation of our effort would lead to unnecessary duplication.
4. Histopathological examinations should be limited to animals exhibiting obvious pathology or animals exposed to stress conditions where a likelihood of induced pathology exists.
5. Dump site surveys should continue on Long Island Sound and in New York Bight. Due to ship limitations the Delaware Bay site has not and can not be adequately sampled and should be dropped from the study. Chemical analyses of tissues from target species should be continued but should be limited to these target species because of personnel limitations. The molluscan target species should be

expanded to include the channeled whelk, Busycon canaliculatum, a species in which elevated cadmium, silver, and zinc levels were detected. A second fish species should also be considered, which would allow the inclusion of commercial or sport fish in the list of target species.

6. An ADP program should be developed to handle previously collected and future data.

APPENDIX I

SAMPLING PROTOCOL FOR MERCURY ANALYSES

Handling of Samples

It is imperative that samples are handled in a way that no metals will be introduced into the sample to be analyzed. Whenever possible the samples should be placed on plastic covered surfaces or wooden surfaces for work-up.

I) Fish

a) Pathology samples

A portion of liver and a portion of muscle should be removed from each individual fish obtained for mercury analysis and preserved in Davidson's Fixative.* To assure adequate fixation these portions of tissue should not exceed 1 cc in volume. It is essential that the individual fish be processed as rapidly as possible so that post-mortem changes in the tissues do not occur. If the fish are too small for routine dissection under field conditions, then 10 individuals other than those taken for mercury may be preserved whole, trimmed in such a way that the liver and a portion of the muscle will be retained and fixed. After 24 hours, samples should be transferred to 70% ethyl alcohol. Tag numbers should correspond to the following mercury samples.

---

*Davidson's Fixitive

(1 gal) stock solution
400 ml glycerin
800 ml formalin
1200 ml 95% alcohol
1200 ml 15% seawater

add 1 part glacial acetic acid to 9 parts stock solution before using.

b) Mercury samples

1) Muscle - For fish roughly 2 pounds and over--cut a a "steak" (cross-section cut) out of the front portion of the fish. After removing the head, cut about a 2-inch-long chunk off for the sample. This chunk can be packaged, tagged and frozen. For fish under 2 pounds, remove a single fillet. Fish too small to dissect should be frozen whole and packaged individually

2) Liver - After removing the pathology sample where applicable, place the remainder of the liver in a plastic bag, tag it and freeze it.

II) Invertebrates Ten individual animals are needed as per the fish. Place the entire animal in a plastic bag, tag and freeze.

Tagging Procedure

Each individual animal or chunk of animal should be placed in a plastic bag and tagged with the specific code number and log reference.

If possible, the best way to ensure the tag to be legible and minimize loss of the tag is to place the tag in a separate plastic bag, tie it off and then put it in the bag with the fish sample. If this cannot be done, tie the tag on the outside of the plastic bag. Use a heavy, strong tag to minimize loss.

Freezing

It is very important that the samples are frozen solid in a

relatively short time (several hours) and maintained in a solid frozen condition to prevent spoilage. Often with freezers on-board ship it is easy to overload the equipment by placing too much " warm " material in the freezer at once; this can result in spoilage. Try to freeze small batches at a time to ensure proper freezing. Samples can be held under refrigeration (36-38°F) for 1 or 2 days prior to freezing if this is required.

APPENDIX II

Scientific and Common Names of Fish Cited. (adapted from a listing prepared by National Marine Fisheries Service, ADP Unit, Feb. 1969).

Bull shark	Carcharhinus leucas
Dusky shark	Carcharhinus osscurus
Smooth dogfish	Mustelus canis
Spiny dogfish	Squalus acanthias
Angel shark	Squalus dumerili
Sharpnosed shark	Scoliodon terrae-novae
Cownosed ray	Rhinoptera bonasus
Bullnose ray	Myliobatis freminvillei
Big skate, Winter skate	Raja ocellata
Brier skate, Clearnose	Raja eglanteria
Little Common skate	Raja erinacea
Thorny skate	Raja radiata
Stingray	Dasyatis americanus
Round herring	Etrumeus sadina
Sea herring, Atlantic	Clupea harengus
Alewife	Alosa pseudoharengus
Blueback herring	Alosa aestivalis
Shad	Alosa sapidissima
Menhaden	Brevoortia tyrannus
Anchovy	Anchoa mitchilli
Striped anchovy	Anchoa hepsetus
Silver hake, Whiting	Merluccius bilinearis
Cod	Gadus morhua
Haddock	Melanogrammus aeglefinus
Pollock	Pollachius virens
White hake, Ling	Urophycis tenuis
Red hake, Squirrel	Urophycis chuss
Spotted hake	Urophycis regius
Cusk	Brosme brosme
American dab	Hippoglossoides platessoides
Fluke	Paralichthys dentatus
Fourspot flounder	Paralichthys oblongus
Yellowtail flounder	Limanda ferruginea
Winter flounder, Blackback	Pseudopleuronectes americanus
Witch flounder, Grey sole	Glyptocephalus cynoglossus
Sand flounder, Windowpane	Scophthalmus aquosus
Gulfstream flounder	Citharichthys arctifrons
Smallmouth flounder	Etropus microstomus

Hogchoker	Trinectes maculatus
Mackerel	Scomber scombrus
Sand tiger	Odontaspis taurus
Atlantic sturgeon	Acipenser oxyrhynchus
American eel	Anguilla rostrata
Sand lance	Ammodytes americanus
Shanny	Leptoclinus maculatus
Striped cusk-eel	Rissola marginata
Wolffish	Anarhichas lupus
Ocean pout, eelpout	Macrozoarces americanus
Cusk-eel	Lepophidium cervinum
Northern puffer	Sphaeroides maculatus
American goosefish	Lophius americanus
Planehead filefish	Monacanthus hispious
Lantern fish	Unclassified
Tongue fish	Symphurus sp.
Butterfish	Poronotus triacanthus
Moon fish	Vomer setapinnis
Big eye	Priacanthus arenatus
Bluefish	Pomatomus saliatrix
Croaker	Micropogon undulatus
Striped bass	Morone saxatilis
White perch	Morone americanus
Sea bass	Centropristes striatus
Pigfish	Opthopristis chrysopterus
Scup	Stenotomus chrysops
Weakfish	Cynoscion regalis
Kingfish	Menticirrhus saxatilis
Black drum	Pogonias cromis
Spot	Leiostomus xanthurus
Redfish, Rosefish	Sebastes marinus
Blackbellied redfish	Helicolenus dactylopterus
Mailed sculpin	Triglops ommatistius
Longhorn sculpin	Myoxocephalus octodecemspinosus
Sea raven	Hemitripterus americanus
Northern searobin	Prionotus carolinus
Striped searobin	Prionotus evolans
Cunner	Tautogolaprus adspersus
Northern stargazer	Astroscopus guttatus

APPENDIX III

CHEMICAL ANALYSES

SAMPLE PREPARATION AND METHODOLOGIES

Sample preparation

Muscle, liver and gill samples were removed on board the vessel, placed in polyethylene bags, and frozen for later transmittal to the laboratory. Field personnel were supplied with a sampling protocol to minimize possible external contamination of the samples.

At the laboratory, samples were thawed in a refrigerator overnight. The muscle samples consisted of whole fillets for small fish and about a two-inch steak from the head end of large fish. The skin and bones were removed from these samples prior to grinding. The samples were ground in a Waring blendor. The rubber gaskets supplied with these assemblies were removed to avoid any possible contamination. Thoroughly cleaned and dried glassware and stainless steel blades were used for each sample. The ground samples were stored in " poly opal " plastic ointment jars (Lermer Corp., Garwood, New Jersey). These jars were rinsed in 10% nitric acid, deionized water and dried before use. Samples were held frozen until analysis.

MERCURY ANALYSIS - ATOMIC ABSORPTION

Tissue samples of 0.1 to 0.5 gm were placed in a 30 cc Kjeldahl flask, 10 ml of concentrated sulfuric - nitric acid (4:1) solution were added and the sample digested by shaking in a water bath at 50-60°C until a clear solution was obtained (usually 1-1/2 - 2 hours). The samples were removed and left to stand for one hour and then, while cooling on ice, fifteen ml of 6% potassium permanganate solution were added. The samples were left overnight (generally 16-20 hours) and then analyzed by a "flameless" atomic absorption technique as follows: using 20% sulfuric acid, the sample was transferred to a gas washing bottle equipped with a fritted end on the stem. Twenty ml of reductant, consisting of about 600 cc of deionized water, 100 cc of concentrated sulfuric acid, 15 gms of sodium chloride, 30 gms of hydroxylamine sulfate and 60 gms of stannous sulfate, were added to the sample and stirred for one minute. Air, at about 1000 cc per minute, was introduced and the mercury swept through a 2.5 by 15 cm cell mounted in the light path of the instrument. Peak heights of recorder response of samples were compared to those of standards for quantitation.

Mercury analyses of sediment samples were conducted by this same procedure.

ANALYSES OF METALS OTHER THAN MERCURY

Neutron Activation

These analyses were conducted on a cooperative basis between the University of Michigan, Phoenix Memorial Laboratory and the Milford laboratory. Frozen samples were prepared by 48-hour lyophilization and ground with a teflon mortar and pestle. The dried material (about 0.4 - 0.8 gram) was loaded in quartz tubing and sealed by heat. A 0.5 ml standard solution was placed in similar quartz tubing and one tube of standard was wired to two tubes containing samples. The bundles of sample and standard were bombarded with neutrons for ten hours and allowed to decay for about three weeks. The quartz tubes were then smashed and the sample transferred to a counting vial with one molar sulfuric acid. The final volume for sample and standard in the counting vial was kept the same. Samples and standards that were irradiated together were counted within a few hours of one another so that no correction for decay time was necessary. The counting was done on a lithium-drifted germanium detector coupled to a 4000 channel pulse height analyzer. After subtraction of background counts, the areas of the gamma ray photo peaks of samples were compared to those of the standard for quantitation. The following metals could be determined by this procedure: selenium, chromium, antimony, silver, nickel, rubidium, zinc and cobalt.

Atomic Absorption

Analytical Services, Inc., Kensington, Maryland analyzed samples for lead, cadmium and arsenic. The methodology employed by this laboratory was the same as described by Dalton and Malonoski (J. Assoc. Official Analyt. Chem., 52 (5): 1969). The samples were ashed at 500°C for 3 hours using magnesium nitrate.

The Milford laboratory analyzed samples for cadmium, chromium, lead, manganese, nickel and silver. Samples were pre-ashed by heating over a bunsen burner and charring and then placed in a muffle furnace at 400°C for one hour, removed, cooled and " wetted" with concentrated nitric acid. This process was repeated every hour for 4-6 hours and a white ash was obtained after 18-24 hours. After ashing, 5 ml of concentrated nitric acid was added to the samples and evaporated to dryness on a hot plate (at low heat). The samples were transferred with 10% nitric acid through filter paper to graduated test tubes and diluted to 10 ml (usually 5-10 gram samples of " wet " biological material were ashed). Samples and appropriate standards were aspirated into the flame of a model 403 Perkin Elmer atomic absorption instrument employing a deuterium background corrector.

Metals were extracted from sediment samples by shaking up to 5 grams of dried sample (dried at 60°C for 48 hours) with 25 ml of 50% nitric acid and deionized water for 1 to 2 hours on a mechanical

shaking apparatus. The samples were diluted, filtered and brought to a final volume of 100 ml with deionized water. The solutions were analyzed by atomic absorption as described above.

PRECISION AND ACCURACY OF CHEMICAL ANALYSES

A sample of oil-packed yellow fin tuna (prepared from one large fish) was obtained from the National Canners Association (NCA), Washington, D. C. This sample was analyzed for mercury by nine laboratories that used atomic absorption for quantitation. The average and range of mercury found by these nine laboratories for this sample was 0.86 ppm and 0.80 - 1.02 ppm, respectively. This sample was routinely included with each batch of samples that were analyzed. Since February 1971, 39 replicate analyses were obtained on this sample with an average of 0.908 ppm and a relative standard deviation of 17.94 percent. To check on its storage characteristics, the sample was analyzed in November of 1971 by neutron activation (Phoenix Memorial Laboratory, University of Michigan); their results were an average of 0.94 ppm (range of 0.80-1.03 ppm for 6 replicates).

The precision of the mercury analyses presented in this report was determined by calculating the percent mean variation for a random selection of duplicate analyses. Duplicate analyses were conducted on all of the samples. Some samples were replicated 4-6 times and the relative standard deviation was calculated for these results as a measure of precision. The results of these precision measurements are shown in Table 1 for three ranges of mercury values. These ranges were selected on the basis of possible differences in value precision due to the sensitivity of the technique.

Table 1. Precision of Mercury Analyses

Range of Mercury Values	N	Precision of Measurement	
		Mean Percent Variation 1]	
(in ppm)		Range	Average
0.08 - 0.25	46	2.8-50.0%	12.8%
0.26 - 0.50	56	1.3-60.0%	11.9%
0.51 - 1.49	26	0.8-19.1%	9.2%
		Relative Standard Deviation 2]	
0.08 - 0.25	15	4.8-54.9%	25.6%
0.26 - 0.50	2	11.4-16.5%	14.0%
0.51 - 1.49	10	11.0-27.7%	19.2%

1] Mean percent variation = $\frac{\frac{x+y}{2} - x \text{ or } y}{x \text{ or } y}(100)$

2] Relative standard deviation = standard deviation expressed as a percent of the average value

Because these values are only slightly above the detection limit for the methodology employed in this study, the results show a greater variation in replicate analyses of values in the range of 0.08 - 0.25 ppm than the other values. Even though the variation among replicates was as high as 50-60% on occasion, the overall variation in replicates was acceptable for the survey work described in this report.

Neutron Activation

The samples from the April collection were analyzed on a detector with a lower efficiency rating than the samples collected in June and September, thus, the detection limits were improved considerably for certain metals in the latter sample collections. Table 2 shows the detection limits for biological and sediment samples for each collection. These values are not absolute for each individual sample that was analyzed, but are intended to show the magnitude of the particular metal needed to be detected by the methodology employed. The results show that the detection limits were improved considerably for some of the metals, in particular, chromium and silver, whereas the detection limits for the other metals did not change significantly. It should be noted that in order to obtain precise analyses the level of the metal in the sample should be several orders of magnitudes above the detection limits.

The April collection of samples was analyzed in duplicate only, since the methodology for the neutron activation work had not been finalized. The precision of those results is not discussed. For the June and September collections of samples, 3-6 replicate analyses were conducted and the relative standard deviation was calculated for these results in order to evaluate the precision of the analyses.

Table 2. Detection Limits for Neutron Activation Analyses of Animals and Sediments Collected for Dump Site Study

METAL (in ppm)	ANIMALS April	ANIMALS June and Sept.	SEDIMENTS April	SEDIMENTS June and Sept.
Antimony	0.04-0.08	0.04-0.08	0.2 -0.4	0.2-0.5
Cobalt	0.02-0.05	0.02-0.04	0.08-1.2	0.1-0.3
Chromium	0.4 -0.8	0.1 -0.3	1.5 -2.0	1-3
Nickel	3-6	2-4	30-40	25-35
Rubidium	0.7 -1.0	0.4 -0.8	8-10	-
Selenium	0.2 -0.4	0.1 -0.3	0.8 -1.2	1-3
Silver	0.5 -0.8	0.1 -0.3	3 -4	1-3
Zinc	2-5	1 -3	interferences prevented detection	

Table 3 shows the range and average relative standard deviations obtained for these collections. The ranges of ppm of the metals determined are also shown. These results show that the precision of the data was about the same for the two collections. Generally, the majority of the metal concentrations determined in these samples were only a few orders of magnitude greater than the detection limits. Thus, the precision of the results shown are quite good and are quite acceptable for the type survey work conducted.

Comparison of atomic absorption and neutron activation

Analyses for metals (other than mercury) by atomic absorption were hampered because of contract problems to outside laboratories and problems in developing the in-house capabilities necessary to conduct these analyses; thus, precision data for the metals that can be analyzed by this technique are not presented in this report.

Some data have been obtained, however, which compare neutron activation to atomic absorption analyses. The results of these analyses are shown in Table 4. The atomic absorption analyses were conducted by the Milford laboratory.

The agreement in values for these two methods for the animal samples was quite good considering that not only were two methods compared but essentially two different laboratories were compared as well. The chromium values did not agree as well as the silver values for the two methods used. Most of the values for chromium were near

Table 3. Precision Data For Neutron Activation Analyses As Shown By Relative Standard Deviations

METAL	PPM Range	N[2]	RELATIVE STANDARD DEVIATIONS[1] JUNE Range	JUNE Average	N[2]	SEPTEMBER Range	SEPTEMBER Average
Chromium	0.51- 1.29	4	5.3-97.6	56.3%	6	11.4-49.3	27.2%
Cobalt	0.08- 0.4	4	14.8-78.1	34.6%	8	11.5-71.0	29.2%
Rubidium	0.35- 1.16	6	12.7-32.6	25.3%	3	24.1-28.9	26.8%
Selenium	0.28- 2.89	11	12.5-42.6	23.6%	8	5.8-30.8	19.8%
Silver	0.13- 4.3	5	12.4-39.8%	24.8%	6	10.9-45.8	26.4%
Zinc	3.7 -72.0	10	1.0-39.6%	19.7%	8	9.4-32.0	18.3%

1] Relative Standard Deviation = The standard deviation expressed as a percentage of the average

2] N = Number of samples that were replicated 3-6 times

Table 4. Comparison of Neutron Activation and Atomic Absorption Analyses of Marine Animals and Sediments Collected for the Dump Site Study

Sample	Tissue	Metal Concentration			
		N.A.A.	At. Abs.	N.A.A.	At. Abs.
		(ppm. wet wt.)			
Marine Animals		Chromium[1]		Silver[1]	
Surf clam	muscle	2.7	2.30	1.02	0.88
Surf clam	muscle	0.74	0.90	1.32	1.00
Surf clam	muscle	1.1	0.67	0.40	0.39
Lobster	muscle	< 0.3	0.50	0.54	0.37
Windowpane flounder	muscle	0.5	1.20	<0.1	0.06
Fluke	muscle	0.68	0.33	<0.1	0.20
Ling	muscle	<0.3	0.70	<0.1	0.30
Ling	liver	0.6	0.40	0.17	0.30
		(ppm. dry wt.)			
Sediments		Chromium[1]		Cobalt[1]	
Station codes:					
BWFA	-	3.0	0.6	0.3	1.2
BWFB	-	9.3	0.6	0.4	1.4
FLR	-	31.0	1.4	1.3	0.6
69D5 (June)	-	12.0	2.2	1.2	0.6
69D5 (Sept.)	-	21.0	<2	0.9	3
1-36	-	6.5	<2	0.6	<2
1-39	-	125	68	5.6	9
1-59	-	315	52	8.6	7
1-70	-	3.9	17	2.8	4
1-82	-	209	63	5.3	8

[1] Values are averages of 2-3 replicate analyses

the detection limits for the neutron activation analyses, thus, a greater disagreement was expected for this metal.

The agreement between these two methods was not as good for the sediment samples as for the animal samples. The consistently higher values for chromium by neutron activation could have meant that there was a substantial amount of chromium which was not acid extractable from the sediment. In the atomic absorption analysis the metal was extracted from the sample by strong acid, whereas, in the neutron activation analysis the sample was analyzed directly without any extraction of the sediment.

APPENDIX IV

Table 1. List of fish collected at the New York and Delaware Bay dump site stations and Barnegat Bay control station.

	STATION 70									
	April 20 1971	May 27 1971	June 23 1971	June 23 1971	June 23 1971	Aug. 31 1971	Aug. 31 1971	Oct. 6 1971	Oct. 6 1971	Oct. 6 1971
Mustelus canis						2	18	8	23	
Squalus acanthias							2			6
Raja spp.						11	8	4	5	2
Rhinoptera bonasus										
Alosa spp.										
Alosa aestivalis	7									
Alosa pseudoharengus										
Clupea harengus harengus		1								
Lophius americanus							1			
Gadus morhua										
Merluccius bilinearis	2	3						2		6
Urophycis chuss										3
Urophycis regius								9	276	3
Macrozoarces americanus										
Centropristis striata									1	
Stenotomus chrysops						29	50	22	1	
Cynoscion regalis								2	2	
Menticirrhus saxatilis										
Tautogolabrus adspersus										
Poronotus triacanthus						22		4		1
Prionotus carolinus						80	38	2189	824	1
Prionotus evolans								4		1
Hemitripterus americanus										
Myoxocephalus octodecemspinosus		15								11
Paralichthys oblongus								1		
Scophthalmus aquosus	2	5		20	10	16	10	76	6	30
Limanda ferruginea		4	4		4					2
Pseudopleuronectes americanus	4	12	7	7	10	2	4			3
Citharichthys arctifrons	1									
Paralichthys dentatus						4		5	11	
Sphaeroides maculatus										

Table 1 (cont.) -2-

	STATION 70			BB					
	Dec. 1 1971	Jan. 4 1972	March 16 1972	April 9 1972	April 20 1972	May 27 1972	June 23 1972	Sept. 1 1972	Jan. 4 1972
Mustelus canis							8	4	
Squalus acanthias	20	3	5			1			
Raja spp.	4	1				24	78		3
Rhinoptera bonasus									
Alosa spp.						115			
Alosa aestivalis		11							32
Alosa pseudoharengus				7					
Clupea harengus harengus			1						
Lophius americanus									2
Gadus morhua		50	51			5			15
Merluccius bilinearis	21*	1	3						4
Urophycis chuss								12	
Urophycis regius		1							1
Macrozoarces americanus									
Centropristis striata						62	10	24	
Stenotomus chrysops								4	
Cynoscion regalis	2							1	
Menticirrhus saxatilis	1								
Tautogolabrus adspersus		2							
Poronotus triacanthus		7				18	1		
Prionotus carolinus						4	23	765	
Prionotus evolans							2	13	
Hemitripterus americanus		1							
Myoxocephalus octodecemspinosus	1	3	3						4
Paralichthys oblongus	1								
Scophthalmus aquosus	28	7	31	10	21	50	39	11	8
Limanda ferruginea	14	35	114	10	19	1			22
Pseudopleuronectes americanus	4		3		8	74	31		7
Citharichthys arctifrons							1		
Paralichthys dentatus						2	1	4	
Sphaeroides maculatus								7	

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	April 8 1972	April 8 1972	April 8 1972	April 8 1972	April 21 1972	May 26 1972	May 26 1972	June 22 1972	Sept. 1 1972	Jan. 4 1972
Mustelus canis					2					
Squalus acanthias		1							8	9
Raja spp.		23	4	4			3	1		1
Rhinoptera bonasus										
Alosa spp.										
Alosa aestivalis				2				1		
Alosa pseudoharengus				3						
Clupea harengus harengus										
Lophius americanus		3					1			
Gadus morhua										
Merluccius bilinearis			4	6		41	29	5	2	
Urophycis chuss		22*	6*	44		57*	130	2	25	8
Urophycis regius										
Macrozoarces americanus		1								
Centropristis striata		1								
Stenotomus chrysops								13	16	70
Cynoscion regalis								2	4	8
Menticirrhus saxatilis								1		
Tautogolabrus adspersus						1	1			1
Poronotus triacanthus						79	20	11		
Prionotus carolinus		1	1	1				6	4	15
Prionotus evolans										
Hemitripterus americanus			1							
Myoxocephalus octodecemspinosus		3								
Paralichthys oblongus		1	1			3				
Scophthalmus aquosus	10	11				1		4		20
Limanda ferruginea	12	18								
Pseudopleuronectes americanus	4	18	1	1	23	8				1
Citharichthys arctifrons						1				
Paralichthys dentatus										1
Sphaeroides maculatus										

APPENDIX V

TABLE I

LIST OF FISH AND INVERTEBRATES COLLECTED AT THE CHINCOTEAGUE STUDY SITE AND FORWARDED FOR CONTAMINANT ANALYSIS

Species	Month Collected
Fish	
Spiny dogfish, *Squalus acanthias*	March 1971
Sand tiger, *Odontaspis taurus*	May 1971
Bull shark, *Carcharhinus leucas*	June 1971
Atlantic sturgeon, *Acipenser oxyrhynchus*	October 1971
Atlantic herring, *Clupea harengus*	March 1971
Blueback herring, *Alosa aestivalis*	March 1971
Silver hake, *Merluccius bilinearis*	April 1971
Spotted hake, *Urophycis regius*	April 1971
Striped bass, *Morone saxatilis*	March 1971
Weakfish, *Cynoscion regalis*	April 1971
Atlantic mackerel, *Scomber scombrus*	March 1971
Butterfish, *Peprilus triacanthus*	May 1971
Northern searobin, *Prionotus carolinus*	May 1971
Summer flounder, *Paralichthys dentatus*	July 1971
Winter flounder, *Pseudopleuronectes americanus*	March 1971
Windowpane, *Scophthalmus aquosus*	*
Invertebrates	
Rock crab, *Cancer irroratus*	*
Surf clam, *Spisula solidissima*	*
Hard clam, *Mercenaria mercenaria*	May 1971
Blood clam, *Arca ponderosa*	May 1971
Longfinned squid, *Loligo pealei*	June 1971

*Target species - collected all cruises when available

TABLE II

LIST OF FISH AND INVERTEBRATES COLLECTED AT THE CHINCOTEAGUE, VIRGINIA, STUDY SITE

		Month and Cruise Number					
		March				April	May
Fish		I	II	III	IV	V	VI
Spiny dogfish	*Squalis acanthius*	52	52	47	3	31	1
Sand tiger	*Odontaspis taurus*	-	-	-	-	-	128
Skates	*Raja* sp.	24	13	5	8	110	54
Blueback herring	*Alosa aestivalis*	92	178	183	283	143	-
Alewife	*Alosa pseudoharengus*						91
American shad	*Alosa sapidissima*	-	2	1	-		17
Atlantic herring	*Clupea harengus*	87	112	46	23	18	44
Atlantic menhaden	*Brevoortia tyrannus*	1	-	1	17	-	-
Bay anchovy	*Anchoa mitchilli*	13	200+	3	-	-	200+
Goosefish	*Lophius americanus*	1	-	-	-	5	9
Silver hake	*Merluccius bilinearis*	1	6	5	2	359	43
Red hake	*Urophycis chuss*				-		
White hake	*Urophycis tenuis*	3	3	1	-	86	37
Spotted hake	*Urophycis regius*	2	-	-	-		65
Atlantic cod	*Gadus morhua*	-	1	-	-	-	-
Ocean pout	*Macrozoarces americanus*	4	1	-	1	-	-
Striped bass	*Morone saxitilis*	4	2	14	9	1	1
Black sea bass	*Centropristis striatus*	-	-	-	-	2	5
Scup	*Stenotomus chrysops*	-	-	-	-	-	19
Pigfish	*Orthopristis chrysoptera*	-	-	-	-	-	1
Weakfish	*Cynoscion regalis*	-	-	-	-	12	353
Northern kingfish	*Menticirrhus saxitilis*	-	-	-	-	-	33
Atlantic mackerel	*Scomber scombrus*	1	34	30	8	10	1
Butterfish	*Peprilus triacanthus*	-	-	-	-	1	5,379
Northern sea robin	*Prionotus carolinus*	-	-	-	-	-	247
Striped sea robin	*Prionotus evolans*	-	-	-	-	-	23
Longhorn sculpin	*Myoxcephalus octodecemspinosus*	3	2	2	3	1	-

Fish		Cruise Number					
		I	II	III	IV	V	VI
Smallmouth flounder	*Etropus microstomus*	1	2	-	-	2	6
Summer flounder	*Paralichthys dentatus*	-	-	-	2	12	37
Windowpane	*Scopthalmus aquosus*	669	271	301	272	476	171
Witch flounder	*Glyptocephalus cynoglossus*	1	1	4	-	1	-
Winter flounder	*Pseudopleuronectes americanus*	19	33	23	36	19	9
Northern puffer	*Sphoeroides maculatus*	-	-	-	-	-	17
Invertebrates							
Horseshoe crab	*Limulus polyphemus*	12	73	50	45	68	470
Hermit crab	*Paguridae*	-	-	-	-	-	11
Lady crab	*Ovalipes ocelata*	12	4	7	-	39	7
Rock crab	*Cancer irroratus*	266	73	89	73	340	23
Spider crab	*Libinia* sp.	-	2	20	-	53	77
Shrimp	*Crangon* sp.	66	1	-	-	-	-
Moon snail	*Polynices* sp.	1	-	-	-	-	9
Conch	*Busycon* sp.	2	5	-	-	26	110
Longfinned squid	*Loligo pealei*	-	-	-	-	2	40
Starfish		28	325	-	-	-	-
Sea mouse		-	-	-	-	1	-

TABLE III

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY7

Species	Station 1			Station 2			Station 3			Total
	No.	Length (CM)		No.	Length (CM)		No.	Length (CM)		No.
		Range	Mean		Range	Mean		Range	Mean	
Bull shark	-	-	-	5	111-120	113	-	-	-	5
Smooth dogfish	13	51-74	59	5	51-71	57	6	55-61	59	24
Atlantic angel shark	1	112	112	1	109	109	1	86	86	3
Roughtail stingray	2	114-116	115	5	107-245	155	1	115	115	8
Bullnose ray	6	71-109	83	2	54-60	57	-	-	-	8
Clearnose skate	-	-	-	29	44-60	56	19	48-65	56	48
White perch	2	16-19	18	-	-	-	-	-	-	2
Black sea bass	-	-	-	12	14-22	20	11	17-22	20	32
Scup	13	9-20	17	3	16-17	17	9	9-14	11	33
Weakfish	33	17-30	22	105	18-31	23	11	21-28	23	149
Northern kingfish	4	24-32	28	11	22-31	26	3	25-29	27	41
Butterfish	56	10-16	11	143	9-16	11	36	8-17	13	235
Northern sea robin	162	16-27	23	3,770	15-28	23	1,270	15-28	23	5,102
Striped sea robin	39	14-36	21	-	-	-	-	-	-	39
Smallmouth flounder	4	5-11	10	25	9-13	11	4	11-12	12	33
Summer flounder	26	27-46	35	23	29-47	37	21	31-54	38	70
Windowpane	43	10-25	12	25	13-26	21	16	21-27	24	84
Spiny boxfish	1	17	17	-	-	-	-	-	-	1
Silver hake	-	-	-	7	12-16	15	1	13	13	8
Spotted hake	11	11-22	18	20	10-24	18	8	17-22	20	39

TABLE IV

JULY 1971

NUMBERS AMD LENGTHS OF FISH COLLECTED ON CRUISE 1CY8

Species	Station 1			Station 2			Station 3			Total
	No.	Length (CM)		No.	Length (CM)		No.	Length (CM)		No.
		Range	Mean		Range	Mean		Range	Mean	
Smooth dogfish	32	35-104	44	2	55-60	58	1	61	61	35
Roughtail stingray	1	75	75	-	-	-	-	-	-	1
Bullnose ray	2	55-107	81	-	-	-	-	-	-	2
Clearnose skate	45	24-63	51	48	24-63	51	25	24-63	51	118
Silver hake	-	-	-	2	15-16	16	10	12-22	16	12
Spotted hake	4	14-24	18	36	11-25	18	63	11-29	19	103
Black sea bass	-	-	-	11	10-24	17	45	15-26	20	56
Scup	27	12-27	14	9	11-13	12	-	-	-	36
Silver perch	2	17-18	18	-	-	-	-	-	-	2
Weakfish	70	11-26	21	3	23-28	26	-	-	-	73
Spot	1,025	10-14	12	-	-	-	-	-	-	1,025
Northern kingfish	33	19-38	27	1	31	31	1	28	28	35
Stargazer	1	19	19	-	-	-	-	-	-	1
Butterfish	15	8-17	13	-	-	-	175	8-21	11	190
Northern sea robin	291	11-29	17	4,302	15-29	22	1,195	15-29	22	5,788
Striped sea robin	69	12-32	20	-	-	-	-	-	-	69
Smallmouth flounder	3	9-10	9	10	10-13	12	8	9-14	12	21
Summer flounder	30	15-51	32	7	34-50	38	6	32-40	36	43
Windowpane	96	12-27	15	25	14-17	16	10	17-30	22	131
Blackcheek tonguefish	3	17-18	17	-	-	-	-	-	-	3
Northern puffer	12	12-20	17	1	20	20	-	-	-	13
				150			Grand Total.....			7,757

TABLE V

AUGUST 1971

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY9

Species	Station 1 No.	Station 1 Length(CM) Range	Station 1 Length(CM) Mean	Station 2 No.	Station 2 Length(CM) Range	Station 2 Length(CM) Mean	Station 3 No.	Station 3 Length(CM) Range	Station 3 Length(CM) Mean	Total No.
Dusky shark	-	-	-	3	106-109	107	-	-	-	3
Smooth dogfish	11	37-48	41	9	39-60	44	1	63	63	21
Atlantic sharpnose shark	-	-	-	1	101	101	-	-	-	1
Atlantic angel shark	1	120	120	-	-	-	-	-	-	1
Clearnose skate	42	Unmeasured		94	28-62	48	73	34-64	52	209
Bullnose ray	2	49-60	55	5	58-78	69	-	-	-	7
Striped anchovy	-	-	-	1	11	11	-	-	-	1
Silver hake	-	-	-	1	19	19	3	17-21	19	4
Spotted hake	100	16-26	20	32	15-26	20	28	15-28	22	160
Black sea bass	6	12-18	16	25	13-20	15	28	14-25	19	59
Atlantic moonfish	-	-	-	1	5	5	-	-	-	1
Scup	-	-	-	9	8-13	11	2	10-13	12	11
Silver perch	1	17	17	-	-	-	-	-	-	1
Weakfish	20	19-25	21	4	20-30	24	89	22-37	26	113
Spot	235	10-16	13	691	11-17	14	-	-	-	926
Northern kingfish	23	14-35	25	4	22-30	27	3	28-30	29	30
Atlantic croaker	-	-	-	2	22-25	24	1	27	27	3
Butterfish	107	6-18	12	-	-	-	7280	7-21	11	7387
Northern sea robin	222	15-25	18	976	14-20	18	2368	16-29	21	3566
Striped sea robin	129	17-30	22	-	-	-	-	-	-	129
Smallmouth flounder	1	13	13	6	8-12	10	20	10-17	12	27
Summer flounder	62	16-44	23	32	16-48	32	33	22-41	36	127
Windowpane flounder	76	14-28	19	126	15-24	18	78	12-30	18	280
Blackcheek tonguefish	1	17	17	-	-	-	-	-	-	1
Planehead filefish	-	-	-	1	9	9	-	-	-	1
Northern puffer	3	8-10	9	-	-	-	1	21	21	4

TABLE VI

September, 1971

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY10

Species	Station 1			Station 2			Station 3			Total
	No.	Length (CM)		No.	Length (CM)		No.	Length (CM)		No.
		Range	Mean		Range	Mean		Range	Mean	
Smooth dogfish				11	47-66	52	2	66	66	13
Clearnose skate				27	43-63	53	32	39-65	53	59
Striped anchovy				-	-	-	1	13	13	1
Spotted hake				70	18-28	22	79	17-28	20	149
Striped cusk-eel				6	18-27	23	-	-	-	6
Black sea bass				11	14-27	20	8	15-25	19	19
Scup				1	16	16	45	9-16	13	46
Weakfish				123	15-39	20	9	21-34	27	132
Spot				386	12-20	16	697	13-22	17	1,083
Northern kingfish				2	30-31	31	-	-	-	2
Atlantic croaker				2	26-29	28	19	23-27	26	21
Butterfish				3	12-16	14	8	8-14	12	11
Northern sea robin				12	16-29	20	127	13-29	20	139
Striped sea robin				6	21-29	24	-	-	-	6
Smallmouth flounder				-	-	-	2	11-12	12	2
Summer flounder				1	22	22	12	22-39	29	13
Windowpane				15	18-26	21	18	18-30	22	33
Blackcheek tonguefish				3	18-19	18	-	-	-	3
Planehead filefish				-	-	-	5	11-12	11	5
Northern puffer				50	7-23	10	34	8-14	10	84

TABLE VII

OCTOBER 1971

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY11

Species	Station 1 No.	Station 1 Length(CM) Range	Station 1 Length(CM) Mean	Station 2 No.	Station 2 Length(CM) Range	Station 2 Length(CM) Mean	Station 3 No.	Station 3 Length(CM) Range	Station 3 Length(CM) Mean	Tota No.
Smooth dogfish	5	52-67	58	12	Unmeasured		15	51-59	55	32
Dusky shark	-	-	-	1	81	81	-	-	-	1
Angel shark	-	-	-	-	-	-	1	62	62	1
Roughtail stingray	-	-	-	2	Unmeasured		1	96	96	3
Clearnose skate	6	54-62	58	25	Unmeasured		16	45-58	51	47
Atlantic sturgeon	-	-	-	2	145-157	151	-	-	-	2
Menhaden	2	12-13	13	-	-	-	-	-	-	2
Bay anchovy	200+	6-10	8	200+	6-10	8	200+	6-10	8	600+
Spotted hake	80	22-33	27	76	21-35	26	36	20-30	27	192
Red hake	-	-	-	1	17	17	-	-	-	1
Striped cusk-eel	-	-	-	1	23	23	-	-	-	1
Black sea bass	-	-	-	-	-	-	1	25	25	1
Scup	-	-	-	-	-	-	5	16-17	17	5
Bluefish	1	16	16	3	15-20	17	6	15-25	18	10
Silver perch	27	10-22	17	17	12-20	15	-	-	-	44
Weakfish	151	8-44	25	331	17-55	28	193	18-41	26	675
Spot	40	13-18	15	19	15-24	18	114	11-21	17	173
Northern kingfish	8	22-36	28	22	26-36	33	7	20-33	24	37
Butterfish	9	10-18	12	9	10-16	11	173	9-19	14	191
Striped sea robin	1	31	31	2	29-30	30	3	24-27	25	6
Smallmouth flounder	-	-	-	-	-	-	1	13	13	1
Summer flounder	3	22-31	28	1	27	27	6	26-40	32	10
Windowpane	1	21	21	2	19-21	20	5	19-26	22	8
Hogchoker	1	13	13	-	-	-	-	-	-	1
Blackcheek tonguefish	-	-	-	1	19	19	-	-	-	1

TABLE VIII

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY12

Species	Station 1 No.	Station 1 Length(CM) Range	Station 1 Length(CM) Mean	Station 2 No.	Station 2 Length(CM) Range	Station 2 Length(CM) Mean	Station 3 No.	Station 3 Length(CM) Range	Station 3 Length(CM) Mean	Total No.
Smooth dogfish	2	52-57	55	2	49-57	53	6	53-69	58	10
Spiny dogfish	15	68-87	78	1	74	74	12	68-84	77	28
Clearnose skate	1	58	58	3	51-67	61	10	42-62	51	14
Little skate	-	-	-	1	48	48	1	42	42	2
Menhaden	-	-	-	3	22-31	27	-	-	-	3
American shad	1	30	30	-	-	-	-	-	-	1
Bay anchovy	*			*			*			
Spotted hake	63	20-33	27	95	12-35	28	42	21-33	27	200
Striped cusk-eel	-	-	-	1	25	25	4	24-26	25	5
Bluefish	3	22-51	32	3	16-25	21	2	17-24	21	8
Silver perch	77	11-24	20	19	12-22	16	3	12-13	13	99
Weakfish	300	17-41	28	99	9-47	28	74	11-47	30	473
Spot	1	16	16	2	14-14	14	32	13-25	16	35
Northern kingfish	-	-	-	-	-	-	1	33	33	1
Butterfish	1	23	23	12	10-18	13	2	16-18	17	15
Striped sea robin	37	14-32	26	61	14-32	25	3	15-29	24	101
Smallmouth flounder	-	-	-	-	-	-	7	8-13		7
Summer flounder	4	22-33	28	3	23-28	25	6	24-30	25	13
Windowpane	10	20-26	23	10	21-28	23	32	19-28		52
Northern puffer	33	11-24	14	35	6-21	12	4	12-14	13	72
									Total	1,139

TABLE IX

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 1CY13

Species	Station 1			Station 2 *			Station 3*			Total
	No.	Length (CM)		No.	Length (CM)		No.	Length (CM)		No.
		Range	Mean		Range	Mean		Range	Mean	
American eel	6	60-65	62							
Atlantic shad	1	34	34							
Menhaden	1	11	11							
Atlantic herring	7	28-31	29							
Goosefish	1	89	89							
Spotted hake	69	11-34	28							
Silver hake	3	34-34	34							
Striped bass	1	46	46							
Weakfish	27	16-44	32							
Spot	6	12-15	14							
Black drum	4	23-26	24							
Striped sea robin	6	9-13	11							
Longhorn sculpin	1	26	26							
Windowpane	60	20-30	25							
Winter flounder	2	15-35	25							

*Station not completed due to severe sea conditions

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 2CY1

Species	Station 1			Station 2			Station 3			Total
	No.	Length (CM) Range	Mean	No.	Length (CM) Range	Mean	No.	Length (CM) Range	Mean	No.
Spiny dogfish	3	68-73		22	61-97	79	31	27-89	77	56
Little skate	1	41	41	-	-	-	-	-	-	1
American eel	1	50	50	-	-	-	-	-	-	1
Blueback herring	4	9-22	16	148	16-26	28	12	18-26	24	164
Alewife	6	16-26	20	37	11-30	21	27	18-32	25	70
American shad	2	15-20	18	2	21-25	23	-	-	-	4
Menhaden	1	9	9	5	19-29	22	-	-	-	6
Atlantic herring	18	27-32	29	27	27-32	29	14	27-31	28	59
Bay anchovy	200+	-	-	200+	-	-	200+	-	-	-
Silver hake	23	10-18	14	20	6-46	17	19	10-44	27	62
Spotted hake	35	13-34	22	-	-	-	3	25-31	28	38
Red hake	25	15-50	27	27	8-51	31	3	27-38	31	55
Weakfish	-	-	-	4	10-10	10	-	-	-	4
Spot	42	10-15	13	1	14	14	-	-	-	43
Atlantic mackerel	-	-	-	-	-	-	3	27-32	29	3
Butterfish	-	-	-	16	7-10	9	36	7-11	9	52
Striped sea robin	-	-	-	-	-	-	3	8-11	9	3
Longhorn sculpin	-	-	-	2	28-28	28	2	27-29	28	4
Smallmouth flounder	-	-	-	1	15	15	4	12-15	14	5
Summer flounder	4	22-26	24	-	-	-	-	-	-	4
Windowpane	60	9-33	26	31	22-28	25	16	22-31	25	107
Winter flounder	2	15-17	16	1	29	29	-	-	-	3
									Total.....	744

TABLE XI

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 2CY2

	Station 1			Station 2			Station 3			
	No.	Length (cm) Range	Mean	No.	Lenth (cm) Range	Mean	No.	Length (cm) Range	Mean	Total No.
Spiny dogfish	-			1	85	85	1	89	89	2
Little skate	-			1	42	42	-			1
Blueback herring	2	8-14	11	1	16	16	1	15	15	4
Alewife	3	13-24	17	-			27	13-30	23	30
Menhaden	2	8-10	9	-			2	8	8	4
Atlantic herring	3	30-31	31	-			36	25-33	29	39
Bay anchovy	3	5- 8	6	4	6- 7	6	-			7
Silver hake	-			11	7-17	13	6	11-17	15	17
Red hake	13	17-29	22	59	11-43	28	2	25-42	34	74
Spotted hake	1	13	13	14	10-23	17	-			15
Ocean pout	-		-				2	51-60	56	2
Striped bass	-			1	82	82	-			1
Spot	1	14	14	1	13	13	1	14	14	3
Longhorn sculpin	-			2	26-33	30	-			2
Smallmouth flounder	-			4	6-12	10	4	11-12	11	8
Summer flounder	5	13-22	19	3	18-22	20	-			8
Windowpane	33	9-28	23	33	8-28	23	21	6-30	23	87
Winter flounder	3	16-27	20	26	13-31	17	2	16-35	26	31
									Total.....	335

TABLE XII

NUMBERS AND LENGTHS OF FISH COLLECTED ON CRUISE 2CY3

	Station 1			Station 2			Station 3			
	No.	Length (cm) Range	Length (cm) Mean	No.	Length (cm) Range	Length (cm) Mean	No.	Length (cm) Range	Length (cm) Mean	Total No.
Spiny dogfish	-			3	76-83	80	5	75-87	80	8
Little skate	14	38-49	43	5	38-47	42	5	41-47	43	24
Blueback herring	-			4	17-20	19	2	17-18	18	6
Alewife	6	24-27	24	202	15-30	18	51	14-26	19	259
American shad	2	24	24	-			-			2
Menhaden	-			-			2	27-30	29	2
Atlantic herring	6	28-32	30	11	27-32	30	15	27-31	29	32
Bay anchovy	-			3	5- 8	7	-			3
Goosefish	-			1	28	28	-			1
Silver hake	14	14-18	15	76	12-50	23	80	11-51	26	170
Spotted hake	14	19-23	21	5	12-20	17	3	14-19	17	22
Red hake	46	18-41	24	94	12-50	27	23	12-50	39	163
White hake				1	53	53	-			1
Striped searobin	-			1	13	13	-			1
Smallmouth flounder	-			8	10-12	11	2	10-14	12	10
Summer flounder	-			4	18-25	22	-			4
Windowpane	36	8-28	21	17	7-28	20	42	10-29	25	95
Winter flounder	-			3	17-27	21	2	17	17	5
								Total.....		808