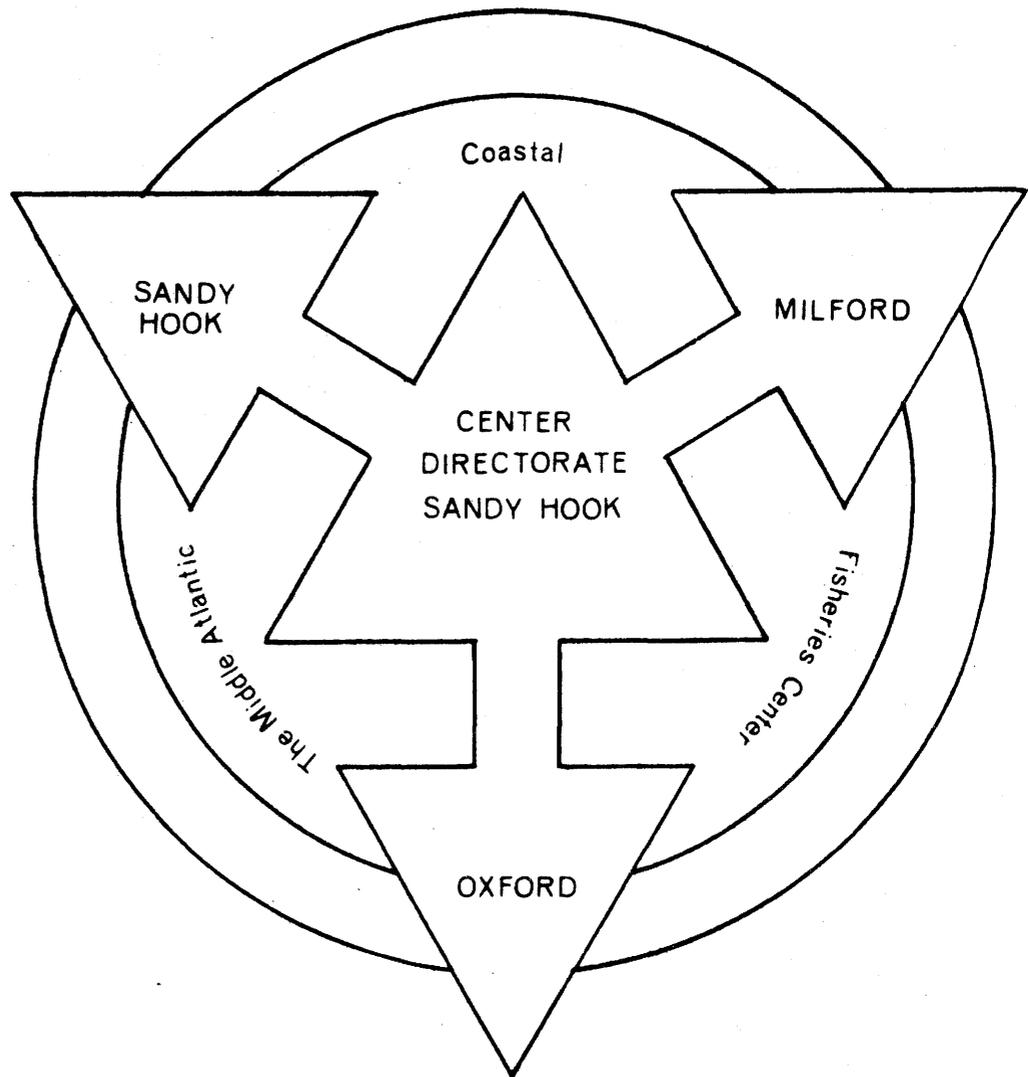




A MULTILABORATORY COOPERATIVE STUDY OF CONTAMINANTS IN THE
COASTAL ENVIRONMENT AND THEIR EFFECTS ON LIVING MARINE
RESOURCES -- SUMMARY REPORT OF OPERATIONS FROM
JANUARY 1 TO DECEMBER 31, 1975

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

MIDDLE ATLANTIC COASTAL FISHERIES CENTER



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MIDDLE ATLANTIC COASTAL FISHERIES
CENTER

NOAA--NMFS

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AND THEIR EFFECTS ON LIVING MARINE RESOURCES

SUMMARY REPORT OF OPERATIONS FROM
JANUARY 1 to DECEMBER 31, 1975

ANTHONY CALABRESE

COORDINATOR

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NOTE:

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INTRODUCTION

A cooperative research program involving all three National Marine Fisheries Service (NMFS) laboratories of the Middle Atlantic Coastal Fisheries Center (MACFC) to study contaminants in marine ecosystems of the northeast and middle Atlantic coasts was initiated in the spring of 1971 and is continuing with the following objectives:

1. Establish environmental baselines, especially for sediments and benthic macrofauna, in Raritan Bay, Long Island Sound, the New Jersey Coast and portions of the Baltimore Canyon Trough, and to periodically reoccupy selected stations in all survey areas to determine impacts of natural and man-induced environmental change upon the baseline characterizations.
2. Measure concentrations of metals and organics in coastal and estuarine waters and determine their forms and interactions, including ionic, chelation, adsorption and other binding characteristics. Investigate cycling of these materials between water, suspended particulates, and benthic sediments.
3. Investigate effects of metals and metal-organics, in various forms, on physiological and biochemical systems in marine animals, particularly on crucial enzyme systems such as those involved in osmoregulation, respiration, and metabolism.

4. Develop models incorporating information on metal-organic interactions, cycling in the marine environment, as well as effects of these contaminants on living marine resources. The models should provide a generalized understanding such that they can be used in prediction and assessment for managing and protecting the marine fisheries.

5. To understand the impact, individually and synergistically, of contaminants and microorganisms on living marine resources, including finfish and shellfish and their associated food chain organisms, and to develop first order models based on the distribution and abundance of contaminants and microorganisms useful in assessing the impact of ocean pollution and dumping in the Middle Atlantic Bight and contiguous waters including Long Island Sound.

6. To provide descriptive baseline data and analysis of marine organic production in the Middle Atlantic Bight.

7. Describe biological, physical and chemical environmental conditions and their influence on living marine resources in the Middle Atlantic Bight.

8. Determine normal patterns of behavior of marine fishes and compare with stress induced change (s) in behavior to assess impact of selected contaminants on a variety of finfish.

9. Determine the lethal effects of a variety of heavy metals, individually and in combination, on the embryonic and larval stages of some mollusks and crustaceans in acute static systems.

10. Determine the long-term sublethal effects of exposure to a variety of heavy metals on the larval, juvenile and adult stages of mollusks, crustaceans and finfish in chronic, long-term exposure systems and define the physiological and biochemical pathways affected and relate them to the metabolic disorders, which result in death or permanent damage to the living marine organism.

11. Understand the actions and interactions of infectious and non-infectious disease (including pollution effects) as causes of "natural" fish and shellfish mortality (i.e., nonfishing mortality) in stressed fishery habitats.

The ultimate goal of the long-range study is 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 group from January 1 through December 31, 1975; for previous information refer to Informal Report, Nos. 5, 26 and 73 of the Middle Atlantic Coastal Fisheries Center entitled "Cooperative Study of Contaminants in the Coastal Environment and Their Effects on Living Marine Resources: Summary Report, 1971-1972"; "A Multilaboratory Cooperative Study of Contaminants

in the Coastal Environment and Their Effects on Living Marine Resources: Summary Report of Operations from January 1, 1974 to December 31, 1974."

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

Sandy Hook Ecosystems Investigations:

Major responsibility for ecological studies of waste disposal areas along the New York, New Jersey and Connecticut shores.

Milford Ecosystems Investigations:

Major responsibility for chemical analyses and for microbiological studies of the environment.

Milford Experimental Biology Investigations:

Responsibility for laboratory experiments to determine the physiological and mutagenic stress caused by contaminants on selected marine species.

Oxford
Milford

Pathobiology Investigations:

Responsibility for all pathological studies and for microbiological studies on or in the living organism.

As a result of the above multilaboratory study of environmental contaminants and their effects on the marine ecosystem and living marine resources therein, thirty-nine staff members of the MACFC were recipients of a NOAA Unit Citation Award for their outstanding contributions to the NOAA/NMFS efforts in this endeavor.

In relation to on-going work in marine contaminant studies, the MACFC sponsored and/or hosted a series of pollution related meetings.

The MACFC and Belle W. Baruch Institute for Marine Biology and Coastal Research of the University of South Carolina, co-sponsored a symposium on "Pollution and Physiology of Marine Organisms" from November 3-6, 1975 at the Milford laboratory. Approximately 55 scientists from throughout the U. S. and England attended. Twenty-six papers were presented on the physiological effects of pesticides and PCBs, heavy metals, petroleum hydrocarbons and thermal pollution on marine organisms. The papers were most interesting and prompted considerable discussion. The proceedings of this symposium will be published by Academic Press and should be available by late 1976.

Following this symposium the MACFC hosted the National Marine Fisheries Service's "Second Environmental Investigations Workshop" at the Milford laboratory from November 6-7, 1975. Dr. Lamarr Trott of the Washington Office brought together people from the Office of Resource Utilization, Environmental Assessment Division

and Office of Resource Research and Centers. The intent of this workshop, attended by approximately 30 people, was to make everyone aware of the moods of the time in environmental conservation, as well as to inform everyone of what other National Marine Fisheries Service elements are doing.

Two Center marine contaminants study meetings were also held this year - the first at the Milford laboratory on April 15, 1975 and the second at the Sandy Hook laboratory October 28 and 29, 1975. These meetings are held at least twice yearly to bring all Center participants up-to-date on on-going research within the Center. These meetings have not been restricted to MACFC staff only; participants from the Washington Office of Resource Research, Southeast Fisheries Utilization Center, and Environmental Assessment Division have also been included.

ECOSYSTEMS INVESTIGATIONS

The principal thrust of Ecosystems Investigations is to understand the natural environment in which living marine resources exist and the impact of man's activities on these environments. Contaminants are viewed by Ecosystems Investigations in the broadest sense; they may include solid wastes such as dredging spoils and sewer sludge, including the multiplicity of elementary and toxic materials present in such wastes, as well as the discrete elements and compounds which are designated by many as microconstituents and which are present in the environment and which may accumulate through food webs in species used for human consumption. Heated waters discharged from steam electric and nuclear electric generating plants are also regarded as contaminants which may have an adverse effect on living resources or which may interact with toxic materials in a synergistic manner.

Previous research activities of Ecosystems Investigations were largely relegated to estuaries and embayments such as Raritan Bay and Long Island Sound as well as the inshore coastal waters of the New York Bight. Ocean dumping in far offshore waters beyond the continental shelf has stimulated a research interest in deepwater offshore environments, some exceeding 2000 m in depth. Commencing

in late 1974, personnel of Ecosystems Investigations became involved in deepwater contaminant research and the results of this research to date are reported herein.

A basic objective of Ecosystems Investigations has been to bring together or focus the various studies being conducted in inshore and coastal environments to provide data useful in developing predictive models of these environments and the impacts of pollution and physical disruption on estuaries and the coastal zone. During the past year substantive progress has been made in focusing the expertise and results of several investigations and tasks on problems common to estuarine and coastal environments.

Six individual investigations or tasks have provided data contained in the contaminants report for calendar year 1975. These include: 1) Environmental Chemistry; 2) Biochemical Modeling; 3) Biological Oceanography; 4) Impact of Environmental Change, Middle Atlantic; 5) Environmental Microbiology; and 6) Behavior of Fishes under Environmental Stress.

ECOSYSTEMS INVESTIGATIONS

ENVIRONMENTAL CHEMISTRY

R. Greig and D. Wenzloff

Trace Metals in Surf Clams and Ocean Quahog

Introduction

Periodic assessments are made of surf clams (Spisula solidissima) and ocean quahog (Arctica islandica) populations in coastal waters of the Middle Atlantic Bight by Resource Assessment Investigations, Middle Atlantic Coastal Fisheries Center. The surf clam is an important resource; 82.3 million pounds of meats representing 60% of the United States clam production were taken in 1973. The clamming industry for these species is concentrated primarily off Delaware, Maryland and Virginia. While the ocean quahog is not presently as valuable a commercial resource as the surf clam, it is abundant in the New York Bight and could be an important resource in future years.

The utilization of these clams might be impaired if they contained pollutants or micro constituents considered undesirable for human consumption. While there are numerous pollutants that could be concentrated by these clams, the current study was conducted to assess the situation in regard to nine metals: silver, arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc.

Materials and Methods

Clams were collected by biologists during 1974 cruises. Clam meats were dissected out on the vessel, frozen in plastic bags, and shipped to Milford, Connecticut. At the laboratory, samples consisting of 4-6 clams per station were pooled for analysis by grinding in an electric blender with stainless steel blades and glass jars.

Arsenic analyses were conducted by dry ashing (500°C) techniques with arsine generation into an atomic absorption spectrophotometer. Mercury analyses were done by digestion of clam meats in nitric and sulfuric acids at 60°C, reduction of mercury to its ground state, and aeration of the mercury through a cell in the light path of an atomic absorption instrument. All other metals were analyzed by digesting the meats in nitric acid at high temperatures (hot plate temperature of < 200°C), dissolution in 10% nitric acid and direct reading on an atomic absorption instrument. Details of these three procedures are available upon request from Mr. Richard Greig, National Marine Fisheries Service, 212 Rogers Avenue, Milford, Connecticut 06460.

Results and Discussion

Silver concentrations generally ranged from 0.1 - 4.0 ppm in surf clams and quahogs; one quahog sample (station 220) had 7.4 ppm of silver (Tables 1-7). In animals collected above 40°N

Table 1. Metal Concentrations in Surf Clams (*Spisula solidissima*) Collected from Stations 1-45 in the Coastal Waters of the Middle Eastern U.S.

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)								
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	40°29.2'	73°48.5'	1.1	2.5	0.1	1.0	3.5	*	1.1	<0.7	18.7
5	40°29.8'	73°23.0'	3.0	3.7	0.1	1.1	2.4	*	0.6	<0.7	18.6
6	40°20.5'	73°29.8'	0.9	2.2	0.1	0.8	2.1	*	0.4	<0.7	17.0
11	40°10.4'	73°54.7'	1.2	2.5	0.1	1.0	3.0	*	0.9	<0.7	17.2
16	40°00'	73°41'	1.1	2.7	0.1	0.8	3.1	*	0.5	<0.7	19.1
17	39°59'	73°49'	0.5	2.5	0.1	0.7	3.5	*	0.4	<0.7	19.1
18	40°01'	73°55'	1.0	2.2	0.1	<0.7	2.0	*	<0.5	<0.7	20.1
19	39°58'	74°00'	1.3	2.0	0.1	0.7	2.3	*	<0.4	<0.7	18.1
22	39°51'	73°47'	1.1	3.0	0.1	<0.7	1.9	*	<0.3	<0.7	16.3
23	39°49'	73°43'	1.3	2.3	0.1	<0.5	0.4	*	<0.3	<0.7	----
26	39°40'	73°45'	1.1	2.6	0.1	0.5	1.4	*	<0.4	<0.7	----
27	39°41'	73°48'	0.8	2.4	0.1	0.7	2.3	*	0.2	<0.7	23.2
28	39°40'	73°55'	1.9	2.5	0.1	<0.4	0.9	*	<0.4	<0.7	----
29	39°40'	74°01'	1.2	2.1	0.1	<0.5	2.3	*	<0.3	<0.7	16.6
30	39°30'	74°08'	0.8	1.0	0.1	0.7	3.2	*	0.7	<0.7	16.5
32	39°30'	73°55'	0.9	1.8	0.2	1.0	4.3	*	<0.4	<0.7	22.4
33	39°30'	73°50'	2.1	2.9	0.2	0.6	3.4	*	0.5	<0.7	13.7
34	39°29'	73°43'	1.4	3.1	0.2	0.6	3.9	*	0.7	<0.7	14.0
36	39°18'	73°41'	0.3	2.1	0.1	0.6	4.0	*	----	<0.8	10.9
38	39°21'	73°57'	1.6	2.5	0.2	0.7	3.1	*	0.7	<0.7	16.7
39	39°20'	74°02'	0.9	2.1	0.1	0.6	3.3	*	0.5	<0.7	14.2
40	39°18'	74°10'	1.0	1.7	0.1	1.1	3.6	*	1.0	<0.7	16.5
41	39°20'	74°14'	0.8	1.5	0.1	<0.7	3.2	*	0.4	<0.7	----
42	39°18'	74°20'	0.6	0.7	0.1	<0.4	2.2	*	0.6	<0.7	8.1
45	38°56'	74°00'	1.0	1.7	0.1	0.5	4.3	*	0.6	<0.7	15.5

* Mercury concentrations were less than 0.06 - 0.09 ppm

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Table 2. Metal Concentrations in Surf Clams (*Spisula solidissima*) Collected from Stations 46-93 in the Coastal Waters of the Middle Eastern U.S.

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)									
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	
46	39°09'	74°15'	1.1	2.5	0.2	0.9	4.6	*	0.8	<1.4	10.8	
47	39°09'	74°09'	1.7	3.2	0.1	0.7	2.5	*	0.8	<0.7	17.8	
54	39°00'	74°34'	0.6	1.6	0.3	0.5	3.0	**	1.7	<1.5	11.0	
55	38°59'	74°30'	1.0	1.6	<0.1	0.6	4.1	*	<0.5	<1.5	12.0	
57	39°00'	74°16'	0.7	1.5	0.1	<0.9	2.3	*	<0.5	<0.6	15.2	
59	38°48'	74°27'	0.5	1.5	0.2	0.6	4.2	*	<0.4	<1.2	10.6	
60	38°52'	74°32'	1.5	2.1	0.1	0.7	3.5	*	<0.7	<1.2	9.0	
61	38°49'	74°40'	0.7	1.8	0.2	0.7	4.6	*	<0.6	<1.4	12.4	
67	38°40'	74°37'	1.2	1.9	<0.1	0.9	6.2	*	0.6	<1.5	12.0	
70	38°30'	74°36'	1.4	2.3	<0.2	1.0	3.2	*	0.8	<1.5	11.8	
71	38°30'	74°39'	0.3	1.4	---	0.5	3.5	*	<0.5	<1.5	10.3	
72	38°30'	74°42'	0.7	2.8	0.1	0.8	3.5	*	0.7	<1.5	9.6	
73	38°30'	74°51'	0.5	1.7	0.2	0.7	3.5	*	0.8	<1.4	11.2	
76	38°20'	74°51'	0.7	1.6	<0.1	0.7	2.8	*	<0.5	<1.5	9.6	
77	38°20'	74°47'	0.4	1.5	<0.1	0.6	3.6	*	<0.7	<1.5	11.2	
80	38°11'	74°33'	0.4	1.5	<0.1	0.8	4.3	*	<0.5	<1.5	12.3	
81	38°11'	74°38'	1.1	2.1	<0.1	<0.5	2.8	*	0.5	<1.5	6.5	
83	38°11'	74°52'	0.2	1.2	---	0.7	3.0	*	<0.5	<1.5	10.8	
84	38°11'	74°57'	0.6	1.8	<0.2	0.7	4.7	*	0.5	<1.5	10.3	
87	38°00'	75°03'	0.3	1.5	---	0.9	5.5	**	0.6	<1.5	11.0	
88	38°02'	75°00'	0.6	1.6	<0.1	0.6	2.9	*	0.5	<1.5	11.2	
89	38°00'	74°51'	0.2	1.4	---	<0.5	3.2	*	<0.5	<1.5	10.5	
90	38°00'	74°46'	0.7	2.1	0.2	0.6	3.6	*	0.4	<1.4	9.8	
91	37°49'	74°52'	0.9	2.6	<0.1	0.9	2.6	*	<0.6	<1.5	9.7	
92	37°49'	74°54'	0.6	2.4	<0.1	<0.5	3.1	*	---	<0.7	8.2	
93	37°51'	75°06'	0.6	2.1	<0.2	<0.5	4.6	*	---	<0.7	9.2	

* Mercury concentrations were less than 0.06 - 0.09 ppm

** Mercury concentrations were less than 0.03 - 0.04 ppm

Table 3. Metal Concentrations in Surf Clams (*Spisula solidissima*) Collected from Stations 100-149 in the Coastal Waters of Middle Eastern U.S.

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)								
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
100	37 ⁰ 42'	75 ⁰ 15'	0.5	2.0	<0.1	<0.5	4.2	*	---	<0.7	8.9
101	37 ⁰ 41'	75 ⁰ 06'	0.5	2.1	<0.1	0.5	2.6	*	---	<0.7	8.1
102	37 ⁰ 40'	75 ⁰ 00'	0.4	2.0	<0.1	<0.5	4.4	*	---	<0.8	9.1
103	37 ⁰ 31'	75 ⁰ 00'	0.2	2.2	<0.1	<0.5	4.6	*	---	<0.7	10.2
104	37 ⁰ 29'	75 ⁰ 04'	0.2	2.3	<0.1	<0.5	7.5	*	---	<0.8	9.6
105	37 ⁰ 29'	75 ⁰ 11'	<0.2	2.1	<0.1	<0.4	3.0	*	---	<0.6	8.3
114	37 ⁰ 20'	75 ⁰ 11'	0.8	2.9	0.1	<0.5	4.2	*	---	<0.7	8.5
116	37 ⁰ 18'	74 ⁰ 57'	<0.1	1.9	<0.1	<0.5	3.6	*	---	<0.7	10.0
117	37 ⁰ 09'	75 ⁰ 04'	<0.1	2.0	<0.1	<0.5	2.8	*	---	<0.7	8.9
118	37 ⁰ 10'	75 ⁰ 13'	0.6	2.1	<0.1	<0.5	3.1	*	---	<0.7	10.0
119	37 ⁰ 09'	75 ⁰ 16'	0.7	2.8	<0.1	<0.5	4.8	*	---	<0.7	10.1
128	36 ⁰ 59'	75 ⁰ 23'	0.3	1.7	0.1	<0.5	4.0	*	---	<1.4	10.2
129	37 ⁰ 00'	75 ⁰ 19'	0.6	2.2	<0.1	<0.5	2.5	*	---	<0.7	10.6
134	36 ⁰ 50'	75 ⁰ 15'	0.6	2.5	0.2	<0.5	2.8	*	---	<0.7	8.7
135	36 ⁰ 49'	75 ⁰ 25'	<0.1	2.1	0.2	<0.5	2.3	*	0.5	<1.5	10.6
137	36 ⁰ 49'	75 ⁰ 36'	0.3	1.4	<0.1	0.5	3.3	*	---	<0.7	9.7
138	36 ⁰ 50'	75 ⁰ 40'	<0.1	1.6	0.1	<0.5	2.4	*	---	<0.8	9.8
143	36 ⁰ 40'	75 ⁰ 36'	0.1	1.7	<0.1	<0.5	3.3	*	---	<0.7	8.1
145	36 ⁰ 39'	75 ⁰ 22'	0.3	1.6	<0.1	<0.5	4.5	**	---	<0.7	8.0
148	36 ⁰ 41'	75 ⁰ 12'	0.7	4.5	0.2	<0.5	1.8	**	---	<0.7	9.1
149	36 ⁰ 44'	75 ⁰ 09'	0.4	3.3	0.2	0.4	3.5	*	---	<0.8	10.2

* Mercury concentrations were less than 0.06 - 0.09 ppm

** Mercury concentrations were less than 0.03 - 0.04 ppm

Table 4. Metal Concentrations in Surf Clams (*Spisula solidissima*) Collected from Stations 150-233 in the Coastal Waters of the Middle Eastern U.S.

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)								
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
150	36°30'	75°05'	0.4	2.0	0.1	<0.5	3.5	**	---	<0.7	10.2
155	36°30'	75°36'	0.3	1.6	<0.1	<0.5	2.4	**	---	<0.7	8.7
156	36°30'	75°41'	0.2	1.6	<0.1	<0.5	2.3	**	---	<0.7	8.1
163	36°20'	75°22'	0.2	1.4	<0.1	<0.5	3.2	**	---	<0.7	9.9
165	36°09'	75°11'	0.3	1.6	<0.1	<0.5	3.1	**	---	<0.7	9.5
170	36°08'	75°37'	<0.1	1.3	0.1	<0.5	2.4	*	---	<1.4	9.4
194	36°40'	74°54'	0.4	1.9	0.1	<0.5	2.8	**	---	<0.7	8.6
195	36°50'	74°53'	0.3	2.9	0.2	<0.5	4.5	*	---	<0.8	10.7
196	37°00'	75°04'	0.5	1.9	0.1	0.5	1.9	*	<0.4	<1.4	10.0
197	37°09'	74°57'	0.4	2.6	0.2	0.5	2.2	*	<0.4	<1.4	8.9
198	37°20'	74°53'	0.3	1.6	<0.1	<0.5	2.7	**	---	<0.7	9.0
199	37°31'	74°53'	0.3	1.2	<0.1	<0.7	2.1	**	---	<0.7	9.5
202	38°00'	74°39'	<0.1	1.1	<0.1	<0.5	2.1	**	---	<0.8	10.0
203	38°00'	74°33'	0.4	1.4	<0.1	<0.5	4.1	**	---	<0.7	10.0
205	38°20'	74°27'	0.2	1.5	<0.1	<0.5	2.7	**	---	<0.7	9.8
206	38°30'	74°26'	0.4	1.4	<0.1	<0.5	2.1	**	---	<0.7	9.0
207	38°39'	74°20'	0.9	2.8	<0.1	0.4	3.3	**	---	<0.8	10.1
208	38°50'	74°22'	1.1	2.0	<0.1	0.5	3.8	**	---	<0.8	12.2
220	40°30'	73°17'	3.8	2.6	<0.1	0.9	3.4	**	---	<1.0	10.7
230	40°48'	72°21'	2.2	2.7	0.5	1.0	5.0	*	0.6	<1.4	14.4
233	40°57'	71°55'	0.6	2.5	<0.1	<0.5	5.4	**	---	<0.7	9.9

* Mercury concentrations were less than 0.06 - 0.09 ppm

** Mercury concentrations were less than 0.03 - 0.04 ppm

Table 5. Metal Concentrations in Ocean Quahogs (*Arctica islandica*) Collected from Stations 2-197 in the Coastal Waters of the Middle Eastern U.S.

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)									
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	
2	40°29.8'	73°43.0'	2.1	2.9	0.4	1.4	6.6	**	<0.4	2.2	17.6	
7	40°20.2'	73°36.2'	2.0	3.6	0.2	0.6	5.2	*	0.5	1.4	8.6	
8	40°20.5'	73°43.0'	1.1	3.3	0.6	<0.9	8.3	*	<0.5	1.1	15.4	
9	40°20.7'	73°50.2'	1.5	3.9	0.5	<0.9	4.9	*	<0.5	1.0	18.2	
12	40°10.0'	73°49.0'	2.5	2.4	0.5	<0.9	5.7	**	<0.5	1.2	21.3	
13	40°09.6'	73°43.3'	2.0	2.0	0.5	1.8	3.4	*	0.5	2.1	12.5	
14	40°09.5'	73°36.5'	1.9	2.6	0.4	1.3	4.2	*	0.6	1.8	16.1	
15	40°09.9'	73°32.9'	1.7	3.2	0.3	<1.0	4.3	*	<0.5	1.0	16.6	
16	40°00'	73°41'	2.7	3.2	0.3	<0.9	5.1	*	<0.5	2.2	14.2	
23	39°49'	73°43'	3.0	2.5	0.4	<0.9	2.7	*	<0.5	3.1	10.0	
25	39°40'	73°36'	1.7	2.2	0.5	<1.0	3.8	**	<0.5	2.3	16.1	
33	39°30'	73°50'	1.9	2.7	0.4	<1.1	3.5	*	<0.5	2.4	15.4	
37	39°20'	73°48'	1.1	2.2	0.5	1.1	3.6	*	0.5	0.8	16.7	
47	39°09'	74°09'	1.6	1.9	0.3	0.8	5.0	*	<0.5	<1.4	14.0	
50	39°10'	73°49'	1.5	2.7	0.3	<0.9	3.0	*	<0.5	<0.6	17.2	
51	38°59'	73°55'	0.6	2.9	0.4	0.9	4.6	*	---	<0.9	11.5	
57	39°00'	74°16'	2.3	2.3	0.4	<0.9	4.1	*	<0.5	<0.9	13.0	
58	39°00'	74°10'	0.8	2.9	0.7	1.1	7.9	*	0.7	<1.5	16.1	
69	38°41'	74°30'	1.8	2.6	0.3	<1.0	3.7	*	<0.5	<0.6	13.5	
80	38°11'	74°33'	0.9	2.4	0.4	1.5	3.7	*	<0.5	<1.5	10.8	
130	36°59'	75°06'	0.3	1.6	0.3	<0.8	2.4	*	<0.4	<0.6	15.1	
197	37°09'	74°57'	0.4	2.2	0.5	<0.8	2.1	**	<0.5	<0.6	12.0	

* Mercury concentrations were less than 0.06 - 0.09 ppm

** Mercury concentrations were less than 0.03 - 0.04 ppm

Table 6. Metal Concentrations in Ocean Quahogs (*Arctica islandica*) Collected from Stations 201-235 in the Coastal Waters of the Middle Eastern U.S

Station	LOCATION		METAL CONCENTRATIONS (PPM, WET WEIGHT)								
	Latitude	Longitude	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
201	37°50'	74°48'	0.5	3.9	0.6	1.0	4.5	*	1.1	4.1	7.8
203	38°00'	74°33'	1.0	2.1	0.4	1.1	2.6	*	<0.5	0.9	11.3
204	38°11'	74°28'	0.4	2.3	0.3	<1.2	1.7	*	<0.5	<0.6	5.5
207	38°39'	74°20'	0.4	2.5	0.4	1.1	4.3	*	<0.5	<1.4	12.0
210	39°09'	73°43'	1.4	2.5	0.4	<1.2	4.2	*	<0.5	0.6	12.5
211	39°19'	73°35'	1.2	3.6	0.6	0.8	4.5	*	0.8	<1.5	11.8
212	39°30'	73°29'	0.7	3.0	0.3	<1.2	3.7	*	<0.5	<0.6	10.8
213	39°40'	73°28'	1.0	3.2	0.4	<1.2	4.0	*	<0.5	0.8	9.8
214	39°50'	73°29'	0.5	3.4	0.3	<1.2	4.2	*	<0.5	<0.6	13.8
215	39°59'	73°30'	0.8	2.8	0.4	<0.5	4.9	*	0.9	<1.5	11.4
216	40°10'	73°29'	2.1	6.9	0.4	<1.2	2.9	*	0.8	<0.7	11.2
217	40°20.5'	73°23.2'	1.7	2.4	0.3	<1.2	7.5	*	<0.5	<0.7	18.6
219	40°21'	73°11'	2.8	3.1	0.5	<1.4	4.3	**	0.7	<0.7	9.9
220	40°30'	73°17'	7.4	3.2	0.3	1.1	10.6	*	0.7	<1.5	19.2
222	40°30'	73°03'	3.1	2.9	0.4	<1.2	6.9	0.06	0.8	0.7	16.6
223	40°28'	72°55'	3.2	4.1	0.7	<1.3	4.7	*	1.0	1.2	9.9
224	40°28'	72°50'	2.4	4.0	0.5	1.8	4.3	**	0.7	0.8	8.8
226	40°38'	72°50'	4.3	3.8	0.5	<1.2	5.6	*	0.8	1.8	13.0
227	40°38'	72°43'	3.9	3.6	0.3	0.6	6.8	*	---	<0.7	11.6
228	40°35'	72°35'	3.1	3.1	0.5	1.1	8.1	*	<1.3	1.9	10.7
229	40°40'	72°30'	2.5	3.4	0.5	0.8	4.6	*	<1.3	2.1	12.2
230	40°48'	72°21'	2.2	2.7	0.5	1.0	5.0	*	0.6	<1.4	14.4
231	40°48'	72°16'	2.7	5.0	0.6	1.2	7.3	*	1.3	2.8	14.8
232	40°49'	72°10'	1.0	3.7	0.5	1.2	12.1	*	<1.5	2.3	11.2
235	40°57'	71°40'	1.4	6.0	1.0	1.4	7.8	*	1.0	2.8	12.8

* Mercury concentrations were less than 0.06 - 0.09 ppm

** Mercury concentrations were less than 0.03 - 0.04 ppm

(Greig, unpublished data). Mercury concentrations were below the detection limits (0.03-0.09 ppm) of our methodology in all surf clam and quahog samples. Nickel was below 1 ppm in most samples of surf clams and quahogs. A substantial number of surf clams could not be analyzed for nickel because of analytical difficulties. Most surf clam and quahog samples had lead concentrations below the detection limit (0.7-1.5 ppm) of our methodology. Ocean quahogs collected in the vicinity of stations 1-37 and 222-235 had lead levels of about 1-4 ppm. Zinc concentrations in these two species of clams were low, with a range of 6-23 ppm, in comparison to American oysters which have been found to contain as much as 1,500 ppm (Greig, unpublished data).

Trace Metals in Lobsters

Lobsters were collected from disposal sites in Long Island Sound off New London and New Haven Harbor over a one year period from July 1974 to July 1975. The trace metals silver, cadmium, copper, chromium, nickel, lead and zinc were determined by wet ashing and direct determination with atomic absorption spectrophotometry.

Results of analyses are shown in Table 8. With few exceptions, there did not appear to be large variations in metal content as a function of time of year samples were collected. The exceptions

Table 8. Metal Concentrations in Lobsters Collected from the New London and New Haven Dump Sites* (ppm, wet weight, standard deviation in parentheses).

Tissue or Organ and Metal	July/Aug. 1974	Jan. 1975	May/June 1975	July/Aug. 1975
<u>Digestive Diverticula</u>				
<u>New London Dump Site</u>				
Ag	8.2 (1.1)	9.9 (2.2)	8.8 (1.6)	7.3 (3.0)
Cd	3.5 (1.3)	3.7 (1.3)	3.2 (1.2)	4.5 (1.9)
Cu	775. (275.)	470. (155)	400. (142.)	370. (200.)
Zn	36. (15.5)	35. (7.1)	27. (12.2)	25. (2.4)
<u>Tail Muscle</u>				
Ag	< 0.2	< 0.15	< 0.2	< 0.2
Cd	< 0.1	< 0.12	< 0.1	< 0.1
Cu	6.3 (2.0)	5.4 (5.2)	7.2 (3.1)	4.8 (0.8)
Zn	13. (1.6)	13. (1.4)	20. (5.2)	19. (4.8)
<u>Gills</u>				
Ag	---	< 0.4	< 0.4	< 0.7
Cd	---	0.47 (0.23)	0.3 (0.17)	0.4 (0.15)
Cu	---	25. (12.1)	19. (4.0)	42. (30.)
Zu	---	15. (3.2)	7.5 (0.8)	11. (3.7)
<u>New Haven Dump Site</u>				
<u>Digestive Diverticula</u>				
Ag	22.1 (5.8)	---	12.4 (1.8)	18.0 (7.4)
Cd	15.6 (6.2)	---	4.9 (2.1)	10.8 (5.3)
Cu	2308. (658.)	---	480. (64.7)	960. (587.)
Zn	61. (33.)	---	27. (10.8)	48 (13.)
<u>Tail Muscle</u>				
Ag	0.23 (0.06)	---	< 0.2	< 0.2
Cd	< 0.1	---	< 0.1	< 0.1
Cu	17.5 (4.6)	---	7.1 (2.8)	5.7 (1.9)
Zn	18.6 (1.2)	---	21. (5.7)	19. (6.0)

*Chromium, nickel, and lead analyses were conducted on these samples and all values were below our detection limits:

Chromium - 0.5 to 0.9
 Nickel - 0.5 to 0.8
 Lead - 0.7 to 1.1

Table 9. Cadmium Concentrations (mean ppm, wet weight) in Various Tissues and Blood of Winter Flounder Exposed to Cadmium (as cadmium chloride) in Seawater for 60 days.

Tissue	No. of Samples ^a	Exposure Level (ppb)		
		Control	5	10
Muscle	4	< 0.15	< 0.15	< 0.15
Liver	4	< 0.5	< 0.5	0.6
Blood	2	< 0.3	< 0.2	< 0.2
Gonad	4	< 0.12	< 0.12	< 0.12
Gills	4	< 0.5	< 0.5	< 0.5

a - The number of samples with pools of tissue or blood from 6 fish per sample.

Table 10. Uptake of Cadmium* by Various Tissues and Organs of Lobsters (Homarus americanus) Exposed to Various Levels of Cadmium (as cadmium chloride) in Seawater for 60 days.

Exposure Level ppb	Digestive Diverticula	Gills	Tail Muscle
0.0	11.5 (3.64)	1.5 (0.09)	< 0.1
3.0	12.9 (1.46)	2.3 (0.29)	< 0.1
6.0	14.2 (1.76)	2.5 (0.35)	< 0.1

* in mean ppm, wet weight - standard error in parentheses.

Table 11. Uptake of Cadmium* by Cunners Exposed to Various Levels of Cadmium (as cadmium chloride) in Seawater for 60 days.

Tissue or Organ	Exposure Level (ppm)		
	Control	0.05	0.1
Muscle	< 0.3	< 0.2	< 0.2
Liver	< 1.9	1.4	---
Gills	< 1.3	< 1.0	1.3
Carcass	< 0.10	0.14	0.28
Blood	< 1.6	< 1.0	< 1.1

* Mean ppm, wet weight - seven individual fish were analyzed for 0.0 and 0.05 ppm exposure level, 4 fish were analyzed for 0.1 ppm exposure.

interest in these data is the fact that cunner and winter flounder did not take up appreciable amounts of cadmium, while lobster accumulated little in muscle tissue but appreciable levels in gills and digestive diverticula. The lack of uptake of cadmium by the cunner is somewhat remarkable in comparison to the lobster in that cunners were exposed to amounts 16 times greater than the lobster.

Uptake of Mercury by Lobster and Winter Flounder

Experiments to determine uptake of mercury were made on lobster and winter flounder exposed for a period of sixty days to low levels of mercury, as mercuric chloride. Lobster gills took up nearly twice as much mercury as winter flounder gills even though they were exposed to about 1/2 the concentration (Tables 12-13). Measurable uptake of mercury was also observed in digestive diverticula and tail muscle of lobster. Mercury was measurable in blood of exposed winter flounder but not in the control animals. Amounts in lobster diverticula and musculature and flounder blood were much less than in gills of both species.

Uptake of Silver by Oysters and Hard Clams

Measurements were made of silver uptake by oysters and hard clams after exposure to low levels of silver as the nitrate for a period of thirty days. Oysters took up considerably more silver

Table 12. Mercury Concentrations* [mean ppm, wet weight - (s. e.)] in Gills and Blood of Winter Flounder Exposed to 5 and 10 ppb Mercury (as mercuric chloride) in Seawater for 60 days.

Exposure Level (ppb)	Gills	Blood
Control	< 0.14 (-)	< 0.04 (-)
5	20.6 (0.72)	2.9 (0.55)
10	42.8 (2.53)	3.8 (0.77)

* The values for gills are the mean of four groups of pools of six fish per group and two groups of four individual fish per group. The blood samples were always pools from 3, 4 or 6 fish.

The range of values for individual fish were:

5 ppb - Gills = 17.8 - 26.1

10 ppb - Gills = 33.1 - 51.9

Table 13. Uptake of Mercury* [mean ppm, wet weight - (s.e.)] by Various Tissues and Organs of Lobsters Exposed to 0, 3, and 6 ppm of Mercury (as mercuric chloride) in Seawater for 60 days.

Gills	Digestive Diverticula	Tail Muscle
	<u>Control</u>	
0.14 (0.025)	0.12 (0.018)	0.23 (0.018)
	<u>3 ppb</u>	
40.9 (4.06)	4.1 (0.86)	0.54 (0.076)
	<u>6 ppb</u>	
85.3 (7.00)	15.2 (3.23)	1.00 (0.101)

* Eight animals per exposure concentration were examined.

(Table 14) at all exposure levels than hard clams (Table 15); the gills of both hard clams and oysters took up greater levels of silver than did the visceral mass of either species.

Trace Metals in Gill and Visceral Mass of Oysters

During the course of these studies of silver uptake by oysters, we became interested in natural levels of the metals in gills versus the remainder of the oyster body. We obtained oysters from a highly polluted area in the Housatonic River, Connecticut and from an uncontaminated area off the North Carolina coast. These two groups of oysters were analyzed in the same fashion: 1) gills were removed from each of ten oysters from each location and kept as individual samples; 2) the bodies (visceral mass) were removed and kept as discrete individual samples; and 3) silver, cadmium, copper and zinc levels were determined for each sample. The results (Table 16) show that in most cases the concentrations of metals in gills were similar to those in the bodies. However, the level of zinc in gills of North Carolina oysters was nearly twice that of the bodies. Based on uptake data from laboratory exposure studies which show that silver is taken up more readily by gills than bodies, one might expect something similar in the natural environment. Such was not the case; gills and bodies seem to be regulated to a greater extent in natural, contaminated environments.

Table 14. Uptake of Silver [mean ppm, wet weight - (s.e.)
by Oysters (Crassostrea virginica) exposed to
Various Levels of Silver (as silver nitrate) in
Seawater for 30 days.

Exposure Level ppm	Gills	Bodies*
0.1	<3.5 (-)	4.5 (0.84)
0.01	31.2 (2.91)	13.8 (1.42)
0.05	74.1 (10.72)	47.0 (3.7)
0.10	91.0 (10.75)	65.3 (8.9)

* Bodies are everything left after removal of shell and gills.

Table 15. Uptake of Silver [mean ppm, wet weight - (s.e.)] by Hard Clams (Mercenaria mercenaria) Exposed to Various Levels of Silver (as silver nitrate) in Seawater for 30 days.

Exposure Level ppm	Gills	Bodies*
Control	< 0.5 (-)	0.4 (0.09)
0.01	6.2 (1.12)	1.2 (0.22)
0.05	10.0 (1.08)	1.4 (0.16)
0.10	9.2 (1.09)	1.2 (0.10)

* Bodies are everything left after removal of shells and gills.

Table 16. Metal Concentrations mean ppm, wet weight -
 (s.e.) in Gills Versus Bodies* of Oysters
 Obtained from the Housatonic River in
 Connecticut and Waters of North Carolina.

Metal	Gills	Bodies
	ppm, wet weight (standard errors in parentheses)	
Housatonic River Oysters		
Ag	1.4	1.9
Cd	3.3 (0.46)	4.5 (0.43)
Cu	203. (35.0)	224. (33.3)
Zn	1124 (184.)	1428. (154.)
North Carolina Oysters		
Ag	0.9	0.2 (-)
Cd	0.9	0.38 (0.03)
Cu	19.3 (4.81)	10.7 (0.84)
Zn	523. (150.)	260. (28.6)

* Bodies are everything left after removal of shells and gills.

Trace Metals in Finfish and Invertebrates
from Deepwater Disposal Site #106

Introduction

In recent years some scientists have become increasingly concerned about the accumulation of toxic heavy metals and other contaminants in marine finfish and their forage species. Several papers and reports have indicated the possible extent of heavy metal buildup or accumulation in invertebrates and finfish taken from estuaries and the coastal zone. Suspected movements of metals from the coastal zones to the deeper seas beyond the shelf-slope break have not been conclusively demonstrated, however, and very little is known about metal contamination of organisms in deeper waters. Mercury concentrations in axial muscle removed from benthopelagic fish caught in 1971 and 1972, as well as specimens taken in 1883 and 1886, have been reported. This study presents values for nine metals measured in four species of deepwater demersal finfish and one benthic invertebrate, the red crab. In addition, data are given for four species of pelagic or surface-dwelling finfish taken in the general area of deepwater disposal site #106 (latitude 38°50'N x longitude 72°15'W). Finally, data are presented on the distribution and abundance of six heavy metals in surficial sediments collected from nine benthic sampling stations located near the deepwater site. This site is utilized for disposal of various industrial wastes deemed too

toxic for inshore disposal operations. Some of these wastes are known to contain heavy metals and other toxic materials.

Materials and Methods

Samples of organisms were collected by various trawling devices utilized in the general area of the so-called deepwater disposal site #106. Sediment samples were collected from the submersible Alvin using metal-free core liners. After collection, fish invertebrates, and sediments were frozen until chemical analysis could be completed. All samples were kept as free as possible of contamination by metals.

It should be emphasized that our heavy metal analyses have been intercalibrated with those of other laboratories using similar techniques as well as through neutron activation methodology for certain metals.

Results and Discussion

The results of our analyses are presented in Tables 17-18. A knowledge of the present abundance and distribution of mercury and other metals in the ocean is necessary to understand the natural biogeochemical flux of these elements through the coastal and deepwater ecosystems and to document and, possibly, predict the impact of man's activities in the world ocean. It is a popular assumption that the deeper parts of the oceans have been the least affected by chemical contaminants. Moreover, however, certain elements of society advocate using the deep seas for waste

Table 17. Metal Concentrations¹ (ppm, dry weight) in Sediments Obtained from a Deep Water Dump Site in the New York Bight.

Latitude ₁	Longitude ₁	Depth (m)	Cd	Cr	Cu	Ni	Pb	Zn
38°31.9'N	72°10.5'W	2812.	1.25	16.7	25.8	29.7	13.	47.8
38°31.2'N	72°12.1'W	2818.	1.25	16.7	23.0	33.1	15.	47.0
38°46'N	72°30.2'W	2351.	1.25	14.6	17.2	19.8	14.	40.2
38°49.9'N	72°34.1'W	2027.	1.25	15.8	18.7	22.2	14.	42.5
38°52.7'N	72°16.6'W	2452.	1.25	14.7	14.9	17.4	13.	39.1
38°56.7'N	72°25.1'W	1688.	1.25	16.2	17.9	20.8	13.	44.3
38°55'N	72°05.5'W	2477.	1.25	13.0	13.8	15.8	8.	32.0
39°09.9'N	71°54.8'W	1959.	1.25	13.5	13.9	15.3	15.	36.7
39°10'N	71°55.1'W	1982.	1.25	6.0	6.5	7.4	7.5	19.5

1. Latitude and longitude given are for the LULU only.

TABLE 18. Metal Concentrations (ppm, wet weight) in Organisms Collected in the Vicinity of a Deep Water Dump Site (#106) in the New York Bight

Species	Tissue	No. of Animals	Average Length (in mm.)	Average Weight (in grams)	Ag	As	Cd	Cr	Cr	Hg	Ni	Pb	Zn
1. <u>Antimora rostrata</u>	Muscle	10	430.	706.	0.09	21.1	0.09	0.52	.50	0.62	0.51	1.00	2.40
	Liver	10	430.	706.	0.13	4.8	0.32	0.52	3.34	-	0.48	1.00	43.00
	Muscle				0.15	-	0.12	0.61	0.51	-	0.51	0.80	2.84
	Muscle				0.12	-	0.12	0.61	0.51	-	0.51	0.80	3.15
	Liver				0.11	-	0.36	0.59	1.96	-	0.45	0.70	12.20
	Liver				0.11	-	0.33	0.57	1.86	-	0.47	1.20	11.10
2. <u>Nematonurus armatus</u>	Muscle	10	355.	189.	0.10	20.0	0.10	0.52	.50	0.28	0.60	1.00	2.9
	Liver	10	355.	189.	-	10.4	1.33	0.52	0.70	0.31	0.50	1.00	50.
	Muscle	7	609.	217.	0.10	10.0	0.10	0.52	.50	0.10	0.50	1.00	1.4
	Liver	7	609.	217.	-	-	1.21	0.86	4.80	-	0.82	1.6	16.2
	Muscle				0.11	-	0.11	0.53	0.44	-	0.44	0.7	3.13
	Muscle				0.14	-	0.14	0.68	0.57	-	0.57	0.9	3.19
3. <u>Halosauropsis macrochir</u>	Muscle				0.12	-	0.12	0.98	1.49	-	0.48	0.7	2.45
	Muscle				0.12	-	0.12	1.17	1.65	-	0.50	0.8	2.37
4. <u>Synaphobranchus affinis</u>	Whole animal	10	-	32.4	0.09	8.0	0.12	0.42	1.62	0.15	0.49	1.00	6.8
5. <u>Geryon</u>	Muscle	7	93.	227.	0.13	16.2	0.10	0.51	8.3	0.23	0.48	1.00	69.
	Gills	7	93.	227.	0.43	9.1	0.81	0.52	31.3	0.16	0.50	1.00	20.2
6. <u>Seriola</u>	Muscle	6	145.	63.6	0.10	1.2	0.10	0.52	.63	0.10	0.50	1.00	3.7
	Liver	6	145.	63.6	0.24	-	0.24	1.26	1.96	-	1.20	2.4	15.5
7. <u>Hygophum hygomi</u>	Whole animal	10	-	-	0.09	-	0.11	0.49	.47	-	0.47	0.95	7.4
	Whole	15	-	-	0.08	-	0.11	0.35	0.64	-	0.74	1.0	8.5
	Whole	15	-	-	0.07	-	0.09	0.31	0.57	-	0.37	0.60	7.7
	Whole	15	-	-	0.10	-	0.07	0.37	0.73	-	0.53	0.75	6.9
8. <u>Monocanthus hispidus</u>	Whole animal	6	-	-	0.07	-	0.14	0.36	.90	-	0.48	1.0	-
9. <u>Stephanolepis hispidus</u>	Whole animal	5	-	21.5	0.09	1.5	0.13	0.52	0.89	0.11	0.49	1.07	10.3

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disposal; it is believed that wastes, even highly toxic materials, will be sufficiently diluted or isolated in the hadal and abyssal regions of the oceans. Others argue that deep-sea benthic communities are particularly subject to any stress and waste disposal may have extensive effects on these stable populations which have evolved through long periods of time within narrow ranges of physical and chemical variation.

Since Barber, Vijayakumar and Cross presented data on a single metal, mercury (Hg), in several fish, our comparisons with their values must be limited to this metal. They noted that Hg (ppm wet weight) ranged from 0.24 ppm in a fish 33.5 cm to 0.76 ppm in one 52.2 cm. These fish were taken either on 28 July 71 or 5 July 72. These authors also analyzed a single fish of the same species of approximately the same length (45.7 cm), but collected in 1883. This fish contained 0.50 ppm of Hg. We analyzed homogenated muscle tissues from ten A. rostrata, averaging 43.0 cm length, and found 0.62 ppm of Hg (Table 18), a value very similar to those found by the above authors in fish of similar length.

The Hg levels in axial muscle and liver from other species of finfish are given in Table 18. Data are also given for eight other metals for most finfish species analyzed.

Although the recent and 1883 fish collected and analyzed by Barber, Vijayakumar and Cross were collected southeast of Cape Hatteras in an area far less likely to be polluted with materials similar to the industrial wastes disposed of at site #106, the values they reported for Hg in axial muscle were similar to those we found in fish of the same species collected at deepwater disposal site #106 off the New York Bight.

Because there does not seem to be any significant variation in Hg in fish taken off New Jersey and Cape Hatteras or, for that matter, in fish taken almost a century apart, it is possible that the other metals given in Table 18 represent the normal levels of metals in deepwater fish.

Table 17 gives the amounts of metals found in sediments collected at benthic stations located near the deepwater disposal site #106. These values are very similar to those previously found in sediments collected from similar stations in 1973.

ECOSYSTEMS INVESTIGATIONS

BIOCHEMICAL MODELING

R. Tucker, A. Draxler, A. Matte and R. Waldhauer

During the last year we carried out extensive analyses of water samples from Raritan Bay for heavy metals. Determination of geographical distribution of soluble, particulate, and total concentrations of cadmium, lead, copper, and zinc give us, for the first time, the ability to model behavior of heavy metals in estuaries. Metals are determined by the sensitive method of anodic stripping polarography. In this technique a voltage, more negative than the half-cell potential of any of the metals of interest, is imposed across a pair of electrodes immersed in the sample. Metal ions migrate to the anode and form an amalgam with the layer of mercury plated on a graphite electrode. After a set sampling period the voltage is gradually increased (a positive ramp) and as the half-cell potential for each of the metals in the sample is reached, the metal is stripped from the anode and the resulting current differential is measured by an additional electrode. By calibrating with known standards, current differential measurements can be converted to metal concentrations in the sample. In Figures 1 and 2, concentrations of lead in water in Raritan and Lower New York Bays are presented.

**Figures 1 and 2. Concentrations of Lead in Water in Raritan
Bay and Lower New York Bay.**

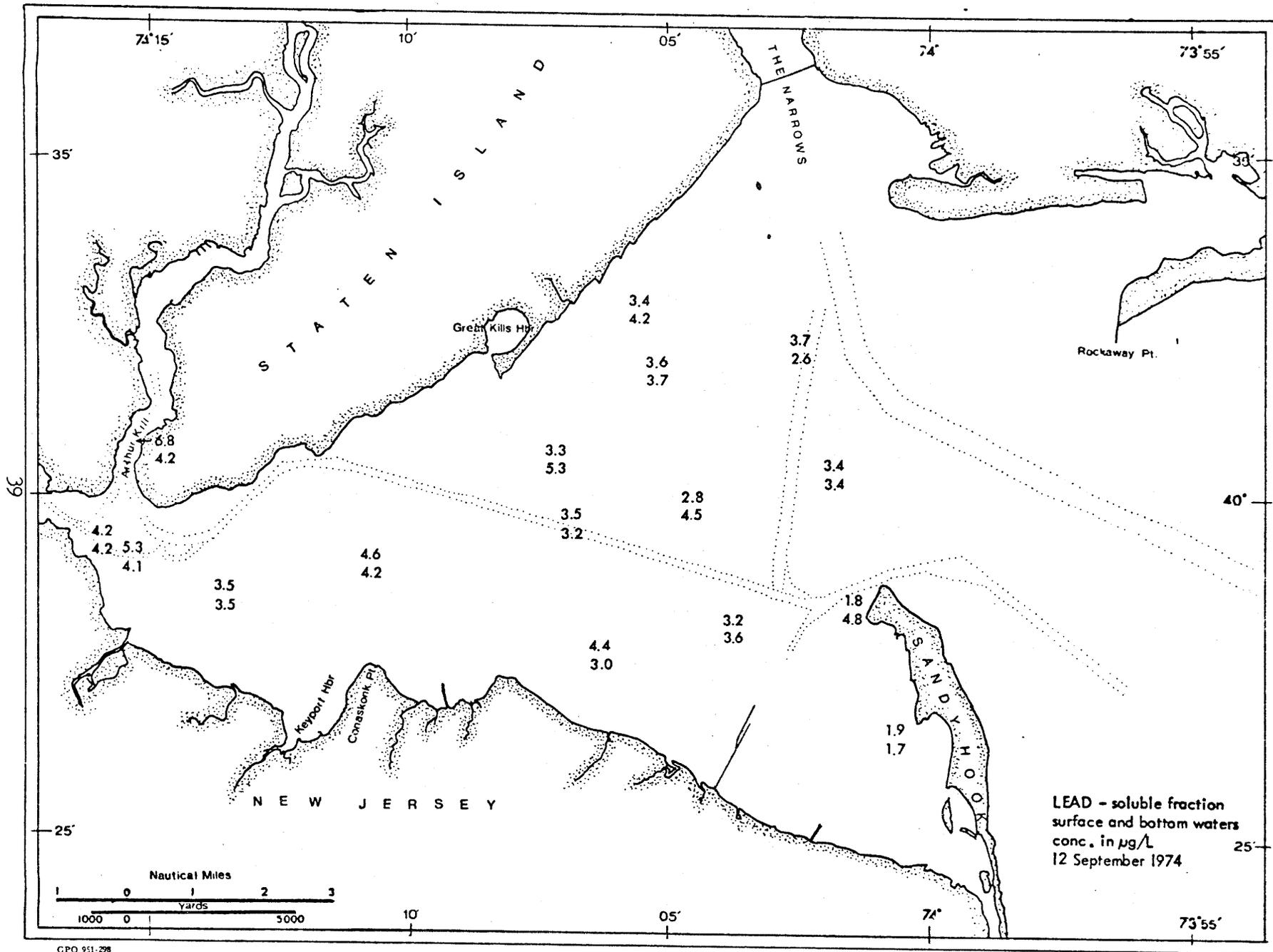


Figure 1A

LEAD - soluble fraction
 surface and bottom waters
 conc. in $\mu\text{g/L}$
 12 September 1974

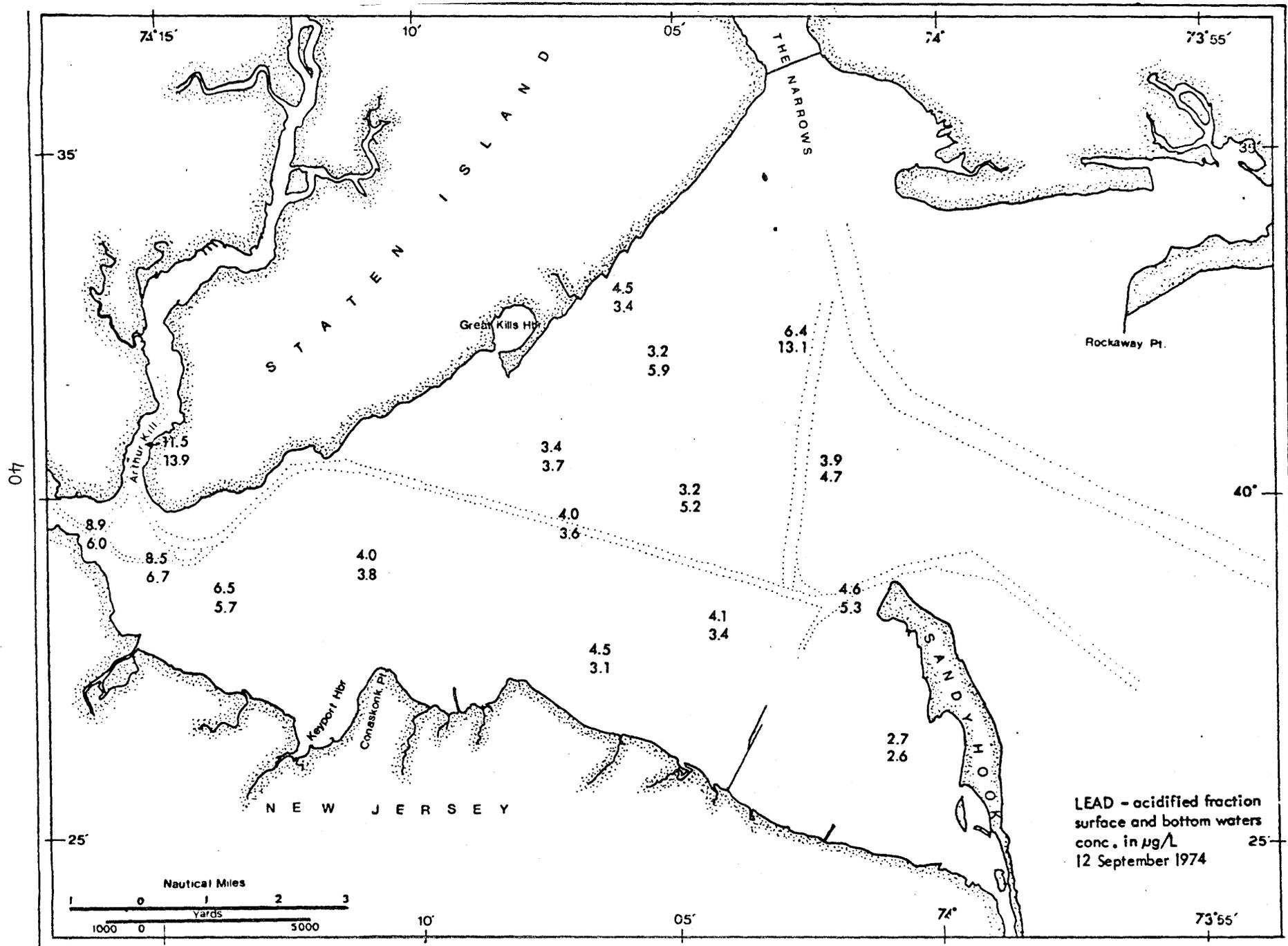


Figure 1B

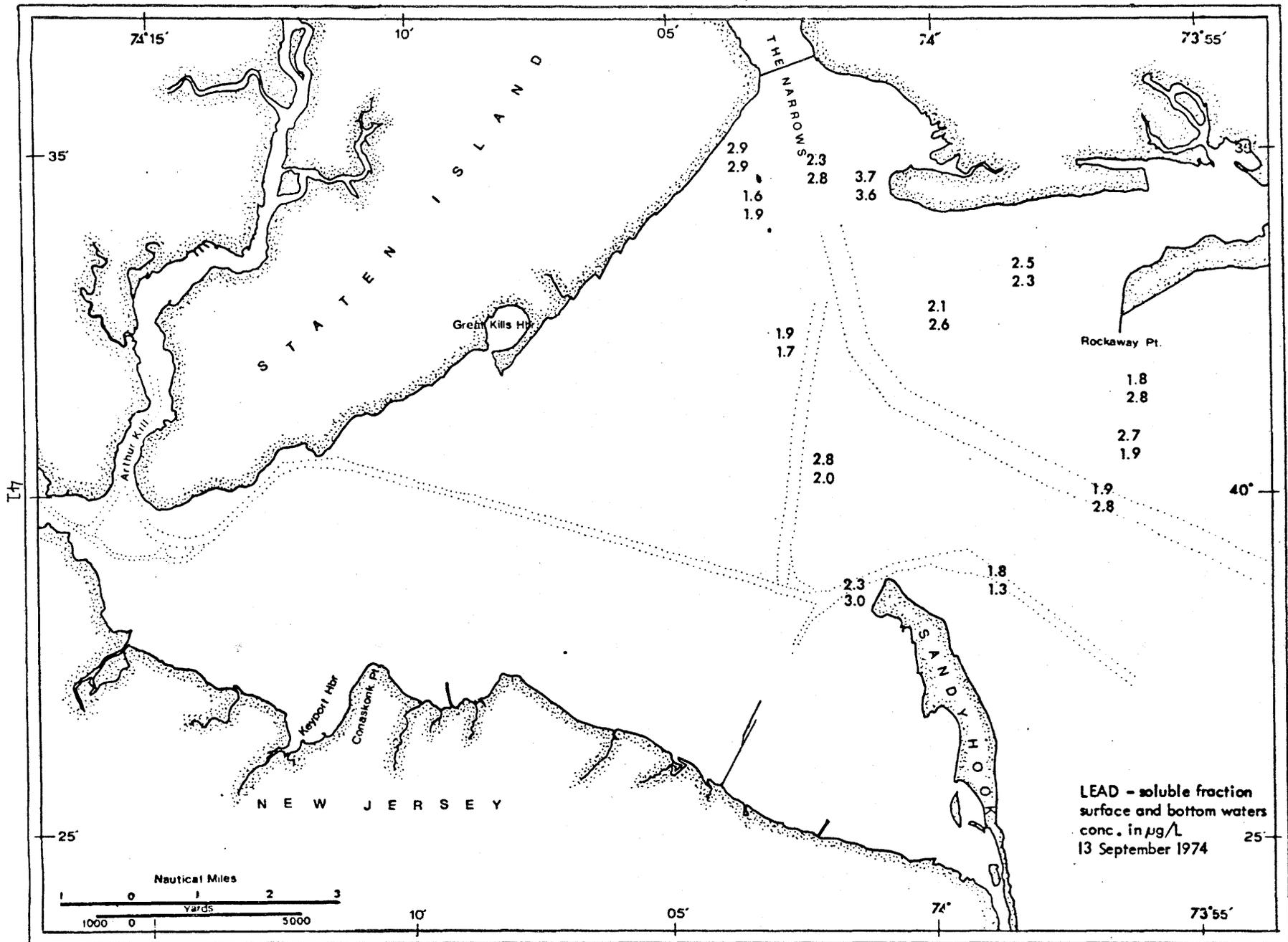


Figure 2A

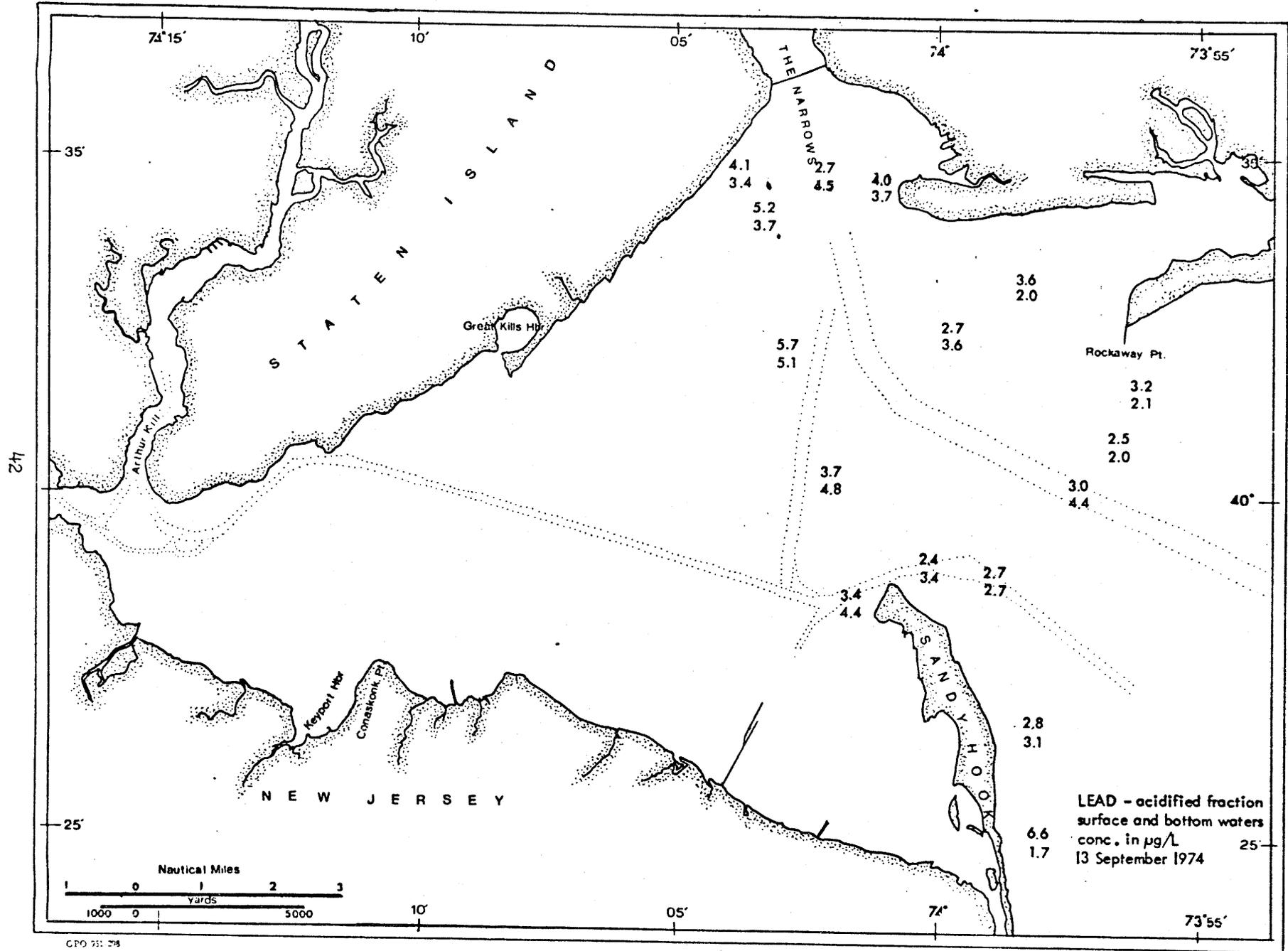


Figure 2B

Figures 3 and 4 give the concentrations of copper in water. The upper section of each figure represents the soluble fraction of the metal; for these determinations water samples were filtered through a 0.45 micron Millipore filter immediately after collection and then acidified to pH2 with ultra pure nitric acid. In the lower section of each figure the acidified fraction of metals in the water samples are presented. These samples were acidified to pH2 upon collection and only filtered just before analysis. The acidified fraction thus includes the adsorbed and most of the bound metal in addition to the soluble fraction. Only metal incorporated within particulate material and that so strongly chelated as not to be released at pH2 is excluded from the analysis. The concentrations of the two metals are generally highest at the western end of the bay, where waters from the Raritan River and Arthur Kill enter the system, and decrease eastward, with elevated values occurring again in the Hudson River discharge. The disparity in values from the four overlapping stations sampled during the two day period are indicative of fluctuations in metal concentration due to tidal currents and sea state between the two sampling periods.

In conjunction with the Long Island Sound survey, we investigated sedimentation rates (no increase in sedimentation one mile from the dump site), carbon content of sediments, and lead concentrations in accumulated sediments near the New London dredging and disposal sites.

Figures 3 and 4. Concentrations of Copper in Waters in
Raritan Bay and Lower New York Bay.

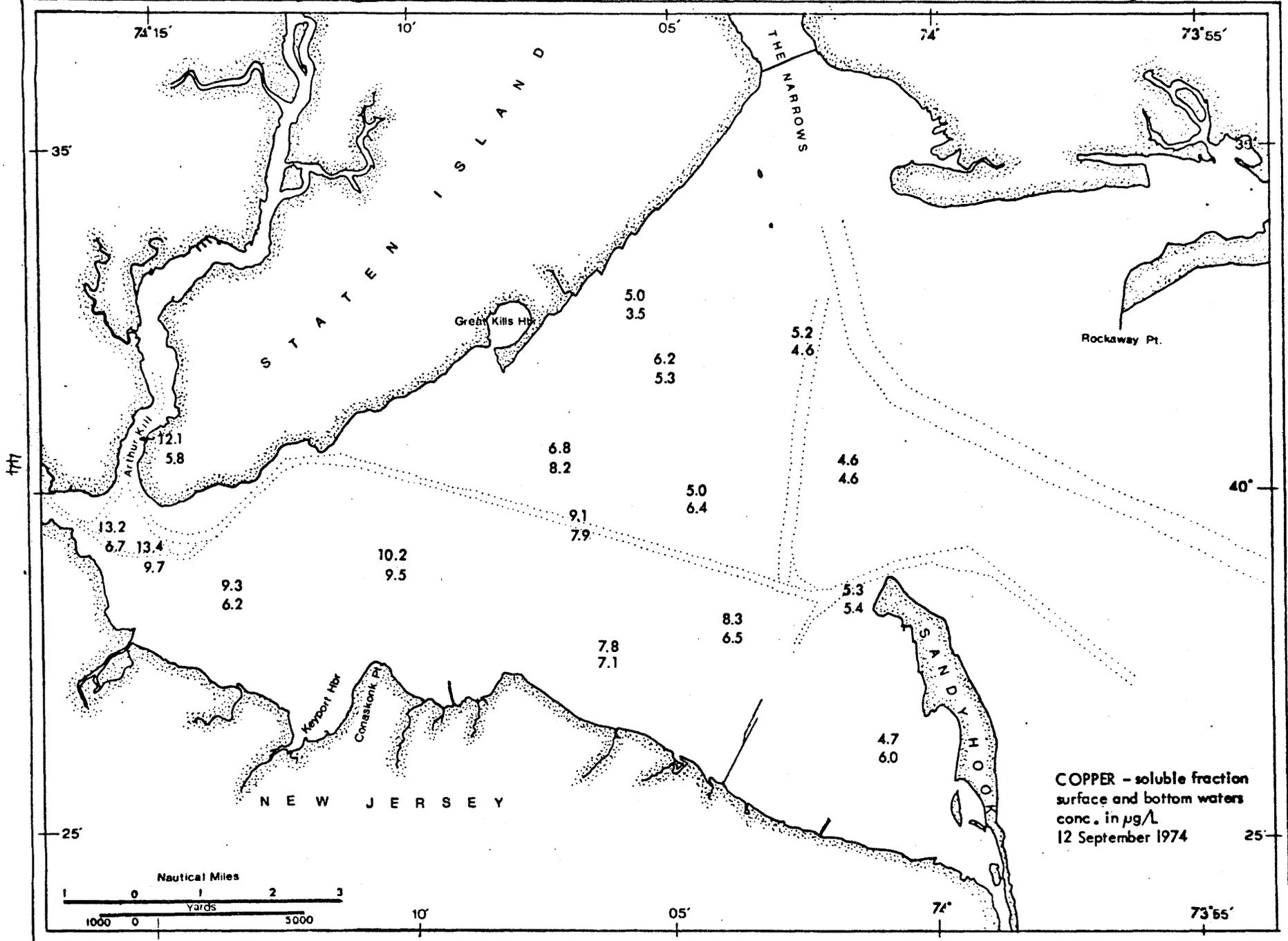
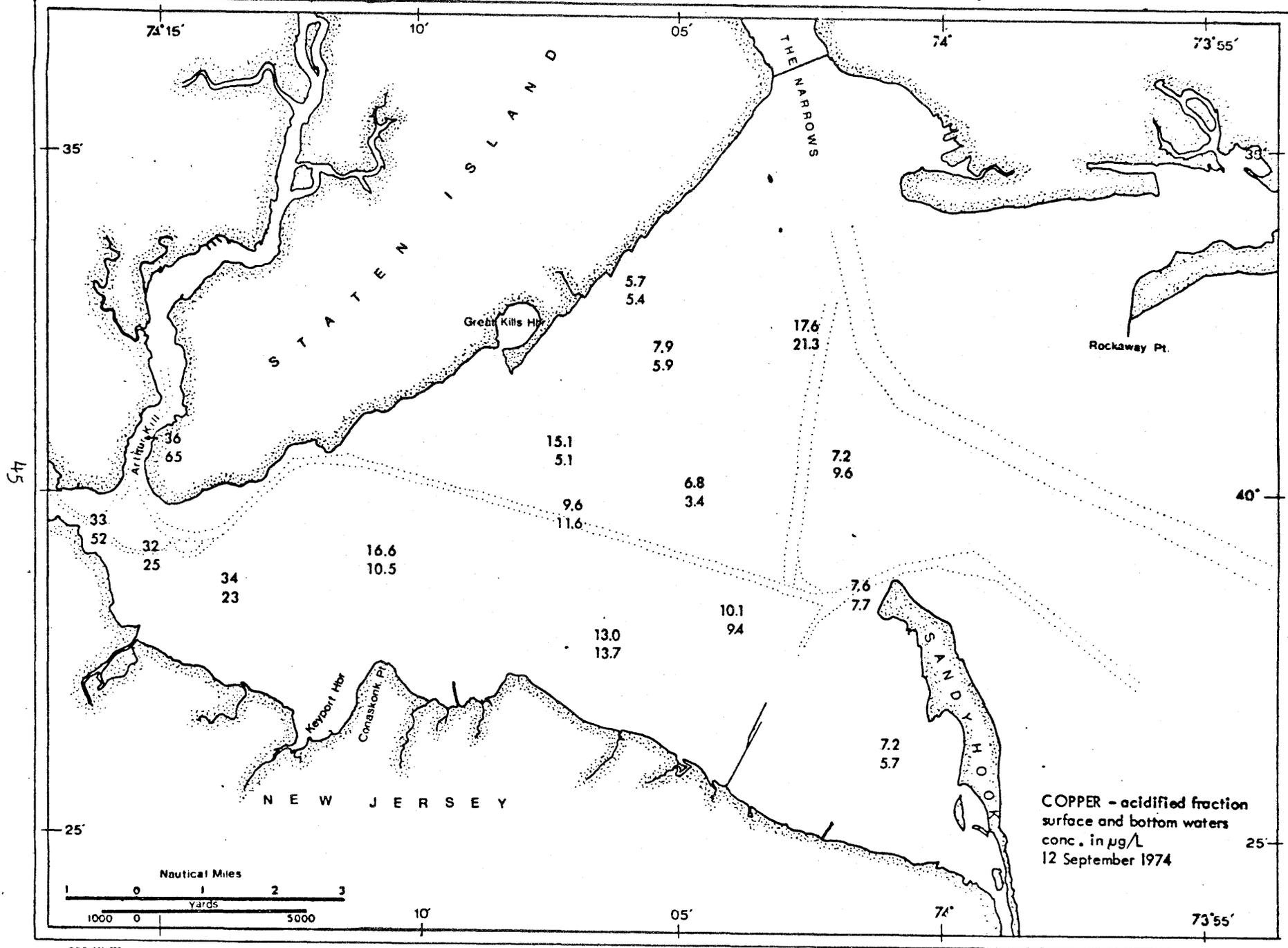


Figure 3A



COPPER - acidified fraction
 surface and bottom waters
 conc. in $\mu\text{g/L}$
 12 September 1974

Figure 3B

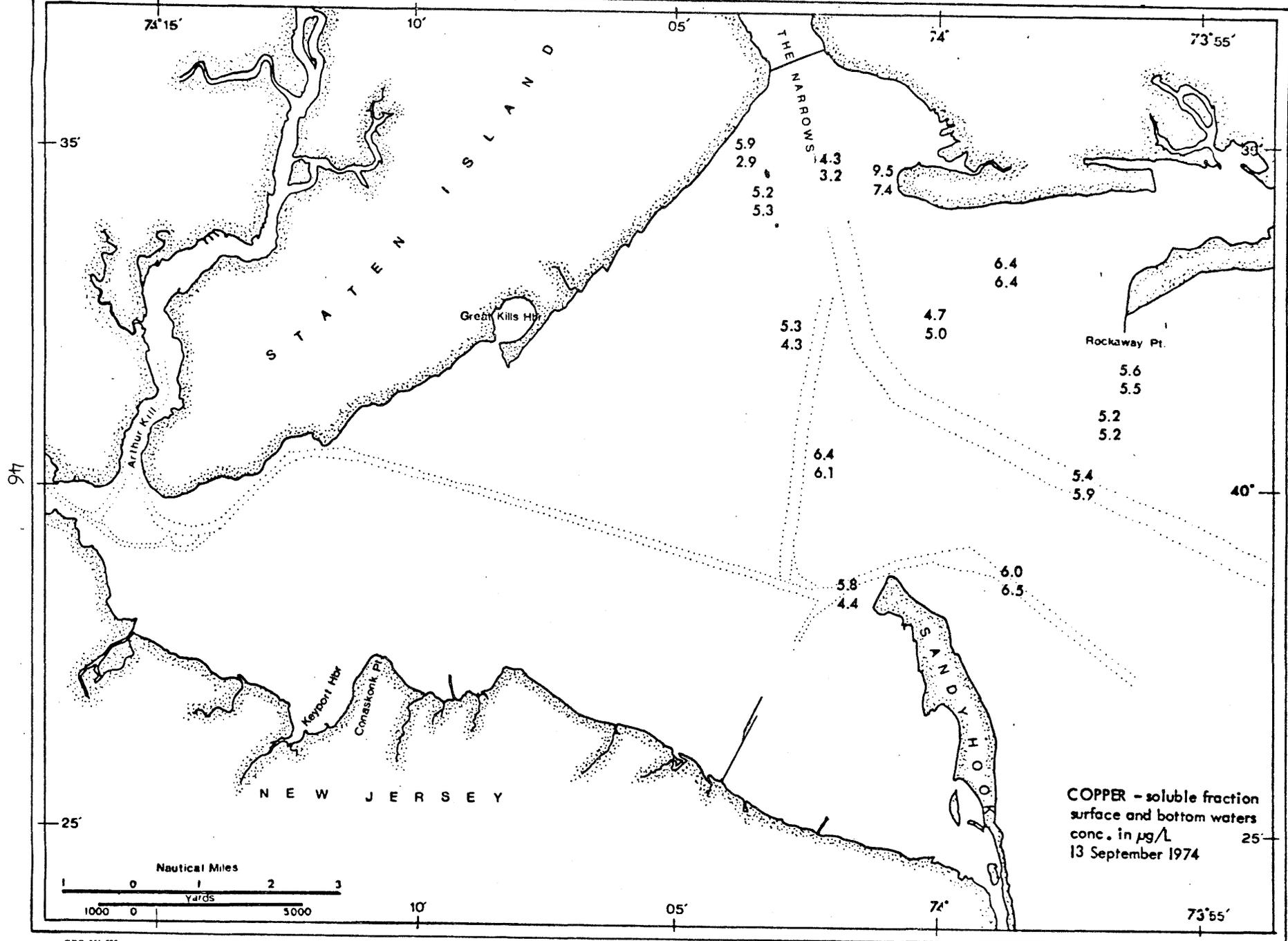


Figure 4A

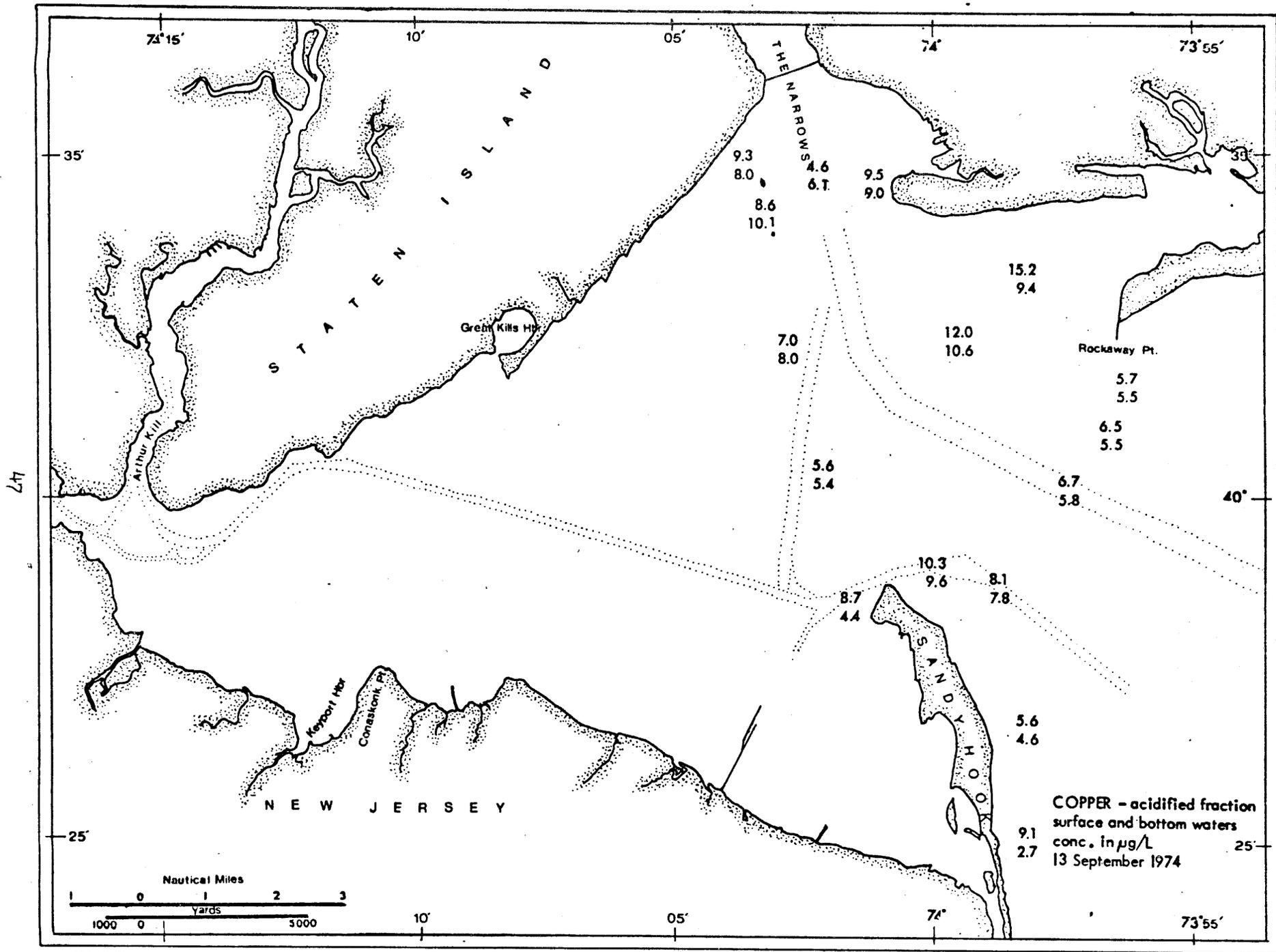


Figure 4B

As part of a continuing cooperative study with the Milford Laboratory we carried out additional determinations of effects of cadmium on lobster gill membrane Na^+K^+ ATPase and on mitochondrial ATPase activity in animals subjected to 6 ppb cadmium for 30 days. There is evidence from these studies that cadmium may cause increased enzyme activity in animals subjected, in vivo, to the metal; this contrasts to our previous findings of in vitro inhibition of the enzymes from crab gill.

ECOSYSTEMS INVESTIGATIONS
COASTAL ECOSYSTEMS INVESTIGATION

R. Reid, R. McGrath, F. Steimle, D. Radosh and A. Frame

Introduction

Environmental studies focusing on the benthic ecology of several coastal areas continued during calendar year 1975. Major emphasis was directed toward determining effects of dredging in the Thames River, Connecticut and spoil disposal at the New London dredging spoils disposal grounds. We also began a survey of a possible alternate disposal site for Thames River spoils, the "East Hole", in Block Island Sound. Field collections were resumed in the Long Island Sound survey, to assess long-term environmental trends and impacts. No sampling was carried out during the past year in Raritan Bay, New Jersey Coast or Baltimore Canyon Trough subtasks. A manuscript is in preparation, in conjunction with Environmental Chemistry, concerning distribution of and relationship between sediments and heavy metals in Raritan Bay. The New Jersey Coast-Baltimore Canyon subtask began workup of existing sediment and benthic macrofauna samples to establish baselines; this was done as part of a larger effort, tentatively to be supported by the Bureau of Land Management, which will provide data against which impacts of eventual offshore oil-

related activities can be measured. Detailed statements of the activities of each project are given below, with emphasis on contaminant related studies and findings.

New London and Thames River Estuary

We continued the quarterly surveys of dredging and spoiling impacts, by collecting data on hydrography, sediment and benthic macrofauna at 39 dump site and 7 river stations (Figure 5) in January, April, June and September. Dredging, the first of two phases of the overall operation, took place from August 1974 to July 1975 and an estimated 1.7 million cubic yards of spoils were removed. The dump site was shifted 600 feet SE of the original location in December 1974. Phase II dredging is scheduled to begin in spring 1976, at which time an additional 1.1 million cubic yards will be removed. A proposal has been submitted by MACFC to the Navy for monitoring Phase II as well as long-term dredging and spoiling effects. Results have been reported to the Navy on a quarterly basis. In 1975 this included MACFC Informal Report Nos. 49, 62, 75 and 84. The surveys to date have consistently indicated that the impact of dredging and spoiling has been restricted to the immediate vicinity of these operations. No long-term reduction of dissolved oxygen has been seen either in the river or at the dump site. No spoil has been detected outside the one-mile-radius circle established

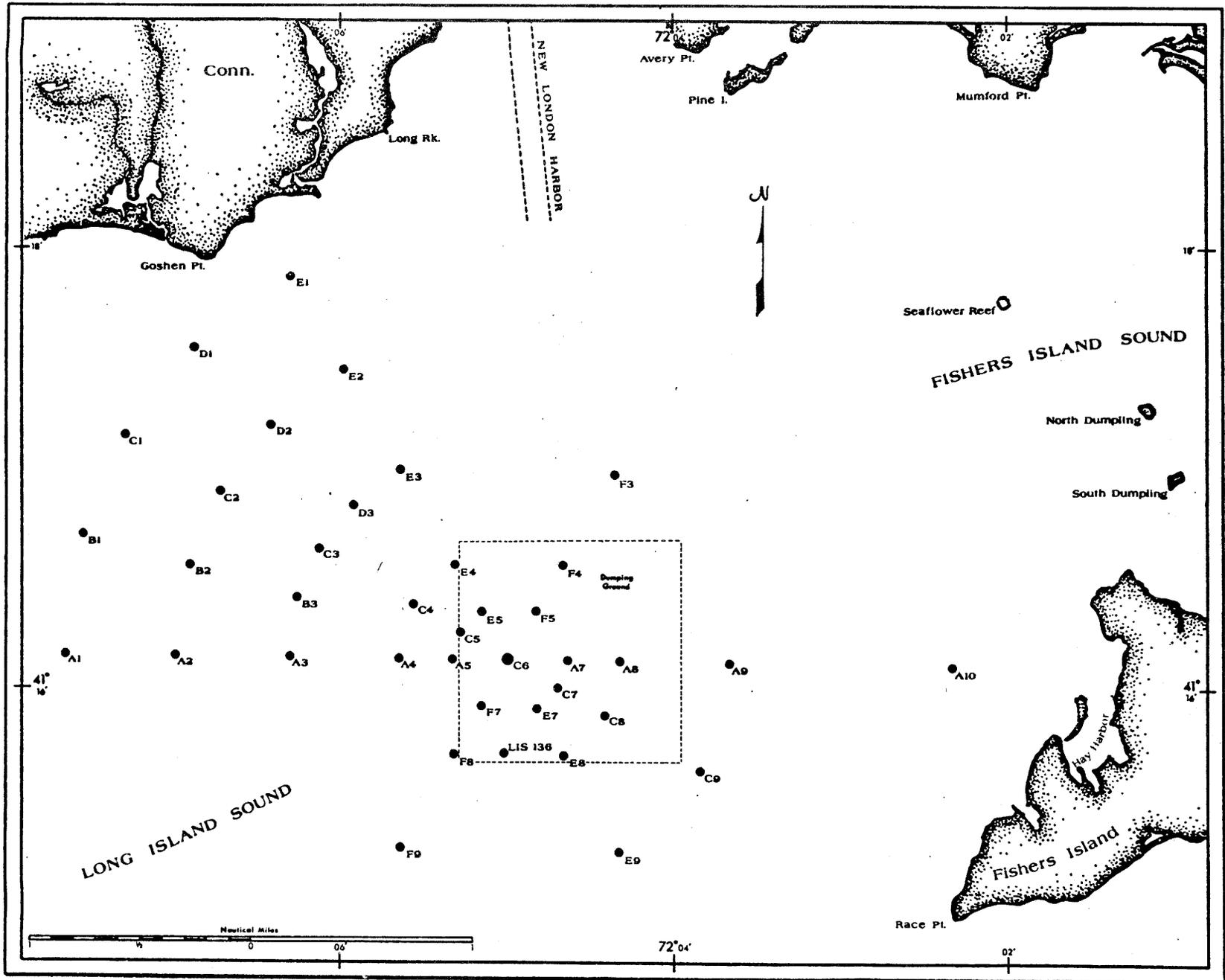


Figure 5. Sampling pattern for sediments and benthic macrofauna.

by the Interagency Scientific Advisory Sub-committee on Ocean Dredging and Spoiling (ISASODS), EPA and the Corps of Engineers as the boundary for acceptable impacts. Maximum horizontal spread of the spoil pile, as determined by grab samples and dive surveys in September-October, appeared to be in a southerly to easterly direction; the spoil extended just over 0.5 n. mi. from the original disposal point in these directions.

Benthic macrofauna populations were reduced or eliminated in areas where substantial spoil accumulation occurred. Where the presence of spoil material was not detected, however, these effects could not be distinguished from the large, seemingly natural population changes occurring throughout the study area. Table 19 compares values for numbers of individuals and species, Shannon-Weaver species diversity, and equitability of evenness of distribution of individuals among species, for 10 stations for which June 1974 (pre-disposal) and June 1975 samples have been analyzed. Large decreases in individuals and species are seen at most of these stations. Two related lines of evidence suggest that these changes were natural rather than spoil-induced: 1) large decreases in species and individuals were found at stations A1 and C1, which we feel confident are "control" stations, and are located 2 miles west and northwest of the original dump point, respectively, while during the same period, station A9, within 0.5 mile of the spoil pile and in the direction of net drift, had much smaller declines; and 2) on the A and C transects

Table 19. Mean Values for Number of Individuals (N), Number of Species (S), Species Diversity (H') and Equitability (J'), from 0.1 m²/Smith-McIntyre Bottom Grab Samples. Upper Value at Each Station Represents June-July 1974 Samples. Second Value is June-July 1975, and Lower Figure is Percentage Change Between the Means of the Two Years. 95% Confidence Limits Given in Parentheses Where Calculated. Bracketed Values Denote Areas in Which 95% Confidence Limits for Succeeding Years do not Overlap. n = Number of Replicate Samples Used in Calculations.

	N	S	H'	J'	n
A1 1974	116.8 (46.9-186.7)	23.4 (13.8-33.0)	2.23 (1.34-3.11)	.708 (.451- .966)	5
1975	38.2 (4.8- 71.6)	16.8 (6.2-27.4)	2.42 (1.85-2.99)	.901 (.843- .959)	5
% change	-67.3	-28.2	+8.5	+27.3	
A3 1974	614.0 (232.4-995.7)	50.5 (35.1-65.9)	2.74 (1.90-3.58)	.697 (.528- .866)	4
1975	121.3 (0 -367.7)	37.7 (0 -81.4)	3.16 (1.93-4.40)	.893 (.794- .992)	3
% change	-80.2	-25.3	+15.3	+28.1	
A9 1974	458.3 (178.5-738.0)	39.5 (31.2-47.8)	2.02 (1.37-2.66)	.529 (.408- .650)	4
1975	344.4 (155.9-533.0)	34.6 (20.1-49.1)	2.18 (1.81-2.55)	.621 (.566- .677)	5
% change	-24.9	-12.4	+ 7.9	+17.4	
C1 1974	1471.4 (294.8-2648.0)	40.0 (33.9-46.2)	0.94 (0.42-1.47)	.259 (.104- .415)	5
1975	382.3 (0 -929.5)	30.7 (26.9-34.5)	1.82 (0 -3.67)	.533 (0 -1.0)	3
% change	-74.0	-23.3	+93.6	+105.8	
C3 1974	[169.4 (73.8-265.0)]	38.0 (23.3-52.7)	3.00 (2.34-3.65)	.831 (.697- .965)	5
1975	[481.1 (328.9-633.1)]	54.5 (41.7-67.3)	2.79 (2.31-3.28)	.699 (.613- .785)	4
% change	+183.9	+43.4	- 7.0	-15.9	
C4 1974	414.2 (220.5-607.9)	44.8 (37.5-52.1)	2.41 (2.07-2.74)	.637 (.529- .744)	5
1975	444.5 (149.1-517.8)	37.8 (21.8-53.8)	2.06 (1.62-2.50)	.574 (.496- .652)	5
% change	-19.5	-15.6	-14.5	- 9.9	
C5 1974	98	31	3.02	.878	1
1975	90.0 (19.4-160.6)	23.8 (13.1-34.4)	2.50 (1.81-3.19)	.796 (.608- .984)	4
% change	- 8.2	-23.2	-17.2	- 9.3	

Table 19 - (continued)

	N	S	H'	J'	n
C6 1974	[424.3 (320.6-528.0)]	[52.0 (41.2-62.8)]	[2.79 (2.03-3.55)]	.706 (.530- .882)	3
1975	[15.3 (0 - 55.8)]	[5.7 (0 -15.1)]	[1.27 (0.63-1.90)]	.838 (.360-1.0)	3
% change	-96.4	-89.0	-54.5	+18.7	
R4 1974	57	6	1.33	.743	1
1975	58.2 (10.3-106.1)	9.2 (5.5-12.9)	1.41 (1.11-1.70)	.650 (.570- .731)	5
% change	+2.1	+53.3	+ 6.0	-12.5	
R5 1974	254	21	1.35	.444	1
1975	125.8 (35.9-215.7)	12.0 (7.6-16.4)	1.51 (0.88-2.13)	.610 (.380- .840)	5
% change	-50.5	-42.9	+11.9	+37.4	

there was no clear gradient of faunal change moving away from the disposal buoy (station C6), while station A3, one mile from the buoy, changed similar to A1, an additional one mile removed from the site of spoiling. The C transect showed large increases in June 1975 in individuals and species at the one-mile radius station, and sizeable decreases at the two-mile control station. A gradient of decreasing change with distance from the point of disposal would be expected if contaminants had a direct effect or were being leached from the spoil pile and affecting the fauna at distance. The lack of a pattern of impact is demonstrated in Figure 6, which depicts changes in numbers of species between the two summers.

Table 19 also shows that although the fauna underwent large fluctuations in most areas, statistically significant (95% confidence level) changes were found at only two stations. C3 had a significant increase in individuals between June 1974 and June 1975. Only C6 had significant decreases between years; here individuals, species and species diversity were all sharply reduced in 1975. Station C6, the original disposal point, is also the only station analyzed where sediments consisted solely or mostly of spoils in 1975. This provides additional evidence that effects of the spoils on macrofauna are largely limited to burial, and that the impact of contaminants acting at a distance from the spoil pile are indistinguishable from natural temporal change.

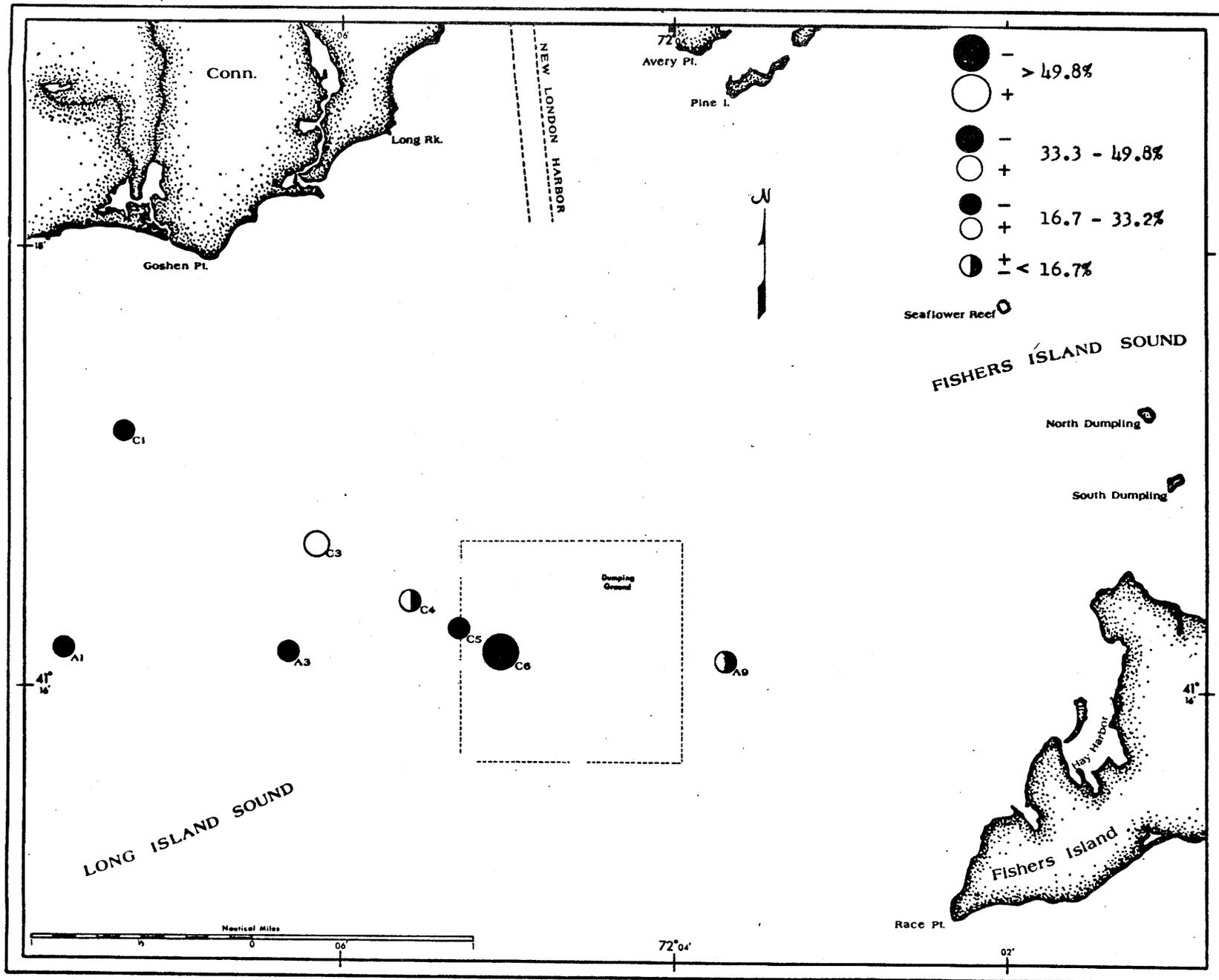


Figure 6. Changes in mean numbers of species per 0.1 m^2 between June-July 1974 and June-July 1975. Actual values are given in Table 1.

We also investigated recolonization of the spoil materials. Figure 7 presents changes in individuals, species and species diversity at the disposal buoy (station C6) from the June 1974 predisposal sampling through September 1975. A precipitous drop is evident in all three parameters after the onset of spoiling in August 1974. Recolonization was slow or lacking through the July 1975 period of sampling; this is probably a result of continued dumping in the area and reduced recruitment known to accompany colder winter months. By September 1975, however, considerable recolonization was apparent. Values for individuals, species and species diversity were all significantly higher (95% confidence level) than for the October 1974 and January and April 1975 collections, though still significantly below predisposal levels. Conspicuous among recolonizing forms were the tube-dwelling amphipods Ampelisca vadorum and Leptocheirus pinguis. Their reappearance is important for several reasons: 1) their tubes have been shown to bind sediments, so that erosion of the spoil pile may be lessened; 2) the "East Hole" studies have revealed these species to be dominant items in the diets of locally abundant demersal finfish and their presence, rather than opportunistic species which may be of less food value, speaks well for a return to productivity of the area; and 3) Ampelisca and Leptocheirus were dominant members of the predisposal community at C6, and their return shows that the spoils are not

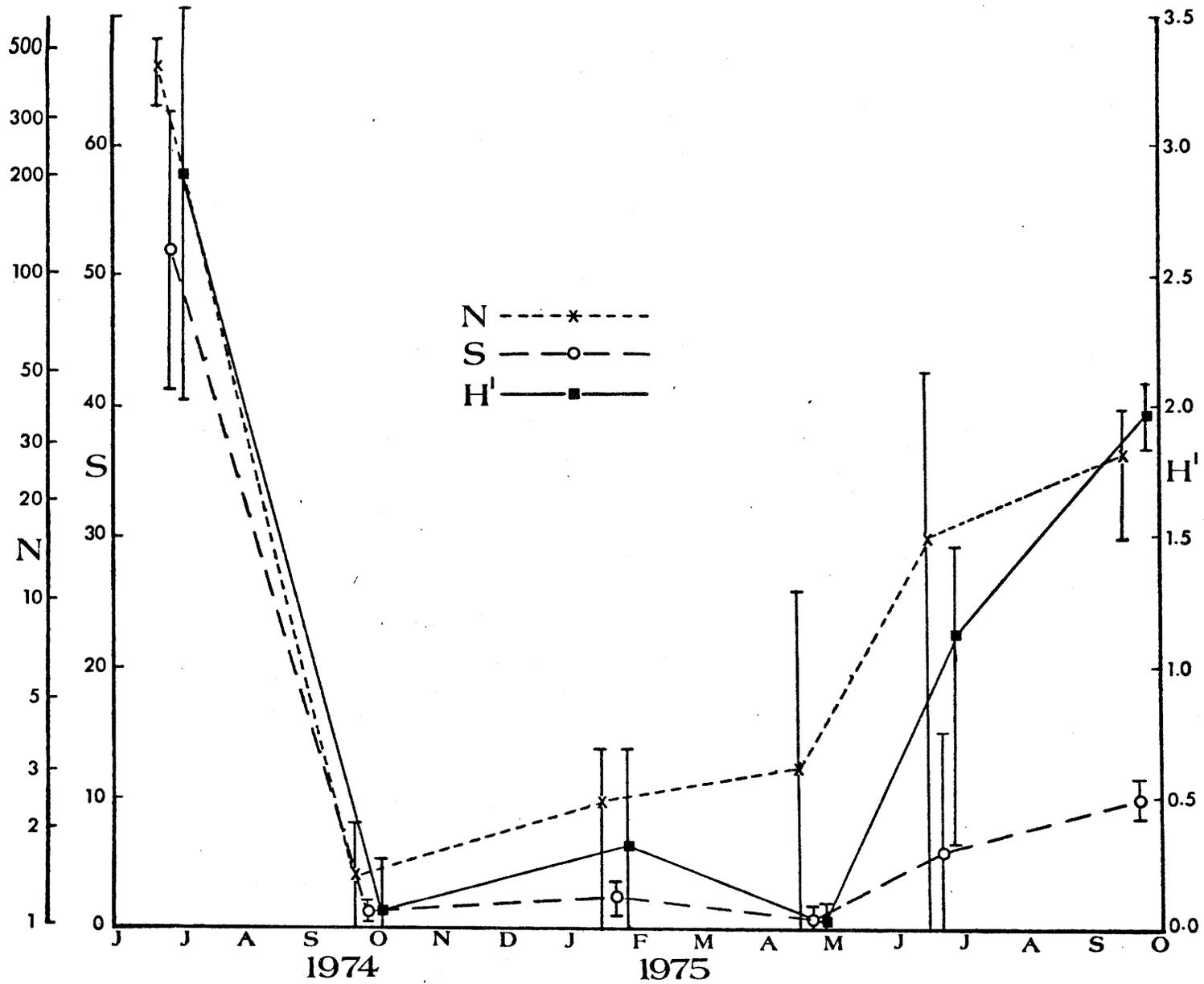


Figure 7 Means and 95% confidence limits for numbers of individuals (N), numbers of species (S) and species diversity (H') at the original disposal point, July 1974 to October 1975; spoiling began in August 1974.

inhospitable to the fauna typical of the Thames River estuary and coastal zone and, further, that fairly complete recolonization may eventually be expected.

We conducted SCUBA surveys of the spoil and adjacent areas in February, May, July and October 1975. The October observations revealed that amphipod and worm tubes, burrows and tracks were abundant over extensive areas of the spoil pile. We believe, therefore, the recolonization discussed above for station C6 was a widespread phenomenon in the spoil materials. Diving surveys outside spoil areas confirmed the habitat variability and small-scale patchiness seen in data from grab samples, but did not uncover any obvious faunal changes from similar predisposal diving observations conducted the previous year. Sediment traps, designed to measure sediment fallout and placed at various distances and compass bearings from the disposal marker buoy, did not demonstrate any increased sedimentation due to the disposal and subsequent movement of spoils. Suspended sediment levels in the disposal area may have been influenced more by riverine input than by resuspension of spoil.

The study of dredging and spoiling impact at New London includes several other projects. The Environmental Microbiology Investigation has been examining microbial distribution in river and dump site water and sediments; their findings appear elsewhere in this report. The New York Ocean Science Laboratory is monitoring the following: currents; fates of sediment "plumes"

resulting from spoiling, and the effects of these on water quality; heavy metals in sediments and suspended matter; Kjeldahl nitrogen; total phosphorus and COD of sediments; and heavy metals in benthic organisms when material is available. Effects of single dumps have been found to be very transient, with water quality measurements indicating rapid return to background levels following both dredging and spoiling. A typical experiment indicated large initial increases in suspended solids immediately following a dump, with values returning close to ambient within approximately 30 minutes of the dump (Fig. 8). Longer-term effects of spoiling on sediments and benthic macrofauna have not yet been detected as natural variability between seasonal and replicate samplings have obscured patterns of contaminant increase in the sediments or fauna outside of the spoil pile. Table 20 presents a typical data set, listing concentrations of seven heavy metals found in representative organisms collected from within two miles of the disposal buoy in July (predisposal) and October 1974, and January 1975.

Effects of dredging on river waters, sediments and shellfish are being measured and interpreted by University of Connecticut personnel. Again, dredging has been found to have only localized impact, both in time and in space, on suspended sediments, heavy metals and other characteristics of the water column. Heavy metals in the bivalves, Crassostrea virginica, Mercenaria mercenaria, and

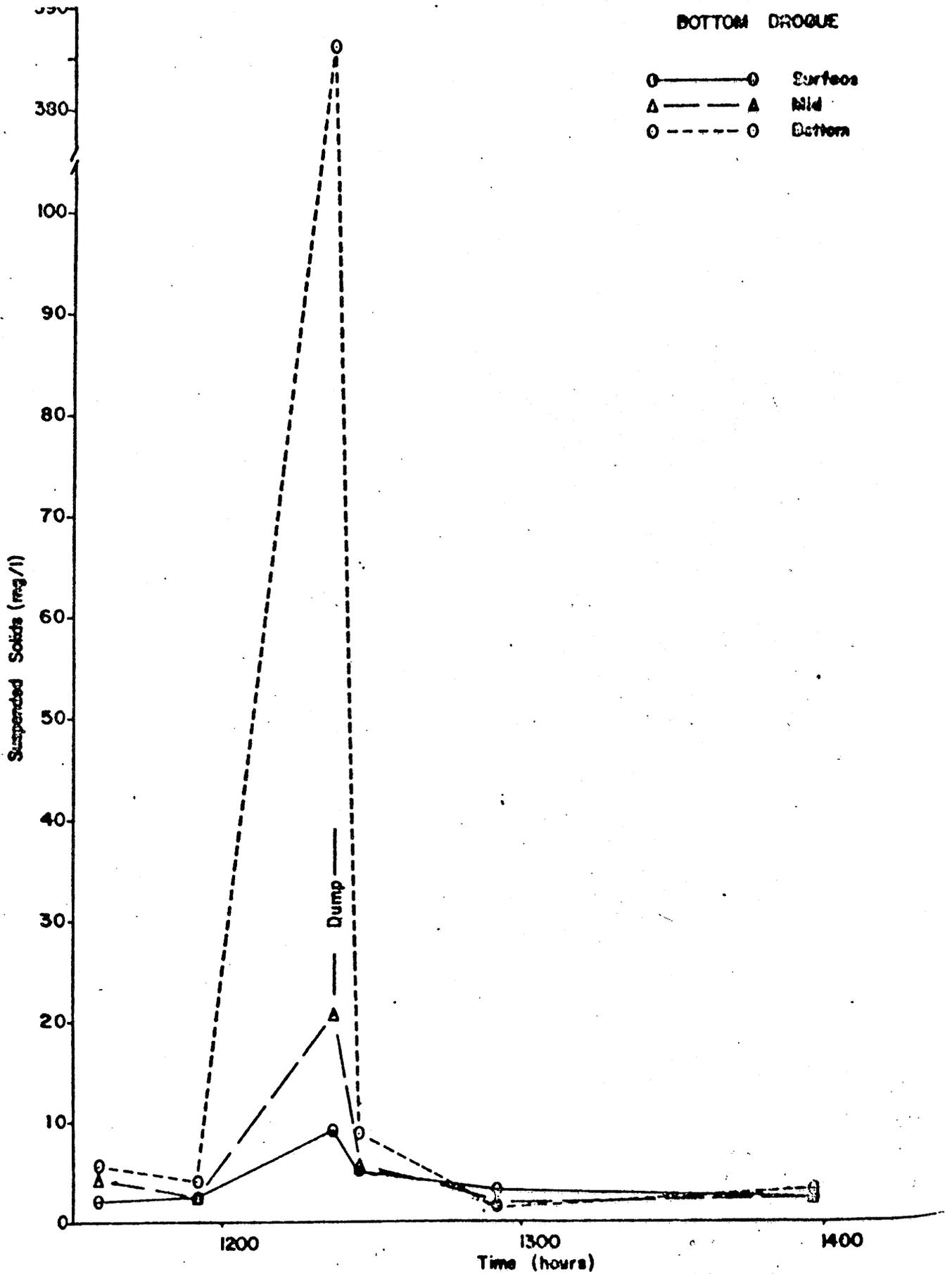


Figure 8. Suspended Solids vs Time
6 March 1975

Pitar morrhuana showed seasonal variations, with higher concentrations of several metals during warmer months. No consistent trends in metal concentrations in bivalves with location relative to dredging were found; thus, no significant effects of dredging could be detected or measured. Tables 21 - 25 give concentrations of zinc, copper, cadmium, nickel and mercury in the three species for four sampling dates from July 1974 through May 1975.

Our overall conclusion based on the New London-Thames River estuary study is that impacts measured to date have been relatively minor and restricted to the immediate proximity of dredging and spoiling operations.

New London Alternate Dredge Spoil Dump Site (East Hole)

During 1975, baseline data were collected to determine benthic invertebrate community structure, using a Smith-M Intyre grab, with individual cores taken from the grab for sediment type and heavy metal analyses during three cruises (April, July, December) at six stations bracketing the center of the proposed site. Preliminary analysis of benthic community structure has been completed for the first two cruises; sediment type analysis was finished for the April cruise. Heavy metal concentrations of sediments taken from three East Hole stations in April have been analyzed by Environmental Chemistry (Table 26). Values were comparable to those found in other studies carried out by MACRC

TABLE 21. Zinc Concentrations in Shellfish (ug/gm freeze dry weight).

Station	July '74	November '74	March '75	May '75
<u>Mercenaria mercenaria</u>				
A				
B	182	---	268	---
C	122	138	181	259
D	164	368	222	237
E	147	231	212	203
F	226	144	226	278
G	144	168	239	256
H	236	87	184	244
O-VII	---	---	---	---
Avg.	174	189	219	246
<u>Pitar morrhuana</u>				
A	201	178	206	306
B	---	---	284	375
C	634	412	390	362
D	281	546	487	430
E	---	706	426	468
F	306	437	---	---
Avg.	356	456	359	388
<u>Crassostrea virginica</u>				
O-II	19,700	14,700	18,600	13,700
O-III	16,900	14,700	12,800	14,400
O-VI	21,200	14,400	11,900	20,900
O-VII	18,100	13,100	14,700	15,900
Av g.	19,000	14,200	14,500	16,200

TABLE 22. Copper Concentrations in Shellfish (ug/gm freeze dry weight).

Station	July '74	November '74	March '75	May '75
<u>Mercenaria mercenaria</u>				
B	25.6	---	36.8	---
C	25.0	18.1	15.6	21.5
D	25.2	17.2	17.5	24.4
E	27.5	24.4	20.3	23.4
F	33.7	22.5	22.5	29.6
G	29.6	25.6	26.5	24.6
H	37.9	27.5	26.8	24.3
Avg.	29.2	22.6	23.7	24.6
<u>Pitar morrhuana</u>				
A	22.3	11.9	12.2	26.8
B	---	---	14.4	26.2
C	19.4	15.9	13.7	20.4
D	21.2	13.7	14.7	15.0
E	---	23.7	16.2	14.4
F	18.1	27.5	---	---
Avg.	20.2	18.5	14.2	20.6
<u>Crassostrea virginica</u>				
O-II	1500	750	1203	703
O-III	1218	768	748	656
O-VI	1405	731	796	1060
O-VII	1275	712	937	795
Avg.	1350	740	921	804

TABLE 23. Cadmium Concentrations in Shellfish (ug/gm freeze dry weight).

Station	July '74	November '74	March '75	May '75
<u>Mercenaria mercenaria</u>				
B	1.34	---	1.12	---
C	1.25	1.16	0.97	1.72
D	1.16	0.56	1.25	1.91
E	1.19	0.84	1.88	2.16
F	0.92	0.37	1.09	1.34
G	0.92	0.69	1.06	1.62
H	0.94	0.31	1.00	1.56
Avg.	1.10	0.66	1.20	1.72
<u>Pitar morrhuana</u>				
A	4.48	4.15	4.15	4.56
B	---	---	---	5.00
C	2.38	3.40	3.40	3.22
D	3.12	2.47	2.47	3.37
E	---	3.00	3.00	3.37
F	1.62	2.37	2.37	---
Avg.	2.90	3.08	3.08	3.90
<u>Crassostrea virginica</u>				
O-II	5.75	2.56	5.69	5.68
O-III	5.31	3.00	4.37	5.12
O-VI	---	3.06	6.18	6.36
O-VII	8.31	3.81	5.68	6.42
Avg.	6.46	3.11	5.48	5.90

TABLE 24. Nickel Concentrations in Shellfish (ug/gm freeze dry weight)

Station	July '74	November '74	March '75	May '75
<u>Mercenaria mercenaria</u>				
B	10.24	---	10.24	---
C	10.50	8.12	5.62	8.74
D	8.82	11.49	6.00	8.75
E	8.37	9.62	5.75	9.06
F	9.12	7.74	4.62	8.74
G	6.16	6.24	4.62	6.50
H	6.16	7.00	4.24	6.87
Avg.	8.51	8.37	5.87	8.11
<u>Pitar morrhuana</u>				
A	7.66	7.12	5.75	9.37
B	---	---	5.24	8.12
C	7.00	7.37	5.74	7.50
D	8.00	8.37	5.12	9.37
E	---	8.49	4.25	7.50
F	8.00	---	---	---
Avg.	7.66	7.84	5.22	8.37
<u>Crassostrea virginica</u>				
O-II	6.50	7.00	4.75	5.00
O-III	5.75	4.75	4.74	6.25
O-VI	5.74	5.00	4.50	6.86
O-VII	4.25	4.75	6.75	6.24
Avg.	5.56	5.38	5.18	6.09

TABLE 25. Mercury Concentrations in Shellfish (ug/gm freeze dry weight).

Station	July '74	November '74	March '75	May '75
<u>Mercenaria mercenaria</u>				
B	.304	---	.185	---
C	.219	.242	.146	.139
D	.277	.221	.195	.159
E	.468	.286	.202	.210
F	.280	.372	.212	.182
G	.307	.254	.320	.220
H	.482	.584	.314	.344
Avg.	.334	.326	.225	.210
<u>Pitar morrhuana</u>				
A	.260	.206	.204	.113
B	---	---	.261	.110
C	.203	.183	.233	.109
D	.205	.234	.224	.136
E	---	.302	.212	.145
F	---	.118	---	---
Avg.	.223	.204	.227	.123
<u>Crassostrea virginica</u>				
O-II	.381	.185	.374	.300
O-III	.368	.233	.356	.215
O-VI	.396	.128	.344	.311
O-VII	.424	.281	.381	.289
Avg.	.392	.207	.364	.279

in nearby inshore waters such as Fishers Island Sound and Gardiners Bay, and considerably lower than concentrations in central and western Long Island Sound. Levels were somewhat elevated relative to concentrations measured in the Baltimore Canyon Trough (see below). Interim reports of East Hole survey results were presented in MACFC Informal Report Nos. 68 and 81. A comprehensive final report of the results of the first two cruises is now being prepared.

During the July finfish assessment cruise, a new line of investigation was initiated to examine the dependence of demersal finfish on benthic invertebrates as food; selected finfish stomach contents are being studied in detail to determine preferred forage species and changes which may occur with spoiling. Also, delineation of food webs culminating in selected species will contribute to a better understanding of how contaminants are or could be concentrated, via the food chain, to edible finfish, crustaceans or mollusks. In line with this type of integrative investigation, in depth review of the life histories and productivity of important finfish and benthic invertebrate species has begun. Preliminary results of these trophic studies were presented in MACFC Informal Report No. 81; these suggest that the winter flounder, Pseudopleuronectes americanus, fed mostly on tube-dwelling amphipods. This was true for scup, Stenotomus chrysops, while windowpane flounder, Scophthalmus aquosus, and

red hake, Urophysus chuss, preferred natatory epibenthic crustaceans such as mysids and sand shrimp. Silver hake, Merluccius bilinearis, and weakfish, Cynoscion regalis, were primarily midwater foragers.

New Jersey Coast - Baltimore Canyon

MACFC is presently awaiting approval of a revised summary proposal for funding of a project to characterize benthic environmental baselines in the Baltimore Canyon Trough (BCT) prior to the beginning of oil-related activities. This proposal involves materials collected during the BCT cruise of 1974 and samples collected during cruises in 1972 and 1973 along the New Jersey Coast (NJC). Heavy metal data from NJC surveys were made available in the 1974 Contaminants Report; BCT data from 14 of 33 stations sampled are included with the present report (Figure 9, Table 27). Although incomplete, these data tend to indicate a relatively uncontaminated area offshore when compared to values from the MESA New York Bight apex stations, particularly in and around the disposal areas.

Personnel from Sandy Hook Laboratory recently calculated a "micropollutant index" for heavy metal concentrations in areas of the New York Bight (Figures 10-12). The metals were analyzed by Environmental Chemistry personnel. The index is derived from a formula recently developed by Papakostidis, Grimanis and Zafiroopoulos (1975). Each index represents a generalized value

Table 27. Metal Concentrations in the Top 1½ Inches of Sediment Collected from the Baltimore Canyon.

Lab Code	Field Code				Metal Concentrations (ppm, dry weight)**					
					Cd	Cr	Cu	Ni	Pd	Zn
15038	BCI -	001 -	GR001	MM-01	ND**	ND	ND	11.8	<12.5	16.5
15039	"	004	"	"	ND	ND	ND	<13.7	<12.5	13.5
15040	"	007	"	"	ND	ND	ND	7.7	ND	6.9
15041	"	010	"	"	ND	ND	ND	7.7	ND	9.5
15042	"	125	"	"	ND	ND	ND	ND	ND	6.3
15043	"	028	"	"	ND	ND	ND	5.8	ND	9.3
15044	"	031	"	"	ND	ND	ND	7.0	ND	10.3
15045	"	037	"	"	ND	ND	ND	ND	ND	10.1
15046	"	048	"	"	ND	ND	ND	<12.0	<17.5	11.5
15047	"	051	"	"	ND	ND	ND	<15.5	<12.5	12.3
15048	"	054	"	"	ND	ND	ND	9.6	ND	11.4
15049	"	063	"	"	ND	ND	ND	5.2	ND	9.8
15050	"	083	"	"	ND	ND	ND	11.5	ND	12.2
15051	"	086	"	"	ND	ND	ND	8.3	ND	9.9

* Values are the mean of duplicate measurements.

** ND = Not Detectable (See Table 26 for detection limits).

Figure 10.

MICROPOLLUTANT INDEX

$$\log \frac{\text{Cr. Cu. Ni. Pb. Zn.}}{\text{Cr}_0. \text{Cu}_0. \text{Ni}_0. \text{Pb}_0. \text{Zn}_0.}$$

August 1973

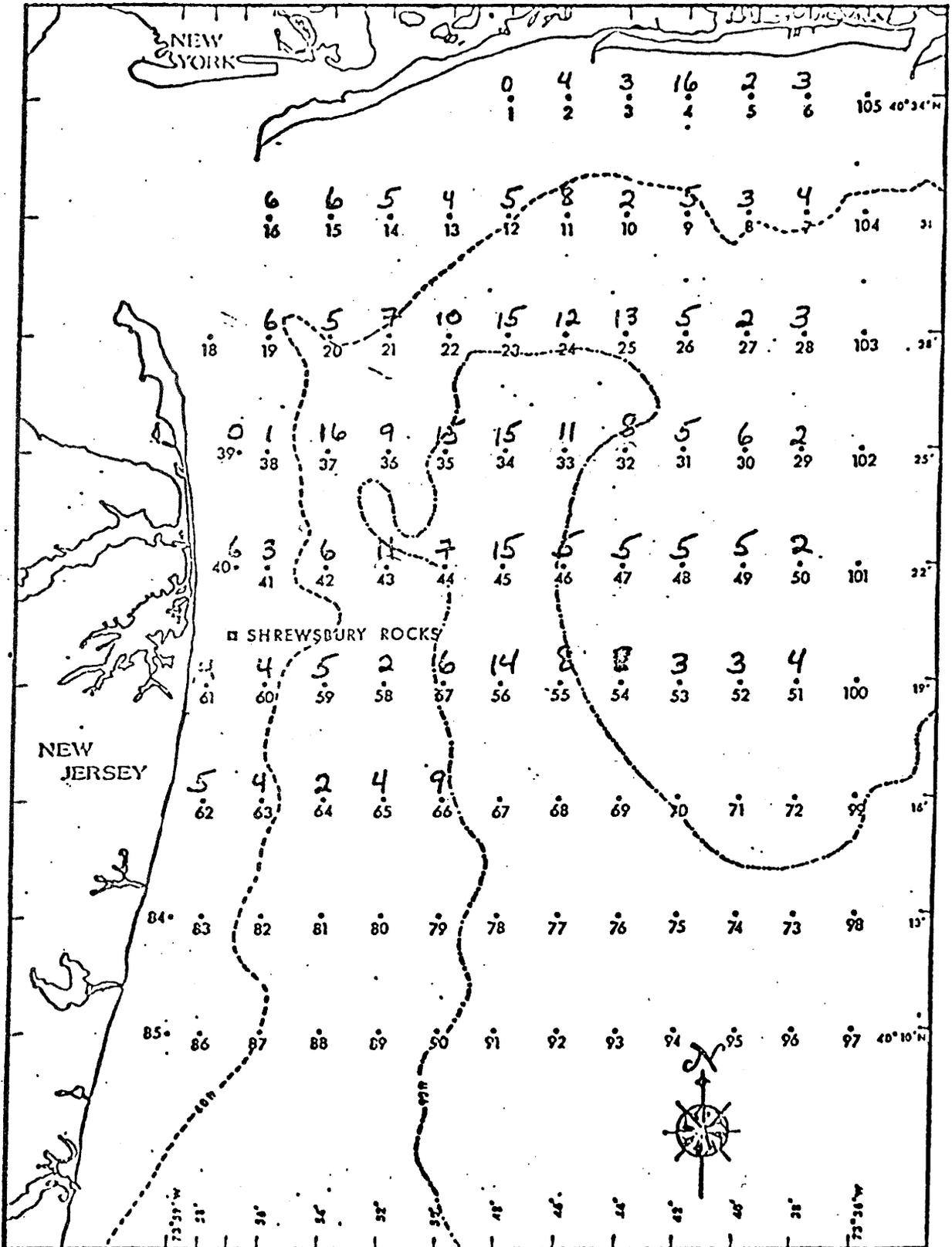


Figure 11.

MICROPOLLUTANT INDEX

$$\log \frac{\text{Cr. Cu. Ni. Pb. Zn.}}{\text{Cr}_0 \text{ Cu}_0 \text{ Ni}_0 \text{ Pb}_0 \text{ Zn}_0}$$

January 1974

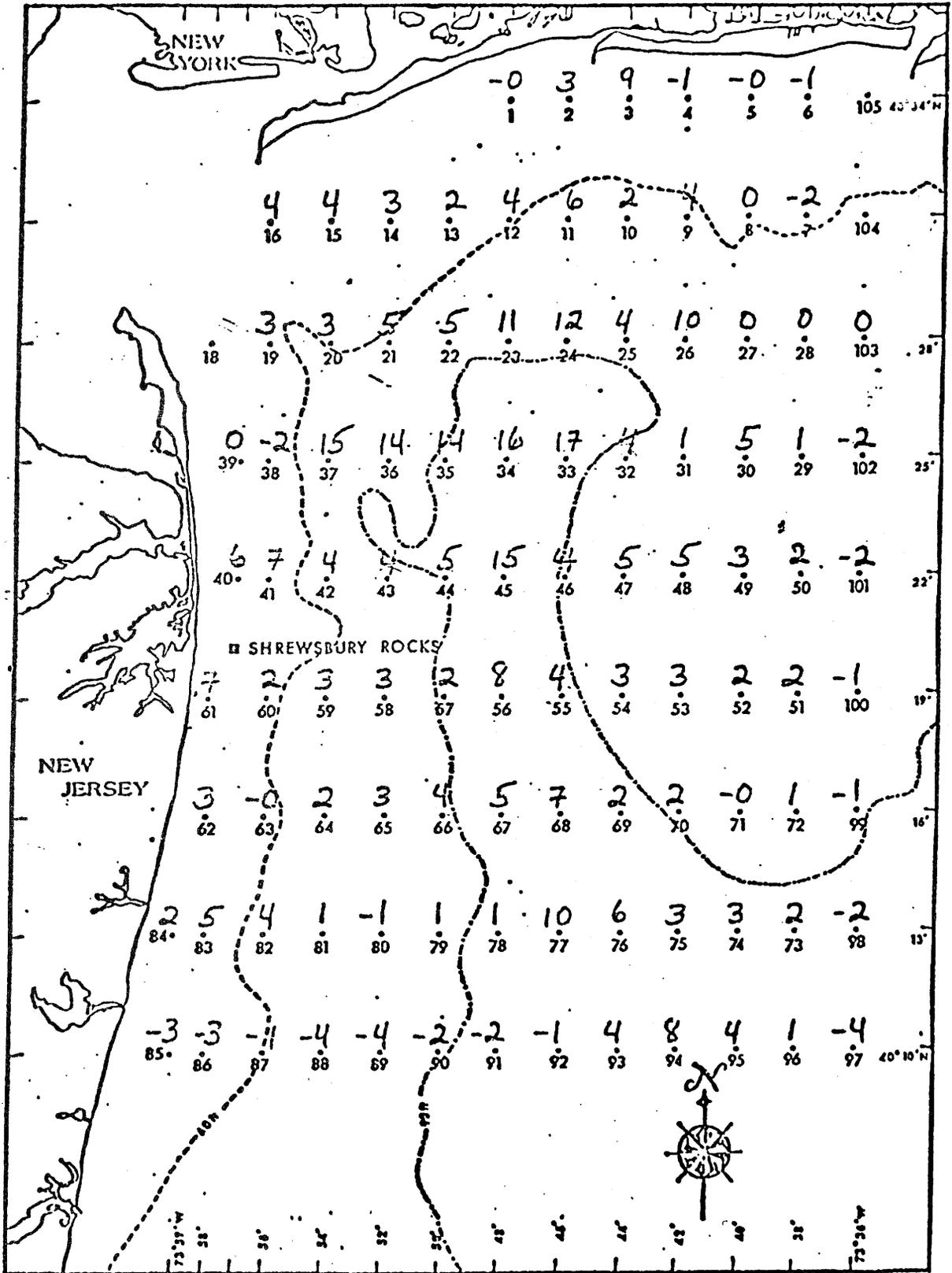
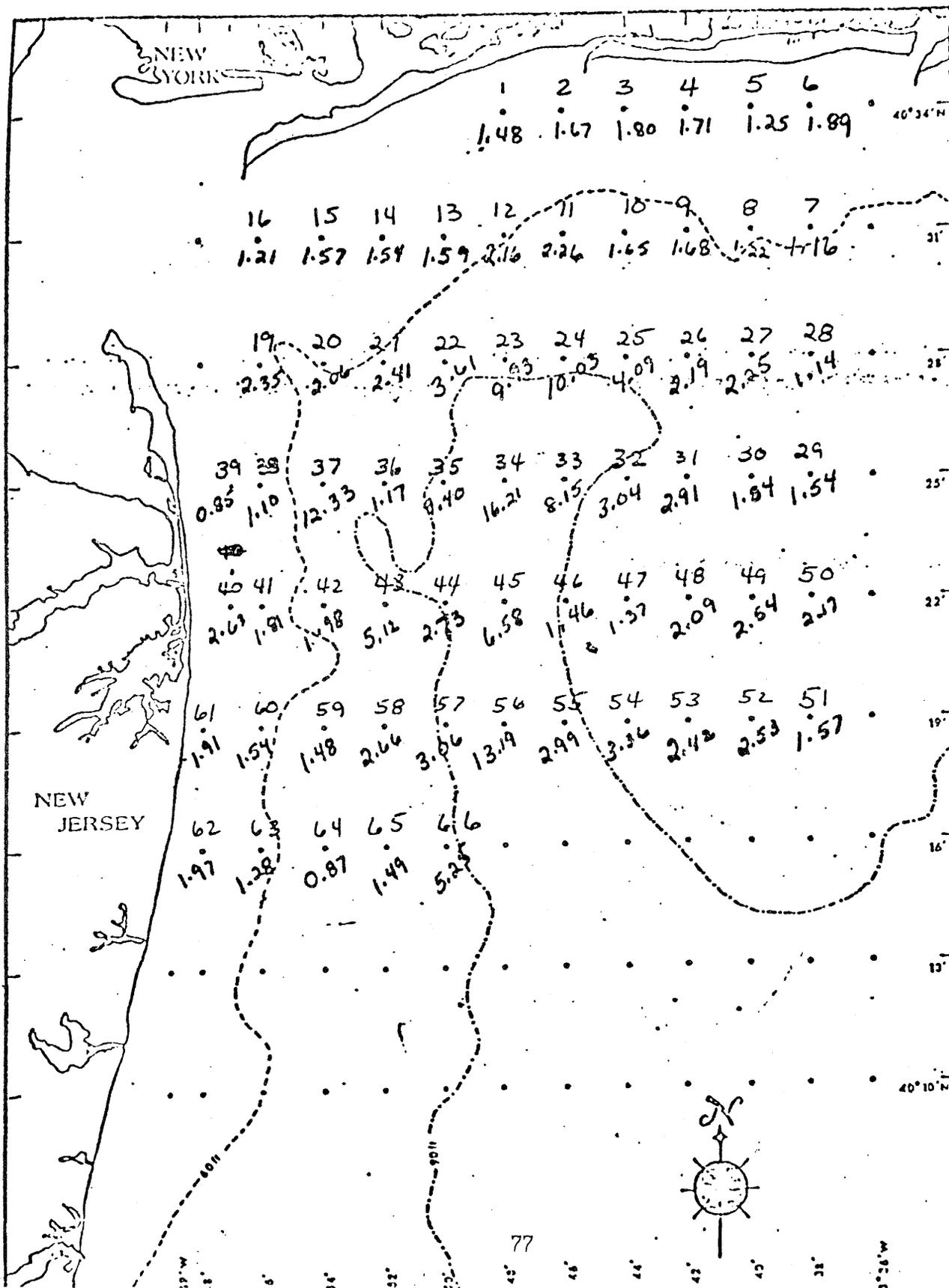


Figure 13

SYMAP STATION #
 8 ORGANIC MATERIAL

(Aug. 73 - all grabs)

ALBATROSS 73
 1st QUARTERLY CRUISE



for a particular experimental station in relation to a reference station, one with low metal concentrations. One can note higher index values in and around the disposal areas (Figures 10 and 11) and in western Raritan Bay (Figure 12). Due to the use of different detection limits in the analysis of offshore samples, representative indices for BCT could not be calculated.

Figure 13 shows percent organic content in sediment samples from the Bight apex. Again, higher values are found in and around the dumping areas. Also, as in the heavy metal indices, generally elevated values exist to the north of the immediate disposal areas. This evidence tends to support hydrographic studies which indicate a new bottom drift in that direction.

Further heavy metal sample analyses are included in the present proposal which involves the BCT and NJC areas from a historical standpoint only. No future sampling or monitoring is outlined for MACFC at this time.

Long Island Sound

Sixty stations from the original Long Island Sound (LIS) survey were resampled in September 1975 for bottom temperature, salinity and dissolved oxygen, sediment type, percent organics and calcium carbonate content, and benthic macrofauna. Sediment samples were also taken for future heavy metals analysis. In combination with the surveys completed in August 1972 and April and September 1973 these samples will provide a basis for

assessment of long-term trends and fluctuations in environmental quality in LIS and provide the integrated data sets essential for management of the living resources of the Sound. The macrofauna samples are of particular interest, in light of a "population crash" which Dr. Rhoads of Yale University detected in benthic community studies in central LIS between the summer of 1972 and 1973. This decline was confirmed by personnel of MACFC (MACFC, Informal Report No. 42). The continued sample collection and workup will enable determination of the areal extent of the "crash" and the nature and rate of recovery; it may also reveal causative agents.

Cluster analysis was begun in 1975 of all macrofauna data generated from the 1972 survey. Results of this analysis will provide a better understanding of the relationships between several biotic and abiotic factors and observed benthic macrofaunal distribution in LIS.

ECOSYSTEMS INVESTIGATIONS

BIOLOGICAL OCEANOGRAPHY AND PRODUCTIVITY INVESTIGATIONS

J. Thomas, W. Phoel, J. O'Reilly and C. Evans

Introduction

The principal thrust of this investigation is to understand the relationship between water column productivity, pollution and eutrophication, benthic community structure and function, and productivity of the marine fishery. To date, studies have emphasized: 1) aspects of primary productivity in the Raritan Bay-Lower Hudson estuary; and 2) seabed oxygen consumption of benthic environments in this estuary, the New York Bight apex and the outer continental shelf. Through the use of multivariate analyses we are relating findings to date to: 1) the distribution and abundance of sediment heavy metals; 2) sediment type and organic content of sediments; and 3) benthic invertebrate community structure and physical/chemical factors such as bathymetry and dissolved oxygen. The following represents a brief review of field work and data analyses completed to date.

Seabed Oxygen Consumption

Seabed oxygen consumption rates and related bottom water hydrographic measurements (temperature, salinity and dissolved oxygen) were obtained during five cruises in the New York Bight

apex between March 1974 and August 1975. The area sampled included the waste disposal sites for sewage sludge, dredge spoils, and industrial acid wastes (Fig. 14). Samples for seabed oxygen consumption were collected with a Pamatmat multiple corer and incubated on shipboard in a water bath thermoregulated to in situ temperature. Four samples per station for each of approximately sixty stations per cruise were collected and processed in this way.

Percent saturation of bottom water dissolved oxygen in the New York Bight apex ranged from near 100% in winter to 13% in summer (Fig. 15). The area of the apex seabed having low percents of saturation can be significant (Table 28) and could affect demersal finfish and the organisms they feed upon.

Rates of total oxygen consumption by the seabed ranged from 1 to 68 ml O₂ m⁻² hr⁻¹ and are comparable to those of other studies in the coastal marine environment, particularly where organic enrichment of the seabed has occurred (Fig. 16). An average of 444 x 10⁶ litres O₂ (183 metric tons carbon) are estimated to be consumed by the apex (1577 km²) seabed each day. The annual cycle for the apex ranged from 288 x 10⁶ litres O₂ per day in February to 689 x 10⁶ litres O₂ per day in August (Fig. 17).

In winter the highest rates of seabed oxygen uptake were measured in the Christiaensen Basin, a topographically low area in the center of the apex adjacent to the sewage sludge disposal site, and in the dredge spoils disposal area, a topographically high

Figure 14. SYMAP Station Numbers and Locations of Stations Sampled for Measurements of Seabed Oxygen Consumption Rates. Dredge Spoils Disposal Site (large dot) Located Near Station 109 at the Center of Encircled Area. Encircled Area Affected by Dredge Spoils, but not Synonymous with Dredge Spoils Disposal Site. Dredge Spoils Disposal Site is Defined as the Area Within a Circle with a Radius of 0.6 Nautical Miles about $40^{\circ}24'$ N and $73^{\circ}51'$ W (large dot). Cross Stippled Area Bounded by 28 m Depth Contour and Stations 55, 56, 57 is Designated Christiaensen Basin. Northwest Corner of Sewage Sludge Disposal Site is Black Square Located Between Stations 32 and 33. Sewage Sludge Drop Area is Located Between $40^{\circ}22.30'$ N and $40^{\circ}24'$ N and $73^{\circ}41'$ W and $73^{\circ}45'$ W.

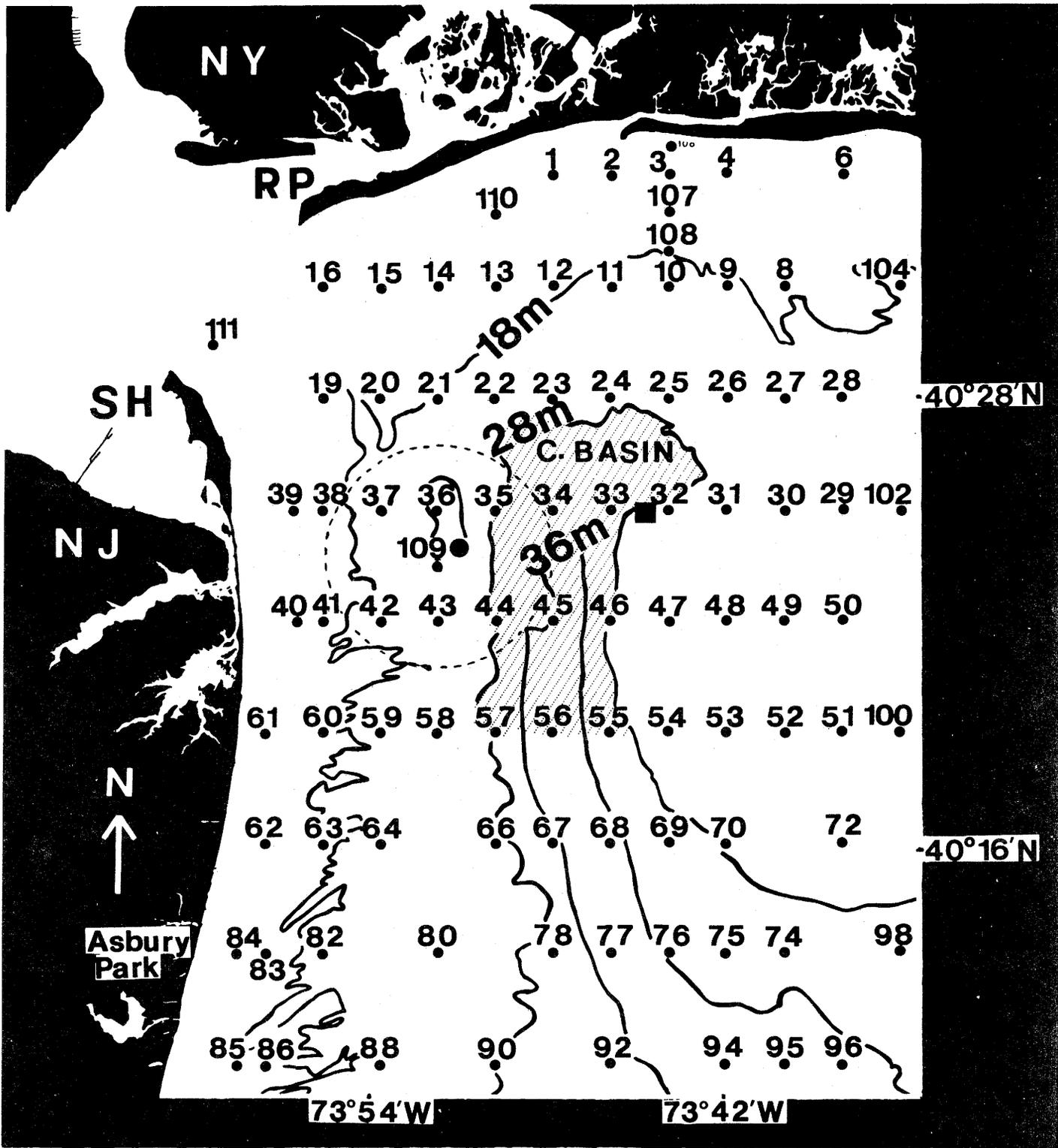


Figure 15. Percent Saturation of Bottom Water Dissolved Oxygen
for Cruise D7409, 26 August - 6 September 1974
(P2) and Cruise D7512, 12 - 25 August 1975 (P5).

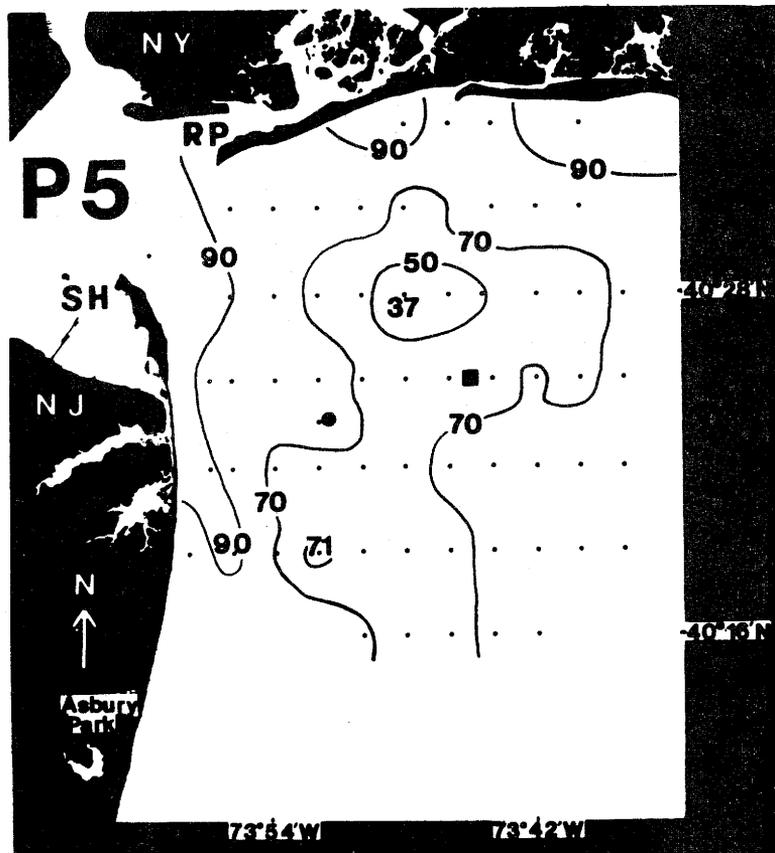
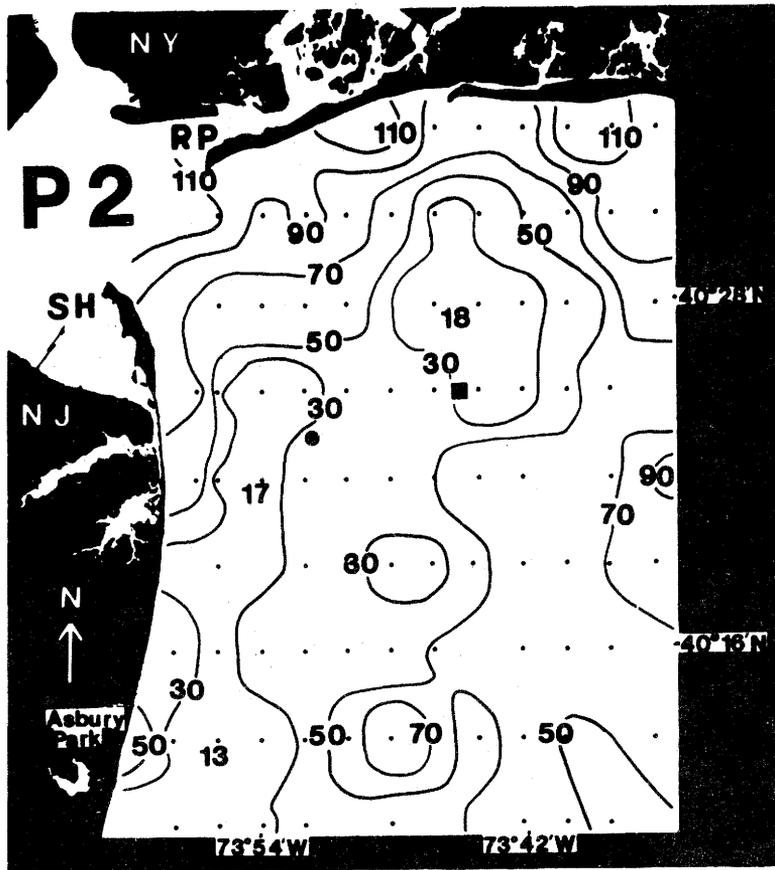


Table 28. Percent Area of Total Apex (1577 km²) with Corresponding Values of Various Levels of Percent Saturation of Bottom Water Dissolved Oxygen for Cruise D7409, 26 August - 6 September 1974 and Cruise D7512, 12-25 August 1975.

Bottom Water Dissolved Oxygen (% Saturation)	% Area of Total Apex*	
	August 1974	August 1975
30%	18%	0%
50	48	2
70	78	31
90	90	89
110	97	100
120	100	100

* Only 76.6% of the total apex area was sampled during August 1975.

Figure 16. Seasonal Distribution of Values for Seabed Oxygen Consumption Rates $\text{ml O}_2 \text{ m}^{-2} \text{ hr}^{-1}$ (C1-C5), Bottom Water Dissolved Oxygen Concentrations in ppm (D1-D5), Bottom Water Temperatures in $^{\circ}\text{C}$ (T1-T5) and Bottom Water Salinity in ‰ (S1-S5).

C1, D1, T1, S1 Represents 21 March-4 April 1974.
C2, D2, T2, S2 Represents 26 August-6 September 1974.
C3, D3, T3, S3 Represents 2-15 December 1974.
C4, D4, T4, S4 Represents 12-24 February 1975.
C5, D5, T5, S5 Represents 12-25 August 1975.

Black Dot LOCATED at Dredge Spoils Disposal Site.
Black Square Located at NW Corner of Sewage Sludge Disposal Site.

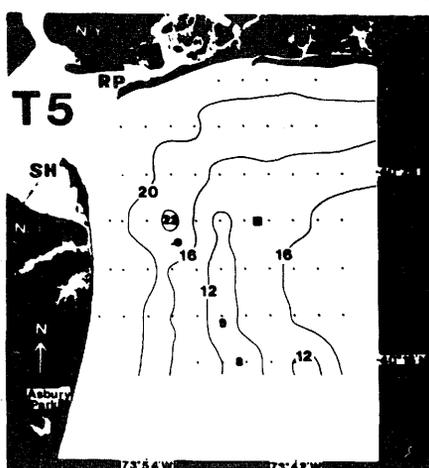
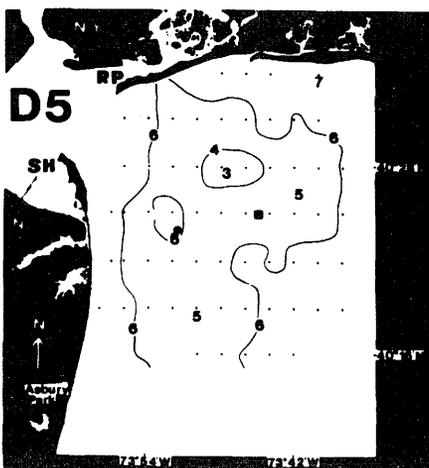
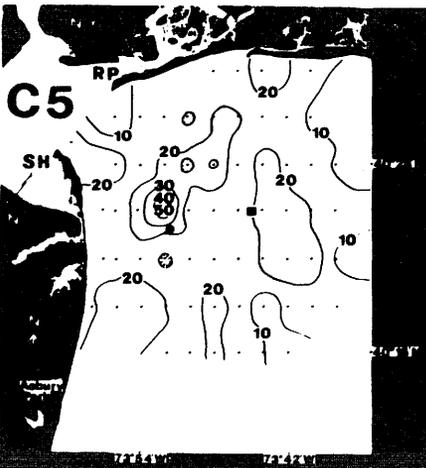
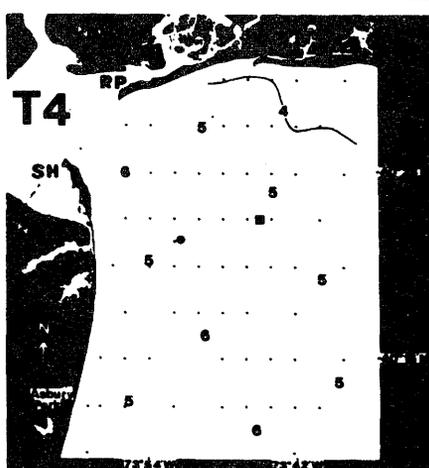
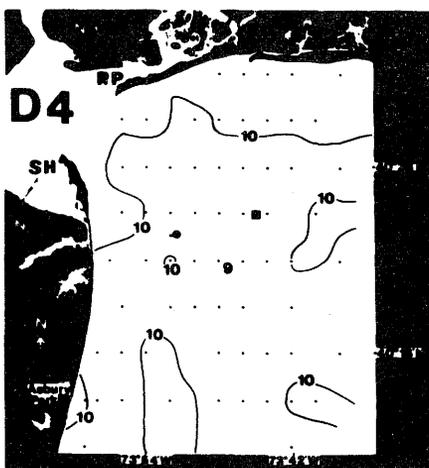
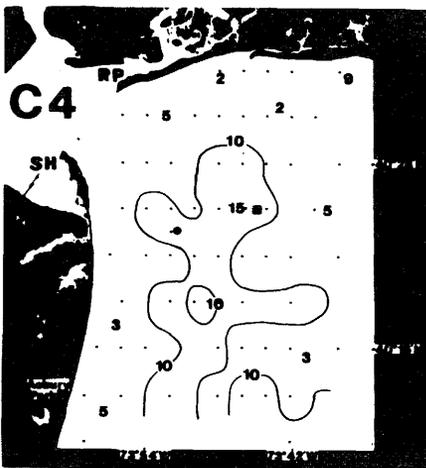
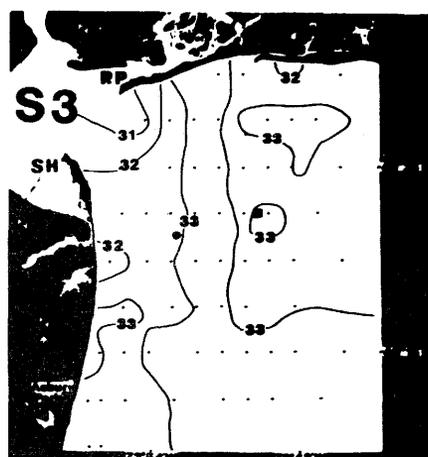
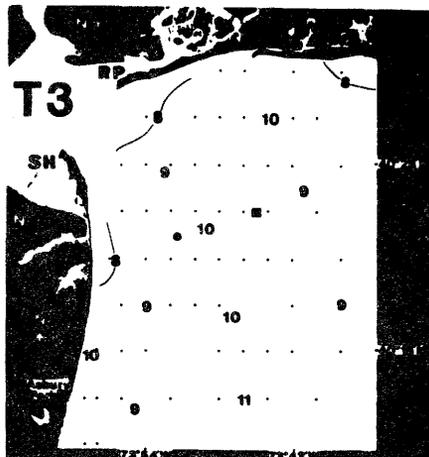
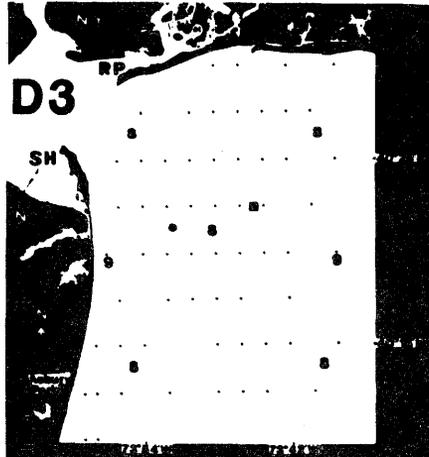
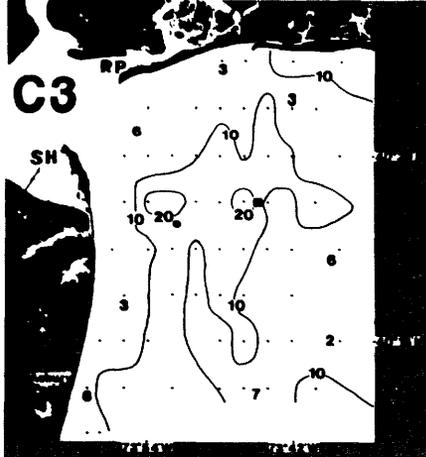


Figure 17. Annual Curve of Total Oxygen Consumption by the Seabed and the Equivalent Carbon Oxidized for the Entire Apex (1577 km²).

SEABED O₂ UPTAKE
10⁶ L O₂/APEX/DAY

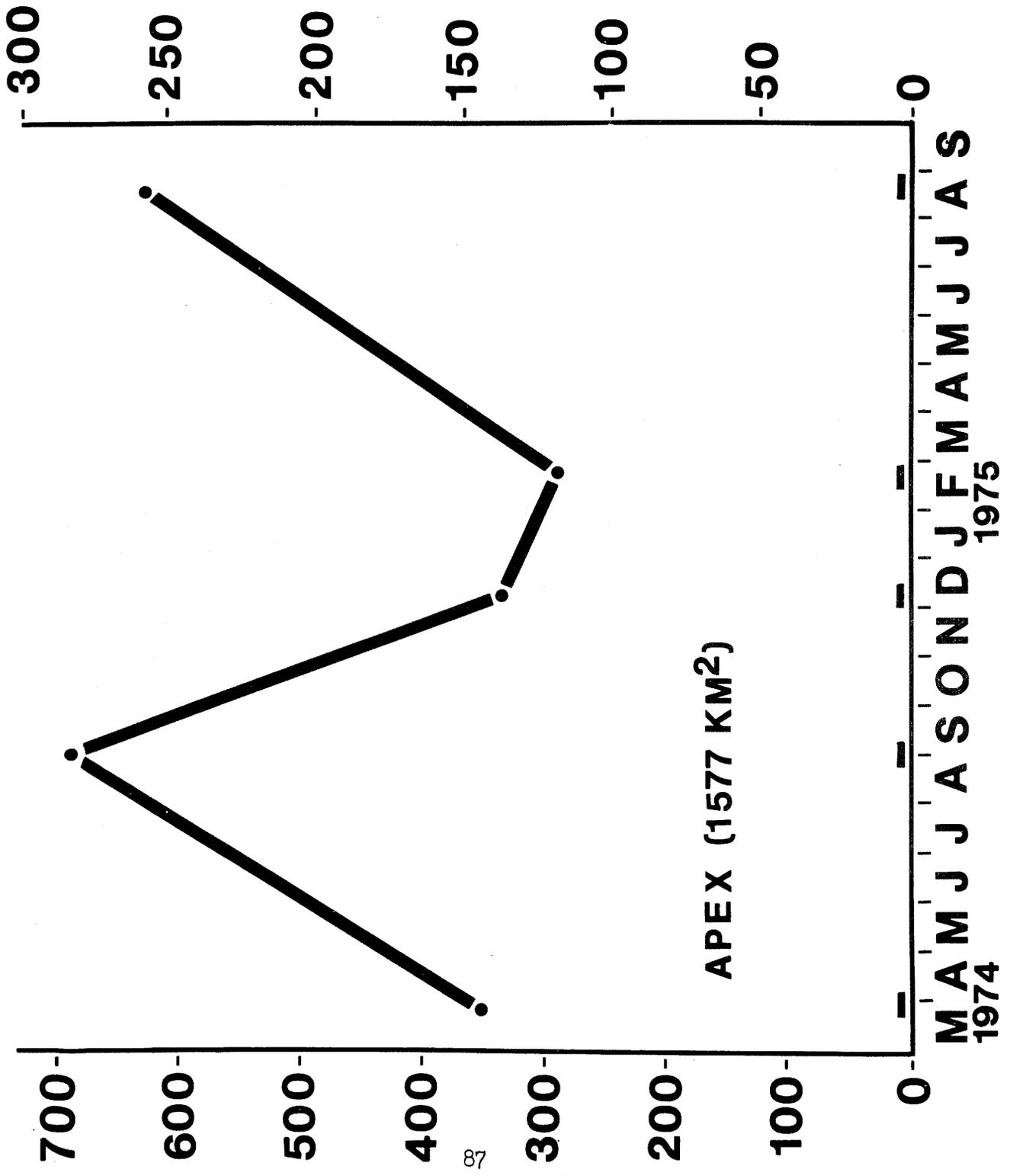
700-
600-
500-
400-
300-
200-
100-
0

CARBON OXIDIZED
METRIC TONS/APEX/DAY

-300
-250
-200
-150
-100
-50
0

APEX (1577 KM²)

M A M J J A S O N D J F M A M J J A S
1974 1975



area to the west of the Christiaensen Basin. Rates were also elevated in the Hudson Shelf Valley, a topographically low area leading seaward from the Christiaensen Basin.

In summer the highest rates were measured in the dredge spoils area. In contrast, rates in the Christiaensen Basin at this time were low compared with the surrounding areas and were more like rates measured in winter. It is hypothesized that differential sedimentation rates of oxidizable organic carbon to the seabed from barge dumped dredge spoils and sewage sludge as mediated by the presence or absence of a thermocline may have resulted in the phenomenon observed between summer and winter in the Christiaensen Basin. The highest rates measured during the study occurred near the site of a municipal sewage outfall off Asbury Park, N. J. Industrial acid wastes produced no discernible effects on rates of seabed oxygen uptake during the study.

Rates of oxygen uptake by the bottom water (89 stations throughout the year) and by the entire water column (3 stations in August 1975) were measured and compared with oxygen uptake rates by the sediment. It was seen that the bulk (95% to 98%) of oxygen uptake in the apex occurs in the water column and not on the seabed (Table 29). However, oxygen uptake by the sediment is still highly significant in terms of energy flow and carbon cycling in the benthic community, accounting for 80.6% of the oxygen uptake in the bottom 12 cm of the water column.

Table 29. An Organic Carbon Budget for the New York Bight Apex Demonstrating the Relationship Between Import and Export Components.

	Apex (1577 km ²)	
	Bulk 10 ⁶ m ³ /yr	Organic Carbon* 10 ⁴ mt/yr
Imports		
1. Primary Production		58.3
2. Transect		54.3
3. Dredge Spoils	5.35	13.9
4. Sewage Sludge	4.27	8.6
TOTAL		135.6
Exports		
5. Seabed Oxygen Uptake (Including bottom 12 cm water)**		6.7
6. Sediment Oxygen Uptake (80.5% of Seabed)		5.4
7. Water Uptake (Bottom 12 cm of Column, 19.5% of Seabed)		1.3
8. Water Uptake (Bottom m ³ of Column)		10.8
9. Water Column Uptake (24 m Ave. Depth)		260.0
10. Total Column (Sediment plus Water)		265.4
11. Percent Total Column due to Sediment		2%
12. Percent Bottom 12 cm of Column due to Sediment		80.6%

* 1 ml O₂ = 0.412 mg organic carbon

** average core water height

Sources: 1. Malone (1975).
 2. Mueller et al. (1975).
 3. Mueller et al. (1975); Gross (1972) Percent total organic carbon.
 4. Mueller et al. (1975); Callaway et al. (1975) Percent solida; Smith et al. (1974) Percent organic carbon.
 5-12. This study.

Dissolved Organic Matter Productivity in Raritan-Lower Hudson Estuary

Sixteen monthly cruises were made in the highly eutrophic Raritan-Lower Hudson estuary (New Jersey-New York) between November 1973 and April 1975 to measure three components of total primary productivity (dissolved organic matter, nanoplankton, netplankton) as well as photosynthetically active radiation, light extinction, nutrients, salinity, temperature, dissolved oxygen, pH, chlorophyll, phytoplankton species composition and abundance. Dissolved organic matter productivity, its significance, and its relationship to the structural and functional aspects of the phytoplankton community and environmental characteristics of the estuary will be presented. Percent of photoassimilated carbon released as dissolved organic matter (DOM) range from 0% to 71.2% (averaged 12.4%, n=1308) during the study. The quantity of DOM released ranged from 0 to 155 mg C m⁻³ hr⁻¹. DOM productivity is positively correlated with total productivity (particulate and dissolved). DOM productivity, netplankton and nanoplankton productivity decreased and percent of photoassimilated carbon released increased toward the mouth of the estuary. Surprisingly, percents of DOM released were uniform with depth (100, 47, 30, 11 and 4% surface light). DOM percents were highest in August-September when the nanno-netplankton productivity ratio was 35 and lowest in March when the ratio was 0.4.

ECOSYSTEMS INVESTIGATIONS
ENVIRONMENTAL MICROBIOLOGY INVESTIGATION

J. Graikoski, J. Babinchak, S. Dudley and M. Nitkowski

Introduction

As part of the marine contaminant program of the Middle Atlantic Coastal Fisheries Center, the objective of Environmental Microbiology has been to assess the degree of microbial contamination in sediments of Middle Atlantic coastal areas to determine the potential presence of pathogenic microorganisms. Sediments represent areas of persistence and proliferation of bacteria in the marine environment and, therefore, sources of contamination of food-chain organisms and resource species. In a previous MACFC Informal Report, No. 73, data on the distribution of fecal coliforms in sediments from Long Island Sound and New York Bight area were reported. For this report, additional information is given for several areas under study.

There has been considerable concern relative to the possible migration of sewer sludge from the designated disposal area in the New York Bight to beach areas on the south shore of Long Island to unrestricted clamming areas. Our previous report covered the results of fecal coliform densities in bottom sediments collected from several cruises at stations located on transects from the

sewage sludge disposal area to Long Island beach areas. In March 1975, sediment samples for fecal coliform analysis were also collected at stations extending from the sewage disposal area to Atlantic beach. This cruise concluded our summer-winter sampling program and comparison of the area.

In July of 1974, we initiated a two-year study in regard to microbiological parameters during the dredging of the Thames River and spoils deposition in the New London dump site. Baseline data on fecal coliform levels in bottom sediments and water were reported in detail in MACFC Informal Report No. 73. The fate and distribution of fecal coliforms in sediments has been monitored at quarterly intervals at several stations over a fifteen-month period and at all stations resampled a year later in July 1975. These results have been summarized in the present report. Ancillary data have also been obtained on total microbial populations, antibiotic resistance of selected fecal coliform isolates, presumptive marine vibrios and Clostridium perfringens in sediments, and selected animal species.

In June 1975, a request for background data on fecal coliform densities in sediments from Eatons Neck disposal site in Long Island Sound and two rivers to be dredged was received from the Corps of Engineers, Waterways Experimental Station, Vicksburg, Mississippi. Sediment samples were obtained through cooperation of personnel of the Corps of Engineers from sites proposed for dredging and disposal sites. These were analyzed for fecal coliforms

and a brief data report prepared. Also included were data obtained from areas of our previous Long Island Sound survey and heavy metal data on lobsters (see section on Environmental Chemistry).

Two cruises to the New York Bight were made by the Microbiology group in March and September 1975 aboard the R/V Kelez and FRV Delaware II, respectively. The objective of the first cruise, in addition to the previously mentioned study on the possible migration of sewage sludge to beach areas of Long Island, was to obtain sediment samples for bacteriological analysis from two proposed EPA alternate dump sites, 2D1 and 2D2, and for our ongoing finrot study. The September cruise in the New York Bight was a combined cruise with MESA personnel. Sediment samples were collected for total aerobic and anaerobic plate counts in areas being monitored for finrot disease at 40 stations located on two transects through the disposal and peripheral areas; MESA personnel collected samples for presence of antibiotic resistant Staphylococcus and phages.

An Informal Center Report on data obtained at the alternate disposal sites and comparison with bacterial data from the existing disposal areas was prepared for the MESA program. This report is included here.

Distribution and Abundance of Fecal Coliforms in Sediments and
Water from the Thames River and New London Disposal Site

A detailed report was presented in MACFC Informal Report No. 73 which outlines protocols, procedures and baseline data on fecal coliform densities in sediments and waters from forty stations located in the spoil disposal site and adjacent areas as well as at five river stations. Sediments from six stations in the disposal site area and a river station were monitored at quarterly intervals for fecal coliforms and total aerobic plate count. Data on antibiotic resistance of fecal coliform isolates as well as the presence of other microbial types were also obtained.

For the present report, reference to procedures will not be made. The data on fecal coliform densities obtained during the fifteen-month cycle of sampling are summarized. The stations sampled and monitored are illustrated in Figure 18. The distribution of fecal coliforms in the uppermost sediments obtained in the baseline study in July 1974 and repeated in July 1975 are given in Table 30. Fecal coliform densities and total aerobic plate counts in sediments obtained from the monitoring stations at quarterly intervals are presented in Tables 31 and 32, respectively.

Fecal coliform counts in upper sediments from the disposal site and adjacent areas continued to remain elevated but were lower than those from river samples during the period of study. A variation in counts was also observed; however, the fecal coliform count in 100 ml of sediment for each station sampled a

Figure 18. Samples Stations in the Thames River and New
London Disposal Site.

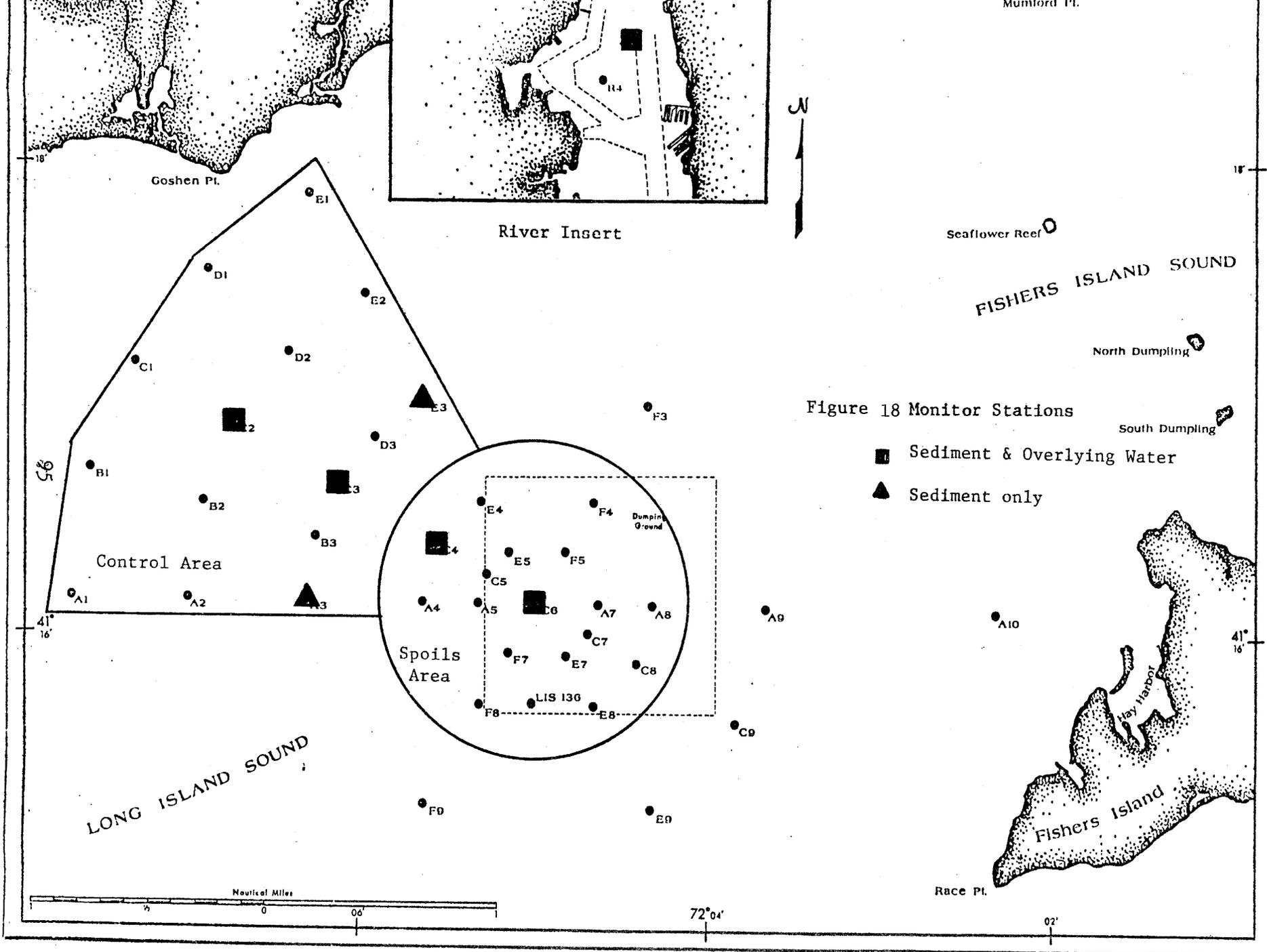


Table 30. Distribution of Fecal Coliforms in Sediments from Thames River-New London Disposal Site - June 26 - July 8, 1974 - July 14, 1975.

Station	Fecal Coliforms/100 ml	
	June 26-July 8, 1974	July 14, 1975
A1	1,300	12
A2	1,720	8
A3	11	14
A4	490	2
A5	240	5
A6	221	---
A7	790	0
A8	460	9
A9	1,410	---
B1	17	13
B2	14	310
B3	2	49
B4	11	---
B5	14	---
C1	172	172
C2	700	79
C3	4,900	33
C4	2,200	33
C5	3,300	11
C6	220	5
C7	330	5
C8	490	13
C9	490	---
D2	221	49
D3	172	172
D4	221	---
D5	130	---
E1	7,900	---
E2	2,400	46
E3	2,210	13
E4	1,090	5
E5	490	5
E7	26	7
E8	109	7
E9	22	---
F3	790	---
F4	460	2
F5	490	9
F7	26	8
F8	172	5
F9	172	---
R1	1,300	1,090
R2	4,900	490
R3	172,000	2,400
R4	22,100	240
R5	24,000	1,090

Table 31. Distribution of Fecal Coliforms in Top Sediments
From Thames River - New London Dredge Disposal Site

Station	Date of Sampling						
	Pre-Dredging			Post-Dredging			
	6-26-74 7-8-74	7-30-74	10-29-74	1-15-75	4-14-75	7-14-75	10-14-75
Fecal Coliforms/100ml Sediment							
C-2	700	490	3,300	4,900	490	79	79
C-3	4,900	240	220	130	330	33	33
C-4	2,200	70	330	221	460	33	79
C-6(NL)	220	79	49	790	310	5	33
A-3	11	5	170	33	490	14	49,49,79
E-3	2,210	-----	490	330	330	49	70
R-4	22,100	17,000	79,000	4,900	70,000	2,240	27,000

Table 32. Total Aerobic Plate Counts in Sediments from the Thames River - New London Disposal Site - June 1974 - October 1975.

Station	Date of Sampling				
	6-26-74				
	7-8-74	1-15-75	4-14-75	7-14-75	10-14-75
C-1	130	-----	-----	250	-----
C-2	170	260	930	200	81
C-3	160	410	940	370	8
C-4	150	76	1,140	200	57
C-6	17	560	1,580	450	87
C-8	120	-----	-----	390	-----
A-3	140	580	590	-----	181
E-2	160	960	550	-----	75
R-1	2,650	-----	-----	4,400	-----
R-2	2,200	---	-----	3,000	-----
R-3	1,080	---	-----	7,000	-----
R-4	6,500	5,300	5,400	8,600	3,600
R-5	930	-----	-----	2,000	-----

year later showed a significant reduction in number. The fecal coliform data obtained during the quarterly monitoring phase did not suggest variation during the initial phase of spoiling on the disposal site. Counts obtained in October 1975 sampling were as low as those obtained during the previous July sampling.

Fecal Coliform Densities in Sediments from the New York Bight-Long Beach Area.

Figure 19 shows the location of sampling stations in the New York Bight-Long Beach area which was resampled in March 1975 to determine possible migration of sewage sludge to the beach areas. Table 33 compares the March data with that from the previous September and shows somewhat elevated fecal coliform counts when compared to September 1974. We have observed this previously, i.e. counts in winter, during the lower ambient environment temperatures, were consistently higher than those obtained in the summer-fall periods when sediment and water temperatures were elevated. The most recent data confirm our previous conclusion that fecal coliform contamination occurring near the shore is possibly from terrestrial sources or short dumps and not from sludge migration from the offshore disposal site.

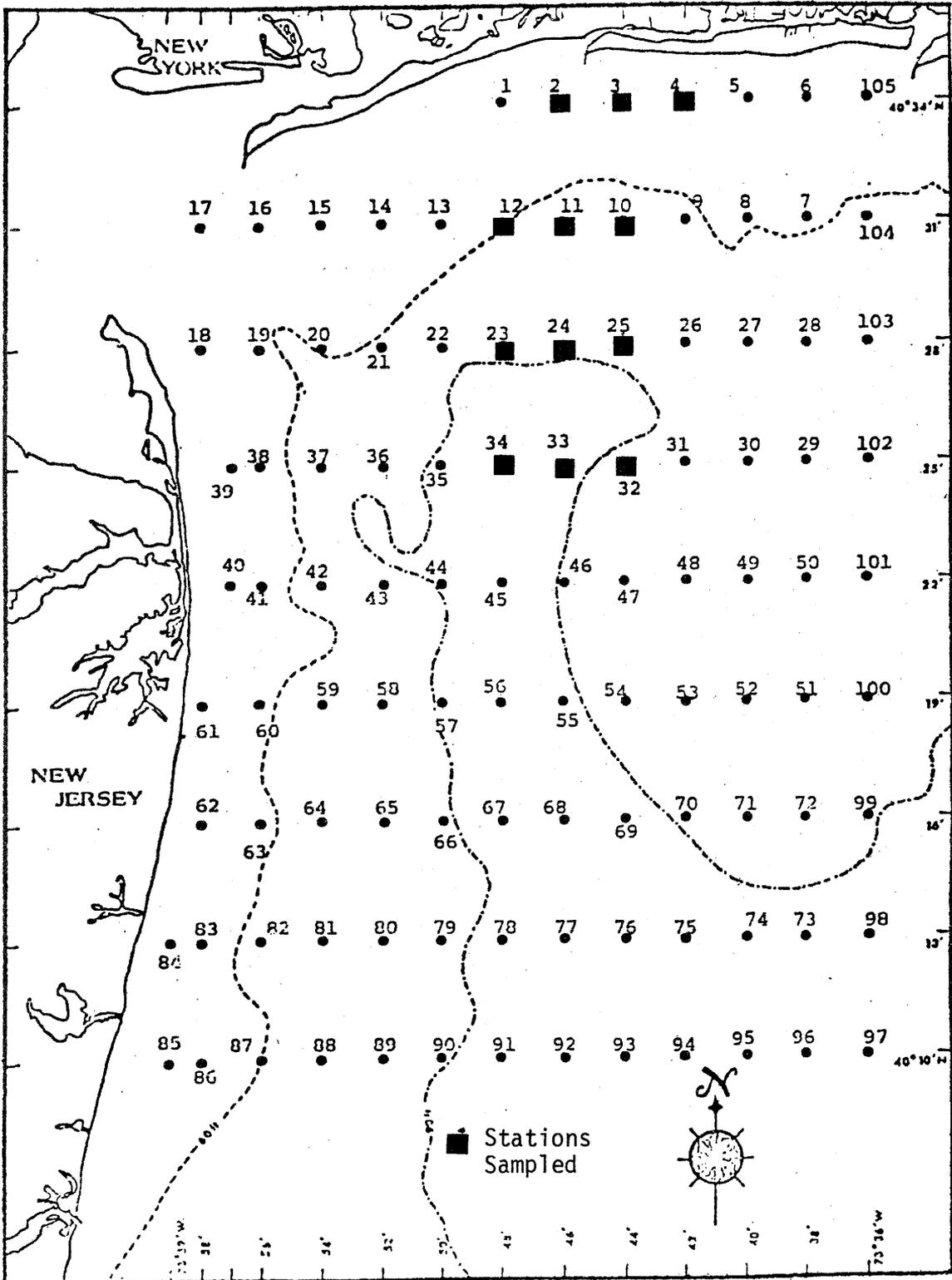


Figure 19 Fecal Coliform Stations- Offshore Atlantic Beach - Long Beach

Table 33. Fecal Coliform Densities in Top Sediments From Atlantic Beach Area - New York Bight.

Stations (MESA - GRID)	Fecal Coliforms/ 100 ml Sediment	
	September 1974	March 1975
2	2	70
3	2	13
4	8	0
10	0	33
11	6	8
12	130	5
21	5	700
22	17	79
23	11	22
30	790	3,100
31	330	6,300
32	11	49

Baseline Bacteriological Data on the Proposed EPA Alternate Offshore Dump Sites

Introduction

Samples for analysis were obtained during a cruise of the R/V Kelez during March 24-27, 1975. Sampling for sediments was conducted for 3 independent, but related, studies in the New York Bight. Phase I consisted of sampling sediments at selected stations on transects from the sewage disposal area beaches on the south shore of Long Island. This study, initiated slightly over a year ago, is being done to determine the possible migration of sludge from the disposal site. Phase II consisted of sampling selected monitor stations for the Center finrot disease study. Phase III involved sampling at two proposed EPA alternate sludge disposal sites, designated 2D-1 and 2D-2, located offshore of the New York Bight apex area.

The following represents bacteriological data obtained on sediments obtained during Phase III of the cruise. As previously mentioned, data from stations in the apex area are included for comparative purposes.

Sampling Plan

Sites of the two proposed alternate dump sites, 2D-1 and 2D-2, are presented in Figure 20. Sampling stations were located on transects diagonally across the proposed dump sites as illustrated in Figure 21. Specific station coordinates, as well

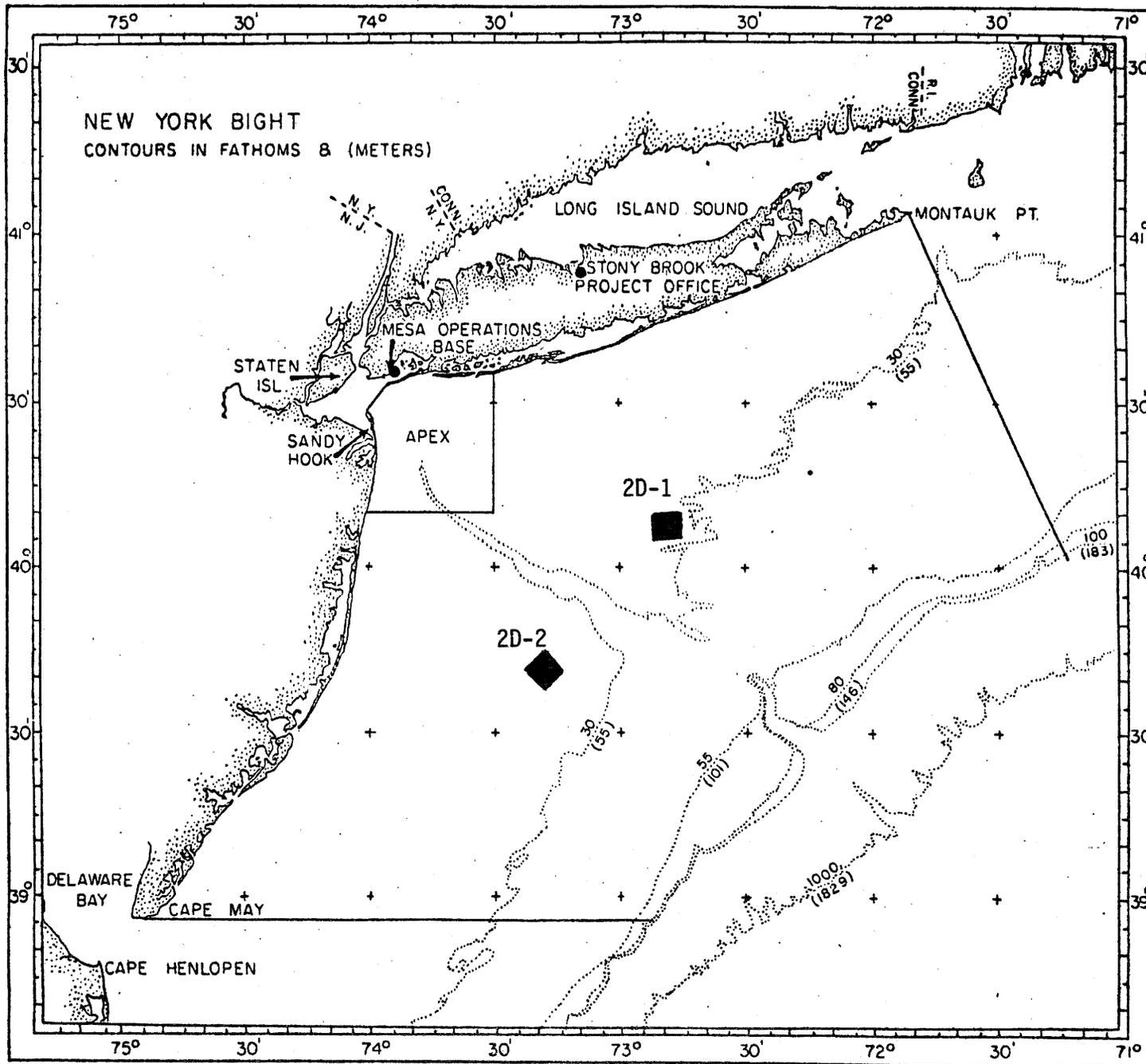
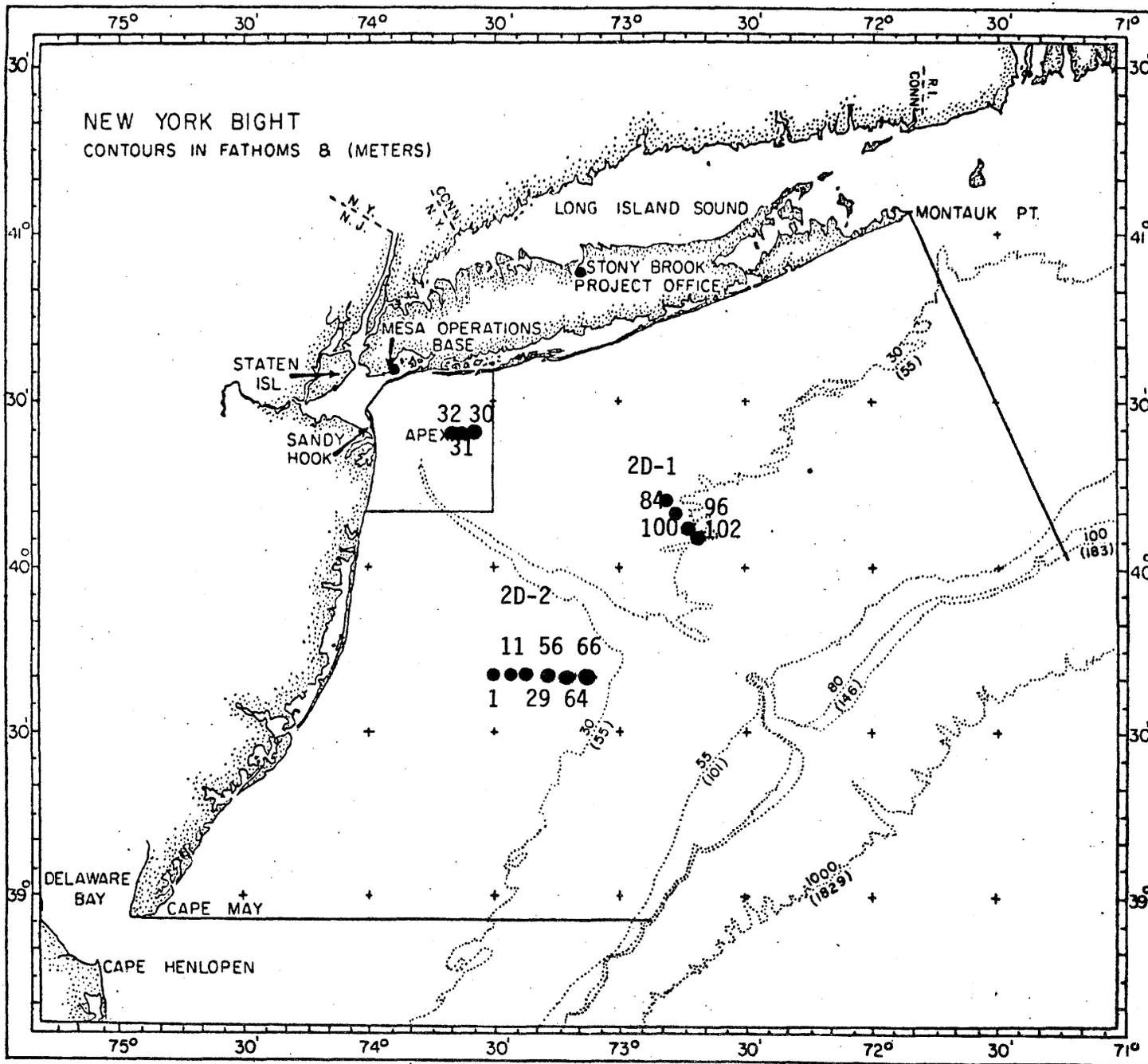


Figure 20 Proposed Alternate Dumpsites - Location, New York Bight.



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Figure 21 Approximate Station Locations on Alternate Dumpsites

as date, time, depth, sediment type and RAYDIST bearings are given in Table 34. This table also includes coordinates of Bight apex stations at which bacteriological data were collected for use in comparisons. The temperatures of the sediments are not included in the table, but ranged between 5^o-7^oC for all stations.

Sediment samples were obtained by means of a Smith-McIntyre grab; the top 1-2 cm of sediment was aseptically removed, placed in sterile bottles, and refrigerated until analysis. Cores were obtained at each station for heavy metal and other chemical analysis and immediately frozen.

Microbiological Methods

Sediments from all 90+ sampling stations in the alternate disposal sites were not examined bacteriologically because of time limitations; however, stations were selected to provide adequate coverage of selected microorganisms in sediments from these areas. In dump site 2 D1 sediments from stations 96 and 102 were analyzed; in 2 D2, sediments from stations 1, 29 and 66 were analyzed.

The following bacteriological analyses were performed on the sediments:

1. Total aerobic count - seawater media - 20^oC.
2. Fecal coliform count.
3. Presumptive Clostridium perfringens (Total Clostridia and anaerobic).
4. Presumptive Vibrio species.
5. Lipolytic.
6. Proteolytic.
7. Starch hydrolysis.
8. Chitin hydrolysis.

**Table 34. Station Coordinates for Alternate Dump Sites Offshore -
New York Bight Area**

Area Station	Date March '75	Time (EDT)	Depth(ft.)	Latitude (R1)	Longitude (R2)
			Sediment Type		
2D-1					
86	26	1510	164.0 s-sh	40°12.62'N 2209.3	72°47.56'W 1410.6
96	26	1420	164.0 s-cl	40°10.65'N 2312.8	72°45.15'W 1488.6
100	26	1320	181.0	40°08.50'N 2422.1	72°42.50'W 1573.7
102	26	1219	184.0 s-sh	40°06.50'N 2525.1	72°40.10'W 1663.7
2D-2					
1	26	0400	114.0 f-s	39°38.95'N 2331.7	73°31.80'W 3134.6
11	26	0445	107.4 f-s	39°38.76'N 2374.1	73°27.30'W 3081.6
29	26	0517	106.8 f-s	39°38.53'N 2424.5	73°23.60'W 3041.2
56	26	0552	119.0 f-s	39°38.40'N 2474.6	73°20.05'W 3003.8
64	26	0617	120.0 f-s	39°37.95'N 2527.2	73°17.25'W 2992.2
66	26	0644	122.0 s-sh	39°37.58'N 2584.7	73°14.10'W 2874.0
Apex					
30	25	1214	76.0 f-s	40°24.95'N 456.0	73°43.95'W 1014.7
31	25	1150	103.0 bk-m	40°25.00'N 418.2	73°45.95'W 1067.7
32	27	0310	104.5 bk-m	40°24.90'N 393.3	73°47.90'W 2159.9
34	27	0411	50.4 s-sh	40°24.95'N 379.9	73°51.60'W 2275.8

s = Sand sh = Shell f = Fine cl = Clay bk - Black m = Mud

Results and Comments

Total Aerobic Count: Total 20°C aerobic plate counts obtained on seawater media for sediments from the 5 alternate and 2 apex stations are listed in Table 35. The counts approximate 1×10^6 organisms per ml of top sediments, except in the sediment from apex station 32, which had a total count 10x higher. The count in sediments from apex station 34, east of the dumping area was ~5x greater.

A duplicate set of plates on seawater media from sediments collected at 103, 1 and 32 and incubated anaerobically at 20°C are listed in Table 36. These counts are significantly lower than the aerobic plate counts, with the highest count for sediment from station 32.

The tendency for total aerobic counts to be higher in sediments from the apex stations is not unexpected when one considers the amount of organic sludge dumped in these areas. One might expect a greater difference, however, in counts at apex stations compared to the offshore stations which receive no added organic material. A comparison of total counts in sediments from the proposed alternate areas to other offshore areas is not now possible because of lack of data.

Table 35. Total Aerobic Count in Marine Sediments From
Proposed Alternate Dump Sites - New York Bight

Dump Site	Station	Count/ML - 20°C	(Anaerobic)
2D-1	102	16.5 x 10 ⁵	(0.11 x 10 ⁵)
	96	7.4 x 10 ⁵	
2D-2	71	20.7 x 10 ⁵	(0.14 x 10 ⁵)
	29	9.8 x 10 ⁵	
	66	11.9 x 10 ⁵	
APEX	32	102.00 x 10 ⁵	(2.5 x 10 ⁵)
	34	16.5 x 10 ⁵	

Table 36. Total Aerobic and Anaerobic Plate Counts in Marine Sediments From Proposed Alternate Dump Sites - New York Bight.

Dumpsite	Station	Count/ML - 20°C	(Anaerobic)
2D-1	102	16.5 x 10 ⁵	(0.11 x 10 ⁵)
	96	7.4 x 10 ⁵	
2D-2	71	20.7 x 10 ⁵	(0.14 x 10 ⁵)
	29	9.8 x 10 ⁵	
	66	11.9 x 10 ⁵	
Apex	32	102.00 x 10 ⁵	(2.5 x 10 ⁵)
	34	16.5 x 10 ⁵	

Biochemical-Types

Counts on various differential media for certain biochemical types for sediments from 2 stations in alternate dump site 2D-1 and the Bight apex are listed in Table 37. Total counts on seawater media were significantly higher than the more complex, enriched differential media. Our previous studies have shown that a minimal nutrient-type media is necessary to obtain maximum total counts from marine waters and sediments.

Since we sampled only once at the alternate dump site, comparisons cannot be made on the presence of the various biochemical types in these sediments. Note should be made in reference to the counts in sediments from station 102; there was a trend towards higher counts for all biochemical types listed at this station. This may be indicative of higher total counts obtained on seawater media but does not correspond with counts from Bight apex station 32, which had higher total counts on seawater media but lower counts on the various differential media.

Fecal Coliform

Fecal coliform counts obtained in 100 ml of sediments from 5 stations are shown in Table 38. No fecal coliform bacteria were detected in sediments from the alternate dump sites. Fecal coliform counts in sediments from Bight apex stations are as high as previously reported.

Table 37. Biochemical Bacterial Types in Sediments from the Proposed Alternate Dump Sites - New York Bight.

Dump Site	Station	Sea Water TC	Count x 10 ⁴ /ML MEDIA							
			Proteolytic TC	Proteolytic Active	Lipolytic TC	Lipolytic Active	Starch TC	Starch Active	Chitin TC	Chitin Active
2D-1	102	165.3	84.0	1	36.	3.	53	--	12.5	2
	96	74.0	3.3	1.6	0.5	0.06	0.61	0.39	16	0.8
Apex	32	1020.0	7.3	2.0	1.1	1.1	0.85	0.27	39	1
	34	165.3	1.1	0.3	0.06	0.03	0.21	.01	2.1	0.03

TC = Total Count

Active = Ability to hydrolize substrate

Table 38. Fecal Coliform Counts in Marine Sediments
From Proposed Alternate Dump Sites -
New York Bight

Dump Site	Station	Fecal Coliforms/100 ML
2D-1	102	0
	96	0
2D-a	1	0
	29	0
	66	0
Apex	30	790
	31	330
	32	11

Clostridium perfringens

A presumptive count for C. perfringens is given in Table 39. This organism is used as an indicator of fecal pollution since it is present in fecal material. An advantage of employing this organism as an indicator organism is that it indicates more persistent types of fecal pollution, perhaps due to movement of sediments. Since it can exist in a spore state it is capable of prolonged periods of survival.

Counts are listed in the table as presumptive since we are still evaluating our methodology in regards to types being scored on our selective and differential media as perfringens types. Also, for this study, a direct plating media was employed for enumeration. The counts on the plate were low for the lowest dilution employed and only estimates could be made as to numbers present; those which were present on the plates, however, had the characteristic morphology of the perfringens types. For confirmation of quantitative presence of perfringens in the sediments from the alternate dump sites a MPN technique should be employed.

Counts from sediment from the Bight apex station were on the order of 1×10^5 /ml sediment. This can be related to the high coliform count observed in these same sediments.

Presumptive Vibrio Count

As part of our ongoing finrot disease study in the New York Bight area, we are interested in the presence of certain Vibrio groups or types. This is of importance since species belonging

Table 39. Presumptive Clostridium perfringens Count in Marine Sediments From Proposed Alternate Dump Sites - New York Bight

Dump Site	Station	Count/ML
2D-1	102	20*
	96	3*
2D-2	1	6*
	29	3*
	66	3*
Apex	32	14.2 x 10 ⁴

* Count Low - Estimate only

to this genus have been implicated in fish diseases, including finfish finrot (anguillarum), and diseases in man (parahaemolyticus, chlorae). We have been evaluating various media for demonstrating and monitoring the presence of Vibrio groups in areas of the New York Bight where finrot disease has been observed to occur with high frequencies. Such data on Vibrio are of importance in reference to studies on ocean dumping and are, therefore, included in this baseline study.

The Vibrio counts listed on TCBS media (Table 40) were obtained at 35°C and 20°C incubation temperatures which are selective for different groups of vibrios. It is listed as presumptive since the identification of groups on this selective media has not been established. No organisms were detected at the lowest dilution plated, 10⁻², when plates were incubated at 35°C. As in the case with C. perfringens, a MPN technique should be employed for quantification.

At 20°C incubation temperatures, counts in all sediments were similar except that there was a trend to a higher count in sediment from Bight apex station 34. The high counts observed in the sediments from the alternate dump sites were unexpected.

We previously observed that the 35°C counts in sediments obtained from the apex area were similar to the 20°C counts when sampling was done in the summer months. It is obvious that the lower environmental temperature is selective against Vibrio groups.

Table 40. Presumptive Vibrio Count* in Marine Sediments
From Proposed Alternate Dump Sites - New York Bight

Dump Site	Station	Count/ML	
		35°C	20°C
2D-1	102	0	9.2×10^3
	96	0	5.5×10^3
2D-2	1	-	3.7×10^3
	29	-	1.3×10^3
	66	-	7.1×10^3
Apex	32	0	1.3×10^4

* TCBS MEDIA

ECOSYSTEMS INVESTIGATIONS

BEHAVIOR OF FISHES UNDER ENVIRONMENTAL STRESS

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Introduction

The search for sensitive and ecologically pertinent measures of pollutant effects on aquatic organisms has stimulated research in a variety of disciplines including animal behavior. Recent work has shown that knowledge of the life habits and requirements of an organism may be used in a variety of ways to assess and predict the effects of contaminants in marine and estuarine ecosystems. Prior to any contaminant experiments in the laboratory, understanding of the organism's normal behavioral repertoire, including its scope of response to natural stresses, may form a sound basis for speculation on its survival potential to man-induced stress. While the organism itself may be able to survive or remain unaffected by a specific contaminant, disruption of components within the ecosystem on which it is dependent, e.g., shelter, food resources, may indirectly reduce its survival capability.

We chose temperature as the stress stimulus or contaminant for our initial studies for two main reasons: 1) it represented a current as well as a future problem for a small but significant number of marine ecosystems being subjected to heated effluents from electric generating plants; and 2) the design of almost any

study on contaminant effects requires consideration of temperature as a primary experimental variable because of the obvious short- and long-term fluctuations of this parameter in estuarine and inshore marine zones. The following represents the results of research and analyses completed during 1975.

Results

Both the bluefish and Atlantic mackerel possess a clearly defined diurnal rhythm of activity, although they swim continuously day and night. Continuous swimming in Atlantic mackerel was not so surprising since they lack any hydrostatic organ, making swimming obligatory to maintain their position in the water column. The bluefish, although possessing such an organ, also swam continuously, but at much lower speeds and with a higher degree of variability, especially at night. Both species generally swam around the tank in a school, although the bluefish were more variable in this activity, especially at night.

The introduction of live food (small bait fish of various species for bluefish; grass shrimp for Atlantic mackerel) caused an almost immediate breakdown of schooling with the fish feeding more or less as individuals. As would be expected for schooling animals inhabiting the upper pelagic zone where light levels are relatively high, the fish were highly visually oriented, using vision as a primary modality for feeding.

While the introduction of food would cause a breakdown in the integrity of the school, the introduction of a "fright" stimulus had the opposite effect. Stimuli such as a sudden flash of light, especially at night, a splash at the surface, or the sudden appearance of an observer above the aquarium would cause an increase in cohesion and speed. At times, the initial response to a startle stimulus would be for the animals to separate, followed within several seconds by regrouping, with the fish significantly closer than before the introduction of the startle stimulus. The fish were highly responsive to any altering stimulus both day and night, with avoidance being manifested by increased speed and reduced interfish distance.

Initial acclimation levels for both species (adult bluefish, 19.9°C, juvenile bluefish, 20.0°C and Atlantic mackerel, 13.3°C) were based on correlations between temperature and distribution. For bluefish, peak abundance off the eastern coast of North America appears to be about 18-20°C, with inshore appearances in the spring along the Middle Atlantic and New England regions occurring as temperatures reach 12-15°C and departures in the fall at 13-15°C. Limits for distribution of Atlantic mackerel along this coast are from about 7-8°C up to approximately 18-20°C, with 12-14°C cited as the optimal range for Scomber scombrus in the eastern North Atlantic.

The response of both species to gradual increases in temperature ($0.02^{\circ}\text{C}/\text{h}$) from these acclimation levels was an increase in speed and a decrease in fish-to-fish distance. As temperatures reached stress levels, the daily rhythmic pattern was no longer evident as the fish schooled at high speed both day and night. Juvenile bluefish, in separate experiments, responded similarly even though the rate of rise was more rapid (mean rate $1.38^{\circ}\text{C}/\text{h}$). Maximum cruising speeds were reached by juvenile bluefish at $32\text{--}33^{\circ}\text{C}$ and by Atlantic mackerel at $20\text{--}22^{\circ}\text{C}$, several degrees below lethal levels.

The response of these two species to increasing temperatures, based on even the most rudimentary physiological interpretation, was not surprising. However, the responses of the adult fish to decreases in temperature from similar acclimation levels, 19.5°C for bluefish and 7.9°C for Atlantic mackerel, were most interesting, if not surprising. A decrease in temperature (mean rate $0.013\text{--}0.03^{\circ}\text{C}/\text{h}$) resulted in an increase in speed similar to that observed in response to a temperature increase. As they had at high stressful temperatures, adult Atlantic mackerel reached maximal cruising speeds before temperature reached lower lethal levels.

Although the response to low temperature might be opposite to what would normally be expected, the distribution of these animals in nature is so obviously correlated with temperature that our laboratory findings simply confirmed that temperature is an important

parameter influencing their distribution. These pelagic species (it remains to be investigated in other marine pelagics) have the capability of actively avoiding or selecting certain thermal regimes. The data indicate that the temperatures avoided or "preferred" were not specific, but rather fell within a range dependent on the specific environmental requirements of each species.

The similarity in response to both increasing and decreasing temperatures by species with similar normal patterns of behavior reflects what has been termed behavioral thermoregulation. It has been shown in situ in fresh water and demonstrated under controlled laboratory conditions that certain fishes have the ability to regulate body temperature behaviorally by selecting water temperatures.

Bluefish and Atlantic mackerel, which are not associated with a specific place but rather to specific thermal ranges, as well as with other environmental parameters, have the capability to move in response to changing temperature, thereby avoiding potentially stressful conditions and maximizing their presence in zones which are selectively advantageous.

We suggest that animals such as these possess the capability of generally avoiding stresses including other contaminants. Whether avoidance actually occurs will depend on a host of variables including their motivation to be in a particular area,

the characteristics of the contaminant, the ability of the animal to detect it and whether or not it represents, within the context of the animal's scope of responsiveness, a noxious or "danger" stimulus.

In contrast to these pelagic fishes are species which are more restricted both in activity and movements. The tautog, one of two members of the Labrid family found in inshore temperate waters of the western Atlantic, is found on or near the bottom, in association with objects which provide shelter, such as rocks, pilings, jetties, and various forms of vegetation. Our knowledge of the natural habits and requirements of this demersal fish was increased during the past year from field studies on populations located in Great South Bay, New York, specifically within the Fire Island Inlet. In our studies, we employed various techniques including direct observation with SCUBA, remote sensing with ultrasonic tracking, as well as examination of digestive tracts of captured specimens.

From our recent underwater observations we found distinct differences in the behavior of the tautog from day to night. During the day they were active and highly responsive, swimming in the water column and feeding along the pilings and rubble in the basin. During evening twilight, the number of fish in proximity to the basin increased. By nighttime, the fish were settled in or on almost any object that afforded cover, lying quiescent and

unresponsive throughout the night to the extent that they could be touched or captured with a net. The tautog resumed activity during morning twilight.

Thus, as is the case with the pelagic species, these fish have a diurnal rhythm of activity, but with the important difference that at night they are completely quiescent with significantly reduced ability to respond to altering stimuli.

Results from sonically tracking adult fish (39-50 cm) from July to October showed that these large tautog would move away from the homesite each morning (some traveling as far as 500 meters) and return each night. In contrast with these adults, young tautog (≤ 25 cm) remained in close proximity to the basin throughout the day, near objects affording shelter.

Underwater observations of the areas where the adults spent significant amounts of time showed large quantities of blue mussels, Mytilus edulis. It seemed probable that the daily dispersal of these large fish was related to feeding.

Recent analyses of digestive tract contents supported this view, indicating that blue mussels, averaging about 12 mm in length, comprised the major food item. The size of mussels ingested, by even the largest tautog, was limited by the pharyngeal mill at the opening of the esophagus. Since tautog of all sizes are restricted in the size of mussels they can ingest, mussels less than three years old would be the largest potential food source for which this population would compete. The daily dispersal of the

adults from the homesite was probably related to more effective utilization of available resources, reserving mussels at the homesite as a food for the young fish.

These patterns of activity and feeding were typical for this tautog population from July through October. However, as temperatures dropped from the 16-24°C range of summer and early fall to about 10°C in November, we no longer saw tautog larger than 30 cm. This corresponds to the results of Cooper who found that fish of similar size moved out of Narragansett Bay, Rhode Island, to winter offshore in a relatively dormant state. In contrast, our results showed that young fish remained in proximity to the homesite, wintering over in a torpid, non-feeding state. It was apparent that for the first 3-4 and possibly 5 years, young fish are highly restricted in their movements, associating closely with the shelter throughout the year regardless of temperature.

There are a number of possible reasons for shelter dependence, but one of the most obvious and important for young and adult tautog is protection from predation, especially critical during the periods of lowered responsiveness. It seemed probable that this high degree of dependence on shelter might well limit or preclude any ability to avoid or escape potentially lethal environmental stress, and we hypothesized that tautog, particularly the young fish, might have different behavioral capabilities for response than we had observed with pelagic fishes.

Based on this premise, we tested the response capabilities of young tautog in the laboratory to high, stressful temperature. Two experimental aquaria (1,400 and 1,500 l), isolated in temperature-controlled rooms and equipped with lighting systems which simulated day-night cycles, were used for testing. One to two clay drainage tiles were placed on the sand bottom of each tank to provide shelter. Temperature was regulated by thermostatically controlled units. In each of four tests, two fish of nearly similar size were acclimated at 19.8-21.1°C while observations of behavior patterns were recorded.

After an initial period of adjustment to the laboratory, the fish would be active during the light period, swimming about, searching for food and engaging in aggressive behavior. The larger of the two fish was always dominant, occupying the shelter, and aggressively defending it against the subordinate. The subordinate would dig a depression in the sand adjacent to the aquarium wall, which would serve as a shelter site. When small clumps of mussels were placed on the sand, the dominant fish, if not satiated, would defend this area, chasing and nipping at the subordinate if it tried to feed. At night, both fish would remain generally inactive and quiescent.

The agreement between behavior observed in both the field and laboratory again indicated that these patterns transcended both situations and could be used as baselines in evaluating thermal stress.

As temperature increased from acclimation levels of 19.8-21.1°C (mean rate 1.26°C/h), at about 28°C (absolute levels varying among fish) activity decreased as association with shelter increased. As the temperature was held at about 30°C (the level varying within a 2°C range between tests), the activity of the fish diminished still further and they became generally unresponsive, showing little or no motivation to feed. Aggression decreased to the extent that the subordinate fish, now highly motivated to enter and share the shelter tile, could do so without being attacked by the dominant. Preliminary findings on the effects of high but sublethal temperatures on adults, indicated that activity as well as aggression was significantly reduced.

The decrease in activity and responsiveness and the accompanying increase in association with shelter at high temperature resembled typical nighttime behavior of tautog. Since we had observed tautog in the natural environment seeking shelter when pursued by predators or when startled by divers, it seemed clear that closed association with shelter would serve as protection during periods of lowered responsiveness, whether the stimulus was the onset of nighttime or a stress such as temperature.

When exposure to sublethal temperatures was of short duration, and the temperature returned to 20°C, several of the fish were able to survive, resuming feeding and normal activity within a few days. In the natural environment, they could apparently withstand thermal

increases of a transient nature, but if exposure were to be prolonged (dependent also on the rate of increase and temperature attained), survival would be impaired since it does not appear that these fish have the behavioral capability to regulate body temperature by moving to more optimal thermal regions.

Other species, with similar dependence on shelter (e.g., many of the coral reef species) may also be restricted in the capacity to move from a given locale under stressful conditions.

Reduced capability for response may also depend on when the stress is imposed. It is apparent that the capability of tautog to respond to or escape altering stimuli at night, when responsiveness is low, would be significantly less than during the day. This is in direct contrast with the pelagic fishes which were highly responsive both day and night.

The contrasting responses of the pelagic species and tautog to thermal stress support our contention that it is important to define, species by species, the normal behavioral capabilities of each as related to their specific environmental requirements before attempting to predict the effects of potentially lethal stresses. While certain physiological and biochemical responses to temperature (and even other contaminants) may be common to a number of species, how an animal may act when subjected to stress is based on its normal scope of behavior. Generalizations cannot be postulated until more is known about species for which only the most meagre information now exists.

ECOSYSTEMS INVESTIGATIONS

BENTHIC MACROFAUNA

J. McNulty, J. Caracciola, M. Halsey and L. Rogers

In recognition of the fact that multivariate analyses of benthic community structure, contaminant distribution, and certain geological/chemical parameters are the goal of present macrofaunal studies, major emphasis has been on procuring additional data and making it available in machine-readable form. Sorting and identification of samples from two more of the five New York Bight seasonal cruises was accomplished and much of the numerical coding of species and other ADP-preparatory work has been completed. We now have seasonal data from at least 64 stations in the apex -- at least one grab per station -- for August 1973, and January, March-April, and August 1974. The fifth cruise has been sorted and identified and data are being prepared for the ADP unit.

We are also working up extra samples taken at the sewage and dredge spoil disposal sites in February and April 1975. The extra samples consist of two grabs per station at 25 stations in the dredge spoil and sewage sludge disposal sites. They were taken to fill in critical gaps between stations that were visited during the five seasonal cruises. Ten of these samples from the sewage sludge disposal site have already been sorted and identified.

We have exchanged information with the MESA staff on how to set up the benthic macrofaunal tape format and are prepared to supply the tapes on all macrofaunal data.

Preliminary analysis of the distribution and abundance of benthic macrofauna as sampled during three seasonal cruises has been completed and reported in the MESA Atlas manuscript by Dr. Pearce. Species distribution can be thought of as falling into three broad categories: (1) a few species that occur regularly at many stations, often in great abundance (Certain species exhibited marked consistency of occurrence, both areally in samples from one season and temporally in samples from all three cruises and can be categorized as widespread and abundant); (2) a few other species that occur irregularly but often in great abundance (Certain species exhibited "contagious" distribution, i.e. huge numbers of individuals of a single species occurred in some samples); and (3) a great many additional species that occur irregularly, at few stations, and in few numbers. Some few species, namely Tellina agilis and Nucula proxima, found in the second category were also in the first category, as illustrated in the list which follows:

Widespread and Abundant

Rhyncocoel sp.

Glycera dibranchiata

Spiophanes bombyx

Tharyx acutus

Tellina agilis

Exhibiting Contagious Distribution

Polydora caulbergi

Spirorbis borealis

Protohaustorius holmes

Protohaustorius wigley

Parahaustorius attenuatus

Lumbrineris fragilis

Unciola irrorata

Nucula proxima

Tharyx acutus

Lumbrineris tenuris

Nucula proxima

All of the widespread and abundant species were found in at least 30% of the samples, and by far the majority of them were found in more than 50% of the samples. The numbers per sample of individuals in the "contagious distribution" category ranged from 25 to 4,200. The latter number, a record to date, was attained by Nucula proxima. We anticipate that scheduled cooperative studies with CEDDA will contribute a great deal to an understanding of the underlying reasons for these distributional variations.

Data management activities have included (1) proofing and correcting a listing of the reconnaissance cruise data from which a final tape is being made, (2) species coding of the data from the April 1975 Outer Continental Shelf cruise (20-35 fathoms), and (3) species coding of the March-April 1974 seasonal cruise.

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EXPERIMENTAL BIOLOGY INVESTIGATIONS

There exists, at all levels of both the public and the private sectors, considerable alarm that the living marine resources of the estuarine, coastal and offshore waters of the Middle Atlantic Bight are being adversely affected by extensive offshore dumping of untreated wastes and by run-offs of highly polluted waters. The mode and intensity of such adverse physiological effects is largely unknown. Baseline findings of marine environmental quality cannot be interpreted without such knowledge nor can rational water quality standards be established or enforced when such knowledge is lacking. Quantitative, controlled exposure experiments, both static and chronic, on living organisms, and involving all stages in their life histories, followed by a battery of analytical tests are necessary to permit evaluation, standards-development, successful enforcement, and resource conservation. The nucleus of such a research team, expert in hatching and rearing of marine invertebrates, culture of phytoplankton for pollutant studies, and in the physiology and mutagenics of marine animals comprises the Experimental Biology Investigations. Although the teams concerned with hatching and rearing of invertebrates and culturing phytoplankton are no longer directly involved with contaminant research due to the

March 1975 reprogramming of these Investigations back into Aquaculture, thus will not be reported here, the information gathered is still of benefit to ongoing contaminant projects.

The objectives of the physiological effects and mutagenics effects investigations are as follows:

- 1) determine lethal effects of a large variety of known pollutants on the larval, juvenile and adult stages of molluscs, crustaceans, and finfish;
- 2) determine the long-term, sub-lethal effects of exposure to a large variety of known pollutants on the larval, juvenile and adult stages of molluscs, crustaceans and shellfish;
- 3) define the physiological and biochemical pathways affected and relate them to the metabolic disorders, tissue abnormalities, etc., which result in death or permanent damage to the living marine organisms;
- 4) determine effects of marine pollutants on the chromosomes, and genetic development of fish and shellfish. Evaluate findings in terms of specific pollutants and population genetics.

The two Investigation reports that follow discuss the results of these studies.

PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS

PHYSIOECOLOGY SUBTASK

A. Calabrese, D. Nelson, J. R. MacInnes, and J. Miller

Experimental Studies

Laboratory experiments in this Investigation were directed toward the evaluation of physiological stress on marine organisms induced by contaminants in the environment. A number of different experiments were conducted and are summarized in this Subtask report and those of the Physiological Effects and Biochemical Effects Subtasks which follow. Reference to exposures conducted by this Subtask will also be made by various investigators in this Informal Report. This Subtask has the major responsibility of exposing marine animals to pollutants in both static and chronic systems because of the facilities located at Milford. Animals are exposed on request from other MACFC investigators and also as a function of this Investigation. For results of previous studies by this Investigation, refer to the following: MACFC Informal Report No. 5, "Cooperative Study of Contaminants in the Coastal Environment and Their Effects on Living Marine Resources: Summary Report of Operations from May 1, 1972 to December 31, 1973"; and Informal Report No. 73, "A Multilaboratory Cooperative Study of Contaminants in the Coastal Environment and Their Effects on Living Marine Resources: Summary Report of Operations from January 1, 1974 to December 31, 1974."

Acute Studies

Bay Scallops

Acute toxicity studies with juvenile bay scallops, Argopecten irradians, were previously completed (see Informal Report No. 73). In subsequent tests juvenile scallops were exposed to silver and cadmium to monitor changes in oxygen consumption rates. These measurements were made on excised gill tissues of scallops exposed for 96 hours to the LC₅ and LC₂₅ values (as determined above) of cadmium (0.94 ppm and 1.23 ppm) and of silver (0.014 ppm and 0.022 ppm). Excised gills were held in 14-ml Warburg-type reaction vessels (1 gill per vessel). Each vessel contained 5 ml of water from the test container in which the animal was exposed. Oxygen consumption was then monitored over a 4-hour period in a Gilson Differential Respirometer at a temperature of 20°C. Scallops exposed to the LC₅ (0.94 ppm) and LC₂₅ (1.23 ppm) levels of cadmium for 96 hours exhibited significantly higher ($P < 0.05$) oxygen consumption rates than the controls; the rates were 12.9% and 17.7% higher, respectively. There was no significant difference between concentrations. Scallops exposed to silver at the LC₂₅ (0.022 ppm) level also respired at a significantly higher rate ($P < 0.05$), 14.7% greater than the control, but those at the LC₅ (0.014 ppm) level respired at a slightly lower rate. Using the "Student's" t-test, no significant difference was noted in oxygen consumption between the controls and those exposed to 0.014 ppm silver ($P < 0.5$). The mean control value for oxygen consumption was $1.66 \mu\text{l O}_2/\text{hr}/\text{mg}$ dry weight of gill tissue.

Preliminary studies were also initiated to determine the LC₅₀ values of cadmium, arsenic, copper, lead, mercury, nickel, silver, and zinc to bay scallop eggs. Two tests were conducted in an attempt to determine the range of concentrations necessary in final tests. Because bay scallop eggs are not always available, the date of further testing will depend upon the supply.

American oysters

Larvae of the American oyster, Crassostrea virginica, were exposed to copper, mercury, nickel, silver, and zinc for 10 days (from 2 to 12 days of age), and the concentrations that killed 50% (LC₅₀) of them were determined. The values were then compared to previous data collected on oyster eggs (Table 41). It is apparent from Table 41 that eggs are more sensitive than larvae to mercury and silver, less sensitive to copper and zinc, and as sensitive to nickel. These data thus illustrate the need to study all life stages of a particular marine organism to determine which stage is the most sensitive to a particular pollutant.

Hard Clams

Larvae of the hard clam, Mercenaria mercenaria, were exposed to copper, mercury, nickel, silver, and zinc in a series of preliminary tests to determine the LC₅₀ values for these metals. Variability between these early tests has indicated a need for further testing. These studies will be completed when eggs become available.

Table 41. Toxicity of Heavy Metals, as Inorganic Salts, to Eggs and Larvae of the American Oyster, Crassostrea virginica. Eggs were Exposed for 48 Hours and Larvae were Exposed for 10 Days.

Metals as Inorganic Salts	Egg Development LC ₅₀	Larval Survival LC ₅₀
Mercuric chloride	5.6 ppb	11.0 ppb
Silver nitrate	5.8	23.8
Cupric chloride	103.0	30.0
Zinc chloride	310.0	84.0
Nickel chloride	1.18 ppm	1.22 ppm

Lobsters

Studies were initiated to determine the effect of heavy metals on survival and growth of larvae of the lobster, Homarus americanus. Optimal systems for culturing and rearing these larvae have been devised, and testing will continue during the next few years.

Chronic Studies

Lobsters

Lobsters, H. americanus, were exposed to silver and mercury individually and to mercury and cadmium in combination during 1975. Lobsters were exposed to these single or combined pollutants in two tests each of 30 days duration. In tests with silver, as the nitrate, the concentrations were 0, 3 and 6 ppb; in those with mercuric and cadmium chloride in combination, the metal concentrations were equivalent to 0 + 3, 3 + 3, and 6 + 6 ppb; in tests with mercury, as the divalent nitrate, the concentrations were 0, 3 and 6 ppb. One test each was also conducted with mercury and cadmium (as chlorides) for 30 days at 0 and 6 ppb. All concentrations used in these studies approximate those found in certain polluted areas of the natural environment. These lobsters were exposed for studies of physiological and biochemical changes, induced histopathological anomalies, and chemical uptake. During the course of these experiments 320 lobsters less than one pound in weight were exposed and distributed to four different subtasks.

Juvenile lobsters, reared in the laboratory from larvae, were exposed for about 5 months to 0.6, 3, and 6 ppb mercury as the divalent chloride. These lobsters were periodically sampled for growth measurements and for physiological testing, i.e., measurement of changes in oxygen consumption rates.

Striped Bass

Striped bass, Morone saxatilis, were exposed to mercury and cadmium (as chlorides) individually for examination of some physiological parameters. These tests are still ongoing.

Cunners

Cunners, Tautoglabrus adspersus, were exposed in two tests of 30 days each to 0, 5, and 10 ppb mercury as mercuric chloride, for oxygen consumption studies.

Rock crabs

Rock crabs, Cancer irroratus, were exposed for 30 days in two tests of 30 days each to 0 and 0.25 ppm cadmium as cadmium chloride. In a similar experiment rock crabs were exposed to cadmium as the nitrate, for physiological and biochemical testing.

Bivalves

A number of tests were conducted with bivalves exposed to silver as the nitrate at 0, 0.01, 0.05, and 0.1 ppm for varying lengths of time ranging from 30 to 60 days. Over 500 bivalves were exposed for determination of changes of oxygen consumption rates. Bivalves used in this study were: the soft-shell clam,

Mya arenaria; the hard clam, M. mercenaria; blue mussel, Mytilus edulis; American oyster, C. virginica; and the false angel wing, Petricola pholadiformis. Two groups of oysters, one from Connecticut and the other from North Carolina, were exposed for comparative purposes.

Winter flounder

Winter flounder, Pseudopleuronectes americanus, were exposed to cadmium in a multidisciplinary experiment that was initiated in December of 1974 and completed in April 1975 (see MACFC Informal Report No. 73). A number of physiological, biochemical, immunological, pathological, and chemical tests were conducted, the results of some of which are reported in other sections of this document.

As a follow-up to the initial winter flounder experiments, tests will be conducted in 1976 with this same species of fish and they will be exposed to mercury, cadmium, and silver, individually, for 2 to 5 months.

PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS

PHYSIOLOGICAL EFFECTS SUBTASK

F. Thurberg, R. Collier, M. Dawson

Physiological studies during the past twelve months have concentrated on the sublethal effects of cadmium, mercury and silver on various marine species after chronic exposure. Lobsters, striped bass, winter flounder and various bivalve species were the principal animals examined. Detailed descriptions of the results obtained this year from these studies follow. Some additional time was spent evaluating the use of ozone gas in red-tide toxin research and two papers were published in this area during the past year. The Brett cruising-speed respirometers are now fully functional and a description of the initial studies using these instruments with striped bass is also included in this report.

Winter flounder

This study was undertaken to determine any physiological damage caused by low levels of inorganic cadmium and mercury on the commercially valuable winter flounder (Pseudopleuronectes americanus) after 60-day's exposure to these metals. The parameters examined were oxygen consumption rate, some aspects of hematology and chemical uptake into the blood and gills. This study was a joint effort of the Physioecology and Physiological Subtasks and the Environmental Chemistry Investigation.

Gill-tissue oxygen consumption in winter flounder was significantly reduced ($P < .05$) after 60 days' exposure to cadmium at 5 and 10 ppb. Flounder exposed to 10 ppb mercury, however, respired at a significantly higher rate ($P < .05$) than the controls, while fish exposed to 5 ppb respired at the same rate as control fish (Fig. 22). The difference in oxygen consumption rate between the two control groups is attributed to seasonal reproductive condition. The cadmium group was tested in February when the fish were gravid, a condition requiring a high metabolic rate and a consequent increase in oxygen consumption. The mercury group was tested in May after the fish had spawned and no longer possessed the metabolic burden of reproduction. Similar high rates of oxygen consumption in brook trout (Salvelinus fontinalis) and other fishes have been reported during spawning season.

Oxygen consumption is a valuable indication of sublethal stress. Any significant variation from the normal or control value might reflect an alteration in the metabolic demand of the fish or damage to the respiratory system. In this study, cadmium depressed oxygen consumption of winter flounder at a concentration as low as 5 ppb, a level found in certain polluted estuarine waters.

There was no significant difference between controls and cadmium-exposed fish for any hematological test, but significant differences were noted in mercury-exposed fish (Table 42). Plasma protein rose from 5.4 to 6.3% in fish exposed to 5 ppb mercury with

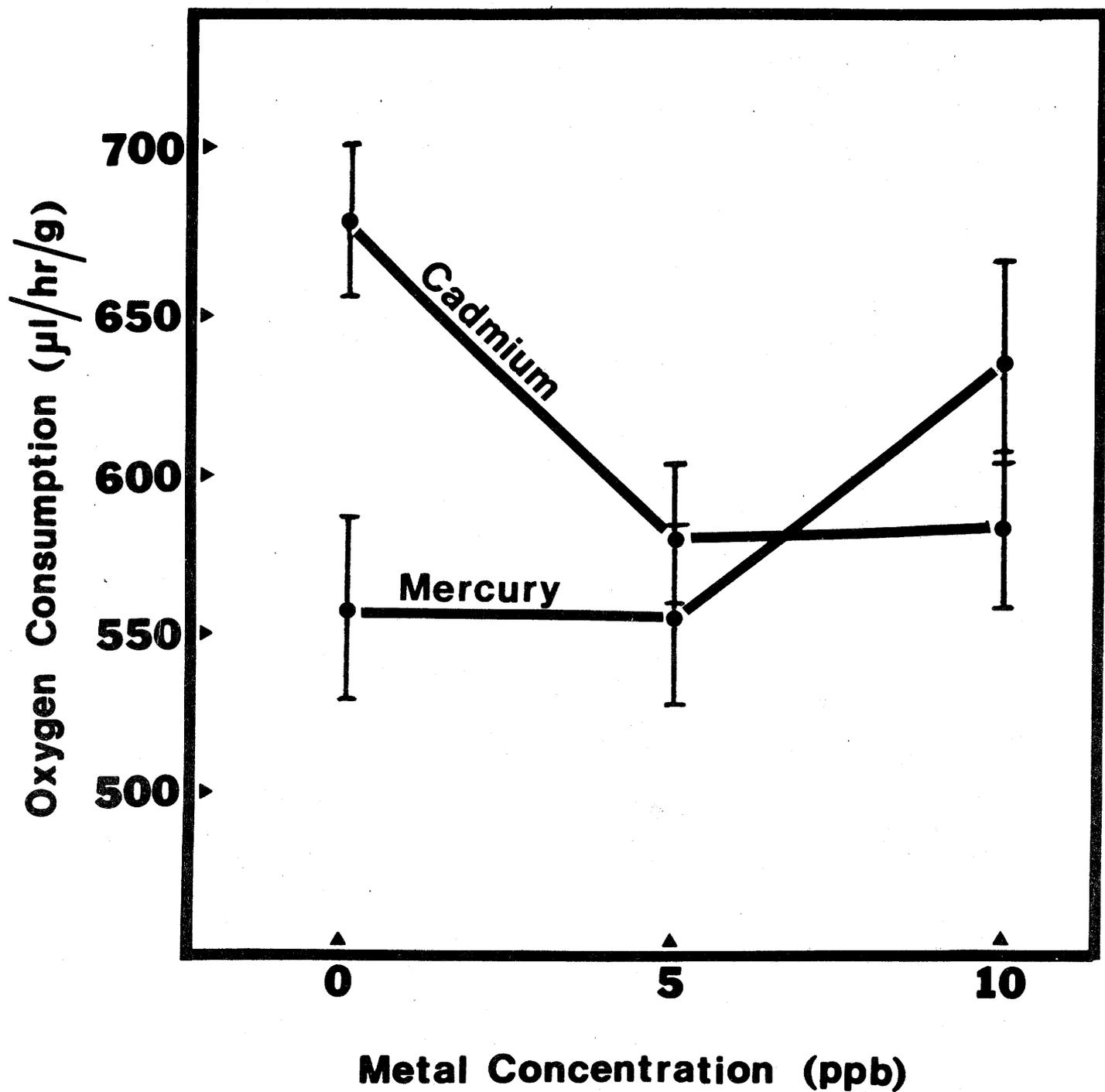


Figure 22. Effects of Mercury and Cadmium on Oxygen Consumption of Winter Flounder. Each Point Represents Mean Gill-Tissue Oxygen Consumption Value of 32 Fish. Bars Represent Standard Errors.

Table 42. Summary of Hematological Data from Winter Flounder Exposed to Mercury or Cadmium for 60 Days. These Data Were Analyzed by the Student's t-test.

Test	Cadmium Concentration					
	Controls		5 ppb		10 ppb	
	Mean ± S.E.	n	Mean ± S.E.	n	Mean ± S.E.	n
Hematocrit (% packed red cells)	35 ±1	35	34 ±1	32	33 ±1	32
Hemoglobin (g/100 ml whole blood)	7.4 ±0.3	32	8.1 ±0.3	31	7.4 ±0.3	32
RBC (10 ⁶ cells/mm ³)	2.90±1.7	17	2.69±0.12	10	2.96±0.18	14
Plasma protein (g %)	6.7 ±0.2	34	6.7 ±0.2	30	6.8 ±0.2	31
Plasma osmolality (mOsm/Kg H ₂ O)	401 ±7	22	380 ±7	22	401 ±5	19
Mean Corpuscular Volume (μ ³ /cell)	121 ±7.0	17	114 ±6.1	9	114 ±5.0	14
Mean Corpuscular Hb (picograms/cell)	26.2 ±1.6	14	27.9 ±3.7	9	26.2 ±1.6	14
Mean Corpuscular Hb Conc. (g/100 ml packed red cells)	22.7 ±0.7	31	23.8 ±1.0	31	22.7 ±0.7	31

Test	Mercury Concentration					
	Controls		5 ppb		10 ppb	
	Mean ± S.E.	n	Mean ± S.E.	n	Mean ± S.E.	n
Hematocrit	28 ±1.6	25	29 ±1.5	25	23 ±1.4*	27
Hemoglobin	5.3 ±0.3	27	5.4 ±0.2	22	4.2 ±0.2**	27
RBC	1.87±0.16	12	2.10±0.18	12	1.78±0.16	11
Plasma protein	5.4 ±0.2	26	6.3 ±0.2**	25	6.0 ±0.2*	27
Plasma osmolality	362 ±2.6	12	348 ±4**	11	360 ±4	15
MCV	151 ±10.5	11	145 ±12	12	127 ±6	10
MCH	30.7 ±2	12	26.5 ±1.5	11	23.5 ±1.9*	11
MCHC	19.4 ±0.8	25	18.9 ±0.4	22	17.8 ±0.6	26

*Significantly different from controls at 0.05 levels.

**Different at 0.01 level.

a decrease in plasma osmolality. The normally hyposmotic blood became even more so. Exposure to 10 ppb mercury also resulted in a number of changes: plasma protein rose significantly while hematocrit, hemoglobin and mean corpuscular hemoglobin MCH decreased. Hematological data from control fish were similar to those observed in winter flounder by other researchers.

Hematological tests have been an important diagnostic tool in medicine for many years, and recent speculation has indicated that they may be equally valuable as indicators of disease or stress in fish. Hematological changes in fish have been related to temperature and season, diet, pesticide stress and metal stress. In this study, cadmium-exposed flounder showed no hematological changes and no detectable uptake of cadmium (see Environmental Chemistry section). Mercury-exposed fish, however, showed high tissue levels of mercury and several hematological alterations.

Striped bass

Juvenile striped bass, Morone saxatilis, were exposed to 0.5, 2.5, and 5.0 parts per billion (ppb) cadmium as cadmium chloride for 30-90 days and to 1.0, 5.0, and 10. ppb mercury as mercuric chloride for 30-120 days. Following the longest exposure to each metal, the fish were allowed to recover for 30 days in clean running seawater.

Control fish exhibited normal variation in oxygen consumption rate, attributable to seasonal variation and growth of the fish; because of this, each exposure group's data were plotted as a percent

of that group's control values (Table 43, Figs. 23, 24). Fish exposed for 30 days to 0.5, 2.5, or 5.0 ppb cadmium consumed significantly less oxygen than did controls ($P < .01$). Fish exposed for 90 days and those allowed to recover for 30 days following a 90-day exposure respired at rates not significantly different at the .05 level from those of controls.

The respiratory rate of animals exposed to 1 ppb mercury did not differ significantly from that of controls, regardless of exposure time. Fish exposed to 5 ppb for 30 days respired at a rate significantly lower than that of controls ($P < .05$). After 60 days, respiration of exposed and control groups was approximately equal; absolute values for both groups had decreased from the 30-day levels. In subsequent periods there was no significant difference between control animals and those exposed to 5 ppb mercury. Animals exposed to 10 ppb mercury exhibited decreased respiration at 30 days, followed by a gradual increase, compared to controls, at 60 and 90 days, reaching a rate significantly higher than that of controls at 120 days ($P < .001$). After 30 days in running seawater, respiration of these fish decreased from 139 percent of controls to 120 percent. In retrospect, a 60-day recovery period would have been valuable.

The oxygen consumption data support the results obtained on other cadmium- and mercury-exposed fish. Cunners, *T. adspersus*, subjected to short- or long-term cadmium exposure exhibited

Table 43. Gill-Tissue Oxygen Consumption¹ of Metal-Exposed Striped Bass, Morone saxatilis.

Length of Exposure	Cadmium Concentration			
	Control	0.5 ppb	2.5 ppb	5.0 ppb
30 days	1.908 ± .064	1.580 ± .083 ³	1.410 ± .066 ³	1.380 ± .086 ³
90 days	.877 ± .076	.812 ± .022	.801 ± .033	.753 ± .027
30-day recovery	.813 ± .057	.829 ± .044	.830 ± .043	.841 ± .042
	Mercury Concentration			
	Control	1 ppb	5 ppb	10 ppb
30 days	1.742 ± .239	1.550 ± .209	1.096 ± .025 ²	.971 ± .038 ³
60 days	.859 ± .037	.789 ± .042	.847 ± .042	.758 ± .038 ²
90 days	.769 ± .038	.747 ± .033	.727 ± .032	.887 ± .047
120 days	.679 ± .037	.673 ± .030	.785 ± .044	.946 ± .055 ⁴
30-day recovery	.822 ± .067	.842 ± .064	.927 ± .050	.986 ± .042

¹ Units are O₂/hr/mg dry wt. ± standard error.

² Significantly different from control at .05 level.

³ Significantly different from control at .01 level.

⁴ Significantly different from control at .001 level.

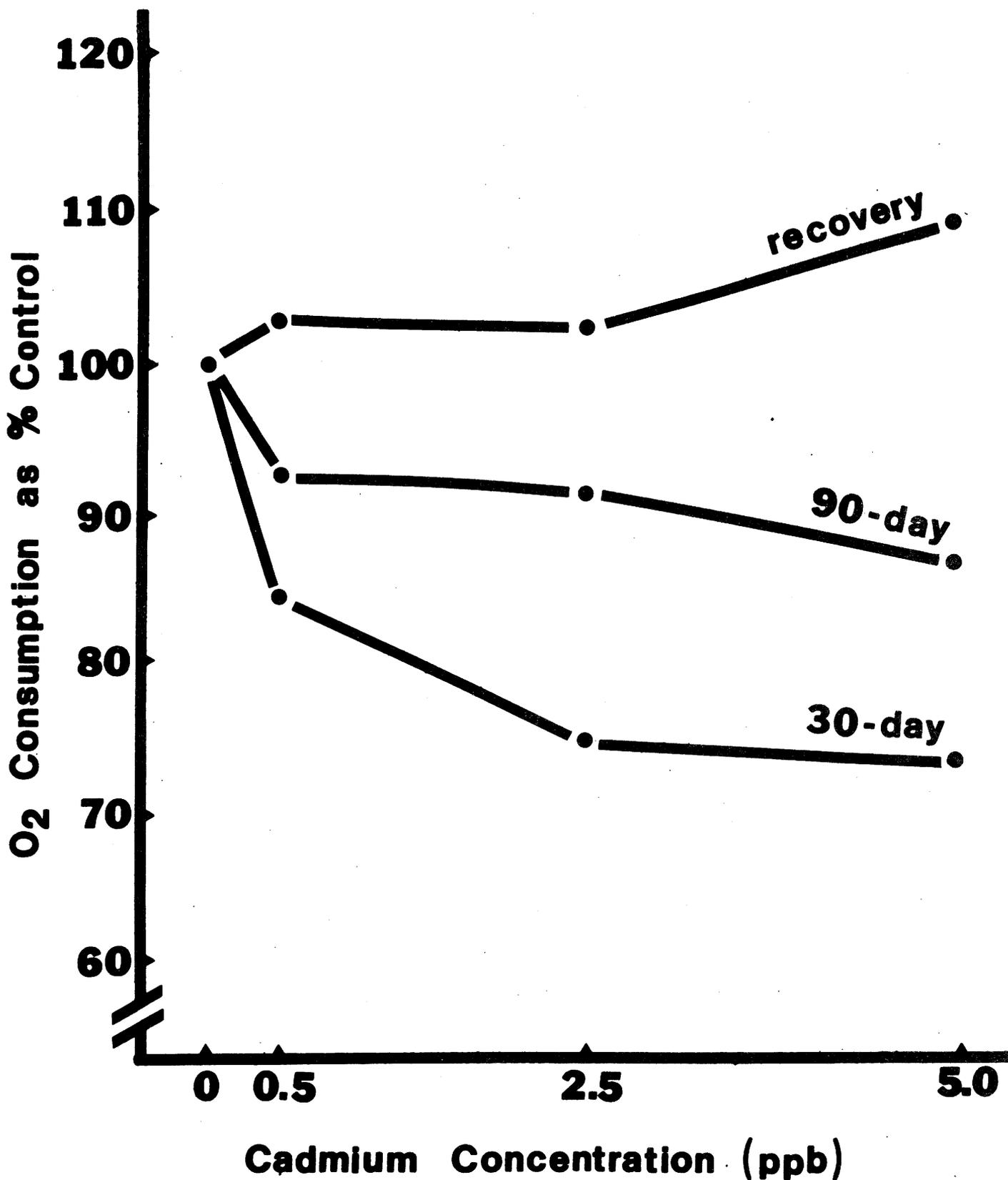


Figure 23. Gill-Tissue Oxygen Consumption of Striped Bass, *Morone saxatilis*, Exposed to Cadmium Chloride. Each Point Represents Mean Respiration of Nine Fish. Recovery Period was 30 Days in Running Seawater Following the 90-Day Exposure Period.

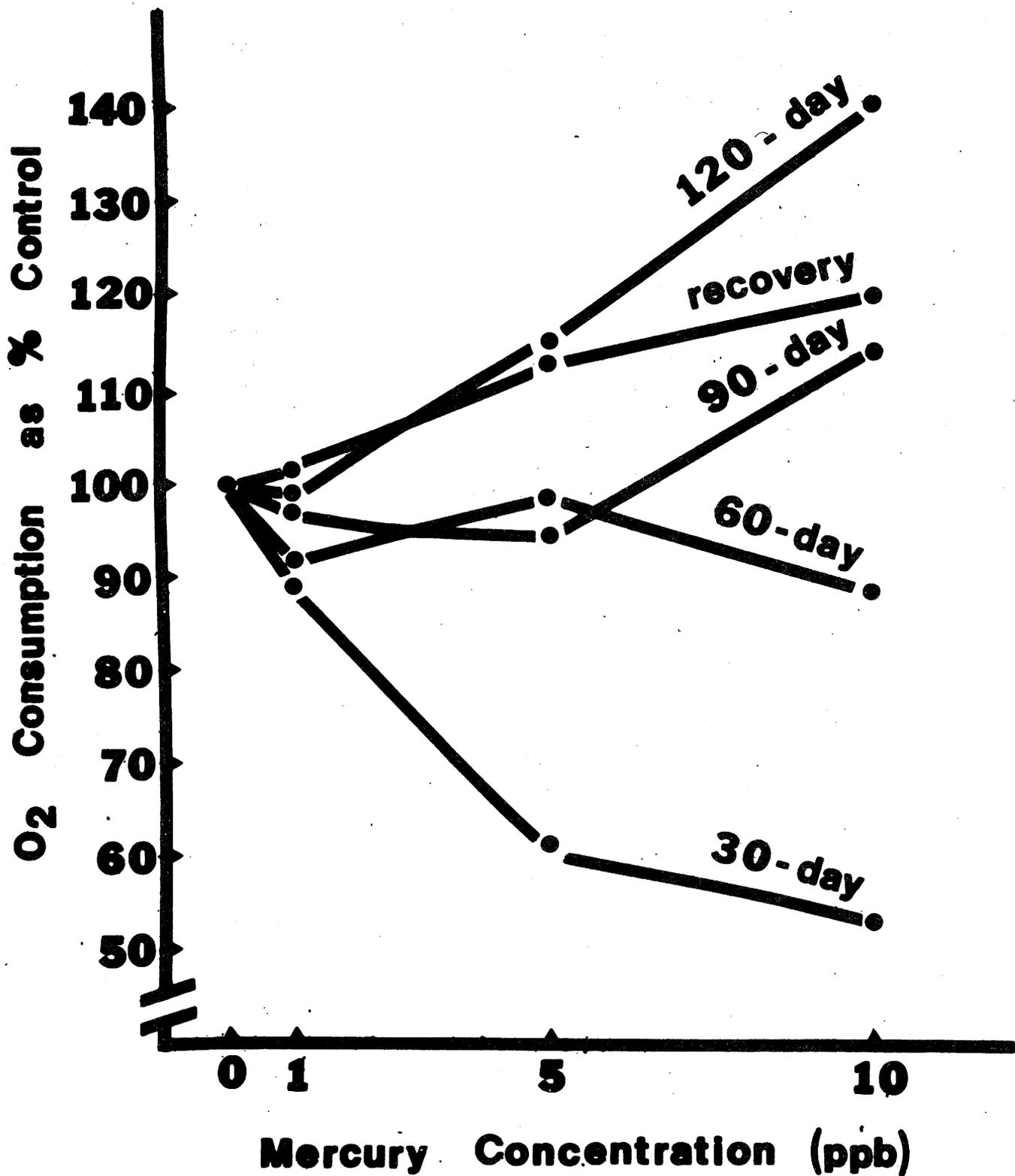


Figure 24. Gill-Tissue Oxygen Consumption of Striped Bass, *Morone saxatilis*, Exposed to Mercuric Chloride. Each Point Represents Mean Respiration of Nine Fish. Recovery Period was 30 Days in Running Seawater Following the 120-Day Exposure Period.

depressed gill-tissue oxygen consumption, while long-term mercury exposure elevated their respiration. We also reported that winter flounder, P. americanus, exposed to 5 and 10 ppb cadmium for 60 days showed depressed oxygen consumption, while those exposed to 10 ppb mercury had elevated levels. Oxygen consumption is a good general indicator of stress. In the case of striped bass it may be particularly valuable since there is some evidence that the limiting factor to striped bass in a grossly polluted natural environment is the oxygen level.

Lobsters

Lobsters, Homarus americanus, were exposed in flowing water systems to sublethal amounts of cadmium and mercury for 30- and 60-day periods. At the end of these exposures, the lobsters were examined for changes in oxygen consumption, serum osmolality, enzyme activity, and metal uptake into body tissues. This cooperative study was conducted by many investigations and subtasks within the Center. Here we report on the physiology contribution; oxygen consumption and serum osmolality.

Changes in gill-tissue oxygen consumption are valuable indicators of stress and are frequently used to evaluate changes in metabolism due to an environmental alteration. Lobsters exhibited significantly elevated ($P < .01$) gill-tissue oxygen consumption values after 30 days' exposure to 3 and 6 ppb cadmium (Fig. 25). Lobsters exposed for 60 days also showed elevated rates

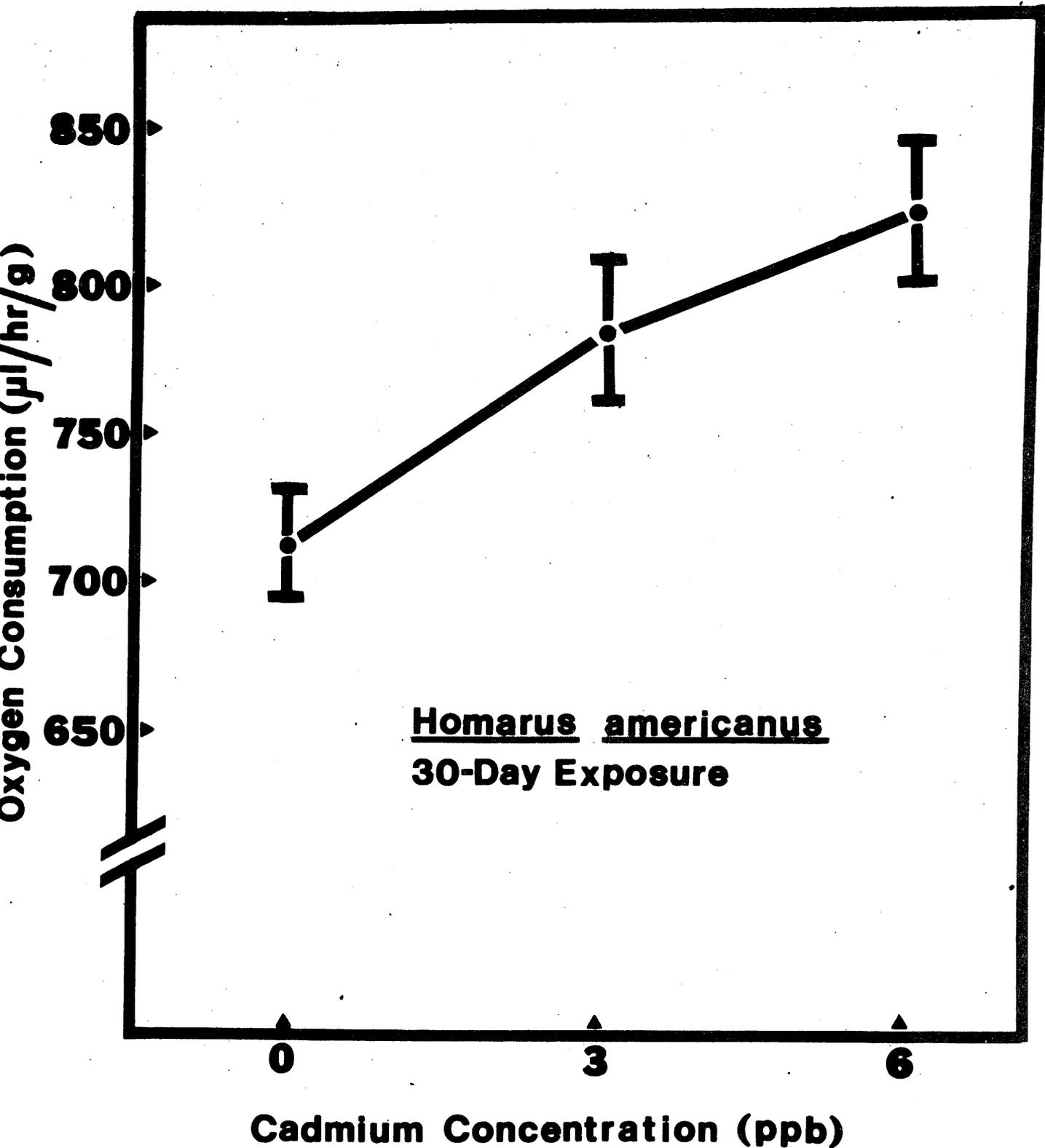


Figure 25. Homarus americanus. Effect of Cadmium on Oxygen Consumption. Each Point Comprises the Mean Gill-Tissue Oxygen Consumption Value of 24 Animals. Bars: Standard Errors. Temperature: 20°C.

but only 6 animals were tested per concentration, a number too low for valid statistical analysis. This elevation in oxygen consumption contrasts with the depression in gill-tissue oxygen consumption we noted in cadmium-exposed green crabs, Carcinus maenas. This contrast may be due to species difference or to the different exposure regimes used; the crabs were exposed for 30 days to lower levels (ppb).

No differences in gill-tissue oxygen consumption were noted between controls and any mercury-exposed group of lobsters. This was true for both 30- and 60-day exposed animals. In contrast, Vernberg and Vernberg reported mercury-induced changes in the respiration of fiddler crabs, Uca pugilator, exposed to 0.18 ppm mercury for 21 days. This may indicate that the lobsters were exposed to levels of mercury too low to provoke detectable physiological damage.

The lobsters used in this study were exposed to estuarine waters with a salinity range from 24-26 ‰. Lobsters possess some osmoregulatory ability and blood is maintained hyperosmotic to the seawater over this salinity range. We previously reported osmoregulatory disruption in the green crab, Carcinus maenas, after 30-days/ exposure to low concentrations (25 ppb) of cadmium. No changes in serum osmolality were noted, however, in lobsters exposed to cadmium or mercury in this study. The serum osmolality of experimental and control animals was maintained at about 40

milliosmoles above that of the seawater. The results of this study were presented at the symposium "Pollution and Physiology of Marine Organisms" held at the Milford Laboratory and will be published by Academic Press.

Larval Lobsters

During this past year several egg-bearing ("berried") female lobsters were conditioned to release larvae in the laboratory. Approximately 600 of these larvae were exposed to cadmium or mercury for various lengths of time; 48 hours to 2 months. All four larval stages were tested and very definite differences in respiratory response and metal uptake were noted for each stage. Animals which molted during exposure also reacted differently from those that did not. These data, as well as differences between the two metals, are being analyzed at this time and the detailed results will appear in a future report.

Brett Respirometer Studies

Two series of striped bass exposed to cadmium have been tested thus far in the Brett respirometers. The larger fish (140-200 g) were exposed for 30 days and measurements of oxygen consumption, ventilation rate and heart rate were made on fish swimming at four different speeds. Similar measurements were made on smaller bass (30-40 g) exposed for 28 days. These studies will continue this spring and we hope to present the initial results of this study at the Spring or Fall NEERS meeting.

In addition to our own studies, we are fortunate to have a pre-doctoral student from the University of Massachusetts working on the respirometers with us. He has been most helpful in modifying and improving the performance of these units and has completed a significant amount of work on his thesis concerning the metabolic efficiency of ram-ventilation in striped bass.

PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS

BIOCHEMICAL EFFECTS SUBTASK

E. Gould

By far the major part of this year's work was with the tissues of winter flounder, Pseudopleuronectes americanus, exposed for 60 days to sublethal levels of either cadmium chloride or mercuric chloride. Tissues from metal-exposed lobsters, Homarus americanus, were the next most intensively studied, and some miscellaneous tidying up was done with hearts from the rock crab, Cancer irroratus (Cd salts, 30 days), and skeletal muscle from the cunner, Tautogolabrus adspersus (Ag salts, 4 days).

Two general observations emerged that are of significance for the physiological interpretation of stress induced by an animal's exposure to realistically sublethal amounts of cadmium. The first has to do with metalloenzymes, which incorporate in their structure a metal ion that is essential to the enzyme's function: sublethal cadmium attack stimulated an increased production of these enzymes, so that their reactions could proceed at near-normal rates, at the expense of metabolic energy. The second has to do with a metal-activated enzyme, glucose-6-phosphate dehydrogenase (G6PDH), which does not require a metal ion for activity, but which is stimulated by it: sublethal cadmium attack causes the loss of

G6PdH's sensitivity to magnesium activation, resulting in the attenuation of an important metabolic control. To a lesser extent, the same is true for exposure to sublethal amounts of mercury.

These subtly toxic effects are seen clearly in data from the flounder experiments. In the discrete tissue mass comprising kidney tubules embedded in hematopoietic tissue (K-HT), the activity of two zinc enzymes, leucine aminopeptidase (LAP, Fig. 26) and carbonic anhydrase (CA, Table 44), increased in flounder exposed to 10 ppb Cd for 60 days; and sensitivity of the key shunt enzyme, G6PdH, to its biochemical modulator (magnesium) was lower in the metal-exposed fish (Fig. 27). The mechanism by which magnesium normally sharpens the efficiency of this enzyme (by increasing the enzyme-substrate affinity) and cadmium's disruption of it were revealed by a study of the enzyme's kinetics in control and exposed animals (Table 45). These data were presented at the Symposium, "Pollution and the Physiology of Marine Organisms," held at the Milford Laboratory in November of this year. Proceedings will be published by Academic Press.

Of the other tissues studied, the most significant findings in cadmium-exposed fish were: in the male gonads, CA activity doubled; in heart muscle, malic enzyme was less sensitive to in vitro Cd; and in skeletal muscle, lactic dehydrogenase (LdH, a zinc enzyme) doubled, and pyruvate kinase (PK, a key glycolytic enzyme that reflects the production of metabolic energy) also increased.

Figure 26. Leucine Aminopeptidase Activity in the Kidney and Hematopoietic Tissue of Flounder Chronically Exposed to Sublethal Amounts of Cadmium Chloride. The Upper Curve Represents the Standard Activity as Measured by the Hydrolysis of L-leucyl- β -naphthylamide. The Lower Curve Represents the Activity in Assays Containing Cadmium Chloride, 0.10 mM Assay Conc. The Difference Between the Two Curves, Cadmium-Inhibited Activity, is Considered to be a Truer Measure of LAP Activity (a metalloenzyme) than the Standard Assay. Significance Level in Fish Exposed to 10 ppb Cd is $< .01$.

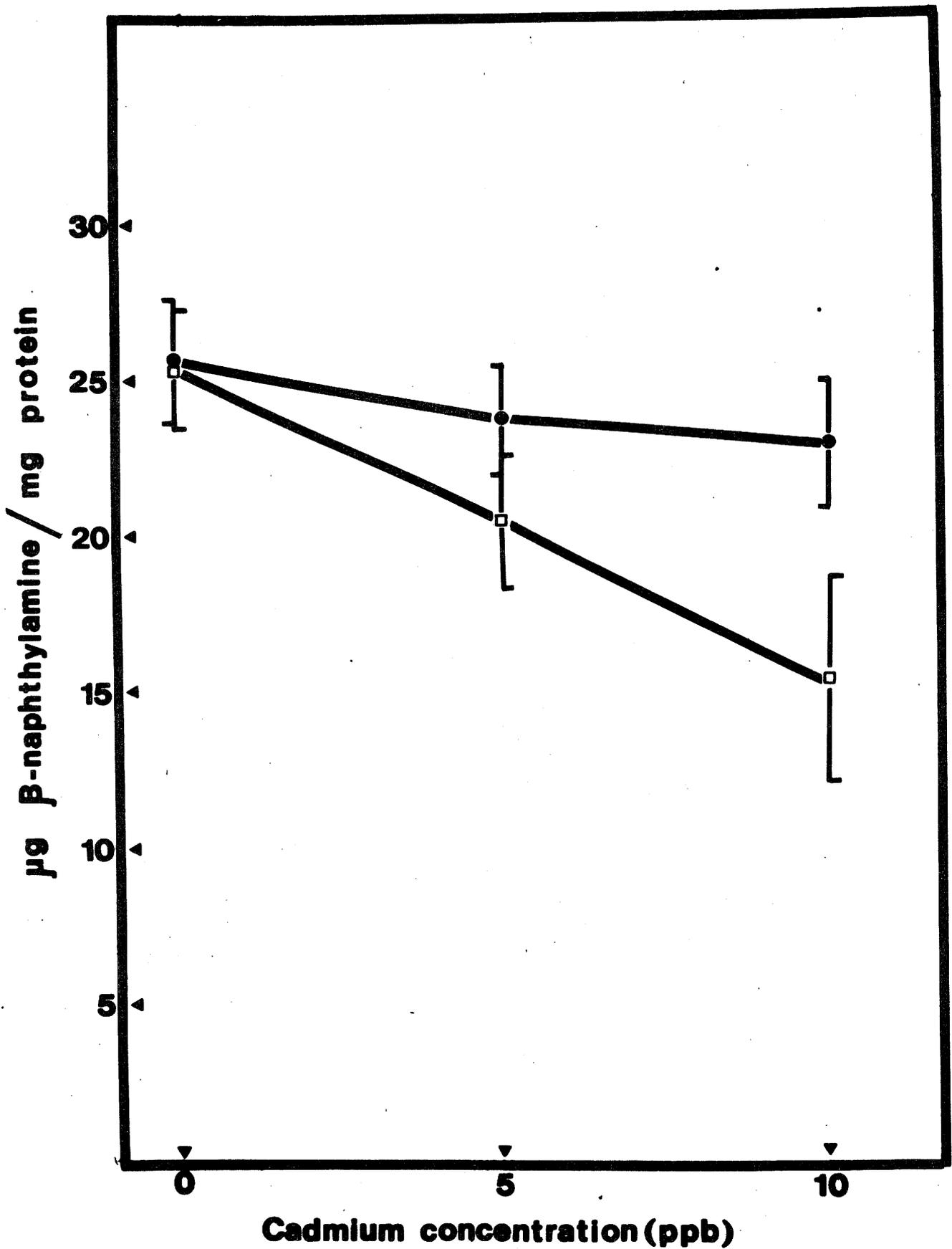


Table 44. Carbonic Anhydrase Activity in the Kidney and Hematopoietic Tissue of Winter Flounder, Pseudopleuronectes americanus, Chronically Exposed to Sublethal Levels of Cadmium Chloride.

Experimental Conditions	Number of Samples	CA activity ^a		Range ^a	Level of Significance
		\bar{X}	± S.E.		
Control	19	70.3	5.5	23-100	
5 ppb Cd	20	84.2	5.5	50-127	
10 ppb Cd	16	100.2	4.8	72-128	P < .001

^aUnit of CA activity = change in absorbance at 400 nm of 0.001/min/mg

Figure 27. Glucose-6-phosphate Dehydrogenase Activity in the Kidney and Hematopoietic Tissue of Flounder Chronically Exposed to Sublethal Amounts of Cadmium Chloride. The Lower Curve Represents the Standard Activity Without Magnesium, and the Upper Curve, the Activity in the Presence of $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, 2.5 mM Assay Conc. The Dotted Line Represents % Magnesium Activation; in Fish Exposed to 10 ppb Cd, the Significance Level is $< .001$.

GOPdH activity (.001 absorbance change / min / mg protein)

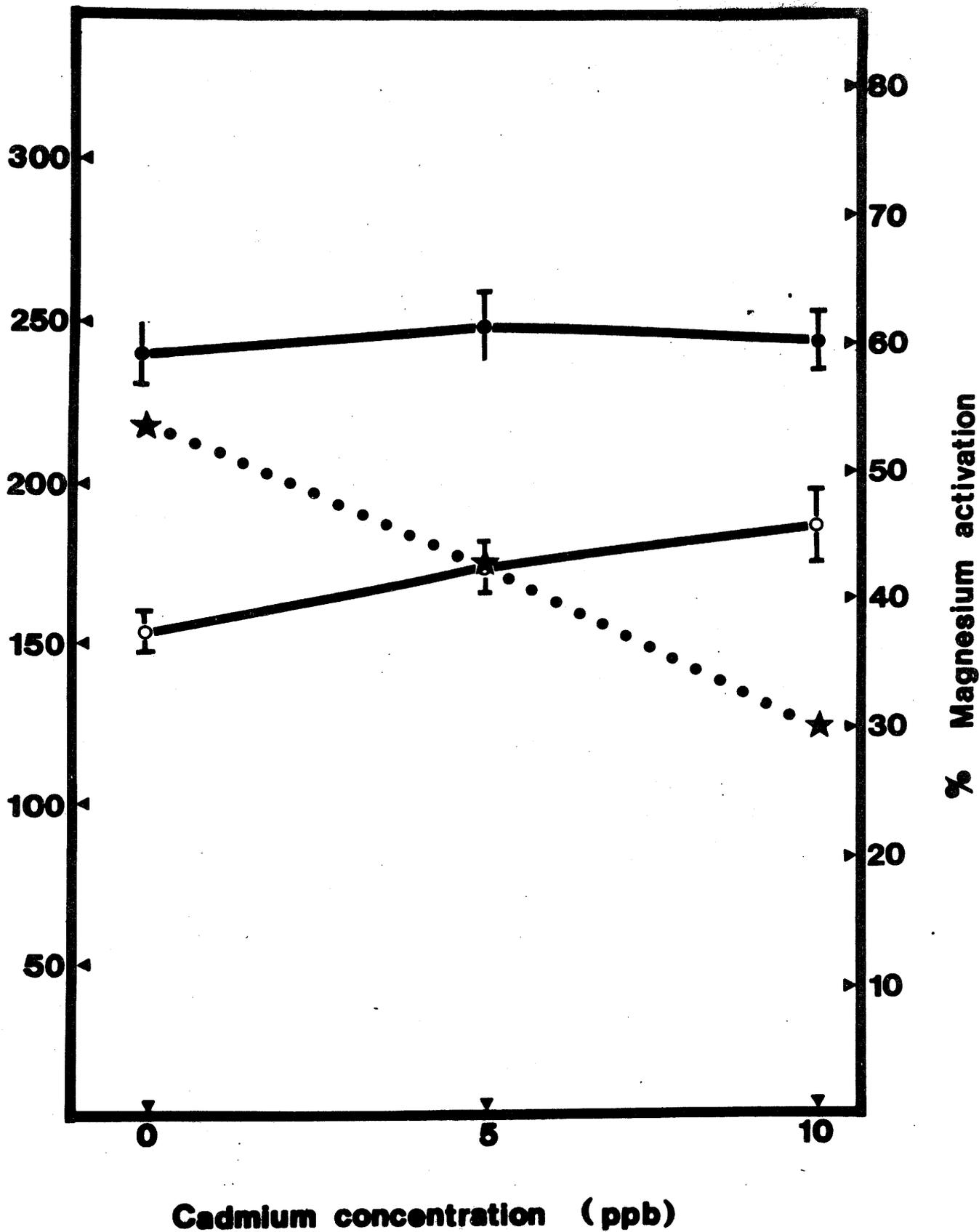


Table 45. Glucose-6-phosphate Dehydrogenase in Kidney and Hematopoietic Tissue of Winter Flounder, Pseudopleuronectes americanus, Chronically Exposed to Cadmium Chloride.

Experimental Conditions	K ^a m(G6P)		V ^b max	
	\bar{x}^c	± S.E.	\bar{x}^c	± S.E.
Control : no Md with Mg ^d	65.4	3.7	176	11
	52.7	3.2 (P<.05)	171	10
10 ppb Cd: no Mg with Mg ^d	64.3	2.6	177	8
	64.3	2.3	200	8 (P < .05)

^aG6P assay concentration, μM .

^bUnit of activity = change in absorbance at 340 nm of 0.001/min/mg protein.

^cArithmetic mean for 6 samples.

^dAssay concentration, 2.5 mM MgCl₂.6H₂O.

For flounder exposed to 10 ppb Hg for 60 days, observations of note were: in the K-HT, G6PDH lost sensitivity to magnesium activation, but no significant change was seen in the zinc enzymes, LAP and CA; in the heart, PK increased (energy demand), but no change was seen in malic enzyme properties; in the female gonad, no change occurred in either CA or PK; and in the skeletal muscle, both PK and LdH increased, but to a lesser extent than in cadmium-exposed fish.

The flounder experiments were preceded by considerable exploratory biochemistry on tissues from normal fish, including a study of the effects of in vitro metal salts. Liver, the least stable of the tissues, produced highly erratic data from samples held 1 month at -29°C . Consequently, in the flounder experiments being repeated during this winter, the liver will be examined as quickly as possible after samples are taken and frozen.

Tissues were taken from lobsters in a series of 30-day exposures to 3 or to 6 ppb CdCl_2 , Cd and Hg in combination, $\text{Hg}(\text{NO}_3)_2$, and AgNO_3 . Heart, antennal gland, and hepatopancreas were packaged and frozen-stored (-29°C) to await testing. Gills were lyophilized and frozen-stored. Of the work done thus far on antennal gland, the following are significant: magnesium sensitivity is lost in animals exposed to 6 ppb Cd or to 6 ppb each of Cd and Hg; LAP increased (on basis of 3 samples per concentration) in cadmium-exposed animals, but not in those exposed to both cadmium

and mercury, nor was there any change in LdH of the latter animals; and little or no CA or PK activity is present in the antennal gland. Work will proceed on the balance of these tissues as time permits.

The observations reported here reinforce earlier work with cadmium-exposed marine animals: the cunner, the rock crab, and the lobster. On the whole, they suggest that sublethal amounts of divalent heavy metals affect both metalloenzymes and enzymes whose catalytic efficiency is largely dependent upon allosteric mechanisms. The implications are that exposure to sublethal amounts of these metals causes, 1) a drain of metabolic energy by reason of increased enzyme biosynthesis, and 2) a loss of metabolic flexibility by reason of reduced sensitivity to magnesium modulation.

Another area of strong interest in the study of physiological effects of heavy metals on marine animals is a membrane-bound enzyme complex in the gills, which regulates the ion flux across the gill membranes. This year, in working out an optimal protocol for lobster gill ATPases, substrate sensitivity seemed to offer some insight into the mechanism of heavy-metal effects on these enzymes. Lyophilized gills, 3 specimens from controls and 3 from lobsters exposed to 6 ppb each Cd and Hg, were assayed for $(\text{Na}^+, \text{K}^+)$ - and Mg^{2+} -ATPase activity both at low assay concentrations of ATP (0.4 mM) and at a tenfold increase in

substrate concentration (4.0 mM ATP). All 3 control specimens had less (Na⁺, K⁺)-ATPase activity at the higher substrate concentration than at the lower, whereas the reverse was true for metal-exposed animals: this enzyme's activity was greater at the higher substrate concentration than at the lower. Moreover, at 0.4 mM ATP, exposed animals had slightly higher Mg²⁺-ATPase activity than controls, and slightly lower (Na⁺, K⁺)-ATPase activity than controls. Because the assay requires much more time and attention than is possible here, however, and because there are many other enzyme systems to be monitored in many other tissues, we plan to have the gill ATPase work done in another marine research laboratory.

MUTAGENIC EFFECTS OF POLLUTANTS SUBTASK

A. Longwell

Chromosome Mutagenesis in Developing Mackerel Eggs Sampled from the New York Bight

Heavy metals and pesticides are recognized mutagens and, as such, along with some other major classes of marine contaminants, may have important implications in survival of fish populations. This may be particularly so for fish using the polluted New York Bight as spawning grounds. Mutagens can cause genetic damage at sub-toxic levels. Many marine contaminants accumulate in the body tissues of fish and other marine species. Cadmium has been shown to be absorbed from seawater by post-spawned fish eggs.

Cells in the meiotic divisions of gametogenesis are particularly sensitive to the damaging effects of mutagens. Early cleavage mitoses of the fertilized egg are even more sensitive. When fish eggs, often already carrying significant contaminant loads, are spawned in polluted waters they have only halfway completed these sensitive meiotic divisions with their intricate chromosome maneuvers. As components of the neuston in surface waters, fertilized fish eggs must then undergo repeated divisions of their chromosomes during the even more sensitive stages of early cleavage.

From studies of mammals, insects and plants we know that most dominant lethal mutations which kill at early stages of development are associated with gross chromosome alterations. In an experimental study of incorporated radionuclides in eggs of commercial turbot (Rhombus maeoticus) and ruff (Scorpaena porcus), Russian workers found increased incidences of chromosome aberrations in normal and abnormal larvae associated with poor hatchability and reduced vigor of hatched larvae.

The chromosomes of developing fish eggs provide a sensitive test for genetically active substances, both experimentally and in naturally polluted waters. Any new determination of mortality of early fish stages, irrespective of its cause, would have important bearing on the general theories of fluctuations of fish populations and on predictions of success of any year class of commercial fish.

It is not necessary to assign genetic damage to specific chromosomes, or to know details of the chromosomes of a fish species, or even to know numbers of the chromosomes of a fish to estimate rate of occurrence of such damage. Whether spontaneous or induced by radiation, chemicals, or physical stress, a significant portion of all chromosome breakage, as well as faulty distributions of the chromosome material, is easily observable and measurable by abnormal orientation, behavior and configurations of the chromosomes in dividing cells. Many chemicals affect the

mitotic (or meiotic) spindle apparatus itself, and cause maldistribution, or non-division of the chromosomes because of their failure to orient together on the defective spindle.

With such test criteria in mind, as well as what may be the special susceptibility of fish eggs to genetic damage in nature, a study has been initiated on fish eggs from 40 sample stations in the New York Bight. These were collected from surface waters during the May 7-18, 1974 cruise of the Westward (of SEA, Sailing Education Association) sponsored by MESA (Marine Ecosystems Analysis, U.S. Department of Commerce, National Oceanic and Atmospheric Administration) and assisted by the Middle Atlantic Coastal Fisheries Center. The New York Bight is simultaneously one of the most heavily polluted coastal areas in the United States and the spawning grounds for large numbers of economically important fish.

Eggs of 15 different samples from 14 stations thus far studied were identified by W. Smith of the Sandy Hook laboratory of the Middle Atlantic Coastal Fisheries Center as being almost exclusively those of the Atlantic mackerel, Scomber scombrus.

Altogether 30,689 embryo cells were scored in 452 eggs from the 14 different Westward stations. Less than 20% of all the eggs had all their dividing cells free from chromosome and division abnormalities. One-third of the 30,689 division figures scored for all the embryos were abnormal. By far the largest portion

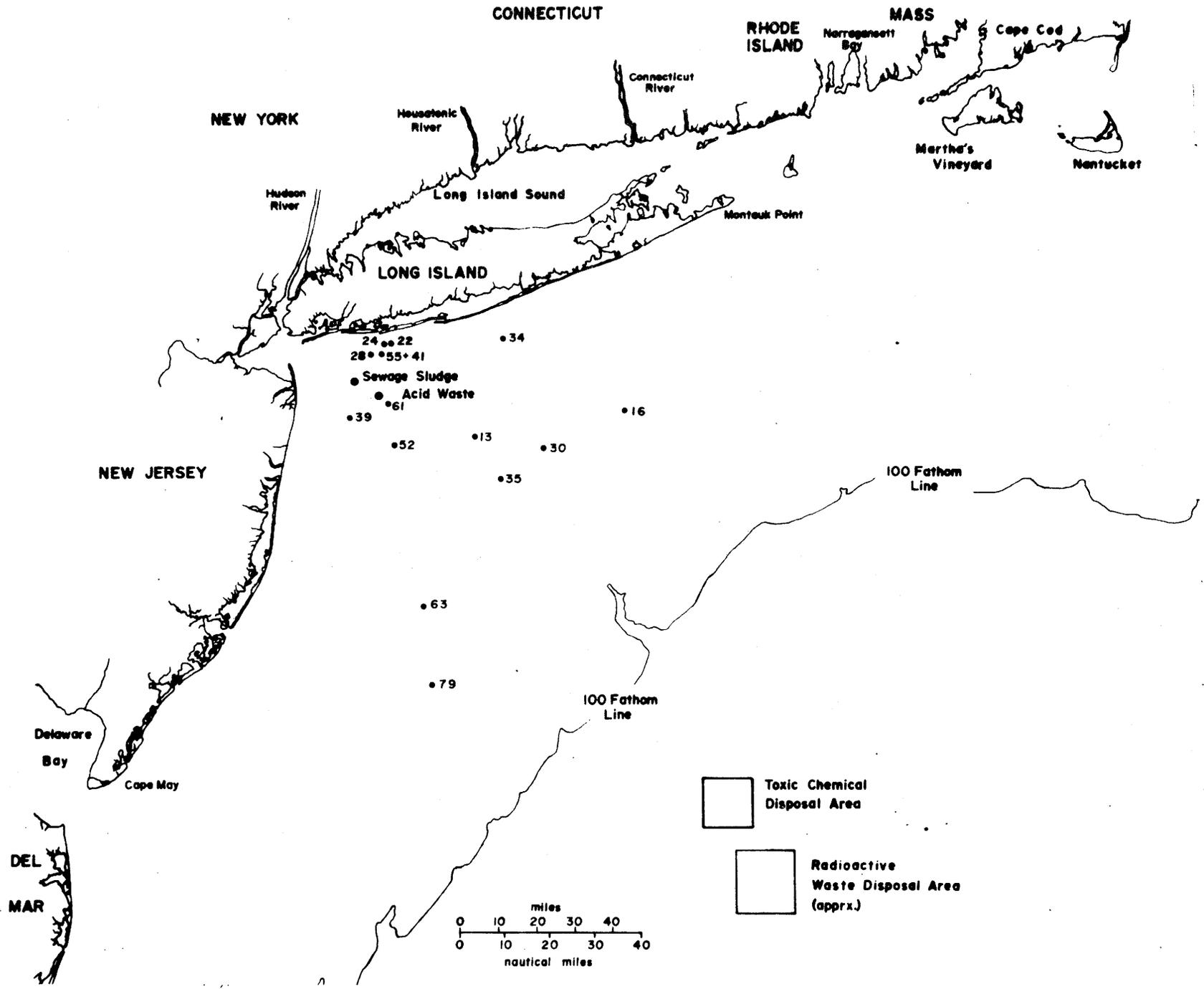
of the data came from the early embryo stage just after gastrulation and formation of the three primitive cell layers.

Abnormalities of the chromosomes extended through the entire range of radiomimetic effects on the chromosomes and their division apparatus, including; 1) extreme stickiness of chromosomes having obvious division difficulties and irregularities, 2) failure of chromosomes to orient on spindles, with consequent loss of chromosomes, and 3) chromosome breakage.

Cells with at least one chromosome or mitotic irregularity for the eggs at any one Westward station varied from a mean low of about 13% to a mean high of about 79%. Interestingly, this low of 13% is close to the frequency of abnormalities reported by Russian workers as background aberrations in the turbot and ruff in their experimental study, using a different scoring system and slightly earlier embryos still in gastrulation. Background mutation rate of fish is, of course, important in interpreting data. Waste disposal sites, station locations, and mean percent of early embryo cells with chromosome abnormalities are presented in Figure 28.

Two stations south of Long Island were among those with the lowest incidences of chromosome aberrations and mitotic irregularities. A third station halfway to Montauk Point had a slightly higher incidence.

Figure 28. The Mean Percent Early Embryo Cells of Atlantic Mackerel Eggs with Chromosome Abnormalities is Indicated Next to the Sample Site. Westward Cruise, May 1974.



A station about 5 miles southwest of the two coast stations in the direction of Sewage Sludge and Dump Sites had an incidence of abnormality only slightly higher than these two coast stations of low aberration rates. A second station, also about 5 miles closer to Sewage Sludge and Dump Sites, and about 5 miles away from this other, had a somewhat higher incidence of abnormality.

Eggs sampled near the Acid Waste Dump Site showed an appreciably higher incidence of abnormality, as did two stations a few miles to the south of the Acid Waste Dump Site.

Four stations, away from dumping sites and coast and about halfway to the edge of the continental shelf, showed relatively low aberration rates akin to those of the two Long Island stations.

Another outermost station, the furthest point from Sewage Sludge and Dump Sites and approximately 55 miles off the New Jersey shore, had the highest incidence of abnormalities. This station was closer (approximately 67 miles) to the Toxic Chemicals Disposal Area, where mostly liquid waste is dumped and to the Radioactive Waste Disposal Area than other samples. Another station in relatively close proximity to this one, about 45 miles off the New Jersey shore and 79 miles from the Toxic Chemicals Disposal Area, had the second highest incidence of abnormalities.

The station with the highest mean off the New Jersey coast was the only one with any significant observable mortality. On the basis of cell contrast and deterioration of the nuclei, 20 of 76 embryos (26%) were already dead. There was not yet any gross deterioration of the embryo or egg. Also, there were more instances of multiple chromosome abnormalities within mitosing cells of embryos from this station.

Winter movements of mackerel are not completely understood. There is a possibility that eggs sampled at the outermost stations came from fish that overwintered and underwent gametogenesis just off the continental shelf in the same general area where they spawned. Eggs studied from stations further north, inshore and along the Long Island coast were more likely to have been spawned by fish migrating north from overwintering areas further south.

Statistical analysis of the data was done using both the "t" test comparing each station in all combinations and Duncan's new multiple range test. The 0.05 level of significance was used. Results of the two tests agreed generally and revealed a similar pattern of statistically significant differences.

Stations in close proximity to each other did not differ significantly, nor did the day and night samples taken at one station. Stations with lowest means, such as the two Long Island shore stations and two of the four northern outermost stations

halfway to the edge of the continental shelf, showed few significant differences with one another. They did differ significantly from stations near the Sewage Sludge and Acid Waste Dump Sites and the southernmost peripheral stations with highest means. Stations with intermediate means, such as two of the four northern outermost stations and the one south of Long Island halfway to Montauk Point, differed in general only from stations with highest and lowest means. There were no significant differences among the four samples with highest mean aberration rates, that is, the samples from the two southernmost stations about 50 miles off the New Jersey coast, the one from near the Acid Waste Dump Site, and one of the two samples taken at the station southwest of the Long Island stations in the direction of the Sewage Sludge and Dump Sites.

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PATHOBIOLOGY INVESTIGATIONS

COMPARATIVE PATHOBIOLOGY - FISH PATHOBIOLOGY SUBTASK

R. A. Murchelano

Chronic Exposure of Winter Flounder, *Pseudopleuronectes americanus*, to Cadmium and Mercury

Materials and Methods

Histopathology

On two occasions during 1975, winter flounder, *Pseudopleuronectes americanus*, exposed to heavy metals were examined for histopathology. Excised pieces of liver, spleen, kidney, gill, intestine, and muscle (with attached epidermis) from winter flounder exposed to cadmium ($\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$) were examined in February and excised tissues from organs of fish exposed to mercury (HgCl_2) were examined in May. Both metals were administered at concentrations of 5 and 10 ppb for 60 days in flow-through aquaria. On both dates, the only fish examined were the controls and those exposed to 10 ppb cadmium and mercury. It was believed that histologic lesions would be more likely to occur in fish exposed to the highest concentration of the heavy metal. In February, 6 controls and 18 winter flounder exposed to 10 ppb cadmium were examined; in May, 6 controls and 17 winter flounder exposed to 10 ppb mercury were examined. All tissues were fixed in 10% seawater formalin, blocked in paraffin, sectioned at 6 μm and stained with hematoxylin and eosin.

Results

Cadmium

No histologic lesions attributable to heavy metal exposure were noted in the 18 winter flounder exposed to 10 ppb cadmium for 60 days. Tissues from 7 of the experimental fish were unremarkable, 5 other fish had vacuolated liver hepatocytes, and 3 others exhibited areas of focal necrosis in liver parenchyma. However, tissues from the 6 control fish exhibited similar histology to the exposed ones. Tissues from two control fish were unremarkable; one control fish exhibited vacuolar degeneration of kidney tubule epithelium. Miscellaneous observations in both exposed and control fish included protozoan and metazoan parasites in gills and intestine.

Mercury

No histologic lesions attributable to heavy metal exposure were noted in the 17 winter flounder exposed to 10 ppb mercury for 60 days. Tissues from two of the fish were unremarkable, nine fish had vacuolated liver hepatocytes, and seven fish exhibited areas of focal necrosis in liver parenchyma. Tissues from six control fish exhibited similar histology to the exposed fish. Miscellaneous observations included protozoan and metazoan parasites in gill and intestine, slight "clubbing," and epithelial hyperplasia of gill lamellae and mononuclear cell infiltration of muscle tissue.

Discussion

The presence of vacuolated liver hepatocytes and areas of focal necrosis in both experimental and control winter flounder lessens the possibility that these nonspecific conditions were induced by either cadmium or mercury. The vacuolated liver hepatocytes may reflect the nutritional status of the fish; the presence of focal areas of hepatic necrosis is not readily explained, especially when found in both control and experimental fish.

Other investigators have noted increased vacuolation of liver hepatocytes in fish experimentally exposed to pesticides; in their studies, however, control fish did not have markedly vacuolated liver parenchyma. Although trawled winter flounder demonstrate some degree of hepatocyte vacuolation, it is not as marked as that of captive, laboratory fish. Focal necrotic areas in the liver parenchyma can be observed as a consequence of exposure to hepatotoxins; in the present study, however, both controls and experimental fish demonstrated focal hepatic necrosis.

In the present study, under the experimental conditions used, histopathology could not be utilized to assess the effects of exposure to heavy metals. Although biochemical changes may occur at the low exposure concentrations used, histopathologic changes were not apparent. The probability of noting histopathologic changes in winter flounder exposed to heavy metals would be

favored by the use of younger fish (homeostatic mechanisms yet vulnerable), higher metal concentrations and longer exposure periods.

PATHOBIOLOGY INVESTIGATIONS

COMPARATIVE PATHOBIOLOGY - FISH PATHOBIOLOGY SUBTASK

M. Newman

Effects of Sublethal Exposure to Cadmium and Mercury Salts on Juvenile Striped Bass (*Morone saxatilis*)

Striped bass, *Morone saxatilis*, were exposed to mercury (HgCl_2) at concentrations of 1, 5, and 10 ppb for periods of 30, 60, 90, and 120 days, and 90 days followed by 30 days recovery in uncontaminated water.

In a similar experiment, striped bass were exposed to cadmium ($\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$) at concentrations of .5, 2.5, and 5.0 ppb for periods of 60 and 90 days, and 90 days followed by 30 days recovery in uncontaminated water.

After tissue was removed for physiological and biochemical studies, the remainder of the fish was fixed in 10% neutral-formalin. Tissues from the following groups were embedded in paraffin, sectioned, and examined for histopathology. Some frozen sections were also prepared for histochemical study of lesions.

<u>Cadmium</u>	<u>Mercury</u>
60 day controls	30 day controls
90 day controls	120 day controls
90 day 5 ppb	
90 day 5 ppb then 30 days uncontaminated	120 day 10 ppb
90 day 2.5 ppb	120 day 5 ppb
60 day 5 ppb	90 day 10 ppb

The only lesion seen which was attributable to exposure to heavy metals was a vacuolar degeneration of the proximal convoluted tubules of the kidney. The vacuoles appeared to be intercellular, at least in the early stages of their formation. More advanced cases appeared to be intracellular also.

These vacuoles did not stain with oil red O on frozen sections and were not PAS-positive on paraffin sections, indicating that they were not filled with lipid or glycogen. I, therefore, believe that they are probably fluid-filled and would call the lesion hydropic degeneration of the proximal tubular epithelium.

The lesions occurred in the following groups:

90 day 5 ppb cadmium (100%) diffuse
90 day 10 ppb mercury (40%) focal
120 day 10 ppb mercury (100%) diffuse

The lesions did not occur in the 90 day 5 ppb cadmium-exposed fishes that had been returned to uncontaminated water for 30 days prior to sacrifice, indicating that the nephropathy is reversible at this stage.

This accumulation of fluid in the kidney might profitably be studied at the ultrastructural and biochemical levels. It would also be of interest to continue the exposures for an additional 60-90 days to observe the progression of these lesions which I believe must ultimately affect the well being of the fish.

Heart and liver were not available for histological examination as these tissues had been removed for enzyme determinations.

PATHOBIOLOGY INVESTIGATIONS

DISEASE AND ENVIRONMENTAL STRESS - IMMUNITY IN MARINE FISH SUBTASK

R. A. Robohm

The Interaction of Temperature with Cadmium Uptake and Antibody Response in a Teleost

In previous work, I have shown that cadmium exposure suppresses antibody production and bacterial clearance in a teleost; however, the possible effects of temperature would be very useful in designing future experiments and may be of value to other investigators of fish physiology: 1) Can lowered temperature reduce the uptake of cadmium into fish tissues? 2) How significant is a lowered temperature in altering antibody production in both cadmium-exposed and non-exposed fish? The following experiment is a modest effort at getting answers to the foregoing questions.

Cunners (Tautogolabrus adspersus) which had been held in 5°C flowing seawater for two months were transferred to static, aerated 16 gallon glass aquaria maintained at 2°C in a walk-in refrigerator. An equal number of fish which had been held for two months at about 14°C were transferred to an aquarium maintained at 16°C. Half the fish at each temperature were exposed to 12 ppm cadmium (as $\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$); the other half served as no-cadmium controls.

At the end of a 96-hour exposure period, the fish were inoculated intraperitoneally with 1×10^8 formalinized Bacillus cereus cells in Freund's complete adjuvant. The 16°C cadmium-exposed fish were placed in flowing seawater at a mean temperature of $16 \pm 3^\circ\text{C}$, and the 2°C cadmium-exposed fish were placed in flowing seawater at 5°C which, within two weeks, rose to a mean temperature of $8 \pm 2^\circ\text{C}$.

Fish were bled after 4 and 6-week holding times and the serum assayed for antibody against Bacillus cereus using tube agglutination reactions in micro-titer wells. Livers from the fish bled at 6 weeks were removed and assayed for cadmium content by atomic absorption spectrometry (courtesy of the Environmental Chemistry group at Milford).

Figure 29 shows at 4 weeks that temperature has a pronounced effect on antibody production. A reciprocal geometric mean titer of 39 at 16°C is reduced to 19 at 8°C . The effect of 12 ppm cadmium treatment is even more pronounced than the aforementioned 8°C decline in temperature (the antibody level in cadmium-treated, 16°C fish is below that of non-cadmium fish held at 8°C). A further reduction in antibody titer is seen in fish treated with cadmium and held at 8°C . Figure 29 shows that this combination of cadmium treatment and lowered temperature results in a barely discernible antibody response. By 6 weeks the antibody titers have diminished (a natural catabolic phenomenon in both fish and mammals) so that differences between treatments are not identifiable in all except the 16°C , no-cadmium fish.

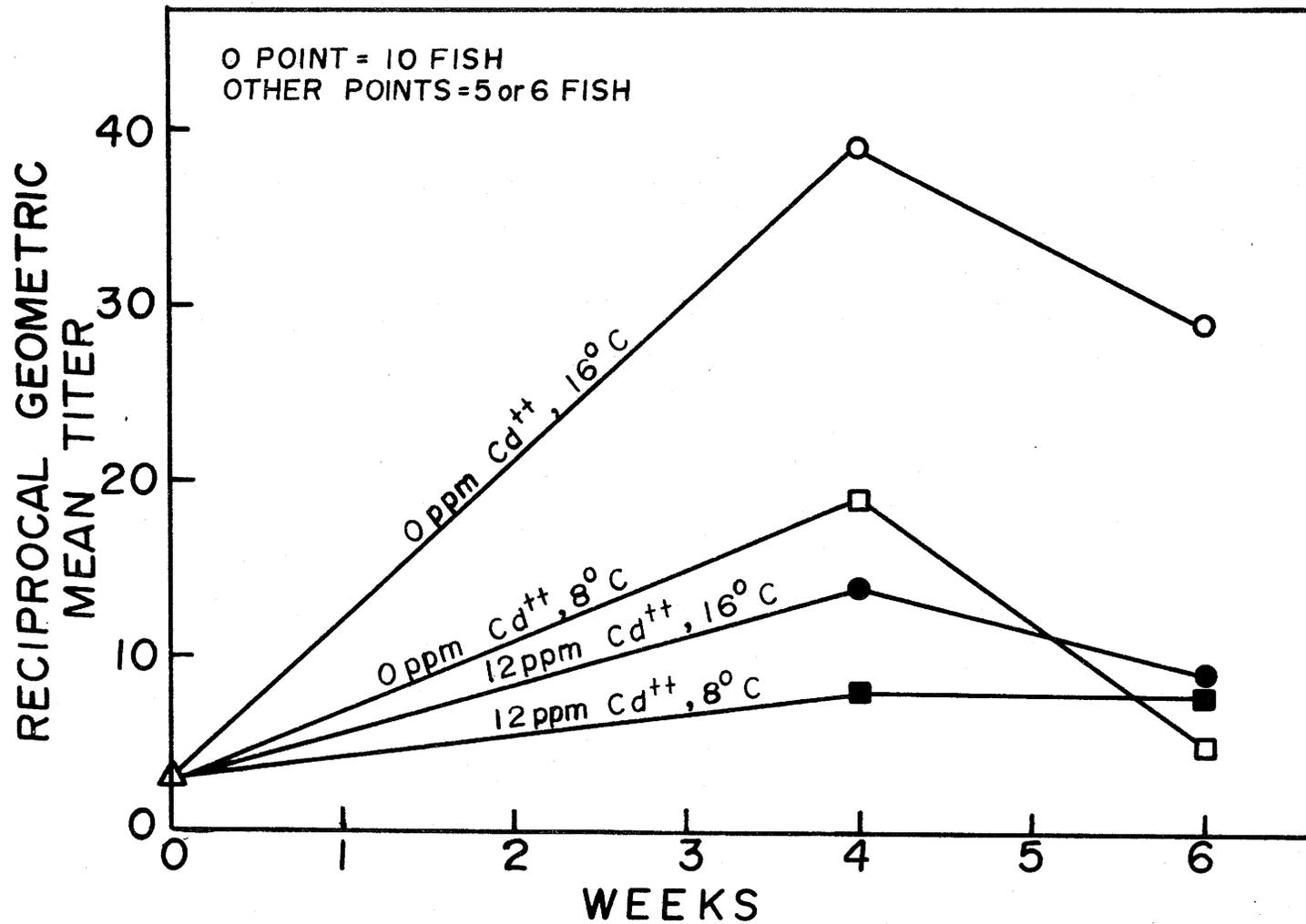


Figure 29. Interactive Effects of Holding-Temperature and 96-hour Cadmium Treatment on Antibody Response to Bacillus cereus in Cunnors (Tautogolabrus adspersus)

Table 46 shows that at 2°C the uptake of cadmium was significantly reduced from that in fish exposed at 16°C. Six weeks after exposure, the liver cadmium levels in fish exposed at 2°C were only $\frac{1}{4}$ of those exposed at 16°C. The actual uptake differences may have been even greater initially since cadmium catabolism and excretion over a 6-week holding period would be expected to be greater at the warmer temperature.

The data suggest an additional experiment, which was not run, but would be of interest; namely, the exposure of fish to 12 ppm cadmium at 2°C followed by immunization and a holding temperature of 16°C. Presumably, this would cause suppression of antibody production of about the same degree as exposure to 3 ppm cadmium at 16°C ($\frac{1}{4}$ the 12 ppm level).

The foregoing data clearly show that both the uptake of cadmium and antibacterial antibody production are dependent upon temperature. It points to the need for careful temperature control, or for an accurate statement of temperature levels in all heavy-metal exposure studies. It also suggests that heavy-metal uptake in fish in polluted environments may be diminished during the cold, winter months and accelerated during the warm, summer months. The suppression of antibody production at colder temperatures should not be detrimental to the health of the animal, since the rate of growth of disease-producing bacteria is also suppressed at colder temperatures.

Table 46. Liver Cadmium Levels in Cunnners 6 Weeks After Termination of Cadmium Exposure.

Temperature during cadmium exposure	Mean ^(a) ppm cadmium (\pm SEM) for fish exposed to the following cadmium levels:	
	12 ppm	0 ppm
2°C ^(b)	15.3 \pm 3.0	< 2.1
16°C ^(c)	62.2 \pm 1.8	< 1.9
Significance ^(d)	0.05	> .5

(a) Each value is the mean from five fish analyzed separately by atomic absorption spectrometry.

(b) Fish were exposed to cadmium for 96 hours at 2°C, then immunized and held in flowing seawater at $6 \pm 1^\circ\text{C}$ for 2 weeks followed by $8 \pm 2^\circ\text{C}$ for 4 weeks.

(c) Fish were exposed to cadmium for 96 hours at 16°C, then immunized and held in flowing seawater at $16 \pm 3^\circ\text{C}$ for 6 weeks.

(d) Significance levels based upon the Student's "t" test.

Antibacterial Antibody Response in a Teleost
Following Short-Term, High-Dose Cadmium Exposure

In last year's Multilaboratory Cooperative Study of Contaminants (MACFC Informal Report No. 73), I showed data indicating that cunners (Tautogolabrus adspersus) exposed for 96 hours to 12 ppm cadmium have a depressed antibody response to injections of bacteria. However, because of variations in antibody titers, the quantity of fish used was not enough to show a statistically significant antibody suppression. Sufficient data has now been obtained to show statistical significance.

Fish were held at 14°C to 17°C, exposed to 12 ppm cadmium for 96 hours, and injected intraperitoneally with 5-10 x 10⁷ formalinized, washed Bacillus cereus cells in Freund's complete adjuvant. Fish were further held in 16°C flowing seawater for 5-6 weeks to allow rise of serum antibody. Bacterial agglutination titers are shown in Figure 30. Analysis of data by two-tailed Student's "t" test shows that antibody levels in immunized, cadmium-treated fish are significantly lower (P= .007) than levels in immunized, no-cadmium fish. The data suggests that exposure to this level of cadmium causes interference with antigen processing or with protein synthesis in antibody-producing cells.

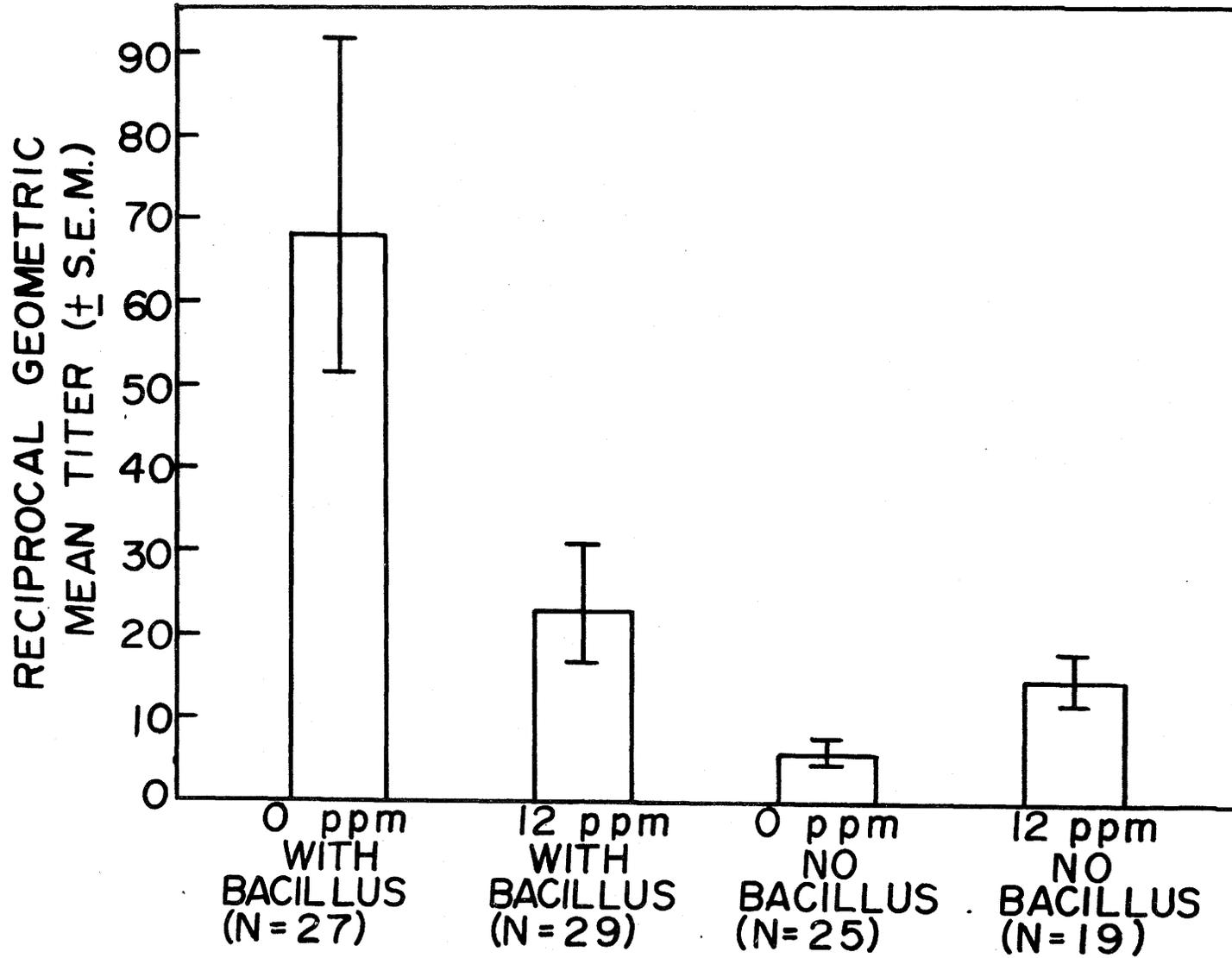


Figure 30. Effect of 96-hour Cadmium Treatment on Antibody Response to Bacillus cereus in Cunnors (Tautogolabrus adspersus) Held at 16 ± 2 C for 5-6 Weeks.