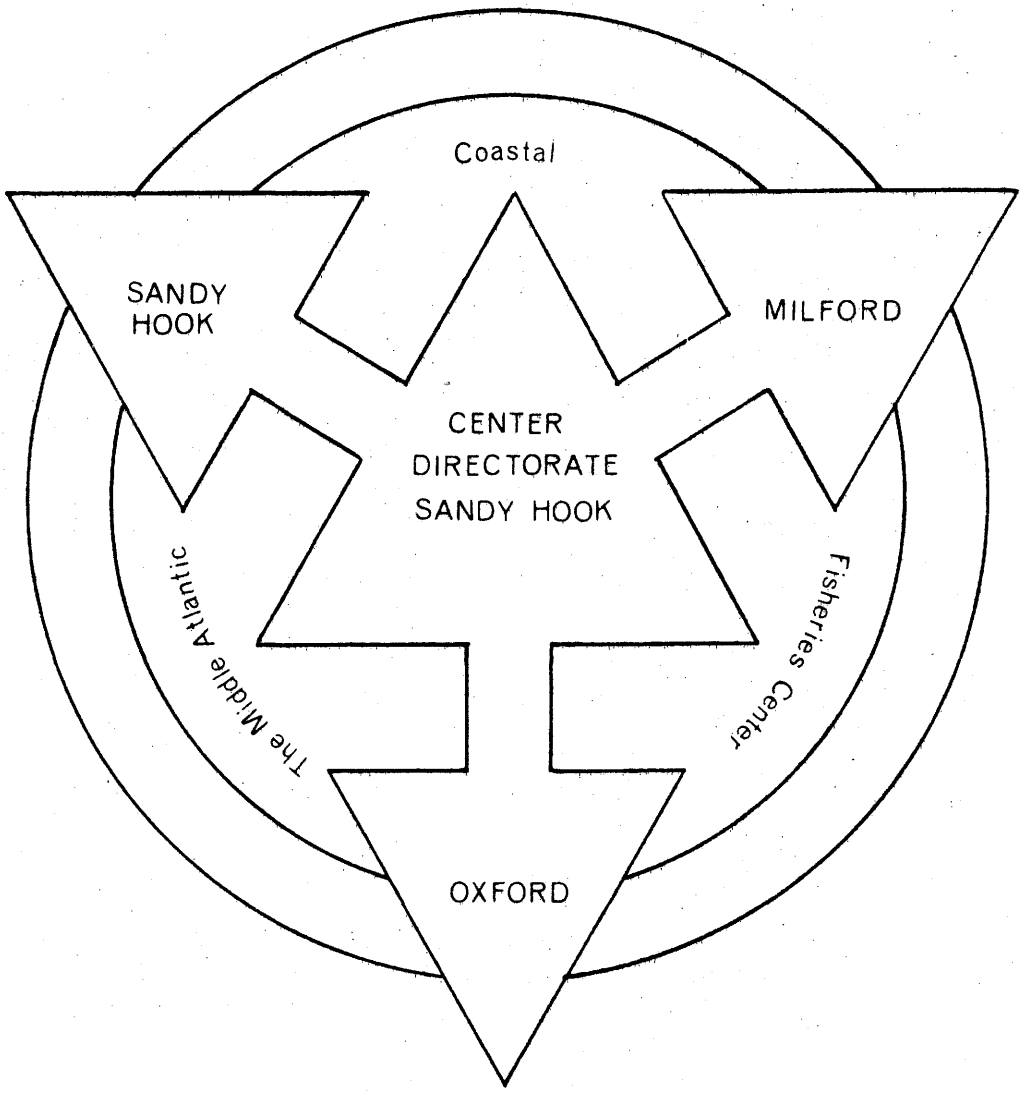
# A MULTILABORATORY COOPERATIVE STUDY OF CONTAMINANTS IN THE COASTAL ENVIRONMENT AND THEIR EFFECTS ON LIVING MARINE RESOURCES: SUMMARY REPORT OF OPERATIONS FROM MAY 1, 1972 TO DECEMBER 31, 1973

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

MIDDLE ATLANTIC COASTAL FISHERIES CENTER




Informal Report No. 26

MIDDLE ATLANTIC COASTAL FISHERIES
CENTER

NOAA--NMFS

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

SUMMARY REPORT OF OPERATIONS FROM

MAY 1, 1972 to DECEMBER 31, 1973

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TABLE OF CONTENTS

LIST OF TABLES . . . . . iii

LIST OF ILLUSTRATIONS . . . . . vi

INTRODUCTION . . . . . 1

ECOSYSTEMS INVESTIGATIONS . . . . . 3

Biological Oceanography and Preliminary MESA Sampling . 3
Biochemical Modeling . . . . . 23
Coastal Ecosystems . . . . . 27

Environmental Microbiology and Chemistry . . . . . 40
Mercury Concentrations of Finfish From North Atlantic Offshore Waters . . . . . 40
Trace Metal Concentrations in Fish and Shellfish From Inshore Waters of the Middle Atlantic Bight . . . . . 57
Trace Metal Concentrations in Sediments From Long Island Sound . . . . . 81
Distribution of Coliforms in Sediments From Long Island Sound . . . . . 85
Effects of Contaminants on Bacterial Clearance . . . 91

Publications . . . . . 96

EXPERIMENTAL BIOLOGY INVESTIGATIONS . . . . . 98

Rearing Marine Organisms . . . . . 98
Physiological Effects of Pollutant Stress - Physioecology . . . . . 110
Development of Exposure Laboratory . . . . . 110
Experimental Studies . . . . . 112

Physiological Effects of Pollutant Stress - Physiology. 121
Physiological Effects of Pollutant Stress - Biochemistry . . . . . 137
Mutagenic Effects of Pollutants . . . . . 140
Effects of Contaminants on Algae . . . . . 144
Water Quality . . . . . 151
Ozonized Water Treatment System . . . . . 151
Waste Water Treatment System . . . . . 154

Publications . . . . . 158

TABLE OF CONTENTS
(continued)

PATHOBIOLOGY INVESTIGATIONS . . . . . 162

Marine Contaminants . . . . . 162

REPORT ON COLLABORATIVE CUNNER STUDY . . . . . 165

APPENDIX I
Cruise Report - 29 July-6 August 1973 . . . . . 176

APPENDIX II
Cruise Report - 19-26 October 1973 . . . . . 187

APPENDIX III
Cruise Report - 22 January-5 February 1974 . . . . . 194

LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1. | Trace metal concentrations in sediments from the New York Bight and Hudson Canyon area . . . . . | 4 |
| 2. | Trace metal concentrations in sediments from the New York Bight and Hudson Canyon area . . . . . | 9 |
| 3. | Reconnaissance stations sampled in the New York Bight | 14 |
| 4. | Sample stations repeated in 1973 . . . . . | 15 |
| 5. | Heavy metal values for 20 replicate grab samples collected at Stations III and X-3 . . . . . | 16 |
| 6. | Heavy metal values for 20 replicate grab samples collected at Stations 49 and 29 . . . . . | 18 |
| 7. | Metal concentrations in water Mgons/L . . . . . | 25 |
| 8. | Enzyme activity in moles $PO_4 \cdot hr^{-1} - gm^{-1}$ . . . . . | 26 |
| 9. | Heavy metal concentrations in Raritan Bay . . . . . | 33 |
| 10. | Composition of Raritan Bay "sand" community . . . . . | 37 |
| 11. | Composition of Raritan Bay "mud" community . . . . . | 38 |
| 12. | Mercury concentrations in tissues and organs of cusk and blackbellied redfish from North Atlantic offshore waters . . . . . | 45 |
| 13. | Mercury concentrations in tissues and organs of spiny dogfish from Georges Bank and the Gulf of Maine . . . | 47 |
| 14. | Mercury concentrations in tissues and organs of spiny dogfish from Cape Cod Bay, the New York Bight and Nantucket Shoals . . . . . | 49 |
| 15. | Average mercury concentrations in muscle for various length groups of spiny dogfish . . . . . | 51 |
| 16. | Comparison of difference in mercury concentrations for spiny dogfish muscle as a function of geographic area of catch . . . . . | 52 |

LIST OF TABLES

(continued)


| Table | | Page |
|---|---|---|
| 17. | Mercury concentrations in spiny dogfish muscle collected from North Atlantic offshore waters . . . . | 55 |
| 18. | Latitude and longitude information for the geographic areas of biota collections listed in Tables 19-21 . . | 65 |
| 19. | Metal concentrations in flesh and digestive glands of rock crab from inshore areas of the Mid-Atlantic Bight | 66 |
| 20. | Metal concentrations in flesh and livers of windowpane flounder from inshore areas of the Mid-Atlantic Bight. | 67 |
| 21. | Metal concentrations in muscle of surf clam and muscle and digestive glands of channeled whelk from inshore areas of the Mid-Atlantic Bight . . . . . | 75 |
| 22. | Metal concentrations in muscle of surf clam from additional areas of the Mid-Atlantic Bight . . . . . | 78 |
| 23. | Metal concentrations in sediments collected from Long Island Sound . . . . . | 82 |
| 24. | Ranges of fecal coliforms found in Long Island Sound . | 88 |
| 25. | Serum hemagglutination titers of fish immunized by intraperitoneal injection of SRBC at the time of 96-hr cadmium exposure . . . . . | 94 |
| 26. | Toxicity of heavy metals, as inorganic salts, to hard clam embryos in synthetic seawater . . . . . | 115 |
| 27. | Toxicity of heavy metals, as inorganic salts, to oyster and hard clam embryos in synthetic seawater . . | 117 |
| 28. | The condition and mean oxygen consumption rates of the mud snail after 72 hr exposure to heavy metals . . . . | 123 |
| 29. | Comparison of mean oxygen consumption rates of the mud snail exposed to copper and cadmium individually and in combination . . . . . | 124 |

LIST OF TABLES

(continued)

Table Page

30. Uptake of silver by bivalves into body and gill tissue after a 96-hr exposure to silver . . . . . 136

31. Effects of three species of marine bacteria on algal growth . . . . . 146

32. The effect on growth of marine phytoplankton of substituting different percentages of cesium for sodium in an artificial seawater medium . . . . . 149

33. The effect on growth of marine phytoplankton of substituting lithium or rubidium for sodium in an artificial seawater medium . . . . . 150

LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1. | Grid of stations from MESA biological sampling in the apex of the New York Bight . . . . . | 12 |
| 2. | Stations for MESA sampling in the apex of the New York Bight . . . . . | 22 |
| 3. | Long Island Sound sampling stations . . . . . | 28 |
| 4. | Raritan Bay geography, station locations and sediment distribution . . . . . | 31 |
| 5. | Distribution of fecal coliforms in Long Island Sound . | 89 |
| 6. | Bacterial clearance from the blood, liver and spleen of cunners . . . . . | 93 |
| 7. | Valvular membrane of recently metamorphosed surf clam. | 104 |
| 8. | Collecting chamber for larval gastropods . . . . . | 107 |
| 9. | Flowing seawater culture system for larval gastropods. | 108 |
| 10. | Oxygen uptake of the mud crab exposed to cadmium . . . | 120 |
| 11. | Oxygen consumption rates of American oyster larvae vs size . . . . . | 127 |
| 12. | *Crassostrea virginica*. Effects of silver on oxygen consumption . . . . . | 130 |
| 13. | *Mercenaria mercenaria*. Effects of silver on oxygen consumption . . . . . | 132 |
| 14. | *Mytilus edulis*. Effects of silver on oxygen consumption . . . . . | 133 |
| 15. | *Mya arenaria*. Effects of silver on oxygen consumption | 134 |
| 16. | Sketch of completed seawater ozone treatment system for improving water quality at the Milford Laboratory. | 153 |
| 17. | Sketch of waste treatment plant for the chronic exposure laboratory at Milford . . . . . | 156 |

NOTE:

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

# INTRODUCTION

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

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

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

This report describes the efforts of the MACFC contaminant study from May 1972 through December 1973; for previous information refer to Informal Report No. 5 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." The cooperating laboratories and their area of specific

responsibility and more general interest are listed below:

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

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

Sandy Hook (Ecosystems Investigations):
Major responsibility for ecological studies of waste disposal areas along the New York and New Jersey shore.

Milford (Experimental Biology Investigations):
Responsibility for laboratory experiments to determine the physiological stress caused by contaminants on selected marine species.

ECOSYSTEMS INVESTIGATIONS

BIOLOGICAL OCEANOGRAPHY AND PRELIMINARY MESA SAMPLING

J. Pearce and J. Thomas

The Marine Contaminants Program of the Middle Atlantic Coastal Fisheries Center is an extension of the New York Bight waste disposal site studies begun in 1968 at the Sandy Hook Laboratory under a contract from the U. S. Army Corps of Engineers. As a result, some data which were used in the Army Corps report were collected under the Marine Contaminants Program, and, likewise, much of the base data from the New York Bight site were collected before the MACFC Marine Contaminants Program existed. It is felt, therefore, that the Army Corps report should be considered as a preliminary ecological study.

The Sandy Hook Laboratory conducted three cruises to the study area between April 1972 and June 1972 and prior to the inception of the MESA Program.

The following is a synopsis of these cruises:

1. D-72-9 - R/V Delaware II 4-7 April 72. We took Smith-McIntyre bottom grabs at 21 stations in the New York Bight and Hudson Canyon area. Paired heavy metal cores were taken from each grab. The results are presented in Table 1. Fish were obtained by otter trawl at 13 stations. Wherever possible, liver and muscle samples were frozen for heavy metal analysis of windowpane, winter and yellowtail flounders and red hake. Lobsters and cancer crabs were also saved for heavy metal analyses.

Table 1. Trace Metal Concentrations in Sediments from the New York Bight and Hudson Canyon Area

| Field | | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| D-72-9-400 | | <1.0 | < 2.0 | < 2.0 | 9.8 | < 2.0 | < 4.0 | 3.6 |
| | | <1.0 | < 2.0 | < 2.0 | 10.6 | 2.0 | < 6.0 | 3.8 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 10.2 | < 2.0 | < 5.0 | 3.7 |
| D-72-9-401 (2) | | <1.0 | < 2.0 | < 2.0 | 9.0 | < 2.0 | 4.8 | 2.6 |
| | | <1.0 | < 2.0 | < 2.0 | 10.2 | < 2.0 | < 6.0 | 3.0 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 9.6 | < 2.0 | < 5.4 | 2.8 |
| D-72-9-402 (1) | | <1.0 | < 2.0 | < 2.0 | 10.8 | < 2.0 | < 4.0 | 3.2 |
| | | <1.0 | < 2.0 | < 2.0 | 11.4 | 2.6 | < 6.0 | 3.2 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 11.1 | < 2.3 | < 5.0 | 3.2 |
| D-72-9-403 (2) | | <1.0 | < 2.0 | < 2.0 | 8.0 | < 2.0 | < 4.0 | 2.0 |
| | | <1.0 | < 2.0 | < 2.0 | 8.4 | < 2.0 | < 6.0 | 2.2 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 8.2 | < 2.0 | < 5.0 | 2.1 |
| D-72-9-404 (2) | | <1.0 | < 2.0 | < 2.0 | 20.4 | < 2.0 | < 4.0 | 2.8 |
| | | <1.0 | < 2.0 | < 2.0 | 25.0 | < 2.0 | < 6.0 | 3.0 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 22.7 | < 2.0 | < 5.0 | 2.9 |
| D-72-9-405 | | <1.0 | < 2.0 | < 2.0 | 7.6 | 2.0 | < 4.0 | 5.4 |
| | | <1.0 | < 2.0 | < 2.0 | 8.4 | < 2.0 | < 6.0 | 5.4 |
| | Avg. | <1.0 | < 2.0 | < 2.0 | 8.0 | < 2.0 | < 5.0 | 5.4 |

Table 1. (cont.) - 2 -

| Field | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| D-72-9-406 (2) | < 1.0 | < 2.0 | 2.0 | 14.8 | < 2.0 | < 4.0 | 5.0 |
| | < 1.0 | < 2.0 | < 2.0 | 18.6 | < 2.0 | < 6.0 | 4.8 |
| Avg. | < 1.0 | < 2.0 | < 2.0 | 16.7 | < 2.0 | < 5.0 | 4.9 |
| D-72-9-407 (1) | < 1.0 | < 2.0 | < 2.0 | 9.6 | 2.0 | 5.6 | 3.2 |
| | < 1.0 | < 2.0 | < 2.0 | 9.6 | < 2.0 | < 6.0 | 3.0 |
| Avg. | < 1.0 | < 2.0 | < 2.0 | 9.6 | < 2.0 | < 5.8 | 3.1 |
| D-72-9-408 (2) | < 1.0 | < 2.0 | < 2.0 | 11.6 | < 2.0 | 4.0 | 3.4 |
| | < 1.0 | < 2.0 | < 2.0 | 14.4 | < 2.0 | < 6.0 | 3.6 |
| | < 1.0 | < 2.0 | < 2.0 | 13.4 | < 2.0 | < 6.0 | 3.8 |
| Avg. | < 1.0 | < 2.0 | < 2.0 | 13.1 | < 2.0 | < 5.3 | 3.6 |
| D-72-9-409 (2) | < 1.0 | < 2.0 | < 2.0 | 9.6 | < 2.0 | 4.0 | 2.4 |
| | < 1.0 | < 2.0 | < 2.0 | 12.0 | < 2.0 | 6.0 | 2.6 |
| Avg. | < 1.0 | < 2.0 | < 2.0 | 10.8 | < 2.0 | 5.0 | 2.5 |
| D-72-9-410 | 1.0 | 2.2 | < 2.0 | 29.8 | 2.0 | 6.8 | 7.6 |
| | < 1.0 | 2.0 | < 2.0 | 34.2 | 2.0 | 6.0 | 8.6 |
| Avg. | < 1.0 | 2.1 | < 2.0 | 32.0 | 2.0 | 6.4 | 8.1 |
| D-72-9-411 (1) | < 1.0 | < 2.0 | < 2.0 | 16.8 | < 2.0 | 8.4 | 4.6 |
| | < 1.0 | < 2.0 | < 2.0 | 20.4 | < 2.0 | < 6.0 | 4.8 |
| Avg. | < 1.0 | < 2.0 | < 2.0 | 18.5 | < 2.0 | < 7.2 | 4.7 |

Table 1. (cont.) - 3 -

| Field | | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| D-72-9-412 | | < 1.0 | < 2.0 | < 2.0 | 18.6 | < 2.0 | < 4.0 | 4.2 |
| | | < 1.0 | < 2.0 | < 2.0 | 19.4 | < 2.0 | < 6.0 | 3.6 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 19.0 | < 2.0 | < 5.0 | 3.9 |
| D-72-9-413 | | < 1.0 | < 2.0 | < 3.0 | 23.8 | 3.0 | < 4.0 | 4.0 |
| | | < 1.0 | < 2.0 | < 2.0 | 30.4 | < 2.0 | < 6.0 | 4.0 |
| | Avg. | < 1.0 | < 2.0 | < 2.5 | 27.1 | < 2.5 | < 5.0 | 4.0 |
| D-72-9-414 (1) | | < 1.0 | < 2.0 | < 2.0 | 11.6 | < 2.0 | < 5.2 | 3.4 |
| | | < 1.0 | < 2.0 | < 2.0 | 15.4 | < 2.0 | < 6.0 | 4.2 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 13.5 | < 2.0 | < 5.6 | 3.8 |
| D-72-9-415 | | < 1.0 | 2.0 | 2.0 | 16.8 | 2.8 | < 4.0 | 5.0 |
| | | < 1.0 | < 2.0 | < 2.0 | 22.8 | 2.0 | < 6.0 | 5.4 |
| | Avg. | < 1.0 | < 2.0 | < 2 0 | 19.8 | 2.4 | < 5.0 | 5.2 |
| D-72-9-417 | | < 1.0 | < 2.0 | < 2.0 | 33.2 | < 2.0 | 5.6 | 5.8 |
| | | < 1.0 | < 2.0 | < 2.0 | 43.2 | 2.0 | < 6.0 | 6.6 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 38.2 | < 2.0 | < 5.7 | 6.2 |
| D-72-9-418 | | < 1.0 | < 2.0 | < 2.0 | 15.6 | < 2.0 | < 4.0 | 4.6 |
| | | < 1.0 | < 2.0 | < 2.0 | 19.0 | < 2.0 | < 6.0 | 4.6 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 17.3 | < 2.0 | < 5.0 | 4.6 |

Table 1. (cont.) - 4 -

| Field | | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| D-72-9-419 (1) | | < 1.0 | < 2.0 | < 2.0 | 52.2 | < 2.0 | < 4.0 | 5.4 |
| | | < 1.0 | < 2.0 | < 2.0 | 64.6 | < 2.0 | 6.0 | 7.0 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 58.4 | < 2.0 | < 5.0 | 6.2 |
| D-72-9-420 | | < 1.0 | < 2.0 | < 2.0 | 11.0 | < 2.0 | 7.2 | 3.6 |
| | | < 1.0 | < 2.0 | < 2.0 | 13.8 | < 2.0 | < 6.0 | 4.4 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 12.4 | < 2.0 | < 6.6 | 4.0 |
| D-72-9-421 #1 | | < 1.0 | < 2.0 | < 2.0 | 10.8 | < 2.0 | 5.6 | 3.4 |
| | | < 1.0 | < 2.0 | < 2.0 | 12.6 | < 2.0 | < 6.0 | 3.8 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 11.7 | < 2.0 | < 5.8 | 3.6 |
| D-72-9-422 | | < 1.0 | < 2.0 | < 2.0 | 19.6 | 2.2 | < 6.0 | 4.6 |
| D-72-9-423 | | < 1.0 | < 2.0 | < 2.0 | 27.6 | < 2.0 | < 6.0 | 5.4 |
| | | < 1.0 | < 2.0 | < 2.0 | 27.4 | < 2.0 | < 6.0 | 5.4 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 27.5 | < 2.0 | < 6.0 | 5.4 |
| D-72-9-424 (1) | | < 1.0 | < 2.0 | < 2.0 | 69.2 | < 2.0 | < 6.0 | 6.6 |
| | | < 1.0 | < 2.0 | < 2.0 | 78.4 | < 2.0 | < 6.0 | 7.2 |
| | Avg. | < 1.0 | < 2.0 | < 2.0 | 73.8 | < 2.0 | < 6.0 | 6.9 |

2. D-72-13 - R/V Delaware II 1-5 May 72. Twenty-three stations were occupied in the same area as D-72-9. Liver and muscle samples were again taken for heavy metals.

3. D-72-16 - R/V Delaware II 30 May-1 June 72. Twenty-three stations were occupied in the Hudson Canyon area and in the New York Bight. Smith-McIntyre bottom grabs were taken at 21 stations. Paired cores from these were sent to Milford for heavy metal determinations. The results are given in Table 2.

Two other heavy metal sampling procedures were employed on this cruise. Yellowtail, winter and windowpane flounders and red hake were taken from the otter trawl collections for liver and muscle tissues. Also a #0 mesh malacostracan net was used on the chain line of the otter trawl. These samples were frozen to determine the heavy metal levels in the food source of bottom feeding animals.

Table 2. Trace Metal Concentrations in Sediments from the New York Bight and Hudson Canyon

May 30 - June 1, 1972 (ppm dry wt., avg. value)

| Station | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| D-72-16-1 | < 1.0 | < 2.0 | < 2.0 | 10.7 | 2.6 | < 6.0 | 1.8 |
| D-72-16-2 | < 1.0 | < 2.0 | < 2.0 | 18.2 | 8.2 | < 6.0 | 2.9 |
| D-72-16-3 | < 1.0 | < 2.0 | < 2.0 | 12.4 | 4.4 | < 6.0 | 2.5 |
| D-72-16-5 | < 1.0 | 2.0 | < 2.0 | 21.3 | 7.1 | < 6.0 | 3.1 |
| D-72-16-6 | < 1.0 | < 2.4 | < 2.0 | 88.0 | 3.4 | 10.0 | 7.5 |
| D-72-16-8 | < 1.0 | 2.6 | 2.1 | 40.7 | 10.4 | 9.0 | 6.7 |
| D-72-16-9 | < 1.0 | 8.0 | 4.4 | 127.0 | 10.6 | 12.0 | 15.8 |
| D-72-16-10 | < 1.0 | 4.0 | 3.3 | 88.0 | 10.4 | 12.0 | 13.0 |
| D-72-16-11 | < 1.0 | 6.3 | 6.0 | 41.9 | 9.7 | 14.0 | 20.3 |
| D-72-16-12 | < 1.0 | < 2.0 | < 2.0 | 49.4 | 3.2 | 6.0 | 4.8 |
| D-72-16-13 | < 1.0 | 4.5 | 3.1 | 58.0 | 6.0 | 14.0 | 9.6 |
| D-72-16-14 | < 1.0 | 2.8 | < 2.0 | 83.0 | 5.2 | < 6.0 | 7.2 |
| D-72-16-15 | < 1.0 | 2.4 | < 2.0 | 120.0 | 4.6 | < 6.0 | 10.6 |
| D-72-16-16 | < 1.0 | 26.4 | 23.7 | 52.0 | 12.9 | 46.0 | 68.0 |
| D-72-16-17 | < 1.0 | < 2.4 | < 2.0 | 11.0 | 6.0 | < 6.0 | 2.7 |

Table 2 (cont.) - 2 -

| Station | Cd | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| D-72-16-18 | < 1.0 | 4.0 | 2.4 | 19.2 | 5.7 | < 6.0 | 11.5 |
| *D-72-16-19 | 3.6 | 148.0 | 142.0 | 158.0 | 30.0 | 180.0 | 250.0 |
| D-72-16-20 | < 1.0 | 5.7 | 4.2 | 21.5 | 7.5 | 18.0 | 18.6 |
| **D-72-16-21 | 10.5 | 138.0 | 229.0 | 41.6 | 26.6 | 259.0 | 380.0 |
| D-72-16-22 | 1.4 | 33.6 | 33.9 | 70.0 | 10.5 | 45.0 | 76.0 |
| D-72-16-23 | < 1.0 | 26.7 | 34.3 | 79.0 | 13.8 | 42.0 | 60.0 |

* Log sheet notes C.R.A.P. in sample.

** Station 59 - Log sheet notes barges dumping off bow.

## MESA New York Bight Research

The Marine Ecosystem Analysis Program (MESA) in the New York Bight is a large, multi-disciplinary program involving physical, chemical, geological and biological investigations. The first phase of the program is concentrated in the apex of the Bight, an area inside intersecting lines of latitude and longitude (40°10'N, 73°35'W). The purpose of the program is to provide the necessary information that is, and will be, required by environmental managers who must regulate the various activities that are, and will be, occurring in the Bight. The Biological Program for MESA is described in detail in MACFC Informal Report No. 13.

The standard grid of sampling stations in the apex of the Bight is presented as Figure 1.

## MESA Biological Reconnaissance Cruises in the Apex of the New York Bight

A series of cruises on the R/V Rorqual and R/V Atlantic Twin were undertaken between March 20 and June 18, 1973 for the purpose of obtaining replicate samples (up to 20 per station) for statistical analyses to determine the within and between station variance for the purpose of determining the placement and number of samples to be taken under the MESA program in the apex of the New York Bight.

Sampling was accomplished using a Smith-McIntyre grab. Three cores were removed from each grab sample. Two of the cores were taken with 38 mm (1.5 inch) diameter plastic core liners. These cores were stored frozen for analyses for heavy metals and the mechanical properties of sediment. Thr third core was taken with a 25 mm (1.0 inch)

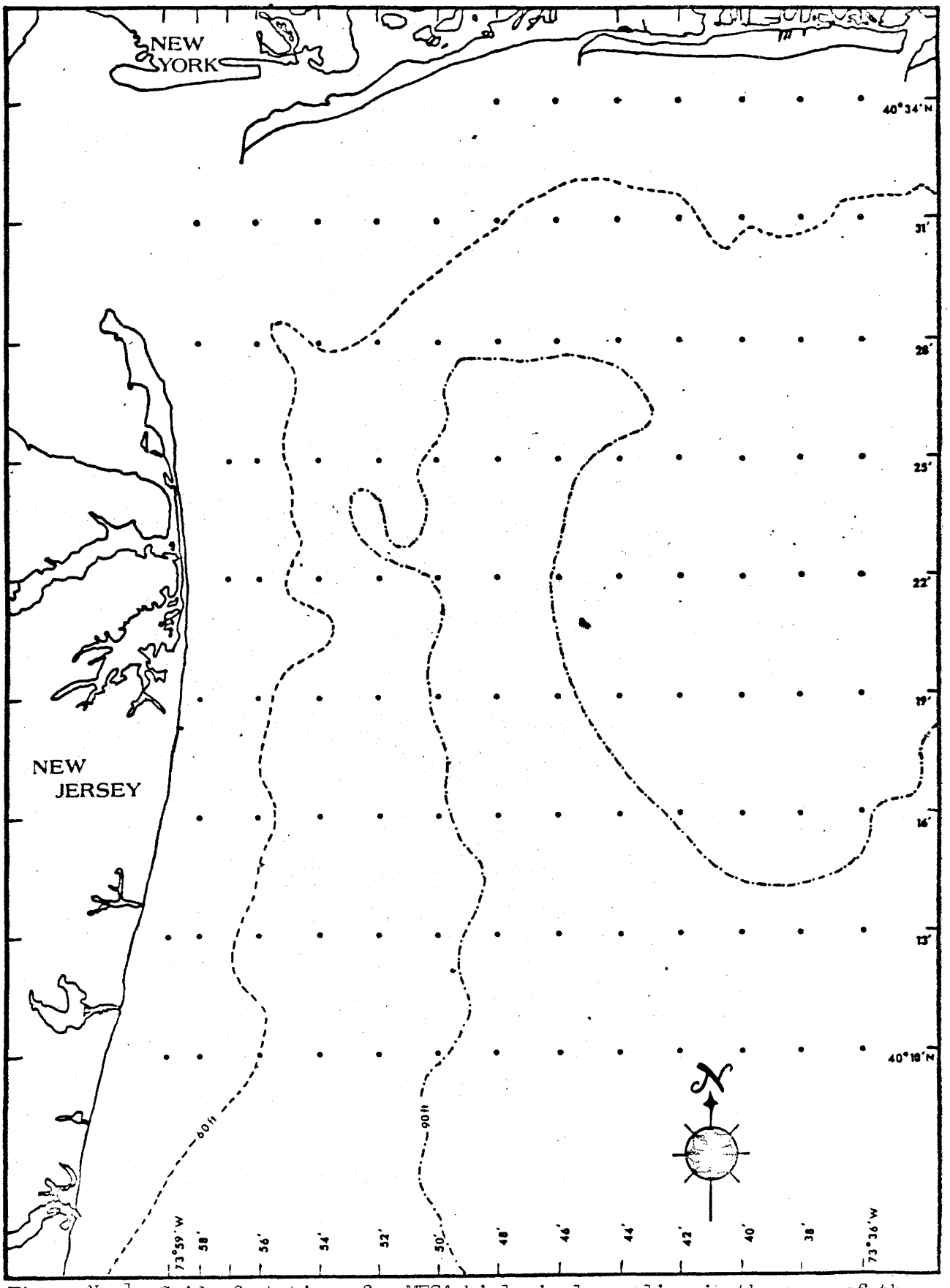


Figure No. 1. Grid of stations for MESA biological sampling in the apex of the New York Bight.

diameter plastic tube and the sample preserved for meiofauna examination. The remainder of the sample in the Smith-McIntyre grab was washed through standard geological screens. Materials larger than 1 mm in their greatest dimension were fixed, preserved and stored for macrofaunal examination.

Thirty-nine reconnaissance stations in the apex of the New York Bight are represented by five Smith-McIntyre samples and associated cores per station and eight stations are represented by 20 Smith-McIntyre samples and associated cores per station (Table 3). Four stations were repeated twice between March 20 and June 18, 1973 (Table 4). In all a total of 47 stations (355 Smith-McIntyre samples and associate cores) representing 43 different locations were taken.

The heavy metal samples were distributed to NMFS/MACFC Milford Laboratory on June 21, 1973. The samples for geological analysis were distributed to Dr. Anthony Cok (Adelphi University) on June 22, 1973. Samples for meiofaunal examination were distributed to Dr. John Tietjen (CCNY) on June 14, 1973. Macrofaunal samples are being sorted, counted, identified and recorded on standard forms by contract personnel (Trenton State College). The macrofaunal information will be sent to Dr. Saul Saila (Rhode Island University) for statistical analysis.

Sediment samples sent for heavy metal burden determinations and grain size distribution have been analyzed. Data from 20 replicate grab samples/station have been furnished to Dr. Saila. A preliminary statistical analysis of the data (see Tables 5 and 6) indicates that

Table 3. Reconnaissance Stations Sampled in the New York Bight

| Cruise & Vessel | Date | Sta.# | Pearce # | Location | Latitude | Longitude |
|---|---|---|---|---|---|---|
| | | | | 3H4 x 3H5 | | |
| R-73-1 | 20 III 73 | 1 | 36 | 4562 x 3304 | 40°24.7' | 73°57.2' |
| Rorqual | | 2 | 64 | 4581 x 3278 | 40°24.8' | 73°53.9' |
| | | 3 | 82 | 4590 x 3264 | 40°24.8' | 73°52.2' |
| | 26 III 73 | 4 | 7 | 4590 x 3220 | 40°21.4' | 73°47.6' |
| | 27 III 72 | 5 | 48 | 4665 x 3230 | 40°33.1' | 73°50.2' |
| | | 6 | 101 | 4684 x 3201 | 40°33.1' | 73°46.9' |
| R-73-2 | 30 V 73 | - | 69 | 4618 x 3228 | 40°25.8' | 73°48.1' |
| Rorqual | | 82 | X-4 | 4580 x 3265 | 40°23.7' | 73°52.6' |
| | 31 V 72 | 3 | X0000 | 4606 x 3267 | 40°26.6' | 73°52.6' |
| | | 4 | 39 | 4600 x 3249 | 40°24.8' | 73°50.4' |
| | | 5 | Z0000 | 4614 x 3254 | 40°27.1' | 73°51.2' |
| | | 6 | V00 | 4592 x 3280 | 40°26.1' | 73°53.9' |
| | 1 VI 73 | 7 | 1 | 4625 x 3235 | 40°26.95' | 73°49' |
| | | 8 | 59 | 4619 x 3221 | 40°24.9' | 73°73.35' |
| | | 9 | IV | 4608 x 3238 | 40°24.9' | 73°49.3' |
| A-73-1 | 5 VI 73 | 1 | 111* | 4615 x 3227 | 40°24.9' | 73°48' |
| Atlantic | 6 VI 73 | 2 | 8* | 4600 x 3217 | 40°22.3' | 73°47.1' |
| Twin | | 3 | 49* | 4598 x 3185 | 40°19.5' | 73°43.65' |
| | | 4 | 29* | 4645 x 3184 | 40°24.15' | 73°43.3' |
| | | 5 | VA5* | 4658 x 3201 | 40°28.6' | 73°45.5' |
| | 10 VI 73 | 6 | X3* | 4583 x 3266 | 40°24.2' | 73°52.6' |
| | 11 VI 73 | 7 | 66* | 4637 x 3226 | 40°27.8' | 73°38.1' |
| | | 8 | 105* | 4668 x 3208 | 40°31.1' | 73°46.9' |
| | 12 VI 73 | 9 | VI A5 | 4662 x 3200 | 40°29.2' | 73°45.5' |
| A-73-1 | 12 VI 73 | 10 | IV A7 | 4661 x 3190 | 40°28' | 73°44.3' |
| Atlantic | | 11 | 67 | 4654 x 3198 | 40°27.75' | 73°45' |
| Twin | | 12 | 109 | 4645 x 3207 | 40°27.3' | 73°46' |
| | | 13 | VI | 4637 x 3220 | 40°27.3' | 73°47.4' |
| | | 14 | A-2 | 4632 x 3221 | 40°26.6' | 73°47.4' |
| | | 15 | B-2 | 4628 x 3221 | 40°26.1' | 73°47.4' |
| | | 16 | 5 | 4625 x 3221 | 40°25.6' | 73°47.35' |
| | | 17 | F-3 | 4617 x 3216 | 40°24.2' | 73°46.75' |
| | | 18 | G-3 | 4613 x 3216 | 40°23.7' | 73°46.75' |
| | 13 VI 73 | 19 | 7 | 4590 x 3220 | 40°21.4' | 73°47.6' |
| | | 20 | H-2 | 4605 x 3221 | 40°23.2' | 73°47.4' |
| | | 21 | G-3 | 4613 x 3216 | 40°23.7' | 73°46.74' |
| | | 22 | F-3 | 4617 x 3216 | 40°24.2' | 73°46.75' |
| | 14 VI 73 | 23 | 13 | 4656 x 3189 | 40°27.3' | 73°44.025' |
| | | 24 | II+ | 4617 x 3233 | 40°25.7' | 73°48.7' |
| | | 25 | III | 4612 x 3232 | 40°24.9' | 73°48.6' |
| | | 26 | V | 4600 x 3240 | 40°24.1' | 73°49.5' |
| | | 27 | Y-4 | 4584 x 3259 | 40°23.7' | 73°51.85' |
| | | 28 | W-4 | 4576 x 3271 | 40°23.7' | 73°53.3' |
| | | 29 | W-3 | 4579 x 3272 | 40°24.2' | 73°53.3' |
| AT-73-1 | | | W-2 | 4583 x 3274 | 40°24.6' | 73°53.3' |
| R-73-2 | | | V-1 | 4583 x 3279 | 40°25.1' | 73°53.8' |
| Rorqual | 18 VI 73 | | 36 | 4562 x 3305 | 40°24.7' | 73°57.2' |

* 20 Smith-McIntyre samples per station
\+ No core samples

Table 4. Sample Stations Repeated in 1973

| Pearce # | Date | Date | Latitude | Longitude |
|---|---|---|---|---|
| 36 | 20 III 73 | 18 VI 73 | 40°24.7' | 73°57.2' |
| 7 | 26 III 73 | 13 VI 73 | 40°21.4' | 73°47.6' |
| F-3 | 12 VI 73 | 13 VI 73 | 40°24.2' | 73°46.75' |
| G-3 | 12 VI 73 | 13 VI 73 | 40°23.7' | 73°46.85' |

Table 5. Heavy Metal Values (PPM in dry sediments) for 20 Replicate Grab Samples Collected at Stations 111 (center of sewage sludge disposal area) and X-3 (center of dredging spoils disposal area). Grabs Indicated with an * had Four Aliquots Removed from a Single Grab Sample.

Station 111

| Grab # | Ag | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 1* | 2.5 | 3.0 | 77. | 73. | 20. | 105. | 145. |
| | 2.5 | 3.0 | 75. | 65. | 20. | 95. | 139. |
| | 2.5 | 3.5 | 76. | 65. | 21. | 100. | 145. |
| | 2.5 | 4.5 | 78. | 64. | 20. | 100. | 140. |
| 2 | < 2.5 | < 2.5 | 57. | 50. | 17. | 75. | 110. |
| 3 | < 2.5 | < 2.5 | 45. | 56. | 17. | 75. | 114. |
| 4 | 2.5 | < 2.5 | 49. | 48. | 15. | 65. | 93. |
| 5 | < 2.5 | 2.5 | 72. | 68. | 20. | 95. | 138. |
| 6 | 2.5 | < 2.5 | 34. | 30. | 11. | 50 | 64 |
| 7 | 2.5 | < 2.5 | 70. | 54. | 16. | 75. | 143. |
| 8 | 2.5 | 2.5 | 73. | 57. | 19. | 85. | 130. |
| 9* | < 2.5 | 2.5 | 61. | 59. | 17. | 85. | 123. |
| | < 2.5 | 3.0 | 60. | 51. | 17. | 80 | 120. |
| | < 2.5 | 3.0 | 61. | 54. | 17. | 80. | 119. |
| | < 2.5 | 3.0 | 62. | 57. | 18. | 80. | 121. |
| 10 | < 2.5 | < 2.5 | 60. | 47. | 17. | 110. | 98. |
| 11 | < 2.5 | < 2.5 | 54. | 45 | 18 | 70. | 98. |
| 12 | < 2.5 | < 2.5 | 38. | 35. | 12. | 60. | 71. |
| 13 | 2.5 | 2.5 | 75. | 67. | 20. | 100. | 143. |
| 14 | 2.5 | 2.5 | 66. | 67. | 19. | 90. | 140. |
| 15 | 3.0 | 2.5 | 80. | 73. | 21. | 110. | 161. |
| 16 | 3.5 | 4.0 | 97. | 92. | 24. | 135. | 198. |
| 17 | < 2.5 | < 2.5 | 41. | 37. | 13. | 65. | 73. |
| 18 | 2.5 | < 2.5 | 55. | 55. | 17. | 85. | 113. |
| 19 | < 2.5 | < 2.5 | 51. | 59. | 15. | 80. | 113. |
| 20 | 3.0 | 3.0 | 81. | 75. | 23. | 120. | 150. |

Table 5 (cont.) - 2 -

| Grab # | Ag | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 1 | 4.0 | 2.5 | 102. | 103. | 37. | 140. | 212. |
| 2 | 3.5 | 3.0 | 127. | 174. | 40. | 160. | 252. |
| 3 | 4.0 | 3.0 | 108. | 127. | 38. | 140. | 223. |
| 4 | 2.5 | < 2.5 | 58. | 72. | 25. | 85. | 138. |
| 5* | 3.0 | < 2.5 | 92. | 108. | 35. | 120. | 205. |
| | 3.5 | 3.0 | 94. | 99. | 35. | 130. | 208. |
| | 3.0 | 3.0 | 92. | 94. | 34. | 120. | 210. |
| | 3.0 | 3.0 | 95. | 104. | 34. | 125. | 208. |
| 6* | < 2.5 | < 2.5 | 43. | 57. | 18. | 60. | 85. |
| | < 2.5 | < 2.5 | 47. | 60. | 19. | 65. | 105. |
| | < 2.5 | < 2.5 | 48. | 58. | 19. | 65. | 102. |
| | < 2.5 | < 2.5 | 49. | 58. | 18. | 65. | 99. |
| 7 | 3.5 | 2.5 | 45. | 165. | 40. | 30. | 233. |
| 8 | 8.5 | 4.0 | 133. | 166. | 41. | 190. | 298. |
| 9 | 4.0 | 3.5 | 94. | 105. | 36. | 140. | 215. |
| 10 | 5.0 | 3.5 | 108. | 152. | 40. | 155. | 243. |
| 11 | 4.0 | 3.0 | 88. | 123. | 34. | 130. | 213. |
| 12 | 4.5 | 3.5 | 105. | 124. | 38. | 145. | 222. |
| 13 | 5.5 | 3.0 | 98. | 149. | 35. | 145. | 225. |
| 14 | 6.0 | 4.0 | 113. | 156. | 39. | 170. | 270. |
| 15 | 5.5 | 3.5 | 112. | 149. | 37. | 160. | 247. |
| 16 | 3.5 | 3.0 | 86. | 95. | 32. | 125. | 193. |
| 17 | 6.0 | 4.0 | 116. | 140. | 38. | 170. | 260. |
| 18 | 4.5 | 3.5 | 98. | 118. | 36. | 125. | 225. |
| 19 | 4.5 | 3.0 | 93. | 132. | 34. | 135. | 223. |
| 20 | 3.0 | 2.5 | 77. | 85. | 29. | 110. | 166. |

Table 6. Heavy Metal Values (PPM in dry sediments) for 20 Replicate Grab Samples Collected at Stations 49 and 29. Both of these Stations are in the New York Bight, but are Not Directly Impinged Upon by Sludge or Spoils. Two Aliquots Were Removed from Grab #1, Station 49.

| Grab # | Ag | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 1* | < 1 | < 1 | 6.8 | < 7 | 2.4 | 8.0 | 16.6 |
| | < 1 | < 1 | 7.2 | < 7 | 2.0 | 10.0 | 17.8 |
| 2 | < 1 | < 1 | 5.6 | < 4 | < 3. | 8.0 | 14.4 |
| 3 | < 1 | < 1 | 6.0 | < 7 | < 2. | 10.0 | 15.2 |
| 4 | < 1 | < 1 | 6.0 | < 7 | < 2. | 8.0 | 16.0 |
| 5 | < 1 | < 1 | 6.4 | < 7 | < 2. | 10.0 | 15.0 |
| 6 | < 1 | < 1 | 6.2 | < 7 | 2.0 | 6.0 | 15.4 |
| 7 | < 1 | < 1 | 5.4 | < 4 | < 3. | 10.0 | 13.6 |
| 8 | < 1 | < 1 | 6.6 | < 7 | < 2. | 8.0 | 16.0 |
| 9 | < 1 | < 1 | 6.6 | < 7 | 2.4 | 6.0 | 16.0 |
| 10 | < 1 | < 1 | 6.0 | < 4 | < 3. | 10.0 | 14.6 |
| 11 | < 1 | < 1 | 6.8 | < 7 | 2.8 | 10.0 | 15.8 |
| 12 | < 1 | < 1 | 8.0 | < 7 | 2.8 | 10.0 | 17.4 |
| 13 | < 1 | < 1 | 6.8 | < 7 | < 2. | 6.0 | 15.4 |
| 14 | < 1 | < 1 | 14.8 | 7. | 4. | 20.0 | 32.0 |
| 15 | < 1 | < 1 | 6.2 | < 7 | 2.0 | 8.0 | 15.8 |
| 16 | < 1 | < 1 | 6.4 | < 4 | < 3. | 10.0 | 14.6 |
| 17 | < 1 | < 1 | 5.8 | < 7 | 2.0 | 10.0 | 15.0 |
| 18 | < 1 | < 1 | 6.0 | < 7 | 2.2 | 6.0 | 15.2 |
| 19 | < 1 | < 1 | 6.6 | < 7 | < 2. | 8.0 | 17.0 |
| 20 | < 1 | < 1 | 6.8 | < 7 | 3.6 | 6.0 | 17.4 |

Table 6 (cont.) - 2 -

Station 29

| Grab # | Ag | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 1 | < 1 | < 1 | 5.8 | < 7 | < 2. | < 6. | 17.6 |
| 2 | < 1 | < 1 | 7.4 | < 7 | < 2. | 6.0 | 18.4 |
| 3 | < 1 | < 1 | 11.2 | < 7 | 2.4 | 16.0 | 21.8 |
| 4 | < 1 | < 1 | 7.0 | 9.2 | < 2. | 6.0 | 14.6 |
| 5 | < 1 | < 1 | 9.0 | < 7 | < 2. | 8.0 | 19.8 |
| 6 | < 1 | < 1 | 7.2 | 10.4 | 2.4 | 6.0 | 13.8 |
| 7 | < 1 | < 1 | 9.8 | < 7 | 2.4 | < 6. | 19.6 |
| 8 | < 1 | < 1 | 9.8 | < 7 | < 2. | 16. | 23.0 |
| 9 | < 1 | 2.0 | 7.6 | 11.0 | 2.8 | 6.0 | 17.4 |
| 10 | < 1 | < 1 | 6.2 | 7.2 | 2.4 | 6.0 | 13.2 |
| 11 | < 1 | < 1 | 7.6 | < 7 | 2.4 | 12.0 | 17.4 |
| 12 | < 1 | 1.2 | 10.8 | 9.8 | 3.0 | 6.0 | 24.6 |
| 13 | < 1 | < 1 | 8.8 | 10.6 | 2.0 | 10.0 | 35.3 |
| 14 | < 1 | 1.2 | 6.2 | < 7 | 4.8 | 6.0 | 16.8 |
| 15 | < 1 | < 1 | 4.8 | 7.4 | 2.6 | < 6. | 11.0 |
| 16 | < 1 | < 1 | 5.8 | < 7 | 2.4 | < 6. | 14.0 |
| 17 | < 1 | < 1 | 5.4 | < 7 | < 2. | 8. | 26.6 |
| 18 | < 1 | < 1 | 4.8 | 15.0 | 2.0 | 18. | 13.6 |
| 19 | < 1 | < 1 | 4.6 | < 7 | 2.4 | < 6. | 10.6 |

in terms of variations of metals in sediments taken at a "single" station, only one or two samples are required to adequately define the station in terms of heavy metal contamination.

MESA Quarterly Biological Baseline Censuses in the Apex

Quarterly benthic studies on the NOAA Ship Albatross IV were initiated between 2-6 August 1973, for the purpose of conducting quarterly baseline censuses of benthic macrofauna and meiofauna (including ciliate, amoeboid, and foraminiferan Protozoa and the Nematoda), heavy metal contaminants, and the mechanical properties of sediments (grain size, etc.) in the apex of the New York Bight. These objectives are more fully explained in MACFC Informal Report No. 13 for the MESA Program in the New York Bight. Stations were selected on a grid (1 min. latitude x 1 min. longitude) overlying the apex of the New York Bight (see Fig. 1). Five Smith-McIntyre bottom grab samples were taken at each station.

Three cores were removed from each grab sample. Two of the cores were taken with 38 mm (1.5 inch) diameter plastic core liners and frozen for analyses of heavy metals and the mechanical properties of sediment. The third core was taken with a 25 mm (1.0 inch) diameter plastic tube and preserved for meiofaunal (nematodes and foraminifera) examination. The remainder of the Smith-McIntyre grab sample was washed through standard geological screens. The material trapped on screens (larger than 1 mm) was preserved for macrofaunal examination.

Sixty-four stations of five Smith-McIntyre grabs per station were sampled (see Fig. 2). In all a total of 320 sediment samples for heavy metals analysis were taken. In addition, samples were taken at each station for bottom dissolved oxygen, salinity and temperature.

Subsequently, two quarterly cruises were made during the periods 19-26 October 1973 and 22 January-5 February 1974. Sampling endeavors similar to the above were made during these two cruises. Details and preliminary results are given for each cruise in Cruise Reports dated 1 October 1973, 4 December 1973 and February 1974. The Cruise Reports for each quarterly cruise are included as Appendices I, II and III.

Finally, it should be noted that a bottom oxygen consumption program was initiated during the 22 January-5 February 74 quarterly cruise.

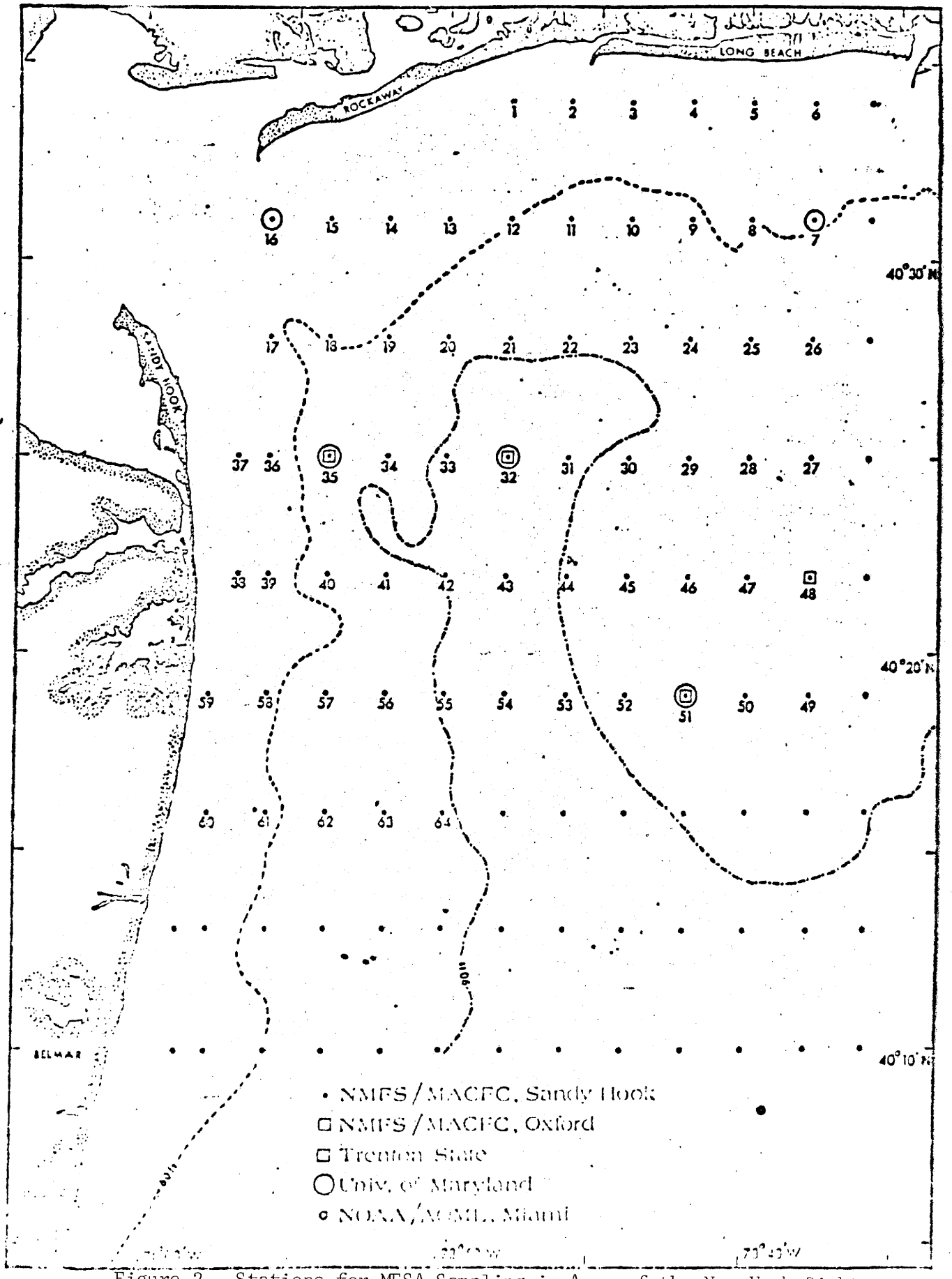


Figure 2. Stations for MESA Sampling in Apex of the New York Bight

## BIOCHEMICAL MODELING

R. Tucker

The objectives of the Biochemical Modeling Investigation include the determination of binding states of metals in the marine and estuarine environment and a study of the effects on animals of metals in the state they naturally occur. We are particularly interested in investigating various physiological systems which might be especially sensitive to environmental contamination. Ion exchange or osmoregulation and respiration are examples.

Some representative preliminary values for metal analysis in Raritan Bay water are presented in Table 7. Pulsed anodic stripping polarography is the method used for metal determinations. The metals are plated onto an electrode at a voltage more negative than their half-cell potentials, the voltage is then allowed to increase at a steady rate (a positive ramp) and the current flow measured when a metal strips off the electrode at its particular half cell potential. Bound and unbound metal can be differentiated by analyzing before and after UV irradiation of the sample to breakdown organic molecules. Such techniques as equilibrium dialysis, ultrafiltration, and tracer labeling may be also used for binding studies.

Initial results of effects of cadmium on gill Na+K+ ATPase of *Cancer irroratus* are shown in Table 8. The assay method is modified from Bonting (1970). The Na+K+ ATPase is differentiated from the Mg++ ATPase by adding ouabain, a specific inhibitor, to one of a pair

of incubation mixtures, the Na+K+ ATPase activity is then represented by the difference. The pairs are run in triplicate as are pairs for testing cadmium inhibition. In the example presented Cd was added to the incubation mixture to give a level of 10 ppm. This level is not at odds with measured environmental levels, since concentration factors of several thousand are not unusual for marine invertebrates. At the 10 ppm level, Cd causes almost 60% inhibition of the Na+K+ ATPase while having no significant effect on the Mg++ ATPase. We are continuing to measure effects at different levels and also with different metals on this and other enzyme systems.

Bonting, S. L. 1970. Sodium-potassium activated adenosinetriphosphatase and cation transport. In: Membranes and Ion Transport. Vol. 1 (Bittar, E.E., editor). Wiley-Interscience, New York. pp. 257-363.

Table 7. Metal Concentration in Water Mgons/L.

| Location | Zn | | Cd | | Pb | | Cu | |
|---|---|---|---|---|---|---|---|---|
| | Total | Inorg | Total | Inorg | Total | Inorg | Total | Inorg |
| Arthur Kill | 23 | | 5.5 | | 208 | | 36 | |
| West End of Raritan Bay | 27 | 14 | 2.5 | 1.6 | 14 | 10 | 40 | 23 |
| Middle Raritan Bay | | 2.8 | | 1.5 | | 9 | | 32 |
| Between Hoffman & Swinburne Island | 51 | 35 | 1.7 | 0.9 | 13 | 7 | | 24 |
| Verrazano Narrows | 11 | 7 | 0.8 | 0.5 | 5 | 4 | 18 | 13 |
| New tip of Sandy Hook | 14 | 3 | 0.9 | 0.3 | 7.3 | 1.4 | 35 | 30 |

Table 8. Enzyme Activity mmoles $PO_4 \cdot hr^{-1} \cdot gm^{-1}$

| Sample # | Na+K+ ATPase No Cd | Na+K+ ATPase With Cd | Mg++ ATPase No Cd | Mg++ ATPase With Cd |
|---|---|---|---|---|
| 1 | 1.55 | 0.94 | 7.15 | 7.03 |
| 2 | 1.56 | 0.92 | 7.33 | 7.65 |
| 3 | 1.15 | 0.44 | 6.32 | 6.01 |
| 4 | 2.56 | 0.66 | 8.26 | 8.02 |
| 5 | 1.04 | 0.16 | 6.15 | 6.70 |
| 6 | 1.46 | 0.76 | 7.59 | 6.99 |

Average Difference of pairs = 0.80 ± 0.46
Difference significant at 99% confidence level

Difference not significant

## COASTAL ECOSYSTEMS

R. Reid, R. McGrath and D. Radosh

This investigation consists of three baseline ecological censuses; in Raritan Bay, Long Island Sound and along the New Jersey coast. All three projects follow the same general pattern, with 109 or more stations being sampled for the following parameters: Benthic macrofauna and meiofauna, sediment grain size and heavy metal content; temperature, salinity, and concentrations of nutrients and dissolved oxygen in the water column. Variations of this pattern, as well as findings of the individual projects, are discussed separately below. A fourth contaminant-related study within this Investigation is the post-sewage abatement survey of water quality and plankton in the Navesink River.

Long Island Sound: Field surveys were conducted 17 July - 25 August 1972, 1 - 18 April and 10 - 28 September 1973, during which 158, 72, and 142 stations, respectively, were sampled for the above parameters. Analyses of sediment heavy metals were undertaken by the Environmental Microbiology and Chemistry groups at Milford. Results from the 1972 cruise revealed consistently high concentrations of eight heavy metals in the extreme western end of the Sound and in the vicinity of several cities on the northern shore. Sampling stations are presented in Figure 3.

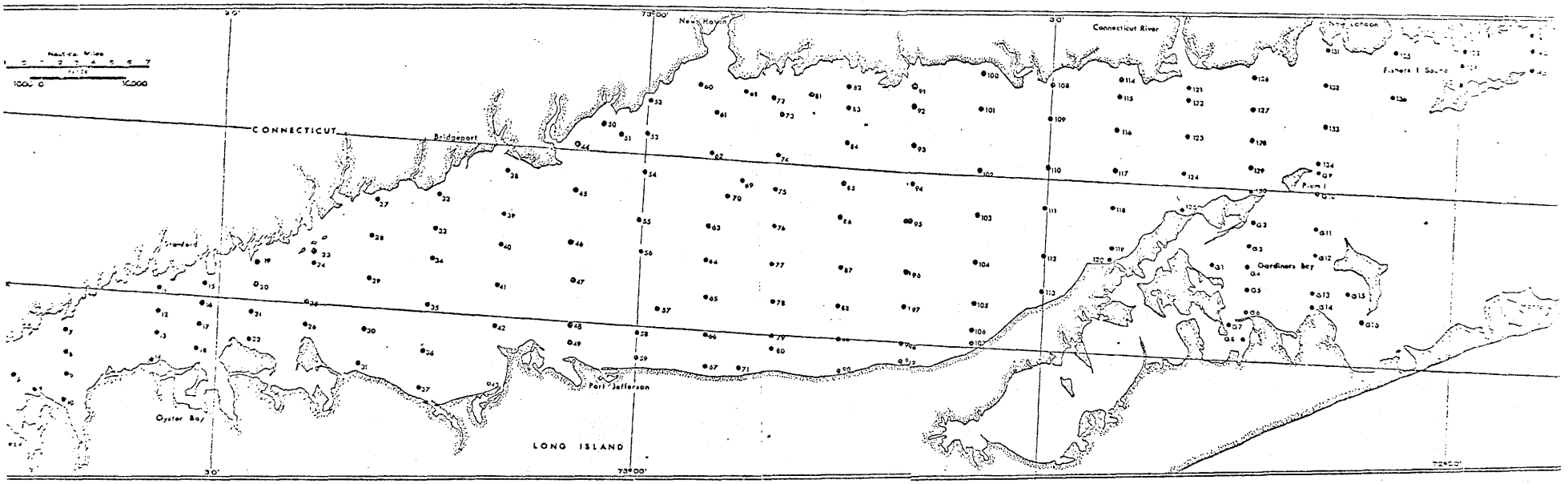


Figure 3. Long Island Sound Sampling Stations.

This pattern is repeated in nutrient concentrations, and inversely for dissolved oxygen levels. Thus, the baseline survey has documented a persistent degradation in heavily-populated areas of the Sound. Preliminary examination of macrofaunal populations indicates that this environmental contamination is correlated with 1) reduced faunal diversity, 2) increased abundance of polychaetes relative to crustaceans and molluscs, and 3) dominance of several species considered indicative of stressed environments.

Tentative comparisons can be made to benthic populations described for 1953-54 off the Bridgeport-New Haven area. 1/ Our samples contained reduced standing crops and diversity of amphipods when compared to the earlier date. The bivalve Nucula proxima appears to have been replaced by the more stress-tolerant Mulinia lateralis at several stations. This implies that the Sound's macrofauna has been affected historically as well as geographically by environmental contaminants.

Navesink River: Three stations were sampled 26 times each between May 1972 and July 1973 to assess any changes (compared to an earlier survey) following sewerage abatement in the Navesink. Nutrient analyses and zooplankton studies were conducted by Biological Modeling and Coastal Ecosystems personnel at Sandy Hook.

Raritan Bay: The present Raritan Bay project was initiated in July of 1972 as an extension of preliminary work by the benthic section of

/1 Sanders, H.L. 1956. Oceanography of Long Island Sound 1952-1954. The biology of marine bottom communities. Bull. Bingham. Oceanogr. Coll. 15: 345-414.

SHL which produced the report: "Review of Aquatic Resources and Hydrographic Characteristics of Raritan, Lower New York and Sandy Hook Bays" (SHL, 1971).

This report indicated that standing crops and species diversity were both severely limited in Raritan Bay. The small number of stations (15) and the limited sampling frequency prevented more extensive conclusions. The depleted fauna was attributed to "pollution" but the types of contaminants, their sources and specific effects on the fauna were not discussed in any detail.

The current study is concentrating its investigation of contaminants on the distribution of 7 heavy metals (Cd, Cr, Cu, Mn, Ni, Pb, Zn) in the sediments of Raritan Bay. While most of these metals are themselves toxic and thus deserving of study in their own right, they also serve as excellent indicators of municipal and industrial wastes with their associated contaminants. Elevated trace metal values are commonly associated with dredge spoils, which is not a factor in Raritan Bay.

Target organisms for the study are macrobenthic infauna which may be considered as sessile for the purposes at hand. The advantages of non-pelagic species as bio-assay organisms are well documented.

Methods: The 78 stations selected for this survey (Figure 4) are based on stations created by the U. S. Public Health Service Raritan Bay Project in 1963. An intensive water quality monitoring program was

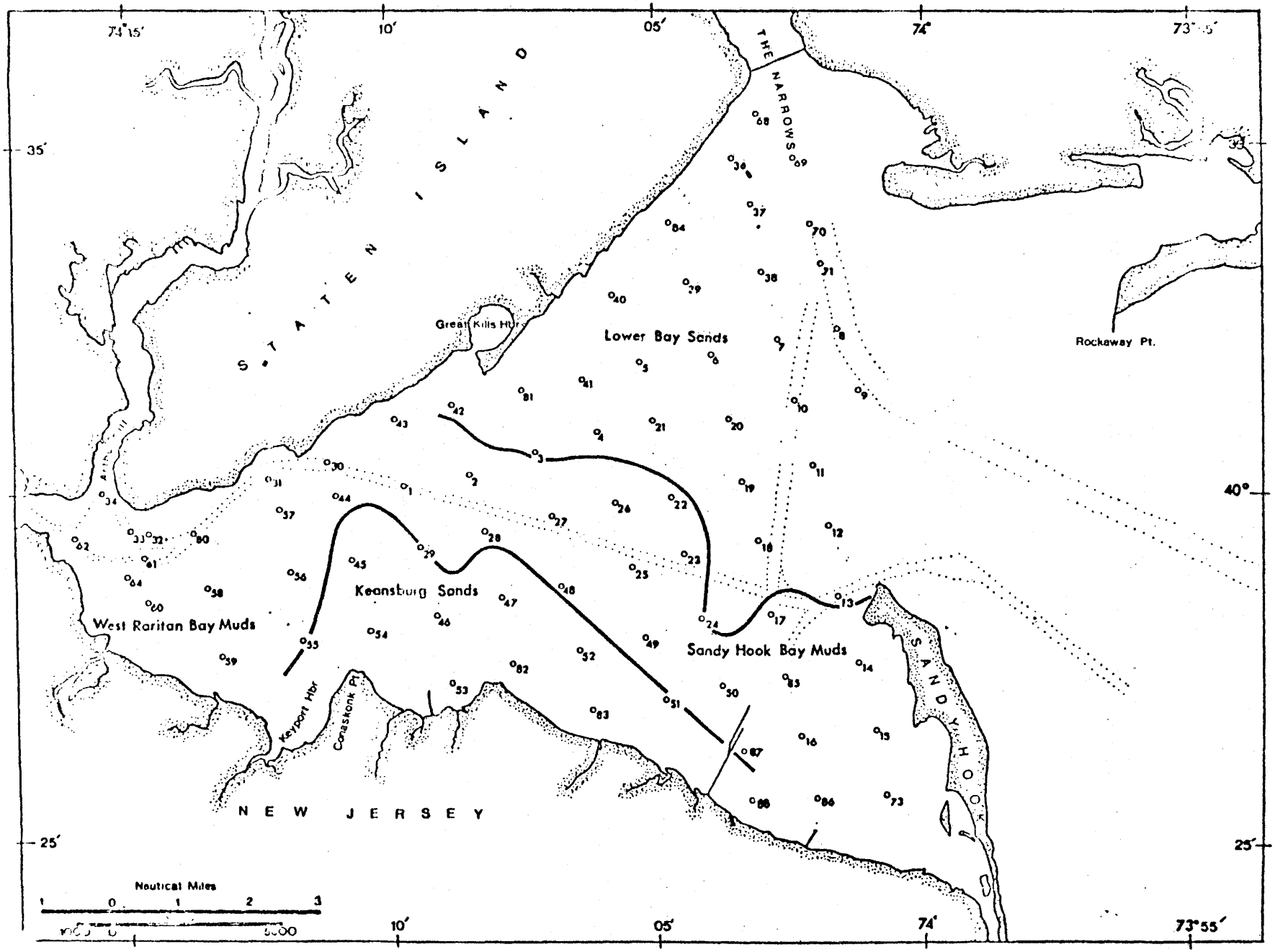


Figure 4: Raritan Bay geography, station locations and sediment distribution

initiated by the Federal Water Quality Administration shortly thereafter and these data are now available through the STORET system. These data will allow long-term environmental patterns to be compared with faunal distributions.

Four seasonal samplings are planned throughout 1973. Two replicate 0.1m$^2$ Smith-McIntyre grab samples are taken at each station. Two 37 mm diameter cores were removed from one grab sample for analysis of meiofauna and heavy metal content respectively. A third core was removed from the second grab for sediment grain-size distribution and organic content analyses. All core samples were immediately frozen. Subsequent treatment of macrofaunal samples can be considered routine for this type of survey and will not be discussed here. The usual complement of physical data were recorded at each station.

Heavy metal cores were transferred frozen to the Milford Laboratory (NOAA, NMFS, MACFC) and analyzed by atomic absorption. Details of the procedure are available in "Cooperative Study of Contaminants in the Coastal Environment and their Effects on Living Marine Resources: Summary Report, 1971-1972" (MACFC Informal Report No. 5, 1972).

Results and Discussion: Samples processed to date indicate clearly elevated metal concentrations in all areas of Raritan Bay for all contaminants investigated (Table 9) . Due to the large contaminant load there is no area within the Bay which can serve as an uncontaminated control. Comparisons are made, therefore, with offshore stations

Table 9. Heavy Metal Concentrations in Raritan Bay (ppm, dry weight)

| Station | Cd | Cr | Cu | Mn | Ni | Pb | Zn | Sediment |
|---|---|---|---|---|---|---|---|---|
| 2 | 5.5 | 42.8 | 72.0 | 195.0 | 14.8 | 89.0 | 188.0 | silt |
| 3 | 4.5 | 30.7 | 41.0 | 163.0 | 7.1 | 43.0 | 160.0 | silt |
| 4 | 1.2 | 21.1 | 12.0 | 160.0 | 5.5 | 61.0 | 208.0 | sand |
| 5 | 2.5 | 24.5 | 26.0 | 106.0 | 5.3 | 49.0 | 140.0 | silt |
| 6 | 3.0 | 23.7 | 28.0 | 188.0 | 8.8 | 57.0 | 79.5 | silt |
| 7 | < 2.5 | 36.3 | 47.0 | 108.0 | 10.0 | 54.0 | 88.0 | silt |
| 8 | < 1.0 | 3.6 | 3.2 | 40.0 | < 2.0 | < 6.0 | 12.2 | sand |
| 9 | 1.8 | 12.6 | 16.0 | 69.0 | 8.4 | 31.0 | 30.4 | sand |
| 10 | 11.0 | 40.8 | 54.0 | 170.0 | 18.5 | 89.0 | 133.0 | sand |
| 11 | < 1.0 | 4.8 | 4.6 | 350.0 | 8.2 | 10.0 | 36.4 | sand |
| 12 | 13.0 | 58.0 | 96.0 | 540.0 | 29.5 | 236.0 | 180.0 | mixed |
| 18 | 7.5 | 97.0 | 145.0 | 308.0 | 23.5 | 162.0 | 295.0 | silt |
| 19 | < 1.0 | 10.4 | 6.2 | 70.0 | 2.0 | 20.0 | 42.0 | sand |

Table 9 (cont.) - 2 -

| Station | Cd | Cr | Cu | Mn | Ni | Pb | Zn | Sediment |
|---|---|---|---|---|---|---|---|---|
| 20 | <1.0 | 9.0 | 4.6 | 83.0 | 2.0 | 22.0 | 34.0 | sand |
| 21 | <1.0 | 20.5 | 16.6 | 174.0 | 6.8 | 55.0 | 400.0 | sand |
| 22 | 2.5 | 37.3 | 37.0 | 129.0 | 12.0 | 50.0 | 165.0 | silt |
| 23 | 4.0 | 69.0 | 110.0 | 245.0 | 20.2 | 125.0 | 220.0 | silt |
| 25 | < 2.5 | 28.0 | 84.0 | 345.0 | 13.1 | 151.0 | 165.0 | silt |
| 26 | <2.5 | 25.5 | 30.0 | 76.0 | 6.5 | 35.0 | 85.0 | silt |
| 27 | 8.0 | 71.0 | 105.0 | 233.0 | 22.3 | 136.0 | 215.0 | silt |
| 36 | 6.0 | 159.0 | 175.0 | 445.0 | 27.5 | 196.0 | 310.0 | silt |
| 39 | < 1.0 | 11.2 | 8.6 | 51.2 | 2.8 | 20.0 | 64.0 | sand |
| 40 | < 1.0 | 20.6 | 19.0 | 110.0 | 6.6 | 24.0 | 94.0 | sand |
| 41 | < 1.0 | 14.8 | 18.0 | 79.0 | 4.8 | 20.0 | 57.0 | sand |
| 47 | < 1.0 | 3.9 | 20.6 | 1110.0 | 35.3 | 34.0 | 148.0 | sand |
| 48 | 4.2 | 145.0 | 231.0 | 266.0 | 22.0 | 208.0 | 380.0 | silt |

Table 9 (cont.) - 3 -

| Station | Cd | Cr | Cu | Mn | Ni | Pb | Zn | Sediment |
|---|---|---|---|---|---|---|---|---|
| 48 | 4.2 | 145.0 | 231.0 | 266.0 | 22.0 | 208.0 | 380.0 | silt |
| 49 | 3.8 | 168.0 | 246.0 | 325.0 | 22.5 | 230.0 | 396.0 | silt |
| 51 | < 2.5 | 24.5 | 37.2 | 62.0 | 13.8 | 40.0 | 155.0 | mixed |
| 52 | 3.8 | 154.0 | 245.0 | 275.0 | 21.8 | 212.0 | 418.0 | silt |
| 61 | 2.5 | 114.0 | 475.0 | 268.0 | 31.5 | 202.0 | 373.0 | silt |
| 68 | 5.0 | 40.0 | 43.0 | 101.0 | 9.3 | 55.0 | 95.0 | mixed |
| 69 | < 1.0 | 13.6 | 13.0 | 48.4 | 5.8 | 24.0 | 49.0 | sand |
| 70 | 3.4 | 8.0 | 8.8 | 96.0 | 9.8 | 34.0 | 30.4 | sand |
| 71 | < 1.0 | 8.4 | 7.8 | 39.8 | 3.4 | 10.0 | 10.0 | mixed |
| Control #1 Jersey Coast 81 | < 1.0 | < 2.0 | < 2.0 | 40.2 | < 2.2 | < 6.0 | 7.3 | |
| Control #2 Jersey Coast 121 | < 1.0 | < 2.0 | < 2.0 | 12.4 | < 2.9 | < 6.0 | 13.6 | |

currently being studied by the Jersey Coast Project as these are the closest stations which can be expected to accurately represent background values. Concentrations in the 'control' areas are generally below the resolution of the atomic absorption technique.

Heavy metals are generally elevated below a line roughly comparable to the east-west ship channel. Exceptions are noticed in certain areas off Keansburg, where lower values have been recorded.

Patterns of faunal and sediment distribution parallel those for heavy metals. The area generally north and east of the channel is composed largely of muddy sands which support a stressed community characterized by the bivalve Tellina agilis and the polychaete Streblospio benedicti (Table 10). South of the channel, in Sandy Hook Bay and West Raritan Bay, the sediment is primarily silt-clay and characterized by Mulinia lateralis and Nephtys incisa (Table 11). The heaviest trace metal contamination appears to be associated with the silt-clay substratum and it is in those areas that the most impoverished fauna are found.

The major question yet to be resolved involves whether or not there is a casual relationship between the observed similarity in faunal distribution and heavy metal levels. Heavy metal distributions also parallel sediment strata in the Bay due to coincident deposition of terrigenous silts along with the largely river-borne pollutants. It also appears that the natural absorptive properties of silt-clay particles may serve to hold and concentrate metals.

Table 10

Composition of Raritan Bay "Sand" Community. Percent Occurrence as Major (<10%) Fraction of Sample.

| Species | % Major Fraction |
|---|---|
| *Tellina agilis* | 63.6 |
| *Streblospio benedicti* | 36.4 |
| *Nephtys bucera* | 31.8 |
| *Nemertea* spp. | 22.7 |
| *Nassarius trivittatus* | 22.7 |
| *Glycera dibranchiata* | 22.7 |
| *Protohaustorius* (?) *deichmannae* | 18.2 |
| *Spio* (?) *setosa* | 13.6 |
| *Polydora ligni* | 9.1 |
| *Scolecolepides viridis* | 9.1 |
| *Nephtys incisa* | 9.1 |
| *Spisula solidissima* | 4.5 |
| *Mulinia lateralis* | 4.5 |
| *Edotea montosa* | 4.5 |
| *Paraphoxus epistomus* | 4.5 |
| *Acanthohaustorius millsi* | 4.5 |

Table 11

Composition of Raritan Bay "Mud" Community. Percent Occurrence as Major (<10%) Fraction of Sample

| Species | % Major Fraction |
|---|---|
| *Mulinia lateralis* | 68.7 |
| *Nassarius trivittatus* | 25.0 |
| *Nephtys incisa* | 18.7 |
| *Nephtys picta* | 12.5 |
| *Nephtys caeca* | 6.3 |
| *Nephtys bucera* | 6.3 |
| *Astarte borealis* | 6.3 |
| *Pectinaria gouldii* | 6.3 |
| *Leptochelia savignyi* | 6.3 |
| *Mercenaria mercenaria* | 6.3 |

It is clear that heavy metals incorporated into sediments are less toxic than equivalent concentrations in water. The toxic level of Cu for molluscs, for example, is in the range of 0.10 to 0.20 ppm while sediments in the Bay routinely contain both molluscs and concentrations in excess of 100 ppm.

It appears at this point that heavy metals are not the primary cause of the impoverished populations in Raritan Bay. It is equally probable, however, that they are a factor acting either additively or synergistically to prevent full productivity in the Bay area.

ENVIRONMENTAL MICROBIOLOGY AND CHEMISTRY - CHEMISTRY TASK

# MERCURY CONCENTRATIONS OF FINFISH FROM NORTH ATLANTIC OFFSHORE WATERS

R. Greig and D. Wenzloff

## SUMMARY

The purpose of this study was to obtain information about the spatial distribution and temporal changes of mercury concentrations in various organs and tissues of spiny dogfish, cusk, and blackbellied redfish collected from North Atlantic offshore waters during the fall of 1972.

Spiny dogfish were collected the most extensively; the areas sampled were Georges Bank, Gulf of Maine, Cape Cod Bay, New York Bight, and Nantucket Shoals. Differences in mercury concentrations as a function of geographic area of catch were examined for only the muscle tissues of dogfish because the highest concentrations of mercury occurred in this sample. Statistical comparisons of average values were made by the student's t-test for various pairs of geographic catch locations (pairs were determined by comparing fish of similar lengths). A statistical difference ($p = 0.01$) was not found for the mercury concentrations in spiny dogfish muscle for any of the pairs of geographic areas compared--these include--Georges Bank versus New York Bight, Georges Bank versus Cape Cod Bay, Georges Bank versus Nantucket Shoals, Gulf of Maine versus New York Bight, and Cape Cod Bay versus New York Bight. The mercury concentrations in the muscle of these dogfish samples ranged from 0.40-0.62 ppm (average values).

Mercury concentrations were determined for several other organs and tissues of the spiny dogfish. Mercury levels in the kidneys averaged about 54% of the level found in the muscle of the dogfish. The gills, spleen, and pancreas of the dogfish generally had mercury concentrations in the range of 0.1-0.2 ppm. Gonads were sampled from just one dogfish collection and the mercury content of this organ was less than 0.05 ppm.

A previous report[1/] presented data on mercury concentrations found in spiny dogfish collected in 1971; some of these collections were from similar areas as the collections obtained in 1972. A statistical difference (student's t-test, P = 0.01) was not found for 1971 versus 1972 collections of dogfish muscle samples for three pairs of samples of similar geographic origin for the two years.

Cusk were collected from just two areas in the 1972 survey. The mercury concentrations in the tissues and organs of this fish for the two areas were: muscle - 0.19 and 0.32 ppm; liver - 0.13 and 0.30 ppm; gills and kidney - range of 0.07 - 0.10 ppm for both samples and for both areas.

Blackbellied redfish were collected from four geographic areas and the mercury concentrations in muscle, liver, gills, and kidneys ranged from 0.05 - 1.12 ppm for all areas sampled.

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1/ Middle Atlantic Coastal Fisheries Center, Informal Report No. 5, Sandy Hook, New Jersey.

## Introduction

In a previous Middle Atlantic Coastal Fisheries Center Report (1), results were presented from a 1971 survey of mercury concentrations in some 40 species of fish collected from Cape Hatteras, N. C. to the Nova Scotian Shelf. The results of this survey showed that the muscle of spiny dogfish (*Squalus acanthias*) and the livers of cusk (*Brosme brosme*), and blackbellied redfish (*Helicolenus dactylopterus*) had the highest concentrations of mercury of the samples examined. The mercury concentrations for the muscle and liver samples just mentioned were in the ranges of 0.4-0.7 ppm (wet wt. basis).

A second survey was conducted in 1972, the purpose of which was to collect more in depth information about the spatial and temporal distribution of mercury in several organs and tissues of the spiny dogfish, cusk, and blackbellied redfish. This report presents the findings of the 1972 survey.

## Materials and Methods

Sample collection and preparation - Ten fish were obtained from each catch location during the fall cruise (mid-Sept. to mid-Nov.), 1972 of the R/V *Albatross* IV. The tissues and organs were removed on board ship, packaged in polyethylene bags, and frozen until received at the laboratory. The samples were ground in electric blenders using glass jars and stainless steel cutting blades. The samples from individual fish were analyzed for mercury with exceptions as noted in the tables.

Chemical Methodology - A full description of the mercury procedure was presented in the previous Middle Atlantic Coastal Fisheries Center Report (1). Briefly, this method consisted of digesting the tissue with 1:4 $HNO_3$: $H_2SO_4$ at 50-60°C for about 2 hours. Fifteen ml of 5% potassium permanganate was added and the samples were left overnight at room temperature. A solution of reductant containing sulfuric acid, sodium chloride, stannous sulfate and hydroxylamine sulfate was added to the digested samples. The reduced mercury was aerated from a gas washing bottle through a quartz cell mounted in the light path of a Perkin Elmer Model 305 atomic absorption spectrometer.

## Results

The results of the mercury analyses from this study are shown in Tables 12-14 Cusk were collected from just two geographic locations, thus information on spatial distribution of mercury for this fish was limited. Mercury concentrations for both muscle and liver averaged about 0.30 ppm* for one collection of cusk, whereas these tissues had an average of about 0.16 ppm for the second collection. The differences in these mercury concentrationswere not significant as tested by the student's t-test (P = 0.01). The main reason that no significant difference could be found for these two collections was the great variability of the data. For example, mercury concentrations in muscle ranged from 0.1 to 0.25 and 0.09-0.54 ppm and the liver concentrations

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* All concentrations of mercury in tissue and organ samples for this report are expressed as ppm (ug. perg), wet weight basis.

ranged from 0.02-0.52 and 0.05-0.62 ppm, respectively, for collections A and B in Table 12.

The gills and kidneys of cusk had mercury concentrations that averaged about 0.08 ppm for both collections of cusk (Table 12).

Blackbellied redfish were collected from four locations. The mercury concentrations in muscle and liver averaged about 0.08 ppm from each of the four catch locations. Mercury concentrations were obtained for gill tissues of redfish from three catch locations and kidneys of redfish from two catch locations. Gill tissue concentrations were 0.05 ppm or less and kidneys were 0.06 and 0.17 ppm.

Spiny dogfish were collected from a total of 8 stations for five major areas. The areas were: Georges Banks, Gulf of Maine, Cape Cod Bay, New York Bight, and Nantucket Shoals. Mercury concentrations for the various organs and tissues collected from these areas are presented in Tables 13 and 14.

Statistical comparisons were made of mercury concentrations in dogfish muscle to determine whether observed differences could be related to geographic area of catch. Fish of the same size were compared since mercury concentrations varied with size of fish as seen from the data in Table 15. Differences in mercury concentrations were not significant by the student's t-test ($p = 0.01$) for the various pairs of comparisons shown in Table 16.

Thus, from the above data, the mercury concentrations in spiny dogfish did not vary significantly as a function of geographic catch location of North Atlantic Offshore waters.

Table 12. Mercury Concentrations in Various Tissues and Organs of Cusk (*Brosme brosme*) and Blackbellied Redfish (*Helicolenus dactylopterus*) from North Atlantic Offshore Waters in the Fall of 1972.

| Collection Number | Species | Latitude | Longitude | Length (cm) Av./Range | Weight (Kg) Av./Range | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | ppm, wet wt. | | | |
| A. | Cusk | 42°12' | 69°26' | 57 / 50-68 | – | Muscle | 0.19 | 0.1 -0.25 | 0.055 | |
| | | | | | | Liver | 0.13 | 0.02-0.52 | 0.162 | |
| | | | | | | Gills | 0.07 | 0.03-0.11 | 0.030 | |
| | | | | | | Kidney | 0.08 | 0.03-0.19 | 0.049 | |
| B. | Cusk | 42°44' | 66°55' | 53 / 39-61 | – | Muscle | 0.32 | 0.09-0.54 | 0.133 | |
| | | | | | | Liver | 0.30 | 0.05-0.62 | 0.208 | |
| | | | | | | Gills | 0.07 | 0.02-0.14 | 0.030 | |
| | | | | | | Kidney | 0.10 | 0.02-0.33 | 0.099 | |
| C. | Blackbellied Redfish | 39°57' | 69°58' | 18 / 16-22 | – | Muscle | 0.08 | 0 -0.22 | 0.075 | |
| | | | | | | Liver | <0.05 | – | – | ** |
| | | | | | | Gills | <0.05 | – | – | ** |
| | | | | | | Kidney | 0.06 | – | – | ** |

Table 12. (cont.) -2-

| Collection Number | Species | Latitude | Longitude | Length (cm) | Weight (Kg) | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Av. / Range | Av. / Range | | ppm, | wet wt. | | |
| D. | Blackbellied Redfish | 40°02' | 70°02' | 17 / 15-18 | - | Muscle | 0.12 | 0.07-0.18 | 0.041 | |
| | | | | | | Liver | 0.11 | - | - | ** |
| | | | | | | Gills | <0.05 | - | - | ** |
| | | | | | | Kidney | 0.17 | - | - | ** |
| E. | Blackbellied Redfish | 40°00' | 70°36' | 16 / 15-19 | - | Muscle | 0.07 | 0.04-0.15 | 0.035 | |
| | | | | | | Liver | 0.07 | 0.01-0.15 | 0.051 | |
| | | | | | | Gills | 0.05 | 0 -0.14 | 0.047 | |
| F. | Blackbellied Redfish | 39°07' | 72°42' | 16 / 13-24 | - | Muscle | 0.09 | 0.05-0.17 | 0.040 | |
| | | | | | | Liver | 0.09 | 0.02-0.19 | 0.054 | |

* Tissues and organs from 10 individual fish were analyzed per location.

** Individual livers, gills and kidneys from these fish were pooled for analysis. Data presented are averages of 2-4 replicate determinations per sample.

Table 13. Mercury Concentrations in Various Tissues and Organs of Spiny Dogfish (*Squalus acanthias*) Collected from Georges Bank and the Gulf of Maine in the Fall of 1972.

| Collection Number | Latitude | Longitude | Length (cm) | Weight (kg) | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. |
|---|---|---|---|---|---|---|---|---|
| | | | Av. / Range | Av. / Range | | ppm, wet wt. | | |
| | Georges Bank | | | | | | | |
| 1 | 41°58' | 67°34' | 91 / 80-99 | 3.8 / 2.7-5.0 | Muscle | 0.62 | 0.37-1.5 | 0.292 |
| | | | | | Gills | 0.20 | 0.07-0.62 | 0.182 |
| | | | | | Spleen | 0.17 | 0.01-0.60 | 0.145 |
| | | | | | Kidney | 0.44 | 0.11-1.3 | 0.379 |
| 2 | 41°50' | 68°25' | 71 / 62-78 | 1.5 / 0.9-1.8 | Muscle | 0.31 | 0.19-0.65 | 0.161 |
| | | | | | Gills | 0.08 | 0.06-0.16 | 0.047 |
| | | | | | Spleen | 0.06 | 0.01-0.23 | 0.085 |
| | | | | | Kidney | 0.15 | 0.02-0.49 | 0.133 |
| | | | | | Gonad | < 0.05 | < 0.05-0.06 | - |
| | | | | | Pancreas | 0.09 | - | - |

Table 13. (cont.) -2-

| Collection Number | Latitude | Longitude | Length (cm) | Weight (kg) | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. |
|---|---|---|---|---|---|---|---|---|
| | Gulf of Maine | | | | | | | |
| 3 | 43°55' | 68°39' | 76<br>63-92 | - | Muscle | 0.41 | 0.14-0.56 | 0.132 |
| | | | | | Gills | - | - | - |
| | | | | | Spleen | - | - | - |
| | | | | | Kidney | 0.21 | 0.05-0.44 | 0.123 |
| | | | | | Pancreas | 0.09 | - | - |
| 4 | 44°40' | 66°30' | 78<br>70-93 | - | Muscle | 0.40 | 0.13-0.69 | 0.182 |
| | | | | | Gills | - | - | - |
| | | | | | Spleen | - | - | - |
| | | | | | Kidney | 0.17 | 0.03-0.80 | 0.234 |
| | | | | | Pancreas | 0.12 | - | - |

* Tissues and organs from 10 individual fish were analyzed per location.

Table 14. Mercury Concentrations in Various Tissues and Organs of Spiny Dogfish (*Squalus acanthias*) Collected from Cape Cod Bay, the New York Bight and Nantucket Shoals in the Fall of 1972.

| Collection Number | Latitude | Longitude | Length (cm) | Weight (kg) | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. |
|---|---|---|---|---|---|---|---|---|
| | | | Av. / Range | Av. / Range | | | | |
| Cape Cod Bay | | | | | | | | |
| 5 | 42°08' | 70°20' | 86 / 78-90 | - | Muscle | 0.48 | 0.3 -0.8 | 0.146 |
| | | | | | Gills | - | - | - |
| | | | | | Spleen | - | - | - |
| | | | | | Kidney | 0.27 | 0.06-1.1 | 0.321 |
| | | | | | Pancreas | 0.09 | - | - |
| New York Bight | | | | | | | | |
| 6 | 41°14' | 71°07' | 86 / 80-91 | 2.8 / 2.2-3.4 | Muscle | 0.61 | 0.31-0.94 | 0.246 |
| | | | | | Liver | 0.13 | 0.01-0.31 | 0.104 |
| | | | | | Gills | 0.21 | 0.11-0.34 | 0.089 |
| | | | | | Spleen | 0.22 | 0.10-0.51 | 0.155 |
| | | | | | Kidney | - | - | - |

Table 14. (cont.) -2-

| Collection Number | Latitude | Longitude | Length (cm) | Weight (kg) | Tissue or Organ | Mercury Concentrations* Av. | Range | Std. Dev. |
|---|---|---|---|---|---|---|---|---|
| 7 | 40°35' | 71°39' | 66 / 56-76 | 1.1 / 0.5-1.6 | Muscle | 0.28 | 0.1 -0.62 | 0.187 |
| | | | | | Gills | 0.14 | 0.09-0.19 | 0.043 |
| | | | | | Spleen | 0.03 | 0.01-0.07 | 0.021 |
| | | | | | Kidney | - | - | - |
| | | | | | Gonad | < 0.05 | < 0.05-0.08 | - |
| 8 | 40°38' | 69°55' | 59 / 48-79 | 0.88 / 0.5-1.6 | Muscle | 0.21 | 0.1 -0.43 | 0.106 |
| | | | | | Gills | 0.05 | 0.02-0.12 | 0.048 |
| | | | | | Spleen | 0.05 | 0.02-0.10 | 0.032 |
| | | | | | Kidney | - | - | - |

* Tissues and organs from 10 individual fish were analyzed per location.

Table 15. Average Mercury Concentrations in Muscles for Various Length Groups of Spiny Dogfish

| Fish Length (cm) | Numbers of Fish | Mercury Concentration Average ppm + Standard error |
|---|---|---|
| 48-75 | 35 | 0.27 ± 0.03 |
| 76-85 | 17 | 0.42 ± 0.04 |
| 86-99 | 25 | 0.60 ± 0.06 |

Table 16. Comparison of Difference in Mercury Concentrations for Spiny Dogfish Muscle as a Function of Geographic Area of Catch.

| Geographic Area | Collection Number | Mercury Concentration* | Statistical Difference in Mercury Concentrations for Spiny Dogfish Muscle** | Mercury Concentration* | Geographic Area | Coll. No. |
|---|---|---|---|---|---|---|
| Georges Bank | 1 | 0.62 | None | 0.61 | New York Bight | 6 |
| Georges Bank | 1 | 0.62 | None | 0.48 | Cape Cod Bay | 5 |
| Georges Bank | 2 | 0.31 | None | 0.28 | New York Bight | 7 |
| Georges Bank | 2 | 0.31 | None | 0.21 | Nantucket Shoals | 8 |
| Gulf of Maine | 3 or 4 | 0.41 or 0.40 | None | 0.61 | New York Bight | 6 |
| Cape Cod Bay | 5 | 0.48 | None | 0.61 | New York Bight | 6 |

* Mercury concentration is expressed as ppm, wet wt. The values are averages of analysis of 10 individual fish.

** Statistical difference was measured by student's t-test at p=0.01.

In addition to the collections of muscle samples, gills, spleens, kidneys, and gonads were collected from spiny dogfish.

Gill tissues were sampled from dogfish for all collections with the exceptions of collections three, four and five (Tables 13 and 14). The highest mercury concentration in gills was found for dogfish from Georges Banks (collection one), with an average of 0.20 ppm (range, 0.07-0.62). The gills of all other dogfish collections had concentrations of 0.14 ppm or less in mercury.

The spleen was sampled from the same dogfish collections as the gills. The mercury concentration in this organ averaged 0.17 ppm, and 0.22 ppm, for collections one and six, respectively. All other dogfish had mercury concentrations in the spleen of 0.06 ppm or less.

Kidneys were sampled from all dogfish collections except collections six, seven, and eight. The highest average mercury concentration (0.44 ppm) was found in kidneys in dogfish from Georges Bank (collection one). Certain individual specimens of kidneys, however, had mercury concentrations as high as 0.8-1.3 ppm. The variation in mercury concentrations among individual dogfish kidneys was great as evidenced by the range of concentrations found for Georges Banks dogfish (collection one) at 0.11-1.3 ppm. The kidneys contained the second highest (muscle samples were highest) average mercury concentrations of all the tissues and organs sampled. The mercury concentrations in kidneys averaged about 54% (range, 43-71%) of the concentrations in muscle.

Gonads of dogfish were sampled from only Georges Bank and the New York Bight (collections two and seven, Tables 13 and 14) and the mercury concentrations in this organ averaged less than 0.05 ppm for both locations.

The pancreas of dogfish was sampled from half the stations (collections two through five). The average mercury concentrations in this organ were in the range of 0.09 to 0.12 ppm for all four geographic locations.

Comparison of 1971 and 1972 Data

There were only single collections of ten fish obtained in 1971 for cusk and blackbellied redfish. Comparison with 1972 data, therefore, was not possible.

Spiny dogfish muscle samples were collected from several areas in both 1971 and 1972. The results of mercury analyses for muscle of dogfish from similar geographic areas for 1971 and 1972 are presented in Table 17. There was no significant difference in mercury concentrations as measured by the student's t-test for the muscle of dogfish from similar size fish and similar geographic areas for 1971 versus 1972 data (collections 10 versus 11; 10 versus 12; 17 versus 18; and 19 versus 10; Table 17). The great variability of mercury concentrations amongst individual dogfish muscle samples within each collection, however, is what prevented the detection of differences of the magnitude observed for 1971 versus 1972 data.

Table 17. Mercury Concentrations in Spiny Dogfish (*Squalus acanthias*) Muscle Collected from North Atlantic Offshore Waters in 1971 and 1972.

| Collection Number | Latitude | Longitude | Fish Length (cm) | Mercury Concentrations* 1971 Av. | 1971 Std. Dev. | 1972 Av. | 1972 Std. Dev. |
|---|---|---|---|---|---|---|---|
| | | | Range | ppm, wet wt. | | | |
| 10 | 40°29' | 72°26' | 60-86 | 0.44 | 0.154 | - | - |
| 11 | 40°35' | 71°39' | 56-76 | - | - | 0.28 | 0.187 |
| 12 | 40°38' | 69°55' | 48-79 | - | - | 0.21 | 0.106 |
| 13 | 40°43' | 70°26' | - | 0.18 | 0.064 | | |
| 14 | 41°50' | 68°25' | 62-78 | - | - | 0.31 | 0.161 |
| 15 | 41°58' | 67°34' | 80-99 | - | - | 0.62 | 0.292 |
| 16 | 42°08' | 70°20' | 78-90 | - | - | 0.48 | 0.146 |
| 17 | 42°20' | 65°35' | 68-75 | 0.23 | 0.052 | - | - |
| 18 | 43°55' | 68°39' | 63-92 | - | - | 0.41 | 0.132 |
| 19 | 44°16' | 66°51' | 81-84 | 0.34 | 0.160 | - | - |
| 20 | 44°40' | 66°30' | 70-93 | - | - | 0.40 | 0.180 |

* Muscle samples from 5 individual fish were analyzed in 1971 and from 10 individual fish in 1972.

Mercury Concentrations in Spiny dogfish Pups

During the 1972 cruise, we were fortunate to obtain six adult female spiny dogfish that had from 3-6 pups per female. The fish were obtained from Georges Banks (41°58'N; 67°34'W). These pups ranged in length from 23-27 cm. The question often arises as to whether mercury can be transmitted from the adult to the young of fish. Samples of the muscle, liver, gill, kidney, and yolks of the pups were therefore dissected for mercury analyses. Mercury concentrations in these tissues and organs of the pups were all below the detection limit of the methodology employed (about 0.03-0.05 ppm, wet wt.). The mercury concentrations in the adult female were: 0.4-1.1 ppm (muscle), 0.10-0.62 ppm (gills) <0.03-0.60 ppm (spleen), and 0.1-1.32 ppm (kidney); all values are ranges and expressed on wet wt. basis. The above data indicate, therefore, that mercury is not transported through the placenta to the young of spiny dogfish (from North Atlantic waters).

Literature Cited

Middle Atlantic Coastal Fisheries Center, NMFS, Sandy Hook, New Jersey. Informal Report No. 5, "Cooperative Study of Contaminants in the Coastal Environment and Their Effects on Living Marine Resources: Summary report 1971-1972.

# TRACE METAL CONCENTRATIONS IN FISH AND SHELLFISH COLLECTED FROM THREE OCEAN DUMP SITES AND THREE CONTROL SITES IN INSHORE WATERS OF THE MIDDLE ATLANTIC BIGHT

## Summary

Rock crab, windowpane flounder, surf clam, and channeled whelk were collected from Long Island Sound, the apex of the New York Bight, several miles off the coast of Delaware, and at Chincoteague Inlet (Virginia). Samples of flesh and livers (or digestive glands) were analyzed for silver, arsenic, cadmium, chromium, copper, manganese, nickel, lead, and zinc. A previous report 1/ presented the results of mercury analyses, primarily, and some data on silver, chromium, cobalt, antimony, selenium, rubidium, and zinc (as obtained by neutron activation analysis) for these collections of fish and shellfish.

The data collected for the report presented here were examined to determine whether differences in metal concentrations in the biota samples correlated with the differences in geographic area of the catch. The rock crab and windowpane flounder collections provided the most useful data of this type.

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1/ Middle Atlantic Coastal Fisheries Center, NMFS, Sandy Hook, New Jersey. Informal Report No. 5, "Cooperative Study of Contaminants in the Coastal Environment and Their Effects on Living Marine Resources: Summary Report 1971-72.

Zinc, copper, silver, and manganese showed the greatest difference in concentrations in the biota for various geographic areas. Zinc and manganese concentrations in rock crab flesh were highest in samples from Long Island Sound. The concentrations were 64 ppm[2/] for zinc and 29 ppm for manganese compared to 32-37 ppm zinc and 0.8-1.4 ppm manganese for the other areas. Zinc levels in the digestive glands of the rock crab were in the range of 26-32 ppm for Long Island Sound, Delaware, and Chincoteague Inlet, whereas the zinc level was about 18 ppm in the digestive gland of crabs collected in the apex of the New York Bight. The concentrations of these metals in windowpane flounder were not appreciably different for various geographic areas. Copper concentrations in rock crab digestive glands were highest for Long Island Sound collections, but the highest copper level in rock crab flesh occurred for collections from the New York Bight. Digestive glands contained about 160 ppm for crabs from the Sound compared to levels of 50-70 ppm in digestive glands of crabs from other areas. Copper analyses of flesh samples were for three locations only - Long Island Sound and two sub-areas of the New York Bight (designated areas A and B in the report). The copper content of flesh samples from area B of the Bight was 25 ppm compared to 13-15 ppm in flesh samples from the other areas.

The highest concentrations of chromium in digestive glands of rock crab and of lead in the flesh of rock crab were found for Long Island

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2/ All concentrations of metals in biota samples are ppm, wet weight basis.

Sound collections. Chromium levels were 1.2 ppm for samples from the Sound compared to levels of 0.4-0.5 ppm for the other areas; lead concentrations were 3.4 ppm for Long Island Sound samples and about 1.3 ppm for the other areas. The number of samples analyzed, however, were few and thus these data provide only a slight indication of differences in concentrations of these metals as related to geographic area. Most of the other samples of rock crab and windowpane flounder had chromium and lead concentrations that were less than 1 ppm for all areas sampled.

Nickel concentrations in rock crab digestive glands were in the range of 2-3 ppm for Long Island Sound, Delaware, and Chincoteague Inlet collections compared to concentrations of about 1.2 ppm for the New York Bight areas. The nickel levels in the flesh of crabs and in the tissues of windowpane flounder did not differ substantially as a function of geographic area of catch; most of these samples from both species had nickel concentrations that were less than 1 ppm.

## Introduction

The study termed the "Cooperative Ocean Dump Site Study" was initiated in April, 1971 and continued for about a year and a half. The objective of this study was to examine primarily the levels of mercury and, to the extent possible, several other metals in three target species of fish and shellfish collected from ocean dump sites in the New York Bight, Long Island Sound (New Haven area), and off Delaware Bay. Sites

picked as control areas were at Chincoteague Inlet (Virginia), Barnegat Bay (New Jersey), and near Charles Island (near Milford, Ct.) in Long Island Sound. The target species were: windowpane flounder (*Scophthalmus aquosus*), rock crab (*Cancer irroratus*), and surf clam (*Spisula solidissima*).

For the first several months of the study, mercury determinations were performed in-house whereas the other metals were determined by outside, contracted groups. Data were obtained on the metals antimony, cobalt, chromium, rubidium, silver, selenium, and zinc by neutron activation analysis at the University of Michigan, Phoenix Memorial Laboratory. A private analytical laboratory (Analytical Services, Inc., Kensington, Md.) provided data for the metals aresenic, cadmium, chromium, and lead through atomic absorption analysis.

The majority of data collected for mercury and the seven metals determined by neutron activation analysis for this study were presented in a previous Middle Atlantic Coastal Fisheries Center report (1). Data on the metals arsenic, cadmium, chromium, and lead as determined by atomic absorption analysis (Analytical Services, Inc.) was not completed in time to be included in that report.

The results of mercury analyses showed there was little difference in concentrations of this metal in both rock crab and windowpane flounder tissues for the various geographic areas sampled. Mercury concentrations ranged from 0.09-0.24 ppm in rock crab samples and from 0.13-0.29 ppm in windowpane flounder samples.

The data for the seven other metals were limited. Nonetheless, no substantial differences in these metal concentrations (Ag, Cr, Sb, Se, Rb, and Zn) in windowpane flounder and rock crab samples were evident for the various geographic areas studied.

Only a small number of surf clam were collected from one location during the first year of the study. Channeled whelk were collected from Long Island Sound in lieu of the surf clam, but these organisms were not collected from the other areas listed above.

In-house capabilities were developed by about June, 1972 to determine the metals Ag, Cd, Cr, Cu, Mn, Ni, Pb, and Zn in biota, thus, most of the samples collected during the study were analyzed by our own staff.

When the Cooperative Ocean Dump Site study phased out, collections of biota and sediment were concentrated on a broader area of the New York Bight (including the ocean dump site area) and Long Island Sound. These studies have been divided into two separate studies and a separate summary is presented for the work conducted on the trace metal concentrations in sediments of Long Island Sound (see next section). Data on biota from Long Island Sound, however, are included in the report presented here to provide a comparison of metal concentrations in the biota from the various geographic areas collected during the Ocean Dump Site Study.

A number of other fish and shellfish than those listed above have been collected from the New York Bight area as part of a baseline study of metal concentrations in biota and sediments from that area. The result of this work is not presented here because the data have not yet been thoroughly analyzed.

The purpose of this report, therefore, is to present previously unreported data on the concentrations of arsenic, cadmium, copper, manganese, nickel, and lead in rock crab, windowpane flounder, surf clam, and channeled whelk collected as part of the Cooperative Ocean Dump Site Study. The levels of chromium, silver, and zinc in these samples are also presented because substantial additional information was obtained since the previous report (1).

## Materials and Methods

### Sample Collection and Preparation

Procedures for preparation of the biota samples were as described in the section titled "Survey of Mercury Concentrations in Finfish from North Atlantic Offshore Waters". Collections of the biota were made by biologists from the Mildord, Conn., Oxford, Md., and Sandy Hook, N.J. laboratories of the NMFS.

### Chemical Methodology

Neutron activation analyses were conducted by the same procedure as described in the section titled "Trace Element Concentrations in Sediments from Long Island Sound - 1972 Survey".

Analytical Consulting Services, Kensington, Md. used the methodology described by Dalton and Malonoski (Journal of the Association of Official Analytical Chemists, 52(5): 1969). Briefly, the samples were ashed at 500°C for three hours using magnesium nitrate as an ashing aid. The residue after ashing was dissolved in dilute nitric acid, diluted to an appropriate volume and analyzed on a Perkin Elmer Model 403 atomic absorption spectrometer.

At the NMFS, Milford, Ct. laboratory, 5-10 g samples were first charred on a hot plate or over a bunsen burner and then ashed at 400°C for about an hour, cooled and "wetted" with concentrated nitric acid. This process was repeated every hour until a white ash was obtained (usually 4-6 additions of acid). After ashing, 5 ml of concentrated nitric acid was added to the samples and evaporated to dryness on a hot plate. Ten percent nitric was used to transfer the residue through filter paper (Whatman No. 2) to flasks for dilution up to 10 or 25 ml. The acid solutions were analyzed on a Perkin Elmer Model 403 atomic absorption spectrometer; a deuterium background correction attachment was used for chromium and lead determinations.

No distinction for methods is made for the metals analyzed by two or more laboratories for the data presented in this report. This was done because the agreement between laboratories analyzing the same metals was considered good enough to average the data for the geographic areas sampled (for each species and tissue).

There were a few sporatic disagreements in the data for lead, in particular, and chromium between the laboratories analyzing these metals. Where the discrepencies were too great, the data were not included in the average values given in the tables.

The arsenic data was obtained only by the Analytical Consulting Services, Inc. Laboratory (Kensington, Md.). Data for cadmium, chromium, and lead were obtained by both the laboratory listed above and the NMFS

laboratory at Milford, Ct. Both the Milford laboratory and the University of Michigan (Phoenix Memorial Laboratory) analyzed samples for silver. Data on copper, manganese, and nickel were obtained only by the Milford Laboratory. The Phoenix Memorial Laboratory was the only lab to obtain data on zinc in these biota samples.

## Results and Discussion

The data from this study were analyzed from the standpoint of comparing differences in metal concentrations in the biota as a function of the geographic area of catch. Rock crab tissue and organ samples and windowpane flounder flesh samples provided most data for this type of analysis.

Because of the limited number of geographic areas covered or the small number of samples collected per area, the surf clam and channeled whelk samples and the livers of the flounder provided very limited data for this type of comparison.

### Rock Crab and Windowpane Flounder

The latitude and longitude information for the geographic areas sampled are shown in Table 18. The data referred to in the following paragraphs are found in Tables 19 and 20.

A marked difference in silver concentrations was found for rock crab flesh obtained from the New York Bight (Area A) compared to rock crab flesh obtained from the other four areas (Long Island Sound, Delaware, Chincoteague Inlet, New York Bight - Area B). The level of silver averaged

Table 18. Latitude and Longitude Information for the Georgraphic Areas of Biota Collections Listed in Tables 19-21.

| Geographic Area | Location by Latitude, Longitude |
|---|---|
| Long Island Sound - Area 1 (New Haven Ocean Dump Site) | 41°09.00' 72°51.60' 72°54.2' 41°08.50' |
| Long Island Sound - Area 2 | 41°09'N; 73°01'W |
| New York Bight - Area A (New York Ocean Dump Site) | 40°28.4' 73°45.0' 73°52.3' 40°24.5' |
| New York Bight - Area B | Samples obtained from the following stations:<br>X - 40°16.5'N; 73°46.9'W<br>Y - 40°12.0'N; 73°44.3'W |
| New York Bight - Barnegat Bay | 39°50.3'N; 74°02.2'W |
| Delaware - Area 1 (Delaware Ocean Dump Site) | 38°46.0'N; 74°46.55'W |
| Chincoteague Inlet | 37°50'N; 75°15'W |

Table 19. Metal Concentrations in Flesh and Digestive Glands of Rock Crab Collected from Various Inshore Areas of the Mid-Atlantic Bight.

| METAL | CATCH INFORMATION<br>Area and Time of Year* | | | | |
|---|---|---|---|---|---|
| | Long Is. Sound<br>Area 2<br>F,W, 1971 | New York Bight<br>Area A<br>Sp,S,F,'71<br>Sp,'72 | New York Bight<br>Area B<br>Sp,'72 | Delaware<br>Area 1<br>Sp,F, 1971 | Chincoteague<br>Inlet<br>Sp,S,F,W, 1971 |
| | Metal Concentrations<br>Average ppm (wet wt.)±standard error** | | | | |
| | FLESH | | | | |
| Ag | 0.28±0.07 | 0.79±0.2 | 0.24±0.03 | 0.38±0.08 | 0.26±0.1 |
| As | -- | -- | -- | 1.9 | -- |
| Cd | 1.0 | < 0.1(8) | < 0.1(4) | 0.08 | < 0.1(3) |
| Cr | 0.6±0.12 | < 0.5(12) | < 0.4(4) | < 0.3(4) | < 0.5(5) |
| Cu | 13.0±1.7 | 14.8±0.5 | 25.4±5 | -- | -- |
| Mn | 28.7±4.5 | 0.8±0.1 | 1.1±0.08 | 1.4 | 0.83 |
| Pb | 3.4 | < 1.3(8) | < 1.1(4) | 0.9 | < 0.5(3) |
| Ni | -- | 0.8±0.2 | 1.5±0.2 | 0.9 | < 0.7(3) |
| Zn | 64.4±7.0 | 32.1±3.8 | -- | 37.3 | 35.5 |
| | DIGESTIVE GLANDS | | | | |
| Ag | 3.1±0.4 | 3.4±0.6 | 2.1±0.5 | 3.1 | 2.6±0.2 |
| As | -- | -- | -- | -- | -- |
| Cd | *** | 1.1±0.3 | *** | 3.2±1.0 | 4.8 |
| Cr | 1.2±0.4 | < 0.6(10) | < 0.5(4) | 0.4±0.04 | 0.5±0.1 |
| Cu | 161 | 73±10 | 48±5 | -- | 66 |
| Mn | *** | 1.9±0.3 | 3.0 | 2.3 | 2.3 |
| Pb | 1.3±0.3 | < 0.6(7) | < 0.6(4) | 1.0±0.2 | 0.8 |
| Ni | 2.5±0.8 | 1.3±0.1 | 1.1±0.1 | 2.2±0.3 | 2.8 |
| Zn | 31.2±3.1 | 18.1±1.5 | 18.5±0.2 | 25.9 | 31.5 |

* Time of year is indicated by--S: Summer, Sp: Spring, F: Fall, W: Winter

** Standard errors were calculated only when four or more sets of animals (10 animals per set) were analyzed. When less than values (<) are reported for averages, the number of sets of animals analyzed is given in parentheses.

*** The cadmium and manganese concentrations for these samples were too variable to average the data. See text for descriptions of these data.

Table 20. Metal Concentrations in Flesh and Livers of Windowpane Flounder Collected from Various Inshore Areas of the Mid-Atlantic Bight.

| METAL | CATCH INFORMATION Area and Time of Year* | | | | | |
|---|---|---|---|---|---|---|
| | Long Is. Sound Area 1 S,F,W,'71 | Long Is. Sound Area 2 S,W,'71 | New York Bight Area A Sp,S,F,'71 Sp,'72 | New York Bight Barnegat Bay Sp,S,'71 | Delaware Area 1 Sp,S,F,W,1971 | Chincoteague Inlet Sp,S,F,1971 |
| | Metal Concentrations Average ppm (wet wt.)±standard error** | | | | | |
| | FLESH | | | | | |
| Ag | <0.1(10) | <0.1 | <0.1(7) | <0.1(6) | <0.1(9) | <0.1(6) |
| As | 2.7 | -- | 1.4 | 2.8±0.5 | 1.8±0.3 | 2.0 |
| Cd | <0.1(9) | <0.1 | <0.1(7) | <0.1(6) | <0.1(10) | <0.1(4) |
| Cr | 0.6±0.3 | <0.3 | <0.5(7) | <0.5(7) | <0.5(10) | <0.2(6) |
| Cu | 0.7±0.15 | 1.4 | 1.0 | -- | -- | -- |
| Mn | 0.4±0.07 | 0.3 | 0.26±0.03 | 0.18±0.01 | 0.23±0.05 | 0.35±0.09 |
| Pb | <0.5(8) | <0.6 | <0.5(7) | 0.5±0.1 | 1.0±0.15 | 0.8±0.14 |
| Ni | 0.3±0.1 | <0.5 | 0.2±0.04 | 0.2 | 0.4±0.15 | <0.2(4) |
| Zn | 5.8±0.9 | 5.0 | 4.6 | 5.1 | 6.2±1.4 | 6.3 |
| | LIVER | | | | | |
| Ag | <0.1(5) | <0.1(2) | 0.6 | <0.5(4) | <0.1(6) | <0.1(3) |
| As | -- | -- | -- | -- | -- | -- |
| Cd | -- | -- | -- | <0.1(2) | 0.1 | <0.1 |
| Cr | <0.7(5) | <0.5(2) | <0.4(3) | <0.3(3) | <0.5(6) | <0.3(3) |
| Cu | -- | -- | -- | -- | 10.5 | -- |
| Mn | -- | -- | -- | 2.5 | 1.7 | -- |
| Pb | -- | -- | -- | <0.5(2) | 1.7 | -- |
| Ni | -- | -- | -- | <0.3(2) | <0.2 | -- |
| Zn | 36.8±1.1 | 34.1 | 38.2 | 41.9 | 32.2±3 | 35.2 |

* Time of year is indicated by--S: Summer, Sp: Spring, F: Fall, W: Winter

** Standard errors were calculated only when four or more sets of animals (10 animals per set) were analyzed. When less than values (<) are presented for averages, the number of animals are given in parentheses.

about 0.8 ppm (wet wet.[3]) in this sample from the first area mentioned whereas this sample from the other areas averaged about 0.3 (± 0.08) ppm. The variability of silver concentrations for individual crab flesh collections was large for New York Bight (Area A) samples. For example, 6 of the 11 collections from this area had levels of silver at 0.3 ppm or less and 5 of 11 collections had levels at 1 - 2 ppm. These differences did not appear to be associated with season of catch. Because of this variability in the data, a statistical significance could not be attached to the differences observed in average concentrations for Area A of the Bight compared to the other four areas sampled. The variability in data was not this great for the collections from the latter four areas.

No appreciable differences in silver concentrations were found for both rock crab digestive glands and windowpane flounder flesh for the various geographic areas sampled. The silver concentrations were about 2 - 4 ppm and 0.1 ppm in these two samples, respectively, for all areas.

Substantial differences in zinc concentrations for various geographic areas were found in both flesh and digestive gland samples of rock crab. Zinc concentrations in rock crab flesh were nearly twice as great for Long Island Sound (Area 2) as for the other three areas of collection, the average levels were about 64 and 32-37 ppm, respectively. The zinc concentrations in rock crab digestive glands were about 1.7 times greater for Long Island Sound samples than for New York Bight samples

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3/ All values referred to in this report are on a wet wt. basis.

(both Areas A and B); the zinc levels in the digestive glands averaged about 31 and 18 ppm, respectively, for these areas.

No appreciable differences were found for zinc concentrations in windowpane flounder flesh and liver samples for the various geographic areas.

The level of manganese found in rock crab flesh was much greater for samples obtained from Long Island Sound (Area 2) than samples obtained from the other four areas. The manganese concentrations averaged about 29 ppm for the Long Island Sound samples compared to an average of about 1 ppm for the other areas.

Manganese concentrations in flesh and liver of windowpane flounder and in digestive glands of rock crab did not differ substantially as a function of geographic areas. Digestive gland samples from Long Island Sound, however, had manganese concentrations that varied greatly for various collections of crabs. Three samples (10 crabs per sample) had levels of manganese at 12-15 ppm whereas two other samples had levels at 2.4 and 3 ppm; the former samples were collected the summer and fall of 1971 and of 1972. There was not sufficient data to attribute these differences to either seasonality or yearly differences in collection periods.

The copper concentrations in rock crab flesh and digestive glands varied greatly between certain geographic areas of catch. Digestive glands of rock crabs obtained from Long Island Sound had the highest

copper concentrations (average of about 161 ppm) while next highest in copper were samples from the New York Bight (Area A) and Chincoteague Inlet areas at about 70 ppm and the lowest concentration found was at 50 ppm for New York Bight Area B samples. The significance of the difference for Long Island Sound samples compared to the other sample collections could not be determined because the number of collections from this area was small (three samples of ten crabs per sample). Somewhat of a reversal in this order (just presented) for copper concentrations was found for rock crab flesh samples. The highest copper concentration in flesh (average level 25 ppm) was found in crabs obtained from New York Bight (Area B) whereas copper levels in rock crab flesh were 13-15 ppm for New York Bight (Area A) and Long Island Sound collections. Copper concentrations were not determined for the Delaware and Chincoteague Inlet collections of rock crab flesh.

Copper analyses were conducted on flesh samples of windowpane flounder from just three areas - Long Island Sound (Areas 1 and 2) and New York Bight (Area A). The level of copper in this sample averaged 0.7 and 1.4 ppm for areas one and two of Long Island Sound, respectively. No significance can be attached to this difference because only two collections of flounder (10 fish per collection) were obtained from area two. Flesh of flounder from the New York Bight (Area A) had a copper level of 1 ppm (average).

Arsenic, nickel, chromium, cadmium, and lead determinations were made in addition to the metal analyses described above.

Arsenic analyses were conducted on just two tissue samples - the flesh of windowpane flounder from five of the six geographic areas and the flesh of rock crab from only one geographic area (Delaware). The average arsenic content of the rock crab flesh sample was 1.9 ppm. The arsenic content in flesh of flounder ranged from 1.4 to 2.8 ppm (average values) for all geographic areas sampled. The differences in the arsenic concentrations in this sample for the various areas was judged to be not significant based on the substantial variation in concentrations observed for samples within a single geographic area.

The nickel concentrations in flesh of rock crab were not substantially different for the two areas in the New York Bight and the Delaware area; concentrations ranged from 0.8 to 1.5 ppm (average value) for these areas. Samples from Chincoteague Inlet had nickel concentrations that were below the detection limit for these particular samples (0.7 ppm). Nickel concentrations in digestive glands of rock crab were about 2-3 ppm for crabs from Long Island Sound, Delaware, and Chincoteague Inlet Areas compared to concentrations of about 1.2 ppm for this sample from both areas of the New York Bight. The number of crabs collected from the first three areas listed above was small (four or less sets of 10 crabs per set), thus, the data presented only give an indication that the nickel concentrations indigestive glands of rock crabs are substantially less than 0.5 ppm in both liver and flesh samples of windowpane flounder.

Analyses for nickel were made on flesh samples from all six areas whereas analyses on livers were conducted on samples from just two areas (New York Bight, Area B and Delaware).

Some differences were found for lead and chromium concentrations that were related to geographic area of catch; however, the levels of metals found generally were quite low and good quantitation was difficult by the methodology employed. The only difference in chromium concentrations was found in rock crab digestive gland samples. The chromium concentration for this sample was 1.2 $\pm$ 0.4 (average $\pm$ standard error) for the Long Island Sound (Area 2) collections compared to concentrations of 0.4 $\pm$ 0.04 and 0.5 $\pm$ 0.1 ppm for the Delaware and Chincoteague Inlet collections, respectively. Samples from both New York Bight Areas had chromium concentrations less than 0.6 ppm. The chromium levels in windowpane flounder (flesh and livers) and rock crab flesh were less than 0.8 ppm for all geographic areas.

The lead concentration in flesh of rock crab from Long Island Sound (Area 2) averaged 3.4 ppm compared to average lead concentrations of less than 1.3 ppm for samples from the other four areas sampled. There were too few rock crab samples analyzed from Long Island Sound (three sets of 10 crabs per set), however, to place significance on these differences. The lead concentrations of rock crab digestive glands and both tissue samples of windowpane flounder were in the range of 0.5 - 1.5 ppm; any differences found at these levels were considered as not significant because the analytical precision was not good for these concentrations.

Cadmium concentrations varied greatly for rock crab digestive gland samples both between various geographic areas and within samples from a single geographic area. For Long Island Sound, cadmium concentrations in this sample were 6.4, 12.0, and 17.3 ppm for three collections (summer and fall, 1971) and 1.5 and 4.3 ppm for two other collections (spring, 1972). For the New York Bight (Area B), one collection of crab had a cadmium concentration of 13 ppm in the digestive gland whereas three other collections had levels of 0.2 - 0.4 ppm in this sample (all collections were made in the spring, 1972). Valid comparisons between areas could not be made because of this variability in cadmium concentrations among samples from a single area. The cadmium concentrations in digestive glands of crabs for the other areas were 4.8, 3.2 $\pm$ 1 and 1.1 $\pm$ 0.3 ppm (average $\pm$ standard error) for Chincoteague Inlet, Delaware, and New York Bight (Area A), respectively.

The flesh of rock crab had an average cadmium content of 1 ppm for Long Island Sound (Area 2) compared to levels that were less than 0.1 ppm for the other four areas. Only three samples (10 crabs per sample) were analyzed for cadmium from the Sound and the significance of differences observed could not be established. Cadmium concentrations in livers and flesh of windowpane flounder were less than 0.1 ppm for all areas sampled.

Surf Clam and Channeled Whelk

Channeled whelks were collected primarily from area one, with some collections from area two of Long Island Sound; one collection from Chincoteague Inlet was obtained also.

Differences in concentrations of silver, cadmium, copper, and zinc in the digestive gland of whelks were found among the three areas from which whelks were collected (Table 21). A note of interest about the digestive gland of the whelk is that this organ had concentrations of these four metals that were as great as 60-100 times greater than in the muscle. This order of magnitude of difference between these tissue samples was not found for the rock crab or windowpane flounder (data described above). Also, the concentrations of these four metals in the digestive gland of whelks were the highest observed of all the samples examined in this study.

Silver concentrations in digestive glands of whelks were nearly three-fold greater for area one of Long Island Sound than the other two areas sampled. The approximate concentrations of silver were 20 ppm and 6-7 ppm, respectively.

Cadmium concentrations were nearly two-fold greater in the digestive gland of whelks from area one of Long Island Sound compared to area two of the Sound and about three-fold greater for area one compared to Chincoteague Inlet. The concentrations of cadmium were about 24, 16, and 7 ppm, respectively. Digestive glands of whelks from areas one and two of Long Island Sound had fairly similar copper concentrations (about 1,100 ppm, average). The copper level in the sample from Chincoteague Inlet was much lower, 32 ppm, than the Long Island samples.

Table 21. Metal Concentrations in Muscle of Surf Clam and Muscle and Digestive Glands of Channeled Whelk Collected from Various Inshore Areas of the Mid-Atlantic Bight.

| METAL | CATCH INFORMATION Area and Time of Year* | | | |
|---|---|---|---|---|
| | Long Is. Sound Area 1 S,F,W,'71 S,F,'72 | Sound Area 2 S,'71 S,F,'72 | Delaware Area 1 Sp,5 1971 | Chincoteague Inlet S.C.--S,'71; W,'72 C.W.--Sp,'72 |
| | Metal Concentrations Average ppm (wet wt.)±standard error** | | | |
| | SURF CLAM MUSCLE | | | |
| Ag | -- | -- | < 0.2(3) | < 0.1 |
| As | -- | -- | -- | 1.3±0.09 |
| Cd | -- | -- | < 0.2(3) | < 0.1(4) |
| Cr | -- | -- | < 0.7(3) | < 0.5(4) |
| Cu | -- | -- | 1.1 | 0.9 |
| Mn | -- | -- | 1.9 | 0.5±0.07 |
| Pb | -- | -- | < 0.5(3) | < 0.5(4) |
| Ni | -- | -- | 1.4 | 1.2±0.2 |
| Zn | -- | -- | 18.4 | -- |
| | CHANNELED WHELK MUSCLE | | | |
| Ag | 0.18±0.04 | < 0.2(5) | -- | < 0.1(1) |
| As | -- | 9.0 | -- | -- |
| Cd | 0.21±0.02 | 0.17±0.05 | -- | < 0.1(1) |
| Cr | < 0.4(23) | < 0.8(5) | -- | < 0.5(1) |
| Cu | 19.3±1.4 | 21±3.1 | -- | 11.9 |
| Mn | 2.4±0.1 | 2.4±0.26 | -- | 3.5 |
| Pb | 0.7±0.1 | < 0.7(5) | -- | 0.9 |
| Ni | 1.0±0.1 | 0.9±0.2 | -- | 2.2 |
| Zn | 26±0.9 | 29.5 | -- | 15.3 |
| | CHANNELED WHELK DIGESTIVE GLAND | | | |
| Ag | 19.7±3 | 6.4 | -- | 6.8 |
| As | -- | -- | -- | -- |
| Cd | 23.8±3.3 | 15.7 | -- | 7.4 |
| Cr | < 0.8(17) | 0.8 | -- | < 0.5 |
| Cu | 1,135±148 | 1,080 | -- | 32.4 |
| Mn | 3.5±0.3 | 4.8 | -- | 5.7 |
| Pb | 1.3±0.1 | 1.1 | -- | 1.7 |
| Ni | 1.2±0.2 | 1.7 | -- | 5.7 |
| Zn | 2,650±183 | 1,025 | -- | 405 |

* Time of year is indicated by S: Summer, Sp: Spring, F: Fall, W: Winter

** Standard errors were calculated only when four or more sets (10 animals per set) were analyzed.

Zinc concentrations in digestive glands of whelks were about twice as great for area one compared to area two of Long Island Sound and about six-fold greater for area one compared to Chincoteague Inlet samples. The average concentrations found were 2,650, 1,025, and 405 ppm for the three areas, respectively.

The chromium, manganese, and lead concentrations in the digestive gland of channeled whelk was not appreciably different for the various geographic areas sampled. The concentrations of these metals in this sample were: less than 0.8 ppm chromium, 3-6 ppm manganese, and 1.0 - 1.7 ppm lead. Nickel concentrations in this sample were 5.7 ppm for the Chincoteague Inlet area and 1.2 - 1.7 ppm for the two areas in Long Island Sound.

Metal concentrations in the muscle of channeled whelk were not appreciably different (with the exceptions of zinc and copper) for the various geographic areas sampled. The copper concentration in muscle of whelk was nearly two-fold greater for Long Island Sound samples (both areas one and two) compared to Chincoteague Inlet samples. As eluded to earlier, the concentrations of zinc and copper in the muscle was much less than in the digestive gland of the whelk; samples from the Long Island Sound areas had zinc levels at about 25-30 ppm compared to 15 ppm in muscle from Chincoteague Inlet. Copper concentrations were about 20 ppm and 12 ppm for these areas, respectively. Data on

arsenic were obtained on just one sample of whelk muscle - from area two of the Sound - thus no comparison between areas was possible; the arsenic concentration in this sample was 9 ppm.

The concentrations of the other metals in the muscle of channeled whelk from all areas were: $<$ 0.2 ppm, silver; $<$ 0.1 - 0.2 ppm, cadmium; $<$ 0.8 ppm, chromium; 2.4 - 3.5 ppm, manganese; $<$ 0.7 - 0.9 ppm, lead; and 1-2 ppm, nickel.

Surf clams were collected from the Delaware and Chincoteague Inlet areas of the total of seven areas sampled for rock crab and windowpane flounder. No appreciable differences in metal concentrations were found in the muscle of surf clam for these two geographic areas; zinc and arsenic data, however, were obtained from just one area and no comparison of areas was possible for these metals. The concentrations of silver, cadmium, chromium, nickel, lead, and zinc were about the same order of magnitude as found in channeled whelk muscle for these metals. The copper and arsenic concentrations in surf clam muscle were much lower than in whelk muscle; about 1 ppm versus 12-20 ppm for copper and 1 ppm versus 9 ppm for arsenic, respectively. Manganese concentrations were slightly lower in surf clam muscle compared to whelk muscle; 0.5 - 1.9 ppm versus 2.4 - 3.5 ppm, respectively.

In addition to the surf clam collections listed in Table 21, surf clams were collected from a number of other geographic locations. The results of metal analyses for these surf clam samples are shown in Table 22. The geographic location is given by latitude and longitude

Table 22. Metal Concentrations in Muscle of Surf Clam Collected from Additional Areas (to those listed in Table 21) of the Mid-Atlantic Bight.

| Collection Number* | Catch Location Latitude | Longitude | Metal Concentrations** ppm, wet wt. Ag | Cd | Cu | Mn | Ni | Zn |
|---|---|---|---|---|---|---|---|---|
| 1 | 41°20' | 71°53' | 0.34 | <0.05 | 1.7 | 0.3 | 0.6 | -- |
| 2 | 40°33.3' | 73°43.4' | 1.2 | 0.34 | 3.0 | 4.8 | 1.6 | 14.4 |
| 3 | 40°31.1' | 73°50.3' | 1.0 | 0.34 | 8.1 | 12.7 | 3.8 | -- |
| 4 | 39°26.5' | 74°14.2' | 0.23 | 0.07 | 1.1 | 0.7 | <0.5 | 17.9 |
| 5 | 39°26.4' | 74°19.0' | <0.05 | <0.05 | 1.7 | 1.7 | <0.5 | 17.7 |
| 6 | 39°26.1' | 74°17.5' | 0.07 | <0.05 | 1.3 | 1.3 | <0.5 | 17.0 |
| 7 | 39°25.5' | 74°19.4' | <0.05 | <0.05 | 1.6 | 2.6 | 3.9 | -- |
| 8 | 39°24.2' | 74°18.4' | <0.05 | 0.08 | 1.2 | 1.3 | <0.5 | 15.1 |
| 9 | 39°24.2' | 74°20.6' | <0.05 | <0.05 | 1.4 | 1.9 | 1.9 | 15.9 |
| 10 | 39°22.5 | 74°20.3' | 0.15 | <0.05 | 1.3 | 1.5 | <0.5 | 18.9 |
| 11 | 39°21.4' | 74°23.5' | <0.05 | 0.22 | 2.4 | 2.5 | 3.5 | -- |
| 12 | 39°20.2' | 74°19.3' | 0.08 | 0.05 | 1.8 | 0.7 | <0.5 | 13.9 |
| 13 | 39°18.6' | 74°22.5' | 0.1 | 0.12 | 1.6 | 1.2 | 1.5 | -- |
| 14 | 39°18.3' | 74°26.3' | <0.05 | 0.10 | 1.5 | 1.3 | 2.0 | -- |
| 15 | 39°18.2' | 74°20.3' | <0.05 | <0.05 | 1.2 | 0.9 | <0.5 | 18.6 |
| 16 | 39°17.3' | 74°24.4' | 0.16 | <0.05 | 2.6 | 1.5 | <0.5 | 16.6 |
| 17 | 39°17.1' | 74°28.3' | 0.23 | <0.05 | 0.9 | 1.1 | <0.5 | 14.1 |
| 18 | 39°15.3' | 74°29.2' | <0.05 | <0.05 | 1.1 | - | - | -- |
| 19 | 39°10.0' | 74°35.2' | 0.09 | 0.10 | 1.1 | 1.5 | <0.5 | 15.7 |
| 20 | 39°09.4' | 74°38.4' | 0.09 | 0.06 | 0.9 | 1.2 | 1.6 | -- |
| 21 | 39°08.3' | 74°36.4' | <0.05 | 0.10 | 1.0 | 1.3 | <0.5 | 16.4 |
| 22 | 39°08.0' | 74°40.3' | 0.2 | <0.05 | 1.8 | 1.6 | 1.7 | -- |
| 23 | 39°07.3' | 74°38.0' | 0.08 | 0.07 | 0.9 | 0.9 | 1.4 | -- |
| 24 | 39°04.2' | 74°39.2' | 0.11 | 0.05 | 1.5 | 1.0 | 1.4 | -- |
| 25 | 39°01.3' | 74°42.0 | <0.05 | 0.12 | 1.9 | 1.2 | <0.5 | 16.2 |
| 26 | 39°00.1' | 74°25.1' | <0.05 | <0.05 | 1.9 | 1.6 | 2.1 | -- |

* Collections 1, 2, were obtained in June, 1971. Collection 3 was obtained Feb. 1972; all others were obtained in June, 1972.

** Analyses were conducted for Cr, Hg, and Pb in addition to those metals listed. Chromium was not detectable (concentrations were less than about 0.6-0.8 ppm, wet wt.) in all samples except collections 2 and 3 at 0.8 ppm and 2.3 ppm, respectively. Mercury was not detectable (less than 0.05 ppm, wet wt.) in any of the samples. Lead concentrations were less than 1 ppm in all samples.

in Table 22 and each collection in the table is assigned an arbitrary number from 1 to 26. Collection one came from Little Narragansett Bay (Rhode Island) in Long Island Sound. Collections two and three came from several miles south of East Rockaway Inlet, Long Island. The other samples came from various locations along the Southern New Jersey coastline from just south of Barnegat Bay to Cape May Inlet.

The metal concentrations in these surf clam samples generally were about the same magnitude as found in surf clams from the Delaware and Chincoteague Inlet areas. Notable exceptions, however, were the surf clams collected from two areas south of East Rockaway Inlet (collections 2 and 3, Table 22).

The silver and cadmium levels in the muscle of surf clams from these two areas were about 1 - 1.2 ppm and 0.34 ppm, respectively, compared to concentrations in this sample for all other areas that generally were less than 0.3 ppm silver and less than 0.1 ppm cadmium. The copper and manganese concentrations in clam muscle differed for these two areas, but both were higher than samples from most other areas. The copper concentrations in these samples were 8.1 ppm for collection three and 3 ppm for collection two, while all other surf clam samples generally had copper levels at 1 - 2 ppm, although two samples had levels at 2.4 and 2.6 ppm copper (Table 22). The manganese concentration in muscle of surf clams was 12.7 ppm for collection three and 4.8 ppm for collection two (Table 22). Surf clam muscle from all other areas were less than 2.6 ppm in manganese.

The nickel levels were highest for collections three, seven, and eleven (Table 22) at concentrations of 3.5 - 3.9 ppm in the muscle of surf clam. Clam muscle from the other areas had nickel concentrations that were less than 2.1 ppm and most were in the range of 0.6 - 1.6 ppm.

# TRACE METAL CONCENTRATIONS IN SEDIMENTS FROM LONG ISLAND SOUND

(1972 Survey)

## Summary

A summary of the results obtained for this study is presented in the next several paragraphs. A more comprehensive report is being prepared that will cover both 1972 and 1973 survey results.

Sediments were collected from 162 stations that covered about 23 north - south transects of Long Island Sound. The top 1 1/2 inches of sediment from a core about 1 3/4 inches in diameter was analyzed for silver, cadmium, mercury, selenium, cobalt, chromium, copper, manganese, nickel, lead, antimony, scandium, and zinc (Table 23).

Five of these metals had fairly similar patterns of distribution in sediments for various areas of the Sound. The general trends in distribution of chromium, copper, nickel, lead, and zinc in sediments for various areas of the Sound are described in the next two paragraphs.

The highest concentrations of these metals occurred at stations in the extreme western end of the Sound (near New York City) and at stations in the mid-western end of the Sound. The stations nearest the Long Island coastline and stations east of longitude 72°30' had the lowest concentrations of these metals for all stations sampled. Sediments from stations west of longitude 73°15' generally had higher concentrations of these metals than sediments from stations in the central part of the Sound (between longitude 72°30' and 73°15').

Table 23. Metal Concentrations in Sediments Collected from Long Island Sound in the Summer of 1972.

| Metal | Metal Concentrations for Various Sections of Long Is. Sound | | | | | |
|---|---|---|---|---|---|---|
| | ppm, dry weight basis | | | | | |
| | Western 1/ | | Central 1/ | | Eastern 1/ | |
| | Average | Range | Average | Range | Average | Range |
| Cd | < 1.5 | < 1- 4.1 | < 1.3 | < 1- 2.9 | < 1 | 1- < 1 |
| Cr | 46.9 | < 2- 127 | 28.8 | < 2-108 | 6.6 | < 2- 35 |
| Cu | 102.4 | < 2- 269 | 69.6 | < 2-269 | 9.9 | 2- 44 |
| Mn | 293.2 | 12-1218 | 187.1 | 15-403 | 149 | 16-409 |
| Ni | 15.5 | 2- 41.6 | 11.2 | < 2- 40.6 | 5.1 | < 2- 18.5 |
| Pb | 55.1 | < 6- 210 | 27.8 | < 6- 63 | 11.9 | < 6- 48 |
| Zn | 140.7 | 4.2- 354 | 87.8 | 2.3-214 | 34.6 | 6-118 |
| | Northern Shore 2/ | | Southern Shore 2/ | | | |
| | Average | Range | Average | Range | | |
| Cd | < 1 | < 1- 1 | < 1 | < 1- 1 | | |
| Cr | 31.6 | 2- 108 | 6.1 | < 2- 88 | | |
| Cu | 68.1 | 5- 269 | 13.5 | < 2-217 | | |
| Mn | 157.7 | 54- 408 | 86.5 | 16-311 | | |
| Ni | 13.1 | < 2- 41 | 7.9 | 3- 31 | | |
| Pb | 29.3 | < 6- 63 | 11.8 | < 6-161 | | |
| Zn | 91.4 | 17- 214 | 28.1 | 6-354 | | |

1/ About 40-50 stations were sampled in each of these sections of the Sound.

2/ Only the stations nearest the coastline were grouped together for these designations. Twenty-four stations were represented in the Northern shore and twenty-one stations for the Southern shore. The Northern shore is the Connecticut, Rhode Island, etc. coastline. The Southern shore is the Long Island coastline.

The highest concentrations found for these metals in the sediments of Long Island Sound were: zinc - 354 ppm*, lead - 210 ppm, copper - 258 ppm, chromium - 280 ppm, and nickel - 42 ppm. The lowest concentrations found for these metals were on the order of 2 - 5 ppm for all metals. The sediment types were described as fine, beach-like, sand for the sediments with the lowest concentrations of metals.

Manganese concentrations in sediments followed somewhat the same pattern of distribution as described for the above five metals. Relatively high concentrations of this metal, however, were found in sediments from the eastern and southern parts of the Sound as well as the western parts of the Sound which was not the case for the metals described above.

The concentrations of silver, cadmium, and selenium were undetectable by the methods employed in the majority of sediments examined from Long Island Sound. The highest levels of these metals, that were detectable, occurred in sediments from the western part of the Sound and the concentrations were on the order of 1 - 6 ppm for all three metals.

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* All concentrations of metals in sediments are expressed on a dry weight basis.

Cobalt, antimony, and scandium concentrations in sediments had more or less a random distribution throughout Long Island Sound. In other words, no particular area had concentrations of these metals that were decidely higher than other areas of the Sound. There was some tendancy, however, for cobalt and antimony concentrations in sediments to be higher for western and central parts of the Sound than for the eastern part of the Sound.

ENVIRONMENTAL MICROBIOLOGY AND CHEMISTRY - MICROBIOLOGY TASK

DISTRIBUTION OF COLIFORMS IN SEDIMENTS FROM LONG ISLAND SOUND

T. Graikoski, J. Babinchak and S. Dudley

Of concern to the fisheries in estuarine and in-shore coastal waters is the degree of microbiol contamination due to water run-offs from contiguous land masses, discharges of rivers and, in some cases, direct discharges or dumping of domestic sewage into waterways. Included with the introduction of the microbiol types is the concomitant increase in nutrient loading which can enhance microbial proliferation. Particular concern is the introduction of pathogenic microorganisms which may induce diseases in marine animals or by contamination resulting in restricted utilization due to transfer of diseases to man. In this regard the degree of fecal contamination has been used as a basis to ascertain the degree of public health hazard of waters from which the animals are harvested. Our objective has been to assess the degree of fecal contamination in sediments of the mid-Atlantic coastal waters in order to determine the potential presence of other disease producing microorganisms. We are primarily concerned with the presence of these organisms in sediments. Sediments would represent the areas of persistence and possible proliferation of organisms in the environments under study.

A previous report of the contaminants group was concerned with the extent of fecal contamination of the sewage disposal site of the New York Bight area. The following report summarizes the results obtained on the survey of coliform bacteria from Long Island Sound of the mid-Atlantic coastal area. Additional microbiological studies are also briefly summarized.

A series of 25 north-south transects across Long Island Sound and approximately 159 stations were sampled for bottom sediments, surface water and plankton during July and August of 1972. The transects were located approximately 5° of longitude apart. Inshore stations were located at depths less than 20' on either shoreline of transect with offshore stations located approximately 2.5° of latitude apart.

Fecal coliform counts, for baseline contaminants research, were determined on sediments collected from inshore stations, the first offshore stations and a center station for every other transect across the Sound. All tests were by standard MPN methods and are per 100 g of wet weight sediment.

A total of 54 stations was tested for fecal coliforms. The 3 highest fecal coliform counts (34,800; 7,900; 2,200) were from stations on the western-most area. Aside from this transect and one across Fishers Sound on the eastern end of Long Island Sound, there were 11 representative transects investigated. Of these transects 22 stations

represent inshore and the first offshore station of the Connecticut coast, and 26 stations represent central inshore and first offshore stations along the north shore of Long Island. The ranges of fecal coliform counts are shown in Table 24 and Figure 5.

In summarizing the data, the entire Connecticut coast generally showed some degree of fecal contamination with the northern coast of Long Island and the center of Long Island Sound being relatively free of fecal contamination.

Aerobic plate counts were determined for all stations examined for fecal coliforms. Two different plating media were compared. Difco Marine agar, and a dilute medium extract made up with Long Island Sound seawater. At 10 stations the counts on both media were the same. At 34 stations dilute seawater media gave the highest count. From these results, the use of marine agar 2216 medium for plate counts will be discontinued. Both aerobic and anaerobic plate counts were variable and difficult to correlate with areas sampled.

Surface water samples were collected from inshore, the first offshore, and center stations of every other transect and cultured for periphytic prosthecate bacteria. The waters are being incubated at 10°C and 20°C in plastic bottles and examined for the development of periphytic prosthecate bacteria in the surface film. The purpose being to monitor the predominating bacterial types developing in the surface film to determine cycling patterns and the isolation of desired bacterial types when they predominate.

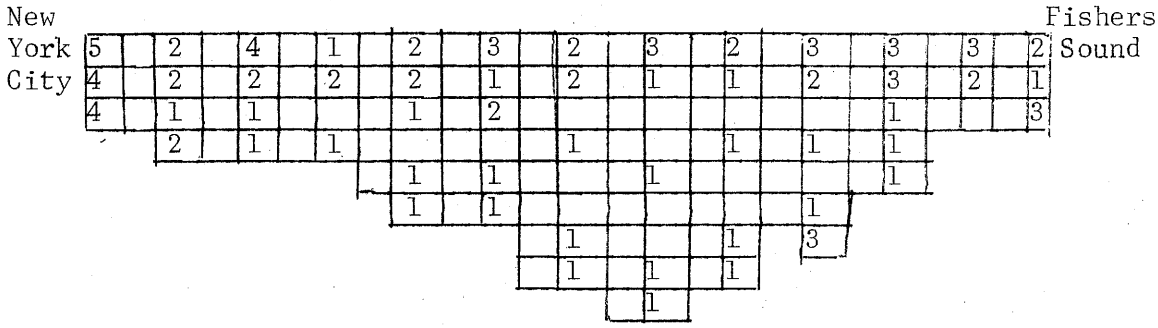
Table 24. Ranges of Fecal Coliforms Found in Long Island Sound

TOTAL STATIONS

| North Shore Long Island | Connecticut Shoreline | Fecal Coliform Ranges/100g |
|---|---|---|
| 23 | 4 | 10 |
| 2 | 9 | 10-50 |
| | 2 | 50-100 |
| 1 | 6 | 100-1000 |
| | 1 | 1000-10,000 |

Figure 5. Distribution of Fecal Coliforms in Long Island Sound

Connecticut Coast




Long Island

Fecal Coliform in Sediment
MPN/100 ml

| | | | |
|---|---|---|---|
| 1 | 0 | - | 10 |
| 2 | 10 | - | 100 |
| 3 | 100 | - | 1,000 |
| 4 | 1,000 | - | 10,000 |
| 5 | 10,000 | - | 100,000 |

A total of 203 primary enrichment cultures were produced from sediments from 159 stations on Long Island Sound for detection of toxin producing anaerobes. From these cultures the supernatant of 59 (29.2%) cultures were toxic for mice. To date, the toxic factor(s) have not been identified.

The presence of marine vibrios in 79 sediment, 74 water and 33 plankton samples was determined through enrichment procedures. Presumptive results indicated vibrios present in 96% of the sediment samples, 51% of the water samples and 100% of the plankton samples. This relative abundance of vibrios correlated with published data which indicated peak vibrio growth during the warm months of July, August, and September.

# EFFECTS OF CONTAMINANTS ON BACTERIAL CLEARANCE

R. Robohm and M. Nitkowski

There is evidence that cadmium poisoning in teleosts disrupts respiratory processes and damages kidneys and gills. The exact mechanisms of these effects are unknown, although some evidence in liver, kidney and other tissues of mammals and fish indicates that enzyme systems are inhibited. If there is inhibition in rapidly growing or metabolizing cells, then cells of the immune system in fish may also be affected (even at non-toxic levels). Identification of such effects, in addition to being useful as indicators of toxicity, may, in part, explain environmental mortalities of fish. For example, if a pollutant can inhibit production of antibody by the lymphocytes or in some way reduce the effectiveness of reticulo-endothelial system phagocytes, fish may become susceptible to infection. A recent report linking bacterial infection of salmon with sudden spikes of copper and zinc levels in a Canadian river is indicative that metal pollution may indeed lower fish immunity.

An investigation was undertaken to determine whether 96-hr exposure of the cunner (*Tautogolabrus adspersus*) to sublethal levels of cadmium would affect two elements of the immune system: 1) clearance of intra-cardially injected bacteria from the bloodstream, and 2) ability to produce antibody against intraperitoneally injected sheep red blood cells (SPBC).

We found that exposure to 12 ppm cadmium increased the rates of bacterial uptake in phagocytes of the liver and spleen but significantly decreased the rates of bacterial killing within these cells (Fig. 6). Exposure of fish at 3 to 24 ppm cadmium failed to influence antibody production against SRBC (Table 25).

These results indicate that cadmium affects one aspect of cellular immunity but not humoral immunity in cunners. The significant finding that cadmium reduces the killing of phagocytized bacteria in the liver and spleen suggests that, in nature, marginally pathogenic bacteria may be allowed to multiply within phagocytes and eventually overwhelm fish with infection. It also raises the possibility that a number of environmental pollutants may be found to cause similar phagocytic dysfunction in fish.

As part of an effort to understand the mechanism of phagocyte impairment, we are examining the pH of the phagocytic vacuole surrounding ingested bacteria. pH changes within the vacuole are known to be influenced by the types and quantities of substances dumped into the vacuole by cellular lysosomes. We found that we can stain bacteria with pH indicator dyes, allow them to be taken up by phagocytes and then determine pH changes in the cells by observing changes in bacterial color.

Using peritoneal macrophages from cunners we have found that the initial pH in the phagocytic vacuole is 7.0 to 7.5; eventually this may

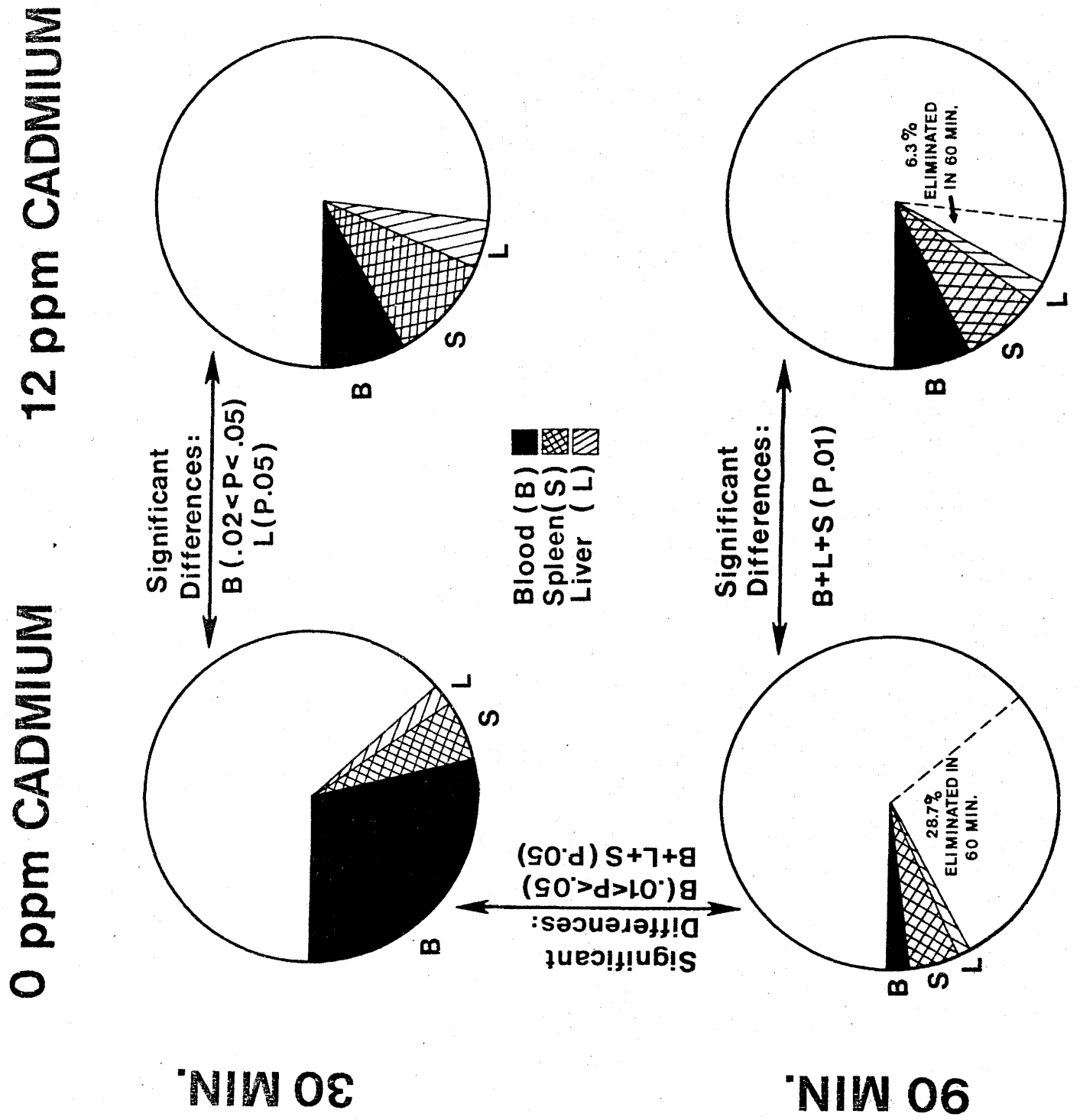



Figure 6. Bacterial clearance from the blood, liver and spleen, of cunners. Diagrams represent mean percent of bacteria remaining (based on number of bacteria injected) after the 30- or 90- min time intervals. Values from 10 or 11 fish were used for each variable.

Table 25. Serum hemagglutination titers of fish immunized by intraperitoneal injection of SRBC at the time of 96-hr cadmium exposure. Sera were drawn two weeks later (one week after a second SRBC injection).

| | Cadmium concentration (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 3 - 6 | | 12 - 24 | |
| | No. tested | titer* | No. tested | titer | No. tested | titer |
| Immunized fish | 12 | 33 ± 11 | 23 | 29 ± 6 | 17 | 30 ± 5 |
| Non-immunized fish | 9 | 6 ± 1 | 12 | 3 ± 1 | 12 | 6 ± 1 |

* Titer is shown as the reciprocal of the mean serum dilution ± standard error.

drop as low as pH 3.0. In eels the initial pH is about 8.0; this drops to about 5.0 after two hr. We have not as yet examined phagocytes of pollutant treated fish; this work has been suspended, for the moment, to work on the finrot disease project.

Another source of information on pollutant stress to immune systems may be resumed following completion of the finrot project; namely, effects of pollutants on phagocytosis in sea squirts (Molgula manhattensis). Since the animal is semi-transparent, it may be observed visually for its ability to clear colored particles such as red blood cells. Two types of poly-nuclear hydrocarbons (dibenzanthacene and 3-methylcholanthrene), which have been found in air, water and soil, were dissolved in peanut oil and injected into sea squirts at a level of 0.0005 - 0.01 mg/gm. Five to seven days later the animals were injected with sheep red blood cells and observed for rates of clearance. In chemically treated animals the clearance was about double that of animals given peanut oil alone.

The results indicate that short term exposure to the hydrocarbons causes activation of phagocytic cells. It would be interesting to examine clearance in chronically exposed animals to determine whether phagocytes remain hyperactive or eventually become damaged by prolonged contact with the hydrocarbon.

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In Press

Greig, R. A., A. E. Adams and B. A. Nelson

Physiological response of the cunner, *Tautogolabrus adspersus*, to cadmium. II. Uptake of cadmium by organs and tissues.

Robohm, R. A. and M. F. Nitkowski

Physiological response of the cunner, *Tautogolabrus adspersus*, to cadmium. IV. Effects on the immune system.

## EXPERIMENTAL BIOLOGY INVESTIGATIONS

## REARING OF MARINE ORGANISMS

W. Landers, E. Rhodes and W. Cable

Attempts to develop a culture methodology for a coastal bivalve to supplement the existing technique for estuarine species progressed as anticipated. The original assumption that, initially, several species must be investigated simultaneously because not all would be amenable to controlled culture, was substantiated. Of the three species chosen for study - the sea scallop, the surf clam and the ocean quahog - only the surf clam has shown sufficient potential as a bioassay organism to warrant further study.

As reported earlier, the sea scallop lives well in our laboratory seawater, ripens and spawns under the proper manipulation and the embryos develop normally to the veliger stage. We have failed, however, to find a food which the veliger larvae will ingest. As a consequence, the larvae will not grow. They can swim actively for as long as 60 days without food, however, a testimony to their inherent durability, but eventually die, presumably from starvation. Thus, even though the sea scallop is a commercially valuable species and information about its life history is important in understanding the dynamics of the natural populations upon which the fishery depends, it lacks promise as a bioassay organism and further study in that direction cannot be justified.

The ocean quahog, also, has failed to respond to the controlled culture environment. Adult clams appear to thrive in the laboratory and ripen completely in this environment. They do not respond to any known spawning stimulus, however. Gametes can be stripped from the ripe animals and some of the eggs made fertilizable by treating them with ammonium hydroxide before adding the sperm. Eggs so fertilized will develop through the free-swimming stages to metamorphosis. This method of producing bioassay organisms is not acceptable, however. Many eggs taken forcibly from the gonad may not be physiologically ripe even if they appear morphologically so. The necessity to expose the eggs to a chemical in order to make them fertilizable would render suspect any subsequent observations of their development in relation to experimental contaminant stress. We can only conclude that the ocean quahog is, also, an unacceptable bioassay organism for studies involving early life history.

Rearing the Surf Clam

Fortunately, the surf clam seems to be amenable to controlled culture through all stages of its development. The adults live well in laboratory seawater if they are hand gathered from shallow beds. Animals obtained from the commercial dredge fishery subsequently suffer a high mortality in the laboratory, due, apparently, to injuries sustained while being dredged.

The normal spawning season in inshore Rhode Island waters where our stocks are collected is apparently the summer since ripe animals from there are only available from June to August. The spawning season can be greatly lengthened in the laboratory by conditioning the clams to ripen out of season. This is done by holding them in flowing seawater at 15°C. Clams subjected to this treatment in early winter become spawnable by March. Ripe animals may be kept in a ripe condition for weeks. Clams taken from the field during their natural spawning season and kept at 10°-15°C in seawater, remain full of usable gametes well into late fall.

The surf clam is an easy animal to spawn. The standard technique for stimulating release of the gametes in ripe animals is to raise the temperature of the seawater suddenly from the conditioning or holding temperature of 10°-15°C to 20°C. One must be careful in handling ripe clams that a sudden inadvertent rise in temperature does not result in spontaneous release of the gametes.

Even mechanical shock, such as that from being dumped from one container to another, can cause a ripe clam to spawn. Gametes can also be obtained by stripping them from ripe individuals. The eggs can then be fertilized directly by adding sperm without resorting to chemical treatment as is necessary with stripped eggs of the ocean quahog. In view of the ease with which live surf clams can be spawned, there is little incentive to resorting to stripping, however, especially for bioassay purposes where the possible introduction of unknown stresses on the eggs during stripping might cast doubt on the results of a subsequent bioassay.

The surf clam is essentially a cold water species being found in the latitude of southern New England chiefly in relatively deep, coastal waters, but its presence in the near shore, surf environment indicates some tolerance to summertime, shallow water temperatures. The response of the developing eggs of the surf clam to temperature is compatible with this observation. Percentage development of fertilized eggs to the early veliger stage at different temperatures is as follows:

| 10°C | 15°C | 20°C | 22°C | 25°C | 30°C |
|---|---|---|---|---|---|
| 10 | 60 | 60 | 55 | 25 | 0 |

The surf clam lives in a high salinity environment. The response of fertilized eggs to different salinities demonstrates their narrow range of tolerance to this factor. Percentage development of surf clam eggs drops sharply below 25 o/oo and above 30 o/oo as shown below:

| 15 o/oo | 20 o/oo | 22.5 o/oo | 25 o/oo | 27.5 o/oo | 30 o/oo | 35 o/oo |
|---|---|---|---|---|---|---|
| 0 | 1 | 4 | 55 | 57 | 60 | 20 |

The changing quality of the natural seawater used by most marine laboratories is a constant threat to the success of experimental culturing efforts. At best, it makes it difficult to standardize culture methods and to predict the timing of sequential events. At worst, it completely inhibits the growth and development of the animals, particularly the early stages. For this reason, synthetic seawater has been considered as an alternative culture medium for certain, especially

sensitive developmental stages, such as the eggs and embryos. We have found that most commercial sea salts will not support development of surf clam eggs. However, we have obtained excellent results in rearing eggs to the veliger larva stage in a synthetic seawater formulated by the Environmental Protection Agency Laboratory in West Kingston, Rhode Island, and used by the bioassay unit at Milford Laboratory. The chief advantage of this medium to us is its dependability; the results obtained with its use are always the same. This characteristic should have special significance to cytologists who have long used surf clam eggs in their studies. In the past, cell research with surf clam eggs has been confined to those places where natural seawater is readily available. By using synthetic seawater as the culture medium, this kind of cytological research can be greatly expanded geographically and, in addition, there should now be possible a standardization of techniques and comparability of results not always obtainable when natural seawaters from different locations are used.

An interesting observation regarding the development of the siphonal system in the surf clam was made. The Mactridae, of which the surf clam is a member, has a siphonal system which, in the adult, includes a valvular membrane, a narrow flange just inside the ring of tentacles of the exhalant siphon. The development of this membrane in the surf clam has never been noted. Recently, we found and described this structure in recently metamorphosed clams. At this period in the

clam's development, the valvular membrane is relatively much larger and more active than it is in the adult clam, being extended in the position seen in Figure 7 when the young clam is pumping water and then being rapidly withdrawn when the clam is disturbed.

Rearing the Slipper Limpet, *Crepidula fornicata*

Any schedule for the development of rearing methods for a variety of marine species must be kept flexible enough to accommodate "organisms of opportunity", i.e., species not included in the schedule initially but whose potential for controlled culture is later realized. The gastropod, *Crepidula fornicata*, commonly called the slipper limpet, is such an organism. *Crepidula* is common in the shallow waters of the Middle Atlantic Bight. Its only claim to fame is a certain notoriety as an oyster pest because it occupies the same ecological environment as does the oyster, attaches to the same substrates and eats the same food. Our attention was drawn to its potential as a bioassay organism when it was accidentally found about a year ago to be breeding in our laboratory seawater at relatively low temperatures during the winter. Since that time, we have succeeded in developing a method for ripening animals sexually and rearing the animals through their complete life cycle at any time of the year. Our studies show that in laboratory culture, *Crepidula* has a number of characteristics which makes it useful as a bioassay organism. These include (1) readily available adults, (2) tolerance to crowding, (3) controllable reproduction, (4) adequately high fecundity, (5) hardy larvae, (6) rapid larval growth, and (7) relatively short generation time.

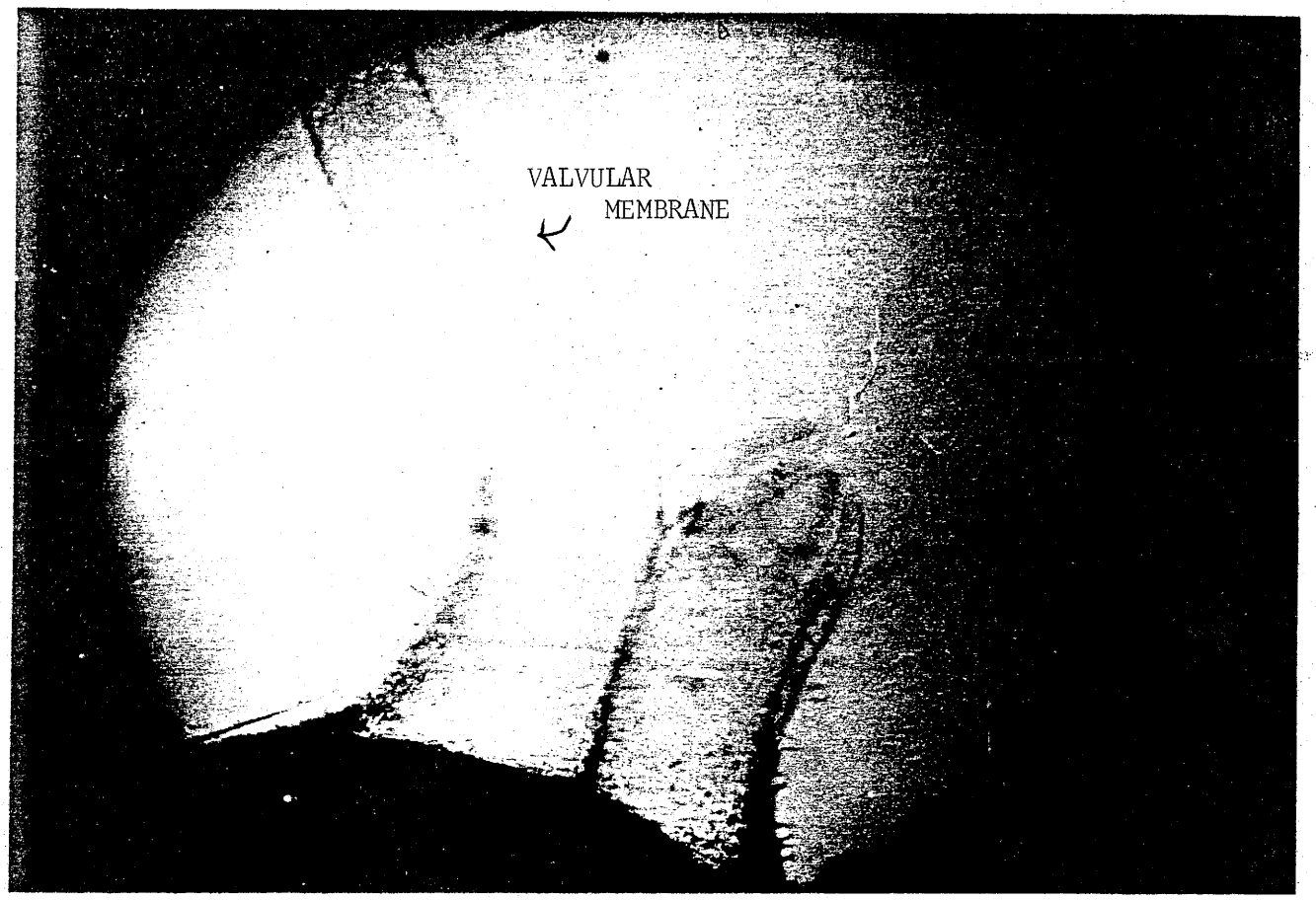


Figure 7. Valvular Membrane of Recently Metamorphosed Surf Clam.

The adults are found on most oyster grounds and are hardy enough to be collected by dredge. Attached to their substrates, the animals can be left out of water for at least 12 hours in cool weather. They can be removed easily from their natural sites and reattached to experimental substrates. They will not leave a substrate to which they have been transferred unless under stress. Stocks of Crepidula can be kept in good condition in the laboratory in unfiltered flowing seawater if the holding tanks are kept fairly free of silt so that the animals will not suffocate.

The natural spawning season of Crepidula in Long Island Sound appears to be mid-spring to late summer or early fall, but they can easily be induced to breed out of season in the laboratory. We have stimulated animals collected in November to reproduce in a few weeks by holding them at temperatures of 18°C or above.

Females lay the eggs in capsules over which they brood during development of the embroyos to the free-swimming larvae stage. If the animals are kept on transparent panels, the color change that takes place as the embryos develop can be followed. The early eggs are pale yellow, while the ready-to-be-released larvae are dark brown or gray. A single Crepidula will reproduce under laboratory conditions for at least six months at temperatures between 15° and 27°C; the same female will lay consecutive broods of eggs. Each brood will produce 1,500 to 10,000 larvae depending upon the temperature; the higher the temperature, the fewer the number of larvae produced per brood, but the more frequently are the egg masses laid.

As the color change in the brood capsules indicates approaching liberation of the larvae, the females are put into a special larvae collector (Figure 8) which, as the larvae are released, quickly takes them out of the proximity of the female. This is necessary because adult Crepidula will efficiently filter their own larvae from the water and incorporate them into the fecal mass.

We first reared the larvae in a flowing seawater, culture system (Figure 9). In this system the larvae are kept in a PVC container with a nylon screen bottom. The water level is determined by the height of the surrounding solid-bottom PVC container. Ultraviolet-treated, 1 μ-filtered seawater and cooled cultured algae are added constantly. With a larvae container of one-liter volume, the filtered seawater is added at the rate of 10 liters per day and the concentration of introduced food is constant at about 150,000 cells per ml. At 25°C, the larvae begin to metamorphose in about 7 days in this system. The larvae can also be reared in static culture, similar to the standard method used for rearing bivalve larvae. If the cultures are changed every day, excellent results can be obtained with this method.

The larvae are sensitive to temperature in that their growth rate is different at different temperatures. In general, the rate increases with increase in temperature, at least up to 30°C. The larvae are quite intolerant of low salinity. Significant growth occurs only at salinities of 20 ppt and higher. High salinities appear to be well

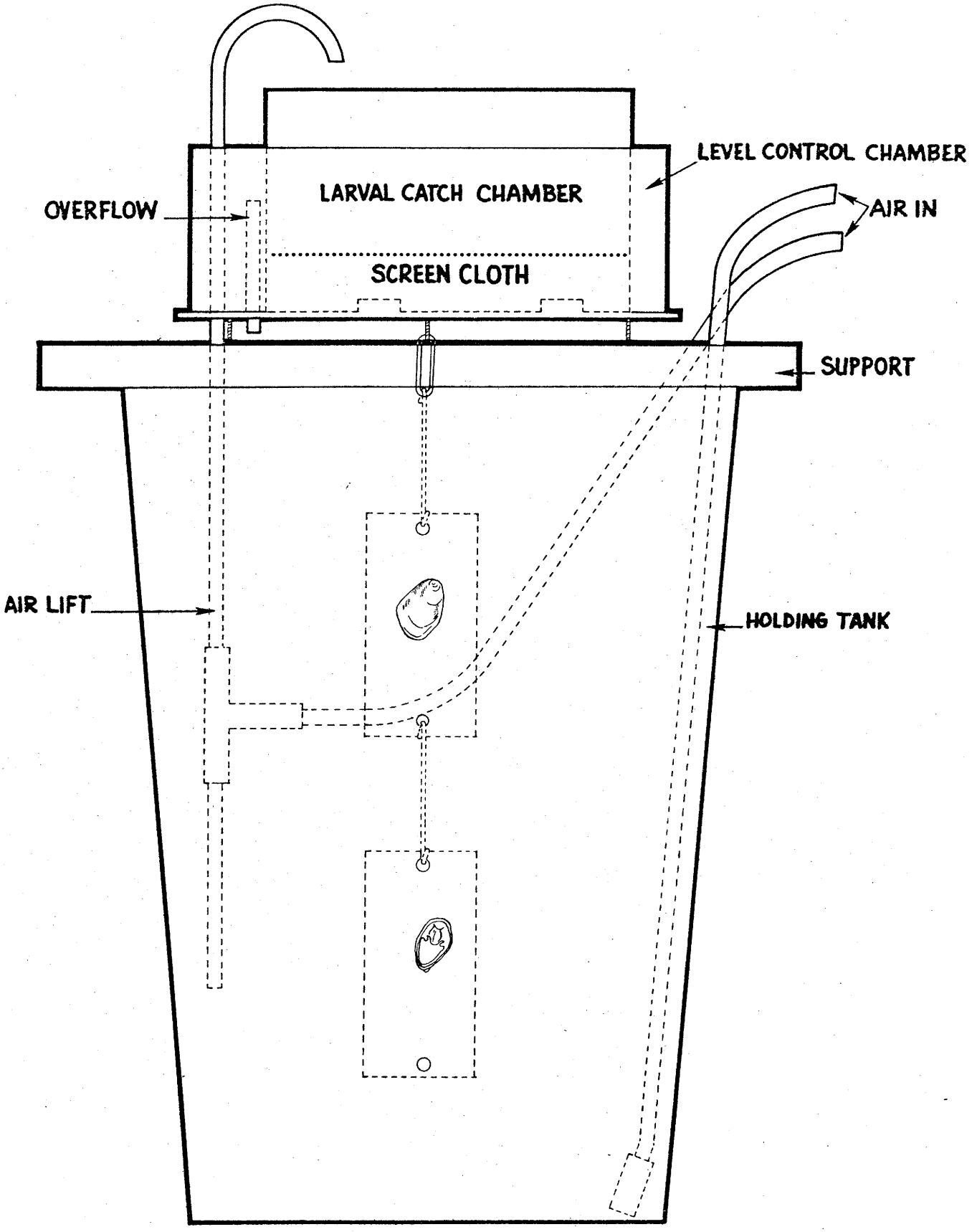


Figure 8. Collecting Chamber for Larval Gastropods

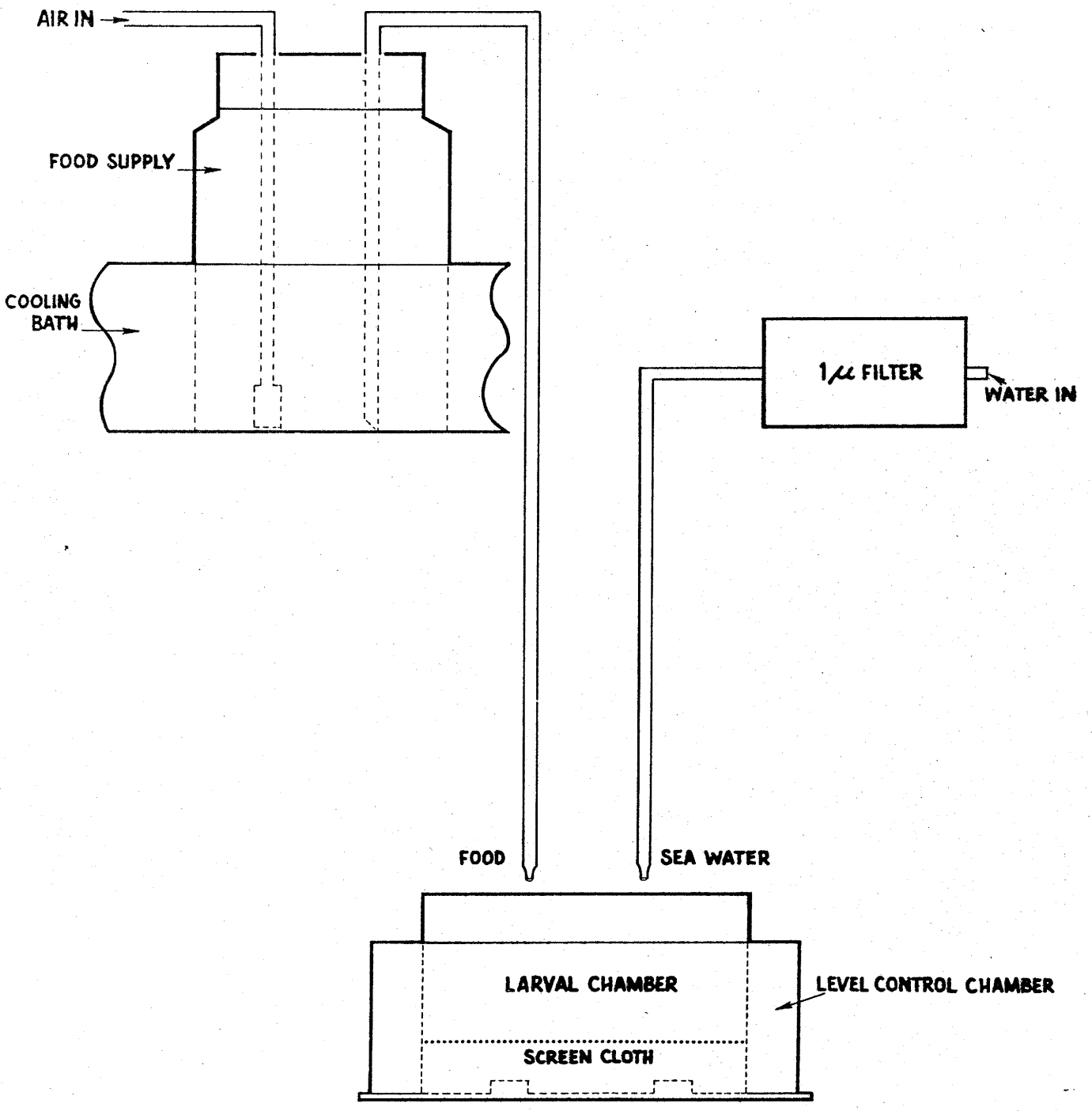


Figure 9. Flowing Seawater Culture System for Larval Gastropods

tolerated, however. Rapid growth and good survival was obtained at salinities as high as 40 ppt, the highest that we have tested to date.

Metamorphosis in larval Crepidula consists of giving up the free-swimming habit and adopting a more or less sedentary life. The larvae do not appear to be fussy about their settlement site. We have had settlement take place on glass, polypropylene, PVC, nylon, fiberglass and plexiglass. The most satisfactory way to grow the juveniles is to place a number together in a large tray of unfiltered, flowing sea-water. This facilitates pairing when the animals reach sexual maturity. Juveniles have also been grown to sexual maturity in static cultures in which the water is aerated, changed every two days and cultured algae added as food.

One of the most advantageous characteristics of Crepidula development from the point of view of the bioassayist (and the geneticist) is the relatively short generation time involved. The fastest generation time that we have obtained is 72 days; this took place in the flowing culture system at 25°C. This might be shortened at higher temperatures but, to date, we have not reared all stages at temperatures higher than 25°C. The number of days required to complete various stages in the development of Crepidula at 25°C in flowing water is shown below. Also, the whole cycle can be accomplished in static culture but requires considerably more time.

| | Egg laying to larval release | Larval period | Settlement to first pairing | First pairing to egg laying | Total = Generation time |
|---|---|---|---|---|---|
| Flowing | 10 | 6 | 34 | 22 | 72 |
| Static | 12 | 9 | 49 | 56 | 126 |

# PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS - PHYSIOECOLOGY

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

## Development of Exposure Laboratory

The exposure facility is designed so that a variety of marine organisms can be exposed to sublethal levels of various pollutants. Heavy metals are being tested at the present time but we have plans for pesticide and PCB exposures in the future. The exposures are accomplished by short-term (24-96 hour) static tests and by long-term (1-12 months) continuous flow tests. At the end of each exposure period, or at intervals during that time, animals are removed and given to investigators for evaluation of the sublethal effects of the test pollutant.

The major portion of the facility is contained in a 40 x 45 foot laboratory on the lower floor of the main building at Milford. Included in this laboratory are:

A. Nine diluter systems that meter precise amounts of pollutants into 20-gallon all-glass aquaria and 55-gallon fiberglass tanks. Each diluter can be set to deliver 3-5 levels of pollutant to 12 aquaria or tanks. These diluters are the heart of the long-term exposures. They provide six complete changes of water per day and precisely maintain the pollutant level.

B. Glassworking equipment for use in the fabrication and modification of diluter systems, including special gas-oxygen burners, a glass saw, glass cutting bits for the drill press, and a power borer for the rubber fittings required.

C. Compressed air lines with automatic valves to turn air on should the water system fail.

D. A three-tiered platform for static, short-term exposures, equipped with twenty-two 20-gallon, all-glass aquaria and twelve 60-gallon, fiberglass tanks. These are fitted with standard spun-glass and charcoal filters and with compressed air lines. They may be filled with natural, artificial, or ozonized seawater.

E. A fiberglass sink with 6-foot drainboard and high faucet and sprayer for cleaning tanks.

F. Eight 300-gallon tanks with continuously flowing seawater for holding large numbers of animals. This system is plumbed to both the ozonized and natural seawater systems.

G. The diluter systems are presently using heavy metals as test contaminants; however, we have the capability of using other pollutants. Pesticides and PCB's are planned for future work. These pollutants will be removed from the waste water before discharging it into Milford Harbor.

## Experimental Studies

Laboratory experiments at Milford 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 here. For the results of previous studies refer to Informal Report No. 5 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."

### Inhibition of Embryonic Development of the Hard Clam, *Mercenaria mercenaria*, by Heavy Metals

Adult hard clams were induced to spawn in natural seawater in the laboratory by thermal stimulation and the addition of a water suspension of stripped sperm from a sacrificed male. After the clams began spawning in natural seawater they were transferred to synthetic seawater. The gametes were thus collected in this synthetic medium. The effect of heavy metals on the survival of clam embryos was determined by placing a known number of fertilized eggs (usually 15,000 to 17,000) into each of a series of 1-liter polypropylene beakers containing synthetic seawater (salinity 25%) at 26 $\pm$ 1°C. Duplicate cultures were established at each of the test concentrations and four untreated cultures served as controls in each experiment.

The metals, tested as inorganic metallic salts, were as follows: lead nitrate ($Pb(NO_3)_2$); mercuric chloride ($H_gCl_2$); nickel chloride ($NiCl_2 \cdot 6\ H_2O$); silver nitrate ($A_gNO_3$); and zinc chloride ($ZnCl_2$).

Static tests were conducted throughout this study and all tests were initiated within 1 hour after the eggs were fertilized. Tests were terminated after 42 to 48 hours because known embryonic development, under normal conditions, is completed by this time and the embryos develop into straight-hinge larvae. To determine the effect of metal toxicity on embryonic development, the embryos that survived and developed into larvae in each culture were collected on a 36-$\mu$ nylon screen. The larvae were resuspended in a 250-ml graduated cylinder and, after thorough stirring to insure uniform distribution of the larvae, a 4-ml quantitative sample was removed and preserved in 5% neutral formalin. The samples were examined under a compound microscope and the number of embryos that had survived and developed into larvae was counted. The counts of samples from duplicate cultures were averaged and the results expressed as a percentage of the average number surviving in control cultures. The results of successive tests were then averaged and the $LC_{50}$ value was determined by straight line graphical interpolation using logrithmic probability paper: percent survival versus log concentration of metal. Under normal conditions in the laboratory, development of shellfish embryos in repetitive tests is somewhat variable; thus, it was not unexpected to find that only two of the metals tested satisfied tests of linearity. It was not feasible, therefore, to use the probit

method of analysis for determining confidence limits of the $LC_{50}$ values. The ranges of the $LC_{50}$ values arising from the individual metal experiments were then determined using the same procedures as with the $LC_{50}$ values. The $LC_0$ and $LC_{100}$ values were derived from actual observation. The results are based on five tests conducted with lead, mercury, and silver, and six with nickel and zinc.

It must be understood that the metal toxicity discussed below is valid only for those forms of inorganic metallic salts tested and does not take into account what form the metals were when in solution. The acute toxicity of heavy metals, as inorganic salts, to embryos of the hard clam is shown in Table 26. These concentrations, not including background levels, are reported in parts per million added to the synthetic seawater medium at the start of each experiment. Of the metals tested, mercury and silver were the most toxic. Mercury was 100% lethal at 0.0075 ppm and silver at 0.045 ppm. The estimated $LC_{50}$ value for mercury was 0.0048 ppm, while for silver it was 0.021 ppm. Zinc and nickel, although not as toxic as mercury and silver, were 100% lethal to clam embryos at 0.25 and 0.60 ppm, respectively, while the estimated $LC_{50}$ values were 0.166 and 0.31 ppm. Lead was the least toxic of the metals tested, although the toxicity was still great in that it was lethal at 1.2 ppm.

Table 26. Toxicity of heavy metals, as inorganic salts, to hard clam embryos at 26 ± 1°C in synthetic seawater (25 o/oo salinity). The concentrations are in parts per million of metal ion added to medium at start, producing mortality of 0, 50 and 100 percent ($LC_0$ and $LC_{100}$ are actual values and $LC_{50}$ is estimated)[1].

| Metals as Inorganic Salts | $LC_0$ | $LC_{50}$ | Range of $LC_{50}$ | $LC_{100}$ |
|---|---|---|---|---|
| Mercuric chloride | 0.0025 | 0.0048 | 0.0038 - 0.0056 | 0.0075 |
| Silver nitrate | 0.010 | 0.021 | 0.019 - 0.025 | 0.045 |
| Zinc chloride | 0.095 | 0.166 | 0.138 - 0.175 | 0.25 |
| Nickel chloride | 0.10 | 0.31 | 0.28 - 0.33 | 0.60 |
| Lead nitrate | 0.40 | 0.78 | 0.72 - 0.80 | 1.20 |

[1] These concentrations do not include background concentrations of heavy metals in the synthetic seawater medium. They were (in ppm): Hg - 0.00003, Ag - 0.003, Zn - 0.029, Ni - 0.0065 and Pb - 0.007.

In comparing previous studies on the effect of heavy metals on embryos of the American oyster, Crassostrea virginica, to the present studies with clam embryos (Table 27), the data indicate that clam embryos are much more sensitive than oyster embryos to lead and nickel, somewhat more sensitive to zinc, less sensitive to silver and as sensitive to mercury. Lead, for example, was 100% lethal to clam embryos at 1.20 ppm, while a concentration greater than 6.0 ppm was required to cause total mortality of oyster embryos. It is not clear why the difference in $LC_{100}$ concentrations of lead was so great between these two species of bivalves.

## Physiological Response of the Mud Crab, Eurypanopeus depressus, to Cadmium

Mud crabs were collected in rocky, intertidal areas of Milford Harbor, Connecticut, and held in the laboratory in tanks of recirculated, artificial seawater at 21 $\pm$ 2°C for at least 1 week before testing. They were fed minced hard shell clams, Mercenaria mercenaria, daily but were unfed 2 days prior to and during the test exposure.

Crabs were exposed to cadmium in 1-gallon glass jars, filled to 3 liters with synthetic seawater. This synthetic medium was prepared using technical-grade chemicals dissolved in fresh well water and adjusted to 25 ppt salinity. The pH of the seawater remained at 7.0 for the range of cadmium concentrations tested. All jars were rinsed with dilute sulfuric and nitric acid between repetitive tests, to prevent any accumulation of metal residue.

Table 27. Toxicity of heavy metals, as inorganic salts, to oyster and hard clam embryos at 26 ± 1°C in synthetic seawater (25 o/oo salinity). The concentrations are in parts per million of metal ion added to medium at start, producing mortality of 0, 50 and 100 percent ($LC_0$ and $LC_{100}$ are actual values and $LC_{50}$ is estimated)[1].

| Metals as Inorganic Salts | $LC_0$ | | $LC_{50}$ | | $LC_{100}$ | |
|---|---|---|---|---|---|---|
| | Clams | Oysters | Clams | Oysters | Clams | Oysters |
| Mercuric chloride | 0.0025 | 0.001 | 0.0048 | 0.0056 | 0.0075 | 0.008 |
| Silver nitrate | 0.010 | 0.003 | 0.021 | 0.0058 | 0.045 | 0.01 |
| Zinc chloride | 0.095 | 0.075 | 0.166 | 0.31 | 0.25 | 0.5 |
| Nickel chloride | 0.10 | 0.10 | 0.31 | 1.18 | 0.60 | 3.0 |
| Lead nitrate | 0.40 | 0.50 | 0.78 | 2.45 | 1.20 | > 6.0 |

[1] These concentrations do not include background concentrations of heavy metals in the synthetic seawater medium. They were (in ppm): Hg - 0.00003, Ag - 0.003, Zn - 0.029, Ni - 0.0065 and Pb - 0.007.

An aqueous solution of cadmium as $CdCl_2 \cdot 2\frac{1}{2}H_2O$ (50 g/l) was added to test jars in various amounts to produce 12 test concentrations. A wide range of concentrations (1.0 - 48.0 ppm) was used initially to determine final test concentrations, which were from 1.0 ppm through 12.0 ppm. All cadmium concentrations mentioned refer to parts per million of the metal ion in solution.

Three crabs, averaging 1 g each, were placed in each test jar of seawater, which was aerated and maintained at room temperature (21° ± 2°C). Each of 10 tests consisted of four jars at each concentration plus four control jars. The crabs were inspected every 24 hours and dead crabs were removed, weighed, and discarded. Exposure was terminated at 72 hours with a final tally of mortality and removal of selected live animals for determination of oxygen consumption.

Oxygen consumption measurements were made on whole animals exposed to 0.0, 3.0, 4.0, 6.0, and 7.0 ppm Cd (10-15 animals per concentration) and on excised gill tissue of animals exposed to 0.0, 4.0, and 7.0 ppm Cd (12 animals per concentration). A high mortality rate precluded the use of animals at higher concentrations. The crabs used in these tests ranged in weight from 0.85 to 1.45 g.

Whole animals were held in 100 ml, wide-mouth, Warburg-type reaction vessels containing 50 ml seawater (one animal per vessel). Excised gill tissues were held in 7-ml Warburg-type reaction vessels containing 2 ml seawater (tissue from two animals per vessel). The seawater in each vessel was taken from the corresponding exposure jar from which the test crab was removed. Oxygen consumption was monitored over a 4-hour period

in a Gilson differential respirometer. The wet weight of each whole crab and the dry weight (oven-dried to a constant weight) of the gill tissue was recorded upon completion of every experiment. Oxygen consumption was calculated as $\mu l O_2$ consumed per hour per gram (wet or dry weight).

The results from each of 10 tests were averaged and the $LC_0$, $LC_{50}$, and $LC_{100}$ values were determined. Values for $LC_0$ and $LC_{100}$ were determined by observation, whereas the $LC_{50}$ value was derived by graphical probit analysis. The $LC_0$, $LC_{50}$, and $LC_{100}$ values were 1.0 ppm, 4.9 ppm, and 11.0 ppm, respectively, with 95% confidence limits for the $LC_{50}$ being 3.9-5.4 ppm.

The oxygen consumption rates of whole animals showed great individual variation, ranging from 35 to 75 $\mu l$ oxygen/hr/g. This variability was true of controls and of all exposure groups. There was no difference in overall oxygen consumption among the various test concentrations. Oxygen consumption rates of the gill tissue alone, however, decreased as the cadmium concentration increased. The mean oxygen consumption rates were as follows: controls, 0.785/$\mu$l/hr/mg ($SE_M$ = 0.060); 4 ppm Cd, 0.725 $\mu$l/hr/mg (SEM = 0.064); and 7 ppm Cd, 0.501 $\mu$l/hr/mg ($SE_M$ - 0.080). Figure 10 illustrates the relation of survival and gill tissue oxygen consumption to increasing amounts of cadmium.

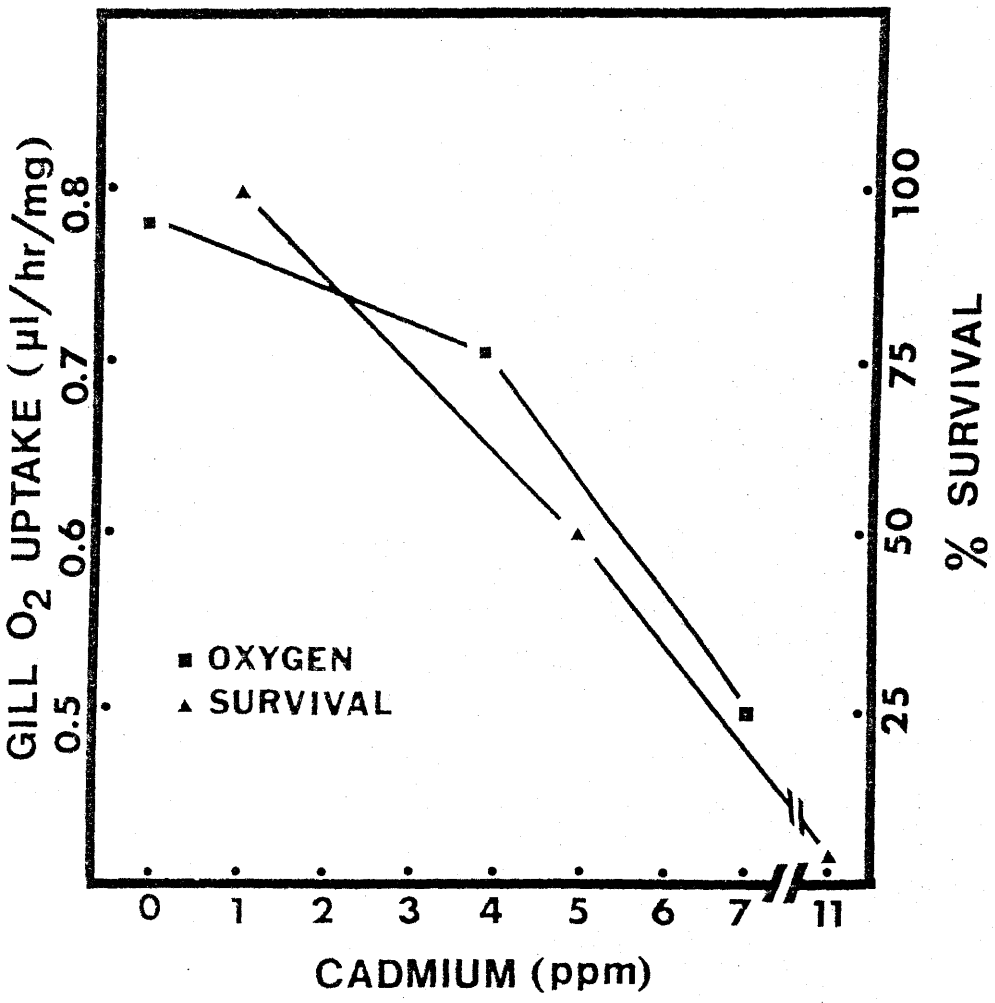


Figure 10. Oxygen uptake of the mud crab exposed to cadmium.

PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS - PHYSIOLOGY

F. Thurberg, M. Dawson and J. MacInnes

## The Effects of Five Metals on the Behavior and Oxygen Consumption of the Mud Snail, *Nassarius obsoletus* Say

The snails used in this study were collected from intertidal areas of Milford Harbor, Connecticut, and held in running seawater in the laboratory up to 2 months. They were unfed 2 weeks prior to and during experimentation. The snails, ranging in weight from 0.24 to 1.14 grams (wet weight, including shell), were randomly selected and placed in 1-liter polyethylene beakers (five per container) containing 1 liter of artificial seawater (Instant Ocean; 25 ppt) maintained at 20 $\pm$ 1°C. Aqueous metal solutions were then added to this water and the snails were exposed to these metals for 72 hours, with similar untreated beakers maintained as controls. Heavy metal stock solutions were prepared from reagent grade chemicals as follows: cadmium chloride ($CdCl_2 \cdot 2\frac{1}{2} H_2O$), cupric chloride ($CuCl_2 \cdot 2 H_2O$), silver nitrate ($AgNO_3$), sodium arsenite ($NaAsO_2$), and zinc chloride ($ZnCl_2$).

At the end of one exposure period, the behavior of five snails was assessed using the following criteria: a normal snail has its cephalopodal body extended, moves about with its foot attached and feeds; a distressed snail has its body extended but its foot does not attach to anything and is unable to move about; a retracted snail has its body completely pulled within its shell. The abnormal behavior of the

distressed snail results from a concentration range which is too low to cause retraction and too high to allow normal behavior. After assessment of condition oxygen consumption rates were measured on randomly selected animals. Each snail was placed in a 15-ml Warburg-type flask containing 5 ml of the seawater in which it had been exposed. The oxygen consumption rate was monitored in a Gilson Differential Respirometer over a 3-5 hour period and calculated as microliters of oxygen consumed per hour per gram (wet weight, including shell) corrected to microliters of dry gas at standard temperature and pressure.

Mud snails exposed to sublethal concentrations of arsenic, cadmium, copper, silver, and zinc exhibited deviations from normal behavior and altered oxygen consumption rates (Table 28). The oxygen consumption rate was depressed after exposure to concentrations of copper and silver greater than 0.5 ppm and to arsenic and zinc greater than 2.0 ppm. Cadmium slightly elevated the oxygen consumption rate over the exposure range of 0.5 to 4.0 ppm. Within the size range of the snails used, there was no size related difference in the ratio of respiration to weight at the 0.1 level of significance. Animals showing altered consumption rates also exhibited distressed or retracted behavior, except those exposed to zinc. Zinc only slightly affected oxygen uptake at concentrations up to 10.0 ppm. The combined effect of copper and cadmium on the uptake rate of snails was greater than each metal individually. As noted previously cadmium elevated the oxygen consumption rate while copper decreased the rate. The combination of metals, however, depressed the rate well below that of copper alone (Table 29).

Table 28. The Condition and Mean Oxygen Consumption Rates (expressed as $\mu l\ O_2/h/g$ wet weight) of the Mud Snail, Nassarius obsoletus, After a 72 h Exposure to Heavy Metals. N=normal, D=distressed, R=retracted.

| Metal Concentration | Condition | Consumption | Condition | Consumption | Condition | Consumption | Condition | Consumption | Condition | Consumption |
|---|---|---|---|---|---|---|---|---|---|---|
| ppm | Cu | | Ag | | Cd | | As | | Zn | |
| 0.00 | N | 28.3 | N | 26.7 | N | 28.0 | N | 27.1 | N | 26.2 |
| 0.10 | D(N) | 23.3 | N | | N | | N | | N | |
| 0.25 | D(N) | 8.9 | D | 27.2 | N | | N | | N | |
| 0.50 | D | 11.5 | D | 11.0 | D(N) | 34.3 | N | | N | |
| 1.00 | D | 8.5 | R(D) | 7.7 | D | 30.3 | N | 29.9 | N | |
| 2.00 | D | 6.8 | R | 5.6 | D | 29.6 | N | 20.4 | N | 16.7 |
| 3.00 | D | | R | | D | 33.3 | D | 7.5 | N | 20.5 |
| 4.00 | R(D) | | R | | R(D) | 28.8 | D | | N | |
| 5.00 | R(D) | | R | | R | | D | | N | |
| 10.00 | R | | R | | Dead | | R(D) | | D(N) | |
| 20.00 | Dead | | Dead | | Dead | | R | | R | |
| 50.00 | Dead | | Dead | | Dead | | Dead | | Dead | |

Table 29. Comparison of mean oxygen consumption rates of the mud snail, Nassarius obsoletus, exposed to copper and cadmium individually and in combination. Consumption rates are expressed as $\mu l$ $O_2$/hr/g wet weight.

| Metal | Concentration | Number of tests | Mean | Standard error |
|---|---|---|---|---|
| Control | 0.00 ppm | 11 | 30.5 | 2.2 |
| Copper | 0.25 ppm | 11 | 12.5 | 2.6 |
| Cadmium | 1.00 ppm | 11 | 40.4 | 3.1 |
| Copper and Cadmium | 0.25 & 1.00 ppm | 11 | 6.4 | 3.0 |

## A New Technique for Measuring the Oxygen Consumption of Larvae of the American Oyster, *Crassostrea virginica*

Adult oysters were induced to spawn by thermal stimulation and by addition of sperm stripped from a sacrificed male. The eggs were collected from more than one female to insure a heterogeneous sample. The number of fertilized eggs per unit volume was determined by microscopic examination of a subsample and approximately 500,000 eggs were then transferred to a 15-liter container maintained in a water bath at 26°C. The larvae were reared in natural seawater (salinity 25 ppt) that had been circulated through 15 $\mu$ and 1 $\mu$ Orlon filters, an ultraviolet light sterilization unit, and an activated charcoal filter. The water was changed every other day, and the larvae were fed laboratory grown phytoplankton cultures of *Isochrysis galbana* and *Monochrysis lutheri*. A sample of larvae was taken prior to each oxygen consumption experiment and the mean length of 50 larvae was determined. The all-glass microrespirometer used in this study was essentially that described by Grunbaum *et al*. and consisted of a capillary with a 0.3 mm bore and two 5 ml flasks, a respiration flask containing oyster larvae and a control or compensation vessel containing seawater but no organisms. Glass loops were formed on each end of the capillary to hold a carbon dioxide absorbent; a filter paper disc soaked with 1% KOH and tied in place. Several hundred larvae, in 2.0 ml seawater, were placed in each respiration flask and then immersed in a constant temperature (26°C) water bath. The amount of oxygen consumed by the larvae was

determined by measuring the movement of the red distilled kerosene indicator in the capillary bore. The change in oxygen is given by K times h where h is the distance covered by the indicator and the proportionality factor is derived from the equation:

$$K = \frac{273}{T} \left(\frac{P-P_w}{P_o}\right) A \left(\frac{V_g}{V_g^1} + 1\right)$$

in which

| | | |
|---|---|---|
| $T$ | = | absolute temperature |
| $P$ | = | atmospheric pressure (mm Hg) |
| $P_w$ | = | vapor pressure of water at T (mm Hg) |
| $P_o$ | = | standard atmospheric pressure (mm Hg) |
| $A$ | = | cross section of area of capillary bore |
| $V_g$ | = | volume of respiration chamber |
| $V_g^1$ | = | volume of compensation chamber |

Readings were recorded every 15 minutes during experiments of at least 2 hours in duration. The respiratory rate was calculated as microliters of oxygen consumed per hour per thousand larvae.

The results of this study are presented in Figure 11. Since the relationship between mean length ($\mu$) of oyster larvae and the oxygen consumption rate is curvilinear, it is best expressed logarithmetically by the equation:

$$10 (\log Y) = -4.556 + 2.941 (\log X)$$

where X = mean length of larvae sampled on the day of the experiment and Y = consumption rate ($\mu$l $O_2$/hr/1000 larvae)

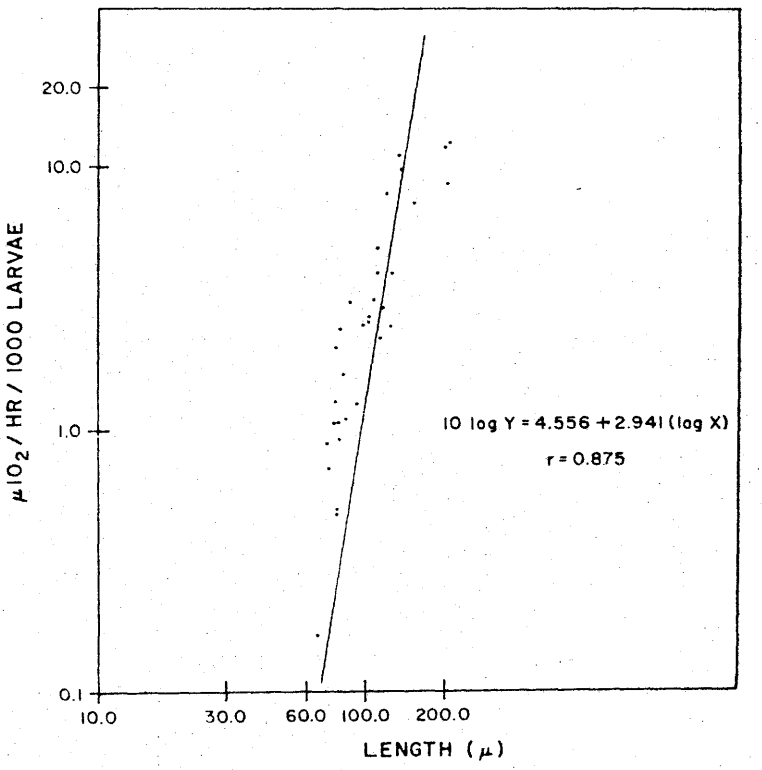


Figure 11. Oxygen consumption rates of American oyster larvae ($\mu$l $O_2$/hr/1000 larvae) vs size (length in $\mu$) at 26°C and 25 ppt salinity.

The high correlation coefficient of the relationship ($r = 0.875$) indicates a rise in oxygen consumption rate as the larvae grew in size. This rate increased from less than 0.2 $\mu$l $O_2$/hr/1000 larvae for individuals 60 $\mu$ in length to 20 $\mu$l $O_2$/hr/1000 larvae for individuals that had grown to 200 $\mu$ in length. Other workers have noted similar increases in oxygen consumption of developing oyster eggs, but little information is available on the normal oxygen consumption of 60-200 $\mu$ larvae.

This study has demonstrated the suitability of this microrespirometer in measuring oxygen consumption of larval bivalves. The small size of this instrument allows great sensitivity and performs well if operated under constant temperature conditions. The results, however, are valid only under the conditions described in this study and may not represent the actual respiratory rates in the environment or in a hatchery situation. The relative values, however, are valuable and should prove useful in future studies of the effects of environmental changes on bivalve larvae.

## The Effects of Silver on Oxygen Consumption of Bivalves at Various Salinities

This study was designed to evaluate the sublethal effects of silver on four bivalve species held at various salinities. Oxygen consumption was chosen as a parameter to assess stress because it is

a valuable indicator of energy expended to meet the demands of an environmental alteration. A number of recent studies have emphasized the importance of synergistic effects of natural environmental factors and pollutants. The physiological effect of a pollutant may be altered when such factors as temperature and salinity are varied. The bivalves used in this study are frequently found in areas of fluctuating salinity; thus, the effects of silver at three different salinity levels were examined.

The four bivalve species used in this study -- the American oyster, Crassostrea virginica; hard-shell clam, Mercenaria mercenaria; blue mussel, Mytilus edulis; and soft-shell clam, Mya arenaria -- were collected in Long Island Sound within 10 miles of Milford Harbor, Connecticut.

The oxygen consumption values of control oysters held at 15, 25, and 35 ppt salinity indicate no difference due to salinity (Figure 12). Sensitivity to silver did, however, vary with salinity. At 35 ppt animals exposed to silver up to 1.0 ppm respired at the same low rate as the controls. At 25 and 15 ppt salinity there was significant elevation in oxygen consumption even at 0.1 ppm silver; the effect increasing with increasing metal concentration. At the two lower salinities, analysis of variance tests indicates significant differences in mean respiratory rates between controls and all treatments at the 0.01 level of significance.

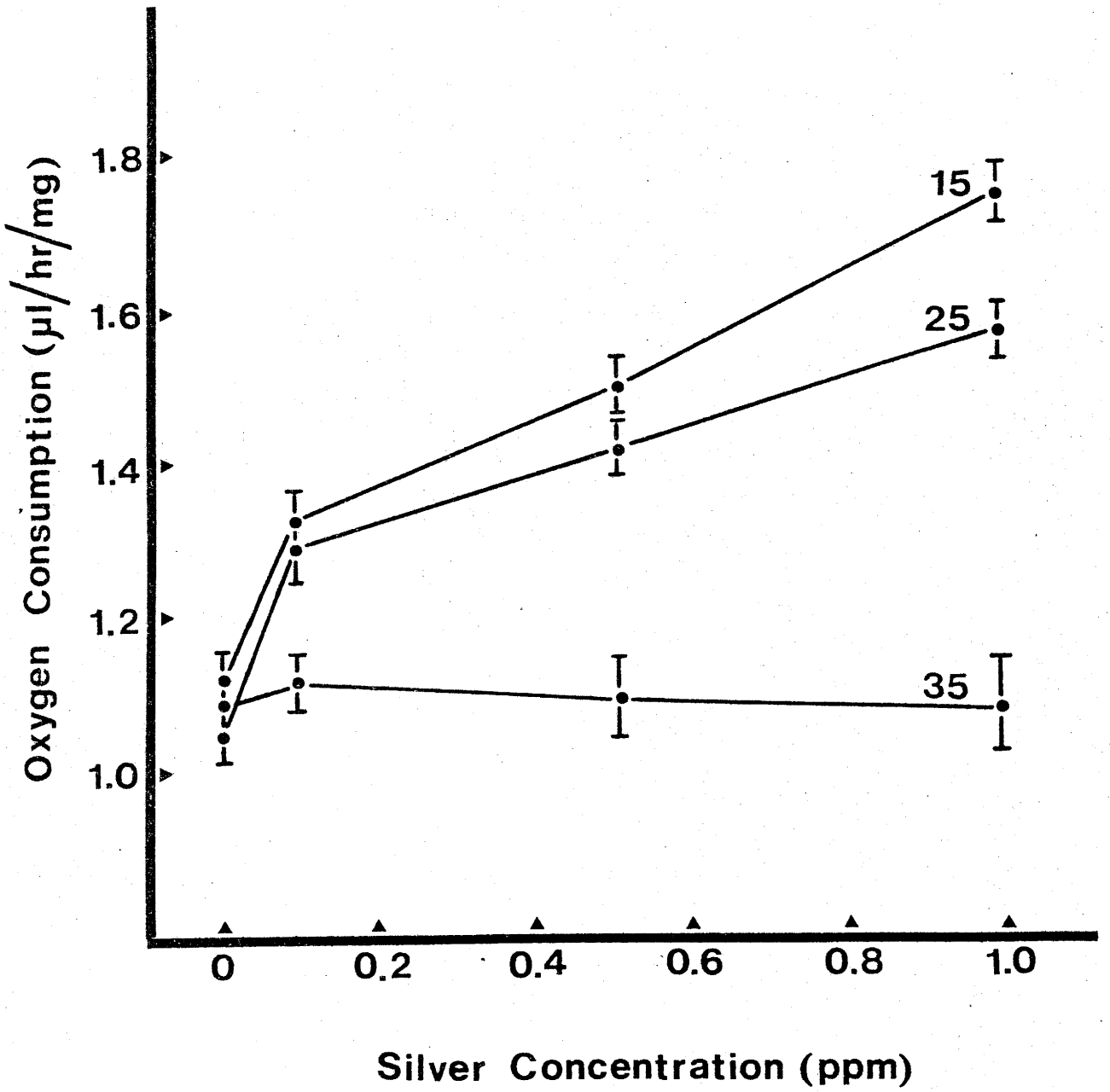


Figure 12. Crassostrea virginica. Effects of silver on oxygen consumption. Eact point comprises the mean gill tissue oxygen consumption value of 16 animals. Bars: standard errors. Each line represents a series of experiments conducted at the salinity shown thereon.

The oxygen consumption of hard-shell clams in control tanks increased with decreasing salinity (Figure 13). In tests conducted at 25 and 35 ppt oxygen, while consumption rates increased with increasing silver concentration, no salinity differences were noted at 0.5 and 1.0 ppm of silver. Analysis of variance tests indicates significant differences in mean oxygen consumption rates between controls and all treatments at the 0.1 level of significance. Silver had no effect on the already highly elevated consumption values in tests conducted at 35 ppt.

Blue mussels exhibited higher oxygen consumption rates at a salinity of 15 than at 25 ppt (Figure 14). These rates increased with increasing silver concentration, an effect that was quantitatively similar at the two salinities. The animals used in this study were not able to acclimate to 35 ppt under the conditions of this experiment and repeated mortality occurred. Analysis of variance tests indicates significant differences in mean respiratory rates between controls and all treatments at the 0.01 level of significance.

At 25 and 35 ppt salinity all of the soft-shell clams died during exposure to 1.0 ppm silver. Animals exposed to this concentration at 15 ppt showed the highest elevation in oxygen consumption (Figure 15). At 0.1 and 0.5 ppm silver significant differences (at the 0.01 level) were noted when comparing the oxygen consumption values with those of the controls. The greatest elevation in oxygen consumption was noted in the experiments conducted at 15 ppt.

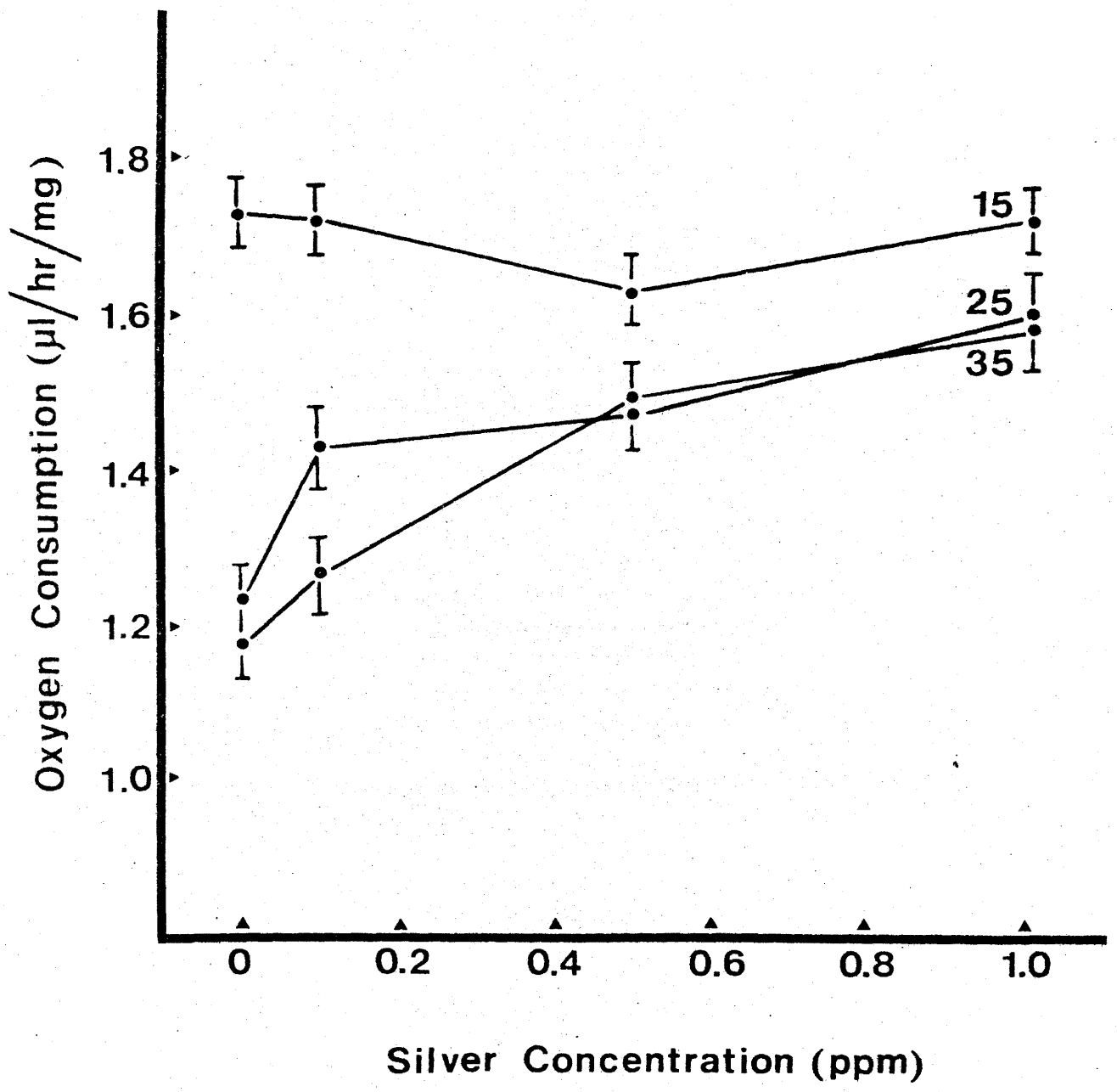


Figure 13. Mercenaria mercenaria. Effects of silver on oxygen consumption. Each point comprises the mean gill tissue oxygen consumption value of 16 animals. Bars: standard errors. Each line represents a series of experiments conducted at the salinity shown thereon.

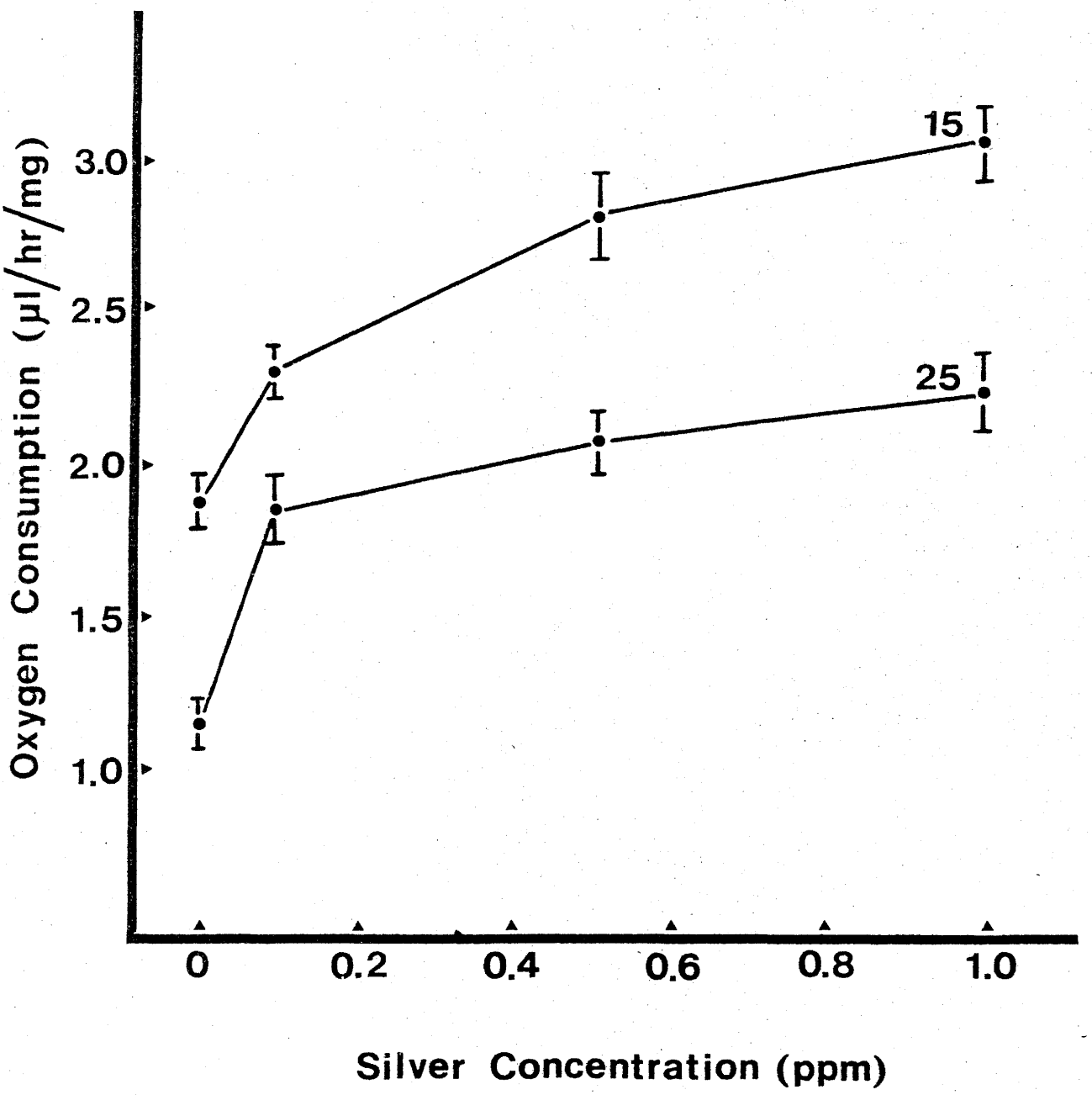


Figure 14. Mytilus edulis. Effects of silver on oxygen consumption. Each point comprises the mean gill tissue oxygen consumption value of 16 animals. Bars: standard errors. Each line represents a series of experiments conducted at the salinity shown thereon.

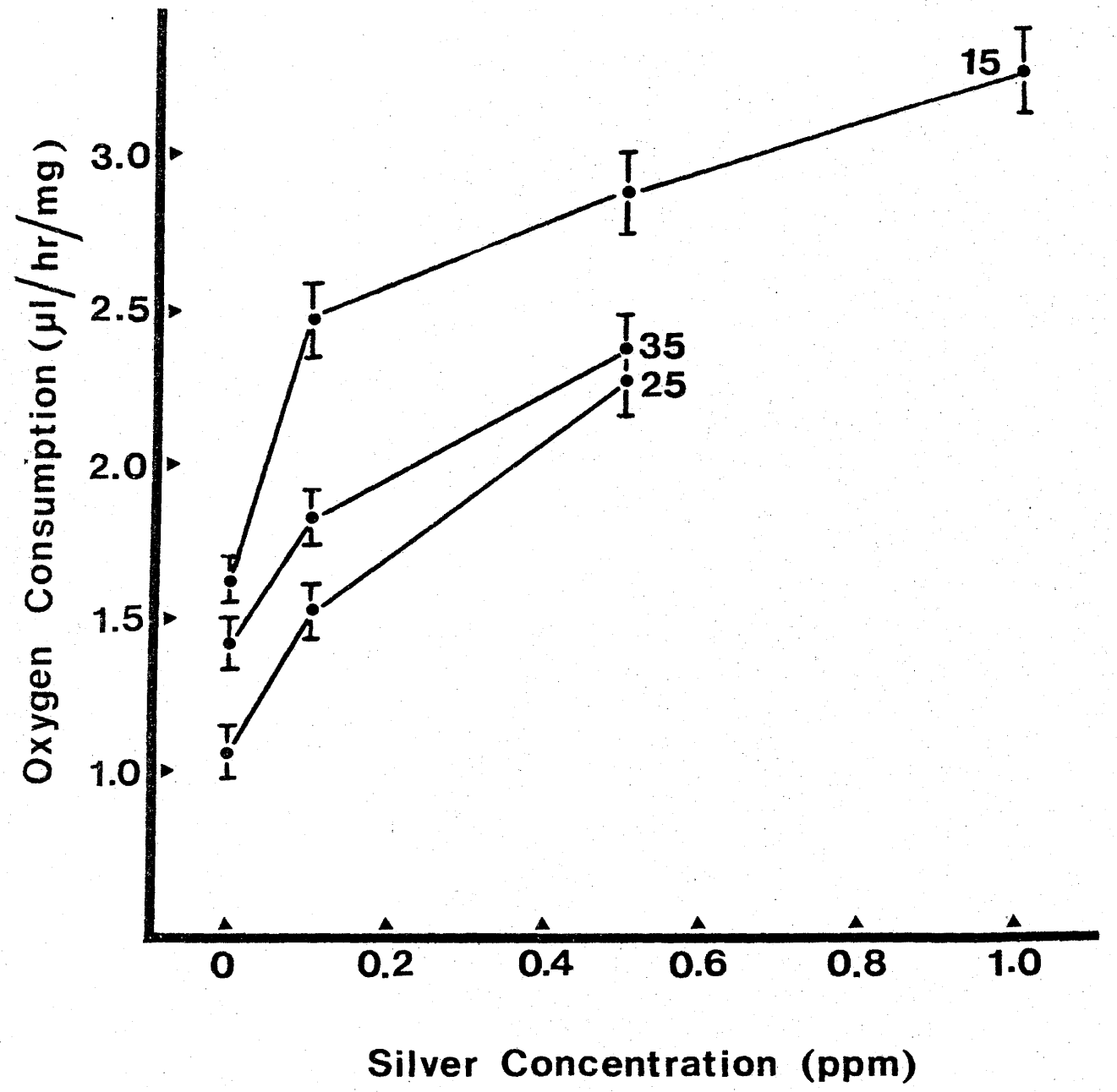


Figure 15. Mya arenaria. Effects of silver on oxygen consumption. Each point comprises the mean gill tissue oxygen consumption value of 16 animals. Bars: standard errors. Each line represents a series of experiments conducted at the salinity shown thereon.

Randomly selected animals (12-20 per species) were prepared for chemical analysis to determine silver concentration in body tissues after exposure. These specimens were chosen from the 25 ppt salinity experiments. Because of the large tissue mass in *C. virginica* and *M. mercenaria*, gills were separated from the whole body and analyzed separately. Only whole body analyses were conducted on the considerably smaller *M. edulis* and *M. arenaria*. The results for all four species are shown in Table 30.

Table 30. Uptake of Silver by Bivalves into Body and Gill Tissue After a 96-hr Exposure to Silver.

| Exposure (ppm Ag) | Silver Concentration in ppm Wet Weight | | | | | |
|---|---|---|---|---|---|---|
| | *C. virginica* | | *M. mercenaria* | | *M. edulis* | *M. arenaria* |
| | Body | Gills | Body | Gills | Body | Body |
| Control | 6.1 | 5.9 | 0.4 | 1.6 | 0.2 | 0.3 |
| 0.5 | 12.4 | 38.0 | 0.8 | 7.6 | 3.7 | 10.4 |
| 1.0 | 14.9 | 33.9 | 1.0 | 6.9 | 5.2 | - |

## PHYSIOLOGICAL EFFECTS OF POLLUTANT STRESS - BIOCHEMISTRY

E. Gould

During the first full year of biochemical research into the response of marine animals to heavy metals in their environment, the focus has been upon metal-protein complexes in teleosts, hemocyanins in crustacea, and a "stress" enzyme, aspartate aminotransferase (AAT), in all animals observed.

A study was completed on cunners, Tautogolabrus adspersus, exposed for 4 days to cadmium chloride. The activities of two liver enzymes changed significantly (1) at exposure levels of 3 ppm and 24 ppm cadmium, AAT activity was 71% and 59%, respectively, of the activity in livers of control fish; and (2), at the 24 ppm cadmium exposure level, a magnesium linked oxidoreductase required 10 times as much magnesium per assay for activity of the same order as in the controls.

Possibly related to the latter observation in cunners was the discovery that the sera of cadmium-exposed blue and rock crabs, Callinectes sapidus and Cancer irroratus, contained 50% more magnesium than did sera from control crabs. These preliminary data for serum magnesium levels were true for acute static experiments only; data from a single chronic experiment did not confirm the short-term experiments.

Work was completed on a study of rock crabs exposed for 4 days to cadmium chloride. AAT activity in heart muscle was higher in the exposed crabs than in the controls by 2 to 9 times, and was also more

resistant to *in vitro* stress (45% residual activity in the controls, and 72% in the cadmium-exposed crabs). A single chronic exposure study corroborated the acute-static data. The increase of AAT is ascribed to the physiological mobilization of amino acids, a response to cadmium's challenge to osmoregulation; and the increased enzymatic tolerance to *in vitro* stress may be related to protective ionic bonding against further denaturation. Serum hemocyanins were examined electrophoretically for changes in state of aggregation and for peroxidatic activity, but no significant difference was found between the cadmium exposed crabs and the controls.

A single analogous exposure of rock crabs to the nitrate salt of cadmium indicated that the cation can markedly alter the cadmium effect; in this case, the relative AAT activities were the reverse of those observed in the cadmium chloride experiments, as were also the residual activities after *in vitro* stress. Work is currently in progress to corroborate these findings.

A collaborative study with the Oxford laboratory was completed, in which blood-protein changes were observed in blue crabs infected with *Paramoeba perniciosa*. The altered electrophoretic patterns of serum protein and especially of hemacyanin could be accurately correlated with the degree of disease stress.

During the course of this investigation, a histochemical stain to detect copper was developed, which is more rapid and sensitive than other methods currently in print. It is particularly useful for detecting sites of hemocyanin on electrophoresed gels.

Work has begun on methodology for studying carbonic anhydrase, an important zinc enzyme present in both vertebrates and invertebrates. It is particularly important in the latter, and is highly susceptible to attack by cadmium. Experimentation to date has been to establish its identity in crude preparations of tissue from contaminant exposed crustacea and molluscs, has entailed only its esteratic activity, and has employed electrophoresis and fixed wavelength rate studies. A recently acquired pH-Stat, however, will soon allow us to measure the hydratase activity, a more specific and sensitive function of this enzyme.

Preliminary observations were also made on silver stressed soft-shelled clams, *Mya arenaria*, whose gill tissues were characterized electrophoretically for total protein and for broad spectrum esterase activity. The latter was weaker in the cadmium-stressed gills than in the controls, a finding that may be at least in part attributed to the inhibition of carbonic anhydrase by cadmium. More sensitive techniques will be brought to bear on this problem, when the pH-Stat becomes fully operable.

Centrifuged tissue fluid from whole bodies of silver stressed oysters, *Crassostrea virginica*, was characterized electrophoretically for total protein and for copper, and the ratio of fluid volume to wet solids was measured, in an attempt to detect a biochemical response to heavy metal stress. First impressions are that there is a greater proportion of fluid and a slight buildup of copper-protein complex in the stressed oysters.

# MUTAGENIC EFFECTS OF POLLUTANTS

A. Longwell, S. Stiles and J. Hughes

In conjunction with the Physiological Effects of Pollutant Stress Investigation, the effects of several heavy metals on the cytogenetics of fertilization, meiosis and cleavage of the oyster are being determined. Oyster eggs were subjected to 48 different conditions and a series of slides were made on each to show the cytogenetic effects of heavy metals on meiosis and early cleavage mitosis in the American oyster. After stimulation with sperm which fertilized the eggs as they were spawned, early cleaving eggs were placed in three different concentrations of silver, cadmium, arsenic and manganese. After 15 minutes, 30 minutes and 1 hour, samples of these eggs were fixed for cytogenetic examination. The purpose of this was to estimate the presence, absence and extent of damage to the chromosomes, nuclei and cell division that could be expected to cause lethality, malformations, lowering of vigor and, finally, the sort of genetic change that could be transmitted to the next generation.

The basic cytogenetics of the oyster has already been thoroughly studied, so mutagen-induced deviations should be readily recognized. A large amount of experience has further been accumulated now with oyster cytogenetics in a variety of experimental situations.

In an extensive study already completed the mutagenic effects of ionizing radiation on *C. virginica* were examined. This work on

ionizing radiation in addition provides a background of expertise on which to base studies of chemical marine contaminants which are potential mutagens and carcinogens.

In this first work done at Milford, and now fully analyzed, some effects were detected, and importantly these were often at a concentration of metal which causes 0% kill. More critical data could have been obtained from analyses of meiotic and fertilization stages, instead of cleavage stages alone, and this should be done next.

Even the lowest concentration of silver - 0% kill - reduces the number of mitosis from an average of about 5 per 1-hour zygote to 0.5. Division irregularities, not including parthenogenetic activities, rose from a control of 4% to about 25% and remained steady through to a $LC_{100}$ dose. Parthenogenetic activation, which leads to severe inbreeding effects, was as high as 50% at the $LC_{100}$ dose.

Cadmium also reduced the mitotic index of the early stage zygotes, and the $LC_0$ dose was just as effective in doing so as the $LC_{100}$ dose. Division abnormalities and irregularities were for the $LC_0$ dose. With the cadmium pollutant parthenogenetic activation seemed confused with the other abnormalities induced and so could not be properly appraised.

Arsenic did not alter the mitotic index at any dose. Increased evidence of abnormalities was not detectable until the latest stage zygotes studied and then only at the $LC_{100}$ doses. At this stage about 50% of the eggs were very grossly abnormal with nuclei indicative of severe metabolic disturbances.

Manganese did not reduce the mitotic index. However, nuclear and division abnormalities increased 54% over the control for the $LC_0$ dose, and remained about the same for the $LC_{50}$ and $LC_{100}$ dose for all the timed samples - 15 and 30 minutes and 1 hour.

The LC doses here were calculated on the basis of the number of normal straight-hinge larvae.

The abnormals produced by manganese would probably have the most pronounced long-term transmittable genetic effects or congenital effects. Unlike those for the other metals which, aside from parthenogenesis, were composed of a variety of abnormals whose genetic effects would come about in a circuitous way - these effects here consisted chiefly of severe direct changes in the ploidy level of the zygotes, and in losses of pieces of chromosomes, and of whole chromosomes. It seems these effects are the result of disturbances of the spindle in the eggs subjected to the manganese contaminant. The spindle is the apparatus formed anew for each division of the cell. The spindle apparatus makes possible the orderly, precise division and distribution of the chromosomes to the two new daughter cells.

Statistical analyses were done on these data and these analyses confirmed the above interpretations of the data and strengthened them.

Gonads from different crabs, clams, mussels and Crepidula exposed to metal contaminants for short periods have been sampled. Analyses of some of this material have begun. This work for the present will consist

mostly in spot-checking. It will be directed toward (1) effects of the contaminants on the gametogenesis and associated genetically critical meiotic stages; (2) effects on cell division and chromosomes that lead to direct genetic effects almost always leading to gamete lethality, semi-sterility or sub-vital mutations.

# EFFECTS OF CONTAMINANTS ON ALGAE

R. Ukeles, B. Rose and J. Bishop

The effect of contaminants on algae is of fundamental significance in the marine environment. Lethal concentrations of potentially toxic contaminants can destroy populations at the base of the food chain, thus exercising an indirect effect on macroscopic marine species of commercial value. Some contaminants, while not directly affecting phytoplankton, can be concentrated to such an extent by these organisms that they pose a threat to the grazing population because of the ingestion of high concentrations of the contaminant with the food. Another effect of a pollutant is that it may bring about a rapid increase in growth of particular algal species to the detriment of other species, perhaps more valuable phytoplankton, as well as macroscopic populations.

This investigation is pursuing inquiries into three different types of pollutants: viable, organic chemical and inorganic chemical.

The presence of high bacterial counts in polluted estuarine areas poses questions as to how the phytoplankton food-chain species are affected. In general, little is known of bacterial-algal interactions although there is now increasing interest in this area of study. A method was developed to evaluate the effect of each of three species of bacteria on each of 12 algal species. In some cases there was no particular response of algal growth to the presence of bacteria; in others, there was stimulation of growth but in no case was there any

inhibition. Stimulation was associated with a viable bacterial population and was inactivated in a heat-killed suspension. Some results from this study are summarized in Table 31. Of particular interest was the observation that two known marine pathogens, Vibrio anguillarum #19264 and Vibrio anguillarum #19109, were not harmful to the algae but, on the contrary, enhanced algal growth.

Polluted estuarine areas are apt to contain high concentrations of organic compounds. Whereas carbon nutrition in algae is usually derived from $CO_2$ utilization, there is evidence that algae with a carbon heterotrophic nutrition (i.e., the assimilation of reduced carbon) do exist in the marine environment. Heterotrophy may be a selective advantage for certain phytoplankton in areas of high organic content and turbid waters. Although isolated pieces of information are available on heterotrophy in algae, a systematic study of related compounds on a wide variety of algal species is needed. This prompted a study of the effects of a homologous series of 18 carboxylic acids, 16 monohydric plus polyhydric alcohols, and 13 sugars on growth in the light and dark of each of 14 representative phytoplankton species in pure culture. Observations of growth in the dark by certain species on glycerol, acetic acid and ethanol were of particular interest. These results will have application to problems of organic pollution in estuarine areas, as well as to the study of metabolic pathways that are independent of photosynthetic mechanisms.

Table 31. Effects of three species of marine bacteria on algal growth. ( + = moderate enhancement; ++ = strong enhancement; 0 = no effect.)

| Algae | *V. anguillarum* #19264 | *V. anguillarum* #19109 | *E. coli* #113-3 | Control | |
|---|---|---|---|---|---|
| | | | | Blank | Medium |
| *Chlorella autotrophica* | ++ | + | 0 | 0 | 0 |
| *Chlorella stigmatophora* | + | + | + | 0 | 0 |
| Chlorophyte U-710 | ++ | + | 0 | 0 | 0 |
| *Dunaliella euchlora* | ++ | + | ++ | 0 | 0 |
| *Dunaliella tertiolecta* | ++ | + | ++ | 0 | 0 |
| *Nitzschia* sp. | + | 0 | + | 0 | 0 |
| *Nannochloris* sp. | + | 0 | + | 0 | 0 |
| *Platymonas* sp. | + | 0 | + | 0 | 0 |
| *Phaeodactylum tricornutum* | ++ | ++ | ++ | 0 | 0 |
| *Pyramimonas* sp. | ++ | + | ++ | 0 | 0 |
| *Stichococcus bacillaris* | + | + | + | 0 | 0 |
| *Tetraselmis maculata* | ++ | + | 0 | 0 | 0 |

* Unpublished data, not to be used without permission of the author.

Pollution from inorganic chemicals arises largely from the effects of excessive levels of metallic cations in the marine environment. Metals, such as copper, mercury, cadmium and zinc, are most often chosen for metal contaminant investigations. Some information is already available on the effects of these metals on algae; inhibitory effects of copper were observed in the early part of the 20th century; mercury, silver, lead, and cadmium are well known inhibitors of numerous enzymatic reactions, and the very potent inhibitory effect of mercury on algae has already been noted (Ukeles, 1962). Therefore, research is being conducted with another group of metals, the alkali earth metals. These metals are in interest for the following reasons: (1) as potential industrial polluters of estuarine areas, (2) to determine if the alkali earth metal, sodium, an essential ingredient of the growth medium, can be partially or entirely replaced by other alkali earth metals, (3) to determine if lithium, which produces well known morphological changes in developing embryos, can also affect algal morphology. Some preliminary data are available that show lithium to have an effect on cell size in certain chain-forming species. This phenomenon could possibly affect the usefulness of these species as a food source for very young larvae. Available experimental results illustrating the extent to which lithium and rubidium can substitute for sodium in the growth medium are shown in Tables 32 and 33.

Two extensive review articles on culture methodology were prepared by invitation of the editors of the reviews: Continuous culture - A method for the production of unicellular algal foods. In Methods of Phycology, J. B. Stein, editor; Cultivation of unicellular algae. In Marine Ecology, O. Kinne, editor.

Table 32. The effect on growth of marine phytoplankton of substituting different percentages of cesium for sodium in an artificial seawater medium. ( + = growth similar to control; ± = partial inhibition; ≛ = severe inhibition; 0 = no growth)

| | 1% | 5% | 10% | 20% | 25% | 100% |
|---|---|---|---|---|---|---|
| *Isochrysis galbana* | + | ± | 0 | 0 | 0 | 0 |
| *Monochrysis lutheri* | + | ± | 0 | 0 | 0 | 0 |
| *Dicrateria inornata* | + | ≛ | 0 | 0 | 0 | 0 |
| *Cryptomonas* sp. | + | 0 | 0 | 0 | 0 | 0 |
| *Rhodomonas* sp. | + | 0 | 0 | 0 | 0 | 0 |
| *Porphyridium cruentum* | + | + | + | ± | 0 | 0 |
| *Phaeodactylum tricornutum* | + | ± | ± | 0 | 0 | 0 |
| *Nitzschia laevis* | + | 0 | 0 | 0 | 0 | 0 |
| *Leptocylindricus* sp. | + | ≛ | ≛ | 0 | 0 | 0 |
| *Chlorella autotrophica* | + | ± | 0 | 0 | 0 | 0 |
| *Chlorella stigmatophora* | + | ± | 0 | 0 | 0 | 0 |
| *Dunaliella euchlora* | + | ± | 0 | 0 | 0 | 0 |
| *Dunaliella primolecta* | ≛ | 0 | 0 | 0 | 0 | 0 |
| *Platymonas* sp. | + | ≛ | 0 | 0 | 0 | 0 |
| *Pyramimonas grossi* | + | + | 0 | 0 | 0 | 0 |
| *Stichococcus* sp. GSB | 0 | 0 | 0 | 0 | 0 | 0 |
| *Stichococcus bacillaris* | + | 0 | 0 | 0 | 0 | 0 |
| *Stichococcus* sp. M | 0 | 0 | 0 | 0 | 0 | 0 |
| *Protococcus* sp. 0-17 | + | ± | 0 | 0 | 0 | 0 |
| *Pleurococcus* sp. | + | + | 0 | 0 | 0 | 0 |

* Unpublished data, not to be used without permission of the author.

Table 33. The effect on growth of marine phytoplankton of substituting lithium or rubidium for sodium in an artificial seawater medium. (+ = growth similar to control, ± = partial inhibition, ⩲ = severe inhibition, 0 = no growth)

| | Lithium | | Rubidium | |
|---|---|---|---|---|
| | 25% | 100% | 25% | 100% |
| *Isochrysis galbana* | ± | 0 | 0 | 0 |
| *Monochrysis lutheri* | ± | 0 | 0 | 0 |
| *Dicrateria inornata* | ⩲ | 0 | 0 | 0 |
| *Cryptomonas* sp. | ± | 0 | 0 | 0 |
| *Rhodomonas* sp. | ± | 0 | 0 | 0 |
| *Porphyridium cruentum* | ± | 0 | ⩲ | ⩲ |
| *Phaeodactylum tricornutum* | ⩲ | 0 | ⩲ | 0 |
| *Nitzschia laevis* | 0 | 0 | 0 | 0 |
| *Leptocylindricus* sp. | ⩲ | 0 | ⩲ | 0 |
| *Chlorella autotrophica* | ± | 0 | ⩲ | 0 |
| *Chlorella stigmatophora* | 0 | 0 | ⩲ | 0 |
| *Dunaliella euchlora* | ⩲ | ⩲ | ± | 0 |
| *Dunaliella primolecta* | ⩲ | 0 | + | ⩲ |
| *Platymonas* sp. | ⩲ | 0 | ⩲ | 0 |
| *Pyramimonas grossi* | ⩲ | ⩲ | ± | ⩲ |
| *Stichococcus* sp. GSB | 0 | 0 | ± | 0 |
| *Stichococcus bacillaris* | ± | ⩲ | ± | 0 |
| *Stichococcus* sp. M | 0 | 0 | ± | 0 |
| *Protococcus* sp. 0-17 | + | ± | ± | ⩲ |
| *Pleurococcus* sp. | 0 | 0 | ± | ⩲ |
| *Melosira* sp. | 0 | 0 | ⩲ | 0 |
| *Stichococcus* sp. 0-18 | ± | 0 | ⩲ | 0 |

* Unpublished data, not to be used without permission of author.

# WATER QUALITY

W. Blogoslawski

## Ozonized Water Treatment System

In March 1972 the Water Quality Project constructed a system to purify raw, unfiltered seawater by ozone gas. It was designed to eliminate troublesome invertebrate fouling associated with piping volumes of seawater, oxidize and remove organic matter, and reduce the possibility of entrance of marine microorganisms pathogenic to fish, mollusks, and crustaceans.

During certain seasons "red tide" metabolites are known to inhibit bivalve spawning and kill developing bivalve larvae. Research by the Milford staff has demonstrated ozone's ability to inactivate toxic "red tide" phytoplankton by-products. Additional work has shown that ozone gas will also detoxify paralytic shellfish toxins produced by the dinoflagellates, *Gonyaulax tamarensis* and *Gonyaulax catenella*.

During the period from October 1972 to October 1973 several modifications were made to the original system to provide completely automatic, 24-hour operation. The changes are listed below:

1. October 1972-December 1972
   - A. Manual operation -- 8 hour production of ozonized seawater at 5 GPM
   - B. Addition of 1.7 cubic feet activated carbon prefilter to remove silt
2. December 1972-April 1973

A. Installation of three activated carbon afterfilters, 6" diameter to replace 3" diameter filters

B. Automatic air dryer installed to dry compressed air to $-70^{o}$ F dew point

C. Automatic operation -- 24-hour, 7 days at 7.5 GPM

3. April 1973-July 1973

A. Ampimetric ozone determinations by Ozone analyzer to maximize efficiency

B. Backup ozone generator put on line, providing fail-safe ozone production

C. Addition of safety flood alarm to warn lab personnel of leaks

D. High capacity pump installation with flow rate of 10.6 GPM

4. July 1973-October 1973

A. Prefilter pressure indicator to warn of blockage

B. Well water back-flush pump installation to reduce use of city water to wash clogged carbon columns

C. Clock totalizer which shows total hours of ozone water production and back-flush.

With this all-PVC system over 13,000 gallons of seawater are treated and used to hold marine animals, prior to, and during acute and chronic exposure to heavy metals. A sketch of the completed treatment plant is shown in Figure 16.

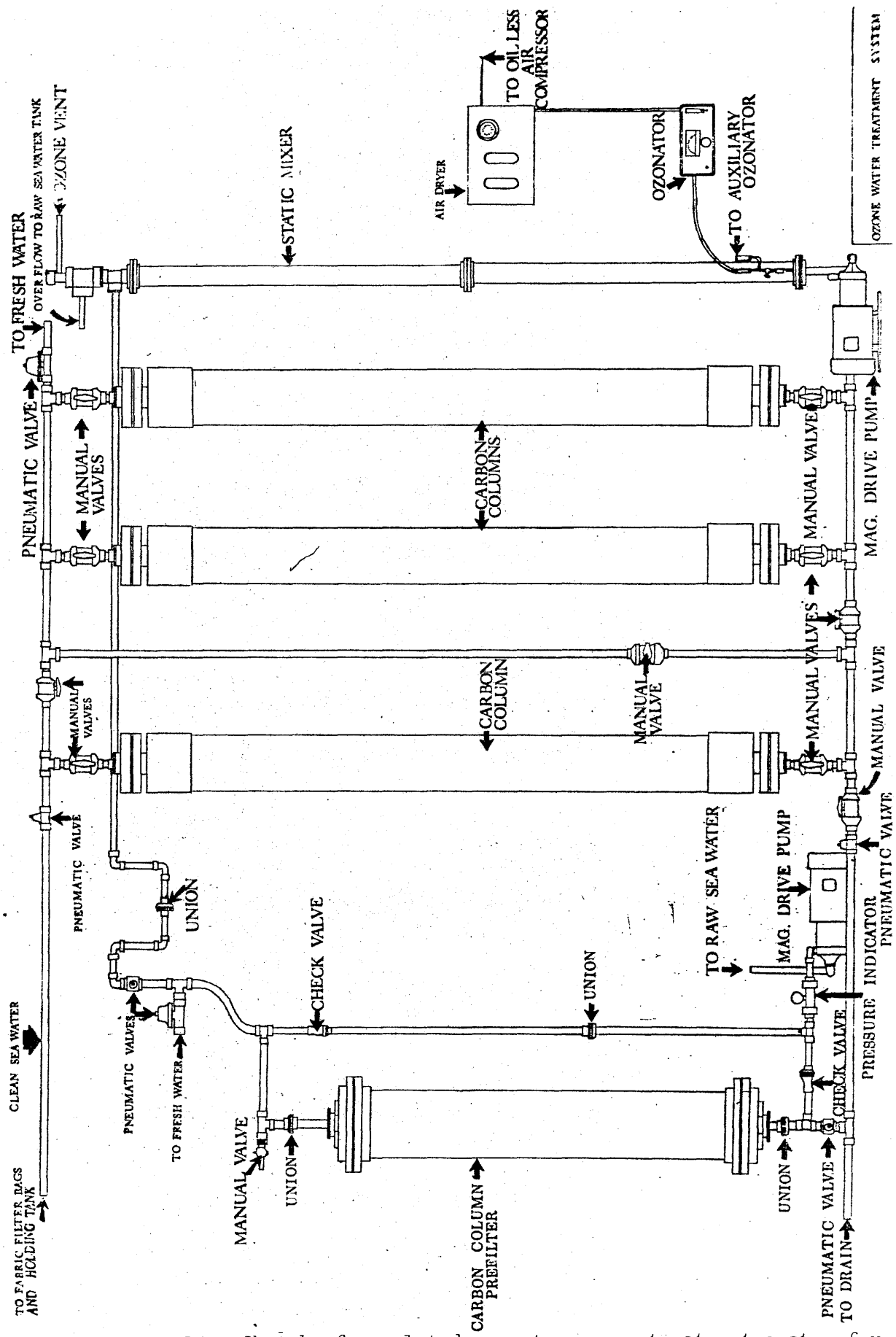


Figure 16. Sketch of completed seawater ozone treatment system for improving water quality at the Milford lab oratory.

The seawater is prefiltered by a 1.7-cubic foot packed column filter containing large mesh coconut shell activated carbon. This step removes algae, silt particles greater than 30$\mu$, and reduces the organic content. The water is then ozonized in a static mixer which maximizes ozone mass transfer by inducing turbulent flow coupled with prolonged interfacial contact.

A magnetic drive, all-plastic pump lifts the ozonized seawater through 10.2 cubic feet of coconut shell activated carbon afterfilters where 5-$\mu$ silt particles are removed and over 95% of the oxidized organic matter is absorbed. These carbon columns also eliminate ozone residual and reduce the presence of active radicals associated with the ozonization of seawater. They are cycle back-flushed about 11 to 12 hours per day to prevent the accumulation of silt and oxidized organic matter. After filtration, the water is stored in a 750-gallon fiberglass-lined tank for gravity distribution. Ozone residual is monitored by an ampimetric ozone analyzer and total plate count determinations are performed to assess microbiocidal efficiency.

Some of the ozonized seawater passes into the chronic exposure laboratory through diluters which meter out precise concentrations of heavy metals or pesticides. This seawater is used to study effects on finfish, mollusks, and crustaceans.

Waste Water Treatment System

The test pollutants will be removed from the waste water before discharging it into Milford Harbor. A description of the waste

treatment facility follows, with a sketch found in Figure 17. The Seawater Quality Control Project was given the task of removing or reducing the toxic metal and pesticide load from the diluter systems' effluent. Based on laboratory and prototype studies a waste treatment system was designed to remove 80-95% of the heavy metals and 99% of the pesticides on a completely automatic basis. The system is based on precipitation and solids separation of heavy metal wastes using commercial grade caustic soda and centrifugation. Pesticide removal is accomplished by activated carbon adsorption. Seawater containing heavy metals will be collected in PVC pipes and treated with 50% sodium hydroxide and flocculant. The hydroxide and flocculant will cause rapid precipitation and coagulation of heavy metal ions as hydroxides. The seawater precipitate mix will be settled and separated in four 100-gallon conical tanks. The seawater will be decanted off and the precipitated, coagulated hydroxide sludge will be separated and strained from the excess seawater by a microstrainer. Sludge will be stored in 55-gallon drums. The strained seawater will be returned to the decanted seawater line and passed through a series of polishing filters that include activated carbon and cloth-wound cartridge types. These filters will be cleaned by freshwater back-flushing on a regular, timed sequence. Finally, the seawater will be sampled and tested for the presence of heavy metal and pesticide carryover to insure all treatment steps are balanced and working at maximum removal efficiency. For pesticide removal, seawater containing these wastes will be segregated from the

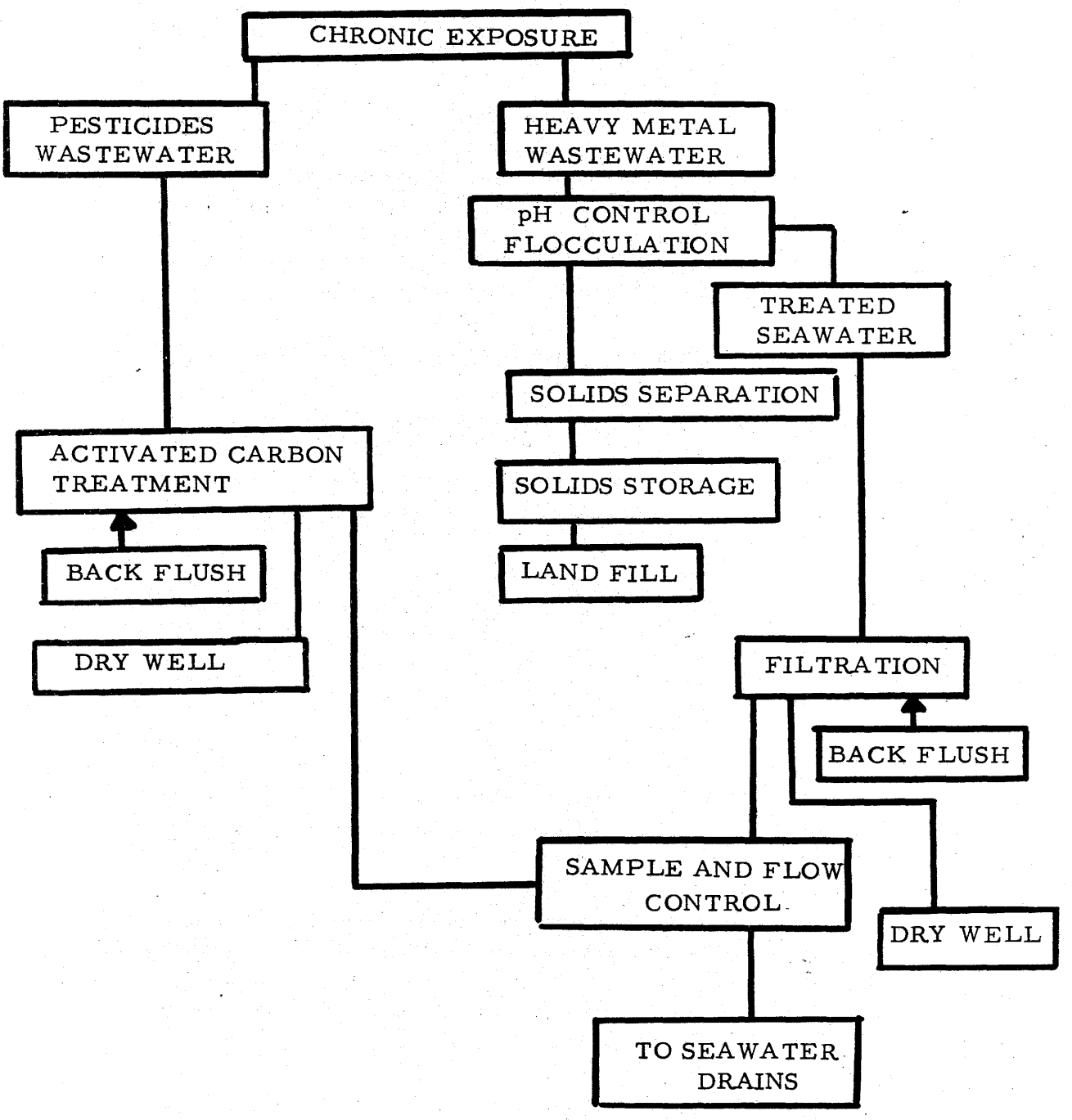


Figure 17. Sketch of waste treatment plant for the chronic exposure laboratory at Milford.

heavy metal seawater physically by separate PVC piping. These wastes will be passed through two 10-cubic feet activated carbon filter beds for adsorption. Two spare filter beds will be available for treatment upon exhaustion of the primary filters. Spent carbon containing pesticides will be returned to the activated carbon manufacturer for regeneration and removal of all pesticides. The carbon beds will be freshwater back-flushed to remove silt and bacterial buildup. This back-flushing will occur on a timed sequence based on actual flow through each filter bed. At this point $15,000 of the Center monies has been spent to complete this waste treatment system. The heart of the system, a continuous flow centrifuge, is presently out on bid. The start-up date for the other components is tentatively January 15, 1974, with the understanding that all deliveries are made on schedule. An additional $2,000 per year operation expense, including back-flush water, electricity, caustic soda, and alum will be required. In addition, one 8-hour shift for one person per week is necessary to check unit operations and clean out the centrifuge. It is to be noted that this waste treatment system is probably unique in that there are no reports in the literature concerning the removal of heavy metals from seawater on a plant scale.

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Thurberg, F. P., and M. A. Dawson

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PATHOBIOLOGY INVESTIGATIONS

MARINE CONTAMINANTS

M. Newman and P. Johnson

The major activity of the Pathobiology Investigations during FY73 in the area of marine contaminants constituted completion of a study on the histopathological changes in cunner (Tautogolabrus adspersus) acutely exposed to cadmium. Histopathology was noted in kidney, intestine, epidermis, and gill. Although quantitative assessments of hematologic pathology were not feasible, qualitative observations revealed that hemopoietic tissue may also be affected. Few significant changes were noted in fish exposed to concentrations less than 48 ppm for 96 hours. Observations made implicate renal failure as the probable cause of death in fish acutely exposed to cadmium. A manuscript "Physiological response of the cunner, Tautogolabrus adspersus, to cadmium. IV. Histopathology" is currently being reviewed prior to publication.

A second series of experiments with estuarine teleosts and cadmium recently has been initiated. Electron microscopy is being utilized to determine ultrastructural changes which may occur at lower concentrations of cadmium or after shorter exposure periods. Epidermis, spleen, anterior and posterior kidney, liver, and intestine were sampled from cunner and the striped bass, Morone saxatilis. Additionally, hematological studies utilizing light microscopy are being conducted

simultaneously. To date fish have been exposed to 12, 24, and 48 ppm cadmium for either 24, 48, or 96 hours. Epon-embedded tissues are being prepared for examination by transmission electron microscopy.

Blue crabs, Callinectes sapidus, have been exposed to 8 and 16 ppm cadmium for 96 hours. In an experiment conducted earlier to determine $LD_{50}$, 60 and 80 ppm cadmium were used for 96 hours. At these concentrations, however, all experimental crabs died. The recently exposed crabs, therefore, were exposed to substantially lower concentrations of cadmium. Tissues dissected and being examined for histopathology with light microscopy include: antennal gland, brain, cardiac stomach, epidermis, eye stalk, swim fin, gill, heart, hepatopancreas, hindgut, midgut, thoracic ganglion, and mandibular organ. Ovary and seminal vesical in females and testis, median vas deferens and posterior vas deferens are being examined in males. As of this date, all dissections have been completed and tissues are being dehydrated preparatory to embedding in paraffin.

## PATHOBIOLOGY INVESTIGATIONS

## PUBLICATIONS DERIVED FROM CONTAMINANT STUDIES

In Press

Newman, M. W., and S. A. MacLean

Physiological response of the cunner, *Tautogolabrus adspersus*, to cadmium. VI. Histopathology. (Special Scientific Report: Fisheries).

REPORT ON THE COLLABORATIVE STUDY OF THE EFFECT OF CADMIUM ON THE CUNNER

The following pages summarize the Middle Atlantic Coastal Fisheries Center's collaborative study on the cunner entitled, "Physiological Response of the Cunner, Tautogolabrus adspersus, to Cadmium."

I. Introduction and Experimental Design

Anthony Calabrese, Ries S. Collier and James E. Miller

II. Uptake of Cadmium by Tissues and Organs

Richard A. Grieg, Albert E. Adams and Betty A. Nelson

III. Changes in Osmoregulation and Oxygen Consumption

Frederick P. Thurberg and Margaret A. Dawson

IV. Effects on the Immune System

Richard A. Robohm and Maureen Nitkowski

V. Observations on the Biochemistry

Edith Gould and John J. Karolus

VI. Histopathology

Martin W. Newman and Sharon A. MacLean

# PHYSIOLOGICAL RESPONSE OF THE CUNNER, *TAUTOGOLABRUS ADSPERSUS*, TO CADMIUM

## I. INTRODUCTION AND EXPERIMENTAL DESIGN

Anthony Calabrese, Ries S. Collier, and James E. Miller

Like most metals, cadmium is stable and does not degrade in the environment. Thus, as increasing amounts of cadmium are refined, more and more of it is circulated in the environment, and increasing amounts may reach man. Cadmium becomes an air and water pollutant through a variety of industrial processes, and is being used in increasing amounts by the storage battery, plastics, plating, and petroleum industries. There is no evidence that cadmium is biologically essential or beneficial, but has, on the other hand, caused severe human health problems. Since cadmium salts are most likely to be found in estuarine areas that are important nursery areas for marine fish and shellfish larvae and juveniles, adult marine fish and shellfish are a potential source of cadmium in the human diet.

Relatively little is known about the effect of cadmium on aquatic animals, particularly those in the marine environment. Most studies on the effect of cadmium to aquatic species have been performed with freshwater forms. More recently, however, research emphasis has been directed toward the effect of cadmium salts on various marine organisms. These studies have progressed from the more classical bioassay tests for simply determining $TL_m$ (that concentration of toxicant causing 50 percent mortality) to those of physiological stress caused by sublethal levels of the pollutant being tested. Studies conducted at sublethal

concentrations of a contaminant material so as to determine physiological damage to the organism concerned may be more important than mortality itself. The gradual elimination of valued marine species by low concentrations of toxicants is no less serious than instantaneous death of those species. In a sense, it is more serious, because it is less likely to be obvious and to be traced to its source in time to permit recovery of the environment. Studies of physiological stress caused by sublethal levels of a toxicant generally require chronic or long-term exposure, but some physiological parameters can be examined in short-term tests. Parameters of physiological damage that can be examined by long-term exposure include growth, life span, reproductive success, adaptation to environmental stress, feeding and mating behavior, changes in respiration and osmoregulation, pathological effects, biochemical anomalies and genetic alterations.

It is apparent that increases in human population and technological development are producing serious stresses on the marine environment, with a resulting decrease in its effective use. These events, plus natural events, are fostering conditions that diminish the harvest of marine resources. The National Marine Fisheries Service (NMFS), as part of the National Oceanic and Atmospheric Administration (NOAA), is concerned about the threat of marine life and is providing a national focus for marine research, to generate the basic knowledge and understanding of marine environmental processes required for effective management of the marine environment and its resource.

The New York Bight, which is receiving international attention because of the large amount of waste material being dumped into it, borders the most heavily populated and industrialized complex in the country. Because the Middle Atlantic Coastal Fisheries Center of the NMFS is located within this geographical area, it is important that this Center undertake studies to determine the impact of man upon the living marine resources of this area. This Center, comprising laboratories in Sandy Hook, New Jersey, Milford, Connecticut, and Oxford, Maryland, has the facilities and scientists to undertake studies of this type. The present study was designed to determine the short-term (96-hours) physiological response of a local fish, Tautogolabrus adspersus, commonly known as the cunner, to cadmium. A multi-disciplinary approach was used to determine the following: 1) Uptake of cadmium into various tissues and organ systems; 2) Changes in osmoregulation and oxygen consumption rates; 3) Changes in enzymological patterns; 4) Immune response to various antigens; and 5) Induction of histopathological abnormalities. Results of these studies are reported in the following sections of this technical report.

Cunners were collected in modified eel pots, a cylinder of 1/2 inch-mesh hardware cloth with a funnel in one end and a hinged door at the other end. Pots were baited with cracked hard clams and fished in 10-25 feet of water in the Stratford to New Haven, Connecticut area of

Long Island Sound. Fish were transported to the laboratory in 15-liter polyethylene buckets and placed in tanks of flowing seawater at ambient temperature. Before being exposed to cadmium, the fish were transferred to tanks of recirculating artificial seawater, adjusted to 25 ppt salinity, and maintained at room temperature for at least one week for acclimation. The first were fed Purina Trout Chow during this time, but were unfed for two days prior to and during the experiment.

Exposure

For exposure to cadmium, the fish were placed in glass aquaria filled to 60 liters, with artificial seawater (Instant Ocean), which was aerated throughout the entire exposure period. Cadmium, as cadmium chloride ($CdCl_2 \cdot 2\text{-}1/2\ H_2O$), was added to test aquaria at concentrations of 3, 6, 12, 24, and 48 ppm of $Cd^{2+}$. Stock solution for all tests was made up with reagent grade cadmium chloride dissolved in distilled water at 50 g $Cd^{2+}$ per liter and acidified to a pH of 2.5 to maintain stability. Proper aliquots of the cadmium stock solution were added immediately prior to the addition of the artificial seawater to obtain desired cadmium concentrations and aeration was begun a few minutes prior to the introduction of test fish. Temperatures ranged from 21 to 25°C and pH levels remained between 7.3 and 7.6 during the entire study. The above five concentrations of cadmium were tested in duplicate, with two aquaria serving as controls, in each of a series of seven tests. Four cunners were placed in each aquarium and were observed daily

throughout the 96-hour exposure period; and, dead fish were removed each day. At the termination of each test the fish were made available to resident scientists at the Milford laboratory and, in addition, specimen samples were prepared for histopathological examination by scientists at the Oxford laboratory. Supplementary tests of the same design were subsequently performed for those research projects needing further samples.

Of a total of 500 fish tested, 126 were sampled for weight and length, averaging 45.2 g in weight and 146.3 mm in length, with a range in length from 115 to 170 mm.

Although the intent of this study was to determine the physiological response of cunners exposed to sublethal levels of cadmium, rather than to determine $TL_m$, some mortality data were attained nevertheless. Concentrations of cadmium (in ppm water) tested and percent mortality (in parentheses) follows: controls (1.8%), 3 (3.5%), 6 (5.4%), 12 (1.8%), 24 (10.7%), and 48 (26.8%). It is obvious from these data that cunners can tolerate high concentrations of cadmium for at least 96 hours. It was also noted in other phases of this study, however, that those fish exposed to 48 ppm of cadmium for 96 hours and then placed in clean seawater all died within a few days.

PHYSIOLOGICAL RESPONSE OF THE CUNNER, TAUTOGOLABRUS ADSPERSUS, TO CADMIUM

II. UPTAKE OF CADMIUM BY ORGANS AND TISSUES

Richard A. Grieg, Albert E. Adams, and Betty A. Nelson

Uptake and clearance data of cadmium were obtained on cunners (Tautogolabrus adspersus) exposed to various concentrations (as cadmium chloride) in artificial seawater.

In the uptake study, cunners were exposed to 0, 3, 6, 12, 24, and 48 ppm cadmium in seawater for 4 days. Cadmium residues averaged 8.2 times higher in livers than in gills. At the 48-ppm cadmium exposure level, the livers averaged 195 ppm as compared to 33.5 ppm for gills (wet wt. values).

In the clearance study, cunners were exposed to 24 ppm cadmium in seawater for four days, after which time half of the fish were placed in clean flowing seawater for one month and half were sacrificed immediately to determine initial cadmium residue concentrations. Gill, liver, blood, muscle, and carcass samples were analyzed. Substantial reductions in cadmium residues were found in the gills and blood of fish held in clean seawater as compared to samples from fish sacrificed immediately after exposure to cadmium. Liver samples produced variable results: livers of fish held in clean seawater for one month contained 62-155 ppm cadmium for 4 fish and 5-11 ppm for 3 fish, as compared to 30-117 ppm for livers from 8 fish sacrificed immediately after exposure to cadmium. Muscle and carcass samples from the "cleared" fish showed very little reduction in cadmium levels.

PHYSIOLOGICAL RESPONSE OF THE CUNNER, TAUTOGOLABRUS ADSPERSUS, TO CADMIUM

III. CHANGES IN OSMOREGULATION AND OXYGEN CONSUMPTION

Frederick P. Thurberg and Margaret A. Dawson

The cunner, Tautogolabrus adspersus, was exposed to various concentrations of cadmium as cadmium chloride ($CdCl_2 \cdot 2\text{-}1/2H_2O$) for 96 hours. At the end of this exposure period tests of blood serum osmolality and gill tissue oxygen consumption were performed. High levels (48 ppm) of this metal resulted in an abnormally high serum osmolality and an exposure as low as 3 ppm reduced the normal rate of oxygen consumption. Both of these parameters may be related to observed tissue damage.

# PHYSIOLOGICAL RESPONSE OF THE CUNNER, *TAUTOGOLABRUS ADSPERSUS*, TO CADMIUM

## IV. EFFECTS ON THE IMMUNE SYSTEM

R. A. Robohm and M. Nitkowski

Two elements of the immune system in cunners (*Tautogolabrus adspersus*) were examined after 96 hour exposure to cadmium: (1) clearance of intracardially injected bacteria from the bloodstream and (2) ability to produce antibody against intraperitoneally injected sheep red blood cells (SRBC). Exposure to 12 ppm cadmium increased the rates of bacterial uptake in phagocytes of the liver and spleen but significantly decreased the rates of fish at 3 to 24 ppm cadmium failed to influence antibody production against SRBC. These results indicate that cadmium affects one aspect of cellular immunity but not humoral immunity in cunners. This affect may increase susceptibility to infection.

PHYSIOLOGICAL RESPONSE OF THE CUNNER, TAUTOGOLABRUS ADSPERSUS, TO CADMIUM

V. OBSERVATIONS ON THE BIOCHEMISTRY

Edith Gould and John J. Karolus

In the liver of cunner, Tautogolabrus adspersus, exposed to 3 ppm and to 24 ppm Cd for 96 hours, aspartate aminotransferase activity was 71% and 59%, respectively, of the activity in livers in control fish.

In the livers of cunners exposed to 24 ppm Cd, nicotinamide adenine dinucleotide reductase activity required 20 mM Mg for activation of the same order that 2 mM Mg produced in control livers.

Although individual variation precludes generalization here, what may be a metal-complexing group of proteins in the serum of cadmium-exposed cunner warrants further electrophoretic study.

# PHYSIOLOGICAL RESPONSE OF THE CUNNER, *TAUTOGOLABRUS ADSPERSUS*, TO CADMIUM

## VI. HISTOPATHOLOGY

Martin W. Newman and Sharon A. MacLean

The histopathological effects of acute exposure of the cunner to water containing cadmium chloride were manifested in the kidney, intestine, hemopoietic tissue, epidermis and gill. Few significant changes were noted in fish exposed to concentrations less than 48 ppm for 96 hours. The results implicate renal failure as the probable cause of death subsequent to acute exposure to cadmium.

# APPENDIX I

# CRUISE REPORT

NOAA Ship Albatross IV

29 July - 6 August 1973

U. S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

MIDDLE ATLANTIC COASTAL FISHERIES CENTER

COASTAL RESOURCE ASSESSMENT INVESTIGATIONS

AND

ECOSYSTEMS INVESTIGATIONS

SANDY HOOK LABORATORY

HIGHLANDS, NEW JERSEY

(Funded by NOAA-MESA appropriations)

## CRUISE OBJECTIVES

### Phase 2 - benthic sampling

Benthic studies on the NOAA Ship Albatross IV were conducted between August 2 and August 6, for the purpose of initiating a quarterly baseline survey of benthic macrofauna and meiofauna (including ciliate, amoeboid, and foraminiferan protozoa and nematodes), heavy metal contaminants, and the mechanical properties of sediments (grain size, etc.) in the apex of the New York Bight. These objectives are more fully explained in MACFC Informal Report #13 for the MESA Program in the New York Bight.

## OPERATIONS

Stations were selected on a grid (1 min. latitude x 1 min. longitude) overlying the apex of the New York Bight (See Fig. 2 and Table 6). Five Smith-McIntyre bottom grab samples were taken at each station.

Each grab sample was brought aboard and slowly drained of the water standing on top of the sediment sample. Three cores were then removed from near the center of the sample. Two of the cores were taken with 38 mm (1.5 inch) diameter plastic core liners. These cores were labeled and frozen for future analyses for heavy metals and the mechanical properties of sediment. The third core was taken with a 25 mm (1.0 inch) diameter plastic tube to a depth of approximately 5 cm. The sample was placed in a labeled jar containing buffered formalin and rose bengal and stored for meiofaunal (nematodes and foraminfera) examination. The remainder of the Smith-McIntyre grab sample was removed from the grab and washed through standard geological screens. The material trapped on screens (larger than 1 mm) was placed in labeled jars and seawater and magnesium chloride was added to narcotize the organisms. After 30 minutes formalin was added and the samples were stored for macrofaunal examination.

In addition, at each station samples were taken using a Niskin water bottle for bottom dissolved oxygen, salinity and temperature. The oxygen samples were titrated on board using a sample volume of 203 ml and titrating with .025 N PAO with liquid starch as the indicator. The salinity samples were stored at Sandy Hook for later analysis using an RS7-B salinometer.

## RESULTS

Each of sixty-four stations in the New York Bight apex are now represented by 5 Smith-McIntyre samples and associated cores collected during the subject cruise. (Table 6 and Fig. 2). In all a total of 320 bottom grab samples were taken.

Three-hundred-twenty frozen core samples for heavy metal analyses are awaiting distribution to Dr. Graikoski, Chief of Environmental Chemistry and Microbiology Investigation, NMFS/MACFC Milford Laboratory. Three-hundred-twenty core samples for geological analyses are awaiting transport to Dr. Anthony Cok (Adelphi University). Three-hundred-twenty samples for meiofaunal (nematodes and foraminifera) examination were furnished to Dr. John Tietjen (CCNY) on 10 August 1973. Macrofaunal samples have been transferred to alcohol and glycerin and are being sorted, counted identified and recorded on standard forms by contract personnel (Trenton State College).

In addition the water column and bottom sediments at four stations (1 control, 1 sewage sludge, 1 dredge spoil, and 1 acid-industrial wastes) were sampled for Dr. Sawyer (NMFS/MACFC, Oxford) to facilitate his investigation of amoeboid protozoa (see Fig. 2). Bottom sediment samples were collected at the same four stations for microbial (primarily bacterial) analyses by Dr. David Rose (Trenton State).

Table 6.

East

40°34'N, 73°48'W
40°34'N, 73°46'
40°34'N, 73°44'
40°34'N, 73°42'
40°34'N, 73°40'
40°34'N, 73°38'

South & then west

40°31'N, 73°38'W
40°31'N, 73°40'
40°31'N, 73°42'
40°31'N, 73°44'
40°31'N, 73°46'
40°31'N, 73°48'
40°31'N, 73°50'
40°31'N, 73°52'
40°31'N, 73°54'
40°31'N, 73°56'

South & then east

40°28'N, 73°56'
40°28'N, 73°54'
40°28'N, 73°52'
40°28'N, 73°50'
40°28'N, 73°48'
40°28'N, 73°46'
40°28'N, 73°44'
40°28'N, 73°42'
40°28'N, 73°40'
40°28'N, 73°38'

South & then west

40°25'N, 73°38'W
40°25'N, 73°40'
40°25'N, 73°42'
40°25'N, 73°44'
40°25'N, 73°46'
40°25'N, 73°48'
40°25'N, 73°50'
40°25'N, 73°52'
40°25'N, 73°54'
40°25'N, 73°56'
40°25'N, 73°57'

Table 6 (continued)

South & then east

40°22'N, 73°57'W
40°22'N, 73°56'
40°22'N, 73°54'
40°22'N, 73°52'
40°22'N, 73°50'
40°22'N, 73°48'
40°22'N, 73°46'
40°22'N, 73°44'
40°22'N, 73°42'
40°22'N, 73°40'
40°22'N, 73°38'

South & then west

40°19'N, 73°38'W
40°19'N, 73°40'
40°19'N, 73°42'
40°19'N, 73°44'
40°19'N, 73°46'
40°19'N, 73°48'
40°19'N, 73°50'
40°19'N, 73°52'
40°19'N, 73°54'
40°19'N, 73°56'
40°19'N, 73°58'

South & then east

40°16'N, 73°58'W
40°16'N, 73°56'
40°16'N, 73°54'
40°16'N, 73°52'
40°16'N, 73°50'

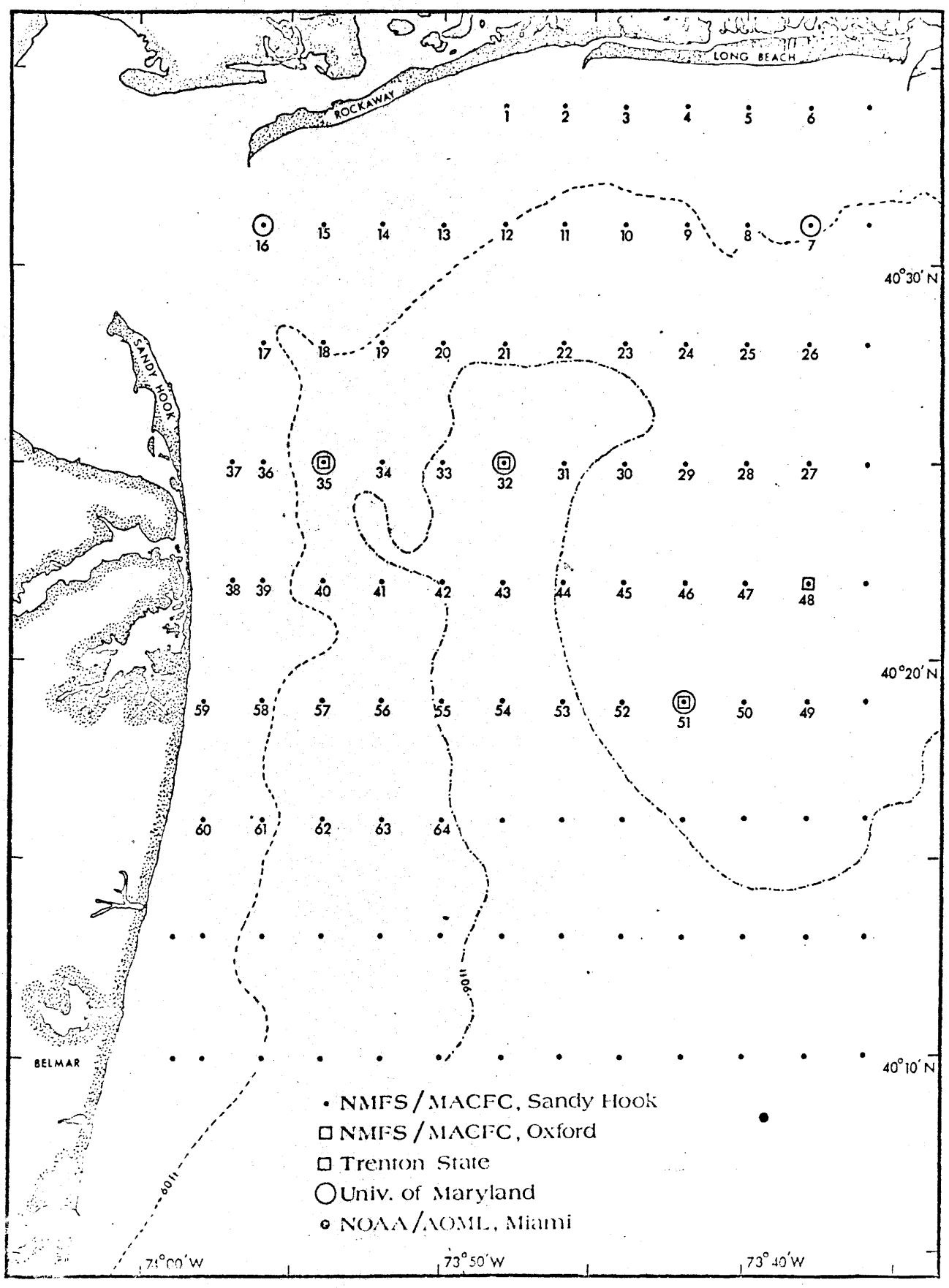

LONG BEACH
ROCKAWAY
SANDY HOOK
BELMAR
40°30′N
40°20′N
40°10′N
74°00′W
73°50′W
73°40′W
• NMFS / MACFC, Sandy Hook
□ NMFS / MACFC, Oxford
□ Trenton State
○ Univ. of Maryland
○ NOAA / AOML, Miami

Figure 2

As part of Phase 2 certain of the stations sampled for macrofauna, nematode meiofauna, heavy metals, and sediment parameters were also sampled for microorganisms, particularly the ciliated protozoa, in both the water column and the bottom sediments. The positions of these stations are indicated in Fig. 2.

Included in this report is a cruise report prepared by Miss Cady Soukup and Miss Sue Suchard, graduate students of Dr. Eugene B. Small (University of Maryland), a principal MESA contract researcher investigating the ciliate protozoa associated with man induced change in the subtidal environment of the New York Bight. They were able to test the usefulness of several types of meiofaunal sampling methods and compare the effectiveness of different extraction and concentration techniques. Their preliminary results include interesting findings with regard to the presence and absence of certain genera of protozoan in the control and disposal areas.

Samples for benthic meiofauna were obtained with a Smith-Mcintyre grab and a series of five-liter Niskin bottles. The Nisken sampling involved determination of the depth of the euphotic zone ($\sim$ 3 times secchi disc reading) which determined the number and depth of the samples. Fifteen liters of seawater were routinely taken at depths of one meter, one to two meters below the determined euphotic zone, and the bottom. If the calculation of the euphotic zone depth exceeded the total depth, the middle sample and bottom sample were combined.

Protozoa were extracted from the sediment cores by means of the Uhlig-sea water ice method, which proved successful at the control and acid sites; the sewage sludge and dredging spoils sites were too silty to use this technique. Four foot and two foot twenty millimeter diameter glass columns with three to four inch sediment corer were set up in an additional attempt to extract ciliates from sediments. This method was used to force the ciliates to the air-water interface as a result of the oxygen imbalance produced at the water-sediment interface; it failed to yield numbers at any of the sites. At all sites a portion of the sediment was placed in jars and maintained at room temperature (after Bovee, summer '73) in order to separate protozoan from sediments; this has proven successful at the sewage sludge site where the Uhlig method was ineffective.

The grab water was filtered through a Millipore system in an attempt to concentrate those present at the sediment-water interface. The water from the Nisken bottles was filtered by gravity through a series of 80u, 35u and 20u filters and examined for protozoa. In addition to live observations, protozoa from all sites were fixed for cytological staining for further identification.

The preliminary results are presented in Tables I - III. We found a fairly diverse and abundant protozoan faunal assemblage at the control sites, mostly in the sediment. Bactiverous protozoa appeared to predominate at the sewage sludge and dredge spoil sites. At these sites the protozoa were primarily at the one meter depth where the temperature exceeded the bottom temperature by approximately 8 degrees. The predominance of the ciliates in the water column was probably a temperature dependent phenomenon, rather than one of distribution according to bathymetry. The fauna at the acid waste site appeared fairly balanced, although the diatom feeders were particularly abundant.

Table I. Efficiency of Sampling Methods

| Sampling Area \ Sampling Methods | Winogradsky column | Spoon's Test Tube Method | Uhlig Sea Water Ice | Culturing (cracked wheat) | Direct Observation A. cores B. grab C. [illegible] | Bovee Jar "Rotting" | Millipore Filtering Grab Water | Cascade of Filters A. Top B. Bottom C. [illegible] |
|---|---|---|---|---|---|---|---|---|
| 15 Control 6/21 | − (10hrs) | | ++ | + | ++ A B | + | / | / |
| 67 Edge of Sewage 6/19 | + (48hrs) | + (48hrs) | − | − | + A | − | / | / |
| 111 Sewage 6/19 | + (48h) | − | − | − | − | ++ | / | / |
| 36 Edge of Dredge Spoils 6/18 | − | + (7h.) | ++ | + | ++ | − | / | / |
| V-1 Dredging Spoils 6/18 | − | + (26h) | + | + | − | − | / | / |
| W-2 Dredging Spoils 6/19 | − | + (24hs) | − | + | − | − | / | / |
| #7 Control 8/3 | − | / | ++ | | ++ A B C | | + | + |
| #16 Control 8/3 | − | / | + | | ++ ABC | | + | + |
| #32 Sewage 8/4 | − | / | − | | + C | | + | + |
| #35 Dredging Spoils 8/4 | − | / | − | | + C | | − | + |
| #48 Acid Waste 8/5 | − | / | ++ | | + A | | + | + |

Table II. June 18-21

| SITE: TENTATIVE GENERA/SPECIES — FEEDING PREFERENCE | BACTERIA | DETRITUS | DIATOMS | DINO-FLAGELLATES | EUGLENOID FLAGELLATES | CILIATES | MICROMETAZOA | HISTOPHAGES |
|---|---|---|---|---|---|---|---|---|
| .5 CONTROL 6/21 | T.K.S. site | | Sandy Substrate | | | | | |
| Uronema marinum | + | | | | | | | |
| Trachelocercids (family) | | | + | + | + | + | | |
| Loxophyllum sp. | | | | | | + | | |
| Litonotus sp. | | | | | | + | | |
| Hypotrichs (order) | + | + | + | + | + | + | | |
| Euplotes sp. | + | + | + | | + | | | |
| Tintinnids (order) | + | | | | | | | |
| Scuticociliates | + | | | | | | | |
| 3½ Edge of Dredge Area 6/18 and 6/21 | | | Coarse Sand Substrate | | | | | |
| Loxophyllum sp. | | | | | | + | | |
| Trachelocercid (f.) | | | | + | + | + | | |
| Hypotrich (o.) | + | + | + | + | + | + | | |
| Trachelocerca sp. | | | + | + | + | + | | |
| Colpoda sp. | | | | + | | | | + |
| small Scuticos (o.) | + | | | | | | | |
| Uronema nigricans | + | | | | | | | |
| Cyclidium dimorphulatum | + | | Black Rubble with Brick Pieces | | | | | |
| W-2 Dredge Spoils 6/18 | | | | | | | | |
| C. dimorphulatum | + | | | | | | | |
| V-1 Dredge Spoils 6/18 | T.K.S. site | | Black Rubble with Oil Globs | | | | | |
| U. nigricans | + | | | | | | | |
| C. dimorphulatum | + | | Sand, Some sewage muck | | | | | |
| 6? Edge of Sewage 6/9 | | | | | | | | |
| Trachelocercid (f.) | | | + | + | + | + | | |
| C. dimorphulatum | + | | | | | | | |
| III Sewage 6/9 | | | Silty Mud | | | | | |
| Trachelocercid (f.) | | | + | + | + | + | | |
| Euplotes sp. | | | | | | | | |
| Scutico sp. 1 | + | | | | | | | |
| Scutico sp. 2 | + | | | | | | | |
| Scutico sp. 3 | + | | | | | | | |
| Scutico sp. 4 | + | | | | | | | |

* All of these organisms were observed on sediment/water interface

Table III. R/V Albatross Cruise. August 3-6

| SITE: FEEDING PREFERENCE / TENTATIVE GENERA/SPECIES | BACTERIA | DETRITUS | DIATOMS | DINO-FLAGELLATES | EUGLENOID FLAGELLATES | CILIATES | MICRO METAZOA | HISTOPHAGES |
|---|---|---|---|---|---|---|---|---|
| #7 CONTROL 8/3 | Coarse | Sand. Gravel | | | | | | |
| Sediment: Lacrymaria sp. 1 | | | | | | + | | |
| Lacrymaria sp. 2 | | | | | | + | | |
| Metopus sp. | + | | | | | | | |
| Litonotus sp. | | | | | | + | | |
| Loxophyllum sp. | | | | | | + | | |
| Trachelorraphis sp. 1 | | | + | + | + | + | | |
| Trachelorraphis sp. 2 | | | + | + | + | + | | |
| small Scuticos (c.) | + | | | | | | | |
| Sed/Water: Pseudoprorodon sp. | | | + | + | | | | |
| Paraspathidium sp. | | | + | + | + | + | + | + |
| Metopus sp. | + | | | | | | | |
| Phagiopyla sp. | + | | | | | | | |
| Water col.: Scutica sp. | + | | | | | | | |
| #16 CONTROL 8/3 | Fine | Sand, Clean | | | | | | |
| Sed: Remanella sp. | | | + | + | + | | | |
| Loxophyllum sp. | | | | | | + | | |
| Amphileptus sp. | | | | | + | + | | |
| Litonotus sp. | | | | | | + | | |
| Trachelocerca sp. | | | + | + | + | + | | |
| Cyclidium sp. | + | | | | | | | |
| Euplotes sp. 1 | + | | + | | | | | |
| Euplotes sp. 2 | + | | + | | | | | |
| Pseudoprorodon sp. | | | + | + | | | | |
| Paraspathidium sp. | | | + | + | + | + | + | + |
| Metopids (5.) | + | | | | | | | |
| Sed/Wat. Euplotes sp. | + | | + | | | | | |
| Water col.: Bottom Euplotes sp. 1 | + | | | | | | | |
| 1m. Frontonia sp. | | | + | + | | | | |
| #32 SEWAGE 8/4 | Black Muck, some (very little) sand | | | | | | | |
| Sed: diatoms (Rhizoselenia setigera), 1 nematode | | | | | | | | |
| Sed/Wat: Scutico Sp. 1 | + | | | | | | | |
| Water col: Scutico Sp. 1 | + | | | | | | | |
| Scutico Sp. 2 | + | | | | | | | |

Table III. R/V Albatross Cruise. August 3-6

| SITE: TENTATIVE GENERA/SPECIES \ FEEDING PREFERENCE | BACTERIA | DETRITUS | DIATOMS | DINO-FLAGELLATES | EUGLENOID FLAGELLATES | CILIATES | MICRO-METAZOA | HISTOPHAGE |
|---|---|---|---|---|---|---|---|---|
| #35 DREDGING AREA 8/4 | Black rubble, muck, some sand | | | | | | | |
| Sed: nothing that moved | | | | | | | | |
| Sed/Water: — | | | | | | | | |
| Water column: Bottom Euplotes sp. | + | | + | | | | | |
| Scutica sp. | + | | | | | | | |
| 7 m ↓: Frontonia sp. | | | + | + | | | | |
| Scutica sp. | + | | | | | | | |
| 1m. ↓: Euplotes sp. 1 | + | | + | | | | | |
| Scutica sp. | + | | | | | | | |
| #48 ACID WASTE 8/5 | Sandy substrate, ferric nodules on surface | | | | | | | |
| Sed: Tracheloraphis sp. | | | + | + | + | + | | |
| Trachelocerca sp. | | | + | + | + | + | | |
| Kentrophorus sp. | | | + | | | | | |
| Lacrymaria sp. | | | | | | + | | |
| Sed/Wat.: Foraminifer, diatoms, radiolarian (Hexalonche hexalonchetta) | | | | | | | | |
| Wat. Col.: Bottom — | | | | | | | | |
| Top. — | | | | | | | | |

# APPENDIX II

# CRUISE REPORT

NOAA Ship Oregon II

19 - 26 October 1973

U. S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

MIDDLE ATLANTIC COASTAL FISHERIES CENTER

ECOSYSTEMS INVESTIGATIONS

SANDY HOOK LABORATORY

HIGHLANDS, NEW JERSEY

(Funded by NOAA-MESA appropriations)

## INTRODUCTION

The NOAA Ship Oregon II departed Sandy Hook at 1000 hrs., 19 October bound for Barren Island, New York, for RAYDIST installation. Vessel arrived at Barren Island 1130 hrs. Departed Barren Island at 2000 hrs. with RAYDIST installed. Due to malfunctioning of RAYDIST, vessel returned to Barren Island at 0800 hrs., 20 October. RAYDIST removed and vessel departed Barren Island at 0930 hrs. Commenced sampling with Smith-McIntyre bottom grab at 1200 hrs. along northern two lines of MESA grid (See Fig. 1).

Suspended sampling at 0930 hrs., 21 October after 20 stations to return to Barren Island. Arrived Barren Island at 1200 hrs. and RAYDIST navigator was installed on vessel. Recorder not installed due to malfunctioning and lack of repair parts. Departed Barren Island at 1400 hrs. Arrived at Ambrose Light Tower at 1500 hrs. for RAYDIST calibration. Calibration completed by 1714 hrs. Commenced sampling with Smith-McIntyre at 1720 hrs. Functioning of RAYDIST was questionable.

Suspended sampling at 1133 hrs., 22 October, after 36 stations. Following a RAYDIST calibration at Ambrose Light, commenced sampling again at 1357 hrs at station 37. Functioning of RAYDIST was questionable.

On 23 October, after 51 stations, we again suspended sampling at 0952 hrs. to steam to Ambrose Light for RAYDIST calibration. The vessel then steamed to "BA' buoy to check calibration. RAYDIST lane count off 150 lanes. Sampling initiated at station 52 based on radar fixes.

On 24 October, again suspended sampling at station 65 at 0743 hrs. to calibrate RAYDIST at "BA" buoy. Following calibration, attempted to arrive at station 66 using RAYDIST. Found error based on radar and LORAN. Initiated sampling at 1127 hrs. at station 66 based on radar fixes. RAYDIST lane count found to be highly variable. Once out of radar range the RAYDIST unit was secured and the remainder of the sampling was accomplished using LORAN.

Sampling was terminated late on 25 October after 91 stations due to rough seas. The vessel then steamed to Barren Island to have the RAYDIST unit repaired for Phase 2 of the cruise. On 26 October, after RAYDIST repairs, vessel steamed from Barren Island to Sandy Hook where it was off-loaded by 1800 hrs. Phase 2 of the cruise began following an Open House at the Sandy Hook Laboratory on 27 October (see AOML cruise report).

## SCIENTIFIC PERSONNEL

Phase 1 - Smith-McIntyre grab (bottom) sampling

| | |
|---|---|
| James Thomas, Party Chief | Susan Sledge |
| William Phoel | Richard McGrath |
| Frank Steimle | Cady Soulup |
| Leslie Rogers | Clyde MacKenzie |
| Christine Evans | Bruce Blauch |

## CRUISE OBJECTIVES

Phase 1 - Benthic sampling.

The objective of Phase 1 of this cruise was to provide baseline data necessary to the accomplishment of MESA Task No. 4: Benthic Macrofauna and No. 5: Benthic Meiofauna (MACFC, Informal Report No. 13). Samples were collected for examination and analyses for macrofauna, meiofauna (amoeboid and ciliated protozoans and nematodes), heavy metal burdens in sediments, and mechanical properties of sediments (grain size distribution, etc.).

## OPERATIONS

Stations were selected on a grid (1 min. latitude x 1 min. longitude) overlying the apex of the New York Bight (see Fig. 1 and Table 1). Five Smith-McIntyre bottom grab samples were taken at each station.

Each grab sample was brought aboard and three cores were removed from near the center of the sample. Two of the cores were taken with 38 mm (1.5 inch) diameter plastic core liners. These cores were labeled and frozen for future analyses for heavy metals and the mechanical properties of sediment. The third core was taken with a 25 mm (1.0 inch) diameter plastic tube to a depth of approximately 5 cm. The sample was placed in a labeled jar containing buffered formalin and rose bengal and stored for meiofaunal (nematodes and foraminfera) examination. The remainder of the Smith-McIntyre grab sample was removed from the grab and washed through standard geological screens. The material trapped on screens (larger than 1 mm) was placed in labeled jars and seawater and magnesium chloride was added to narcotize the organisms. After 30 minutes formalin was added and the samples were stored for macrofaunal examination.

In addition, at each station samples were taken using a Niskin water bottle for bottom dissolved oxygen, salinity and temperature. The oxygen samples were titrated on board using a sample volume of 203 ml and titrating with .025 N PAO with liquid starch as the indicator. The salinity samples were stored at Sandy Hook for later analysis using an RS7-B salinometer.

## RESULTS

Each of 91 stations in the New York Bight apex are now represented by five Smith-McIntyre samples and associated cores collected during the subject cruise (Table 1 and Fig. 1). In all, a total of 455 bottom grab samples were taken.

Table 1

East

40°34'N, 73°48'W
40°34'N, 73°46'W
40°34'N, 73°44'W
40°34'N, 73°42'W
40°34'N, 73°40'W
40°34'N, 73°38'W

South & then west

40°31'N, 73°38'W
40°31'N, 73°40'W
40°31'N, 73°42'W
40°31'N, 73°44'W
40°31'N, 73°46'W
40°31'N, 73°48'W
40°31'N, 73°50'W
40°31'N, 73°52'W
40°31'N, 73°54'W
40°31'N, 73°56'W

South & then east

40°28'N, 73°58'W
40°28'N, 73°56'W
40°31'N, 73°36'W
40°34'N, 73°36'W
40°28'N, 73°54'W
40°28'N, 73°52'W
40°28'N, 73°50'W
40°28'N, 73°48'W
40°28'N, 73°46'W
40°28'N, 73°44'W
40°28'N, 73°42'W
40°28'N, 73°40'W
40°28'N, 73°38'W

South & then west

40°25'N, 73°38'W
40°25'N, 73°40'W
40°25'N, 73°42'W
40°25'N, 73°44'W
40°25'N, 73°46'W
40°25'N, 73°48'W
40°25'N, 73°50'W
40°25'N, 73°52'W
40°25'N, 73°54'W
40°25'N, 73°56'W
40°25'N, 73°57'W

Table 1 (continued)

South & then east

40°22'N, 73°57'W
40°22'N, 73°56'W
40°22'N, 73°54'W
40°22'N, 73°52'W
40°22'N, 73°50'W
40°22'N, 73°48'W
40°22'N, 73°46'W
40°22'N, 73°44'W
40°22'N, 73°42'W
40°22'N, 73°40'W
40°22'N, 73°38'W

South & then west

40°19'N, 73°38'W
40°19'N, 73°40'W
40°19'N, 73°42'W
40°19'N, 73°44'W
40°19'N, 73°46'W
40°19'N, 73°48'W
40°19'N, 73°50'W
40°19'N, 73°52'W
40°19'N, 73°54'W
40°19'N, 73°56'W
40°19'N, 73°58'W

South & then east

40°16'N, 73°58'W
40°16'N, 73°56'W
40°16'N, 73°54'W
40°16'N, 73°52'W
40°16'N, 73°50'W
40°16'N, 73°48'W
40°16'N, 73°46'W
40°16'N, 73°44'W
40°16'N, 73°42'W
40°16'N, 73°40'W
40°16'N, 73°38'W

South & then west

40°13'N, 73°38'W
40°13'N, 73°40'W
40°13'N, 73°42'W
40°13'N, 73°44'W
40°13'N, 73°46'W
40°13'N, 73°48'W
40°13'N, 73°50'W
40°13'N, 73°52'W
40°13'N, 73°54'W
40°13'N, 73°56'W
40°13'N, 73°58'W

Table 1 (continued)

| South & then east |
|---|
| 40°10'N, 73°59'W |
| 40°10'N, 73°58'W |
| 40°10'N, 73°56'W |
| 40°10'N, 73°54'W |
| 40°10'N, 73°46'W |
| 40°10'N, 73°44'W |

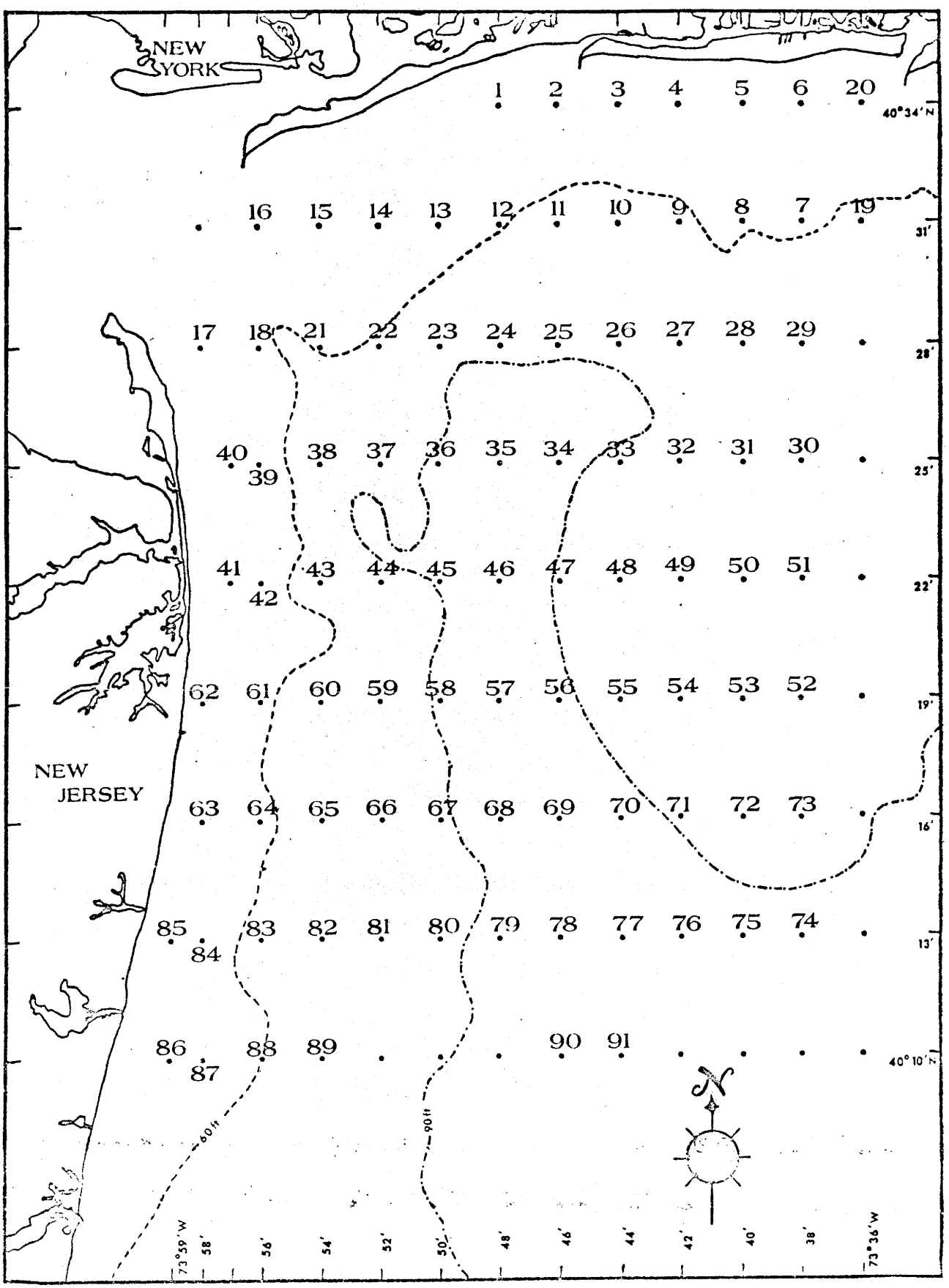

NEW YORK
NEW JERSEY
1 2 3 4 5 6 20
16 15 14 13 12 11 10 9 8 7 19
17 18 21 22 23 24 25 26 27 28 29
40 39 38 37 36 35 34 33 32 31 30
41 42 43 44 45 46 47 48 49 50 51
62 61 60 59 58 57 56 55 54 53 52
63 64 65 66 67 68 69 70 71 72 73
85 84 83 82 81 80 79 78 77 76 75 74
86 87 88 89 90 91
40°34'N
31'
28'
25'
22'
19'
16'
13'
40°10'N
60 ft
90 ft
73°59'W
58'
56'
54'
52'
50'
48'
46'
44'
42'
40'
38'
73°36'W

Figure 1.

Four-hundred fifty-five frozen core samples for heavy metal analyses are awaiting distribution to Dr. Graikoski, Chief of Environmental Chemistry and Microbiology Investigation, NMFS/MACFC Milford Laboratory. Four-hundred fifty-five core samples for geological analyses were transported to Dr. Anthony Cok (Adelphia University) on 13 November. Four-hundred fifty-five samples for meiofaunal (nematodes and foraminifera) examination are awaiting transfer to Dr. John Tietjen and Dr. John Lee (CCNY). Macrofaunal samples have been transferred to alchohol and glycerin and are being sorted, counted, identified and recorded on standard forms by contract personnel (Trenton State College).

Samples for examining ciliated protozoa were collected by Cady Soukup and Susan Sledge for Dr. Eugene B. Small (University of Maryland) at stations 7 (control), 16 (control), 35 (sewage sludge), 38 (dredge spoil), 54 (acid wastes), 85 (control), and 91 (control). Their cruise report follows:

Sampling methods used during this cruise were those found most successful on previous cruises for investigating the protozoa of the water column, sediment water interface, and sediment. Coverage of the Bight study area was broadened two stations by adding two new control areas along the New Jersey shoreline to the two control areas previously sampled along the Long Island shore and the three stations previously sampled in the three impacted areas. The new stations will broaden our data base and provide us with a better idea of what is actually happening.

Our new methods now include quantitative sampling of the water column. The Secchi disk method of determining the depth of the euphotic zone was used to determine whether two or three 30 liter Nisken bottle samples were taken at a station (as previously described in the July 1973 R/V Albatross IV Cruise Report). The total water filtered was determined to 0.1 l and 20 mls. of millipore filtered water were placed with 80u, 35u, or 20u filters. Ten mls. of the resulting plankton "soup" were preserved in "Bouin's" fixative for counting, and 10 mls. were reserved for live examination. The Uhlig seawater ice extraction technique for concentration of sand protozoa was extremely successful in all but the sewage and dredge areas. Results from the millipore filtered grab water proved to be good for examining the interface microfauna.

In conclusion, the protozoa in the water column were less numerous during this cruise than during this past summer, but the sediment protozoa were still present in more or less the same relative quantities as during this past summer.

In addition, the water column and bottom sediments at three stations were sampled by Cady Soukup and Susan Sledge for Dr. Sawyer (NMFS/MACFC, Oxford) to facilitate his investigation of amoeboid protozoa. A copy of his cruise report follows:

# APPENDIX III

# CRUISE REPORT

NOAA Ship Albatross IV

22 January - 5 February 1974

U. S. Department of Commerce
National Oceanic and Atmoshperic Administration
National Marine Fisheries Service

Middle Atlantic Coastal Fisheries Center

Ecosystems Investigations

Resource Assessment Investigations

Sandy Hook Laboratory

Highlands, New Jersey

(Funded by NOAA-MESA Appropriations)

INTRODUCTION:

The NOAA Ship Albatross IV arrived Sandy Hook at 0830 hrs., 22 January 1974 and loading commenced immediately. The RAYDIST had been previously installed at Woods Hole, Mass. Loading completed, the vessel departed Sandy Hook at 1530 hrs. to calibrate RAYDIST off Monmouth Beach. Following calibration the vessel proceeded to station 1 to commence sampling at 2000 hrs. The weather was excellent and the cruise proceeded smoothly. RAYDIST operations were still subject to problems, although these did not interfere with the completion of the cruise. Smith-McIntyre grab bottom sampling, multiple core sampling and sampling for ciliated protozoa were completed by 0800 hrs. on 30 January. The vessel was then met off Monmouth Beach by the R/V Rorqual for the purpose of taking on board Lt. Cdr. Stubblefield and George Lapiene (AOML) to operate the Substrate Monitoring Program (SUMP). During this phase personnel from the Ecosystems Investigation at Sandy Hook assisted by collecting 88 bottom grab samples with the Smith-McIntyre. From each sample AOML removed two 12 dram quantities of sediment from one-half the surface area of the Smith-McIntyre sample. The remainder of the sample was treated according to procedures outlined later in this report under operations. The significance is that in addition to the SUMP parameters being sampled, heavy metals, the mechanical properties of sediment, meiofauna (nematodes and foraminifera), and macrofauna (greater than 1 mm in size), samples were also collected from the same grab sample to facilitate biological and geological comparisons. SUMP operations terminated at 1800 hrs. on 31 January.

SCIENTIFIC PERSONNEL:

Phase 1 - Smith-McIntyre grab (bottom) sampling and multiple core operations:

| | |
|---|---|
| James Thomas, Party Chief | Michael Davis |
| William Phoel | Richard Carl |
| Clyde MacKenzie | Phillip Fallon |
| Frank Steimle | Allen Poriando |
| Leslie Rogers | Nick Prahl |
| Cady Soukup | Robert Robinson |
| Richard Hurd | |

Phase 2 - Substrate Monitoring Program - AOML

William Stubblefield, Party Chief

| | |
|---|---|
| George Lapiene | Richard Hurd |
| James Thomas | Richard Carl |
| Clyde MacKenzie | Phillip Fallon |
| William Phoel | Allen Poriando |
| Frank Steimle | Nick Prahl |
| Leslie Rogers | Robert Roush |
| Cady Soukup | Robert Robinson |

South & then east

40°22'N, 73°57'W
40°22'N, 73°56'W
40°22'N, 73°54'W
40°22'N, 73°52'W
40°22'N, 73°50'W
40°22'N, 73°48'W
40°22'N, 73°46'W
40°22'N, 73°44'W
40°22'N, 73°42'W
40°22'N, 73°40'W
40°22'N, 73°38'W

South & then west

40°19'N, 73°38'W
40°19'N, 73°40'W
40°19'N, 73°42'W
40°19'N, 73°44'W
40°19'N, 73°46'W
40°19'N, 73°48'W
40°19'N, 73°50'W
40°19'N, 73°52'W
40°19'N, 73°54'W
40°19'N, 73°56'W
40°19'N, 73°58'W

South & then east

40°16'N, 73°58'W
40°16'N, 73°56'W
40°16'N, 73°54'W
40°16'N, 73°52'W
40°16'N, 73°50'W
40°16'N, 73°48'W
40°16'N, 73°46'W
40°16'N, 73°44'W
40°16'N, 73°42'W
40°16'N, 73°40'W
40°16'N, 73°38'W

South & west

40°13'N, 73°38'W
40°13'N, 73°40'W
40°13'N, 73°42'W
40°13'N, 73°44'W
40°13'N, 73°46'W
40°13'N, 73°48'W
40°13'N, 73°50'W
40°13'N, 73°52'W
40°13'N, 73°54'W
40°13'N, 73°56'W
40°13'N, 73°58'W
40°13'N, 73°59'W

East

40°34'N, 73°48'W
40°34'N, 73°46'W
40°34'N, 73°44'W
40°34'N, 73°42'W
40°34'N, 73°40'W
40°34'N, 73°38'W

South & then west

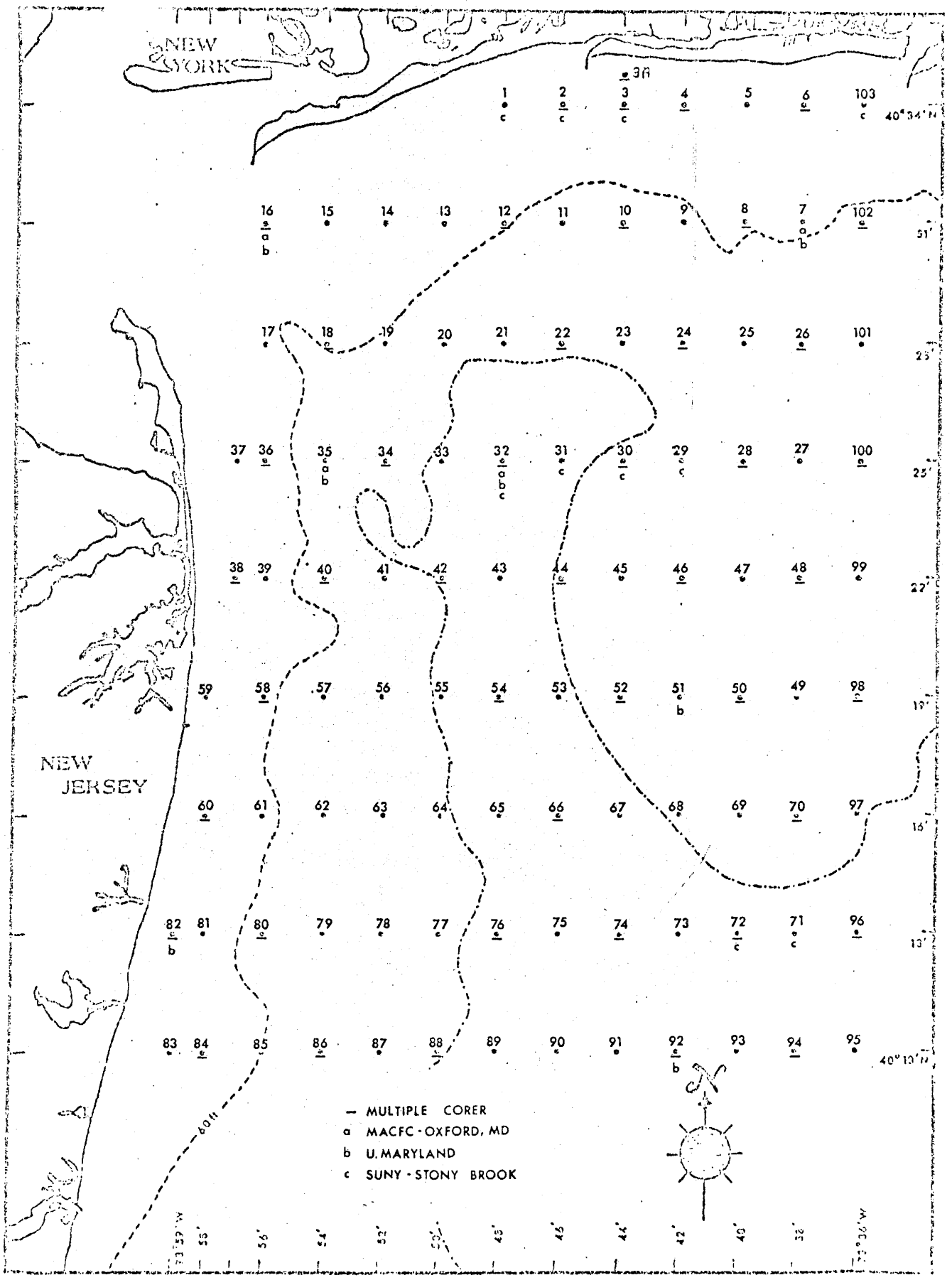
40°31'N, 73°38'W
40°31'N, 73°40'W
40°31'N, 73°42'W
40°31'N, 73°44'W
40°31'N, 73°46'W
40°31'N, 73°48'W
40°31'N, 73°50'W
40°31'N, 73°52'W
40°31'N, 73°54'W
40°31'N, 73°56'W

South and then east

40°28'N, 73°56'W
40°28'N, 73°54'W
40°28'N, 73°52'W
40°28'N, 73°50'W
40°28'N, 73°48'W
40°28'N, 73°46'W
40°28'N, 73°44'W
40°28'N, 73°42'W
40°28'N, 73°40'W
40°28'N, 73°38'W

South & then west

40°25'N, 73°38'W
40°25'N, 73°40'W
40°25'N, 73°42'W
40°25'N, 73°44'W
40°25'N, 73°46'W
40°25'N, 73°48'W
40°25'N, 73°50'W
40°25'N, 73°52'W
40°25'N, 73°54'W
40°25'N, 73°56'W
40°25'N, 73°57'W


NEW YORK
NEW JERSEY
40°34'N
40°13'N
73°59'W
73°36'W
— MULTIPLE CORER
a MACFC - OXFORD, MD
b U. MARYLAND
c SUNY - STONY BROOK

be sampled with the multiple corer due to the coarseness of the bottom. These stations were abandoned after five unsuccessful multiple core casts. At stations successfully sampled, a minimum of four cores per station were used to measure total oxygen consumption by the sea-bed according to the methods of Pamatmat (1971). The cores were equilibrated for 1 hour in a water bath regulated to within one degree of in situ temperature. Following equilibration the oxygen consumption was monitored for approximately 12 hours. Initial and final dissolved oxygen samples were taken and processed according to the azide modification of the iodometric method using 0.025N PAO instead of sodium thiosulfate. Reagents were added to the sample with a 1 ml insulin syringe. A 2 ml gilmont microburet with needle was used in the titration of the 26 ml samples.

At stations where the multiple corer was used a Niskin bottle with reversing thermometer was attached to the multiple corer to collect bottom water for salinity and dissolved oxygen determinations and to record bottom temperature.

RESULTS:

Each of 103 stations in the New York Bight apex are now represented by five Smith-McIntyre samples and associated cores collected during the subject cruise (Table 1 and Fig. 1). In all, a total of 515 bottom grab samples were taken.

Five hundred fifteen frozen core samples for heavy metal analyses are awaiting distribution. Five hundred fifteen core samples for geological analyses were transported to Dr. Anthony Cok (Adelphi University) on 22 February and five hundred fifteen samples for meiofaunal (nematodes and foraminifera) examination were transferred to Dr. John Tietjen and Dr. John Lee (CCNY). Macrofaunal samples have been transferred to alchohol and glycerin and are being sorted, counted, identified and recorded on standard forms by contract personnel (Trenton State College).

Forty-five stations (Fig. 1) were sampled to measure total oxygen consumption by the sea-bed. The data from these samples are now being processed.

CRUI OBJECTIVES:
Phase 1 - Smith-McIntyre grab (bottom sampling and multiple core operations.

Objective of Phase 1 of this cruise was to provide baseline data necessary to the accomplishment of MESA Task No. 4: Benthic Macrofauna and No. 5: Benthic Meiofauna (MACFC, Informal Report No. 13). Samples were collected for examination and analyses for macrofauna, meiofauna (amoeboid and ciliated protozoans, nematodes and foraminifera), heavy metal burdens in sediments, and mechanical properties in sediments (grain size distribution, etc.). Multiple coring operations for benthic respiration were initiated during this phase of the cruise (Task No. 3 in MACFC, Informal Report No. 13).

OPERATIONS:

Stations were selected on a grid (1 min. latitude x 1 min. longitude) overlying the apex of the New York Bight (see Fig. 1 and Table 1). Five Smith-McIntyre bottom grab samples were taken at each station.

Each grab sample was brought aboard and three cores were removed from near the center of the sample. Two of the cores were taken with 38 mm (1.5 inch) diameter plastic core liners. These cores were labeled and frozen for future analyses for heavy metals and the mechanical properties of sediment. The third core was taken with a 25 mm (1.0 inch) diameter plastic tube to a depth of approximately 5 cm. The sample was placed in a labeled jar containing buffered formalin and rose bengal and stored for meiofaunal (nematodes and foraminfera) examination. The remainder of the Smith-McIntyre grab sample was removed from the grab and washed through standard geological screens. The material trapped on screens (larger than 1 mm) was placed in labeled jars and seawater and magnesium chloride were added to narcotize the organisms. After 30 minutes buffered formalin was added and the samples were stored for macrofaunal examination.

At each station samples were taken using a Niskin water bottle with reversing thermometer for bottom dissolved oxygen, salinity and temperature. The oxygen samples were titrated on board using a sample volume of 203 ml and titrating with .025 N PAO with liquid starch as the indicator. The salinity samples were stored at Sandy Hook for later analysis using an RS7-B salinometer.

Multiple core casts to obtain undisturbed bottom sediment with overlying bottom water were made at every other station (Fig. 1) to measure sea-bed oxygen consumption. Certain stations could not

South & then east

40°10'N, 73°59'W
40°10'N, 73°58'W
40°10'N, 73°56'W
40°10'N, 73°54'W
40°10'N, 73°52'W
40°10'N, 73°50'W
40°10'N, 73°48'W
40°10'N, 73°46'W
40°10'N, 73°44'W
40°10'N, 73°42'W
40°10'N, 73°40'W
40°10'N, 73°38'W

Additional stations

40°10'N, 73°36'W
40°13'N, 73°36'W
40°16'N, 73°36'W
40°19'N, 73°36'W
40°22'N, 73°36'W
40°25'N, 73°36'W
40°28'N, 73°36'W
40°31'N, 73°36'W
40°34'N, 73°36'W

Samples for examing ciliated protozoa were collected by Cady Soukup and Michael Davis for Dr. Eugene Small (University of Maryland) at stations 7 (control), 16 (control), 32 (sewage sludge), 35 (dredge spoil), 51 (acid wastes), 82 (control), and 92 (control) (Fig. 1). Their cruise report follows:

As expected numbers on this winter cruise were generally low compared to earlier cruises last summer and fall. The small bactivorous Scuticociliates were nearly absent (we are finding them in cultures made from the water, so they were present). Tintinnids, the only group of loricate ciliates, were present in the plankton to a greater extent than has been previously seen. They are reported to eat predominantly microagae and possibly bacteria. A possible factor in their presence is the increased dissolved oxygen values found during this cruise compared with values found on previous cruises. Phytoplankton numbers also were high, comparable to what was found on the August 1973 cruise. The major changes in the phytoplankton were the predominant species, although many of the same species were present both times. Psammobiotic ciliates were less numerous than during the fall months. Diversity did not appear to decrease with decreasing numbers; many of the genera and species found before were represented by at least one individual. As before, these ciliates were found in the sediment at the relatively clean sites.

Photomicrography with the Nomarski phase interference Zeiss microscope proved to be very successful aboard ship. The "bugs" have been worked out of the system and it is now set up so that the vibrations of the ship are nullified. We look forward to using additional sampling methods for the next cruise since several pieces of long awaited equipment have finally arrived. These new sampling methods will give us a further idea of the diversity and numbers of ciliates in the plankton, a component which we have found to be important.

Additional samples for other investigations were also taken during the cruise. A deep water sample to be used as sub-standard water for salinity determinations was taken at station 92 for Robert Reid, Sandy Hook Laboratory. Nine sediment cores (one each from stations 1, 2, 3, 29, 30, 31, 71, 72 and 103) were removed from the Smith-McIntyre grab (bottom) sample and frozen for Drs. Duedall, Araktingi, O'Connor and Miloski at the State University of New York, Stony Brook.

Three stations (16, 32, and 35) were sampled by Cady Soukup for Dr. Thomas Sawyer, MACFC/Oxford, Md. His report follows:

Preliminary observations have been made on surface water and water immediately above the sediment (grab sample water), and cultures have been prepared for further work with pure strains of amoebae.

Direct observations on material from water collected on Millipore filters have been made and are summarized below:

| #16 Surface | #32 Surface | #35 Surface |
|---|---|---|
| Tintinnids | Tintinnids | Not Done |
| Euplotes sp. | Euplotes sp. | |
| Hypotrich (Kahlia?) | -- | |
| Flagellates (colorless) | Flagellates (colorless) | |
| Asterionella | Asterionella | |
| Coscinodiscus | Coscinodiscus | |
| Thalassiothrix | Thalassiothrix | |
| Skeletonema | Skeletonema | |
| Chaetoceros | -- | |
| Corethron | Corethron | |
| Gyrosignum | -- | |
| Guinardia (?) | Guinardia | |
| -- | Melosira | |
| -- | Thallasiosira | |
| -- | Rhizoselenia | |
| -- | Navicula | |
| -- | Silicoflagellate | |
| -- | Ceratium | |
| -- | Gyrosignum | |

| #16 Bottom | #32 Bottom | #35 Bottom |
|---|---|---|
| Scuticociliate | Scuticociliate | Scuticociliate |
| Flagellates (Colorless) | Flagellates (Colorless) | Flagellates (Colorless) |
| Asterionella | -- | -- |
| Coscinodiscus | Coscinodiscus | Coscinodiscus |
| Skeletonema | Skeletonema | -- |
| Gyrosignum | Gyrosignum | Gyrosignum |
| Melosira | Melosira | Clams (Tiny) |
| Biddulphia | Rhizoselenia | |
| Nematode | | |

Comments:

a. Surface water had a high diversity of phyto- and zooplankton with Skeletonema, Thalassiothrix, Chaetoceros, and Asterionella making up most of the biomass.

b. Bottom water had less species diversity than surface water and biomass was sparse.

c. Station #16 (control) was peculiar in that bottom water sample contained numerous fibers in matted clusters (possibly paper). Biddulphia was found for the first time in this sample.

d. Grab water and sediment from station #32 and 35 were black muck and difficult to examine. A colorless diatom, probably Gyrosignum, was present in moderate numbers in #35, a species which has been found in other samples. A second larger Gyrosignum, golden yellow-brown has been found in all stations.

Identifications of marine amoebae will be reported later. Growth studies and the preparation of pure strains require about 30 days to complete.