The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System

The Chesapeake Research Consortium, Inc.

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THE CHESAPEAKE RESEARCH CONSORTIUM, INC.

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November 1976

CRC Publication No. 54

Published for The Chesapeake Research Consortium, Inc.,
by The Johns Hopkins University Press, Baltimore and London

Manufactured in the United States of America

The Johns Hopkins University Press, Baltimore, Maryland 21218
The Johns Hopkins Press Ltd., London

Library of Congress Catalog Card Number 76–47392
ISBN 0–8018–1945–8

Library of Congress Cataloging in Publication data
will be found on the last printed page of this book.

Preface

During June 1972 Tropical Storm Agnes released record amounts of rainfall on the watersheds of most of the major tributaries of Chesapeake Bay. The resulting floods, categorized as a once-in-100-to-200-year occurrence, caused perturbations of the environment in Chesapeake Bay, the nation's greatest estuary.

This volume is an attempt to bring together analyses of the effects of this exceptional natural event on the hydrology, geology, water quality, and biology of Chesapeake Bay and to consider the impact of these effects on the economy of the Tidewater Region and on public health.

It is to be hoped that these analyses of the event will usefully serve government agencies and private sectors of society in their planning and evaluation of measures to cope with and ameliorate damage from estuarine flooding. It is also to be hoped that the scientific and technical sectors of society will gain a better understanding of the fundamental nature of the myriad and interrelated phenomena that is the Chesapeake Bay ecosystem. Presumably much of what was learned about Chesapeake Bay will be applicable to estuarine systems elsewhere in the world. Most of the papers comprising this volume were presented at a symposium held May 6-7, 1974, at College Park, Maryland, under the sponsorship of the Chesapeake Research Consortium,Inc., with support from the Baltimore District, U.S. Army Corps of Engineers (Contract No. DACW 31-73-C-0189). An early and necessarily incomplete assessment, *The Effects of Hurricane Agnes on the Environment and Organisms of Chesapeake Bay* was prepared by personnel from the Chesapeake Bay Institute (CBI), the Chesapeake Biological Laboratory (CBL), and the Virginia Institute of Marine Science (VIMS) for the Philadelphia District, U.S. Army Corps of Engineers. Most of the scientists who contributed to the early report conducted further analyses and wrote papers forming a part of this report on the effects of Agnes. Additional contributions have been prepared by other scientists, most notably in the fields of biological effects and economics.

The report represents an attempt to bring together all data, no matter how fragmentary, relating to the topic. The authors are to be congratulated for the generally high quality of their work. Those who might question, in parts of the purse, the fineness of the silk must keep in mind the nature of the sow's ears from which it was spun. This is not to disparage the effort, but only to recognize that the data were collected under circumstances which at best were less than ideal. When the flood waters surged into the Bay there was no time for painstaking experimental design. There were not enough instruments to take as many measurements as the investigators would have desired. There were not enough containers to obtain the needed samples or enough reagents to analyze them. There were not enough technicians and clerks to collect and tabulate the data. While the days seemed far too short to accomplish the job at hand, they undoubtedly seemed far too long to the beleaguered field parties, vessel crews, laboratory technicians, and scientists who worked double shifts regularly and around the clock on many occasions. To these dedicated men and women, whose quality of performance and perseverance under trying circumstances were outstanding, society owes an especial debt of gratitude.

It should be noted that the Chesapeake Bay Institute, the Chesapeake Biological Laboratory, and the Virginia Institute of Marine Science, the three major laboratories doing research on Chesapeake Bay, undertook extensive data-gathering programs, requiring sizable commitments of personnel and equipment, without assurance that financial support would be provided. The emergency existed, and the scientists recognized both an obligation to assist in ameliorating its destructive effects and a rare scientific opportunity to better understand the ecosystem. They proceeded to organize a coordinated program in the hope that financial arrangements could be worked out later. Fortunately, their hopes proved well founded. Financial and logistic assistance was provided by a large number of agencies

that recognized the seriousness and uniqueness of the Agnes phenomenon. A list of those who aided is appended. Their support is gratefully acknowledged.

This document consists of a series of detailed technical reports preceded by a summary. The summary emphasizes effects having social or economic impact. The authors of each of the technical reports are indicated. To these scientists, the editors extend thanks and commendations for their painstaking work.

Several members of the staff of the Baltimore District, U.S. Army Corps of Engineers, worked with the editors on this contract. We gratefully acknowledge the helpful assistance of Mr. Noel E. Beegle, Chief, Study Coordination and Evaluation Section, who served as Study Manager; Dr. James H. McKay, Chief, Technical Studies and Data Development Section; and Mr. Alfred E. Robinson, Jr., Chief of the Chesapeake Bay Study Group.

The editors are also grateful to Vickie Krahn for typing the Technical Reports and to Alice Lee Tillage and Barbara Crewe for typing the Summary.

The Summary was compiled from summaries of each section prepared by the section editors. I fear that it is too much to hope that, in my attempts to distill the voluminous, detailed, and well-prepared papers and section summaries, I have not distorted meanings, excluded useful information or overextended conclusions. For whatever shortcomings and inaccuracies that exist in the Summary, I offer my apologies.

Jackson Davis
Project Coordinator

Acknowledgements

The Chesapeake Research Consortium, Inc. is indebted to the following groups for their logistic and/or financial aid to one or more of the consortium institutions in support of investigations into the effects of Tropical Storm Agnes.

U. S. Army
- -- Corps of Engineers, Baltimore District
- -- Corps of Engineers, Norfolk District
- -- Corps of Engineers, Philadelphia District
- -- Transportation Corps, Fort Eustis, Virginia

U. S. Navy
- -- Naval Ordnance Laboratory
- -- Coastal River Squadron Two, Little Creek, Virginia
- -- Assault Creek Unit Two, Little Creek, Virginia
- -- Explosive Ordnance Disposal Unit Two, Fort Story, Virginia
- -- Naval Ordnance Laboratory, White Oak, Maryland

U. S. Coast Guard
- -- Reserve Training Center
- -- Coast Guard Station, Little Creek, Virginia
- -- Portsmouth Supply Depot
- -- Light Towers (Diamond Shoal, Five Fathom Bank, and Chesapeake)

National Oceanic and Atmospheric Administration
- -- National Marine Fisheries Service (Woods Hole, Massachusetts and Sandy Hook, New Jersey)

The National Science Foundation

Food and Drug Administration

Environmental Protection Agency

U. S. Office of Emergency Preparedness

State of Maryland, Department of Natural Resources

Commonwealth of Virginia, Office of Emergency Preparedness

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D. Biological Effects

THE EFFECT OF TROPICAL STORM AGNES ON HEAVY METAL AND PESTICIDE RESIDUES IN THE EASTERN OYSTER FROM SOUTHERN CHESAPEAKE BAY [1]

M. E. Bender [2]
R. J. Huggett [2]

ABSTRACT

The concentrations of cadmium, copper, and zinc in the eastern oyster, *Crassostrea virginica*, are compared for samples collected before and after Tropical Storm Agnes. The "before" samples consisted of 475 animals from 95 stations collected in January 1971 and the "after" samples of 285 animals from 57 stations collected in January 1973. Shifts in the areal concentrations distributions were observed, apparently due to Agnes.

Analyses of hard clams, blue crabs and oysters for chlorinated hydrocarbon pesticides showed influx of these compounds to be minimal as reflected by the residue levels observed. Comparison of residue levels in oysters to pre-Agnes conditions revealed a decrease in pesticide body burden.

INTRODUCTION

The rainfall and subsequent runoff from Agnes modified the chemical environment of organisms capable of concentrating pollutants by altering ambient exposure levels and by changing their "normal" physiological regime. Metals and pesticides contained in bottom sediments were both resuspended and in the case of some metals possibly desorbed. In addition to mobilization of these once "stored" substances, their levels were augmented by massive amounts of erosional products.

In order to assess the actual impact of the storm on these pollutants, residue analyses for the metals Cu, Cd and Zn and for chlorinated hydrocarbon pesticides were performed on the eastern oyster (*Crassostrea virginica*). Comparisons were made with the previously published studies of Huggett, Bender and Slone (1973) for metals and with those of Butler (1973) for pesticides.

METHODS

Sampling locations were chosen to correspond where possible to those of previous studies (Huggett, Bender & Slone 1973; Butler 1973). Five oysters were sampled from each of the stations shown in Figs. 1, 2 and 3, during January 1973. In some cases samples were difficult to obtain due to high mortalities at the upstream stations and in the Hampton Roads segment of the James River.

The analytical procedures utilized to determine residue levels have been described previously (Huggett, Bender & Slone 1973; Butler 1973)

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[1] Contribution No.774, Virginia Institute of Marine Science

[2] Virginia Institute of Marine Science, Gloucester Point, Va. 23062

RESULTS

Average levels of each metal at a station were determined to ascertain the areal distribution of metals in the various river systems. The means showed that a concentration gradient similar to that observed previously existed in all systems and that each metal generally increased in concentration as fresh water was approached (Figs. 4, 5 & 6).

To test whether Agnes had measurably altered these concentration gradients, those stations for which data from 1973 were available were statistically compared with the pre-Agnes period. Comparisons could be made on 9 stations in the James, 7 in the Rappahannock and 5 in the York (Table 1). Significantly different concentrations (t test, $\alpha = 0.05$) for copper were observed in 4 of 21 comparisons. Of these, one station decreased while the other 3 showed increased levels. Those showing increased concentrations had levels less than 5 ppm prior to Agnes with increases to about 12 ppm after Agnes.

Zinc levels showed a significant increase at only one location in the upper York River.

The following is based upon a comparison of the areal concentration pattern as shown in Figs. 4, 5 and 6 with those previously published by Huggett, Bender and Slone (1973). Although it is not possible to statistically evaluate these data, we believe some insights may be gained from this descriptive approach.

James River

Cadmium. The upper river appears to be "cleaner" with respect to cadmium since Agnes. In 1971 concentrations in the Deep Water Shoals and Burwell Bay areas were greater than 1.6 ppm but after Agnes fell to between 1.1 and 1.5 ppm while the lower part of Burwell Bay decreased to less than 1 ppm. Between Burwell Bay to about five miles below the Warwick River concentrations ranged from 1.1 to 1.5 ppm in 1971, but fell to between 0.6 to 1.0 in 1973.

Prior to Agnes the Nansemond River showed levels between 1.1 and 1.5 ppm, while after the storm the levels decreased to between 0.6 and 1.0 ppm. Concentrations in the Nansemond Ridge area increased from 0.6-1.0 to 1.1-1.5 ppm.

Levels in the lower portion of the Elizabeth River decreased from 1.1-1.5 ppm in 1971 to 0.6-1.0 ppm after Agnes. In the upper portion the levels were unchanged.

Residues in Willoughby Bay increased considerably with levels averaging 4.6 ppm in 1973 and ~2.5 in 1971.

Copper. As was seen for cadmium, oysters in the upper James River appear to have decreased in copper concentrations since 1971. Except for a small area in the upper section of Burwell Bay, the levels have dropped from 101-150 ppm to 51-100 ppm. The area of high residues, from 151-200 ppm, found in the middle of Burwell Bay in 1971 is now absent. The concentrations from Burwell Bay to the James River Bridge were unchanged since the 1971 survey.

The Nansemond Ridge oyster beds show that this region has worsened since the previous survey with concentrations increasing from 26-50 ppm to 101-150 ppm.

The Nansemond River showed an increase with levels after Agnes between 51-100 ppm as compared to 26-50 ppm in 1971.

Table 1. Comparison of Zn & Cu Levels in Oysters 1971 vs 1973.

River	Station	Mean Copper (ppm) 1971	Mean Copper (ppm) 1973	DF	t	Mean Zinc (ppm) 1971	Mean Zinc (ppm) 1973	DF	t
James	1	141.0	97.8	8	1.42	1465.0	1097.2	8	1.22
	2	172.6	124.1	8	1.66	1253.0	1090.4	8	0.55
	3	95.7	79.2	7	0.51	643.2	902.0	8	1.15
	4	142.2	91.1	8	2.09	1030.8	987.6	8	0.19
	7	82.0	82.7	8	0.03	858.4	903.2	8	0.21
	8	91.8	92.8	8	0.07	887.8	1184.4	8	1.29
	9	84.1	84.7	8	0.04	1350.6	1182.0	8	0.78
	10	51.9	71.3	7	0.96	905.8	1159.0	7	0.61
	11	73.1	112.1	7	1.84	881.3	1362.2	7	1.60
Rappahannock	5	16.2	12.5	6	1.15	324.0	376.6	7	0.74
	6	6.4	12.2	8	1.96	253.6	311.8	8	0.94
	7	4.2	12.8	7	*9.77	213.8	298.8	8	1.56
	8	39.8	26.6	9	0.71	454.8	487.0	9	0.22
	9	28.8	31.3	8	0.39	440.0	410.8	8	0.76
	10	34.9	21.7	7	1.21	456.5	232.6	7	1.58
	14	4.6	20.3	5	*7.15	376.7	502.4	7	2.51
York	1	21.1	33.6	8	0.49	266.6	448.2	8	1.23
	2&3	19.5	17.5	18	*3.02	604.9	875.4	18	1.81
	4,5&6	21.7	15.6	25	1.70	486.9	892.5	25	*4.51
	7	3.8	9.5	7	*4.65	315.3	335.6	7	0.34
	8	6.4	9.2	5	1.75	424.5	330.0	5	1.81

*Significant difference at 95% level.

The Elizabeth River samples indicate an increase of copper. In 1971 the levels ranged between 26-50 ppm throughout most of the river, but in 1973 the concentrations were all greater than 50 ppm.

Zinc. The upper James River decreased with respect to its oyster-zinc levels since the previous sampling in 1971. The upstream part of Burwell Bay and Deep Water Shoals dropped from 1201-1600 ppm to 801-1200 ppm.

The remainder of the river appears unchanged with the exception of Nansemond Ridge and Willoughby Bay. The samples from Nansemond Ridge showed an increase in zinc since Agnes with levels increasing from 401-800 ppm in 1971 to 1201-1600 ppm in 1973. Willoughby Bay samples indicated a decrease since Agnes of from 801-1200 ppm to 401-800 ppm.

The Elizabeth River remained the most contaminated area sampled. Although not obvious from the figures, one station yielded an animal with 20,000 ppm zinc. This is the highest level ever recorded by this laboratory and as far as we can ascertain, the highest ever recorded anywhere.

York River

Cadmium. The cadmium levels in oysters from the York River showed no apparent change from the 1971 study. The concentration range and distributions were approximately the same.

Copper. The copper levels in oysters from this river are generally higher in the middle and lower segments of the stream relative to the 1971 samples. Levels have increased from 26-50 ppm in 1971 to a range of between 51-100 ppm in 1973.

Zinc. As was the case with copper, the zinc concentrations have increased from 401-800 ppm in 1971 to 801-1200 ppm in 1973.

Rappahannock River

Cadmium. The cadmium distribution appears to have changed since the 1971 study. The concentrations were lower in the upper river decreasing to between 0.6-1.0 ppm from 1.1-1.5 ppm in 1971. In addition, an apparent anomaly exists at the mouth of the estuary. This "high" cadmium level may be due to the influence of the storm waters that came down the Bay from the Potomac and Susquehanna Rivers.

Copper. The copper data indicate that the concentration range was not different from that found in 1971; however, the distribution changed in the upper estuary. From previous work, we expected the highest concentrations to appear in the low salinity waters. After Agnes, residues in the upper portion were lower followed by an area of higher concentrations with a return to lower levels in the downstream segment.

Zinc. The zinc distribution followed a pattern very similar to that of copper. The concentration range was unchanged since 1971, but the distribution was altered.

Mobjack Bay, Poquoson River, Back River

Samples from these areas did not indicate any significant changes in either concentration ranges or distributions since the 1971 study. This was most likely due to the immediate proximity of these areas to the Chesapeake Bay proper and therefore the lesser effects of the storm waters from Agnes.

It has been shown (Huggett, Bender & Slone 1973) that within similar drainage basins a relationship exists between the amount of zinc and copper taken up by oysters. Regression analyses were performed on the 1971 and 1973 data (Cu vs. Zn) for each river system in an attempt to ascertain if Agnes had modified the relationships shown previously. The results of these analyses are presented in Table 2 and depicted graphically in Fig. 7. As can be seen from the figure, generally good agreement exists between the Cu and Zn relationships in all three river systems. Statistical tests cannot be applied to the data because both variables are independent; however, the data suggest that copper levels relative to zinc are slightly lower in the post-Agnes period.

Table 2. Regression Equations, Metals in Oysters.

	RIVER					
	James		York		Rappahannock	
	1971	1973	1971	1973	1971	1973
Cu(y) vs Zn(x)						
Slope	0.033	0.075	0.088	0.075	0.090	0.035
Intercept	57.47	4.36	3.18	-12.21	-12.86	3.76
N	95	75	53	124	45	70
Correlation(r)	0.53	0.78	0.71	0.92	0.79	0.66
Cd(y) vs Zn(x)						
Slope		0.0004		0.0008		0.0007
Intercept		0.59		0.17		0.33
N		70		49		71
Correlation		0.43		0.75		0.45
Cd(y) vs Cu(x)						
Slope		0.005		0.010		0.018
Intercept		0.51		0.26		0.28
N		70		49		71
Correlation		0.59		0.83		0.64

Regressions relating the concentrations of Cu to Cd and Cd to Zn calculated on the 1973 data are tabulated in Table 2 and are graphically shown in Fig. 8.

A comparison of pesticide residues found in oysters at four stations is presented in Table 3. Although the data are limited, the conclusion suggested, i.e. that Agnes did not elevate pesticide residues, is supported by the fact that in 9 samples of 12 hard clams each, no residue higher than 0.001 ppm was detected.

In addition, in 5 samples, each containing the meats of 12 blue crabs, the highest residue obtained was 0.04 ppm with an average of 0.02 ppm.

Table 3. Comparison of Pesticide Residues in Oysters 1971 vs. 1972.

Location	DDT (family) ppm		PCB's ppm	
	1971	1972	1971	1972
Lynnhaven Bay	0.047	0.002	ND	ND
Cherrystone Inlet	0.052	0.024	0.350	ND
Old Plantation Creek		0.033		ND
Poquoson River		0.001		ND
Pages Rock	0.010	0.001	ND	ND
Bells Rock	0.010	0.015	0.450	ND

DISCUSSION

The data indicate that the residues of cadmium, copper, and zinc in oysters from the upper segments of the James and Rappahannock Rivers have decreased since Agnes. The residues in the middle segments of these rivers have remained nearly unchanged since the previous sampling in 1971. A plausible hypothesis to account for the observed decreases in the upper reaches is that the oysters metabolized stored food reserves, i.e. proteins, containing nonspecifically bound metals at a faster rate than they picked up residues from the water. This occurred because their pumping rates were slowed due to depressed salinities. Support for this hypothesis can be obtained from the results of Huggett and Lunz (1974) who showed that metals were depurated from oysters when subjected to unknown stresses caused by high concentrations of sewage effluent.

In the Rappahannock, oysters were subjected to lowered salinities not only in the upper reaches but also in the lower river due to large influxes of fresh water from the Susquehanna and Potomac drainages. Oysters from this region showed higher than expected levels of cadmium and zinc. These elevations may be attributed to metals either being transported to the system with the fresh waters from up-Bay or by mobilization of sediment-stored metals by the low salinities and accompanying low pH's.

Although salinity changes were less dramatic in the York than in the other river systems, zinc levels in the upper portion of the system were higher than previously recorded. Agnes may have been partly responsible for the observed elevation in residues by moving polluted sediments with their associated metals further downstream (Huggett, Cross & Bender 1974).

ACKNOWLEDGEMENTS

The project was funded, in part by contract funds from the Food and Drug Administration (Contract No. 73-10).

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Huggett, R. J., F. A. Cross, and M. E. Bender. 1974. Trace metals in tidal rivers and biota. In: Mineral Cycling in Southeastern Ecosystems, Augusta, Georgia.

Huggett, R. J. and J. L. Lunz. 1974. Heavy metal uptake by oysters from sewage. Interim Progress Rep. to National Science Foundation (Research Applied to National Needs Program).

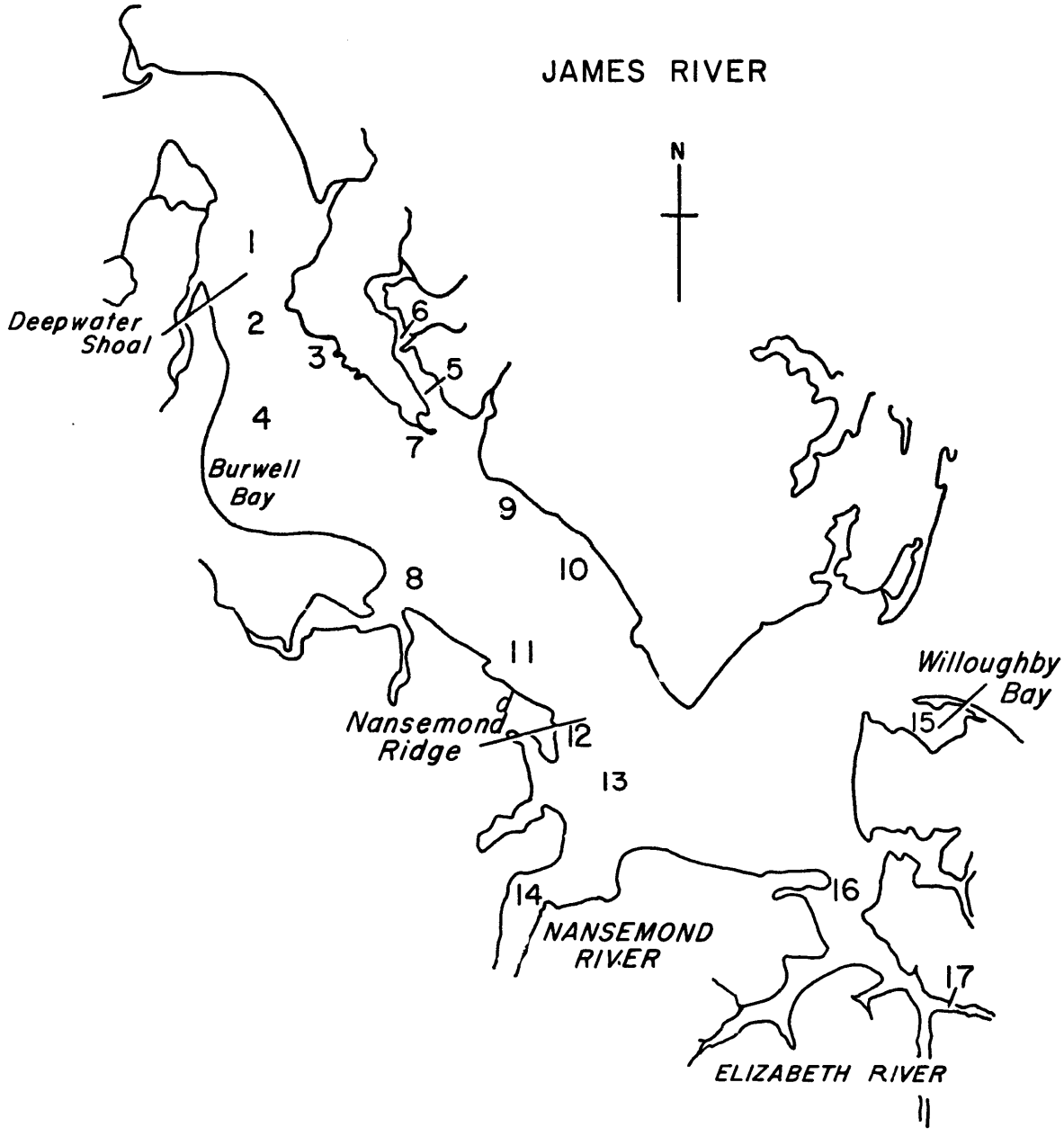

Figure 1. Sampling locations in the James, Elizabeth, and Nansemond Rivers.

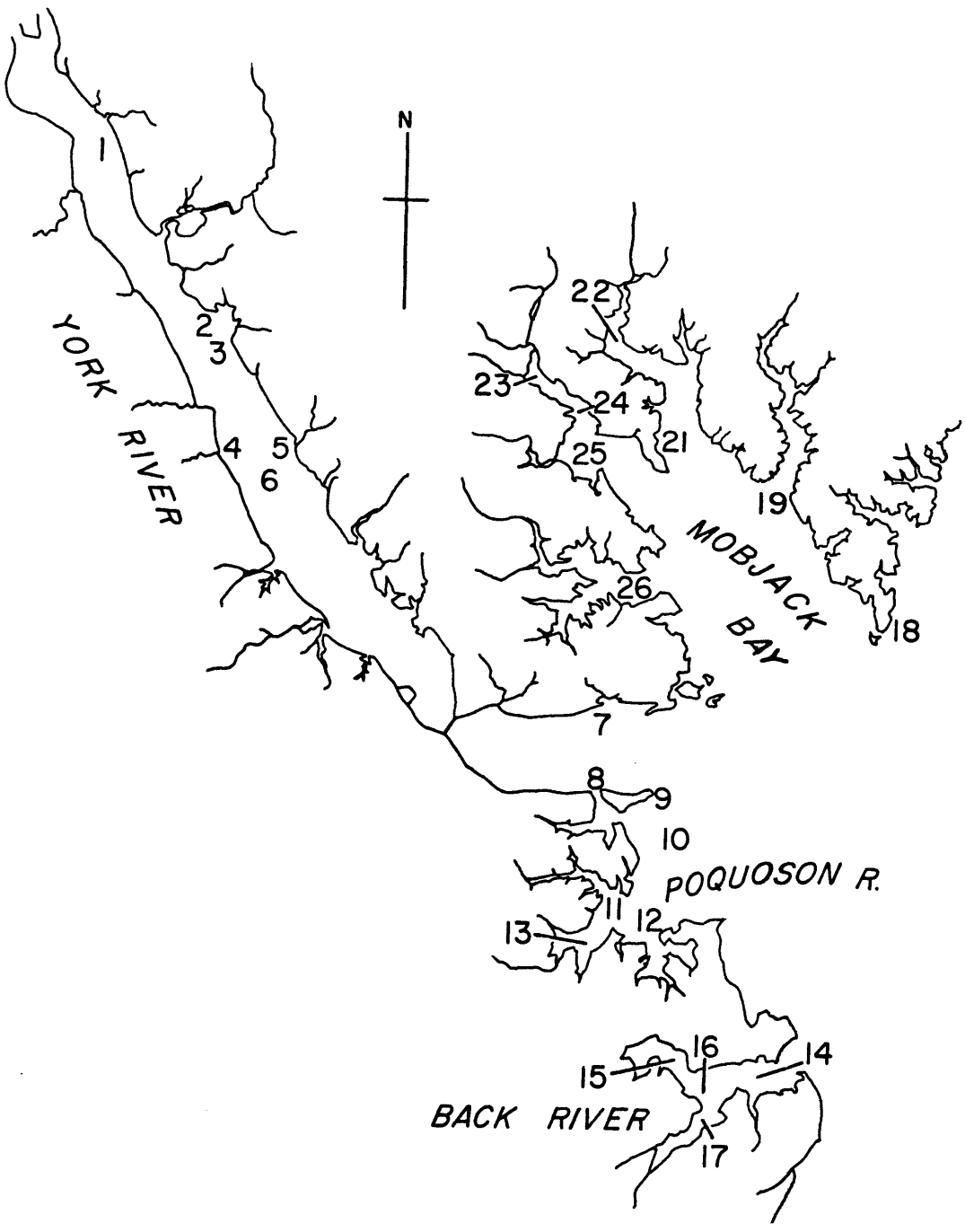

Figure 2. Sampling locations in the York, Back, and Poquoson Rivers and Mobjack Bay.

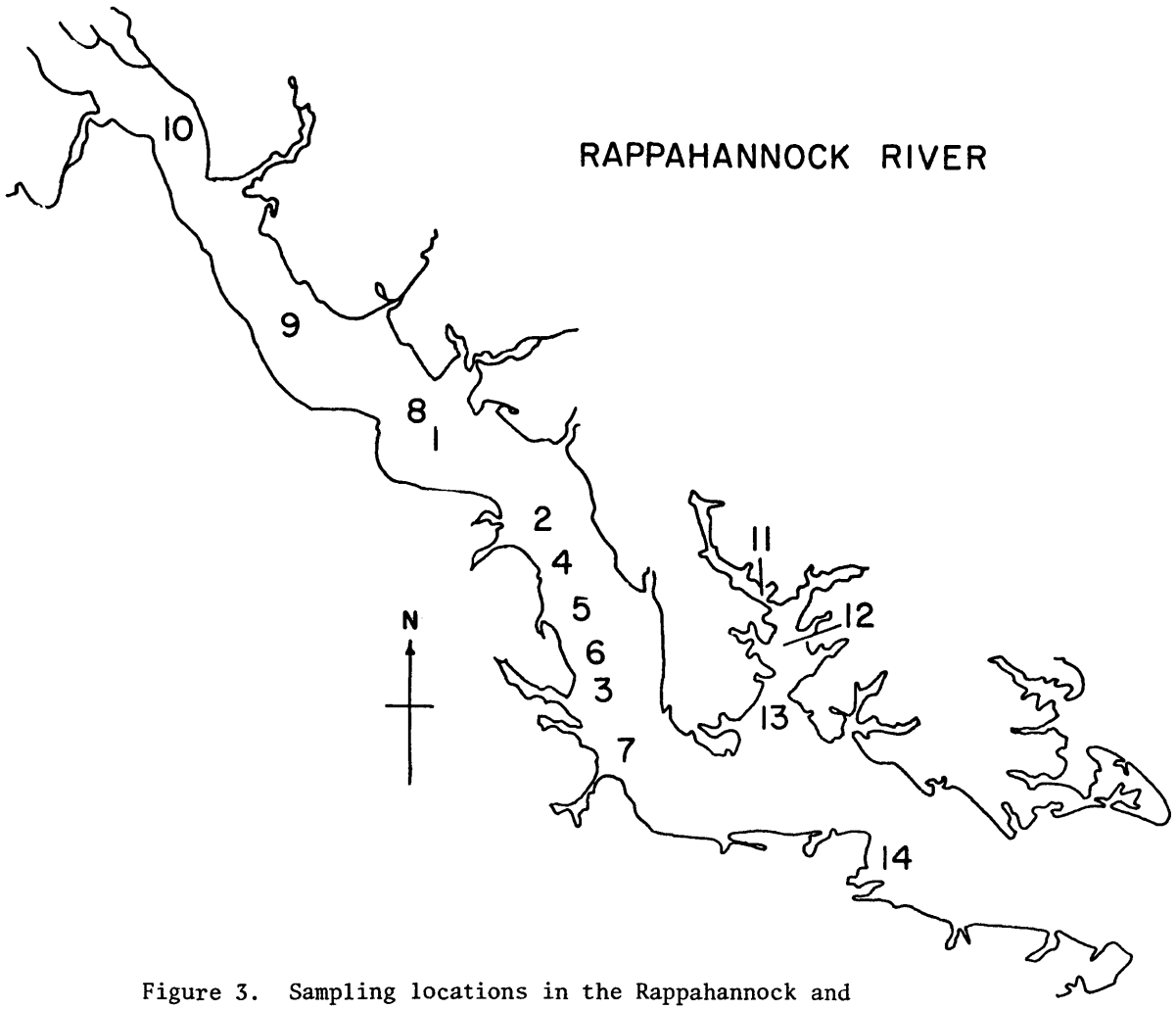

Figure 3. Sampling locations in the Rappahannock and Corrotoman Rivers.

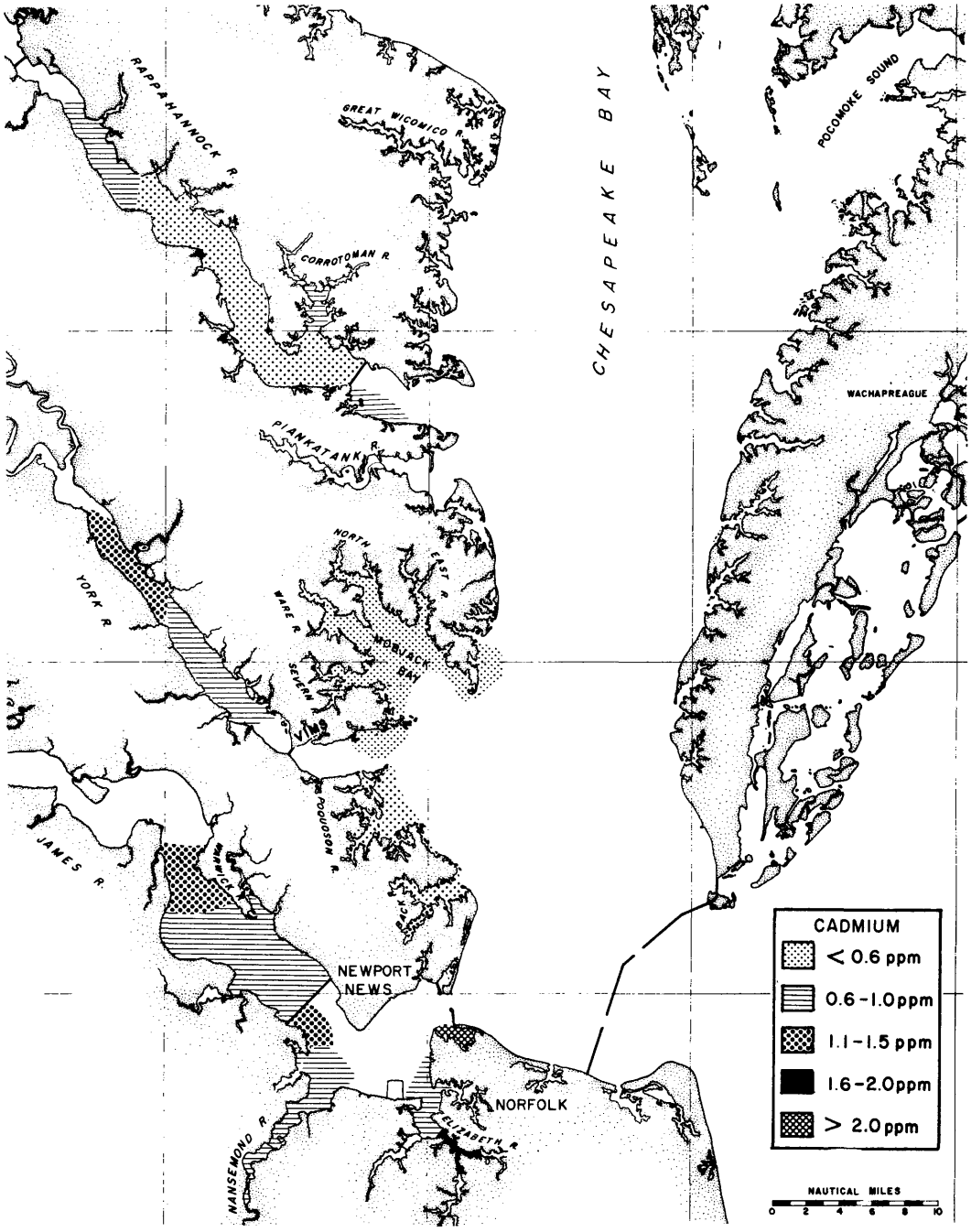

Figure 4. Distribution of cadmium in oysters sampled in January 1973.

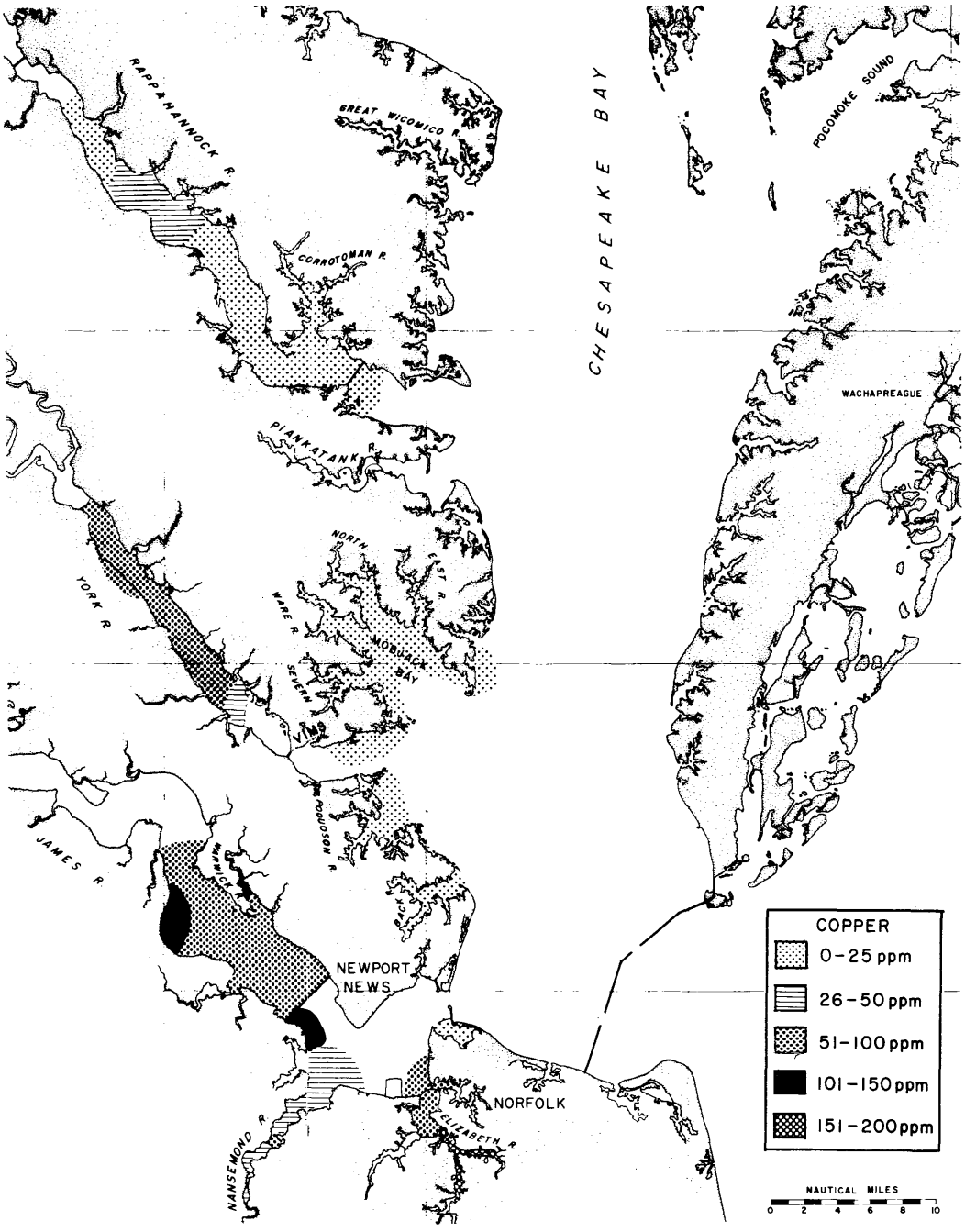

Figure 5. Distribution of copper in oysters sampled in January 1973.

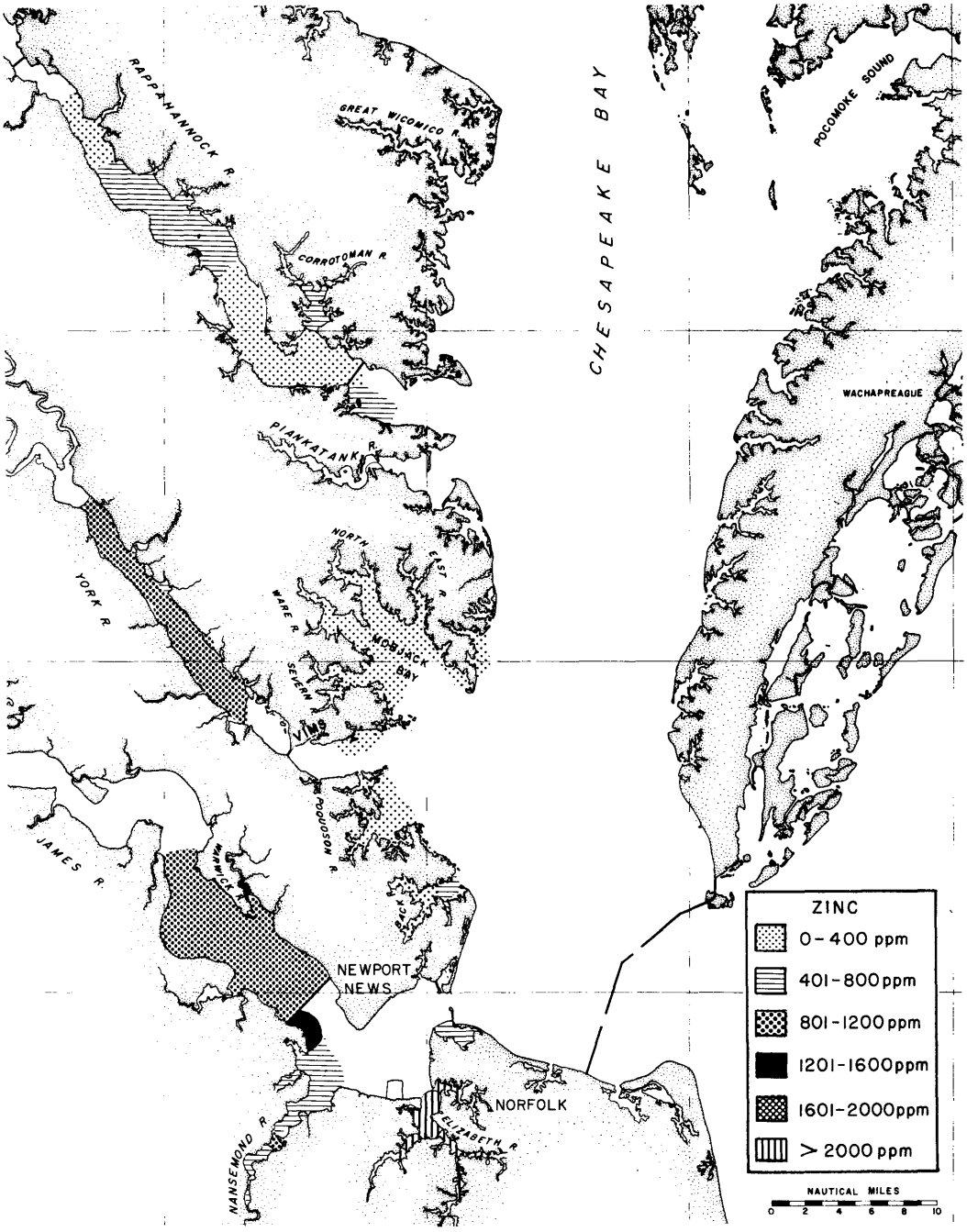

Figure 6. Distribution of zinc in oysters sampled in January 1973.

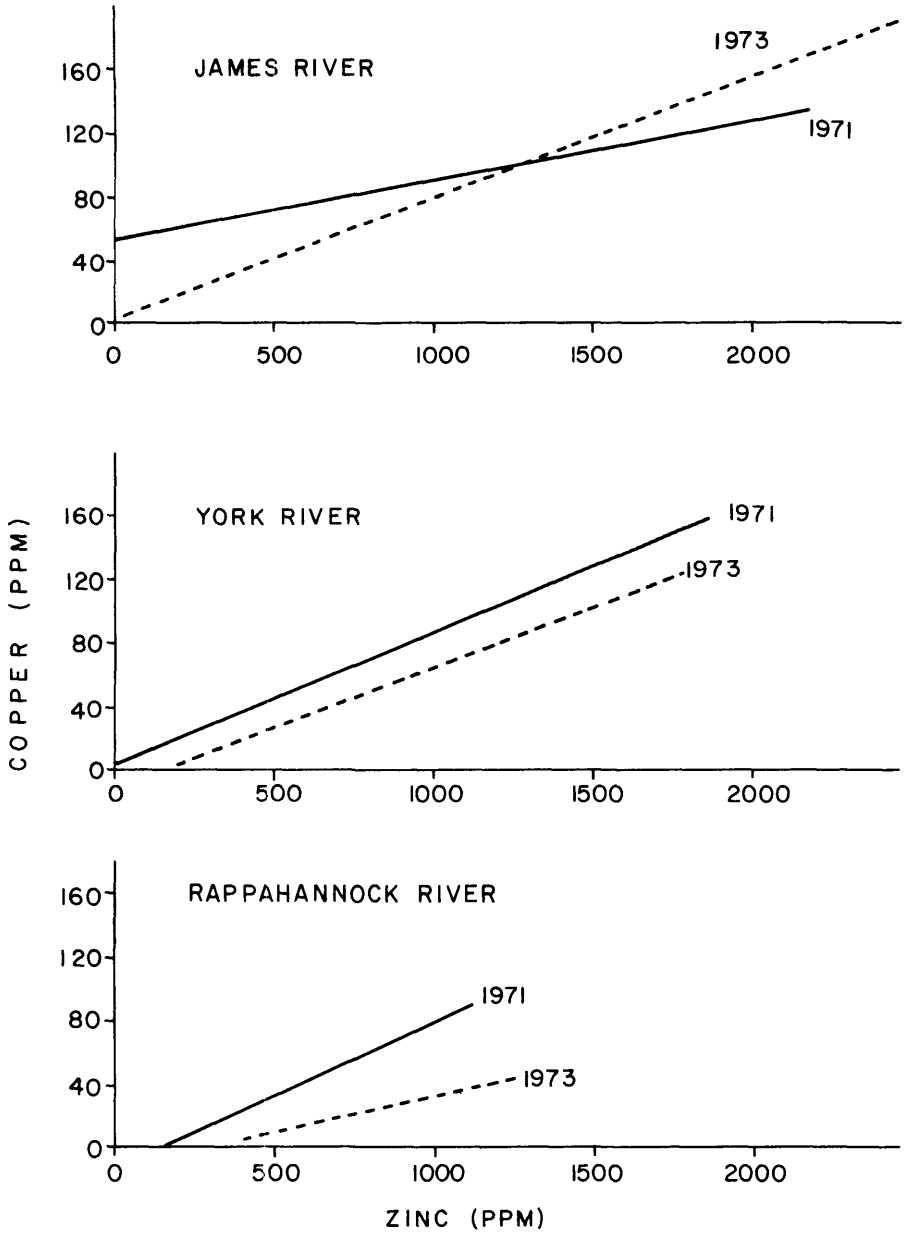

Figure 7. Regressions of Cu vs. Zn in oysters.

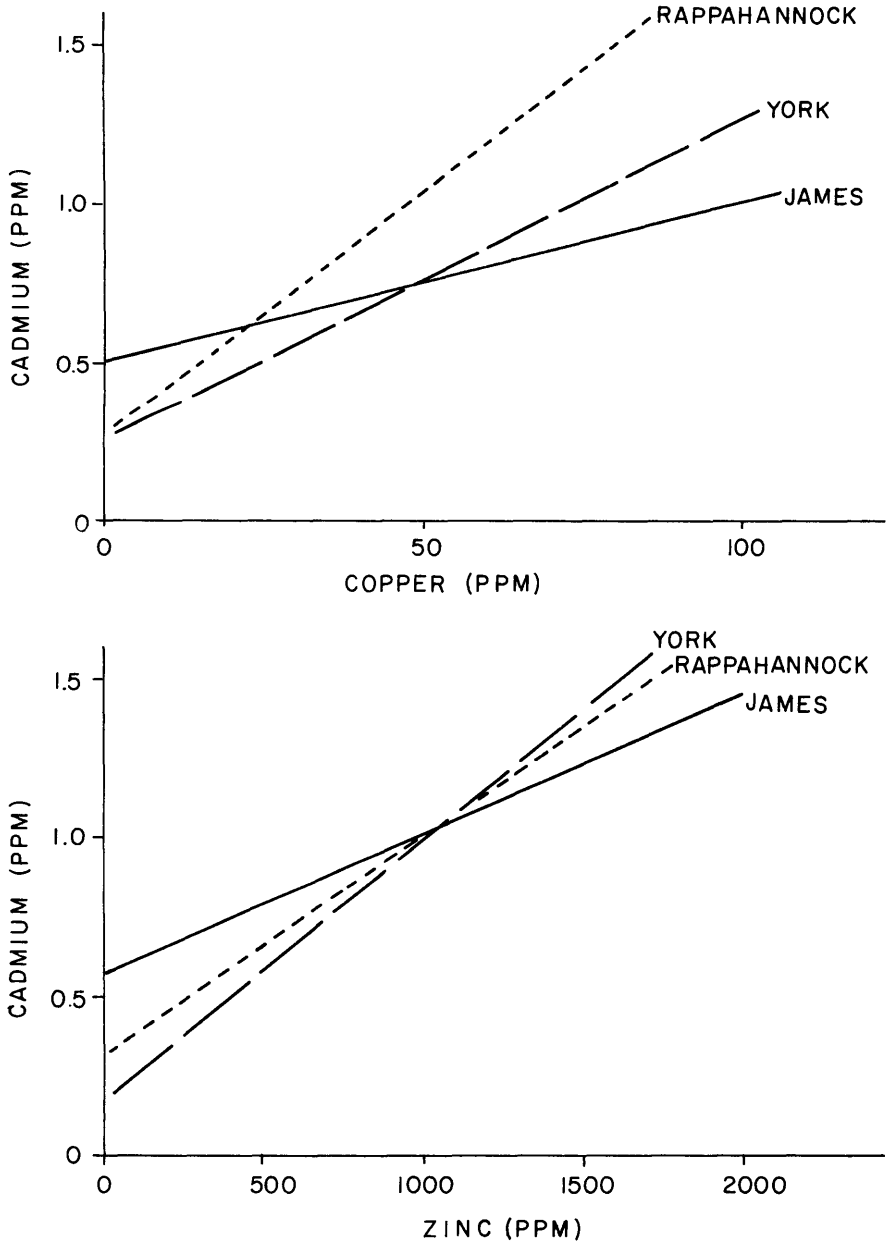

Figure 8. Regression of Cu vs. Cd and Cd vs. Zn in oysters.