

1976

## The Effect of Tropical Storm Agnes on Oysters, Hard Clams, Soft Clams, and Oyster Drills in Virginia

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### Recommended Citation

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

The Chesapeake Research Consortium, Inc.

**THE EFFECTS OF TROPICAL STORM AGNES  
ON THE CHESAPEAKE BAY ESTUARINE SYSTEM**

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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*

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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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THE EFFECT OF TROPICAL STORM AGNES ON OYSTERS, HARD CLAMS,  
SOFT CLAMS, AND OYSTER DRILLS IN VIRGINIA<sup>1</sup>

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## ABSTRACT

Tropical Storm Agnes had a major effect on the molluscan fisheries of Virginia. One effect was the direct mortality of oysters, *Crassostrea virginica*, in the upper parts of many estuaries. Typical losses on leased bottoms were: the James River, 10%; the York River, 2%; the Rappahannock River, 50%; and the Potomac River tributaries (Virginia) 70%. Economic loss was in excess of 7.9 million dollars. There was a nearly complete absence of oyster larvae attachment (setting) in 1972. Other effects of Agnes included a nearly complete loss of soft clams, *Mya arenaria*, in the Rappahannock River. Hard clams, *Mercenaria mercenaria*, were killed in the upper part of the York River. Oyster drills, *Urosalpinx cinerea*, were eliminated from the Rappahannock and reduced greatly in numbers in the York and James Rivers.

## INTRODUCTION

Agnes entered the Chesapeake Bay area on 21 June 1972 where it released massive quantities of rain on the watersheds of many of the river systems which support oysters and clams in their lower reaches. This excessive rainfall followed a period when salinities in the principal estuaries from the Potomac to the James had already been depressed by unusually heavy rainfall during the preceding two months (Chesapeake Bay Research Council 1973).

As a direct result of this new influx of fresh water there was a displacement of the 0.5 ppt salinity isohaline line in certain systems as far as 18 miles down-river from its usual location. Sedentary animals such as mollusks could not escape these abnormal salinities. In many sections, a complete destruction of existing populations occurred. The severity of mortality depended on the region, species, salinity, length of exposure, temperature, and, in some locations, on dissolved oxygen (DO) levels.

Oysters (*Crassostrea virginica*) are active only when average salinity values exceed about 4 ppt. Below this they close their shells and become inactive (do not pump water or feed). The length of time oysters will survive in salinities less than 4 ppt depends in part on genetic factors and conditioning, but water temperature is by far the more important aspect. During the cooler months (<5.5C), oysters are inactive (Galtsoff 1964) and, therefore, salinity levels ranging from 0.0 to 4.0 ppt cause little mortality over periods of 2 to 3 months. But as the temperature rises, mortalities increase. At these salinities, 3 weeks is about the maximum period that oysters can survive at 21 to 27C (Andrews, Quayle, & Haven 1959).

<sup>1</sup>Contribution No. 762, Virginia Institute of Marine Science

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Hard clams (*Mercenaria mercenaria*) are more sensitive to low salinities than oysters, but little information exists concerning their resistance to prolonged periods of stress. Available evidence suggests that during the warmer months salinity levels below 10 ppt for 1 to 2 weeks are lethal (Castagna & Chanley 1973).

Soft clams (*Mya arenaria*) are killed when salinities below 2.5 ppt persist for one to two weeks (Castagna & Chanley 1973).

Oyster drills (*Eupleura caudata* and *Urosalpinx cinerea*) are less tolerant than oysters to low salinities. Salinities of about 9 ppt are lethal in 2 or 3 weeks at summer temperatures (Carriker 1955, Zachary & Haven 1973).

Planktonic larvae of mollusks were also subject to abnormal conditions as a result of Agnes. Larvae were exposed to high turbidity and unfavorable currents which swept them from setting areas; in many areas salinities were below their tolerance limits. Many clams and oysters failed to spawn since they were inactivated by the low salinities.

Low oxygen was detected in many rivers after Agnes. There has been little research on chronic effects of low oxygen on survival of hard clams and oysters. Recent studies at the Virginia Institute of Marine Science (VIMS), however, indicate that if levels are below 1.5 mg/l, pumping and feeding efficiency of both species is impaired. Levels of about 0.8 mg/l cause nearly 100% mortality in oysters in about one week; hard clams show complete mortality in about 3 to 4 weeks. Larvae of both species survive less than one week at 0.8 mg/l (Haven, Walsh & Bendl 1973).

To estimate the impact of Agnes on Virginia's molluscan resources, on 22 June 1972, VIMS began a major program to evaluate its impact on the oyster, the hard clam, the soft clam, and the oyster drills. These species will be covered in four separate sections.

#### OYSTER MORTALITY AND ECONOMIC IMPACT

##### Methods

The objectives of this study were to estimate the quantity and value of oysters killed on public and private bottoms by Agnes. Ideally, such estimates should be based on the density of oysters (numbers or bushels per unit area) in a given area prior to the storm in relation to similar data collected after the mortality period. Quantitative data of this type were lacking, but on file were many years of information on the percentage of live to dead oysters on many representative public bottoms and private leases. This baseline information indicates what normal mortalities were in each region and, when compared with similar data collected after Agnes, made possible an estimate of the percentage killed in various areas. Later, the percentage mortality data were used, as will be discussed below, to estimate quantities of oysters killed on leased bottoms and in estimating the percentage of the total resources killed on public bottoms.

Estimates of the percentage of oysters killed were based upon an extensive series of weekly or biweekly samples of bottom material collected from public oyster rocks and private oyster leases beginning on 21 June 1972 and extending to December 1972. About 1,200 stations were visited in 110 separate field sampling trips between 21 June and December 1972. Frequent sampling in many areas established limits and gradients of mortality in respect to water depth and time. Bottom material was dredged or tonged from the bottom and numbers of

live, dying, and recently dead oysters (recent boxes) in these samples were counted. The percentage mortality was calculated as:

$$\text{Percentage Mortality} = \frac{\text{No. recent boxes} + \text{No. dying}}{\text{No. alive} + \text{No. recent boxes} + \text{No. dying}} \times 100$$

Live oysters had tightly closed valves. The valves of dying oysters gaped open but their meats were intact. A recently dead oyster (recent box) had valves still attached, with inner surfaces still white and clean.

On leased bottoms the number of oysters killed by Agnes was determined by sampling only those areas known to contain oysters, information supplied principally by the lease holders. The total killed was then determined by multiplying the percentage dead with estimates of the number of bushels of oysters on the bottoms prior to Agnes. The number of bushels actually on the bottom was determined by multiplying the total volume of seed oysters planted in 1969-1970, 1970-1971, and 1971-1972 seasons (because it takes three seasons for seed to grow to market size) by a factor of one or two, depending upon the area (because Virginia growers obtain from one to two bushels of mature oysters from every bushel of seed they plant). The number of bushels lost was then multiplied by the expected price per bushel to arrive at an estimate of economic loss.

For public oyster grounds, it was possible to chart the areas in each system where public bars were located from records on file at the Virginia Marine Resources Commission (VMRC). On these public beds, almost all oysters originated from a natural set of oysters. Therefore, total volume present on the bottom could not be estimated as it was on leased bottoms. Also on these same bottoms there has never been a quantitative study of the density of oysters. However, data were obtained from the VMRC as to the approximate percentage of the State's total resource growing in river systems. Also, the productive regions were delimited (as they were for leased areas) by hydrographic factors and diseases. Data on annual production for public bottoms were obtained from the annual reports of the VMRC.

### *Hydrographic Data*

Data on oxygen, salinity and temperature presented in this paper were obtained from a previous report on Agnes (Chesapeake Bay Research Council 1973). Additional information on the hydrography of the study area is presented earlier in this volume.

### *Oyster Mortality in the James River*

*Introduction.* The James River is the major oyster producing region in Virginia and the source of over 75% of all seed planted in the state by private growers. Oysters grow in commercial quantities from Deep Water Shoals, the up-river limit of oyster production, down to the mouth of the Nansemond River (Fig. 1). In 1971 its public rocks produced 439,294 bushels of seed and 170,849 bushels of market oysters (Table 1). As outlined previously, accurate production data for private leases are not available.



Table 1. Oyster production in bushels from public grounds in Virginia and from the Potomac River, 1969, 1970, and 1971.

River	1969	1970	1971	Average
Potomac <sup>1</sup>				
Virginia tributaries	25,642	13,074	31,824	23,513
Potomac				
Landed in Md. <sup>3</sup>	91,113	117,818	210,989	
Landed in Va. <sup>1</sup>	220,022	266,275	172,403	
Total (Md. & Va.)	311,135	384,093	383,392	359,540
York <sup>1</sup>	204	360	716	427
James <sup>1</sup>				
Market <sup>2</sup>	157,669	143,778	170,847	157,431
Seed	486,536	264,203	439,294	430,011
Rappahannock <sup>1</sup>	29,402	23,698	65,949	39,683

<sup>1</sup> Source - Annual Reports Virginia Marine Resources Commission.

<sup>2</sup> Mostly 2½ inch oysters.

<sup>3</sup> Source - Fisheries Statistics of the USNMFS.

*Hydrographic Data.* Salinity levels in the James River fell rapidly in response to the influx of flood water into the estuarine portion of the system and by 28 June, 5 days after the flood waters crested, the surface water was fresh (0.05 ppt) just below the James River Bridge which is about 29.0 km below the point where the 0.05 ppt isohaline normally occurs. Recovery was relatively rapid, and by 19 July all beds except those at Deep Water Shoals showed from 1 to 5 ppt. By 25 August, salinities on all beds exceeded 5 ppt, except at Deep Water Shoals and Horsehead where they ranged from about 1 to 4 ppt which is not high enough to sustain activity. Subsequently, there was further recovery in all down-river areas except at Deep Water Shoals and Horsehead where salinities remained low for the rest of the year because of continued rains.

Water temperatures and DO were within tolerable levels for oysters.

*Mortality - Public Grounds.* Oysters began dying on the public rocks at Deep Water Shoals, Horsehead Bay, and Mulberry Point (1.6 km above Horsehead) between 10 and 14 July, about 14 days after the onset of the excessive freshwater flows associated with Agnes. By 24 July, when salinities again permitted oyster activity, the following mortalities were estimated: Deep Water Shoals, 57%; Mulberry Point, 25%; and Horsehead, 18% (Andrews, unpublished). Low salinity conditions (less than 1 ppt) returned in September 1972 due to excessive rainfall and by December 1972, mortality had increased to 95% at Deep Water Shoals and to 40% at Horsehead. Mulberry Point showed little change. Samples collected from downriver oyster rocks such as Point of Shoals, Wreck Shoals, and below, where about 85% of the oysters occur, indicated no significant mortalities due to low salinity.

Based on the preceding data, we estimate that about 5% of the oysters on public rocks in the James River System were killed by flood waters associated with Agnes.

*Mortality - Private Leases.* Monitoring oyster mortality on private leases did not begin until 8 September 1972. At that time it was reported that certain shallow-water beds (1.2-1.8 m) close to the shoreline had suffered moderate to heavy mortality; adjacent deep-water beds had not. This mortality probably coincided with that on the public bars up-river, i.e., between 10 and 14 July 1972. Significant mortalities along shore at depths less than about 1.8 m, extended almost 4 miles further downriver than they did in the deeper water toward the center of the river. The most probable reason for this pattern is the horizontally stratified nature of the salinity pattern. That is, oyster beds in the shoreline waters were subjected to lower salinities than those in the deeper waters.

Off the mouth of the Warwick River and off Mulberry Island in very shallow water (1.8 m) on the northern shore of the James, the percentage killed ranged from 20 to 96%.

Along the southern shore of the James significant mortalities were observed only in a small area of leased bottom at a depth of about 1.8 m in the upper river about 0.2 km below Point of Shoals. Down river from there, in the open river, mortalities were normal (<10%).

Oysters in three adjacent tributary creeks on the southern side of the lower James River suffered significant mortality due to fresh water from their head waters. In the Chuckatuck and Nansemond Rivers, oysters near the upper reaches of each system and in very shallow water (2-4 feet) showed an average mortality of about 24%. In the upper part of the Pagan River in very shallow water, mortality ranged from 20 to 23%. In the deeper water in all three systems, oysters showed less than 10% mortality, which is about normal for the region and season.

Interviews with VMRC and oyster growers indicated that about 20% of all the oysters growing in the James on leased bottoms were located in the mortality area. Estimates based on comparison of percentages killed in relation to this distribution indicate that about 10% of all oysters on leased bottoms in the James were destroyed as a result of Agnes.

#### *Oyster Mortality in the York River*

*Introduction.* York River oysters grow in commercial quantities from Bell Rock to about 3.2 km below Pages Rock (Fig. 1). In the last few years, public rocks production has been very low; in 1971 only 716 bushels were produced (Table 1). Oyster production is unknown from private leases in the York area.

*Hydrographic Data.* Salinities were strongly depressed in the York River after Agnes. On 5 July 1972, 11 days after the flood crest passed the fall line, the 2 ppt surface isohaline was at Bell Rock and the 10 ppt at Gloucester Point, significantly below a normal of about 10 ppt and 18 ppt, respectively for this period. Conditions slowly improved, but substantial vertical stratification was not evident until 24 July 1972.

Water temperatures stayed within tolerable levels for oysters, and although DO was not measured no evidence of anaerobic conditions was apparent from the dredged samples.

*Mortality - Public Grounds.* Oyster mortality on public grounds in the York River was negligible. At the furthest up-river productive public rock

(Bell Rock) salinities did not persist at critical levels long enough to kill significant numbers of oysters.

*Mortality - Private Leases.* Oysters killed on private leases were confined to shallow depths (0.6-1.2 m) on the west side of the river extending about 3.2 km downriver from Bell Rock. As in the James, oysters died prior to 11 July; the percentage killed on these beds was estimated at 33%. Because over 95% of all private plantings are located further downriver, only about 2% of the oysters on leased bottoms in the York were killed as a result of Agnes.

#### *Oyster Mortality in the Rappahannock River*

*Introduction.* Oysters are harvested commercially from Accaceek Point to about 3.5 km below the Norris Bridge (Fig. 1). Production from the public oyster rocks in 1971 was 65,949 bushels (Table 1). Production from leased areas in 1971 is unknown.

*Hydrographic Data.* Salinities were low for over a month in the upper Rappahannock River prior to the arrival of Agnes, with values at Bowlers Rock fluctuating from 1 to 5 ppt. No unusual oyster mortalities, however, were reported prior to 21 June 1972.

Five days after Agnes struck, the 1 ppt isohaline was located below Jones Point, where it remained, with minor fluctuations, through 11 July. During this same period, the 5 ppt isohaline extended from Jones Point at a depth of 6.1 to just below the Norris Bridge where it reached the surface. By 24 July conditions had partially recovered and at Accaceek Point, near the up-river limit of oyster culture, salinities ranged from 1 ppt at the surface to about 5 ppt at the bottom. By the second week in August, conditions had slowly improved and salinities were averaging about 5 ppt at Bowlers Rock.

Neither water temperature nor DO were critical in the areas where the major oyster mortality occurred. On 14 July, however, water on the bottom of the channel near Bowlers Rock contained only 1.0 mg/l oxygen, a level that will stress oysters if they are open and pumping.

*Mortality - Public Grounds.* Extensive sampling of the public beds in the Rappahannock from Bowlers Rock to the river mouth showed no mortality associated with Agnes. It is within this area that an estimated 98% of the oysters on public bottoms occur. The single exception to the preceding evaluation of mortality was at Russ Rock, a small isolated area, located 8 km above Accaceek Point. This area was not investigated, but verbal reports suggest that nearly all oysters died there. Based on these data, we were able to estimate that less than 2% of the oysters on the public rocks on the Rappahannock were killed as a direct result of Agnes. The absence of mortalities on public bottoms was due to their location at depths where salinities did not reach critical values for a sufficient time.

*Mortality - Private Leases.* Oysters began dying in the upper river on leased bottoms at depths less than 1.8 m about 30 June, and by 10 July oyster mortality was progressing at such a rapid rate that thousands of oyster meats were observed floating at the surface near Bowlers Rock where they were fed upon by seagulls. This period of peak mortality occurred after oysters had been subjected to salinities averaging 1 ppt or lower for about two weeks and to levels averaging from 1 to 5 ppt for at least a month before this. Although mortality

decreased as salinities rose to higher levels, oysters continued to die until about the second week in August.

The area where oyster mortalities were highest on the south side of the river began at the up-river limit of oyster culture on leased bottoms, about 0.8 km above Bowlers Rock, and extended about 4.8 km down-river. Within this zone most of the oysters had been planted at depths ranging from 1.2 to 1.8 m, and here mortalities ranged from 69 to 100%. At slightly greater depths (1.8 to 3.1 m), where salinities were slightly higher, mortalities were lower and ranged from 19 to 74%. At depths exceeding about 3.0 m, mortalities were still lower, but few oysters are planted at those depths in the up-river section of the river because suitable bottoms are not available. Below the region of heavy mortality on the south side and extending down-river to McKans Bay, there were a few isolated pockets of mortality ranging from 22 to 50% in shallow water (0.9 m).

The area of maximum mortality on the north side on leased bottoms also occurred in shallow water at depths less than 1.8 m and it extended from Accaceek Point to about 1.6 km below Farnham Creek. In this zone mortality ranged from about 48 to 86%. Mortality was lower (19 to 74%) at depths between 1.8 m to 3.1 m. In deeper water, oyster mortality was lower, but again most oysters in this portion of the river are planted at depths less than about 3.0 to 4.4 m. Mortality caused by fresh water was light to zero below Farnham Creek.

We estimated, on the basis of interviews with oyster growers and officials of the VMRC, that prior to Agnes, about 70% of the oysters growing on leased bottoms in the Rappahannock existed in the area of heavy mortality extending from 0.8 km above Bowlers Rock to about 3.2 km below. Within this area the mean mortality based on 61 samples was 67%; therefore, about 47% of the resource was killed. Additionally, we estimated that about 3% of the oysters downstream were killed, largely those in McKans Bay. Therefore, we conclude that about half of the oysters on leased bottoms were killed by Agnes.

#### *Oyster Mortality in the Corrotoman River*

This river is a tributary on the north shore of the lower Rappahannock River (Fig. 1). Its public rocks in 1971 produced 1,911 bushels of market oysters (VMRC 1971), but the annual harvest from private leases is not known.

A single survey made on public and private oyster grounds on 22 September 1972 showed that mortality in the uppermost portion of the river on private leases ranged from 20% at the Otterman Wharf Ferry Landing to 22% off John Creek. The public rocks had less than 20% mortality.

#### *Oyster Mortality in the Potomac River*

*Introduction.* The Potomac River exclusive of its tributaries contains no leased bottoms. In 1971 the entire river produced over 383,392 bushels of market sized oysters (Table 1). Oyster mortality was nearly complete in the up-stream reaches of this system as a direct result of Agnes.

*Hydrographic Data.* Salinities in the upper half of the oyster-producing region of the Potomac River had been abnormally low for about 3 months prior to Agnes. From mid-April to 16 June in the area extending from the Potomac River Bridge to Colonial Beach, surface salinities ranged from 1.0 ppt to 4.2 ppt (Chesapeake Bay Research Council 1973). On 28 June, 6 days after Agnes,

salinity had dropped below the measurable level (0.5 ppt) there. Salinity levels during the next 16 days, except for minor effects due to tidal fluctuations, remained virtually unchanged, and on 14 July there was almost no measurable salt in the surface water as far downstream as Swan Point. By 29 August salinity levels had risen enough to permit normal physiological activity in oysters at Cedar Point where salinities were about 4 ppt at the surface and 6 ppt at the bottom.

Low DO was not a factor in mortalities of the upper Potomac River nor was temperature. DO in mid-channel from Cobb Island to the up-river limits of oysters ranged from 3.9 to 6.6 mg/l on 28 June. Surface temperatures there ranged from 18.0 to 20.5C. By 20 July when oysters were dying rapidly, DO in the same region ranged at the bottom in mid-channel from 4.1 to 7.8 mg/l. Surface temperatures ranged from 25.4 to 27.5C.

*Oyster Mortality.* A few oysters began to die on the uppermost public bars in the Potomac River a week or two prior to Agnes due to low salinities which had prevailed there for about three months. Thereafter, with the influx of added fresh water due to the storm, mortality slowly increased. By 20 July, after exposure to fresh water for about three weeks, mortality increased sharply reaching 21 to 46% from Cobb Island to the up-river limit of oysters. By 1 August mortality climbed to nearly 100%. Salinities returned to normal at the end of August after which mortality among surviving oysters returned to typical levels (about 5% per year).

Estimates based on production records on file at the Potomac River Fisheries Commission indicated about half of the oysters existing in the Potomac River were located above Cobb Island, where mortality approached 100%.

The boundary line in the river which divided the zone of nearly complete mortality from that where mortalities were not significant was a line extending from Cobb Island in Maryland across the Potomac to Popes Creek in Virginia. Below this line, mortality was light and by mid-July less than 6% of the oysters had died on any of the downriver bars. By the end of August, 11% mortality had occurred among oysters further down the Potomac River at Coles Point.

Oysters on Bluff Point Bar, in St. Clements Bay, however, were all killed. By 1 September, oysters living in the lower Potomac River appeared in good condition as shown by surveys of VIMS and the Chesapeake Biological Laboratory.

#### *Oyster Mortality in the Virginia Tributaries to the Lower Potomac*

*Introduction.* Oyster mortality occurred on public and private bottoms in Virginia creeks tributary to the lower Potomac River, as well as in main stem of the system. Major mortality occurred in Lower Machodoc and Nomini Creeks, and scattered mortality was observed in Yeocomico River, Bonum, Jackson and Gardner Creeks (Fig. 1).

*Lower Machodoc Creek.* A survey on 20 July 1972 indicated that up to 40% of the oysters had died in the lower reaches of this system. In the upper half, few if any, died. Surface salinities in the creek varied from 1.9 to 2.3 ppt and DO in channel bottom water varied from 4.2 to 6.8 mg/l. By 28 July mortalities began to increase and in a section near the mouth (Glebe Creek) average 80%; an adjacent down-river location showed 17% dead. Upstream, mortality

ranged from 43 to 75%. At this time DO in the channel ranged from 3.8 to 2.6 mg/l which is not considered critical. By 22 August, however, DO had declined to critical levels with values below 0.5 ppm. As a result, mortality of oysters reached nearly 100% over most of the system.

*Nomini Creek.* A survey on 20 July showed 12% of oysters on public rocks near the mouth dead; up-river mortality was higher, from 24 to 93% on some private beds. Channel salinities ranged from 6.1 to 7.7 ppt.

On 22 August 1972 anaerobic conditions developed in the mid-section of the system, with less than 0.5 mg/l DO in the bottom water in some sections. As a result, the oysters and oyster shells became black and smelled of hydrogen sulfide when lifted from the water. By 22 August nearly all oysters had died in Nomini Cut near the creek entrance and at many other locations up-river.

*Yeocomico River.* The Yeocomico River was not surveyed in the month following Agnes. A survey on 28 July showed oysters in 3.0-3.7 m near the mid-portion of the system apparently unaffected. Surface salinities near the mouth on 28 July averaged 3.3 ppt; marginal for oyster survival. Bottom water samples in mid-channel on 24 August showed 1.4 to 5.1 mg/l DO and salinity 6.1 to 8.4 ppt. Water temperatures were 29.8C to 28.2C at the surface and from 26.2C to 28.2C at the bottom.

Surveys in December 1972 indicated that several leased areas in shallow water in Shannon Creek (an arm of the Yeocomico) had experienced from 60 to 95% mortality. It was impossible to assign a specific cause to the mortality in Shannon Creek then, but depressed salinity and oxygen conditions associated with Agnes were probably responsible.

*Bonum, Jackson, and Gardner Creeks.* A survey in November 1972 showed that scattered kills had occurred in these three creeks tributary to the Potomac River below Lower Machodoc Creek, but inadequate sampling makes it impossible to generalize about the timing or cause of mortalities.

*Conclusions on the Tributaries.* In evaluating the percentage of the oyster populations killed in the Potomac River tributaries on the Virginia side of the system, it was difficult to generalize due to the scattered nature of the plantings and the wide variation in mortality. Interviews with oyster growers and VMRC officials plus data on percentage mortality caused us to conclude that about 70% of the oysters in these tributaries were killed by Agnes.

#### *Regions Not Suffering Oyster Mortalities from Agnes*

Watersheds associated with the Eastern Shore (Seaside and Bayside), the Piankatank and Great Wicomico Rivers, the Mobjack Bay Region and Lynnhaven Inlet received relatively little input of fresh water from Agnes. Thus, their oyster populations were less affected by the storm. However, these areas all were influenced by the storm in that salinities were lower than average and typical patterns of circulation of the water masses were influenced. This secondary effect while difficult to evaluate undoubtedly had an adverse effect especially in respect to setting of oyster larvae.

*Estimates of the Economic Loss by Private Planters Due to Agnes*

*Introduction.* One of the most pertinent problems was to determine where seed was planted in the 1969-1971 period. Based on information supplied by oyster growers and VMRC officials, it was determined that in this period the following percentages of the state's entire seed production were planted in the indicated rivers: James, 5%; York, 10%; Rappahannock, 50%; and Potomac tributaries, 25%. A summation of mortalities on leased bottoms in the same system, as shown in the preceding section, gave the following: James, 10%; York, 2%; Rappahannock, 50% and Potomac tributaries, 25%.

Using the preceding data plus additional information on total seed production for the state, values were calculated for economic loss due to Agnes (Table 2). A value of \$5.10 per bushel (from records of the Potomac River Fisheries Commission) was assigned for 1969. This value was increased 20% each year to compensate for inflation and an increased demand.

Table 2. Losses of oysters in four estuaries of Virginia, in terms of volume and dollars.

Estuary	Seed Planted		Oysters Killed <sup>1</sup> (Bushels)	Value Lost to <sup>2</sup> Growers
	Year	Bushels		
James (10%) <sup>3</sup>	1969	27,058	5,412	\$ 27,601
	1970	18,308	3,662	22,411
	1971	28,284	5,657	41,522
	Sum	73,650	14,731	91,534
York (2%)	1969	54,116	2,165	11,042
	1970	36,616	1,465	8,966
	1971	56,568	2,263	16,610
	Sum	147,300	5,893	36,618
Rappahannock (50%)	1969	270,580	270,580	1,379,958
	1970	183,082	183,082	1,120,462
	1971	282,804	282,804	2,075,781
	Sum	736,466	736,466	4,576,201
Potomac Tributaries (70%)	1969	135,290	189,406	965,971
	1970	91,541	128,159	784,333
	1971	141,420	197,989	1,453,239
	Sum	368,251	515,554	3,203,543
Totals	1969	487,044	467,563	2,384,572
	1970	329,547	316,368	1,936,172
	1971	509,076	488,713	3,587,152
	Sum	1,325,667	1,272,644	7,907,896

<sup>1</sup>Estimated by multiplying the seed planted by the percentage killed and assuming that the oysters would have doubled in volume by harvest time.

<sup>2</sup>Estimated by multiplying bushels killed by a yearly market value (\$5.10 for 1969, \$6.12 for 1970, and \$7.34 for 1971. See text).

<sup>3</sup>The parentheses contain the estimated percent mortality caused by Agnes.

Evaluation of these data shows the estimated minimal loss of oysters in Virginia was about 7.9 million dollars. We regard this estimate as minimal because there was no way to account for the loss of natural set. In addition, indirect economic damage was not assessed, for example, after a planting suffered oyster mortalities of 50% or more, the planter involved may have found it uneconomical to harvest the remaining low density populations which may die later from predators or diseases. Additional losses were sustained due to loss of markets and other similar economic factors.

*THE EFFECTS OF AGNES ON OYSTER SETTING  
IN VIRGINIA IN 1972*

*Introduction*

Oyster set (attachment of larvae to solid substrate such as shells) in Virginia River Systems dropped to the lowest level on record in 1972. Our studies indicate that this phenomenon was the direct result of the effects of Agnes. Low set occurred in all major oyster producing areas in the state; no area received sufficient set to be of any commercial value.

*Methods*

The virtual absence of a set in all river systems in Virginia in 1972 was established on the basis of an extensive program of monitoring conducted by VIMS since 1947. The data collected over the years by Andrews (unpublished) and later by Haven (Marine Science Bulletin 1969-1972) have been summarized. Three techniques have been used in the bay to monitor setting:

- 1) Fall or winter surveys are made on representative public oyster bars. In this program, bushel samples of bottom material are dredged or tonged from the bottom. Later, numbers of spat, small oysters, market oysters, shells and boxes are counted. This technique measures the surviving spatfall as it occurs under natural conditions in the estuary. It is influenced by predators such as drills or crabs which may eat the small spat and by fouling organisms such as Bryozoa, Tunicata, or barnacles which may cover the shell and inhibit setting of the larvae. In this study, only data on numbers of spat per bushel are presented.
- 2) Small wire bags containing about  $\frac{1}{4}$  bushel of oyster shells are placed at representative locations in the estuary in June just prior to the onset of setting. They are recovered in October after the setting season has ended. This method shows the surviving set on shell and indicates what the set might be if shell is planted each year as it is often done in repletion activities and by private growers.
- 3) Ten to fifteen oyster shells are strung on a piece of wire and suspended at representative stations from ropes off the bottom each week during the setting season. At the end of the week the strings are removed and replaced. Oyster spat setting on the smooth side of each shell are counted with the aid of a microscope and the results are tabulated for each station as the average numbers of spat per shell face per week. In this study the weekly set is summed to give the total set per season at each station. This latter parameter is termed the total theoretical set; it indicates what the set might be under optimum conditions where predators and fouling organisms had little effect.

Although information on setting has been collected since 1947, only that part collected since 1961 is used to show the impact of Agnes on setting. The reason is that beginning about 1960 there began a gradual decline in setting in the lower bay (Haven unpublished). Therefore, this recent period is regarded as more typical of conditions just prior to the storm.



To illustrate the impact of Agnes on setting, the average set for each of the three preceding techniques was tabulated for representative stations in each river system for the 1961 to 1971 period and the ranges compared to values for the 1972 set.

The stations selected for comparison are representative of the range of the productive natural rocks in each system. The stations selected for study in this paper (Fig. 1) are: the James, from Deep Water Shoals to the James River Bridge; the Rappahannock, from Bowers Rock to 1 km above the Norris Bridge; and the York, from Bell Rock to Gloucester Point. In the Corrotoman, Great Wicomico, and Piankatank Rivers, the stations were located from the mouths of each system to the upper limit of oyster culture.

### *Results*

In the James, York, and Rappahannock Rivers, with two minor exceptions, the 1972 set for all three methods of measuring was lower than for any single year during the preceding 10 years (Table 3).

In the Piankatank, Great Wicomico and Corrotoman Rivers, the 1972 set without exception was lower than the average for any of the years for which data exist within the 1961-1971 period.

### *Discussion*

The absence of a set or the very low set which occurred on shellbags or natural cultch at the end of the 1972 season might have been due to an excessive mortality associated with unfavorable environmental conditions. However, this was not the case, because few spat set on the shell strings. Significant setting simply did not occur in 1972.

There are several reasons why setting in Virginia reached such low levels following Agnes. Some of the reasons are apparent, others cannot be clearly documented.

Oysters spawn in Virginia from late June to the last of September, with peak spawning occurring during the months of July, August, and September. Therefore, it is evident that Agnes hit at the start of the spawning season and many oysters especially in the Potomac, Rappahannock, York, and James were inactivated by low salinities. Therefore, oysters did not spawn (if at all) until much later in the season.

Another factor was that salinities were low (5 ppt or below) far into the summer and oyster larvae do not develop or may die if exposed to 5 ppt or less for a week or two (Galtsoff 1964).

In river systems such as the Great Wicomico, the Piankatank, and in Mobjack Bay which typically received fair to moderate sets, the fresh water did not kill appreciable numbers of oysters and the salinity remained above levels that cause inactivity. Nevertheless, conditions associated with the storm are believed to have adversely influenced set. Possible reasons include the disruption of normal circulation patterns (Wood & Hargis 1971). Other reasons might include excessive silt levels, and low levels of DO.

Table 3. Effects of Agnes on oyster spatfall in Virginia. The post-MSX period (1961-1971) is compared with similar data for 1972.

River	Method	No. Stations	Period	Range
James	Shell bags (spat/shell)	3	1961-1971	0.9 - 4.3
			1972	0.0 - 0.1
	Shell Strings (spat/shell face)	4	1961-1971	3.8 - 9.8
			1972	0.7 - 3.3
	Natural Cultch (spat/bushel)	5	1961-1971	62 - 216
			1972	0 - 26
Rappahannock	Shell bags (spat/shell)	5	1961-1971	0.0 - 3.8
			1972	0.0 - 0.03
	Shell strings (spat/shell face)	8	1969-1971	0.0 - 3.8
			1972	0.0 - 0.0
	Natural Cultch (spat/bushel)	5	1961-1971	5 - 93
			1972	0 - 0
York	Shell bags (spat/shell)	4	1963-1971	0.1 - 4.0
			1972	0.0 - 0.03
	Shell strings (spat/shell face)	1	1963-1971	44.1
			1972	0.3
	Natural Cultch (spat/bushel)	4	1961-1971	9 - 25
			1972	0 - 10
Piankatank	Shell bags (spat/shell)	6	1963-1971	1.4 - 4.2
			1972	0.01- 0.14
	Shell Strings (spat/shell face)	4	1964-1971	12.7 - 67.9
			1972	0.0 - 1.2
	Natural Cultch (spat/bushel)	5	1961-1971	277 - 546
			1972	0 - 10
Great Wicomico	Shell bags (spat/shell)	6	1965-1971	2.4 - 8.2
			1972	0.01- 0.05
	Shell strings (spat/shell face)	10	1964-1971	19.0 - 2.34
			1972	0.0 - 3.1
	Natural Cultch (spat/bushel)	10	1968-1969	2.0 - 200
			1972	0.0 - 0.01
Corrotoman	Natural Cultch (spat/bushel)	5	1961-1972	183 - 256
			1972	0 - 2

In the James River seed-oyster area, the density of oysters on the bottom had been slowly declining since 1960 and the 1972 failure represented a further reduction in the number of 1 to 2 inch seed oysters available for harvest in 1973 and for 3 to 4 years thereafter. In the Piankatank and Great Wicomico Rivers, setting was below average in 1970 and 1971 and the failure in 1972 intensified the seed problem.

The availability of market oysters from the public bottom in Virginia has been slowly declining since the onset of MSX (Andrews 1967), and the absence of recruitment for 1972 will bring lower densities later in 1974 and 1975 when the oysters would normally reach maturity.

MORTALITY AND GROWTH OF HARD CLAM POPULATIONS  
ASSOCIATED WITH AGNES

*Introduction and Methods*

In Virginia, hard clam production is largely from public bottoms, and two of the most productive areas are the York and James Rivers. The latter area, however, is classed by the Virginia Bureau of Shellfish Sanitation as restricted for the harvest of shellfish, which means that clams harvested there may not be sold directly for human consumption unless they are replanted (relaid for cleansing or depuration) on pollution-free bottoms for 15 days with water temperatures higher than 50 F. Such relaying of presumed polluted James River clams is widely practiced. Therefore, in evaluating losses of hard clams associated with Agnes it was necessary to consider: 1) losses on public bottoms in the James River and elsewhere; and 2) losses of relaid clams held on leased bottoms.

Mortality on leased bottoms was determined by collecting clams from the bottom with hand tongs. The number of recent boxes (valves still attached by a hinge) in the total sample was used to determine the percentage dead.

On public bottom, hard clam populations were sampled with a hydraulic tow dredge. Again, percentage mortalities were determined.

Areas referred to in this section are given by their local name and also as the number of km above the mouth of the river systems (Fig. 1).

*York River*

*Public Bottoms.* On 10 and 11 August 1972, 12 tows were made in the lower York River in an area extending from the Vepco Power Plant (4.0 km) to Queen's Creek (17.7 km). The study showed only a light mortality (5.3%) (Table 4).

Table 4. Numbers of live hard clams and boxes at various locations in the York River, Virginia, taken with a hydraulic tow dredge 10-11 August, 1972.

Station	Km Above Mouth	Number Live	Number Boxes	Water Depth (m)
<u>Northside River</u>				
Green Point	12.3	0	0	1.4
Mumfort Island	10.5	4	0	1.4
R-28	8.8	8	1	1.4
Waterview	6.4	12	0	1.2
Gaines Point	5.6	31	1	1.5
Perrin	3.2	62	2	1.4
<u>Southside River</u>				
Queen's Creek	17.7	0	0	1.4
Sandy Point	12.1	19	2	1.4
N-27	8.0	14	1	1.4
Yorktown	6.4	7	1	1.4
Wormley Creek	6.4	12	0	1.4
VEPCO	4.0	12	1	1.4

*Private Beds.* In the Perrin River near the mouth of the York River (2.4 km) there was a serious mortality of relaid hard clams on bottoms leased by one clam-processing firm. An investigation on 10 and 11 August 1972, showed that in one area 58% of the clams on a hard bottom had died, presumably during the past month. Clams stored in floats in an adjacent area suffered 82% mortality.

Off Timberneck Creek (12.8 km) clam beds belonging to a second company were sampled. On one plot in 1.2 m of water, 33% of the relaid clams died. Further inshore in shallower water, a bed containing 1,000 bushels of small hard clams experienced 100% mortality. These clams were valued by their owner when planted at \$25 per bushel. Therefore, their loss was estimated at about \$25,000.

Clams in very shallow water in the lower York River were exposed to salinities about 10 ppt or less for at least a month after Agnes. Studies have shown that hard clams cannot tolerate salinities ranging below about 10.0 to 12.5 ppt (Castagna & Chanley 1973). We conclude, therefore, that the fresh water associated with Agnes was the cause of the mortality. It is not clear why clams died on private leases and not on public bottoms. A probable reason may be that clams on the leased bottoms were subject to a salinity stress plus an added stress due to harvest, transport, and replanting.

In the month following Agnes, clam boxes washed up along shore in several locations in the York River from about 0 km to 19.3 km. The number was never large and ranged from about 5 to 20 per 50 m of shoreline. No estimate of percent mortality could be made because the density of the population these clams came from was unknown.

#### *Poquoson River*

Two companies with relaid clams on leased bottoms were visited on 11 August 1972; both sustained serious losses of hard clams originally harvested in the James River. Six separate sites belonging to one company were visited. Most of these clams had been transferred from the lower James River to the Poquoson River in the three week period after Agnes. Mortality ranged from 11 to 100%, averaging 44%. But even before Agnes clam mortality in this area was high. Clams which had been moved from the James River by a second company were sampled in early June 1972. The average mortality was 40% in four areas sampled. Salinity levels during the mortality period were not measured. Therefore, it is not possible to tell why these clams died.

#### *James River*

Ten stations sampled during August 1972 in the lower James River in the vicinity of Newport News (8.8 km) yielded no abnormal mortalities.

#### *Adverse Effects on Growth*

From 1968 to 1972 VIMS personnel conducted a study of hard clam growth in the lower Chesapeake Bay. A comparison of growth rates in years of normal salinity range with years of low salinities indicated a significant decline in the growth of clams in 1972 in the lower York and James Rivers as a result of Agnes (Loesch & Haven 1973).

### Conclusions

The high mortality occurring among clams held in leased areas in the York and Poquoson Rivers probably resulted from the stress of moving and marginal salinities. A light mortality of undetermined magnitude occurred in the York River in very shallow water along shore from the mouth to about 19.3 km up-river.

### MORTALITY OF SOFT CLAMS POPULATIONS ASSOCIATED WITH AGNES

#### Introduction and Methods

Mortality of the soft clam, *Mya arenaria*, was investigated in the Rappahannock River in March 1973, and near the mouth of the Piankatank River (off Gwynns Island) in October 1972, with a conventional Maryland-type, hydraulic, soft clam escalator. The R/V *Mar-Bel*, a VIMS vessel, was employed in the former area; at the latter site a privately owned commercial vessel was chartered by the VMRC. In making these surveys, the vessels were operated on public and private grounds where surveys completed in previous years showed soft clams to be present.

In addition to escalator samples, observations were made in the York River by washing clams from the bottom with a water jet produced by a portable gasoline powered pump.

Areas referred to are followed by station location expressed as km above the mouth of the river and may be located by reference to Fig. 1.

#### Rappahannock River

Fifteen stations were occupied in the river at seven separate locations on 12 and 13 March 1973. No living soft clams were found. However, shells were collected at many of these locations, indicating existence of previous populations.

Prior studies in the Rappahannock River by VIMS personnel and a private company indicated soft clams had formerly been abundant at several of the stations sampled in the study. An oyster grower (Mr. Ferguson) located at Remlick, Va., stated (personal communication) that about 25 to 30 bushels of soft clams per day could be harvested at the time he ceased commercial escalator harvesting on his grounds in the Morattico area (Fig. 1) in 1968. A similar abundance on these same bottoms were noted in a study by VIMS personnel when 38 bushels of soft clams were escalated from a ½ acre plot in approximately 8 hours in 1968. Again, in 1969, in the same location, 34 bushels of soft clams were harvested by VIMS in about 13 hours. Down-river at Parrott Island, 34 bushels of soft clams were escalated in 13 hours. Below Parrott Island to the mouth of the Rappahannock River, soft clams were represented by sparse populations during 1969 (Haven, Loesch & Whitcomb 1973).

The total absence of soft clams in the 1973 survey in relation to their former abundance indicated populations died in the Rappahannock River cataclysmically. This probably occurred in the aftermath of Agnes due to the dramatic decrease in salinity, because *Mya arenaria* cannot tolerate salinities below 2.5 ppt for more than two weeks (Castagna & Chanley 1973). Salinities in the vicinity of the Norris Bridge in the lower river on 28 June 1972 were between 1 and 5 ppt. Therefore, we conclude that salinities were low enough to have produced the observed mortality.

*York River*

Samples collected with the jet sampler on 4, 10 and 15 July and 1 August 1972 indicated no unusual mortality of soft clams had occurred at Gloucester Point (8 km). Similar results were obtained from additional samples collected at Foxes Creek (26 km) from 10 to 31 July 1972. Salinity levels at the above sites never fell below 5 ppt.

*Mouth of Piankatank River (Gwynns Island)*

Eighteen stations were occupied in the study of soft clam populations off Gwynns Island on 2 October 1972. Shells of soft clams were abundant. Living clams were observed at 11 of the 18 stations but not in great densities; the best catch was about 10 clams per minute. The salinity levels soft clams were exposed to in this location after Agnes are not known.

*MORTALITY OF OYSTER DRILLS (UROSALPINX CINEREA AND  
EUPLEURA CAUDATA) FOLLOWING AGNES*

*Introduction and Methods*

The oyster drills *Urosalpinx cinerea* and *Eupleura caudata*, are the most destructive predators of oyster spat and small oysters in Chesapeake Bay where salinities exceed about 15 ppt (Andrews 1955). Salinities ranging from 7 to 10 ppt may kill oyster drills in 8 to 14 days (Zachary & Haven 1973). Agnes undoubtedly had a major influence on drill populations because of their sensitivity to low salinities. VIMS personnel evaluated the extent of this effect during August and September 1973 at locations where drills were a problem prior to Agnes.

The method used in detecting the presence of drills was commonly used in past studies (Andrews 1955). It consisted of constructing small wire bags (1.5 inch mesh) about 1 foot wide and 18 inches long which were filled with small freshly collected live oysters. Ten of these wire bags were attached by ropes 30 feet long to a 500-foot collecting line. At weekly intervals the wire bags were raised and shaken over a fine mesh wire screen which retained all drills attached to the live oyster "bait" during the past week. These data were used to show catch per trap per week.

Drill traps were placed in the lower parts of the James, York, Rappahannock, and Piankatank Rivers during August, September, and the first week of October 1973. The locations of specific rocks or areas mentioned in these sections are also given as km above the river mouth.

*Results*

The survey showed fresh waters associated with Agnes effectively killed drills in many areas where they were formerly abundant (Table 5).

In the James River, prior to Agnes, the range of drills extended from about 1.6 km above the James River Bridge 14.5 km to the mouth of the river (Hargis 1966). After Agnes, drills were absent from the upper half of the range. None were collected on traps placed at the James River Bridge and at the mouth of the Nansemond River (8.8 km). At Hampton Flats (5 km) the catch was 3.0 per trap per week, indicating that salinities had not appreciably reduced population levels there.

Table 5. Drill trap catch of *Urosalpinx cinerea* and *Eupleura caudata* following Agnes at various locations during August and September, 1973.

Location	Upriver Location (km)	No. of Weeks Traps Exposed	Total Catch	Drills/Trap/Week
<u>James River</u>				
James River Bridge (Brown Shoal)	14.5	3	0	0
Nansemond River	8.8	3	0	0
Hampton Flats	5.5	3	52 <sup>1</sup>	1.7
<u>York River</u>				
Gloucester Point	8.0	2	41 <sup>2</sup>	2.1
Green Rock	14.5	2	2	0.1
Pages Rock	16.1	1	0	0
<u>Rappahannock River</u>				
Parrott Island	9.0	2	0	0
Mouth Corrotoman River (Towles Point)	18.0	3	0	0
<u>Great Wicomico River - Gwynn I.</u>				
Mouth of system	0	1	0	0

<sup>1</sup>28 *Eupleura*<sup>2</sup> 1 *Eupleura*

In the York River before Agnes, drills infested the area from off Aberdeen Creek (16 km) to the mouth of the river. Drills were still found at Gloucester Point (8 km) after Agnes, but the up-river range was greatly diminished by the fresh waters. Only two were captured at Green Rock (14.5 km) and none at Pages Rock (16.1 km), locations where drills caused extensive damage prior to Agnes.

The lower Rappahannock River, below Towles Point (18 km), has had a long history of drill infestation. In a study conducted in 1961 *Urosalpinx cinerea* were trapped at Towles Point. In addition, egg cases were obtained here indicating reproduction was occurring (Griffith & Engle 1961). No drills were collected in our study during the fall of 1973 from just south of Towles Point to Parrotts Rock (9 km) (Fig. 1).

Salinity levels in the Rappahannock River were below 10 ppt for about a month after the onset of Agnes in the lower river. This was sufficient to kill the drills.

No drills were obtained in traps set at the mouth of the Piankatank River in our study. Surveys made by laboratory personnel in previous years showed heavy drill infestation in this area prior to Agnes.

It is estimated that drills will not regain their former levels of abundance in the areas where they were killed for at least three or four years, thus oysters in this period will have a good chance for survival.

## SUMMARY

Agnes had a major influence on all aspects of the molluscan fishery in Virginia waters of the Chesapeake Bay. Mortality of mature oysters on leased bottoms in the major systems was estimated as follows: Rappahannock: 50%; Potomac tributaries: 70%; James: 10%; and York: 2%. The economic loss on the private leases was estimated at 7.9 million dollars.

Oyster losses on public bottoms were low within the state and were estimated as follows: James River: 5%; York: 0%; and the Rappahannock: 2%. Losses on the public bottom in the Potomac were about 50%. As a direct result of the storm, the set of oyster larvae was the poorest on record. Hard clams were killed by Agnes in the York River by fresh water. Mortality, however, was heaviest in replanted populations. No effect was noted in the James River. There appeared to be a complete mortality of soft clams in the Rappahannock River from the Morattico region to the river entrance. In the York River and off Milford Haven, losses appeared minimal. Agnes greatly reduced oyster drill populations in the upper parts of their range in the James and York Rivers. In the Piankatank and Rappahannock Rivers it appears that most of the drills were killed.

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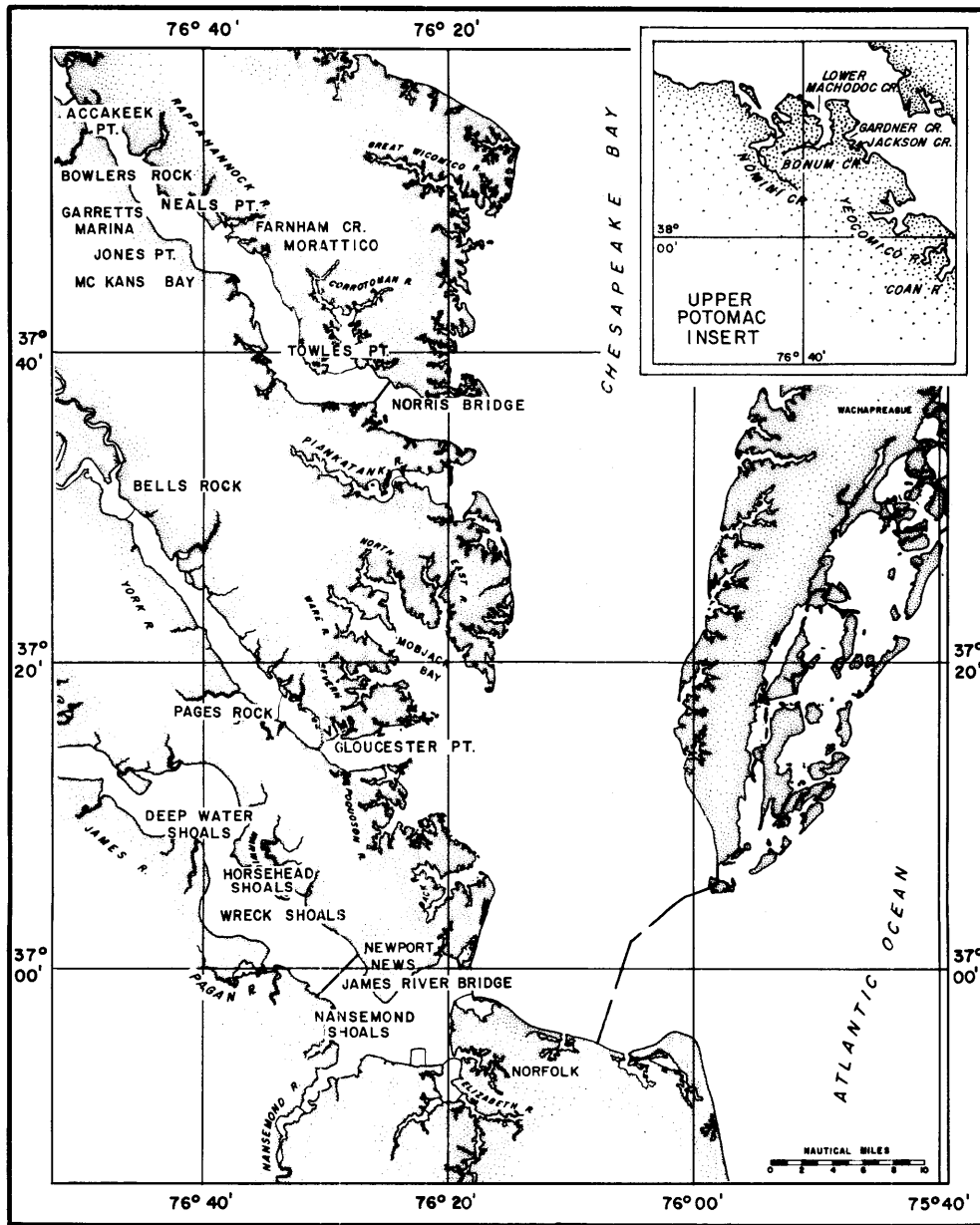


Figure 1. Location of river systems in Virginia.