THE OYSTER INDUSTRY OF VIRGINIA: ITS STATUS, PROBLEMS AND PROMISE

A COMPREHENSIVE STUDY OF THE OYSTER INDUSTRY IN VIRGINIA

by

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VIRGINIA INSTITUTE OF MARINE SCIENCE
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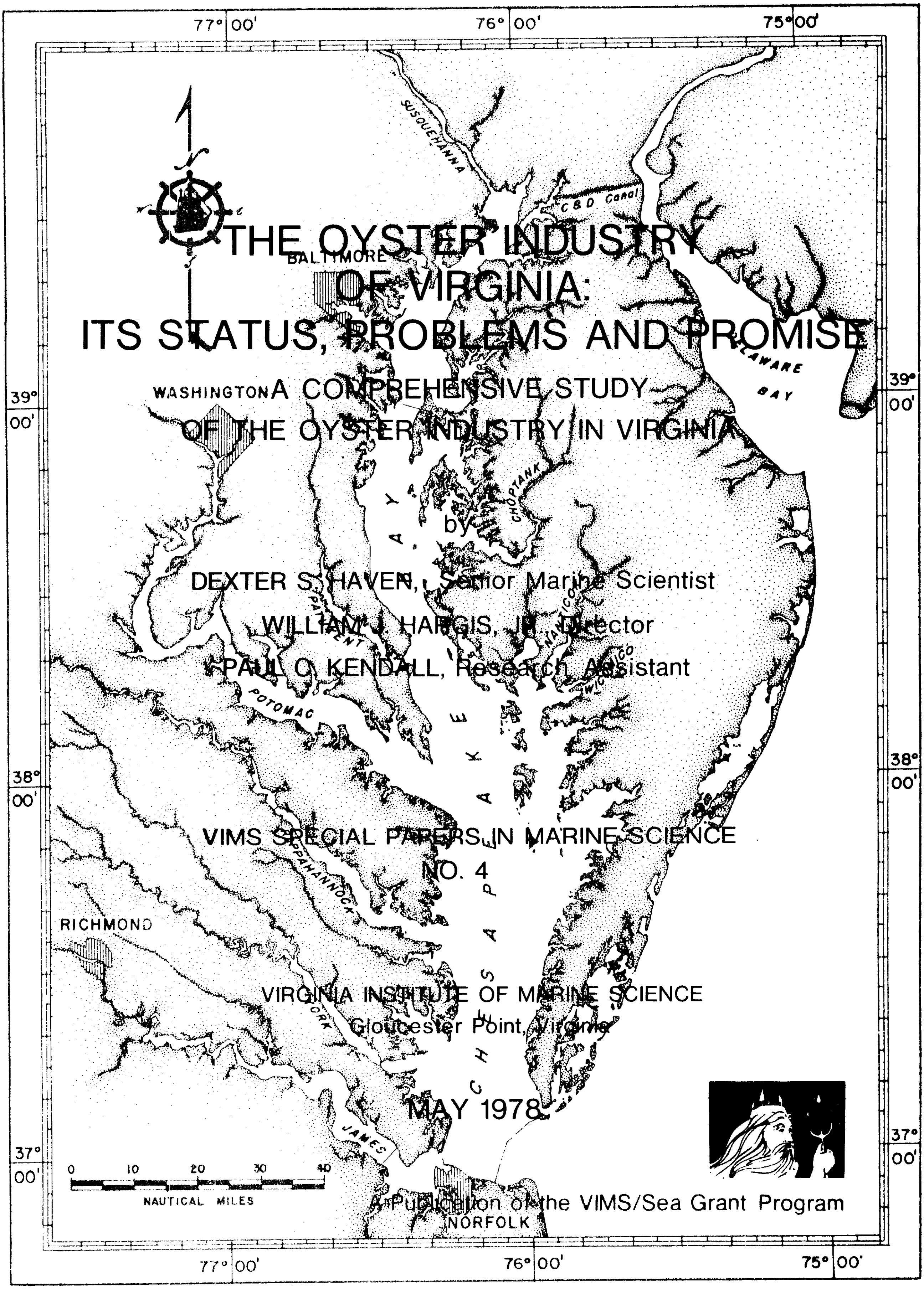

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Its Status, Problems and Promise

VIMS Special Papers in
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ERRATA

May, 1978

Page	Line	
822	21	More recently Ms. Nancy T. Windsor of the Department of Marine Culture at VIMS has successfully crossed *C. virginica* x *C. gigas* and its reciprocal (Windsor, personal communication).

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OF VIRGINIA:

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A Comprehensive Study
Of The Oyster Industry In Virginia

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PREFACE

Since the beginning of government supported research into the fishery resources and the environments on which they depend, the primary objectives of that research have been to improve management of those resources and the productivity and profitability of the fisheries industries. Though modern efforts at fishery science by the Commonwealth of Virginia may be said to date back to the hiring of Dr. Victor Loosanoff by the old Virginia Fisheries Commission in the early thirties, organized scientific efforts at improving the oyster fisheries of the Chesapeake Bay may be traced at least to the activities of Dr. W. K. Brooks, a marine scientist who served as a Maryland oyster commissioner in 1883. Also active in the period was Lt. Francis Winslow of the U. S. Navy, on loan to the U. S. Coast and Geodetic Survey, who studied oyster production in Tangier Sound.

Technical efforts in Virginia directed at increasing oyster yields may be traced to the delineation of those grounds most suitable to public culture of oysters in the late 1800's by Lt. J. B. Baylor of the U. S. Coast and

Geodetic Survey, i.e., the Baylor Survey.[1] Virginia had asked the federal government for help. The U.S. Coast and Geodetic Survey responded.

Organized research into the biological resources and the fisheries of the Maryland portions of the Chesapeake Bay had been undertaken much earlier by various groups such as the old U.S. Commission of Fisheries and persons such as W.K. Brooks of Johns Hopkins, and later the Chesapeake Biological Laboratories, also of Maryland. The U.S. Fish and Wildlife Service, with participation from the Commonwealth of Virginia, including the College of William and Mary, established a laboratory at Yorktown, Virginia to study the effects of estuarine pollution and diseases on oysters in the York River and the lower Chesapeake in the thirties. In 1940 this latter organization was physically replaced by the Virginia Institute of Marine Science (then the Virginia Fisheries Laboratory) which has continued the work on oysters and on other aspects of estuarine biology.

Though these are probably not the earliest beginnings of attempts at application of fishery science and technology

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[1]In his report to the Governor of Virginia of 1893, Lt. Baylor urged, among other things, encouragement of the leasing and private planting activity. Thus, the man whose name is synonymous with the public grounds and public oyster fishery was convinced even as he reported the results of his survey that "the future of the oyster industry of Virginia...must rest on its planting interests" (Baylor, 1894).

to the oyster fishery and this account is certainly not detailed, they will serve adequately for purposes of this preface to indicate that the effort to improve or preserve the oyster fisheries of the upper and lower Chesapeake by scientific and technical means has been underway for sometime. Interestingly, early marine biologists recommended improvements which are still being urged, but which have not as yet been adopted. These voices from the past should be heard and heeded.

It is only fair to point out for most of this period investment of money, facilities and manpower in these scientific endeavors was extremely sparse. Only in the last ten to fifteen years have investments in research been significant in Virginia. This is far too short a period to allow development of an understanding of the complex natural and economic problems involved in the many fisheries important to the lower Chesapeake. Much remains to be learned.

In carrying out such research one must be concerned not only with the complex nature of the species involved but also of the fisheries' activities which depend upon them. Especially important is an understanding of the impacts upon these fisheries by environmental factors and by other users.

It is a difficult and many-faceted business not to be easily or quickly fathomed. Much is as yet unknown.

Despite the shortages and gaps in our knowledge more detailed scientific understanding and technical capabilities have been developed than put into use. There are many reasons for this lack of transfer and application of knowledge and manipulative capability into improved management and increased yields and economic benefits. Some of these are: 1) archaic practices and attitudes within industry itself; 2) economic and political conflict between segments of industry, and between the fisheries and other users and uses; 3) lack of firm and consistent purpose and practice by industry and by the State toward achievement of realistic and improved management; and 4) continuation of legal restrictions and economic practices which actually mitigate against and prevent improvements in the fisheries. Destruction or debilitation of estuarine and marine environments by man-made and natural changes (some of which may or may not be induced or aggravated by the activities of society) have materially affected yields, generally by reducing them. Then, too, overfishing has taken its own toll of the stocks.

Perhaps part of the failure in achieving control over the fishery resources and of the industry based thereon is due to the lack of comprehensive analyses of the problems of the fisheries' industries and of existing knowledge related to fisheries' stocks, environmental conditions, socioeconomic aspects and of fishery technology. Convinced of the necessity for such analyses, the administration and staff of the Virginia Institute of Marine Science has determined to undertake a series of careful fishery-by-fishery studies which began in 1971 and will require several years more to complete. From these studies we hope to be able to develop comprehensive, yet detailed, management recommendations to the Virginia Marine Resources Commission and other elements of the Executive Branch and to the General Assembly (constituting the public managers) and to the various segments of the oyster industry. The goals are: 1) to slow and hopefully stop and reverse the trend of diminishing yields from public and private oyster-producing grounds of Virginia and from the other fisheries; 2) to bring about increased productivity from Commonwealth waters and bottoms; 3) to increase dependent and related economic activity, and 4) to increase activity, income and profit at all stages in the fishing industries involved.

Whether all or part of these goals will be attained is for the future to tell. However, we are determined that the lack of careful, complete and candid analysis and development of clear scientific and technical recommendations and communications of same to industry and to the State will not be the excuse used if natural and managed oyster production continue to wane and industry diminishes still further.

It is also intended that these studies will result in development of better, more economical and more productive programs of fishery research, fishery engineering, and advisory services in the Commonwealth and in the Chesapeake Region. Too, we expect to receive guidance in the planning and scheduling of fishery-related research activities. We fervently hope and expect that this series of "white papers" or working documents on the fisheries of Virginia will contribute materially to attainment of these objectives.

As an aid in understanding the complexity of Virginia's oyster industry and its problems, a general review of the catastrophic decline in Virginia landings follows.

INTRODUCTION TO THE WORK

Virginia was the most important producer of the American oyster, *Crassostrea virginica*, in the nation in the early part of this century and even until the 1950's. Middens from prehistoric periods demonstrate wide use of oysters by American Indians. Similar shell piles attest continued consumption in pre- and post-Revolutionary periods. Civilians and soldiers from all periods of military history until World War I have left remains of meals and feasts containing millions of shells around the shores of the Bay. Large masses of buried shells have been found in the rubbish piles and dumps of the many permanent and temporary encampments and fortifications around Tidewater, Virginia dating from McClellan's Peninsula campaign and the long occupation of Eastern Virginia by Southerners and Yankees alike. Many thousands, sometimes hundreds of thousands, of men were involved often for fairly long periods of time. They and the inhabitants ate a lot of oysters.

During the mid-1800's millions of bushels from Chesapeake Bay were consumed locally each year or sold to distant markets in New England and even as far away as California and England (Brooks, 1891). By the early 1900's production had decreased somewhat as the natural oyster beds became depleted to the point where annual production was down a reported 4 to 7 million bushels. Though a decline, this amount was large by national, even worldwide, standards and Virginia out-produced all other East Coast states.

According to the early records this level was maintained up until 1925 when there began a drastic decrease in landings and in 1931 only 2,848,477 bushels were harvested. This was a reduction of from two-thirds to one-half--not an insignificant drop! Probably, the Depression years (low demand) were responsible for a major portion of this early decline, but this needs investigation since other factors may have been involved.

After 1931 production slowly increased to 3.5 million bushels in 1954. Following this a record decline took place and in 1975 Virginia produced only 895,597 bushels. One of the principal reasons for the recent decline was the disease produced by the oyster pathogen, *Minchinia nelsoni* (MSX), which appeared in the Chesapeake Bay population in 1960 and killed large numbers of oysters in high-salinity areas. As we will see, other causes have contributed to the decline and for the continuance of low production.

To determine the reasons for this diminishment and the persistence of lowered productivity we have conducted a detailed study of the Virginia oyster industry for the period 1931 to 1975. This period has been chosen because sufficiently reliable and comprehensive information exists in the literature concerning the fishery to support such an analysis.[2] This report examines the major problems facing the industry. Emphasis is placed on determining the reason or reasons for recent major reductions in oyster production and the persistent lack of recovery.

Information for this study has been obtained from published materials, unpublished data and manuscripts, historical and legal records, tax data on file at the Virginia Marine Resources Commission, records from several private oyster producers, and from interviews with oyster growers, dealers, inspectors, planters, packers and processors. The geographical area emphasized in the study was the lower Chesapeake Bay and its tributaries and the Seaside of the Eastern Shore, but pertinent material was included for Maryland.

A review of available information showed little was known in detail about the Virginia oyster industry as a whole.

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[2] Even now (1976-77) adequate data on production are lacking but sufficient information exists to allow our current analytical efforts and support their conclusions.

Many persons have generalized knowledge; a few know many or most details of specific portions of the industry, but almost no one has details of all segments. Many papers and articles on individual aspects have been published, but little of this information has been recorded and treated as a comprehensive whole. Our purpose was to do so.

A quotation from a recent report from the Marine Resources Study Commission dated 27 November 1967, describes the present situation:

> The planting and harvesting of oysters is taken for granted by oystermen and natives of Tidewater, Virginia, in the same manner as citizens of rural areas consider farming; it is a livelihood and a way of life. With the exception of those persons having direct contact with the oyster industry or a personal knowledge from having resided in the Tidewater area, few persons have a comprehensive knowledge of the mechanics or the complexity of this phase of Virginia's economy.

For analysis, the factors and phases of the oyster industry, both public and private, have been divided into several categories. These are: oyster production on public and leased areas, the condition of the public rocks, economics of the industry, possible methods of management, predators and diseases, pollution, oyster culture, laws and recommendations.

Tropical Storm Agnes hit Virginia on June 21, 22 and 23 of 1972 and dropped unprecedented quantities of water on the major water sheds emptying into the tributaries of the Chesapeake Bay. As a direct result of this storm many millions of dollars worth of oysters were killed. Losses of oysters were estimated as follows: James - 10%; York - 2%; Rappahannock - 50%; Potomac Tributaries (Virginia) - 70%. No attempt was made to analyze the impact of Agnes on the economy of the State in this paper since this information has been summarized elsewhere (Haven et al, 1976). It was sufficient here to point out that it caused more than eight million dollars worth of damage. Even so, it only accelerated, but did not otherwise change, the long-term trends established here.

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CHAPTER I. OYSTER CULTURE IN VIRGINIA - PAST AND PRESENT

To provide a framework against which later details may be considered, it is necessary to begin with a general discussion of where and how oysters are grown, methods of harvest, processing techniques, diseases and other aspects.

Value and Magnitude of the Resource

Values of oysters as landed in Virginia as well as value of the shucked or processed oyster are summarized yearly by the National Marine Fisheries Service (NMFS), formerly the United States Bureau of Commercial Fisheries (USBCF). According to statistical data for the period 1880 to 1925, Virginia was producing enormous quantities of oysters, ranging annually from 4 to 7 million bushels. According to Dr. W. K. Brooks (1891) the records of C. S. Maltby, who evaluated oyster production for the whole Bay in 1865, indicated that dredging yielded 3,663,125 bushels in Maryland and 1,083,209 bushels in Virginia while tongers harvested 1,216,375 bushels in Maryland and 981,791 bushels in Virginia or 4,879,500 bushels for Maryland and 2,065,000 for Virginia. Thus, the entire Bay was recorded as having produced 6,954,500 bushels of oysters in 1865. Ten years later, in 1875, the annual production had increased to 17,000,000 bushels and it continued to increase "year after year up to the last few years" (Brooks, op. cit.). If Maltby's and Brooks' statistics are accurate, and we see no reason to challenge them, oyster production in the Bay may have reached 20,000,000 bushels or more per year in the period between 1875 and 1885.[1]

Based upon these figures Dr. Brooks calculated that during the fifty-six year period after 1834, when the business of packing oysters for shipment to the interior was established in Maryland, the average annual production from the Bay was 7,000,000 bushels per year, or 392,000,000 bushels for the period. This massive harvest was almost entirely wild, natural or unaided production. Sometime during or after this period, Maryland's oyster production dropped below that of Virginia. This reduction may have been due to the development of the private leasing system in Virginia in the late 1800's, or to overfishing and/or increasing destruction of the public bottoms in Maryland or all three. The early 1900's saw Virginia become and remain the largest producer of oysters in the Chesapeake Region and on the entire Atlantic seaboard. From 1931 to 1960 annual production decreased but was still high and Virginia

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[1] We must remember that "oyster bushels" as measures are not now the same in volume between Maryland and Virginia--perhaps they were then! Since these are the only data available for the period before 1880 and "bushels" may have been "bushels" in those days before the sophistication of official measurements was introduced, we assume equality. In any case, the official Virginia bushel is the largest of the two now. If it was also then, any error would tend toward conservatism, i.e., there would be a conservative bias against Virginia's figures.

remained foremost producer on the East Coast. The average annual production in this period from the State ranged from about 1.3 to 3.5 million bushels.

Beginning around 1959 the Virginia industry began to suffer a serious decline, with the initial cause being the oyster disease MSX. The latest complete NMFS data available for the 1974-75 season show that a significant reduction in quantity to slightly less than 1 million bushels landed in that year. This catch was worth about 3.7 million dollars at dockside. The value of the processed meats from the oysters (shucked, raw, steamed or breaded) was over 12 million dollars. Despite a recent decline in landings the oyster industry remains a multi-million dollar business activity significantly contributing to the economy of the State.

Most persons are unfamiliar with the details of the Virginia oyster industry. Many regard it as a simple business of harvesting nature's bounty or planting some seed oysters and dredging up marketable oysters after a few years. Actually, the oyster industry is complex, and all of its many parts are interrelated. As a consequence, something which influences one part will ultimately influence the many other aspects and the economic repercussions may be widespread. An outline showing the industry in all of its organizational and operational complexities is shown in Figure 1.

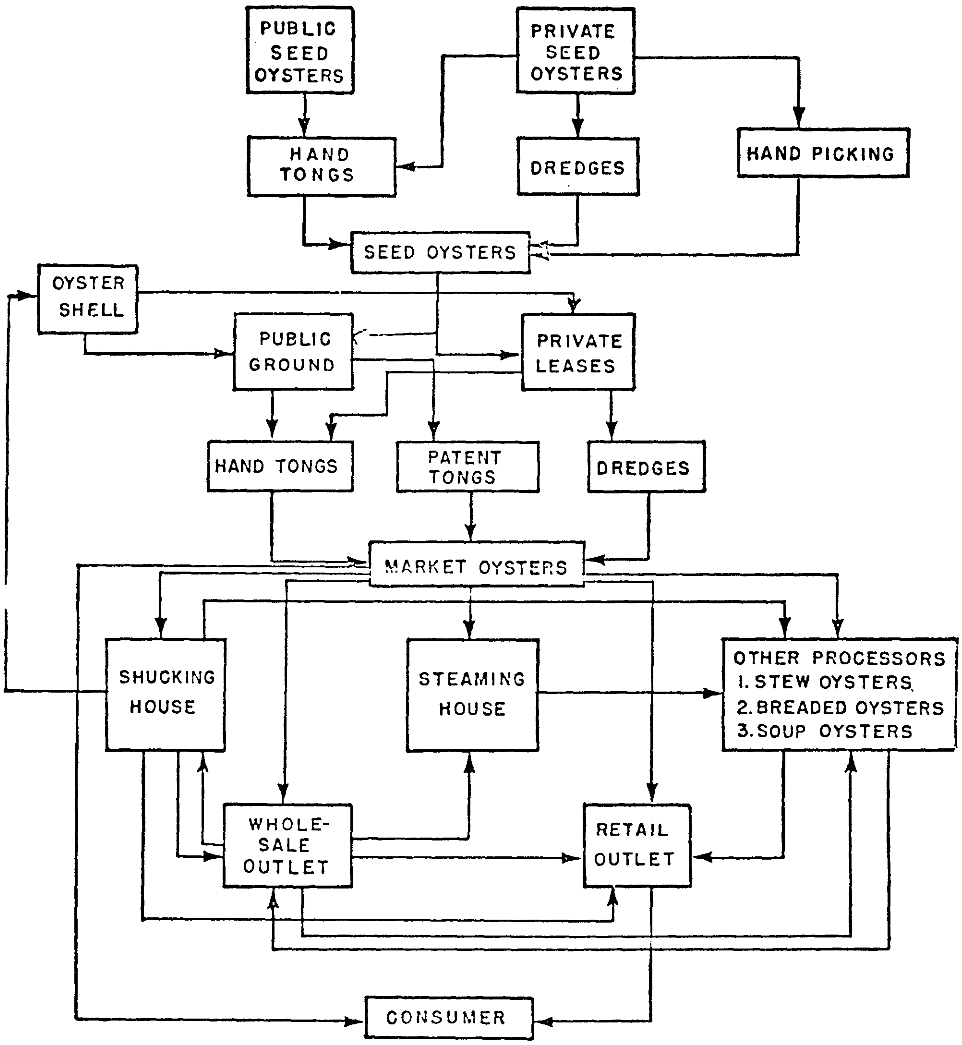
Natural History

The American oyster, *Crassostrea virginica*, occurs along the Atlantic and Gulf Coasts of North America. This mollusc has always been a desirable and nutritious seafood from early times, when it was consumed by Indians, and later by colonists (at first somewhat reluctantly by many), until the present. Middens and refuse pits and shell piles of all ages and stages of human habitation attest to this statement.

The oyster is a suspension feeder which extracts and retains particulate matter suspended in the water drawn into its shell from the outside upon its gills. To bring in food and other essential materials water is pumped through these gills by the action of small cilia. The quantity of water pumped is large for mature oysters and may amount to as much as 15 liters (3.9 gallons) per hour. In a 24-hour period the volume pumped and strained by a bed bearing thousands of oysters would be tremendous. Material retained by the gills is transported by ciliary action to the mouth and then to the oyster's stomach where absorption of nutrients takes place. Waste products which have passed through the gut are voided as feces. Materials which have

Figure 1

Stages in the harvesting, processing and distribution of seed and market oysters in Virginia.


PUBLIC SEED OYSTERS
PRIVATE SEED OYSTERS
HAND TONGS
DREDGES
HAND PICKING
SEED OYSTERS
OYSTER SHELL
PUBLIC GROUND
PRIVATE LEASES
HAND TONGS
PATENT TONGS
DREDGES
MARKET OYSTERS
SHUCKING HOUSE
STEAMING HOUSE
OTHER PROCESSORS
1. STEW OYSTERS
2. BREADED OYSTERS
3. SOUP OYSTERS
WHOLE-SALE OUTLET
RETAIL OUTLET
CONSUMER

been brought into the shell cavity but not into the gutwhich have been selected out or rejected and segregated from the flow that passes into the "mouth," are then agglomerated by mucus on the gills and discharged as pseudofeces in the form of loosely compacted flocs or strings. Rejected in this fashion are large amounts of silt and other presumably undesirable particles. This adaptation enables the oyster to survive in many coastal and estuarine waters whose turbidity and silt burdens are extremely high. Turbid waters are characteristic of the shallow bays and estuaries in which oysters do best.

Though sex may reverse in individuals, the sexes at any one time in oysters are separate. Hence, individuals of both sexes must be available so that a suitable mixture of sperm and eggs results at spawning time. Spawning may occur during an extensive period from late June to October. However, most spawning in Virginia waters takes place during July, August and September. The eggs are released into the water from the female and then fertilized by sperm released by males. Fertilization and the early stages of blastulation and gastrulation occur in the waters nearby. In less than a day oyster larvae are able to use their cilia to propel themselves about in the water column. The larvae swim freely for about 8 to 22 days before attaching (setting) on some hard object such as an oyster shell. Embryonic shells begin to develop even before the larvae attach.

After setting or attaching oysters are called spat. Growth thereafter is rapid: a length of 1 to 1-1/2 inches may be reached by the end of the first summer. At this early stage the small oysters are known as "seed." As they reach 1-1/2 to 2-1/2 inches they may be harvested and purchased by companies for use in making soup. Oysters for the soup and chowder trade, or "soups" as they are called, have occupied an increasing percent of the market in recent years. So-called "traditional market oysters," from 3 inches on up, are sold to the shucking or raw-bar market.

According to available data each estuary has a characteristic pattern of setting both in timing and quantity of set. Furthermore, geographical patterns of setting are unique. On the Seaside of the Eastern Shore, the set of oysters has always been high, with 10 to 30 spat attaching to a shell 3 to 4 inches long during a season. Furthermore, there does not seem to have been a long-term or consistent decline in intensity of set in recent years on Seaside. In fact, often too many spat have attached themselves rather than too few. Overly heavy sets often result in large numbers of oysters (from 3 to 10, perhaps more) being attached to each other in a single cluster or clump at maturity. This makes them difficult to separate and "shuck" (or open) and oysters are not "well-shaped."

On the Bayside of the Eastern Shore, the set of oysters generally is much lower than on Seaside and, in many regions, such as Pocomoke Sound, too few small oysters attach to maintain the productivity of natural oyster rocks. This low set on Bayside does not seem to be a recent development, for the limited records available suggest little change in setting intensity in this area over the past 20 years.

On the Western Shore of the main portion of the Bay proper and in the York, James, Rappahannock, Great Wicomico, Piankatank, Corrotoman and other primary and secondary tributaries, the set of oysters varies over wide limits.

Historically, the James River has been the best setting area in the State. However, in recent years there has been a serious decline in its productivity of seed and soup-sized oysters. The Piankatank and the Great Wicomico are also systems in which setting is often good.

Where Oysters Grow--Public and Private Grounds

The business of packing Bay oysters for shipment into the interior, which ushered in an era of increasing demand, seems to have developed earliest in Baltimore around 1834 (Brooks, op. cit.). If this time is correct, demand developed rapidly. As early as the mid-1800's the vast natural oyster beds of Virginia were being heavily exploited. Yields were as high as 6 to 7 million bushels annually. Oysters were being shipped in boats to New England for use as seed and "bedding" (overboard storage in the water for later recovery and consumption). Great quantities were also consumed locally or packed for shipment to California and England (Ingersoll, 1881). Large numbers went inland.

Records indicate the Indians, the colonists and succeeding generations of Tidewater inhabitants used oysters and oyster shells in tremendous amounts for food and construction or buildings and roads. The middens of Indians and trash dumps of the Revolution and Civil War military activities contain millions of bushels of shells and many of the older roads and driveways of the Chesapeake Bay country were paved with oyster shells. In addition, until very recently, oysters were harvested just for lime-burning or road construction. The meats were wasted.

Depletion of many of the natural rocks in the late 1880's led to the establishment of regulations by public fisheries' agencies and in 1894 large acreages of the best natural oyster bottom in the Commonwealth were set aside by legislative action for public use. These areas became known as the Baylor Survey Grounds.

Most areas of bottom, below mean low water, outside the Baylor Survey Grounds, are also under State jurisdiction. Some of the non-Baylor grounds are leased to private oyster growers, some are designated as public clam grounds; others are unassigned. At present all publicly-owned "bottoms" in Chesapeake Bay below mean low water are administered by the Virginia Marine Resources Commission.

Baylor Survey Grounds

When completed in 1896, the survey of Lt. Baylor, USN, who worked for the Coast and Geodetic Survey in Virginia, included most of the natural oyster producing regions in Virginia. That is, they incorporated areas where oysters set and grew without assistance. They also encompassed barren areas where oysters did not grow naturally.

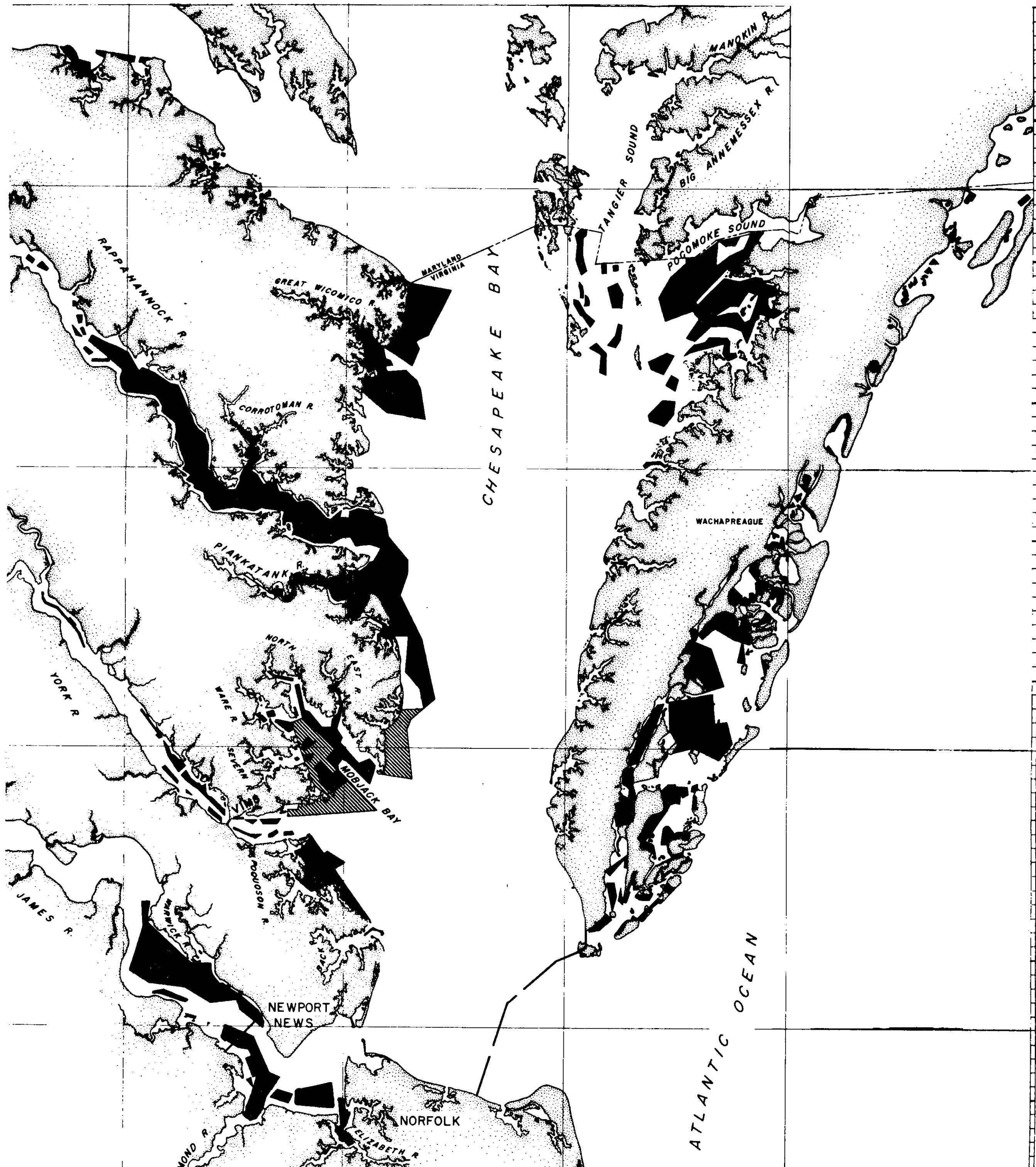
Bottoms inside the Survey boundaries cannot be leased but are held in public trust for public use. When set aside they are known or presumed to be the best naturally productive oyster rocks or beds in the State. Bottoms outside Baylor Survey Grounds may be leased, and many are, for oyster culture from the Virginia Marine Resources Commission (VMRC, earlier the Virginia Commission of Fisheries and, before that, the Virginia Board of Fisheries) by individuals or companies. In most instances these leased plots are not "natural oyster bottoms" since they are not "self perpetuating." Rather, they are areas where oysters normally do not occur in numbers without intervention of man. Often these leased bottoms have been built by firming (usually by shells) the bottom at considerable cost and effort.

The Baylor Survey Grounds, or public oyster rocks, are scattered throughout Tidewater, Virginia in the principal tributaries (Figure 2). The naturally productive rocks within the Baylor Survey Grounds often have a firm sand-clay or shell bottom on which oysters occur. However, they also include areas of mud bottom or deep water unsuitable for oyster culture as currently practiced. In some cases, deeper waters cannot be used regardless of methods because of other factors. The size of a "rock" may range from a few square feet to a thousand acres or more. They occur from the intertidal zone to depths of around 25 feet. Most, if not all, surviving bars and some only recently depleted, are designated by names known to all watermen which have been passed down for many generations (Figures 3, 4 and 5).

The size at which oysters may be harvested from public rocks in Virginia is specified by law. The purpose of these size restrictions is to prevent unnecessary destruction of undersized individuals and to allow them to grow to market size as conceived in the days before processed soups and chowders became popular and began to demand small

Figure 2

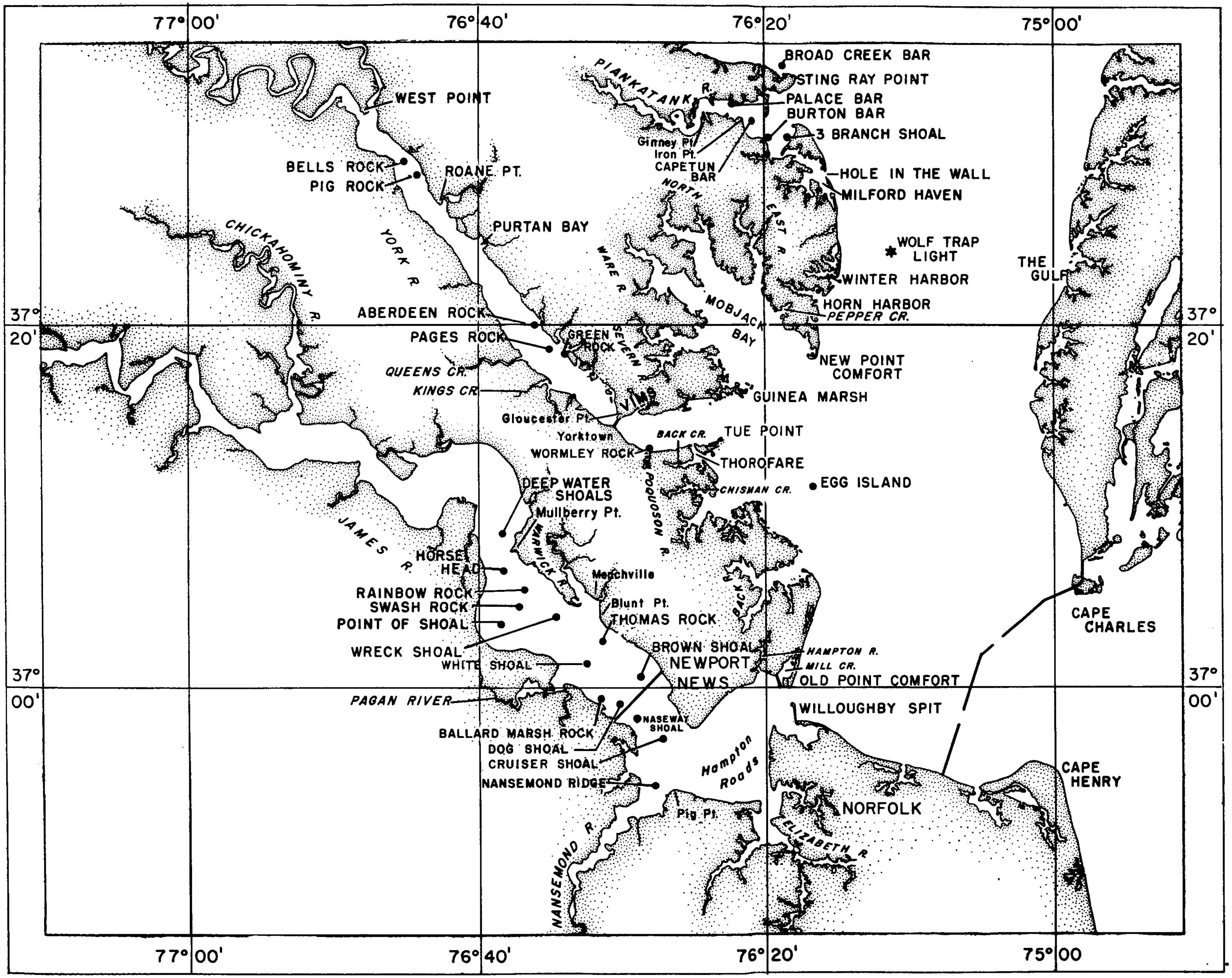
Map of Tidewater Virginia showing public oyster ground and public clam ground. From maps on file at the VMRC. The Baylor Bottoms are in black; public clam bottoms are shaded.



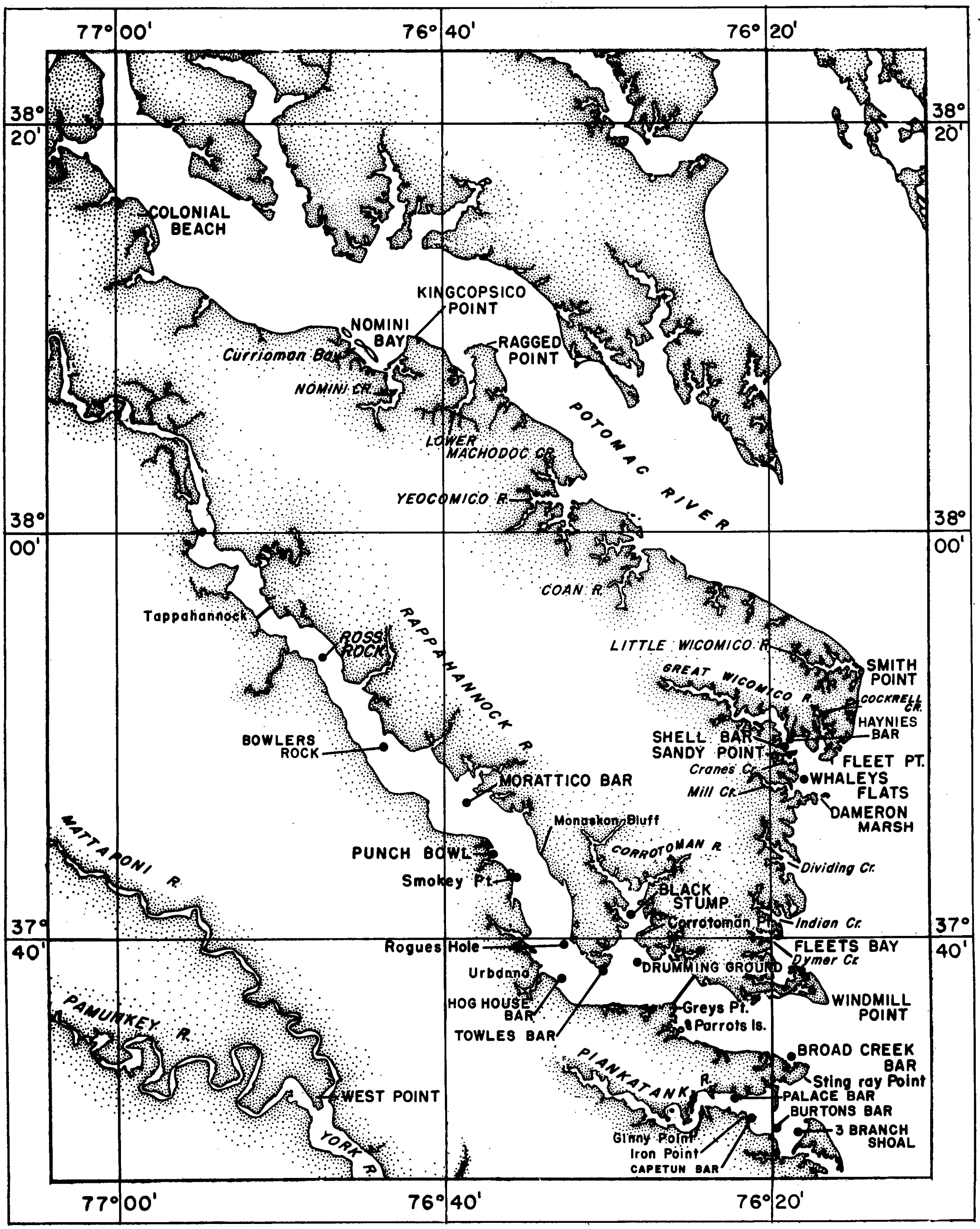
MANOKIN R.
TANGIER SOUND
BIG ANNEMESSEX R.
POCOMOKE SOUND
MARYLAND
VIRGINIA
GREAT WICOMICO R.
RAPPAHANNOCK R.
CORROTOMAN R.
CHESAPEAKE BAY
WACHAPREAGUE
PIANKATANK R.
NORTH
EAST R.
WARE R.
YORK R.
SEVERN
MOBJACK BAY
POQUOSON R.
JAMES R.
WARWICK R.
NEWPORT NEWS
NORFOLK
NANSEMOND R.
ELIZABETH R.
ATLANTIC OCEAN
10'
38° 00'
50'
40'
30'
20'
10'
37° 00'
50'
50'
40'
30'
20'
10'
76°00'
50'
40'

Figures 3, 4 & 5.

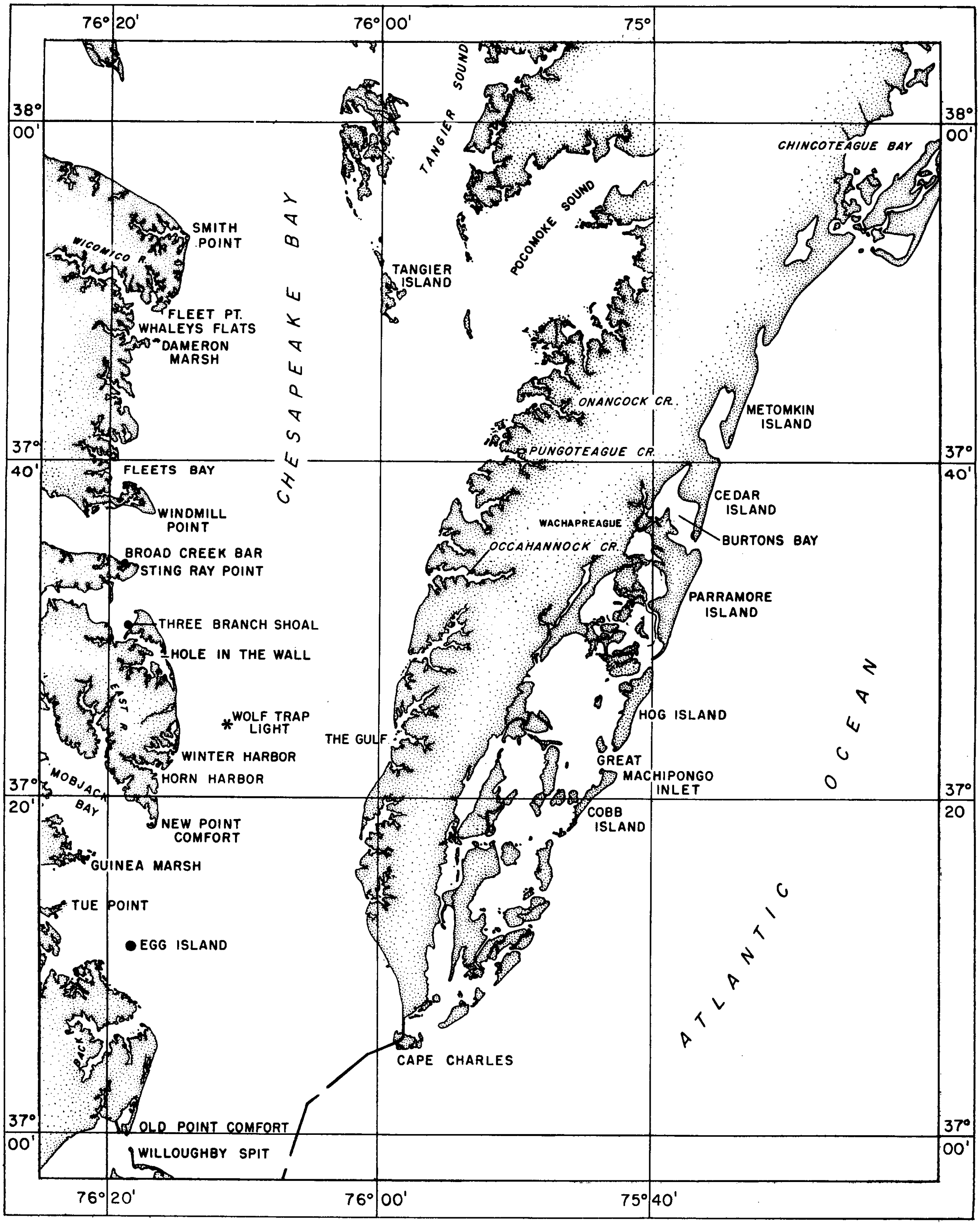
Maps of Tidewater Virginia showing names of oyster rocks, geographical points, towns and bodies of water mentioned in this report.



77° 00'
76° 40'
76° 20'
75° 00'
37° 20'
37° 00'
BROAD CREEK BAR
STING RAY POINT
PALACE BAR
BURTON BAR
3 BRANCH SHOAL
HOLE IN THE WALL
MILFORD HAVEN
WOLF TRAP LIGHT
WINTER HARBOR
HORN HARBOR
PEPPER CR.
NEW POINT COMFORT
GUINEA MARSH
TUE POINT
THOROFARE
EGG ISLAND
CHISMAN CR.
BACK CR.
PIANKATANK R.
Iron Pt.
CAPETUN BAR
NORTH R.
EAST R.
WARE R.
MOBJACK BAY
SEVERN R.
WEST POINT
BELLS ROCK
PIG ROCK
ROANE PT.
PURTAN BAY
YORK R.
CHICKAHOMINY R.
ABERDEEN ROCK
PAGES ROCK
GREEN ROCK
QUEENS CR.
KINGS CR.
Gloucester Pt.
Yorktown
WORMLEY ROCK
POQUOSON R.
DEEP WATER SHOALS
Mullberry Pt.
JAMES R.
WARWICK R.
HORSE HEAD
RAINBOW ROCK
SWASH ROCK
POINT OF SHOAL
WRECK SHOAL
WHITE SHOAL
Blunt Pt.
THOMAS ROCK
BROWN SHOAL
NEWPORT NEWS
BACK R.
HAMPTON R.
MILL CR.
OLD POINT COMFORT
WILLOUGHBY SPIT
PAGAN RIVER
BALLARD MARSH ROCK
DOG SHOAL
CRUISER SHOAL
NANSEMOND RIDGE
NASEWAY SHOAL
Hampton Roads
Pig Pt.
NORFOLK
ELIZABETH R.
NANSEMOND R.
THE GULF
CAPE CHARLES
CAPE HENRY



77° 00'
76° 40'
76° 20'
38° 20'
38° 00'
37° 40'
COLONIAL BEACH
KINGCOPSICO POINT
NOMINI BAY
Currioman Bay
NOMINI CR.
RAGGED POINT
POTOMAC RIVER
LOWER MACHODOC CR.
YEOCOMICO R.
COAN R.
Tappahannock
ROSS ROCK
RAPPAHANNOCK R.
LITTLE WICOMICO R.
GREAT WICOMICO R.
SMITH POINT
COCKRELL CR.
HAYNIES BAR
SHELL BAR
SANDY POINT
FLEET PT.
Cranes Cr.
WHALEYS FLATS
Mill Cr.
DAMERON MARSH
BOWLERS ROCK
MORATTICO BAR
Monaskon Bluff
MATTAPONI R.
CORROTOMAN R.
PUNCH BOWL
Dividing Cr.
Smokey Pt.
BLACK STUMP
Corrotoman Pt.
Indian Cr.
Rogues Hole
FLEETS BAY
Dymer Cr.
Urbanna
DRUMMING GROUND
HOG HOUSE BAR
WINDMILL POINT
PAMUNKEY R.
Greys Pt.
Parrots Is.
TOWLES BAR
PIANKATANK R.
BROAD CREEK BAR
Sting ray Point
WEST POINT
PALACE BAR
BURTONS BAR
Ginny Point
3 BRANCH SHOAL
Iron Point
YORK R.
CAPETUN BAR



76° 20'
76° 00'
75°
38° 00'
TANGIER SOUND
CHINCOTEAGUE BAY
SMITH POINT
WICOMICO R.
CHESAPEAKE BAY
POCOMOKE SOUND
TANGIER ISLAND
FLEET PT.
WHALEYS FLATS
DAMERON MARSH
ONANCOCK CR.
METOMKIN ISLAND
37° 40'
PUNGOTEAGUE CR.
FLEETS BAY
CEDAR ISLAND
WINDMILL POINT
WACHAPREAGUE
BURTONS BAY
OCCAHANNOCK CR.
BROAD CREEK BAR
STING RAY POINT
PARRAMORE ISLAND
THREE BRANCH SHOAL
HOLE IN THE WALL
EAST R.
OCEAN
WOLF TRAP LIGHT
HOG ISLAND
THE GULF
WINTER HARBOR
GREAT MACHIPONGO INLET
MOBJACK BAY
HORN HARBOR
37° 20'
COBB ISLAND
NEW POINT COMFORT
GUINEA MARSH
TUE POINT
EGG ISLAND
ATLANTIC
CAPE CHARLES
37° 00'
OLD POINT COMFORT
WILLOUGHBY SPIT
76° 20'
76° 00'
75° 40'

oysters for processing. Oysters may be harvested only when they reach 3 inches, except in certain low salinity regions where growth is slow and the legal size is 2½ inches, or in seed areas. Certain public bottoms, such as those in the James River and parts of the Great Wicomico and Piankatank rivers, are designated as seed areas and oysters from recently-set spat up to those of the largest size may be harvested.

Opening or Closing Public Rocks

There are laws regulating the catching of oysters in Virginia. However, with the exception of the Great Wicomico and Piankatank rivers, these laws are seldom used to maximum advantage.

The Commission, or the Commissioner with the approval of the Commission may, whenever it deems it advisable to do so to protect or promote the growth of oysters, close or open any area or restrict the manner or method of taking oysters in any area of the natural or public rocks, grounds or shoals for the purpose of rehabilitation, and may establish seed beds and plant shells and other cultch thereon or transfer seed thereto or take any other restorative measures which it or he may deem best. Subject areas may be closed for an entire season, or part of a season, or for so many days a week (Code of Virginia 28-1-85).

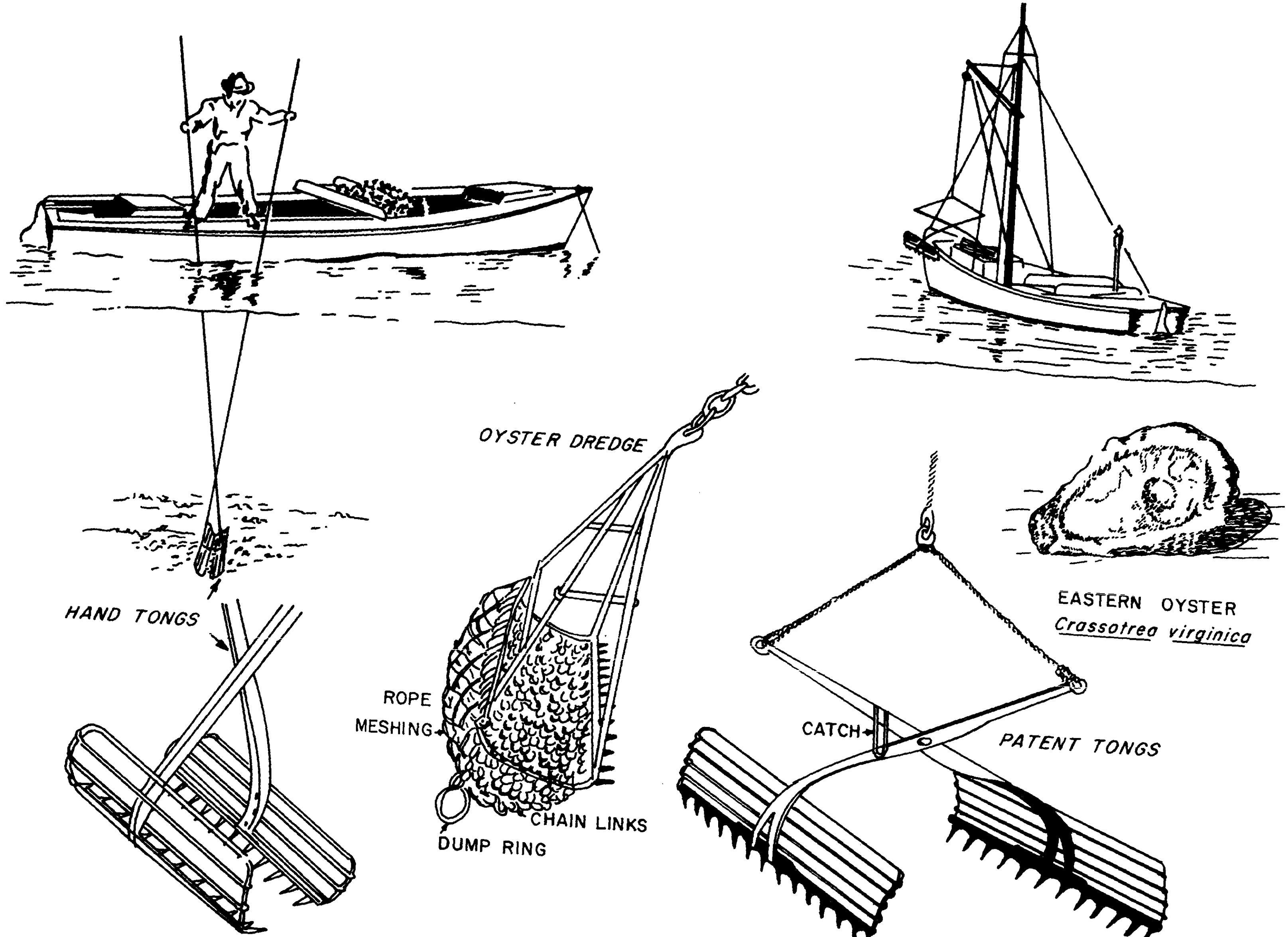
Oyster Harvesting Devices

Oysters are harvested from public rocks (Baylor Grounds) with oyster tongs which are two rake-like heads with sharp teeth attached to two long wooden shafts (Figure 6). They are placed in scissor-like opposition to each other to provide a "basket" when closed. Length of tong shafts are sometimes as long as 32 feet but most range from 18 to 22 feet. Hand tongs are the only gear which may be legally used to harvest oysters from most of Virginia's public rocks. These rules were established to prevent overharvesting and depletion of the oyster populations on the natural rocks. An exception is the limited legal use of mechanized, larger and heavier patent tongs in deeper waters of the lower Rappahannock and in Bay waters outside certain rivers (Figure 4). Also dredges may be used during certain seasons in two or three areas in Tangier Sound.

Oyster tongers operate from shallow draft boats 20 to 45 feet long, usually possessing a cabin forward and a large open cockpit aft where the oysters harvested by the tonger are heaped. The boats have a wide washboard on which hand tongers may stand while harvesting. Free-board is generally 2 to 4 feet. The crew generally consists of two or three men. One man "culls" the catch, while one or two men "tong." If market oysters are being caught, culling

Figure 6

Pictures of various oyster harvesting devices used in Virginia.



OYSTER GEAR
CHESAPEAKE BAY

and sea-keeping qualities than those of fulltime watermen have become fairly common. The catches of the casual or avocational groups are unrecorded and unknown to anyone save themselves.

Season of Harvest

The season when oysters may be taken from public rocks is regulated. In the James River oysters may be taken from sunrise to sunset from 1 October to 1 June, and on the Seaside of the Eastern Shore from 1 November to 1 April. In all other regions of Virginia oysters may be harvested from 1 October to 1 June.

Private Grounds

Private leases used to produce oysters as a business venture are scattered throughout Virginia, generally occupying marginal (in terms of natural production or unaided potential) areas between the Baylor Survey Grounds and shore, or bottoms in deeper, high salinity waters which are or were not considered to be "natural" oyster bottoms when the original Baylor Survey was made. These areas, in most instances, do not receive significant natural sets but must be planted with seed, if they are to produce oysters. Frequently the bottoms are unsatisfactory (too soft) for oyster culture without stabilization. Should this be the case, "shelling" consists of returning to the water, as prescribed by law, all oysters less than legal size. Empty shell must also be returned. When a waterman is working in a seed area the minimum size limit does not apply. However, all shell which does not bear visible small oysters must be culled from the catch and returned to the water. This rule is intended to slow or eliminate the destruction of the rocks caused extensively in the past by removal of the shell substrate so important to continued productivity.

In general, catch of market oysters per boat will range from 10 to 30 bushels daily. Seed catch is usually higher and daily catches may range from about 20 to as high as 50 to 100 bushels per boat. Where possible, market oysters are sold (by the bushel) the same day they are harvested to the owner of the shucking house or to a packer who specializes in the sale of unshucked or "raw-bar" oysters.

Seed oysters for planting on leased bottoms are handled in a different way. At the end of a work period, usually a day, the tonger generally sells his catch to the operator of a "buy-boat." Buy-boats may be 60 to 80 feet long and may be capable of carrying a deck load of several thousand bushels of seed which the operator purchases from a number of tong boats. In all cases, the quantity sold to the buy-boat is measured by the bushel (the Virginia oyster bushel), and there is occasionally controversy between the buyer and seller as to whether the bushel measure is properly filled.

In recent years the practice of selling seed or market oysters to truckers instead of buy-boats has become quite common. In this process the tonger transports his oysters to a dock where they are off-loaded onto a conveyor belt which empties into a truck. There is little effort to remember or denote the precise locations at which the seed was originally harvested; hence, records of production from specific oyster rocks are virtually non-existent. Thus, efforts at evaluating the effects of specific repletion efforts are nearly impossible.

For various reasons transactions between the tonger and buyer have usually been in cash. Up to October 1975 this aspect made it difficult to obtain valid statistics on price, volume or source of seed. However, a recent regulation by the VMRC has changed this aspect and price and other economic aspects determined.[2]

Recently part-time and sport or avocation tongers who frequently use outboard-powered boats of lesser substance

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[2]Since October 1975 the tonger must sign a VMRC Buyer's Slip if cash is paid.

with up to 10,000 bushels of oyster shells per acre is required. This provides a substrate on which larvae may set or a firm foundation for a later planting of seed oysters. In the past and until 1963 and 1964, private grounds produced 3 or 4 times as many oysters per acre as did the public grounds. Today (1975-1976) production from the two areas is about equal.

The primary basis for the private oyster industry in Virginia are the productive public seed rocks in the James River. Other lesser public seed sources, however, exist on public "rocks" in the Great Wicomico and Piankatank rivers. Without these important seed sources the private oyster growing industry of Virginia, as it is today, would cease to exist.

Additional, but minor sources of planting stock to private growers are those quantities of seed produced on certain private leases located in the James, Great Wicomico and Piankatank rivers and on the Seaside of the Eastern Shore.

Seed obtained from the James and other areas is usually transported to planting areas by buy-boats. However, in certain instances trucks transport the small oysters overland and then reload onto boats for planting. When the growing area is reached the seed is shoveled or washed over the side and distributed or "planted" at rates which may average from 500 to 1,000 bushels per acre. In most areas two or three years are required for the seed oysters to reach maturity. On the Seaside of Virginia seed is left on growing grounds 12 to 18 months depending on the location of the area. If left longer, usually the grower experiences unacceptable losses of oysters due to predators and diseases. (Distribution of predators and diseases, and hence survival and production of both seed and market-sized oysters is often related to salinity.)

While higher yields have been assumed by earlier writers, and in some instances actually been experienced, our studies show that the statewide average yield is a single bushel of market oysters realized from each bushel of seed planted.

To the extent funds are available, oyster shells are planted by the Marine Resources Commission in areas where unavoidable pressure exists or where a natural strike is expected. Private growers also plant shells to firm bottoms or provide cultch for spatfall, or both. Such shell plantings may be at densities ranging from 5,000 to 10,000 bushels per acre. Small oysters attaching to these shells are often harvested and sold as seed. Sometimes they are allowed to remain and grow to market size in the area.

Oysters from private leases may be harvested by tongs but generally towed dredges designed to catch oysters are used (Figure 6). Dredge boats may be 40 to 60 feet long although smaller ones are sometimes used. In Virginia all are powered by internal combustion engines. Interestingly, in Maryland sailing vessels are still used as a conservation measure though restrictions of dredges to sail-power alone are weakening.

Oysters are transported to the shucking house or to the place of sale by these boats.

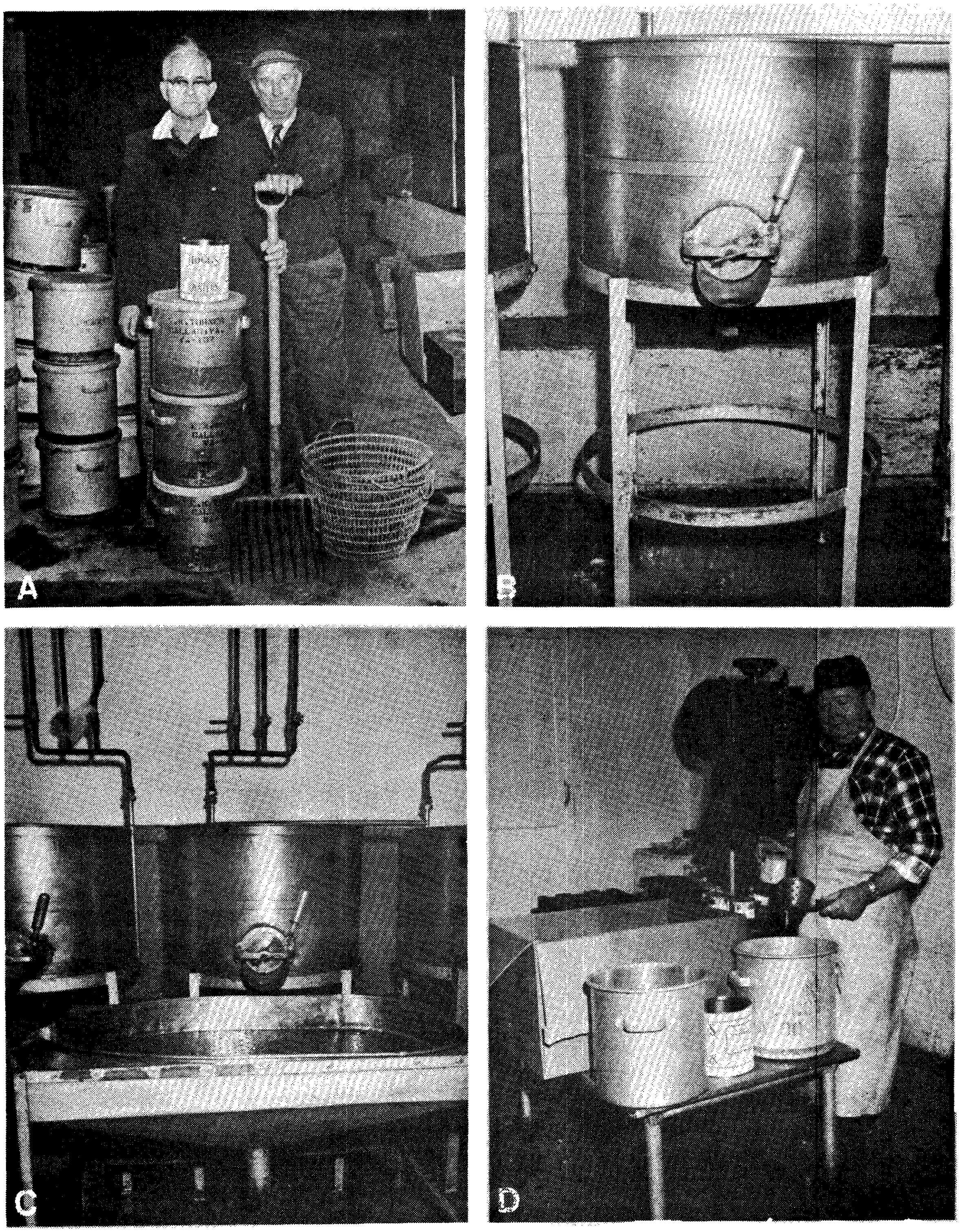
Shucking Houses

Oysters from public rocks as well as private leases are processed or opened in shucking houses which are scattered along most rivers. Formerly many more such houses existed but a number have been closed as the industry has declined. The current number is estimated at 227.

Oysters are transported from the dredge boat to a small storage room adjacent to the shucking house by a wheelbarrow or by a mechanical conveyor. There on waist-high benches rests a small elevated block on which the oysters are placed while being opened. The method of shucking or opening oysters has changed little in the past 100 years (Figure 7). Shuckers may use a small hammer to break off

Figure 7

Methods of shucking and processing oysters.


A
B
C
D

the thin bill of the oyster so a knife may easily be slipped between the shells. Some merely insert the oyster knife between the shells without breaking the shell. The shucker deftly cuts one end of the adductor muscle loose from the shell with the knife and the shells are forced apart with a quick twist of the wrist and blade. The other end of the adductor muscle is separated from its anchorage on the other valve and the meat is dropped into a gallon container half-full of fresh water.

When this container is filled with meats it is emptied onto a stainless steel table perforated with round holes, sized so that water and bits of shell fall through while retaining the meats. Tax payment for shucked oysters is based on the volume of drained meats.[3]

Meats are next placed in a large stainless steel tank holding several hundred gallons of fresh water. These tanks have air jets at the bottom (to "blow" or agitate the meats) and the meats may be held in this apparatus for no longer than 30 minutes (Figure 7). "Blowing" time (the time air jets are on) has two effects. First, the meats are cleared of mucus, sand, mud and small bits of residual shell. Secondly, the meats take up fresh water and volume may be increased from 10 to 20 percent.

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[3]See Appendix 1 for tax on shucked oysters and other taxes.

After blowing, oysters are cooled to 40-45°F and then packed into containers ranging in capacity from less than a pint to five gallons which are then packed in ice. In this form they may be shipped by truck to markets all over the United States. Some are frozen for later consumption. In some instances the shucked oysters are processed as breaded oysters. Other oysters, "soups," are steamed open without shucking. This latter practice usually precedes further processing into stews or soups.

Shucked and cleaned oysters are sold commercially in graded sizes. Ranges in numbers per gallon are: Standards--300 and up; Selects--210-300; Extra Selects--160-210; Counts--160 or less.

Regionally there are major differences in quality. The reason for this is not known exactly, but it is known to be largely due to the plankton and other sources of food and nutrients in the water. Other aspects of water quality may also be involved.

Of course, not all oysters are shucked or processed. Some are shipped in the shell for opening and processing elsewhere as for the raw-bar trade. The "packing" required to get such oysters to market or to the consumer is relatively simple.

Price

The factors governing price paid by the processor or shell-stock shipper to the grower or harvester for whole oysters are discussed in Chapter V. In actual practice the price paid is usually on the basis of how many pints of meats the oysters will "shuck" per bushel. This is usually determined by taking a small sample prior to shucking them or by paying for the yield on the entire lot after the oysters are sold.

Types of Business (Wholesale Level)

In the United States dealers shipping oysters interstate must be certified by the U. S. Food and Drug Administration. Consequently, there is a listing of certified companies published monthly. Basically there are four types of businesses:

> RS-Reshipper--Shippers who trans-ship shucked stock in original containers, or shell-stock from certified shellfish shippers to other dealers or to final consumers. (Reshippers are not authorized to shuck or repack shellfish.)
>
> RP-Repacker--Shippers, other than the original shucker, who pack shucked shellfish into containers for delivery to the consumer. A repacker may shuck shellfish or act as a shell-stock shipper if he has the necessary facilities and permits.
>
> SS-Shell Stock Shipper--Shippers who grow, harvest, buy or sell shell-stock. They are not authorized to shuck shellfish or to repack shucked shellfish.

SP-Shucker-Packer--Shippers who shuck and pack shellfish. A shucker-packer may act as a shell-stock dealer.

As of 1975 the following numbers of businesses in each category in Virginia were:

Reshipper	0
Repacker	46
Shell-Stock Shipper	54
Shucker-Packer	83

The manner in which the businesses listed above may interact to influence price is almost completely unknown. There is, from all available information, much activity in which several shuckers ship oysters to a packer, who in turn may sell to a repacker. Complete understanding of the oyster industry of Virginia would require careful and comprehensive study of this phase of the industry.

Yields

Factors governing oyster quality or yields are only partly understood. As will be discussed in Chapter VIII, yields of meats may vary seasonally and regionally. A statewide average might be 6.0 to 6.5 pints per bushel. The range, however, is from 4.0 to about 8.0 pints. A yield of 7.5 or over is regarded as exceptional.

Predators

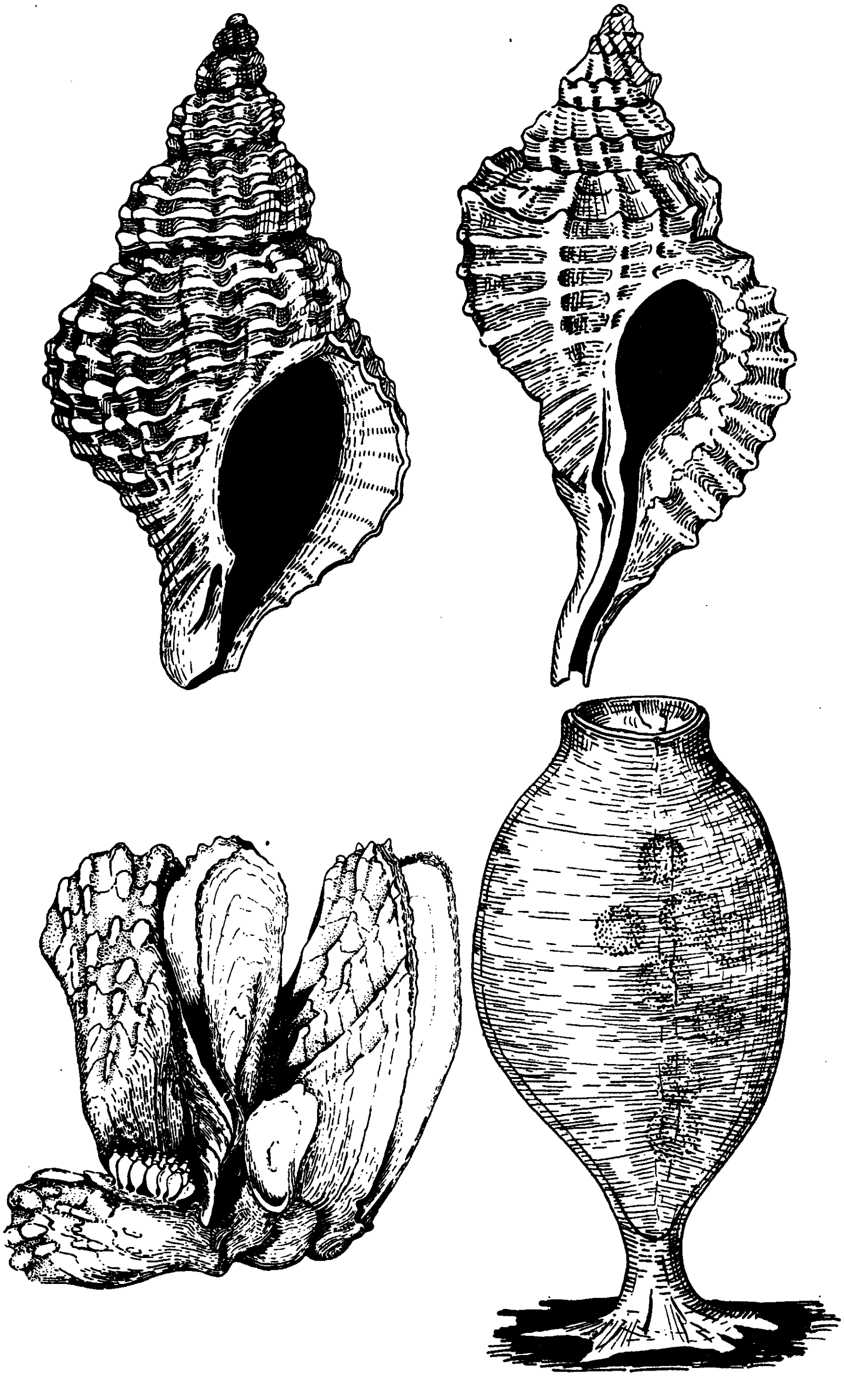
Among the principal predators of small oysters and oyster spat are oyster drills. These marine gastropods kill small, developing oysters as well as adults by drilling a small hole through the shell and ingesting the meats. When salinities average less than about 15%, drills do not live; about and above this value, they do and are serious and destructive pests. Within Chesapeake Bay the two screwborers or oyster drills, Urosalpinx cinerea and Eupleura caudata, are problems with the former being the more prevalent and serious (Figure 8).

On the Seaside of the Eastern Shore the drills are somewhat different from those within the Bay. Here there are two subspecies, Urosalpinx cinerea follyensis and Eupleura caudata etteri. These subspecies are larger than the animals found within the Bay and they occur in nearly all oyster-growing regions because there are few or no low salinity areas. With appetites matching their size, their destructiveness is very great. Where oysters are planted in areas of heavy drill abundance, few survive to market size.

Appetites of drills of all sizes for small oysters whose thinner shells are easily penetrated, are enormous. Other predators of small oysters are the oyster leach, Stylochus ellipticus, mud crabs, Panopeus, and blue crabs, Callinectes sapidus. Oysters are also eaten by fish such as drum and cow-nosed rays. In recent years (1972-77),

Figure 8

Pictures of both species of oyster drills (screw-borers) found in Virginia.



Showing the two kinds of oyster drills that occur in Tidewater—*Urosalpinx* (upper left) and *Eupleura* (upper right); the drill egg cases of *Urosalpinx* (lower left) attached to shells and an individual egg case (lower right) with 8 embryos. (By J. G. Mackin) cownosed rays have been especially destructive on leased bottoms in the Rappahannock River.

Pathogens

There are three known oyster pathogens in Virginia which cause varying degrees of mortality in oyster populations.

One which has evidently always been a problem in Chesapeake Bay is *Dermocystidium marinum* or "Dermo." This fungus disease has been in the Bay probably since oyster culture started, or before, and losses from it have always been an anticipated aspect with which oyster producers had to deal. Deaths occur during mid- to late summer, and the death rate in two- and three-year old oysters may average as much as 25% annually, although a lesser rate is usually experienced. The disease is active only when mean salinities exceed 12-15 parts per thousand (‰). With proper management losses to oyster growers may be minimized. Timing of planting and of harvesting is important. If practical, oysters should be harvested before the heavy losses of mid-summer occur. They should be planted early enough to allow maximum growth before harvest. Removal of all old oysters prior to planting new crops may reduce losses. A planting density (less than 1,000 per acre) is also recommended. For reasons as yet unknown, *Dermocystidium* causes only limited mortality on Seaside of the Eastern Shore even though it is the highest-salinity area where oysters are grown in Virginia.

The major oyster disease of the Virginia Seaside is caused by the "Seaside Organism" or SSO. The scientific name of the organism believed responsible is Minchinia costalis. It occurs in populations from Cape Henry, Virginia to Cape Henlopen, Delaware. However, since the original discovery of this disease in 1966, there has been little effort to study its range and distribution. This pathogen kills both native and imported oysters, mostly in the month of June. The death rate tends to be high, but the duration of mortalities is short and well-defined by season. SSO may kill up to 36 to 44 percent of a crop during the second year, but losses usually range from 12 to 14 percent annually. Oysters held beyond the usual 12 to 18 months from seed planting usually experience heavy mortalities; therefore, planters should make every effort not to carry oysters over to another year. On the Bayside of the Eastern Shore SSO is only a minor factor as a cause of mortality.

A disease of major importance in Virginia has been caused by the pathogen, Minchinia nelsoni (or MSX), which entered or became apparent in Chesapeake Bay about 1959. The effect of this organism was catastrophic, since it killed most of the oysters in the high-salinity regions of the Bay.

Since 1958-59 MSX, more than any other single factor, has been responsible for the decline in yields from those public and private beds, formerly the mainstay of production in the Commonwealth. Because of the great impact of this Minchinia-caused disease on the industry, it will be briefly reviewed here.

As far as we know, MSX was first observed in Virginia in February 1959, in lower Chesapeake Bay and in two years its effect was noted throughout the Bay in nearly all areas where average salinity exceeded about 15‰.[4] It did not cause appreciable losses on the Seaside of the Eastern Shore.

The areas heavily influenced include nearly all of Chesapeake Bay from the mouth of the Rappahannock south, and the lower oyster-growing regions in the James, York and Rappahannock rivers. Even now, 17 years after the onslaught, annual losses in susceptible seed stocks in high-salinity areas may approach 50 to 70% (Andrews, 1968). The high mortalities associated with this disease made commercial oyster culture almost impossible in these regions in the 1960's. The

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[4]Oyster mortalities have occurred in times past in the Chesapeake. The causes are unknown but much consternation resulted when they occurred. It is, of course, possible that those epizootics were caused by the same organisms as are active today in the Bay.

loss of these growing areas to private planters caused a major drop in production for the State. Public rocks also suffered significant reductions.

The effects of MSX on oysters taper off in regions where mean salinity begins to fall below 15 ppt, and the disease is virtually absent where salinities average below about 12 ppt. In most river systems there is a transition zone of varying extent where the intensity of the disease decreases from high to low intensity. Many public oyster grounds are located within this transition zone where productivity has declined in recent years. Private growers still hold many leases in this zone adopting the policy of planting only areas above this transition zone where they feel they will not suffer significant losses.

One major effect associated with MSX is the decline in setting of small oysters on the important James River seed beds. This complex question will be discussed in Chapters IV and IX.

According to certain evidence oysters setting in certain high-salinity regions, where heavier mortalities occurred earlier, may show only minor losses from MSX in recent years, i.e., since 1972. However, data are required to allow determination of whether this is a permanent change or only temporary.

Availability of Oysters to the Fishery

A fact requiring emphasis at the start of this work, especially in reference to oysters from public bottoms, is this--the number of spat or oysters existing in an area at any given time is the sum total of a multitude of interrelated environmental and man-associated factors. Basically it is determined by the initial set, as modified by natural and fishing mortality. In the following chapters various aspects associated with these three points will be discussed. It is pertinent to state here that fair to good information exists concerning the basic set of oysters. Also available are quantitative data on natural mortalities associated with predators such as drills and diseases such as MSX, *Dermocystidium* and SSO.

Lacking, however, are data on fishing mortality (the quantities of oysters removed from natural populations by harvesting activities) associated with the annual harvest from the Baylor Grounds.

Fishing mortality may be evaluated in two basic ways:

1. On the basis of catch-per-unit-of-effort data in which the daily or yearly catch is related to information on effort, based on numbers of boats fishing, or man-hours.

2. By relating annual catch in bushels or numbers of oysters to the magnitude of that portion of the resource which remains on the bottom.

It is emphasized that production of oysters from leased bottoms occurs, in most instances, only when the area is planted by a grower. It is the growers' expectation of an adequate economic return which determines whether or not leased bottom will be planted. In the past, and to a lesser extent today, most of the oysters produced in Virginia came from leased bottoms. It has been the decline in landings from leased bottoms which has been responsible for the major part of the decline in total landings from the State since 1960. Even if our public beds are restored by a major repletion effort to their former productivity, Virginia's waters will not attain their full level of total productivity, potential or even past production levels unless production from leased areas increases. If market oyster production is to be restored, seed production must also be restored and markets must be found or developed.

CHAPTER II

EXTENT AND CHARACTERISTICS OF OYSTER GROWING GROUNDS---PUBLIC AND PRIVATE

CHAPTER II. EXTENT AND CHARACTERISTICS OF OYSTER-GROWING GROUNDS--PUBLIC AND PRIVATE

Baylor Survey Grounds

Virginia today has many areas where oysters grow naturally, but they were much more extensive in the past than they are now. Until 1894 these areas or rocks were harvested by anyone wanting to. There were few private planters then because the supply of market oysters from natural rocks met the demand and there was no protection from poaching available to planters nor were there provisions for legalized leasing. During that period private growers simply staked out claims, which by convention were usually recognized. They also frequently employed armed guards to protect their oysters.

During this early period there were few if any studies of the natural rocks. The first survey of natural oyster rocks in the Maryland portion of the Bay was made by Lieutenant Winslow of the United States Navy working under the Superintendent of the U.S. Coast Survey in 1878-79, and a detailed study of the same area was later carried out by W.K. Brooks in 1882 (Brooks, 1891, 1905). These surveys included part of Tangier Sound but no other areas in Virginia.

As early as 1880 private enterprise was allowed to grow oysters on "barren public bottoms." However, there was difficulty in determining, to everyone's satisfaction, what was barren bottom and what was "natural rocks." Therefore, the State General Assembly decided that an engineering survey of all natural rocks was needed to solve the problem and in 1892 it passed "an Act to Protect the Oyster Industry of the Commonwealth" which said, in part:

> All areas of Chesapeake Bay and its tributaries not embraced in the survey of the natural oyster beds, rocks and shoals authorized by the act shall be construed to be, in all courts of the Commonwealth, barren area and disposable by the Commonwealth for the purpose of the planting or propagating oysters thereon. . . .

It was stipulated that grounds outside the Baylor Survey area would be available for private leasing (Board of Fisheries, 1904). These were the beginnings of the dual management of the bottom grounds of Virginia and the system of public and private oyster culture.

The essential elements of the original act are outlined in Article XI of the recently revised Constitution of Virginia. This article states:

> The natural oyster beds, rocks, and shoals in the waters of this State shall not be leased, rented, or sold, but shall be held in trust for the benefit of the people of this State, subject to such regulations as the General Assembly may prescribe, but the General Assembly may from time to time define and determine such natural beds, rocks, or shoals by surveys, or otherwise.

The Constitution does not precisely define the terms "natural oyster beds, rocks, and shoals" but leaves this to the General Assembly.

The provisions in the 1892 Act were carried out by a survey of the natural rocks. For this purpose the Commonwealth obtained the assistance of Lt. James B. Baylor, also of the Navy assigned to the U.S. Coast and Geodetic Survey. Consequently, public grounds in Virginia are known today as Baylor Survey Grounds. This study did not provide an examination of the density of oysters on the bottom. Depth was the only parameter given in addition to coordinates. It was primarily a delineation of boundaries of oyster-bearing bottoms as distinct from bottoms which did not have oysters, and information was not given on number of shells, living or dead oysters, etc. The published data on the survey briefly states that a sounding pole and tongs were used to determine "the location and extent of the natural oyster beds, rocks, and shoals" (Baylor, 1894). Information published after the survey stated:

> No examination whatever was made on the beds, the Commissioners using their judgement and local knowledge in selecting the corners, and the engineers with their theodolite cutting in the points indicated from shore stations, ... (Moore, 1910)

When Lt. Baylor completed his survey he had delineated 210,477 acres of public rocks (Table 1). The original act, however, provided that areas of public grounds might be increased by legislative action or by petition of local residents. Since the original survey about 32,794 acres

Table 1

Acres of Public Oyster Rock in Various Counties as Originally Outlined by the Baylor Survey in 1894

Accomac County Bayside	36,318.6
Accomac County Seaside	14,242.2
Essex County	615.4
Gloucester County	4,391.0
Isle of Wight County	4,939.6
Lancaster County	15,280.3
Mathews County	19,538.5
Middlesex County	26,378.6
Nansemond County	4,459.0
Norfolk County	6,944.0
North Hampton County Bayside	305.3
North Hampton County Seaside	30,349.3
Northumberland County	21,864.6
Princess Ann County	986.0
Richmond County	2,725.2
Warwick County	18,425.0
Westmoreland County	461.9
York County	2,252.2
Total	210,476.7

have been added to the State's public grounds either by petition or by legislative action after 1894 (Table 2). Total acreage on record since 1958 has been 243,271 acres. Since the mid-50's Baylor Survey acreage has been used by landfills like Craney Island and by channels in areas like the Elizabeth River, the Eastern Shore, in the James, and perhaps elsewhere. The exact area so occupied has not been determined.

Public clamming grounds are not considered Baylor Grounds (Commission of Fisheries, 1931), so they are not included in the above figures. Total acreage of declared public clam ground is about 33,000 acres.

Virginia has jurisdiction over all bottoms below mean low water (Code of Virginia, Section 28.1-100). The areas outside the public clam grounds and Baylor Survey grounds may be leased to persons, companies or corporations for oyster culture. These areas may also be leased as bathing grounds or assigned by license to use by fishermen operating fixed-fishing gear such as fish and crab pounds, staked gill nets, and fykes; but the area so leased is not large. Leased acreage varies and at present totals about half that of public bottoms. While leased and public ground constitute a large area there remains a vast acreage of unassigned bottom held solely by the State. Use of these bottoms for any purpose must be approved by the VMRC.

Table 2

Additions[1] to Public Grounds Since 1928 in Virginia

Year	Acreage	Location	Pertinent Statutes[2]
Prior to 1900	10,000	Entire State	(3)
1928	302	Mobjack Bay	28.1-150
1930	2,406	Nomini & Currioman Bays James & York Rivers	28.1-159
1936	10,186	Rappahannock River (mid-river), Little Carter Rock, Russ's Rock	28.1-144 & 28.1-149
1954	1,130	Piankatank River and Milford Haven	28.1-151 28.1-154
1956	490	Piankatank River	28.1-156
1956	485	Pocomoke Sound	28.1-155
1958	600	Mobjack Bay	28.1-158
1958	6,170	Mouth of Poquoson River	28.1-157
1958	340	Piankatank River	28.1-152
1958	685	Chesapeake Bay	28.1-153
Total:	32,794		

Notes:

1. Estimated from maps on file at the VMRC.
2. Code of Virginia 1950 and 1970 supplement.
3. Acts of Va. Assembly of 1893-4, p.605; section 2138a, Pollard's Supplement; or pp.7-9, Rpt. of the Va. Board of Fisheries of 1903-4.

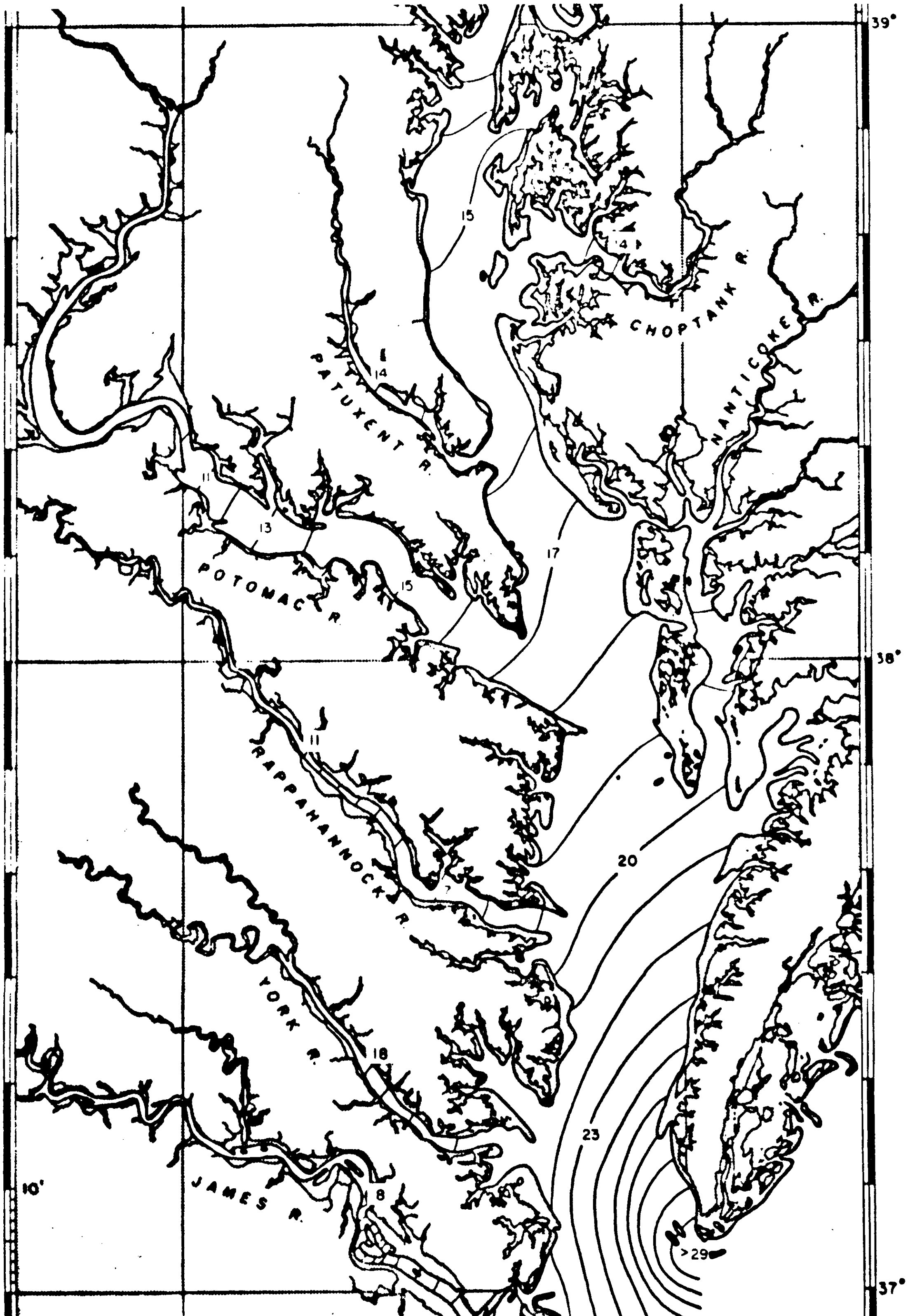
The Location of Natural Rocks in Relation to Salinity

There is a definite pattern in the location of the natural oyster rocks in respect to salinity gradients. To illustrate this relationship spring and fall salinities at 10 feet (3.0 meters) have been selected (Figures 9 and 10). The three meter level is used because average depth of many public grounds in Chesapeake Bay is there. This pattern of depth in relation to salinity is not present on the seaside of the Eastern Shore where there is little fresh water run-off, where waters are generally shallow, and where high-salinity ocean waters are close by.

Salinity changes with depth and distance upriver are seen in the Bay where the tributary tidal rivers receive considerable quantities of fresh water at their upper ends and growing waters are deeper. The upriver limit of most of the Baylor-delineated natural rocks is located where average spring salinities approach 5 $^{o}/oo$ (five parts per thousand), which is about the lower limit of the salinity tolerance of oysters (Galtsoff, 1964). The downriver limits of most of the naturally productive rocks in Chesapeake Bay coincides with the spring 15 $^{o}/oo$ isohaline. Here salinity per se does not limit distribution directly because oysters are able to live at much higher salinities. It is in this downriver

Figures 9 and 10

Average salinities at 10 foot (3 m) depth for autumn and spring in Chesapeake Bay and tributaries. From atlas of salinity and temperature distributions in Chesapeake Bay 1952-1961 and seasonal averages 1949-1961. Graphical summary report 2. E. D. Stoup and R. J. Lynn. Chesapeake Bay Institute. The Johns Hopkins University. February 1963.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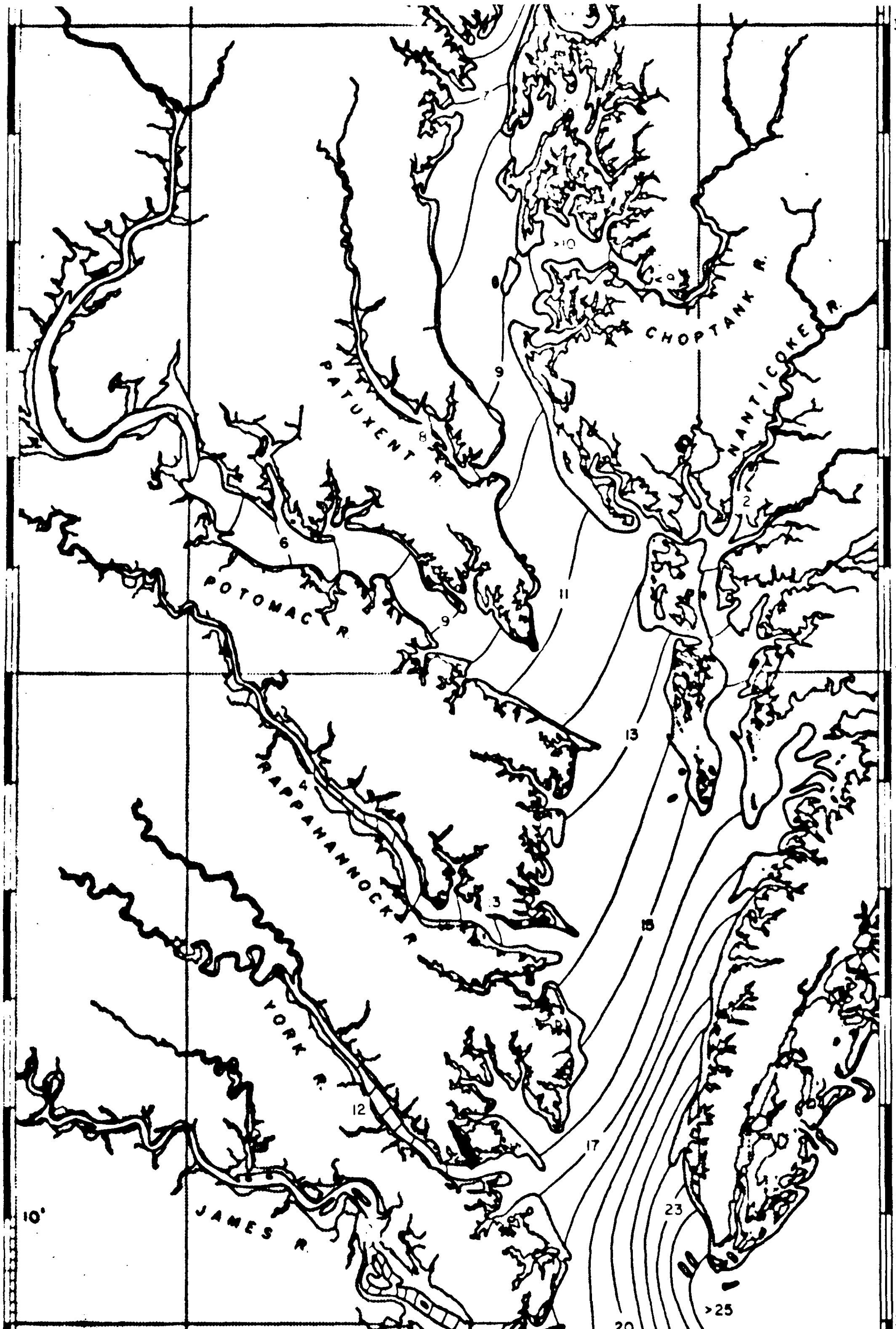

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region where predators, disease, and/or hydrographic conditions associated with higher salinity levels, operate to reduce survival of oysters to very low levels. The salinity distribution described in relation to the Baylor Grounds is shown in Figures 9 and 10. Few of the Baylor Grounds are located in the lower Chesapeake Bay where spring salinities exceed 15°/oo (Figure 2). This is no coincidence. Lt. Baylor delineated those grounds known to be productive. Due to high mortalities the Bay's high salinity grounds have been unproductive through recent history.

Natural rock areas within each tributary system may have major differences in numbers and density of oysters on the bottom. Populations vary from large to sparse in the same salinity range. Oyster populations decline at the upper and lower ends of the oyster distribution ranges of most tributaries. Annual variations in populations due to environmental changes are greatest at these two extremes. Populations tend to be more stable in the central portion of the geographical range. There are even differences in natural productivity between specific locations on a single oyster bar or a closely oriented group of bars. For some of these differences the reasons are apparent. For others they are not.

Locating Baylor Grounds--Surveys of Populations

Charts showing the location of each of the many small sections of Baylor Survey Grounds as redefined by F.E. Ruediger, county engineer of Accomac County in 1936, are on file at the offices of the Virginia Marine Resources Commission in Newport News, Virginia. The files contain plats of each section showing size and location in respect to latitude and longitude and to shore locations. Theoretically, these data enable the State surveyor to establish the exact location of any plot in the State.

While the aforementioned data are on file at the Commission offices, the actual bounds of the public rocks (Baylor Survey Grounds) in the estuaries are in most instances not marked by stakes or buoys; shore markers are few. Consequently, locations, while known generally to local watermen and inspectors, cannot be established by those in the river except in a general manner or by careful resurvey. The charts on file at the Commission are, with the exception of those for the James River and a few other places, old and do not show depths or bottom type, and outlines of many shore lines differ from those which exist today.

With the exception of the Moore Survey of 1909 in the James River, there has never been a comprehensive quantitative study of any of the public rocks in Virginia.[1] This is not to say that general surveys have not been made. Staff personnel of the Virginia Marine Resources Commission and the Virginia Institute of Marine Science sample many of the more important rocks at frequent intervals each year to determine mortality, spatfall, and number of seed and market oysters per bushel of bottom cultch. Lacking is a comprehensive quantitative study to show density of oysters and shells per unit area, the bottom type, depth and exact location on hydrographic charts for each of the large and small plots in the Baylor Survey. Because of the absence of this information, statements concerning relative productivity, degree of depletion, and density of oysters or shells per unit area of bottom type of Baylor Survey Grounds cannot be made with any degree of accuracy.

The Baylor Survey of 1894 encompassed most of the choice oyster-growing areas in Virginia. Generally, these grounds were located in the central part of each river where bottom type and depths were optimal for oyster culture. This left primarily the less desirable areas, i.e., those close to shore in very shallow water, in deep water, on muddy

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[1] In 1976 such a survey was started by VIMS. To date, the Rappahannock River has been studied. Other rivers will follow as funds become available.

bottoms, or exposed areas of shifting sand, available for private lease.

Additionally, the public grounds are generally large areas or infrequently small blocks. In contrast, the private grounds in many areas resemble pieces in a jig-saw puzzle and are frequently crowded between the Baylor Grounds and the shore.

The location of public oyster beds was plotted on a large scale chart of the Bay in preparing this report (Figure 2). The sources of these data were the many copies or plats of the Baylor Grounds obtained from the extensive files of the Virginia Marine Resources Commission. Outlines of the grounds, obtained from the plats, were transferred to the chart with the aid of a scaling compass. While the completed chart shows locations as closely as possible, bounds are not drawn to exact scale. In addition to plotting Baylor Grounds the chart includes locations of public clam grounds.

Today it would be almost as difficult to define the exact bounds of many of the Baylor Grounds in Virginia as it was in Ruediger's day. For some of the grounds it would be impossible because Baylor's and Ruediger's delineations of the beds were made on the basis of shore reference points like concrete bench markers, houses, water towers and barns.

Many of these reference points have disappeared. Most certainly it would be desirable to establish new, more accurate and more permanent boundaries.

The Moore Survey

On February 3, 1909, the U.S. Bureau of Fisheries received from Claude A. Swanson, Governor of Virginia, a communication enclosing the following resolution of the Commissioners of Fisheries to the United States:

> Resolved, That the Governor be requested to enlist the services of the United States Bureau of Fisheries in determining and defining the fertile and the barren areas in the James River, marking and platting same, provided it can be done without expenditure by the State.

As a result of this request Dr. H.F. Moore, assistant in the Bureau of Fisheries, was directed to do the study. The work began in August 1909 and was completed in 1910 (Moore, 1910). Until recently this was the first and only study ever made in Virginia which showed density of oysters per unit area of bottom in relation to precise points established by triangulation on hydrographic charts.[2] During the study 10,440 soundings were taken from which the condition of the bottom was determined and plotted. Density of oysters was established by a tonger taking samples at 590 places. Data on density of

[2]In 1972, 1973 and 1975 a limited acreage of Baylor Bottoms in the James River were surveyed by VIMS.

oysters was presented in tabular form as numbers and bushels of spat, culls, or counts per square yard or per acre.

As indicated analysis of Moore's data was based on the availability of oysters to a tonger. Based on this concept, and taking into consideration the number of oysters per bushel on the different beds, as determined by actual counts, tables were prepared showing the number of oysters per square yard necessary to yield to the tonger one bushel of oysters per day of tonging for each foot of depth. These data were used to evaluate rocks on the basis of catch of a tonger per nine hour day (less time for culling), (Table 3).

Moore found that about 73% of the total acreage included in the Baylor Survey in the James was barren or depleted. He suggested that these barren grounds might be leased to private growers to make them productive even though they were within the Baylor Grounds. Even in 1910 this solution was obvious as it had been earlier to Brooks (1891) and to Lt. Baylor (1894).

Other Surveys and Studies

Studies by the Commission showed extensive encroachment by private planters in the Rappahannock (Commission of Fisheries report 1919-1921):

Table 3

Classification of Oyster Grounds in the James River

by Moore

I. BARREN BOTTOM

A. No oysters or shell.

II. DEPLETED

A. Less than three bushels/day market oysters

B. Less than four bushels/day seed oysters

III. VERY SCATTERED

A. 3-5 bushels/day market oysters

B. 4-8 bushels/day seed oysters

IV. SCATTERED

A. 5-8 bushels/day market oysters

B. 8-12 bushels/day seed oysters

V. DENSE

A. Eight bushels or more/day market oysters

B. Twelve bushels or more/day seed oysters

> A petition made and presented with bond attached, as required by Section 15 of the Virginia oyster laws, was presented to the Commission for the resurvey of the Baylor line in certain waters of the Rappahannock River. Mr. F.E. Ruediger, the county engineer of Accomac County, was found to have had years of experience with former commissioners and he was employed to conduct the survey. After he had conducted said survey, it developed that the condition of the Rappahannock and other important oyster grounds was such as to make it necessary to have an engineer attached to the commission for the running of the lines between natural rocks and planting grounds in the waters of the State. The practice in many places of the planters has been to secure an assignment of planting ground bordering on public rock and to move their stakes out into the river, enclosing public rock, and holding it for their private ground which is contrary to law. These conditions caused the commission to employ Mr. Ruediger on an annual salary for the purpose of defining the Baylor line in the waters of the State, triangulating the rivers, setting up permanent marks on shore, so that these lines together with the notes of the Baylor Survey would enable anyone in the future to be certain of where the lines between planting ground and public rocks run . . . .

The lack of adequate funds, however, caused this work to progress slowly, and Ruediger was not appointed permanent engineer of the Commission of Fisheries until ten years later in 1928 (Chapter 266, Acts of Assembly of 1928, approved March 19, 1928).

Mr. Ruediger faced a formidable task. The original Baylor Survey assumed points on geodetic maps, but established no permanent triangulation points. Also, by 1928 many of the markers on which the original study was based had disappeared. By 1936, however, Mr. Ruediger had largely completed his resurvey (Va. Comm. Fish., 1936), and the Baylor Survey Ground boundaries were reestablished as they largely exist and are employed today.

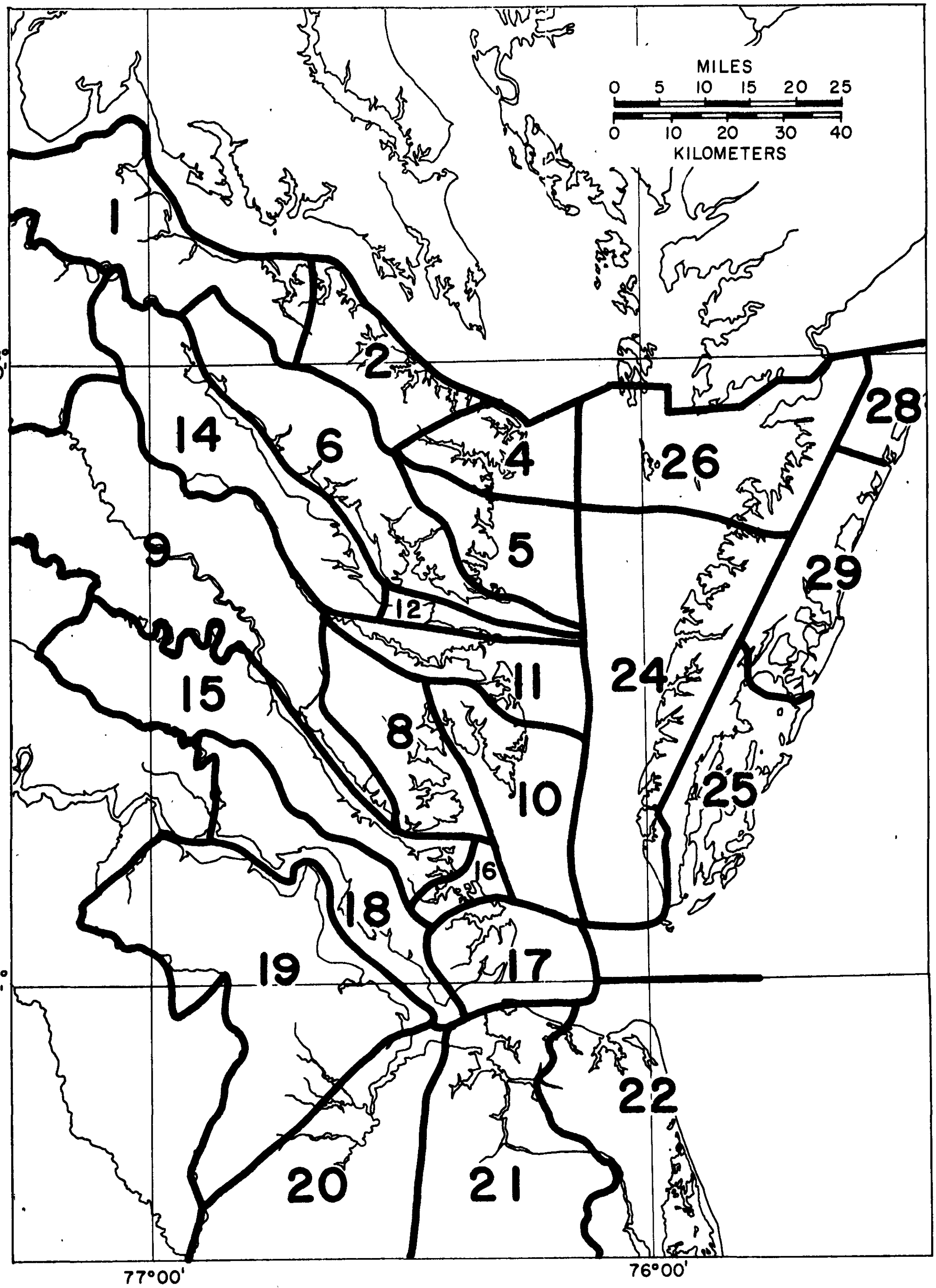
Districts in the Baylor Survey

Around 1900 districts were formed to aid the old Virginia Board of Fisheries in carrying out their responsibilities. Since then the number of districts and their boundaries have been changed several times. In 1923 there were 29 districts. Since then five have been eliminated by combination with other districts. The number established in 1944, 24, persists to this day.

Districts are irregular in shape and do not follow county lines. In most instances they extend to the center lines of the various river systems (Figure 11). The river systems are thus split. The 1923 divisions were probably well suited to the period when roads were poor, adequate bridges did not exist, and land travel over the many long and tortuous dirt roads was slow. The area of each district was such that it might be covered by a single inspector in a single day.

Figure 11

Map of Tidewater Virginia showing the boundaries of the oyster districts.


MILES
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Much of the information related to oyster culture is still reported to the VMRC in relation to these districts. All information on leases and that for the inspection tax on oysters is recorded by districts. It would be advantageous in developing a management program to reform and reestablish the districts so that each river system is within a single district.[3]

Tabulations were made in this study of the acreage of Baylor Grounds in each district. Afterwards the districts were combined to give a generalized concept of size of Baylor Grounds for rivers and river systems (Table 4).

Private Leases

The practice of growing oysters on "private" bottoms has existed in Virginia since the mid-1800's, even before the Baylor Survey was conducted. There are, however, no records which describe how the first privately used grounds were held or if any fee was charged. Available information suggests these planted, "staked"

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[3]In 1977 the system was revised so that catch data are now recorded by area fished (See Chapter IV).

Table 4

Acreage of Public and Private Oyster Ground in Virginia by Regions for 1970

Region	District	ACRES Private[1]	ACRES Public[1]	PERCENT OF STATE TOTAL Private	PERCENT OF STATE TOTAL Public
Potomac	1 & 2	8,818	2,988	7.8	1.2
Lt. & Gr. Wicomico & Indian Creek	4 & 5	5,680	24,438	5.0	10.1
Rappahannock	6, 12, & 14	15,883	55,185	14.0	22.8
Piankatank	11	3,466	15,297	3.0	6.3
York River	9, 15 & part of 8	15,165	3,850	13.5	1.6
Mobjack Bay & Horn Harbor	8 & 10	13,080	24,634[2]	11.5	10.1
Poquoson	16	3,447	7,824	3.0	3.2
James River System	17, 18, 19, 20 & 21	14,813	27,841	12.9	11.4
Back River	part of 17	2,091	0	1.8	0
Chesapeake Bay Entr. to Little Creek	22	2,545	0	2.2	0
Eastern Shore (Bayside)	24 & 26	11,198	36,623	9.8	15.0
Eastern Shore (Seaside)	25, 28 & 29	17 644	44,591	15.5	18.3
TOTALS:		113 830	243,271		

Notes: 1. Records at VMRC January 1970. (These data (now 1977) being revised.

2. Total for Districts 8 and 10 is 24,952, but 318 acres (in District 8) are in the York River.

or marked bottoms were simply regarded as the private property of those who occupied or marked them. However, certain bottoms were "set aside" for public use and were not available for private interests (Ingersoll, 1881). Little can be ascertained about the existence, location, or legal status of the regulations under which these arrangements were made and perpetuated.

With the establishment of the Baylor Survey Grounds in 1892 provisions were made for legally leasing grounds in Virginia in 1892. Many leases were on file by 1894. Information concerning leasing from 1894 to 1900 is lacking. There were 47,803 acres under lease by 1900 and this total slowly increased to 59,436 acres in 1927. Leasing arrangements in this early period with the Commonwealth were lax and as late as 1922 no detailed records of the areas under lease were kept by the State (Corson, 1930). In respect to these early leases Corson states:

> Eight years ago (1922) no records were kept of the areas under lease. The lessee had much choice as to whether he would pay rent. This condition existed despite the most obvious need for such a record and the appropriation of a special fund as early as 1904 for the making of such a record. The present record built up since 1923 is admitted to be incomplete. Individuals who enjoyed the use of planted grounds without the payment of rents are brought to light from time to time.

Rent on Leased Ground

The rent charged per acre of leased ground is very low today and has changed little since it was first instituted in 1926. Today annual rent on leases granted after 1960 is: $1.50 per acre for leases in the rivers, up to 75¢ per acre on leases in the Chesapeake Bay, and $1.50 per acre on leases on the Seaside.

Failure to pay rent on leased ground by the 30th of June after the rent is due results in the lease reverting back to the State after one year.

Since rent on leased bottoms is very low, lease holders are able to retain large tracts at a comparatively small expense. As will be discussed later, this may have an adverse effect on oyster production.

Increase in Leased Acres

In 1931, when more adequate recordkeeping began, there were 63,422 acres leased in Virginia; and by 1947 88,327 acres were under private lease. After World War II leased land increased rapidly to 126,927 acres in 1955. Acreage increased very slowly to 134,492 acres in 1967. Beginning in 1968 the total dropped sharply reaching a level of 100,662 acres in 1975 (Table 5).

Table 5

Acreage and Yield of Privately Leased Oyster Grounds in Virginia 1930-1 thru 1974-5

Season	Total Leased Acreage[1]		Market Oysters Harvested[2]		Average
1930-1	63,422		1,830,836		28.87
31-2	63,731		1,404,952		22.04
32-3	63,846		1,402,231		21.96
33-4	67,564		1,689,860		25.01
34-5	68,149		1,871,116		27.46
35-6	66,422		1,993,418		30.01
36-7	63,206		1,230,304		19.46
37-8	64,455		1,458,308		22.62
38-9	65,065		1,834,298		28.19
39-40	65,984		2,057,271		31.18
1940-1	67,609		2,092,864		30.96
41-2	67,833		1,797,363		26.50
42-3	68,925		N/A		N/A
43-4	69,960		N/A		N/A
44-5	75,804		1,906,500		25.15
45-6	79,328		2,346,535		29.58
46-7	88,327		1,953,155		22.11
47-8	89,787		2,517,992		28.04
48-9	98,183		2,423,447		24.68
49-50	103,132	1,321,847	2,034,097	33,844,547	19.72
1950-1	105,464		1,969,207		18.67
51-2	110,523		2,259,970		20.45
52-3	115,023		2,372,742		20.63
53-4	124,384		2,951,458		23.73
54-5	126,927		2,766,137		21.79
55-6	126,183		2,820,318		22.35
56-7	128,217		2,601,353		20.29
57-8	129,471		2,926,750		22.60
58-9	127,816		3,347,170		26.19
59-60	130,107	1,224,115	2,533,275	26,548,380	19.47
1960-1	132,847		2,237,736		16.84
61-2	132,993		1,815,001		13.65
62-3	133,528		906,243		6.79
63-4	133,786		1,288,093		9.63
64-5	133,665		1,647,645		12.33
65-6	132,438		1,273,888		9.62
66-7	134,492		725,453		5.39
67-8	119,182		840,749		7.05
68-9	114,371		650,445		5.69
69-70	111,911	1,279,213	818,943	12,204,196	7.32
1970-1	109,144		836,014		7.66
71-2	105,373		928,404		8.81
72-3	101,614		394,121		3.88
73-4	100,230		424,277		4.23
74-5	100,662	517,023	491,860	3,074,676	4.89

Table 5 (Contd.)

1. Data from the VMRC.

2. NMFS production figures were used to figure yield for 1931-1963.

N/A - Data was not available.

The slow increase in leased acreage from 1931 to 1960 was apparently associated with the economic growth of the industry. That is, more grounds were needed by planters to grow more oysters. An increase in total leased acres from 1960 to 1967 was brought about by several complex factors: 1) the effect of MSX; and 2) the establishment of arrangement for rent remission.

Rent Remission

MSX killed many millions of bushels of oysters in the lower Bay beginning in the spring of 1960. At first oystermen thought that the disease was temporary and most retained their leases even in locations where mortalities of oysters had been severe.

The disease did not disappear, but was still there in 1961. Consequently, in 1962 certain areas in the lower Bay were declared disaster areas by the Commission of Fisheries on the advice of the Virginia Institute of Marine Science. This action enabled the Virginia Commission of Fisheries (VMRC) to exempt under Section 28.1-114 Code of Virginia for 1962, specifically passed for this purpose, those areas from paying rent on the leased grounds within the disaster area. The law reads as follows:

> 28.1-114. Relief from rent. The Commission of Fisheries may forgive ground rent for oyster leases in any area declared a disaster area for oyster culture. A disaster area may be declared when any natural or man-made condition arises which precludes satisfactory culture of oysters in that area. Such declaration for an area shall be made by the Commission of Fisheries upon the advice of the Director of the Virginia Institute of Marine Science on or before the first day of July of each year, and ground rent due and payable in September following such declaration may be forgiven for the ensuing tax year and such relief may continue until the Commission of Fisheries with the approval of the Virginia Institute of Marine Science shall declare the area again productive.

Acres exempted varied from 34,226 to 48,748 (Table 6).

Rent remission continued until June 1967 when it was officially ended because MSX was not a temporary situation, and some production might be expected from the afflicted areas. In many areas clam production was also possible. The effect of rent remission and its termination are easily seen in data for the total leased acres (Table 5). There was an increase in leased acres during the remission period. This suggests that growers were holding title to grounds afflicted by MSX and additionally, obtaining new leases in areas not influenced by the disease. The decrease in leases after 1967 was due to the abandonment of leases in regions where MSX made oyster culture unprofitable. Other factors also may have contributed.

Table 6

Acres of leased oyster ground for which rent was remitted 1962 to 1967 and total leased acres[1]

Season	Acres of Rent Remission	Total Leased Acres in Virginia[2]
1962-3	47,651	133,528
63-4	34,226	133,786
64-5	41,448	133,665
65-6	41,442	132,438
66-7	48,748	134,492

1. Data obtained from annual reports of the Virginia Marine Resources Commission 1963-1967.

2. Rent is paid on oyster ground a year in advance and is due in September. Total leased acres reported as of 30 June each year.

Elimination of the rent remission practice also was directly involved in these releases of grounds.

A summary of acres exempted from paying rent under Section 28.1-114, Code of Virginia, effective 1 July 1962, is given:

1. James River below the James River Bridge including Hampton Creek, Mill Creek, Willoughby Spit and the Elizabeth River.
2. Back and Poquoson Rivers.
3. Lower York River up to about King's Creek.
4. Mobjack Bay (tributaries not included).
5. Rappahannock River below the Gray's Point Bridge.
6. Chesapeake Bay (Windmill Point to Willoughby Spit, including Horn Harbor and Dyer's Creek).
7. Eastern Shore--all inlets on the Seaside but none on the Bayside.

In 1963 the area exempted from rent remission was scaled down. It included:

1. Chesapeake Bay from Gwynn's Island to Virginia Beach and Cape Henry (tributaries and coves not included).
2. Mobjack Bay (tributaries and coves not included).
3. Lower York River up to Queen's Creek (tributaries and coves not included).

4. Hampton Roads (tributaries and coves not included).

In 1964 the area included was again modified and expanded. It now included:

1. Chesapeake Bay (essentially the same as in 1963).
2. Mobjack Bay (the same as in 1963).
3. York River (the same as in 1963).
4. Hampton Roads (the same as in 1963).
5. Horn Harbor (was added).
6. Creeks on the Bayside of the Eastern Shore (were added).
7. Chismans Creek, Back Creek, the Guinea Marsh area, and the Thorofare at the York River mouth (were added).

The areas of rent remission in 1965 had been stabilized so that they were essentially the same as in 1964. The areas included in 1966 were the same as for the preceding two years with the exception that Tangier Sound was added.

Rent remission was officially ended on 27 June 1967 when a resolution was passed by VMRC which stated:

> That the present relief from the payment of oyster ground rent will not be granted for any year subsequent, and ground taxes must be paid on all leases beginning in 1968 (VMRC, 1967).

Applications for leases were again on the upswing by the summer of 1976 according to VMRC despite the lack of rent remission and the continued persistence of MSX in high salinity areas. This is a highly interesting development. It may also be partially attributed to the low rents which the system requires. It does not cost much to lease and hold onto a leasehold.

Leasing Procedures

Leases are granted by the State to individual or collective citizens for twenty-year periods with the option of renewing. Rent is due (for the year to come) annually on 1 September. The lease may be sold or transferred to another person or may be bequeathed.

There are three ways of obtaining oyster ground in Virginia:

1. An individual may lease grounds which have not previously been leased.
2. An individual may "buy" or inherit the lease of another and have it transferred to his ownership.
3. An individual may obtain grounds (0.5 acres) as "Riparian Rights." These are associated with highland holdings by the applicant.

Though oyster grounds belong to the Commonwealth, it usually must be condemned by court action.

New Leases

New leases may be obtained by making application for ground through a local oyster inspector. Notice of intent is forwarded by the inspector to the Virginia Marine Resources Commission. Additionally, a notice of intent to lease is posted and published with a description of size and location. The proposed lease is reviewed by the Commission, and if there are no objections by citizens and the Commission approves (or does not object), the grounds are surveyed and upon payment of necessary fees, title is given to the applicant. A plat or map of the lease showing its shape, location, district, and other pertinent data is maintained in a file at the Commission.

Riparian Rights

The Code of Virginia provides that property owners holding more than 105 feet of land on a tidal water may apply for a riparian right of up to half an acre of oyster ground. The exact rules and regulations concerning these rights are complex and will not be covered here. The pertinent point is that these riparian leases are all one-half acre or less, too small to be of significance in oyster culture for income. There were 711 pieces of riparian ground on record with a total acreage of 337.3 acres as of 1970. This was only 0.3 percent of all the land held by individuals in the State, but they were held by 12.8 percent of all holders. Methods of obtaining these riparian grounds are in general the same as for new leases. No rent is paid on riparian grounds.

Transfer of Existing Leases

Existing leases may be transferred to others upon payment of a fee to the Virginia Marine Resources Commission. A survey may be made at the request of the lessee or the Commission if doubt exists about location of the boundaries, with the lessee paying the costs. A new plat of the land prepared by the Commission may be filed replacing the old one in the event the land is leased. Frequently a new survey consolidates several adjacent separate plots, all held by one owner, into a single plot. If title to the lease is transferred without a survey, then the original plat remains on file.

A summary of fees necessary to obtain a lease on oyster planting grounds follows:[4]

1) Application fee (paid to inspector)	$ 25.00
Survey fee (paid to surveyor)	
for the first 5 acres or under	30.00
for each acre or fraction more than 5 up to 10	3.00
for each acre between 10 & 20	2.00
for each acre between 20 & 30	1.00
for each acre between 30 & 50	.50
for each acre over 50	.25

[4]Code of 1950 and 1970 Supplement--Section 28.1-109(7).

2)	Fee for drawing the plat (orig. + dup.) (Paid to surveyor)	
	for the first 4 or less corners	4.00 @ corner
	for all corners over 4	1.00 @ corner
3)	Recording fees (paid to inspector)	
	for recording in the county clerk's office	6.00
	for recording at the VMRC	6.00

When leasing was first instituted in 1894, individuals seeking such grounds naturally sought the best grounds available. The characteristics of these desirable bottoms were, and are today, well known to growers with local knowledge and oystering experience. A good oyster bottom has a firm, stable, shelly or sand-clay bottom, depths from 5-15 feet, moderate currents, protection from wave damage, and average salinities above five parts per thousand. If grounds were located where a natural strike or set of young oysters occurred, a further advantage existed.

Grounds having the preceding characteristics were not readily available to private growers even after 1894, since most of the bottoms having these characteristics had been declared public grounds by the Baylor Survey. As a consequence, the original lessees took up the less desirable grounds outside the Baylor Grounds.[5] Attempts by the lessees

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[5] Pertinent records indicate many of these near-Baylor leases to have been the bases from which encroachment onto natural bottoms was perpetrated.

to acquire the better bottoms often resulted in a patchwork or mosaic pattern of leases. Few plots were square, and small one or two acre plots were often located adjacent to large 100 acre plots.

Degree to Which Private Leases are Used

In Chapter III the productivity of private oyster leases will be discussed by district. It should be noted that there is no published information on the productivity of private leases by river system or for individual leases. Furthermore, basic data on this point are rare. Only a few scattered records of private companies are available. These, too, are totally insufficient to formulate opinions as to the productivity of individual leases. There is no way to accurately determine the degree to which a leaseholder "uses" his leased grounds. Also, no data are available on the use of riparian holdings.

Indirect evidence suggests that vast areas of leased bottoms (and a large percentage of riparian leases) are held by individuals or companies who have little interest in growing oysters. Careful numerical estimates are not available. According to available evidence based on observations by the authors, interviews with growers, and other sources, over 90% of the leased bottoms are not in use today and have not been for a long time! For example, from 1960 to 1975 state-wide production from all leased bottoms averaged only 8.3 bushels per acre (Table 5). This is very low when it is realized that some lease holders may average 300 bushels a year per acre from planted bottoms. That is, $\frac{8.3}{300} = 2.8\%$. Were a larger portion under active culture the production would be greater.

There are many reasons why leased bottoms may be held by private lessees such as:

1. Lease holders may hold bottoms to grow oysters.
2. Lease holders may hold title to good bottoms to exclude others from the area, or to eliminate competition.
3. The right to lease bottoms may be inherited. Often, those who inherit these bottoms reside out-of-state, or have no interest or ability in oyster culture. Title is held since it costs very little to do so, because there are sentimental attachments to these inherited grounds, or on the basis that someday it may be of value. In any event, valuable oyster bottom becomes unavailable to others.
4. A company or individual may hold title to good bottoms which do not now produce marketable oysters because of pollution, disease

or economic reasons. However, the lease or leases is (are) held because of the possibility that the adverse circumstances which prevent culture may improve.

5. Leases are held by individuals or companies who may seek to profit (due to damages or loss of lessee rights) when channels, piers, bridges, shore-side projects, etc., are completed or in the vicinity of the lease.
6. Large industrial companies may obtain title to areas of bottom to prevent law suits for damages by adjacent lease holders. For example, as will be shown later in this chapter, in 1970, 31 percent of all leased bottoms in the York were under lease by the Chesapeake Corporation and by a holding company representing the Amoco Oil Refinery in Yorktown.

Legal Size of Holding

The total acreage which may be held by an individual, a group of individuals, or a company may not exceed 3,000 acres. Under existing law single lessees may lease only 250 acres of new or additional ground yearly. This law was designed so that an individual could not acquire large amounts of land, but it has not been very effective in achieving its purposes since applications of 250 acres are commonly filed separately by a husband and his wife or by one or more of their children, or by some similar arrangement so that large acreages are acquired. This is not to say that large unit holdings should not be allowed. Like land farming, oyster culture will work better on adequate contiguous holdings. However, efforts should be made to prevent too much concentration.

There is no law regulating minimum size of leases, but holdings of less than one acre are discouraged by the Commission.

Do Private Leases Encroach on Public Bottoms?

The exact bounds of private leases in Virginia are defined by triangulation on shore points such as barns, houses, water towers or concrete monuments. Since many of the leases on file at the Commission were applied for years ago, a large number of these reference points have ceased to exist due to shoreline erosion or the destruction of the markers. This is not to say that the boundaries of all private leases cannot be defined. Due to age and disappearance or alterations of original landmarks, it is logical to expect that some of these areas cannot be precisely defined today. Efforts should be made to update inadequate surveys. Until this is done, it will not be possible to determine whether some private leases do not encroach significantly on public bottoms.

In recent years the Commission has made certain efforts to resurvey many areas, specifically in the case of new or transferred leases or where dispute occurs.

Distribution of Private Leases and Public Oyster Grounds in Virginia by Districts

Introduction

This section will consider the size of public grounds and leased bottoms by river systems and by districts, the magnitude of the holdings of individual leases and economic problems of small leases.

The largest tracts of surveyed public bottoms exist in the Rappahannock River followed by the Eastern Shore and then the James River system. Other regions contain lesser amounts of Baylor Grounds (Table 4).

There are similar patterns for leased areas in respect to size of holdings in nearly all river systems. To illustrate the point, representative state-wide averages are given here. That is, out of the 4,940 persons holding leases in 1970, a majority (4,104 or 83%) held bottoms whose total size was less than 20 acres. The average size of these leases was 4.7 acres! The larger acreage of 100 acres or more were held by a very few companies or individuals. Specifically, 209 or 4% of the lease holders held title to 68,079 acres--60% of all the leased bottoms in Virginia.

Lease holds whose total size is less than 20 acres are not large enough to serve as the sole source of income.

To examine these points data obtained from the files of the VMRC were tabulated in the following way: Data on each individual lease as recorded at the Virginia Marine Resources Commission as of 1 January 1970 were tabulated by district under the owner or lessee (Tables 7 and 8). For example, if it were determined that John Doe held three leases in District 1: 2.0 acres, 30.0 acres, and 1.0 acres; the tabulation was--John Doe 33.0 acres. Leases held by John Doe in other districts were tabulated in the following size catagories based on acres: riparian lands:[6] .1-1; 1-2; 2-3; 3-4; and .1-5; 5-10; 10-20; 20-50; 50-100; over 100 and totals. Acreage limits stop just short of the next higher interval in the tabulations. The 5-10 acre catagory included holdings of 5.0 to 9.9 acres.

These tables are more detailed than is necessary. However, they constitute the first systematic presentation of all of the data. For discussion in this chapter, the data have been grouped into eight divisions: 1 to 5 acres; 5 to 10; 10 to 20; over 20; 20 to 50; 50 to 100; over 100; and totals.

All data on size or location of public ground in this section are shown in Figures 3, 4 and 5; Table 4). All

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[6]Data on size of riparian lands are not included in totals for leased grounds in the state.

Table 7

Number of Lessees of Oyster Ground in Virginia Who Held 5 Acres or Less and the Acreage Held as of January, 1970[1]

Type or Size of Holdings:	Riparian only		0.1-1 Acres (excluding riparian)		1-2 Acres		2-3 Acres	
	Number Holders	Total Acreage	Number Lessees	Total Acreage	Number Lessees	Total Acreage	Number Lessees	Total Acreage
District:								
1	0	0	0	0	2	3.3	5	12.3
2	14	6.6	53	37.1	86	127.0	53	131.1
4	10	4.6	55	38.3	77	115.4	57	142.4
5	27	12.9	26	17.5	39	59.2	32	81.5
6	120	58.0	27	17.2	44	67.2	33	82.0
8	72	35.2	14	10.3	23	34.2	41	104.6
9	25	12.3	10	6.7	14	23.0	9	23.0
10	24	11.9	11	7.4	24	36.1	24	60.0
11	66	31.2	30	20.9	34	48.7	25	62.1
12	18	8.6	10	7.6	11	14.2	10	25.2
14	18	8.8	9	5.4	12	18.3	6	16.0
15	77	37.0	7	5.1	14	21.5	8	20.9
16	34	16.1	5	4.2	13	18.2	18	46.3
17	34	16.5	12	8.2	20	28.8	14	35.7
18	0	0	0	0	0	0	2	5.1
19	7	3.5	4	1.9	5	8.0	9	22.1
20	11	5.4	4	3.4	11	15.8	3	7.8
21	0	0	9	5.0	1	1.8	1	2.6
22	105	46.2	19	11.5	16	26.2	17	41.2
24	9	4.1	13	9.5	26	39.7	27	68.3
25	0	0	3	2.1	10	15.3	6	16.4
26	11	5.2	11	7.6	22	32.3	17	40.3
28	19	9.0	23	14.9	28	41.4	24	58.6
29	10	4.2	8	5.1	8	12.4	10	26.5
Virginia Totals:	711	337.3	363	246.9	540	803.0	451	1,132.0

1. Data from VMRC.

Table 7 (Contd.)

Type or Size of Holdings:	3-4 Acres Number Lessees	Total Acreage	4-5 Acres Number Lessees	Total Acreage	0-5 Acres Number Lessees	Total Acreage
District:						
1	1	3.6	2	8.8	10	28.0
2	39	137.2	25	111.5	270	550.5
4	30	105.3	29	131.1	258	537.1
5	18	63.8	19	85.8	161	320.6
6	33	117.2	21	95.6	278	437.1
8	26	92.8	20	91.2	196	368.3
9	13	46.4	10	45.1	81	156.6
10	28	98.6	23	101.4	134	315.5
11	34	118.0	22	100.3	211	381.2
12	4	14.6	1	4.4	54	74.6
14	4	14.1	3	14.2	52	77.7
15	7	23.7	12	53.0	125	161.0
16	6	21.6	6	27.2	82	133.6
17	8	28.2	6	29.3	94	146.8
18	2	7.2	0	0	4	12.3
19	3	9.8	7	29.4	35	74.7
20	5	16.8	6	26.7	40	75.9
21	0	0	1	4.7	12	14.2
22	9	31.7	9	41.6	175	198.2
24	28	100.6	27	124.7	130	346.9
25	2	6.8	4	18.3	25	59.0
26	10	35.6	11	50.4	82	171.3
28	24	83.3	10	45.1	128	252.2
29	5	17.5	9	40.0	50	105.7
Virginia Totals:	339	1,194.4	283	1,278.8	2,687	4,999.0

Table 8

Number of Lessees of Oyster Ground in Virginia and Acreage Held as of January 1, 1970*

Size of holdings:	0.1-5 Acres		5-10 Acres		10-20 Acres		0-20 Acres	
	Number Lessees	Total Acreage	Number Lessees	Total Acreage	Number Lessees	Total Acreage	Number Lessees	Total Acreage
District:								
1	10	28.0	12	82.2	12	179.3	34	289.5
2	270	550.5	76	565.7	37	509.7	383	1,625.9
4	258	537.1	68	475.9	35	486.4	361	1,499.4
5	161	320.6	33	244.3	23	311.0	217	875.9
6	278	437.1	66	488.7	40	588.4	384	1,514.2
8	196	368.3	56	403.7	49	667.3	301	1,439.3
9	81	156.6	35	243.9	28	416.2	144	816.7
10	134	315.5	59	434.0	32	420.4	225	1,169.9
11	211	381.2	70	527.6	48	690.3	329	1,599.1
12	54	74.6	23	165.0	17	230.8	94	470.4
14	52	77.7	21	172.3	10	154.9	83	404.0
15	125	161.0	23	174.2	12	167.8	160	503.0
16	82	133.6	27	209.3	12	166.9	121	509.8
17	94	146.8	35	262.5	13	193.8	142	603.1
18	4	12.3	4	28.0	11	167.9	19	208.2
19	35	74.7	10	83.8	14	200.0	59	358.5
20	40	75.9	21	146.3	11	148.4	72	370.6
21	12	14.2	4	31.2	3	43.5	19	88.9
22	175	198.2	24	169.7	25	342.8	224	710.7
24	130	346.9	83	628.2	46	661.3	259	1,636.4
25	25	59.0	17	120.3	14	208.1	56	387.4
26	82	171.3	29	216.5	18	255.4	129	643.2
28	128	252.2	37	268.2	25	352.1	190	872.5
29	50	105.7	25	190.1	24	352.3	99	648.1
Virginia Totals:	2,687	4,999.0	858	6,331.6	559	7,915.0	4,104	19,245.6

* Data from VMRC.

Table 8 (Contd.)

Size of holdings:	20-50 Acres		50-100 Acres		Over 100 Acres		Virginia Total	
	Number Lessees	Total Acreage	Number Lessees	Total Acreage	Number Lessees	Total Acreage	Lessees	Acreage
District:								
1	14	468.9	6	398.4	9	2,750.4	63	3,907.2
2	36	1,137.3	7	580.2	11	1,567.5	437	4,910.9
4	11	335.9	5	364.8	3	658.5	380	2,858.6
5	20	602.5	9	693.8	3	649.6	249	2,821.8
6	32	1,047.2	16	1,074.2	15	4,037.6	447	7,673.2
8	33	1,022.0	11	832.4	10	6,785.7	355	10,079.4
9	18	535.2	3	218.8	5	3,121.9	170	4,692.6
10	16	494.1	9	654.4	7	2,767.0	257	5,085.4
11	33	968.8	11	782.0	1	116.6	374	3,466.5
12	11	328.0	2	160.0	0	0	107	958.4
14	16	526.9	8	504.3	23	5,816.5	130	7,251.7
15	11	351.8	9	604.1	17	6,928.4	197	8,387.3
16	4	107.2	2	116.3	3	2,713.2	130	3,446.5
17	18	559.7	3	200.1	5	2,281.9	168	3,644.8
18	7	173.9	7	467.0	6	1,948.5	39	2,797.6
19	7	250.0	6	410.7	6	1,811.1	78	2,830.3
20	17	585.4	11	719.6	14	3,409.4	114	5,085.0
21	8	294.8	3	226.6	4	1,936.5	34	2,546.8
22	20	629.2	4	240.7	6	964.7	254	2,545.3
24	42	1,325.5	21	1,369.2	10	3,067.1	332	7,398.2
25	20	652.2	13	871.6	22	7,664.9	111	9,576.1
26	12	363.4	10	674.0	9	2,119.6	160	3,800.2
28	24	712.3	5	282.6	11	2,917.2	230	4,784.6
29	13	410.9	3	178.9	8	2,045.5	123	3,283.4
Virginia Totals:	443	13,883.1	184	12,624.7	209	68,079.3	4,940	113,832.7

average size and distribution of leases are shown in Figures 12 through 16 and Tables 7 and 8 unless otherwise specified.

Potomac River--Virginia Tributaries, Districts 1 and 2

The main part of the Potomac River is "owned" by Maryland whose jurisdiction extends to the mouths of Virginia's creeks and rivers and to mean low water on the Virginia Shore of the main body of the river. This jurisdiction in the open Potomac is shared with Virginia for purposes of fisheries management under terms of the Potomac River Fisheries Compact. Virginia's Baylor Survey Grounds in the Potomac system are small, widely scattered blocks located in the Coan and Yeocomico rivers and Lower Machodoc and Nomini creeks. Baylor Grounds in the two districts into which Virginia's Potomac oyster areas are divided total 2,988 acres or 1.2 percent of all public ground in Virginia. The Potomac area is considered a good growing area and is free of drills and MSX.

Private leases located in District 1 start in the tributaries of the upper Potomac and end at Nomini Bay. The district contains 3,907.2 acres of leased ground (Table 8). Many of these lessees hold large tracts of 100 acres or more. In this division, 70.4 percent or 2,750 acres of the district is held by only nine persons. Many lessees hold

Figure 12

Distribution of leased oyster planting ground in Virginia, Districts 1, 2, 4, 5, 6 & 14, as of January 1970, according to size of holdings. Data obtained from files of VMRC.

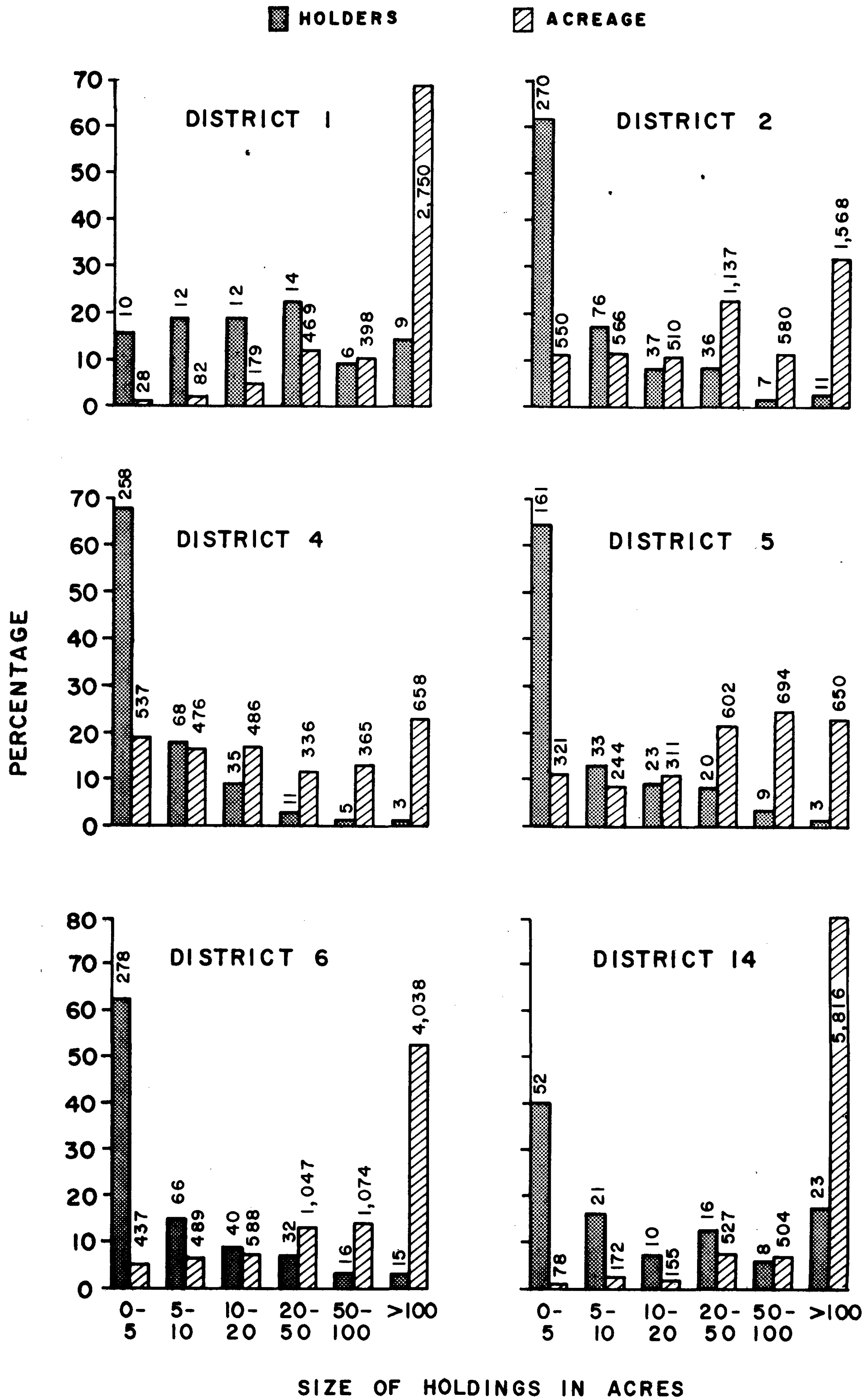

HOLDERS
ACREAGE
DISTRICT 1
10
28
12
82
12
179
14
469
6
398
9
2,750
DISTRICT 2
270
550
76
566
37
510
36
1,137
7
580
11
1,568
DISTRICT 4
258
537
68
476
35
486
11
336
5
365
3
658
DISTRICT 5
161
321
33
244
23
311
20
602
9
694
3
650
DISTRICT 6
278
437
66
489
40
588
32
1,047
16
1,074
15
4,038
DISTRICT 14
52
78
21
172
10
155
16
527
8
504
23
5,816
PERCENTAGE
0- 5
5- 10
10- 20
20- 50
50- 100
>100
SIZE OF HOLDINGS IN ACRES

Figure 13

Distribution of leased oyster planting ground in Virginia, Districts 8, 9, 10, 11, 12 & 15 as of January 1970, according to size of holdings. Data obtained from files of VMRC.

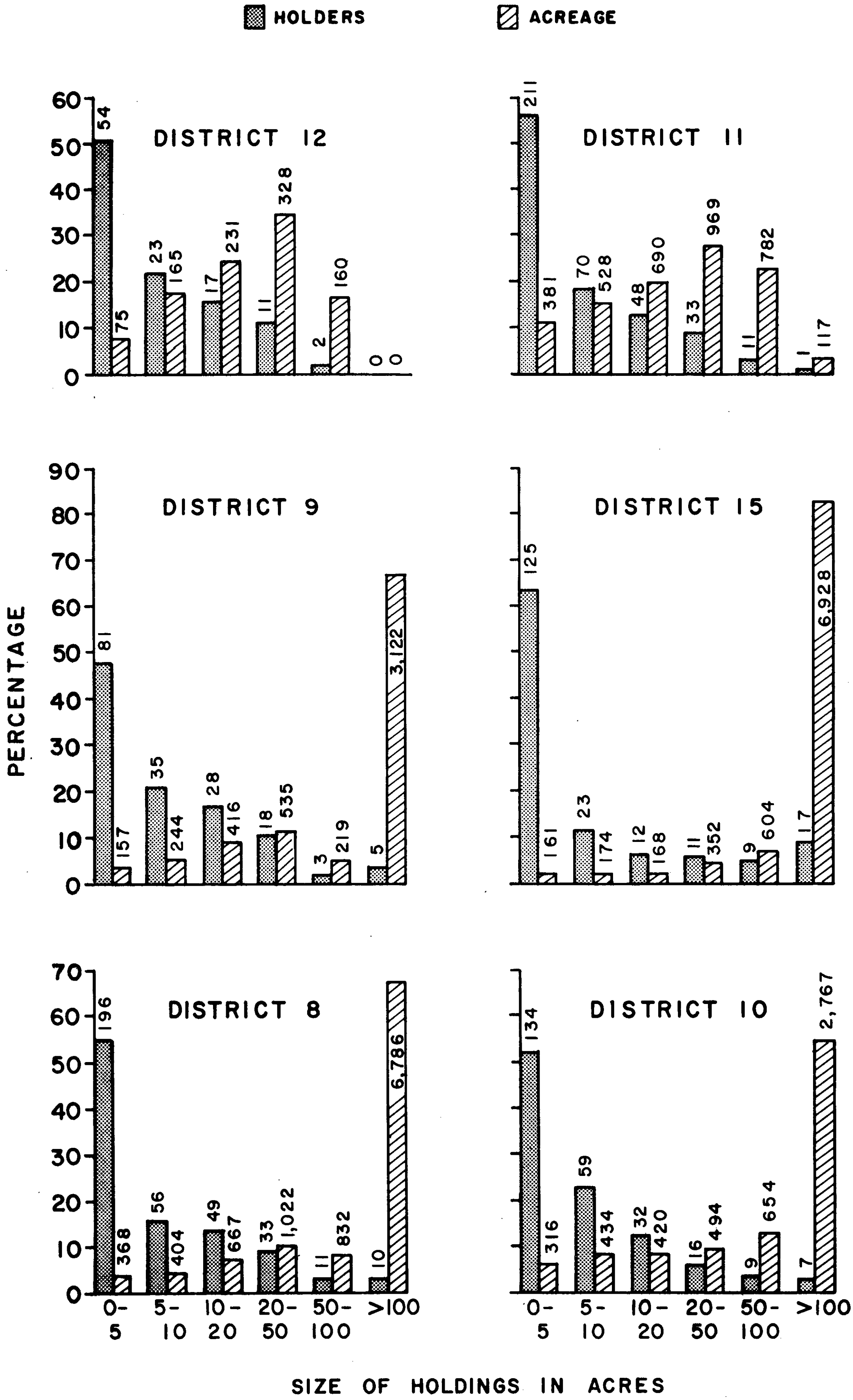

HOLDERS
ACREAGE
DISTRICT 12
54
75
23
165
17
231
11
328
2
160
0
0
DISTRICT 11
211
381
70
528
48
690
33
969
11
782
1
117
DISTRICT 9
81
157
35
244
28
416
18
535
3
219
5
3,122
DISTRICT 15
125
161
23
174
12
168
11
352
9
604
17
6,928
DISTRICT 8
196
368
56
404
49
667
33
1,022
11
832
10
6,786
DISTRICT 10
134
316
59
434
32
420
16
494
9
654
7
2,767
PERCENTAGE
0-5
5-10
10-20
20-50
50-100
>100
SIZE OF HOLDINGS IN ACRES

Figure 14

Distribution of leased oyster planting ground in Virginia, Districts 16, 17, 18, 19, 20 & 21, as of January 1970, according to size of holdings. Data obtained from files of VMRC.

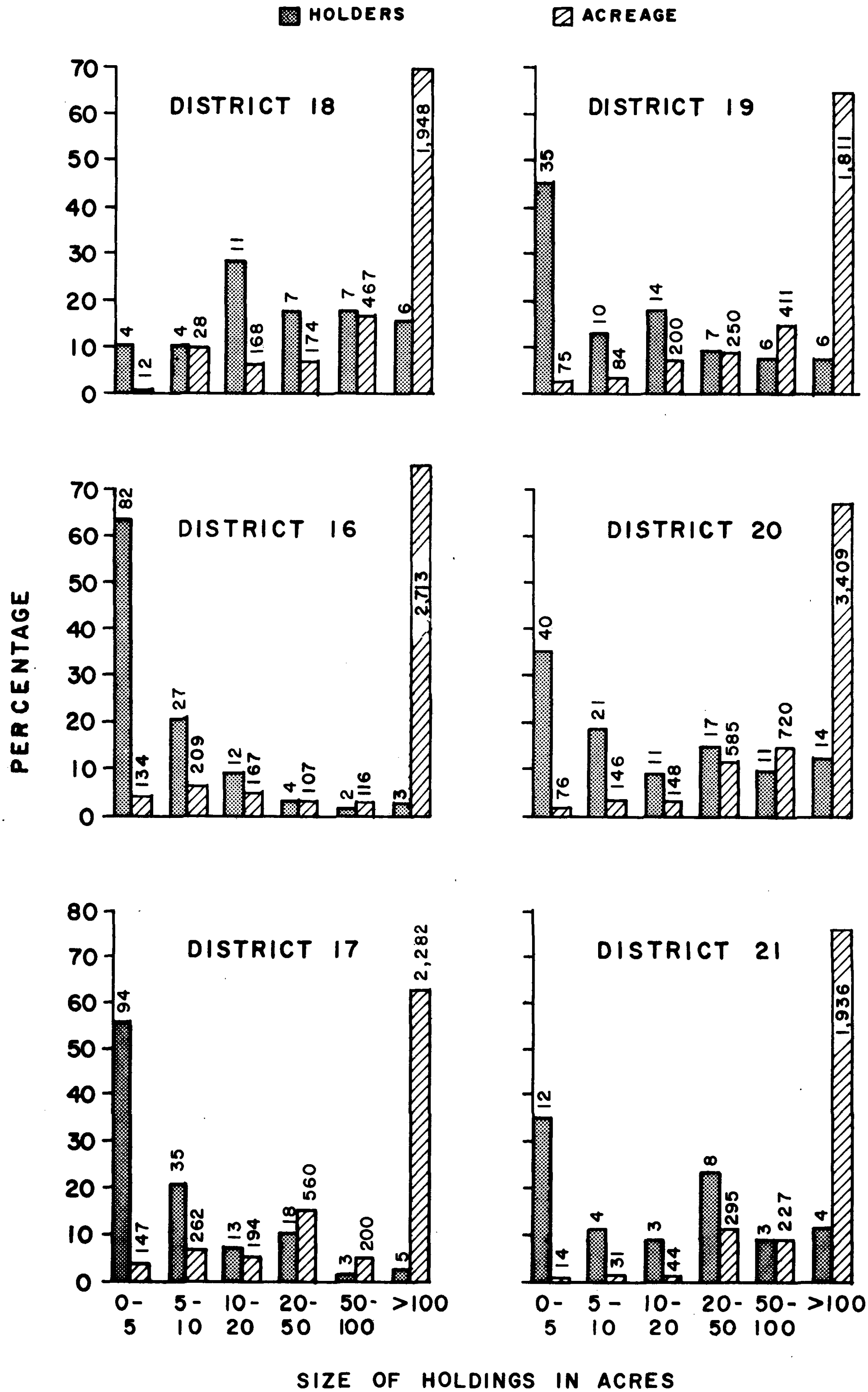

HOLDERS
ACREAGE
DISTRICT 18
DISTRICT 19
DISTRICT 16
DISTRICT 20
DISTRICT 17
DISTRICT 21
PERCENTAGE
0-5
5-10
10-20
20-50
50-100
>100
SIZE OF HOLDINGS IN ACRES

Figure 15

Distribution of leased oyster planting ground in Virginia Districts 22, 24, 25, 26, 28 & 29, as of January 1970, according to size of holdings. Data obtained from files of VMRC.

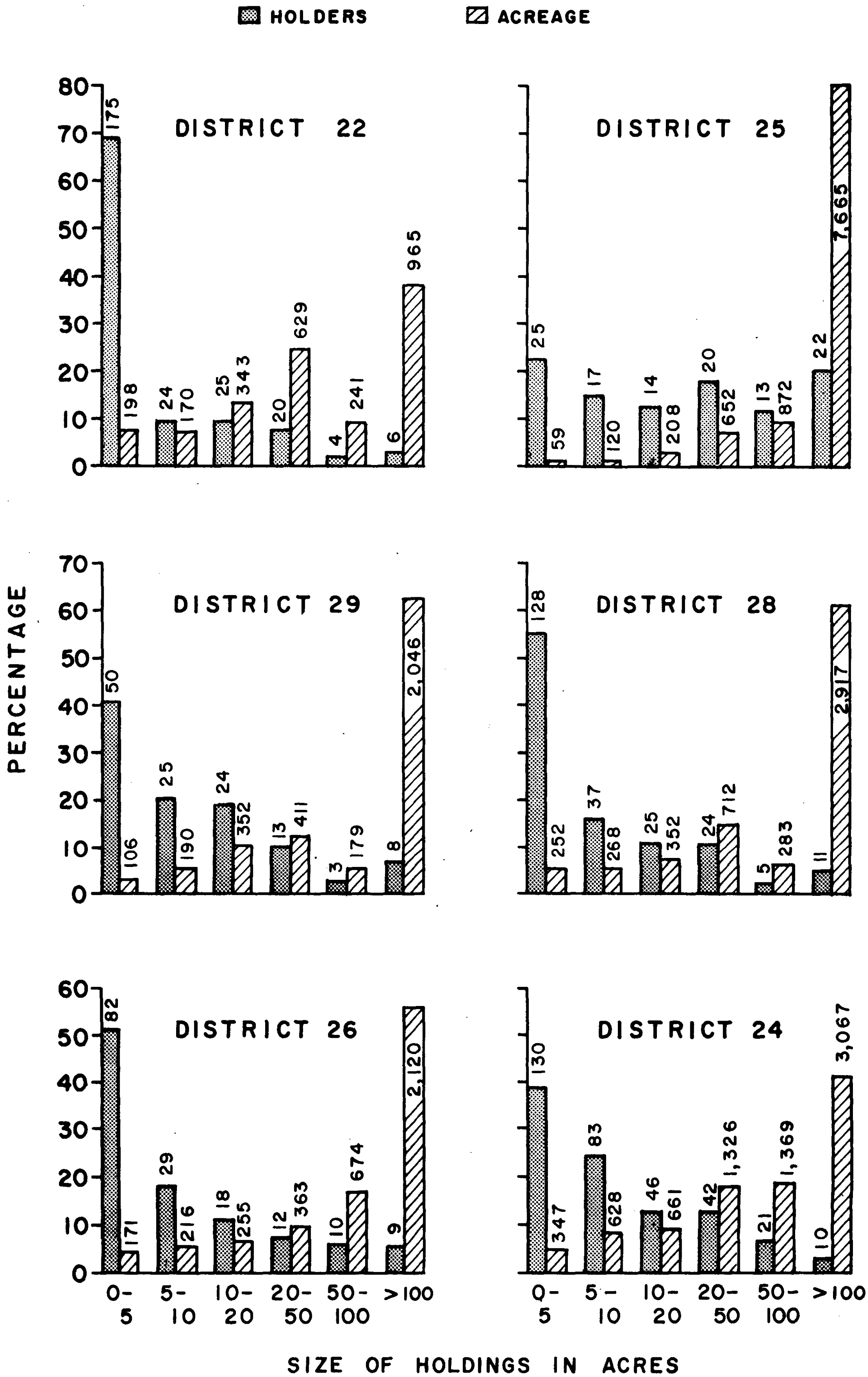
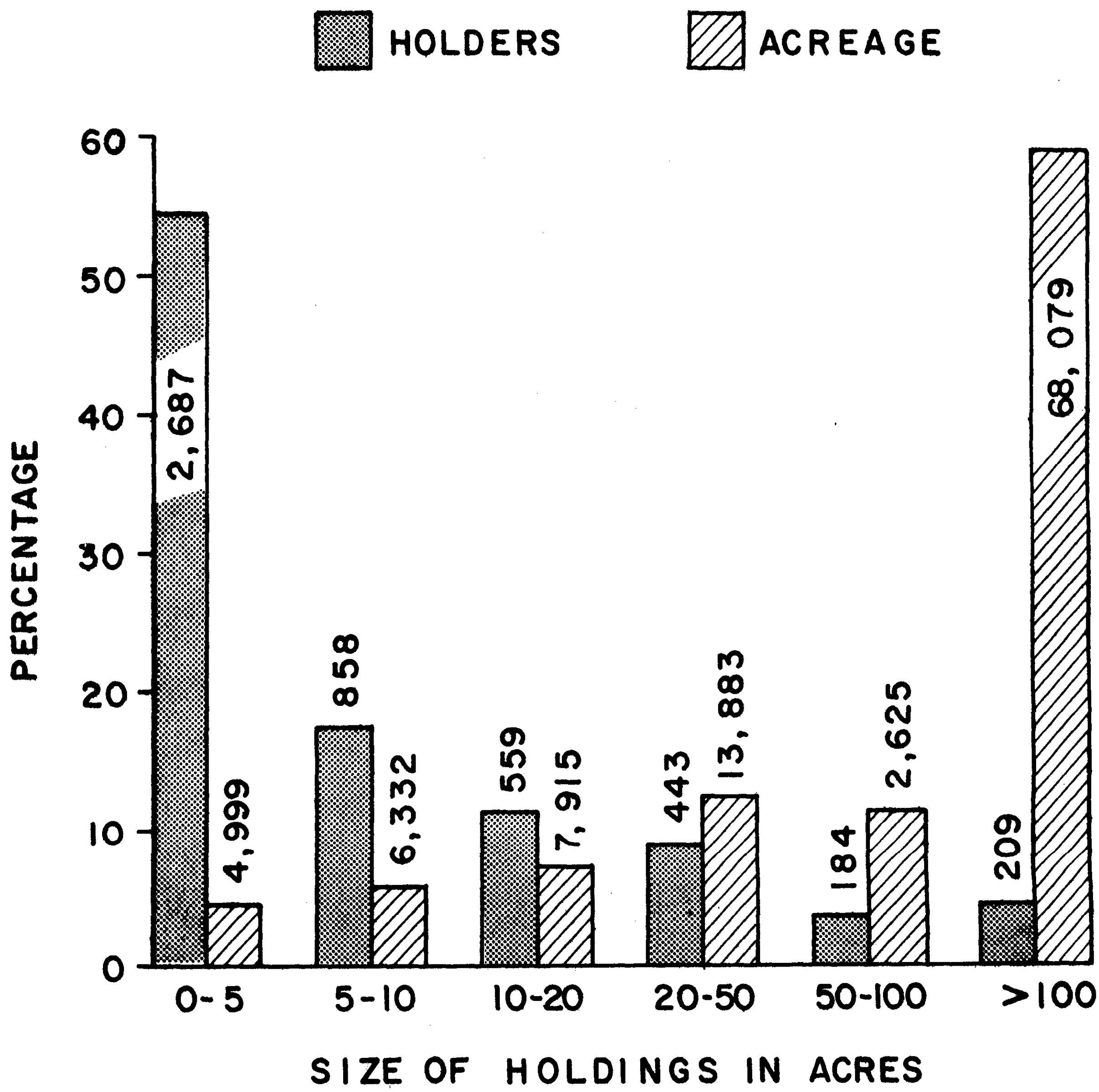

HOLDERS
ACREAGE
DISTRICT 22
DISTRICT 25
DISTRICT 29
DISTRICT 28
DISTRICT 26
DISTRICT 24
PERCENTAGE
175
198
24
170
25
343
20
629
4
241
6
965
25
59
17
120
14
208
20
652
13
872
22
7,665
50
106
25
190
24
352
13
411
3
179
8
2,046
128
252
37
268
25
352
24
712
5
283
11
2,917
82
171
29
216
18
255
12
363
10
674
9
2,120
130
347
83
628
46
661
42
1,326
21
1,369
10
3,067
0-5
5-10
10-20
20-50
50-100
>100
SIZE OF HOLDINGS IN ACRES

Figure 16

Distribution of leased oyster planting ground in Virginia as of January 1970, according to Total Ground Leased by an Individual (a Lease-holding). Data obtained from files at VMRC.


HOLDERS
ACREAGE
PERCENTAGE
60
50
40
30
20
10
0
2,687
4,999
858
6,332
559
7,915
443
13,883
184
2,625
209
68,079
0-5
5-10
10-20
20-50
50-100
>100
SIZE OF HOLDINGS IN ACRES

very small acreages. In fact, 34 lessees or 54.0 percent of those in the district have holdings of 20 acres or less. However, their total holdings are unimportant and add up to only 289.5 acres, or 7.4 percent of the leased acreage in the district.

District 2, including the region from Lower Machodoc Creek to Smith Point, contains 4,910.9 acres held by 437 lessees. The major difference between Districts 1 and 2 is that in the former area, there are fewer lessees holding less than 20 acres than in District 2. For example in District 2, 383 lessees or 87.6 percent of the total hold less than 20 acres. Large lease holdings of 100 acres or more are not common and only 1,567.5 acres or 31.9 percent of the total bottom in the district is in this category. This acreage is leased by 11 persons or 2.5 percent of the district total. There are only 14 riparian holders in this district.

Little and Great Wicomico and Indian Creek, Districts 4 and 5

Baylor Grounds number 24,438 acres, or 10.1 percent of the State total. An estimated 84 percent, or 20,532 acres, of the public bottom in these two districts is located in the open portion of Chesapeake Bay. About 15 percent (3,666 acres) is located in the Great Wicomico River which is an important seed area and about 1 percent (240 acres) in the

Little Wicomico River which produces market oysters. The large Baylor Ground area of 20,532 acres in the Bay has produced seed or market oysters according to statements of oyster inspectors and local watermen. It is not known why a ten-mile stretch of public ground existing between the Great Wicomico and Rappahannock rivers was not included in the Baylor Survey.

Private leases in these two districts are mostly located in the tributary creeks in a 16-mile stretch from Smith Point south to Windmill Point. The principal reason for this distribution of private bottoms is because the Baylor Grounds occupy nearly all of the bottom in this stretch outside the entrances to the creeks.

The pattern of lease-holds in the two districts is similar. Most lessees hold only small acreages and there are few whose holdings total over 100 acres. In the two districts, 5,680.4 acres of leased land are held by 629 persons. In the group holding 20 acres or less, 578 lessees or 91.9 percent of the area total hold 2,375.3 acres or 41.8 percent of all leased land. Only a small amount of land is held in units of 100 acres or more. In this last division (100 acres or more), six persons hold a total of 1,308.1 acres or 23.0 percent of the total. Riparian right grounds total 17.5 acres and are held by 37 persons.

Only about one-quarter of the acreage in these two districts is held in units which could be considered adequate in terms of economic return.

Rappahannock and Corrotoman Rivers, District 6, 12 and 14

These districts encompass 55,185[7] acres, or 22.8 percent of the State total (Table 4) comprising the largest single block of Baylor Grounds in one river system in Virginia. About 10,000 acres were added to the original Baylor Survey in 1936 to make up this total (Table 2). These public grounds start in the lower river at Windmill and Stingray points, extending 23 miles upriver in a single section all the way to Morattico Bar. Grounds in the lower Rappahannock River are continuous with those in the Corrotoman River. The boundaries of the public ground extend to within one-third to one-fourth mile from shore leaving only inshore shallows for private leasing.

The extent of Baylor Bottoms declines above Morattico since at this location it narrows and extends about five miles further upriver, leaving about half the river open for private leases on the west side. Above this large section there are several small acreages of Baylor Ground in the vicinity of Russ's Rock, 33 miles above the mouth of the river.

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[7]This acreage is being recalculated by the VMRC.

The Baylor Grounds in the Rappahannock are extensive, but even a casual inspection of the U.S. Hydrographic Chart of the river below Towles Point shows about one-third or perhaps more of the Baylor Ground in that location to be in water deeper than 30 feet. Such deepwater beds are usually not productive for a variety of reasons. An additional amount is located in exposed situations or in areas with unstable bottoms. For these reasons we determined that at least one-half of the Baylor Ground below Towles Point is unsuitable for oyster culture.

Private leases in this system occupy marginal strips along each shore of the river. There are 156 riparian holders with total holdings of 75.4 acres in the entire river system. Total leased land in this system is 15,883.3 acres with 684 lessees.

Holdings in the three Rappahannock-Corrotoman districts differ. District 6 occupies the entire north shore of the system and includes the Corrotoman River. There are 120 riparian right holders who hold 58.0 acres. There are numerous small lease holders (those under 20 acres per lessee) in this district with total holdings of 1,514.2 acres, or 19.7 percent of all acres in the district. This acreage is held by 384 lessees, or 85.9 percent of the district total. Over half of the land is held by relatively few individuals in units of 100 acres or more and 15 lessees or 3.4 percent of the district total hold 4,037.6 acres or 52.6 percent of all leased bottoms in the district.

District 14 encompasses the south-side of the Rappahannock from Tappahannock to about four miles below Urbanna. There are only 18 holders of riparian rights with a total of 8.8 acres. This region is presently one of the most satisfactory in the entire State for oyster culture. It is nearly free of MSX and other diseases and oyster drills are not a problem. It contains 7,251.7 acres which are held by 130 lessees. Most of this acreage is held in units of 100 acres or more with 23 lessees holding 5,816.5 acres. This is 80.2% of all bottom in the district. There are only 404 acres of land held in units of 20 acres or less (83 lessees) in the whole district.

District 12, in the lower-third of the Rappahannock on the south-side, is small containing only 958.4 acres held by 107 lessees. Riparian rights number 18 and total 8.6 acres. There are no large holdings in this area which total over 100 acres. Almost half the land is held in small blocks and 49.1% of all acreage (471 acres) in the district is held in units of less than 20 acres by 94 individuals or 87.8% of the district lease holders.

It is apparent from the preceding paragraphs that over half of the land in the Rappahannock River is held by individual lessees as units which total over 100 acres.

Piankatank River, District 11

Baylor Grounds in this district encompass 15,297 acres and constitute 6.3% of the total in the State.

Total acreage inside the mouth of the Piankatank River is about 1,200 acres or 7.8%; the remainder of the grounds (about 14,097 acres) are in the Bay where they form a broad area one to two miles wide and ten miles long extending south to Wolftrap Light. The upper portion of the Baylor area in the Piankatank is productive and has been developed by the VMRC as a seed area. The lower part of the river is normally infested with oyster drills.

The area at the mouth of the river has never been productive, probably due to predators and diseases. This opinion is corroborated by conversations with local oyster inspectors and watermen who state that the area has never produced significant amounts of seed or market oysters.

Private leases are restricted to a narrow band around the shore margins of the Piankatank and its tributaries.

None are located in the Bay. Nearly all the central portion of the lower Piankatank River is occupied by Baylor Survey Ground. It seems remarkable that with such a small area available for leasing, there are still 3,446.5 acres held by 374 lessees. There are 66 riparian holdings in the area totaling 31.2 acres.

Half of the bottom in this district is held in small units and 46.1% of all leased ground or 1,599 acres consists of units of less than 20 acres held by 87.9% of the lease holders. There is only one lessee with over 100 acres and this holding consists of 117 acres.

<u>Mobjack Bay and Horn Harbor, Districts 8 and 10</u>

Baylor Grounds consist of 24,634 acres of bottom in Districts 8 and 10, which is 10.1% of all surveyed public ground in the State. In general the public ground is located in two large blocks. One is located along the east-side of Mobjack Bay with narrow projections extending into the North and East rivers. A second large block is located on the western side of Mobjack Bay. Public grounds were set aside in the Severn with only six small plots located in the Ware River. Those in the North and East rivers are extensive. The pattern of distribution of these grounds is so odd that it is difficult to determine the rationale underlying their establishment, if there was one.

These surveyed public oyster grounds in Mobjack Bay were once productive (Ingersol, 1881). However, as long ago as 1914 they were producing few oysters (Galtsoff, et. al., 1947).

There are 612 lessees and 15,164.8 acres in District 8 and 10, which are combined for this discussion. Ninety-six riparian owners hold 47.1 acres in the area.

District 8 includes a small part of the north shore of the lower York River. This bottom in both districts is held in a similar way to that in the Rappahannock. Most of the acreage is held in large units which total 100 acres or more. In this category (100 acres or more) 17 lessees control 9,552.7 acres, or 63.0% of all acreage in the area. These lessees represent only 2.8% of the area total. There are a large number of lessees who lease bottom in units of 20 acres or less. In this catagory there are 526 lessees, or 85.9% of the total area, who lease 2,609.2 acres.

Prior to 1960 leased ground in Mobjack was most productive and was used by one of Virginia's largest oyster growers, based in Norfolk, as the principal planting area. Since MSX entered the Bay in 1959, there has been little production from Districts 8 and 10.

York River, Districts 9 and 15

Baylor Ground in the York River contrasts sharply in total acreage with that in the Rappahannock. When the Baylor Survey was conducted in 1894 only 3,850 acres of the York or 1.4 percent of the State total were considered of sufficient quality to be declared public oyster rocks (Table 4). The reason for this is not known. Perhaps the York has always produced fewer oysters (per year) than other river systems and this lack of natural productivity was the reason for the paucity of inclusion of its bottom acreage within Baylor's boundaries. Those Baylor Grounds which are there are situated discontinuously in the York with about 80.0 percent located in the lower-half of the river in broken strips adjacent to the deep main channel. Information exists in the literature concerning the depleted condition of public beds in the York after 1910 (Galtsoff, et al., 1947; Wheatley, 1959; Quittmeyer, 1957; and others). Possibly the decline in the public rocks occurred prior to 1900. There is evidence to support this. It was stated in 1881, "The York River . . . was once famous for its oyster beds, but now these are practically exhausted" (Ingersol, 1881).[8]

[8]The lower York has been the site of major military occupations since 1781. Large piles of oyster shells are associated with the Revolutionary War, Civil War and World War I periods. It is possible that feeding these concentrations of men, especially of the Civil War period, contributed to the harvesting pressures that brought the York River low. With low natural recruitment pulses of fishing pressure could well deplet an area below the level of recovery.

Private acreage for districts 9 and 15 is 13,079.9 acres which is held by a total of 367 lessees. There are 102 riparian holders totaling 49.3 acres. Most of the bottom in the two districts is held by lessees whose total holdings exceed 100 acres. Twenty-two lessees or 6.0 percent of the area total hold 10,050.3 acres, or 76.8 percent of all leased acres in the area. As in many other areas, there are many individuals who hold 20 acres or less. In this category there are 304 individuals or 82.8 percent of the lessees in the two districts. Acreage involved in this latter category was small, amounting to 1,319.7 acres or 10.1 percent of the leased acreage in these districts.

Two large industrial organizations own a significant percentage of the private ground in the York River making it unique in respect to all other Virginia river systems. The Chesapeake Corporation, a large pulp and paper company at West Point, leases 2,838.6 acres. An additional 826 acres are leased by two executives of the Chesapeake Corporation. A Virginia holding company leases 1,161.9 acres for an oil refinery, whose headquarters are located in another state. Total acres held by these two companies (1970) are 4,000.5 acres or 30.6% of all leased ground in the two districts.

In the past the holdings of the Chesapeake Corporation in the York River were subleased to a private corporation known as the York River Oyster Corporation. At one time this company produced oysters on racks under the trade name Sea Rac Oysters. However, around 1972 this company became inactive and about 1974 a second company which produced oysters subleased an unknown portion of these bottoms from the Chesapeake Corporation.

It is our understanding that the lease held by Waterview Oyster Company (the American Oil Company) has never been used for active oyster culture on a commercial scale.

Poquoson River, District 16

Baylor Ground in the Poquoson River covers 7,824 acres or 3.2% of the State total. Only 1,654 acres were considered of sufficient quality to be included in the original survey of 1894. However, in 1958, 6,170 acres were added by legislative action (Table 2). A portion of the public grounds in this area are located in the lower fourth of the Poquoson River. In the opinion of the local watermen and oyster inspectors the public rocks off the mouth of the Poquoson River have never produced appreciable quantities of market oysters and no seed. In view of their low natural and commercial productivity, it is difficult to determine why 6,170 acres were added in 1958. It is possible that the grounds added were intended as public clam grounds since hard clams are abundant in the region or they may have been added at the request of local independent watermen who wished to favor themselves or excluded potential leasing.

Private leases in this district total 3,447 acres and are held by 130 lessees. Private leases exist upriver from the Baylor Grounds and in the open Bay. Some of these "off-shore" grounds are still leased to the Ballard Fish and Oyster Company which used them for large-scale plantings prior to the 1960 outbreak of MSX. There are 34 riparian holders in the district who hold 16.1 acres.

Most of the acreage in this district is held in units totaling 100 acres or larger by three lessees, or 2.3 percent of the district total. This number "owns" 2,713 acres, or 77.7 percent of all leased ground in the district. As in all other districts, there are many lessees who hold grounds in units of less than 20 acres. In this division there are 121 lessees or 93.1 percent of the district total holding 509.8 acres, which is 14.8 percent of the district total.

James River, Nansemond and Back River Systems, Districts 17, 18 19, 20 and 21

Baylor Grounds in the James, Nansemond and Back river systems total 27,841 acres or 11.4 percent of the State total. For discussion the area within the James River system is divided into two units which are: 1) those bottoms in the lower river below the James River Bridge, Districts 17, 20 and 21; and 2) those above, Districts 18 and 19 (Figure 14).

The Baylor Grounds in the lower James begin at an imaginary line extending from above Pig Point across the river to Newport News Point (Figure 2). It occupies the southwest or Portsmouth side of the James opposite the main channel in three large blocks, one of which extends for a short distance into the Nansemond River. In general these public bottoms begin from one-half to one mile from the southside shore. Well-known and formerly productive oyster rocks included in this area are Nansemond Shoal, Ballards Rock, and Naseway Shoal. Most of this public ground today is only marginally productive.

Extending in an upriver direction the second large block of public grounds in the James system begins on the northeastern shore or Newport News side of the James as a narrow strip above Newport News Point. This strip gradually widens until it occupies most of the central reaches of the James River between the Pagan River and Mulberry Point. This mid-river portion was in the past and is today very productive. Most of the seed and a large portion of the soup oysters harvested from the public rocks of Virginia come from this section. It is emphasized again--seed oysters from this part of the James are a basic need of the private oyster industry. Without seed from this source (or another which could produce seed in equal volumes and time), the industry would largely cease to exist.

The principal oyster rocks above the James River Bridge, presented in the order of their upriver location, are: Brown Shoal, Dog Shoal, Thomas Rock, White Shoal, Wreck Shoal, the Swash, Rainbow Rock, Horse Head Rock, and Deep Water Shoal. The public grounds in the upper river as in the lower river begin far off shore. On the northeast side they start about one-half to one-third miles off, and on the southwest side they begin from one-and-one-half to three-quarters of a mile off.

Private grounds in this area total 16,904.5 acres or 14.8% of the State total. Some of this ground is located in Hampton Roads but large acreages are held above the James River Bridge. Addition of new leases above the James River Bridge is no longer permitted. This regulation was adopted in 1952 by an act of the General Assembly and was embodied in the Code of Virginia as Section 28-201-1. Leases in existance prior to 1952 were allowed to remain in effect.

There are 62 riparian owners holding 25.4 acres in this area.

Most of the oyster grounds in these five districts are held in units which exceed 100 acres. There are 11,387.4 acres or 67.4% of all leased land in the area in this size range. This total is held by only 35 persons or 8.1% of the lease holders. In the division of 20 acres or less there are only 1,629.3 acres or 9.6% of all the leased land in the area. This land is held by 311 persons or 71.8% of those holding leases. Evidently most of this bottom acreage is held in units which favor large-scale "farming." A large percentage of the acreage in the James in Hampton Roads under private lease is influenced by MSX and has not been productive since the early 1960's.

Eastern Shore--Bayside, Districts 24 and 26

Baylor Grounds on the Bayside of the Eastern Shore contains 15.0 percent of the State total and 9.8 percent of all private leases. Most of the surveyed public oyster rock in these two districts is located in Pocomoke Sound. There is one large block of several thousand acres in this area which touches the Maryland-Virginia border. Surrounding it are scattered small plots between Tangier and Watts islands and the Eastern Shore. There is little surveyed public ground in the creeks to the south of Pocomoke Sound. Creeks in which public grounds are located are: Occohannock, Nassawadox, and Pungoteague. The absence of public grounds in the other creeks suggests that they were either unproductive in 1894 in respect to the occurrence of natural oyster rocks. Perhaps a number of productive oyster rocks were not charted. Whatever the cause, most of this public ground in these two districts is depleted and produces few oysters.

Private ground in these two districts contained 11,198 acres which are held by 492 lessees. There are 20 riparian holders in the entire area controlling only 9.3 acres. All of 5,186.7 acres or 46.3 percent of the total were held in units of 100 acres or more by 19 lessees. This latter figure was 3.8 percent of the total. There were 388 lessees or 78.9 percent who held 2,279.6 acres or 20.4 percent in units totaling less than 20 acres.

Eastern Shore--Seaside, Districts 25, 28 and 29

Baylor Grounds on the Seaside of the Eastern Shore as a unit contain 18.3 percent of all public oyster grounds in Virginia. The 44,591 acres are scattered in large and small blocks all the way from Cape Charles to Chincoteague Bay.

The vast acreages set aside on the Seaside of the Eastern Shore in 1894 suggest that the area was highly productive at the time. This fact is substantiated by a number of authors who mention the extremely heavy sets in many Seaside localities (Loosanoff, 1932; Mackin, 1946; and others). This entire area today produces few oysters.

Private acreage on the Seaside total 17,644.1 acres leased to 464 lessees in three separate districts. For all of its extensive shoreline, only twenty-nine riparian owners hold a total of 13.2 acres.

In the three districts 1,908 acres or 10.8 percent of all leased ground was held in units which totaled 20 acres or less. These leases were held by 345 lessees or 74.4 percent of all those leasing bottoms in the district. Most of the leased bottoms were held in units totaling 100 acres or larger. In this latter category there were 12,628 acres or 71.6 percent of all that held in the district. This was held by 41 lessees which represented 8.8 percent of those holding leases in the three districts.

Lease Size As a Factor in Oyster Production

While there are many lease holders in Virginia, only a relatively few hold leases whose total size exceeds 100 acres. In searching for a reason for today's low oyster production and harvest, we will next investigate the question: Are most leases being held in units or blocks whose size is such that they cannot return an adequate income at today's inflated costs and prices?

Data relevant to this question are largely lacking. We may, however, examine the problem in a limited manner by recognizing several points and making several assumptions.

One fact we must recognize initially--our data give no indication as to whether or not the leases held by a specific lease are contiguous. For this presentation, therefore, we will recognize the obvious point that adjacent leases may be "farmed" more economically than similar acreages separated within a river system. We believe that the over-riding point is not the locating of one piece of leased ground in respect to another, but that there must be a certain critical size of total holding necessary to return an adequate income. For example, no grower can make an adequate living from 1 or 2 acres, therefore, total acreage will be given special attention.

In developing other points necessary to discuss lease size, we must draw on material presented in later sections of the paper. These data will be outlined immediately below to provide a basis for these discussions. A full treatment will be given in the appropriate chapters. These basic points follow:

1. In Virginia in 1970, a grower could average a return of about 1.0 bushel of market oysters for every planted bushel of seed (Table 9).
2. The average gross return in 1969-70 and 1970-71 seasons on a bushel of market oysters from the Rappahannock was $2.17 (calculated from Tables 62 and 64). This is a maximal value based on sale price of market oysters, cost of seed planted, and harvest cost. Many other expenses, such as taxes, overhead, interest and labor are not included.
3. Growers planted an average of about 750 bushels of seed with a range of from 500 to 1,000 bu/acre.
4. It is assumed that it takes, on the average, 3 years to grow a crop of market oysters (Chapter VIII). Therefore, on a sustained basis with all bottoms planted, a grower cannot expect to realize more than one-third of the total sale value of the oysters on his grounds.

After making the preceding assumptions, and using data presented previously, we may then develop estimates of "approximate annual income" for the following categories of holdings: 0.1 to 20 acres, 20-100 acres, and over 100 acres.

Table 9

Virginia Private Market Oyster Harvest Compared to Total Virginia Seed Planted
1932-3 thru 1974-5

PRIVATE MARKET Oysters[1] Season	Quantity (Va. bu.)		TOTAL SEED[2] Quantity (Va. bu.)		Season	RATIO[3]	
1932-3	1,402,231		1,619,063		1930-1	0.87	
33-4	1,689,860		1,586,061		31-2	1.06	
34-5	1,871,116		1,507,268		32-3	1.24	
35-6	1,993,418		2,057,991		33-4	0.97	
36-7	1,230,304		1,835,810		34-5	0.67	
37-8	1,458,308		1,254,733		35-6	1.16	
38-9	1,834,298		729,401		36-7	2.51	
39-40	2,057,271	13,536,806	986,081	11,576,408	37-8	2.09	1.17
1940-1	2.092,864		814,979		38-9	2.57	
41-2	1,794,363		930,860		39-40	1.93	
42-3	---------		890,592		1940-1	----	
43-4	---------		932,699		41-2	----	
44-5	1,906,500		---------		42-3	----	
45-6	2,346,535		---------		43-4	----	
46-7	1,953,155		1,628,352		44-5	1.20	
47-8	2,517,992		2,391,011		45-6	1.05	
48-9	2,423,447		2,118,633		46-7	1.14	
49-50	2,034,097	12,815,953	2,130,229	10,014,064	47-8	0.95	1.28
1950-1	1,969,207		2,438,281		48-9	0.81	
51-2	2,259,970		2,405,646		49-50	0.94	
52-3	2,372,742		2,665,658		1950-1	0.89	
53-4	2,951,458		2,258,120		51-2	1.31	
54-5	2,766,137		2,200,411		52-3	1.26	
55-6	2,820,318		2,794,763		53-4	1.01	
56-7	2,601,353		3,184,851		54-5	0.82	
57-8	2,926,750		2,738,891		55-6	1.07	
58-9	3,347,170		2,997,595		56-7	1.12	
59-60	2,535,275	26,548,380	2,472,212	26,154,428	57-8	1.02	1.02

Table 9 (Contd.)

PRIVATE MARKET Oysters[1] Season	Quantity (Va. bu.)		TOTAL SEED[2] Quantity (Va. bu.)		Season	RATIO[3]	
1960-1	2,237,736		1,911,211		1958-9	1.17	
61-2	1,815,001		2,588,469		59-60	0.70	
62-3	906,243		1,481,576		1960-1	0.61	
63-4	1,288,093		1,656,104		61-2	0.78	
64-5	1,647,645		941,338		62-3	1.75	
65-6	1,273,888		959,148		63-4	1.33	
66-7	725,453		681,522		64-5	1.06	
67-8	840,749		997,744		65-6	0.84	
68-9	650,445		837,579		66-7	0.78	
69-70	818,943	12,204,196	764,088	12,818,779	67-8	1.07	0.95
1970-1	836,014		591,548		68-9	1.41	
71-2	928,404		493,728		69-70	1.88	
72-3	394,121		673,001		1970-1	0.58	
73-4	424,277		421,398		71-2	1.01	
74-5	491,860	3,074,676	446,104	2,625,779	72-3	1.10	1.17
					1946-7 thru 1974-5	1932-3 thru 1974-5	
	Correlation Coefficient				0.91	0.82	
	Ratio of Market to Seed				1.04	1.13	

Notes:

1. Data for 1932-3 thru 1961-2 from Fish. Stat. U.S. NMFS. Later data from VMRC. This combination of data gives the most accurate landings available.

2. Data for 1930-1 thru 1961-2 from Fish Stat. U.S. NMFS. Later data are VMRC figures for public seed sold by tongers + NMFS data for private harvest of seed; they are used in preferance to the NMFS total figures because they are believed to be more accurate, and they are larger in most years than NMFS figures for total seed. Figures shown in this column are actually the quantities of seed harvested; use of these figures is based on the safe assumption that this was the quantity planted and that exports and seed planted by the state on public rocks before 1962-3 was relatively small. The figures in this column have been offset two years from those in the previous column because oysters are harvested for market roughly two years after the seed are planted.

Table 9 (Contd.)

3. Ratio shows the number of bushels of market oysters harvested per bushel of seed planted by private growers.

0.1-20 Acres

In the 0.1- to 20-acre category, there are 4,104 lessees which comprise 83.1 percent of all those "owning" grounds. These individuals or companies rent only 16.9 percent of the entire leased acreage in Virginia (Table 8). The average size of all leases in the 0.1- to 20-acre classification as calculated from Table 8 is only 4.7 acres! Based on preceding data on possible yield under current average methods of culture, leases in this category would return on an annual sustained basis the following theoretical income:

4.7 (acres X 750 bushels/acre) X \$2.17/bu = \$7,649

Assuming only one-third of the ground to be productive during a single year, because of the time required to secure suitable growth (about three years), the maximum that might be expected on a sustained basis would be \$2,550 annually. This is clearly inadequate as an individual's or a company's sole source of income.

20-100 Acres

In the 20- to 100-acre category, which earlier was thought to be marginal as far as producing sufficient income to sustain an individual producer, 26,508 acres were held by 627 companies or individuals. These lessees comprise 12.7 percent of all those in the State or about 23% of the leased bottom. The average of total holdings in this size range was 42.3 acres (Table 8). Average leaseholds in this category would return on an annual sustained basis the following gross income:

42.3 (acres X 750 (bushels/acre) X $2.17/bu = $68,843

Assuming only one-third of the ground to be harvestable during any single year, except in emergencies, the most that might be expected on a sustained basis would be about $22,948 annually. This gross is thought to be insufficient or marginal as a sole source of income for an individual or a company, since it does not include overhead, interest, labor costs, etc. Also, all of the bottoms under lease by any one producing unit may not be productive.

Leases 100 Acres or Larger

There are a total of 68,079 acres in Virginia held in units of 100 acres or larger; these acres are held by 209 lessees (Table 8; Figure 16). That is, on the average, in 1970, 4.2 percent of the lessees in the State controlled or "owned" 59.8 percent of the State's leased acres. Average total size of each holding (calculated from Table 8) was 326 acres. These large holdings are fairly typical of many of the good growing areas in Virginia. It is recognized, however, that some good growing areas, which are free of MSX, contain few leases with holdings of this size. For example, the Corrotoman contains no leases over 100 acres. The Piankatank has only 3.4 percent of its average in units over 100 acres; the Little and Great Wicomico and one of the Potomac River tributaries have from 23 to 32 percent of their leases in units over 100 acres.

Based on an average total holding of 326 acres, calculations show:

326 (acres X 750 (bushels/acre) X $2.17/bu = $530,565

If all land involved in each was used, these leases would gross on an annual sustained basis one-third of this amount of $176,855. This is clearly a gross which might be expected to net an adequate income after deducting expenses.

As outlined previously, no documented data are available on the extent to which leased ground is used. We have assumed total use as a basis of our "income per leased tract total" calculation. Watermen, growers, and oyster inspectors state, however, that seldom are all bottoms in a single lease used or even useable. As a consequence, our estimates of gross income shown in the preceding paragraphs are <u>clearly</u> <u>maximal</u>.

While the preceding assumption has shown that 40 percent of the leased acres in Virginia are held in units whose average total size would discourage their use as a source of full-time income, there is every reason to expect that these small leases can be and are used for oyster culture. For example, a farmer might work his lease in winter, a person holding a regular job might "work" his lease on weekends, a marine operator might also raise oysters on the side and a processor or restaurant owner might grow his own in a "vertically integrated" business operation. The extent to which these types of activity took place in the past and are taking place today is an important but unanswered question. Considering the lack of public data and of available private records on this point, the Commonwealth probably never will have this important information unless a definite program is instituted to obtain it.

A person may utilize leased land belonging to others. This process is known as subleasing. No information is available on costs associated with subleasing, but very limited information obtained from various growers suggests that the added expense would probably further reduce the already narrow margin of profit so that the practice would be less profitable than utilizing his own grounds.

Probably the utilization of small leases was extensive in the past. It is likely that during the past decade as labor and seed costs increased and as other job opportunities in the State increased, the smaller and less productive leases have been used to a lesser extent. This aspect may be an important reason for the decline in the total oyster production in Virginia in the past ten years.

Increasing Leasing Fees

Several aspects of leasing need special consideration. The first is that the present leasing rate of $1.50 per-acre-per-year is too low considering the rights obtained by lessees and the potential income from these public lands which can be realized by lessees. It should be raised by a significant amount. This would provide more income for State repletion activities and would compensate for the increased administrative costs which have risen sharply due to inflation.

The increased leasing fee would also help prevent retention of productive grounds by lease holders who hold these bottoms with no intent of using them. Low fees encourage misuse, i.e., occupancy without intent to grow oysters, and the possible exclusion of those who wish to grow them. Other recommendations relating to these important points are discussed in Chapters VII and XII. It is further recommended that proof of use of leased bottoms be a condition for holding a title to it.

Summary

Baylor Grounds

A basic cornerstone of Virginia's Oyster Industry was established in 1892 by an Act of the General Assembly. It was decreed that the natural oyster beds, rocks, and shoals in the State were not to be leased, rented or sold, but were to be held in trust for the benefit of the people of the State. A study establishing the bounds of the natural rocks was completed by Lt. James B. Baylor, U.S.N., under auspices of the U.S. Coast and Geodetic Survey in 1894. Unfortunately, this survey was quite superficial and relied only on the opinions of local officials and did not include an examination of the density of oysters on the bottom. These designated areas probably incorporated large sections of unproductive bottoms which has caused a great deal of controversy since.

With the exception of a single study made in 1910 in the James River and one underway by VIMS, there never has been an adequate quantitative study to determine the extent of productive[9] and unproductive bottoms within the bounds of the Baylor Survey.

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[9] The major effort in this study is to determine extent.

The original acreage set aside by Lt. Baylor was 210,476.7 acres. This was increased in subsequent years until 243,271 acres were involved by 1958. The largest tracts of Baylor Grounds exist in the Rappahannock River followed by the Eastern Shore and then the James. These and the remaining public bottoms are administered and supervised by the Virginia Marine Resources Commission whose offices are located in Newport News, Virginia.

The Baylor Grounds may be "fished" commercially by persons paying the necessary license fee and a tax based on bushels harvested. The seasons for harvest and other legal aspects of the fishery are clearly stated in the Code of Virginia. Not all are soundly based or necessary! The Baylor Grounds are divided into districts.

Private Leases

The practice of growing oysters on "private" bottoms has existed since the mid-1800's, even before the Baylor Survey, but the arrangement under which private operations occupied these bottoms was informal and probably amounted to an individual or company simply occupying unused bottom. It was not until 1892 that provisions were made for leasing growing areas outside the bounds of Baylor Grounds. By 1900, 47,803 acres were leased and this increased to an all time high of 134,492 acres in 1967. Leased acres have declined since then, until by 1975 only 100,662 acres were leased.

The cost of leasing bottoms is very low. In the Bay, it is 75 cents per-acre-per-year, while on the Seaside and in the rivers it is $1.50 per-acre-per-year. This cost has remained virtually unchanged since 1926. In view of today's inflated costs and the need for more money for the State management program, the possibility of increasing it should be studied by the appropriate agencies.

It is emphasized that most of the bottoms leased by private growers are not, by and large, naturally productive since those known to have produced oysters historically (hence, the best natural producers) were included within the Baylor Survey. As a consequence of this selectivity by Lt. Baylor and his successors, most leased bottoms must be planted with seed oysters before they will produce.

Riparian Rights

The Code of Virginia has made provisions so that property owners holding more than 105 feet of land on tidal waters may apply for a riparian right up to half an acre of oyster ground. There were 337 recorded acres in 1970 classed as riparian leases. These holdings contribute virtually nothing to commercial oyster production of Virginia.

Distribution of Private Leases

Locations of all leased bottoms are one file at the Virginia Marine Resources Commission which maintains charts on plots of each lease.

Not only do the leased bottoms of the State occupy the marginal areas outside the large blocks of bottom Baylor Ground, but for the most part, they are irregular in shape. Our study showed that in 1970 there were 4,940 persons and companies holding leases. Eighty-three percent (83%) of these lessees held bottoms whose total size was less than 20 acres; average size of each holding was only 4.7 acres! In contrast, the larger acreage of 100 acres or more were held by a very few companies or individuals. That is, 4.2 percent (or 209) of the lease holders held title to 68,079 acres. This was 60 percent of all the leased bottoms in Virginia.

Income from Leased Bottoms

Most of the total holding of leased bottoms were held in units which were too small to provide the sole income of an individual or a company. It was shown that 40 percent of all the leased acres in the State are held in units whose average size would discourage their use as a source of full time income. The extent to which the smaller lease holders "use" their bottoms in their part-time oyster-related activities is unknown.

Other Aspects

It is strongly recommended that a more comprehensive study of lease use and productivity be undertaken. According to the Code, grounds leased for oyster production are supposed to be utilized for this purpose.

If oyster production, or production of other shellfish, is to be encouraged in Virginia, it is important that suitable grounds for culture not be held by persons or organizations who have no intention of growing oysters. The present fee structure is set so low that there is little incentive for unused or unproductive land to be released for use by others or for other uses. Of course, we do not wish to discourage those legitimate uses other than oyster culture such as culture of hard clams or other commercial species of molluscs or public projects, etc.

The first rule of good agricultural management (which is what oyster culture by private planters is) is to keep good records and have detailed knowledge of the productivity of each productive unit. The necessity of good records seems so obvious as to require no exposition. Unfortunately, few planters have maintained careful, specific records of the productivity of their respective holdings. The State has been little better until recently. Better records are necessary on both the public and private sectors.

An important adjunct of increased production would be development of appropriate culture strategies which would take advantage of the characteristics of an individual planter's holdings, his capabilities and of the general area (i.e., Seaside with its drills and the lower Bay with its MSX disease). To develop such strategies greater knowledge of the characteristics of the various types of bottoms, productivity of leases, conditions of productions and other relevant functions are needed. The State and the industry should set about developing such knowledge rapidly.

CHAPTER III

OYSTER PRODUCTION IN VIRGINIA--
PAST AND PRESENT

CHAPTER III. OYSTER PRODUCTION IN VIRGINIA--PAST AND PRESENT

Introduction

Although this chapter is primarily about oyster production it first deals in detail with the tax structure of the Virginia oyster industry since the tax revenues provide the basis for production data.

The tax data result from records established when the tax levied by the State on processed or landed oysters is paid. This information is filed at the VMRC office at Newport News, Virginia.

An oyster tax was first levied in 1926 when market oysters from public and private grounds became subjected to taxation by State law. Beginning at this time it became possible to estimate landings based on the magnitude of this tax. Until we did so for this report, tax revenue data from 1931 to 1962 had not been translated into bushels taxed. Beginning in 1963, however, the Commission annually published oyster production data based on oyster buyers' reports. Since then production in bushels has been reported regularly in reports submitted by the buyers. They provide the basis for estimates without conversion. It is stressed--these are considered minimum estimates; even with the last major revision in the methods of obtaining tax information in 1975, there are no regular efforts to verify the completeness or validity of the buyers' reports. It is the buyer who records the information on the forms and there is no consistently applied check on the figures involved. Despite these drawbacks information on oyster production data is regarded as much more reliable than other fisheries data regularly available in the State.

Additional Sources of Data

Two additional sources of information on landings are used in this report other than that available from VMRC. After describing them we can consider the implications of the data reported. These additional sources are:

1. Virginia Landings--Another office of the NMFS in Virginia Beach, Virginia, publishes monthly as well as yearly summaries of landings of oysters in Virginia by region. These data are published soon after they are collected. They are based, at least in part, on the tax information held by the VMRC. They are not regarded by the NMFS as absolutely correct and are subject to revision as outlined in the next paragraph. Furthermore, except for broad regional areas presented in the data, nothing is discernable about the specific point of harvest.

2. Fisheries Statistics of the United States--These data are tabulated by the regional offices of the NMFS at Easton, Maryland, and in Washington, D.C., and are published three or four years after collection. In respect to oyster production in Virginia, the data are largely based on "Virginia Landings." The final tabulation several years later in Fisheries Statistics of the United States seldom agree since additional sources of information necessitate revision of the production figures in the latter publication. Again, while reports are identified by broad regions, specific points of production are not indicated.

Interpreting Data

Care must be exercised in interpreting the true significance of changes in the records of landings (data on production published by NMFS or the VMRC). Increases or decreases in landings from public rocks are not necessarily related to the actual quantity of oysters on the bottom. A public oyster rock may maintain (biologically) a constant rate of productivity over the years. The quantity of oysters harvested (production) from that oyster rock, however, will, within limits, depend on the fishing effort which may vary with economic factors like demand or market, availability of labor, labor costs, cost of equipment, weather, as well as with the available supply of oysters.

In contrast, landings from private leases do indicate that which existed on the bottom. On private leases, the growers usually plant their bottoms with seed oysters at considerable expense, and, barring some natural castastrophe or disease, must harvest as much of their crop as possible to regain their original investment and assure a profit. Stated in another way--leased bottoms usually are not naturally productive, and what exists on them as a crop is usually planted. Harvest may be delayed a year or two but harvest at some date is a necessity if the expenses of planting are to be recovered, profits are made, and the grower is to remain in business.

In developing concepts of production for this study, the basic question needing immediate answers was: In presenting Virginia production, should the basic VMRC data be used or should those tabulated in the annual reports of Fisheries Statistics of the United States be considered as representative? Are they in reality the same, and if not, which are the most accurate? An inspection of the annual reports of the NMFS was of little help in answering this question. As noted in these reports beginning with 1938 NMFS-acquired data were "augmented" by VMRC tax data, and from 1962 on, that VMRC data were used as the basis of their annual reports (BCF & NMFS, 1938-1962).

The first decision made in relation to our current investigation of oyster production was that the basic landing data would be shown in terms of the biological year and not by the calendar year. To secure such a biological-year estimate, one must add the NMFS data for the fall of one year to those for the following spring. Oyster landings presented this way correspond with the oyster season which generally begins 1 October and ends in late spring on 31 May or before.

Additionally, we decided that production figures would be presented in terms of Virginia bushels. The Virginia bushel (3003.9 cubic inches) differs in volume from the U.S. bushel (2,150.4 cu. in.) which the Federal Government uses in reporting landings in the publication Fisheries Statistics of the United States. Both bushels differ from that used in Maryland (2,800.7 cu. in.). Conversion factors recognized by statisticians are used to convert from one "bushel" to another (Table 10). These conversions were made in order to avoid being mislead by superficial comparison of statistics from Federal sources which use the smaller U.S. bushels with

Table 10

Conversion Factors Used in this Study

Units Given	Units Desired	Action Taken
U. S. Standard bushel	Virginia bushel	U. S. bushel multiplied by .716 since the volume of a U. S. bu. is 2,150.4 cu. in. and that of a Va. bu. is 3,003.9 cu. in. Ex: 100 U. S. bu. x .716 = 71.6 Va. bu.
Maryland bushel	Virginia bushel	Md. bu. multiplied by .932 since the volume of a Md. bu. is 2,800.7 cu. in. and that of a Va. bu. is 3,003.9 cu. in. Ex: 100 Md. bu. x .932 = 93.2 Va. bu.
Pounds of shucked meats	U. S. Standard bushel	Lbs. divided by factor "Average Weights of Shellfish" listed in each volume of <u>Fish. Stat. U. S.</u> Ex: 420 lbs ÷ 4.20 = 100 U. S. bu.
Pounds of shucked meat	Virginia bushel	Performed above action and multiplied by .716 (When an approximate figure was desired lbs. were divided by 6). Ex: 600 lbs ÷ 6 = 100 Va. bu.
Gallons of shucked meat	Pounds of shucked meat	Gallons were multiplied by 8 since there are 8 pints in a gallons and approximate 1 lb. in a pint.
Calendar Year	Virginia Oyster Season	Since quantity and value of oyster catch is given in <u>Fish. Stat. U. S.</u> for Fall and Spring of each calendar year, the Fall of one calendar year was added to the Spring of the following calendar year to get data for a season.

those obtained from the VMRC which use larger Virginia bushels. To avoid such confusion all data on bushel production from the annual reports of the NMFS have been converted into Virginia bushels.

Production data are also shown in the Fisheries Statistics of the United States in gallons and pounds and in many instances these are converted by the NMFS into U.S. bushels. Unfortunately, conversion of pounds or gallons of shucked meats to bushels is often inaccurate! This is because the factors used in making conversions are based on averages. Most oysters sold commercially in Virginia average about 6.0 to 6.4 pints of meats per bushel, and values between these average values are used by the U.S. Bureau of Commercial Fisheries to convert bushels to pounds or pints (Wheatley, 1959). An example of the possible range of variation follows: In years when the yield or quality of oysters is poor, yields of meats would be poor--less than six pints per bushel. Consequently, the calculated total oyster harvest in bushels would be less than the actual landings. Conversely, when oysters were of very good quality, with yields of about eight pints per bushel, the calculated landings in bushels would be about 25.0% too high.

It would be advisable if those responsible for using those conversion factors would use more representative data which would be determined annually.

Virginia Tax Data

Changes in Tax Arrangements Over the Years

The taxes imposed by the Commonwealth of Virginia on oysters landed or processed in Virginia have gone through many changes since they were first started in 1926. The method of collection, however, has remained virtually unchanged (Table 11). The basic structure of the system has always been that the processors or persons in the oyster business are required by law to keep written records, and tax is collected on the basis of these records. However, the State does not monitor landings nor does it monitor production from the shucking houses to determine if records submitted by companies or individuals are correct. Without such checks it is, of course, impossible to determine the validity of the records! It would be surprising if violations did not occur but it is sufficient to indicate that unaudited records are seldom considered reliable indicators where careful management is intended.

A tax was first imposed in 1926 on market oysters harvested from public rocks (Code of Virginia, 1924 and 1926--Supplement 3247 A) and was known as the Inspection Tax. It was collected monthly by inspectors who kept ten percent

Table 11

Tax Rate on Oysters for Selected Years in Cents*

	1926	1931	1936	1941	1952	1962	1966	1970	1972	1976
A. Oysters taken from Virginia waters.										
1. Inspection Tax										
Private Grounds										
on bushels	1	2	1¼	1	1	1½	1½	1½	1½	3
on gallons	NR	NR	2	2	2	2	2	2	2	-
Public Grounds										
on bushels	1	2	1¼	1	1	1½	1½	1½	1½	3
on gallons	NR	NR	2	2	2	2	2	2	2	-
2. Replenishment Tax										
Public Grounds										
on bushels	NR	NR	NR	NR	-	See below**				-
3. Export Tax										
Public Grounds										
on bushels	3	8	2	2	2	2	20	20	20	20
B. Oysters Imported										
on bushels	NR	NR	NR	NR	NR	1½	1½	1½	1½	3
on gallons	NR	NR	NR	NR	NR	2	2	2	2	-

NOTES:

* Data for 1926, 31, 36, and 40 taken from reports of the Commission of Fisheries of Virginia for those years; data for 1952, 62, 66, 70, 72 and 76 taken from reprints of the Code of Virginia, Section 28, Laws of Virginia Relating to Fisheries of Tidal Waters.

** Tax on oysters taken from public rocks (Replenishment Tax)

	1962	1970
a) Oysters selling for $1.50 per bushel or less, tax per bushel	.03	.05
b) Excluding the seed area of the James River; oysters selling for $1.50 per bushel or less which are caught or taken from any public grounds where the State has planted shell, tax per bushel	.03	.10

Table 11 (contd.)

	1962	1970
c) Oysters selling for $1.51 through $2.50 per bushel, tax was	.10	.10
d) Oysters selling for $2.51 through $3.50 bushel, tax was	.15	.15
e) Oysters selling for $3.51 through $4.50 bushel, tax was	.20	.20
f) Oysters selling for $4.51 through $5.50 bushel, tax was	.25	.25
g) Oysters selling for $5.51 or more per bushel, tax was	.30	.30

NR. No record of tax found.

to supplement their pay.[1] The tax collected was then reported to VMRC by inspectors whose jurisdiction was over specific districts (Figure 11).

The law was amended in 1928 to require purchasers or buyers to keep strict, accurate account of all oysters handled in a book which at all times must be open for inspection.

Several changes were enacted in 1930 when the Inspection Tax was expanded to include market oysters from private as well as public beds, and the inspectors were no longer allowed to keep 10% of the amount collected. Taxes were forwarded to the Commission in Newport News and recorded (Code of Virginia, 1930-3247 A). There was little change in the Inspection Tax until 1936 when the law was amended to allow the processors to pay a tax of two cents a gallon on shucked oysters, or one and one-half cents per bushel, as they choose (Code of Virginia, 1936). The gallon tax was dropped in 1975 and an inspection tax of three cents per bushel was imposed on oysters from public or private grounds and on imported stocks. The time for paying the three cents a bushel tax was stipulated as being:

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[1]It might have been more accurate than some of the systems of collection which followed immediately after because of this!

Within the first five days of each month immediately following that in which oysters are shucked, barrelled, packed, shipped or marketed (Code of Virginia, 1950 and 1975 Supplement, 28.1-87).

The Repletion Fund--Reporting Tax

Beginning in 1928 a part of the proceeds from the Inspection Tax was set aside in a special fund called the Repletion Fund, which was established to provide monies to partially underwrite costs of public oyster repletion programs (Commission of Fisheries, 1928). The need for additional revenue for this fund resulted in the addition of a new tax called the Repletion Tax in 1952. This new tax was imposed on all seed and market oysters from public rocks (Code of Virginia, 1950 and 1952 Supplement, 28-102). The enactment of this law meant that:

1. Seed oysters from public rocks were taxed for the first time under the Replenishment of Repletion Tax.
2. Market oysters from public rocks now had two taxes:
   a. the "old" Inspection Tax;
   b. the "new" Repletion Tax;

   Where market oysters exported from the State, an Export tax would have to be paid.

3. Oysters from private beds were still subject to the same tax as previously, that is, they paid only the Inspection Tax.

The revised tax rates (Table 11) for oysters taken from public and private beds were clearly delineated in the 1952 to 1956 Cumulative Supplements for the Code of Virginia.

In respect to the Inspection Tax, the law of 1952 stated:

> A strict account of oysters taken or purchased as aforesaid shall be kept by the purchaser, planter, or packer, and the tax on the same shall be paid by the purchaser, planter, or packer . . . between the first and tenth day of such month . . . .All purchasers, planters and packers shall keep an accurate account and a complete itemized daily record of oysters barrelled, packed, shucked or marketed by them in a book . . . which . . . shall be at all times open for inspection by the Commissioner or any employee designated by him to inspect the same. . . . (Code of Virginia 1950 and 1952 Supplement, 28-102).

This change in the laws perpetuated a historic weakness in the productivity data. There was still no requirement to keep records on the origin of oysters in respect to rocks or beds or even to district or river system. This was a serious shortcoming for management.

In relation to the new tax on oysters from public ground the Code stated:

> There is hereby imposed a tax on all oysters taken from the public rocks. . . .The person

taking such oysters shall be liable for the payment of the tax and all persons buying such oysters in the State shall collect such tax and pay the same to the Commission. (Code of Virginia 1950 and 1952 Supplement, 29-137).

The taxes listed in the annual reports of the VMRC from 1952 to 1962 were: 1) The "old" Inspection Tax on public rocks; 2) Tax on oysters from leased grounds; 3) Tax for transporting oysters out-of-state (Export Tax); 4) Two cent per bushel tax (Repletion Tax).

Data on the Repletion Tax were reported by district in the 1952 to 1962 period, but the point of origin (the river system) of the oysters so taxed was not recorded. It is possible, however, to estimate James River seed production by assuming that all revenue reported as Repletion Tax for districts 18, 19 and 20, for the period 1952 to 1962 was for seed from the James River, since production of soups and market oysters during this period was insignificant. Few, if any, oysters were exported from the James in the period from 1952 to 1962. Therefore, exports are not a source of error in our basic assumption.

A major change in the tax structure was initiated in 1961 by a special "Seafood Study Commission" (Commission to Study and Revise Title 28 of the Code of Virginia: House Document No. 14, 1961). Recommendations made in this report by a committee of lawyers, scientists and seafood dealers resulted in legislation to increase the taxes on public grounds to levels ranging from 3 to 30 cents per bushel depending on their value. This was an effort to raise sufficient funds from the industry to help pay for the actual costs incurred in public management efforts. Prior to that time the token taxes required were totally inadequate. A second major change provided for in the law was that for the first time origin of oysters harvested from public rocks was required to be recorded in a special book kept by the purchaser.

A third aspect of the new laws was that information for the Repletion Tax had to be recorded in a special form known as the Buyer's Report provided by the Commission. This form showed dates, rivers, bushels, prices, and amount of tax (Figures 17 and 18). Unfortunately, it did not show the precise location where the catch was produced, i.e., rock. Copies of these reports were kept by the buyer and the Commission.

During 1975 the Buyer's Report Form (Figures 17 and 18) was discontinued and the new forms VMRC 53 and 55 substituted (Figures 19 and 20). On VMRC 53 is recorded the buyer's and the seller's name. If transactions are in cash the seller's signature is required. Other information required is: Sources of oysters from public and leased areas,

Figures 17 and 18

Oyster Buyer's Report Form (Front and Back) respectively.

C. F. 32 A

COMMONWEALTH OF VIRGINIA
COMMISSION OF FISHERIES

OYSTER BUYER'S REPORT
(SPECIAL PUBLIC OYSTER ROCK REPLENISHMENT FUND)

I, ______________________________ (Buyer), of ______________________________ (Address) do hereby certify and make oath that the following is a complete report of all oysters purchased by me from the PUBLIC GROUNDS to date, as required by Section 28.1-92 and 28.1-93 of the Code of Virginia. (See instructions and rates on reverse side).

DATE	NAME OF RIVER, CREEK OR BAY	AREA	BUSHELS	PRICE PER BU.	TAX RATE	TOTAL TAX

Given under my hand this, the ________ day of ______________________ 196____

____

BUYER

____

License Number

\- - - - - - -

I hereby acknowledge receipt for payment of ______________________ Dollars and ____________ Cents ($________) for the Replenishment Tax on the oysters reported herewith. If these oysters are to be transported after payment of the aforesaid tax, this receipt shall be carried in the possession of the master of the boat or operator of truck or other vehicle, and shall be exhibited upon request of any authorized officer of the Commission of Fisheries.

Given under my hand this, the ________ day of ______________________ 196____

______________________________ Dist. ____________

INSPECTOR

INSTRUCTIONS FOR SUBMITTING OYSTER BUYERS REPORT
(PUBLIC OYSTER ROCK REPLENISHMENT FUND)

On or before the 5 th day of each month, each oyster buyer shall send to the Commision a complete report of all oysters purchased the preceding month, on the obverse side of this form, setting forth the *date of purchase; the name of the river, creek or bay, and the general area from which taken; the total number of bushels; the price and the tax rate paid; together with all taxes collected,* as required by Section 28.1-92 and 28.1-93, Code of Virginia: Tax on oysters taken from public rocks, (replenishment tax)

(1) Oysters selling for $1.50 per bushel or less, tax per bushel .... .05

(2) Oysters selling for $1.51 through $2.50 per bushel, tax per bushel .... .10

(3) Oysters selling for$2.51 through $3.50 per bushel, tax per bushel .... .15

(4) Oysters selling for $3.51 through $4.50 per bushel, tax per bushel .... .20

(5) Oysters selling for $4.51 through $5.50 per bushel, tax per bushel .... .25

(6) Oysters selling for $5.51 or more per bushel, tax per bushel .... .30

All buyers of oysters from the seed area of the James River shall file with the Commission the complete report as specified in Section 28.1-92 and shall pay to the Commission the proper amount of taxes due and collected. Both the report and the taxes due shall be filed and paid to the Commission at the time they pass the inspection point located in the area and before leaving the area.

BE SURE TO SPECIFY YOUR OYSTER BUYER'S LICENSE NUMBER BELOW YOUR SIGNATURE.

All buyers of oysters elsewhere in this State shall complete this report and shall forward same, along with the taxes collected, to the Commission on or before the 5th day of each month.

The permit, or license of any person purchasing, buying or selling oysters taken or caught from Public Grounds who fails to comply with these requirements, shall be subject to revocation by the Commision. Any person who violates any provisions of Article 2 of the Code shall be guilty of a misdemeanor.

Figures 19 and 20

Oyster buyers forms from VMRC.

Forms 53 and 55, respectively.

Figure 19

SOLD BY

SOLD TO

Date

BUYER - COMPLETE SLIP FOR SALES BETWEEN A VIRGINIA HARVESTER AND A PURCHASER, PLANTER, PACKER OR SHIPPER. HARVESTER - COMPLETE SLIP WHEN MARKETING, PLANTING, PACKING OR SHIPPING OWN CATCH. SLIP MUST BE COMPLETED FOR EACH LOAD HARVESTED.

Date Caught	Check How Caught: 1. ☐ Shaft Tong 2. ☐ Dredge 3. ☐ Patent Tong 4. ☐ Other
Area Taken-See Map	Check How Oysters To Be Used: 1. ☐ Seed 2. ☐ Shucking 3. ☐ Soup 4. ☐ Export

TYPE	NO. OF BUSHELS	PRICE PER BU.	AMOUNT
Public Grounds			
Private Grounds			
TOTAL			

Name or Number of Seller's Boat

Seller's Signature*

*Seller Must Sign If Paid In Cash

A 000999 **COMMONWEALTH OF VIRGINIA MARINE RESOURCES COMMISSION** MRC-53 BUYER'S COPY

Figure 20

Sold By

Sold To

Date

SLIP MUST BE COMPLETED BY THE BUYER ON ALL PURCHASES OF UNSHUCKED STOCK FROM OTHER PURCHASERS, PACKERS OR SHIPPERS OR WHEN UNSHUCKED STOCK IS IMPORTED INTO VIRGINIA. COMPLETE ONE SLIP FOR EACH TRANSACTION.

TYPE	NO. OF BUSHELS	PRICE PER BU.	AMOUNT
Public Grounds			
Private Grounds			
Imports			
TOTAL			

IMPORTS ONLY: HARVESTED IN

1. Potomac River
2. Other: ____________ (Name of State)

Seller's Signature

A 016421 **COMMONWEALTH OF VIRGINIA MARINE RESOURCES COMMISSION** MRC-55 BUYER'S COPY number of bushels purchased and bushel price, total bushels, the gear used to harvest oysters, the name or numbers of the seller's boat, the date caught, and the area where the oysters were harvested. Information on the area of harvest is identified by the applicable number. A chart issued by the Commission designates harvest areas by number (Figure 21).

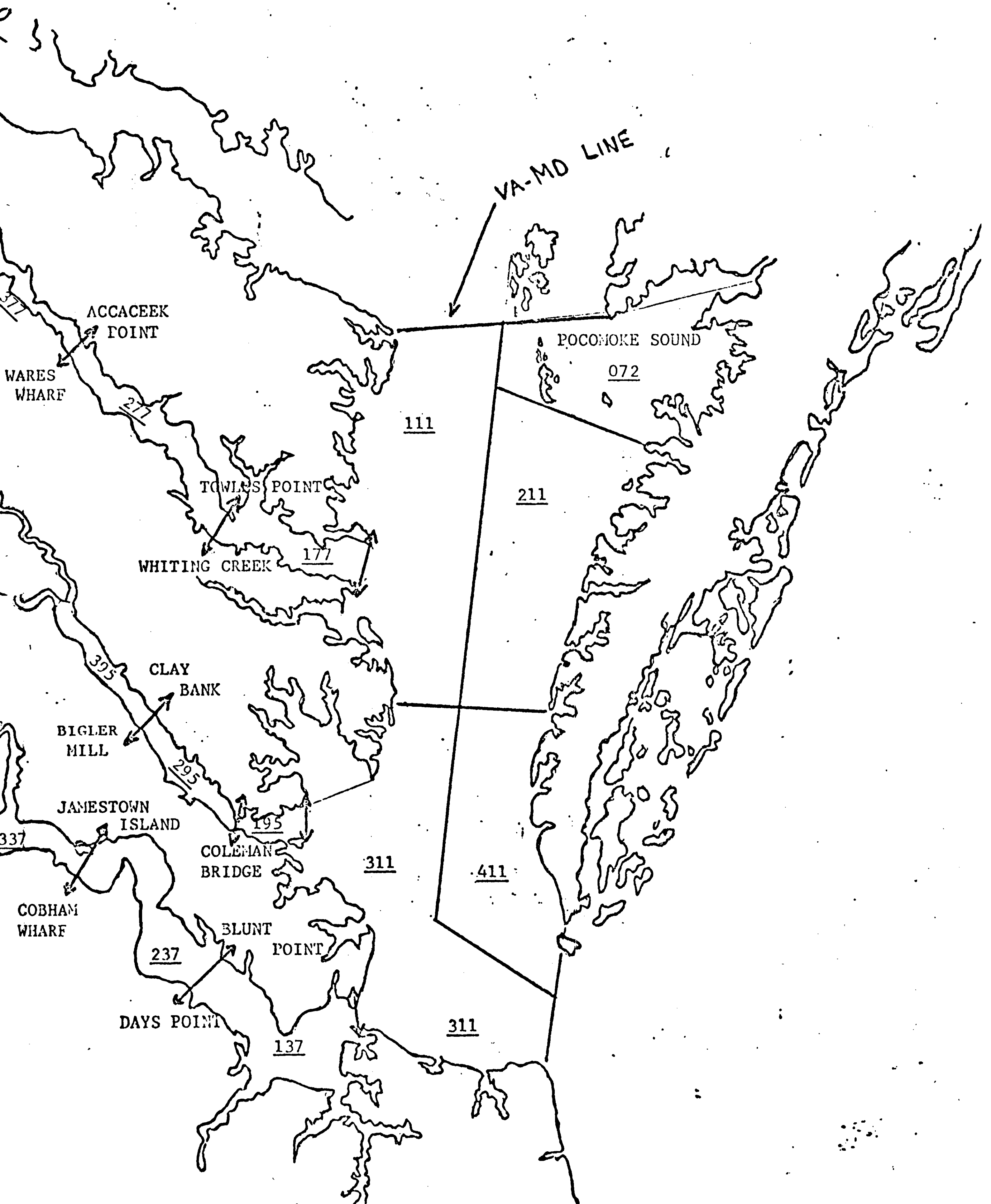
Form VMRC 55 must be completed when a buyer sells or purchases oysters from another processor or buyer or when a buyer imports oysters from the Potomac River (Figure 20). Information required on this form includes: The buyer's and the seller's names, source of oysters from public and private beds, number of bushels, total price, and information on source of imports.

A third form required today by the Commission is one which must be filled out by masters of boats or operators of motor vehicles transporting oysters (Figure 22). This form shows number of bushels and price, the buyer's signature, source of oysters public or private, the tax if any, and dates of tax payments.

Section 28.1-92 of the Code of Virginia states that information collected on forms 53 and 55 (Figures 19 and 20) and on the boat forms (Figure 22) "shall be used only for the collection of taxes mentioned in this section

Figure 21

Locations to be used by buyers when reporting purchases of oysters.



VA-MD LINE
ACCACEEK POINT
WARES WHARF
277
377
POCOMOKE SOUND
072
111
211
TOWLES POINT
WHITING CREEK
177
CLAY BANK
BIGLER MILL
395
295
JAMESTOWN ISLAND
337
195
COLEMAN BRIDGE
COBHAM WHARF
311
411
BLUNT POINT
237
DAYS POINT
137
311

001 Back Bay

003 Back River

005 Bogue Bay

007 Bradford Bay

009 Burtons Bay

111 Chesapeake Bay (Upper western section)

211 Chesapeake Bay (Upper eastern section)

311 Chesapeake Bay (Lower western section)

411 Chesapeake Bay (Lower eastern section)

013 Chickahominy River

015 Chincoteague Bay

017 Coan River

019 Currioman Bay

021 Corrotoman River

023 East River

025 Elizabeth River

027 Fleets Bay

029 Great Wicomico River

031 Hog Island Bay

033 Horn Harbor

137 James River (Lower section)

237 James River (Central section)

337 James River (Upper section)

039 Lafayette River

041 Little Wicomico River

043 Lower Machodoc Creek

045 Lynnhaven Bay

047 Magothy Bay

049 Mattaponi River

051 Metomkin Bay

053 Milford Haven

055 Mobjack Bay

057 Nansemond River

059 Nomini Bay

061 North River

063 Outlet Bay

065 Pagan River

067 Pamunkey River

069 Piankatank River

070 Pocomoke River

072 Pocomoke Sound

073 Poquoson River

175 Potomac River (Lower section)

275 Potomac River (Lower central section)

375 Potomac River (Upper central section)

475 Potomac River (Upper section)

076 Potomac River Tributaries (Unclassified)

117 Rappahannock River (Lower section)

277 Rappahannock River (Central section)

377 Rappahannock River (Upper section)

079 Severn River

081 South Bay

083 Swash Bay

085 Upper Machodoc Creek

087 Ware River

089 Warwick River

091 Willoughby Bay

093 Yeocomico River

195 York River (Lower section)

295 York River (Central section)

395 York River (Upper Section)

097 Unclassified seaside bays and rivers

099 Unclassified tributaries of Cheaspeake

Figure 22

VMRC form used by transporters of oysters.

COMMONWEALTH OF VIRGINIA
MARINE RESOURCES COMMISSION
OYSTER TAX REPORT

B 08878

1. ______________________________
(name of purchaser, packer, planter, importer or shipper)

2. ______________________________
(mailing address)

____
(town/city) (state) (zip code)

3. License Number: ____________ Type (check one): SBPB ____

SBBT ____ Planter ____ Catcher ____ Other ____ (specify)

REPORT FOR THE PERIOD

From: ________ to ________

TICKET NUMBERS USED

From: ________ to ________

From: ________ to ________

From: ________ to ________

From: ________ to ________

INSPECTION TAX 28.1-87

	VIRGINIA PUBLICS	VIRGINIA PRIVATES	IMPORTS
1. Numbers of bushels purchased or handled			
2. MINUS bushels planted INSTATE			
3. MINUS bushels resold			
4. EQUALS bushels on which tax is due	X3¢	X3¢	X3¢
5. TAX PAID			

PUBLIC OYSTER GROUNDS REPLENISHMENT TAX 28.1-93

1. Number of bushels valued at $1.50 per bushel or less taken from areas where the State has planted shells. ________ X 10¢ = ________
2. Number of bushels valued at $1.50 or less ________ X 5¢ = ________
3. Number of bushels valued at $1.51 to $2.50 ________ X 10¢ = ________
4. Number of bushels valued at $2.51 to $3.50 ________ X 15¢ = ________
5. Number of bushels valued at $3.51 to $4.50 ________ X 20¢ = ________
6. Number of bushels valued at $4.51 to $5.50 ________ X 25¢ = ________
7. Number of bushels valued at $5.51 or more ________ X 30¢ = ________

TOTAL BUSHELS ON WHICH TAX IS DUE ________ TOTAL TAX DUE ________

EXPORT TAX 28.1-89

1. Number of bushels from Public Grounds shipped unshucked from State. ________ X 20¢ = ________

I, ______________________ located at ______________________
(name of purchaser, packer, planter, importer or shipper) (name of city/town)

do solemnly swear that the information contained hereon on the oysters purchased or otherwise handled by me is accurate to the best of my knowledge.

______________________ Given under my hand this ______ day of ____________, 19______

TOTAL TAX DUE & REMITTED: ____________

MRC RECEIPT NUMBER: ____________ ______________________
(signature of payee)

NOTE: This report shall be carried in the possession of the master of any boat or operator of any vehicle transporting oysters and shall be exhibited upon request of any authorized officer of the Virginia Marine Resources Commission.

MRC—Agency Copy

and for information to the Virginia Institute of Marine Science."

The additional information now available on the new forms is more detailed than that reported on the old Buyer's Report and is useful to the Commission for tax purposes, and to the Institute. However, it is emphasized that even today it is still the buyer who records the basic information on catch, location and price; therefore, underreporting of landings is still possible. Admittedly, the new system of recording tax information is better than the preceding way since it gives the Commission the opportunity, if it desires, to check the buyer's and seller's records. However, if both underreport to the same degree the Commission cannot detect it.

Information on taxes listed in the annual reports of the Commission from 1962 to the present include: 1) Tax on oysters from leased ground; 2) Tax on oysters from public rocks (Inspection Tax); 3) Public oyster ground Repletion Tax; 4) Tax on exported oysters; and 5) Tax on imported oysters.

Summary of Taxes at Present

Today persons buying oysters taken from public rocks must pay two taxes, the basic Inspection Tax and the

Repletion Tax. If the oysters are exported, the Export Tax is added. The first buyer pays the Repletion Tax. This is different from the procedure set down in Section 28.1-93 (Code of Virginia of 1950 and the 1970 Cumulative Supplement) which states that the tonger will pay the tax to the buyer who will forward it to the VMRC. The first buyer also pays the Inspection and Export taxes when oysters are exported. The last person to buy the oysters in the shell pays the Inspection Tax when oysters are not exported.

An example may show the present extent of these taxes. If a bushel of oysters from public ground is sold at $5.52, 30¢ in Repletion Tax and three cents in Inspection Tax will be paid wholly by the first buyer. If exported, there is an additional 20¢ tax paid by the exporter. The three taxes made a total of 53¢ added to the cost. Tax on oysters from private grounds are subject to the Inspection Tax of 3¢ per bushel. This tax is paid by the buyer who is generally the operator of a shucking house.

Tax information collected by the VMRC since 1963 on oysters from public grounds is the most complete of all such data to date and shows landings based on taxes for individual rivers and districts for both market and seed oysters. These data are published annually by the Commission. Additionally, landing data expressed in bushels are totaled monthly and are on file at the Commission. Of course, as pointed out above, these final reports do not indicate specific origin of the oysters.

Tax Collection

Inspection Tax

The prescribed method of collecting the Inspection Tax today is outlined in the Code of Virginia 1975, Cumulative Supplement, Section 28.1-87. It will be quoted since the way it is collected differs from the way the Repletion Tax is collected.

> The tax shall be collected by the Commissioner or any employee designated by him to collect such tax from the owner, master or operator of any boat or shipper, regardless of whether he is a packer, planter or an individual working on public grounds, immediately when each boat, vessel or motor vehicle is loaded or arrives in the State when the oysters do not go to a shucking or packing house. If the oysters are going to a shucking or packing house located in the Commonwealth of Virginia for their use, then the tax will be collected from the shucking house or the packer. If the tax has not previously been paid, the tax shall be paid by such purchaser, packer, importer or shipper within the first five days of each month immediately following the month in which such oysters are shucked, packed, shipped or marketed.

Repletion Tax

The Repletion Tax, which requires the filling out of a VMRC Form 53 (Figure 19), is supposed to be collected at least monthly (Code of Virginia 1950, and 1970 Supplement 28.1-93).

> The tax shall be collected by the oyster buyer from the person taking or catching said oysters from public rocks, beds, or shoals at the time said oysters are purchased. All buyers of oysters from the seed area of the James River shall file with the Commission the complete report (Oyster Buyer's Report) as specified in the paragraph 28.1-92 and shall pay to the Commission the proper amount of taxes due and collected.

In actual practice the Repletion Tax and the Inspection Tax are collected as follows:

1. At major producing areas during peak harvesting seasons, inspectors are present on the grounds to collect reports of oysters handled and the taxes before the oysters leave the area. This is usually the case in the James, Piankatank, and Great Wicomico rivers. During the oyster season in the James River inspectors are located at the Tax Office in Newport News Small Boat Harbor, at Deep Creek, and on boats in the river. When the seed areas in the Great Wicomico and Piankatank rivers are opened in the spring, VMRC boats and inspectors are there to collect the tax.
2. In other locations the tax forms and payments may be remitted to the Commission by mail or

collected by inspectors who may visit the processors.

Records of monies resulting from levies on oysters imported into the Commonwealth were included with and were inseparable from taxes from native oysters prior to 1962. As a consequence it is not possible to separate Virginia production from outside production from these tax data. In reality this presents no problem in estimating Virginia production for this study since the quantities of oysters imported prior to 1960's were negligible. From 1960 to 1962 Virginia production data included an unknown quantity of imported oysters. The Inspection Tax was extended in 1962 to cover imported oysters. Since then collections from this source have been separately identified.

Interpreting Tax Data

Calculating Oyster Landings from VMRC Data

To determine quantity of oysters landed in early years from private and public grounds in Virginia the revenue collected each year for the inspection tax was divided by the tax rate for that year to get the number of bushels landed (Table 12). Since 1963 VMRC has reported landing of bushels which has been based on the Inspection Tax and on the Repletion Tax. Those data are shown here.

Table 12

Market Oyster Catch in Virginia in Va. Bushels[1]
1930-1 thru 1974-5

Season	From Public Ground		From Private Ground		Total Bushels
1930-1	450,846		1,236,068		1,686,914
31-2	523,982		858,469		1,382,451
32-3	433,284		949,900		1,383,184
33-4	619,207		1,566,586		2,185,793
34-5	419,679		1,492,213		1,911,892
35-6	465,514		2,130,125		2,595,639
36-7	370,853		1,202,255		1,573,108
37-8	364,711		1,208,690		1,573,401
38-9	490,591		1,695,727		2,186,318
39-40	616,587	4,755,254	1,783,541	14,123,574	2,400,128
1940-1	687,558		1,656,969		2,344,527
41-2	744,574		1,518,901		2,263,475
42-3	749,410		1,857,321		2,606,731
43-4	845,721		1,338,603		2,184,324
44-5	829,231		1,625,062		2,454,293
45-6	999,833		2,067,264		3,067,097
46-7	911,501		2,179,542		3,091,043
47-8	854,680		1,971,417		2,826,097
48-9	995,090		1,816,832		2,811,922
49-50	650,848	8,268,446	2,195,201	18,227,112	2,846,049
1950-1	436,302		1,799,462		2,235,764
51-2	529,598		1,861,232		2,390,830
52-3	455,634		2,346,491		2,802,125
53-4	443,257		2,755,142		3,198,399
54-5	607,541		3,056,901		3,664,442
55-6	486,189		2,383,457		2,869,646
56-7	566,614		2,549,529		3,116,143
57-8	697,579		2,447,823		3,145,402
58-9	661,576		2,536,970		3,198,546
59-60	566,307	5,450,597	2,196,851	23,933,858	2,763,158
1960-1	946,960		2,615,871		3,562,831
61-2	714,171		2,167,639		2,881,810
62-3	267,995		906,243		1,174,238
63-4	576,857		1,288,093		1,864,950
64-5	615,864		1,647,645		2,263,509
65-6	605,982		1,273,888		1,879,870
66-7	226,855		725,453		952,308
67-8	262,996		840,749		1,103,745
68-9	227,577		650,445		878,022
69-70	192,187	4,637,444	818,943	12,934,969	1,011,130
1970-1	281,001		836,014		1,117,015
71-2	260,241		928,404		1,188,645
72-3	157,890		394,121		552,011
73-4	374,522		424,277		798,799
74-5	403,737	1,477,391	491,860	3,074,676	895,597

1 1931-63 Catch calculated from tax revenue reported in annual reports of the Va. Commission of Fisheries. Data from 1963 to 1975 obtained from publications of VMRC. Mid-Potomac River catch is not included in data after 1964.

Accuracy of the Data and Underreporting

In the preceding pages we have indicated that opportunities exist for underreporting the quantity of oysters harvested and the tax required. It is very likely that significant short reporting occurred in the past and still does today.

Most seed oysters harvested from public ground are reported in the presence of VMRC inspectors in the following manner. The tongers in the James, Piankatank and Great Wicomico rivers pull their boats alongside one of the tax offices or one of the inspector's boats. At that time inspectors have the opportunity of estimating by visual observation the quantity of oysters loaded on the boat and comparing it with the quantity shown on Form 53 which is handed to him. The accuracy of reports made in this manner is determined by: 1) the veracity of Form 53; 2) the accuracy of the inspector's estimate; and 3) of his reports.

In areas other than the major seed-producing regions, oysters (mostly market oysters) harvested from public ground are required to be reported by the buyer, but the actual load is not observed by any VMRC personnel. Instead the buyer mails his report to the VMRC office at the close of each month. When the buyers' reports are received at the VMRC office clerical personnel often can do no more than check the mathematical calculations for total oysters harvested and tax due. It is possible for an unscrupulous buyer to get by with reporting only a very small percentage of the actual quantity of oysters which he handled.

The largest part of the market oyster harvest from private grounds and public bottoms ends up at the shucking house. The shucking house operators are responsible for reporting the quantity they handle on the Inspection Tax Report. This record is open for inspection by the Marine Resources Commissioner or any employee designated by him to inspect the same. However, since shucking house operators are not required to keep written documentation to support their records there is no way to check the data included in the daily record book or on the Inspection Tax Reports.

The system of recording taxes in the Potomac by the Potomac River Fisheries Commission is more accurate than that adopted for Virginia. PRFC requires dual reports on all oysters harvested in the Potomac River. One report is required of oyster tongers (Regulation II, Section I and 1A of PRFC Regulations) and another from the buyers (Regulation IV, Section I and 1A of PRFC Regulations). PRFC personnel may compare data from the two reports as a cross-check. If

VMRC personnel were able to cross-check in a similar manner, Virginia would have a more reliable reporting system. However, the possibility of collusion between reporters and duplication of sellers' and buyers' records makes even the PRFC method weak.

In reporting total oyster landings for Virginia and for Maryland ("Virginia Landings" and "Maryland Landings"), the NMFS data includes part of the Potomac Landings in the Virginia total and part to Maryland. Separation is based upon the state where the oysters are landed. Since 1964, data collected by the PRFC have been the basis for the NMFS determinations on how many bushels were credited to Virginia and how many to Maryland. How the NMFS made this determination before the beginning of the PRFC is unknown. The VMRC considers, for tax purposes, that all oysters landed in Virginia from the Potomac are imported and reports them as such. VMRC data on Potomac River imports were available for three years and were compared to NMFS data. In all three years VMRC data were lower. We interpret the difference to be due to nondeclaration of information on imports by watermen or dealers. The NMFS data were based on buyers' reports which are submitted weekly with their tax to the PRFC. In contrast the VMRC did not require such frequent reports. NMFS data are used herein to show Virginia landings of Potomac River oyster because we believe them to be more accurate than those obtained by VMRC. Beginning in 1975 information on price and volume of Potomac imports was required on the VMRC Form 53.

It should be noted that Potomac imports may be separated from Virginia State totals. They were not added to the total landings for Virginia by the VMRC as shown in Table 12.

Estimations of total actual production of oysters from public rocks may be understated due to other causes. An undetermined quantity is taken by persons desiring oysters for family use. This practice is legal since Virginia law allows a resident of Virginia to take up to a bushel daily from public rocks during the legal seasons for family use. The quantity so taken from Baylor Grounds, however, is probably small.

Summary of Underreporting

Tax data for calculating production are only as accurate as the methods of reporting and collection of taxes are effective. In reviewing this question there is little information on how effective tax collecting has been over the years. The period when efficiency of collections are probably lowest was between 1931 and 1937. VMRC (then VCF) reports for those years list only one or two clerical workers at the Newport News Office. This number hardly seems sufficient for even the most routine work. Recordkeeping was lax in these years and inspectors were not even enforcing the cull law (Corson, 1930).

From 1963 to the present efficiency of tax collection and recordkeeping have reached an all time high. Even with this improvement records and tax collections cannot be verified and underreporting is probably the rule.

Comparison of Data From NMFS and VMRC for Oyster Production

Prior to presenting and discussing the trends in oyster production resulting from our study tabulated data obtained from NMFS are compared with those obtained from the VMRC for the period 1931 to 1975. This comparison is made for market and seed oysters from both public and private grounds. It is necessary since our preliminary inspection of data from two sources often showed wide differences between years and even in short-term trends. There was a question as to which should be used in this report.

For example, in 1931 the VMRC showed a total of 1,686,914 bushels of market oysters landed while the NMFS showed 2,848,477 bushels (Table 12 and 13, respectively). The ten-year average for the 1931 to 1940 period for public grounds

Table 13

Market Oyster Landings from Virginia's Public and Private Oyster Grounds
1930-1 thru 1974-5[1]

Season	Public Ground (Va. bu.)		Private Ground (Va. bu.)		Total (Va. bu.)	Potomac Landings Credited to Va.[3] (Va. bu.)	Va. Landings Minus Potomac Landings (Va. bu.)
1930-1	1,017,641		1,830,836		2,848,477		
31-2	991,335		1,404,952		2,396,287		
32-3	934,537		1,402,231		2,336,768		
33-4	1,155,640		1,689,860		2,845,500		
34-5	1,028,023		1,871,116		2,899,139		
35-6	565,824		1,993,418		2,559,242		
36-7	598,345		1,230,304		1,828,649		
37-8	619,407		1,458,308		2,077,715		
38-9	733,871		1,834,298		2,568,169		
39-40	824,383	8,469,006	2,057,271	16,772,594	2,881,654		
1940-1	726,241		2,092,864		2,819,105		
41-2	606,498		1,797,363		2,403,861		
42-3	2		2		2		
43-4	2		2		2		
44-5	634,179		1,906,500		2,540,679		
45-6	997,843		2,346,535		3,344,378		
46-7	1,060,147		1,953,155		3,013,302		
47-8	962,284		2,517,992		3,480,276		
48-9	1,015,035		2,423,447		3,438,482		
49-50	586,412	6,588,639	2,034,097	17,071,953	2,620,509		
1950-1	444,474		1,969,207		2,413,681		
51-2	374,013		2,259,970		2,633,983		
52-3	419,063		2,372,742		2,791,805		
53-4	510,333		2,951,458		3,461,791		
54-5	517,178		2,766,137		3,283,315		
55-6	650,333		2,820,318		3,470,651		
56-7	592,181		2,601,353		3,193,534		
57-8	586,304		2,926,750		3,513,054		
58-9	703,915		3,347,170		4,051,085		
59-60	699,420	5,497,214	2,533,275	26,548,380	3,232,695		
1960-1	781,783		2,237,736		3,019,519		
61-2	227,921		1,815,001		2,042,922		
62-3	278,830		1,652,880		1,931,710		
63-4	381,861		1,628,999		2,010,860	58,738	1,952,122
64-5	571,502		1,463,939		2,035,441	74,662	1,960,779

Table 13 (Contd.)

Season	Public Ground (Va. bu.)		Private Ground (Va. bu.)		Total (Va. bu.)	Potomac Landings Credited to Va.[3] (Va. bu.)	Va. Landings Minus Potomac Landings (Va. bu.)
65-6	740,541		960,272		1,700,813	109,976	1,590,837
66-7	678-880		735,474		1,414,354	395,838	1,018,516
67-8	558,196		612,892		1,171,088	328,571	842,517
68-9	525,371		442,464		967,835	201,065	766,770
69-70	500,689	5,245,574	726,967	12,276,624	1,227,656	245,932	981,724
1970-1	493,109		828,799		1,321,908	210,989	1,110,919
71-2	418,914		639,090		1,058,004	139,617	918,387
72-3	157,890[4]		394,121[4]		552,011	58,339	552,011
73-4	374,522[4]		424,277[4]		798,799	31,747	798,799
74-5	403,737[4]	1,848,172	491,840[4]	2,778,147	895,597	47,146	895,597

Notes:

1. Data from Fish Stat. U. S. (NMFS) - US bushels converted to Va. bushels.
2. Data for only half a year available.
3. Data from "Va. Landings" - (NMFS) data are provisional and subject to correction.
4. Data from publications of the VMRC.

based on VMRC data (Table 12) was 371,375 bushels a year less than the comparable average for the NMFS figures (Table 13)--a difference of 44%. For private grounds, over the same period, VMRC data averaged 264,902 bushels a year less than that shown by NMFS. This was a difference of 16%.

Also the two sets of data did not agree closely for individual years from 1941 to 1950. Ten-year total production for public oyster grounds averaged 3,265 bushels more for VMRC data than that for NMFS (a difference of 0.4%). For private grounds VMRC data for annual production averaged about 311,260 bushels more than the NMFS data, which is a difference of about 14%.

Production data for individual years in the 1951 to 1960 period still differed and short-term trends were not always the same. For the ten-year average, however, the two sets of data agreed closely. Data on total landings of the VMRC and NMFS data were almost identical for public grounds (i.e., only 0.8% different). The VMRC data on private grounds were lower by about 261,452 bushels annually than the NMFS data (about 10% less).

From 1960 to 1972 (final NMFS data are not available after 1972) data from the two sources still did not agree for individual years. For the 12-year period for public bottoms

NMFS data averaged annually about 81,576 bushels more each year than did VMRC data. The VMRC data were 16% less than the NMFS data.

The higher NMFS landings might have been expected since they include part of the Potomac River landings attributed to Virginia (Table 13), whereas VMRC landings (Table 12) do not. However, this one factor does not resolve the difference. The Potomac River catch (attributed to Virginia) from 1963 to 1972 totaled 1,765,388 bushels (Table 13). When this total is subtracted from the total NMFS public landings for the same period (4,869,063 bushels) the result is 3,103,675 bushels. This is now almost equal to the VMRC total (3,249,560 bushels) for public bottoms in Virginia for the same period.

Landings from NMFS and VMRC for leased areas coincide from 1960 to 1972 with the VMRC data being about 7% higher.

Why VMRC and NMFS Data Differ for Market Oyster Production -- Summary

There exists no adequate explanation for the differences between the NMFS and VMRC data for market oyster production from 1931 to 1950 except that VMRC records were incomplete. Also NMFS data may have been supplemented with additional information. However, data in recent years from the two sources on the average closely agree with respect to production. For public grounds, from 1951 to 1972 when the data are tabulated in ten and twelve year periods, VMRC data ranged from 0.8 to 16% less than NMFS data. NMFS data for private bottoms in the 1951 to 1972 period averaged from 11% more to 6% less than VMRC.

When the overall differences in trends and magnitude of the two sets of data on market oysters are considered, there are two possibilities. The NMFS method of collection independently arrived at similar production data as shown by tax returns, or the NMFS data are based in part on tax data from 1931 to 1950 and wholly on VMRC data in the period 1951 to 1960. We believe that the latter possibility is most likely since the NMFS in the past and today lacks the personnel to collect and process the basic raw data from Virginia dealers, processors, growers, and harvesters. If this conclusion is accepted, then the production records of oysters as shown by NMFS data for recent years is only as accurate as the tax collection system of VMRC was efficient. This latter aspect undoubtedly results in an underestimate in production by both agencies or by anyone using their data since it is evident that all oysters harvested were not reported. A second source of error would result from the process converting gallons to bushels.

Accuracy and Availability of Data on Seed Oyster Production

Reliable data on seed production from individual river systems has been available from the VMRC only since 1963.[2] For this study these data were extracted from the monthly reports published by that agency (Table 15). Data based upon the Repletion and Inspection Tax records in effect from 1952 to 1962 did not distinguish market from seed oysters. Prior to 1952 the Inspection Tax data also failed to differentiate between seed and market oysters. Therefore, there is no way to determine seed production from the VMRC tax reports prior to 1963.

An explanation of the VMRC public ground seed data shown in Table 15 is necessary since "seed" production for Virginia is divided into two parts: 1) that portion harvested by tongers and sold commercially, which is the largest; and 2) that portion which is harvested by the VMRC and is used by the Commission for planting on Baylor Grounds (may be called the non-commercial catch). This latter amount has been about 9.5% of the total from 1963 to 1975,

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[2] Data on seed oyster production from public and private grounds are available from Fisheries Statistics of the United States from 1930-31 through 1971-72 and afterward from "Virginia Landings" (Table 14). These data are considered to be of limited value for the reasons outlined previously.

Table 14

Virginia Seed Oyster Production[1] in Bushels from Public and Private Grounds[2]

Season	Public Ground (Va. bu.)	Private Ground (Va. bu.)	Total (Va. bu.)
1930-1	1,610,063	9,000	1,619,063
31-2	1,573,061	13,000	1,586,061
32-3	1,471,668	35,600	1,507,268
33-4	1,968,323	89,668	2,057,991
34-5	1,782,942	52,868	1,835,810
35-6	1,239,693	15,040	1,254,733
36-7	729,401	(3)	729,401
37-8	983,681	2,400	986,081
38-9	814,979	(3)	814,979
39-40	930,860	(3)	930,860
1940-1	890,592	(3)	890,592
41-2	932,699	(3)	932,699
42-3	(4)	(4)	(4)
43-4	(4)	(4)	(4)
44-5	1,622,950	5,402	1,628,352
45-6	2,376,007	15,004	2,391,011
46-7	1,975,597	143,036	2,118,633
47-8	2,111,499	118,730	2,130,229
48-9	2,223,927	214,354	2,438,281
49-50	2,188,092	215,554	2,403,646
1950-1	2,461,289	204,369	2,665,658
51-2	2,079,550	178,570	2,258,120
52-3	1,944,513	255,898	2,200,411
53-4	2,216,951	577,812	2,794,763
54-5	2,743,479	441,372	3,184,851
55-6	2,230,777	508,114	2,738,891
56-7	2,245,426	752,169	2,997,595
57-8	2,321,954	150,258	2,472,212[5]
58-9	1,850,231	60,980	1,911,211[5]
59-60	2,480,450	108,019	2,588,469
1960-1	1,428,580	52,996	1,481,576
61-2	1,557,234	98,870	1,656,104
62-3	1,040,707	51,577	1,092,284
63-4	766,577	35,956	802,533
64-5	634,725	33,003	667,728
65-6	974,941	8,774	983,715
66-7	808,504	19,504	828,197
67-8	756,417	20,159	776,576
68-9	502,214	4,439	506,653
69-70	346,218	4,758	350,976
1970-1	508,917	83,143	592,060
71-2	391,172	0	391,172
72-3[6]	401,067	5,968	407,035
73-4[6]	524,818	2,550	527,368
74-5[6]	392,504	0	392,504

1. U.S. Bushel converted to Virginia bushel; data from Fish.Stat. U.S. (NMFS).

2. Harvest reported solely from Virginia for the seasons 1930-1 through 1942-3 and 1960-1 through 1974-5; a small (about

Table 14 (Contd.)

1% or less) Maryland harvest is included in figures for 1943-4 through 1959-60.

3. No data reported.

4. Data available for half a year only.

5. Computed from data in Fish. Stat. U. S. (NMFS).

6. Data from "Va. Landings" (NMFS); data are provisional and subject to correction.

Table 15

Total Seed Harvest From Public Grounds in Virginia
in Va. bu.

	Great Wicomico River			Piankatank River		
Season	Tongers[1]	VMRC[2]	Total	Tongers[1]	VMRC[2]	Total
1962-3	0	11,725	11,725	0	0	0
63-4	0	38,550	38,550	0	31,049	31,049
64-5	102,016	7,280	109,296	91,152	0	91,152
65-6	232,739	11,500	244,239	99,275	18,900	118,175
66-7	146,103	0	146,103	60,090	0	60,090
67-8	88,513	15,687	104,200	71,704	15,776	87,480
68-9	50,776	35,618	86,394	3,848	21,748	25,596
69-70	98,380	71,719	170,099	3,581	25,637	29,218
1970-1	126,387[2]	86,543[2]	212,930	0[2]	27,024	27,024
71-2	0	70,765	70,765	0	40,113	40,113
72-3	0	0	0	0	0	0
73-4	0	0	0	0	102,236	102,236
74-5	0	8,310	8,310	0	34,269	34,269
Total	844,914	357,697	1,202,611	329,650	316,752	646,402
Percent of State Total	10.2	41.3	13.1	4.0	36.6	7.1

Season Ending	James River Tongers[1]	VMRC[2]	Total	Seaside, Eastern Shore Tongers[1]	VMRC[2]	Total
1962-3	843,833	0	843,833	45,928	4,616	50,544
63-4	840,675	0	840,675	82,517	12,751	95,268
64-5	424,234	0	424,234	31,117	2,297	33,414
65-6	611,167	18,275[3]	629,442	45,789	0	45,789
66-7	532,569	22,500[3]	555,069	79,313	0	79,313
67-8	483,690	0	483,690	100,022	0	100,022
68-9	486,536	0	486,536	45,949	0	45,949
69-70	264,203	0	264,203	122,806	0	122,806
1970-1	439,294[2]	19,343[2]	458,637	24,177	0	24,177
71-2	381,250	0	381,250	40,148	0	40,148
72-3	396,169	0	396,169	43,967	0	43,967
73-4	352,872	19,665	372,537	53,045	0	53,045
74-5	317,003	0	317,003	19,888	0	19,888

Table 15 (Contd.)

Total	6,373,495	79,783	6,453,278	734,666	19,664	754,330
Percent of State total	76.9	9.2	70.5	8.9	2.3	8.2

	Lower Rappahannock River			Corrotoman River		
Season	Tongers[1]	VMRC[2]	Total	Tongers[1]	VMRC[2]	Total
1962-3	0	7,942	7,942	0	0	0
63-4	0	0	0	0	0	0
64-5	0	0	0	0	0	0
65-6	0	19,150	19,150	0	27,600	27,600
66-7	0	7,500	7,500	0	7,500	7,500
67-8	0	0	0	0	21,955	21,955
68-9	0	0	0	0	0	0
69-70	0	0	0	0	0	0
1970-1	0	0	0	0	0	0
71-2	0	0	0	0	0	0
72-3	0	0	0	0	0	0
73-4	0	0	0	0	0	0
74-5	0	0	0	0	0	0
Total	0	34,592	34,592	0	57,055	57,055
Percent of State Total	0	4.0	0.4	0	6.6	0.7

Total For All Areas

Season	Tongers[1]	VMRC	Total
1962-3	889,761	24,283	914,044
63-4	923,192	82,350	1,005,542
64-5	648,519	9,577	658,096
65-6	988,970	95,425	1,084,395
66-7	818,075	37,500	855,575
67-8	743,929	53,418	797,347
68-9	587,109	57,366	644,475
69-70	488,970	97,356	586,326
1970-1	589,858	132,910	722,768
71-2	421,398	110,878	532,276

Table 15 (Contd.)

Season	Tongers[1]	VMRC	Total
72-3	440,136	0	440,136
73-4	405,917	121,901	527,818
74-5	336,891	42,579	379,470
Total	8,282,725	865,543	9,148,268

Notes:

1. These figures show the quantity of seed caught by tongers and sold to planters and to Potomac River Fisheries Commission. From reports of the VMRC.

2. It is assumed that these figures which have been taken from reports of the VMRC, were not included in the figures to the left because of great differences in several years. For example, in 1964 the VMRC transplanted 69,599 bu. of seed from the Great Wicomico and Piankatank rivers, but it was not reported as being caught and sold. It is assumed that this system of reporting was used by the VMRC through 1970, since a 1970 report for the Piankatank River lists 3,581 bu. sold by tongers and 25,637 bu. harvested by the VMRC. In 1971 the reporting system was changed; VMRC data for total seed harvest for that and following years include the amounts harvested and transplanted by them and the amounts sold by tongers on the open market. Since 1971 the amount harvested by the VMRC has been subtracted from the total reported to get the amount caught and sold by tongers.

3. These seed were dredged from the upper and lower ends of the seed areas of the James and planted in the middle. (Minutes of the C. of F. Meeting May 26, 1966 and mimeographed report of the VMRC for 1971.)

but it is not considered as part of the total seed production for Virginia by the NMFS or by the VMRC. It is, however, a part of total seed production or harvest from State waters and for this reason both quantities are presented in Table 15. For purposes of this study we do wish to examine total seed harvested as well as total seed available.

Data on seed production from private grounds which are shown in Table 14 are thought to incorporate errors. For example, records for certain years of exposed private seed at the VMRC include totals which are much greater than those shown by NMFS data in Table 14 as total private seed harvest.

Reliable seed production data were available from the VMRC from 1963 to 1975. Its production figures averaged 2.9% higher than the NMFS data. Both sets of data, however, showed the same downward trend (Tables 14 and 15).

Choice of Data to be Used in Report

After comparing all sources of information on seed and market oyster production from public and private beds, it was decided that even though VMRC data provided the base for the NMFS data the latter would be used to consider long-term trends. Final NMFS data were unavailable from 1973 to 1975, so VMRC data were used.

The reasons for using NMFS data were:

1. From 1930 to 1972 average landings of market oysters as reported by NMFS usually averaged higher for public and private bottoms than comparable VMRC data. Obviously, VMRC data had been supplemented by additional information and, while they probably underestimated production despite this augmentation, are for the entire period more accurate than VMRC data for the <u>entire</u> period.
2. Other studies and reports have used NMFS data.

The data presented by VMRC from 1962 to 1975 are regarded as the most accurate available for detailed comparison, as in the case of comparisons of in-state production to imports and exports.

Market Oyster Production from 1880 to 1925

Production data for the early 1800's are not available to us. In 1865 C.S. Maltby made a very careful computation of the oyster production of the whole bay for that year. Presumably this was market oyster production. Maltby estimated that production in the whole bay was

6,944,500. That for Virginia was 2,065,010 bushels (Brooks, 1891). Ten years later (1875) the Bay-wide production as estimated by Brooks (1891) was 17,000,000 bushels. There is no separation of Virginia production in this estimate. We have no better estimates of production prior to 1880 at this time.

Data from 1880 to 1925 are available (NMFS). As documented by Corson (1930), these data are not complete and landings are shown for only twelve years of the entire 45 year period (Table 16). Annual production averaged 5,447,142 bushels from 1880 to 1897; 6,251,653 from 1901 to 1908, and about 4,842,028 bushels from 1912 to 1925. A.F. Mayrey (1895) stated that oyster beds in Virginia yielded 10 million bushels annually. These production figures are nearly twice what they were in later years, and authors have cited these data to show how high production was during the early years of industry. The methods by which the U.S. Bureau of Commercial Fisheries collected information during these early years are not known. In this respect they could have had little assistance from the Virginia Commission of Fisheries which was not in existance from 1880 to 1884 and was poorly staffed from 1884 to 1925 (Commission reports 1900 to 1925). Pertinent to the reference on accuracy is a statement by Corson in 1930 that the numbers of fishery inspectors in

Table 16

Oyster Production in Virginia from 1880 to 1925 for Certain Years.[1]

Year	Bushels	Pounds of Meats
1880	6,837,320	47,861,240
1887	2,921,140*	20,447,980
1888	3,664,433	25,651,031
1890	6,074,025	42,518,175
1891	6,162,086	43,134,602
1897	7,023,848	49,166,936
1901	6,067,669	42,473,683
1904	7,612,289	53,286,023
1908	5,075,000	35,525,000
1912	6,206,098	43,442,686
1920	3,963,569	27,744,983
1925	4,356,416	30,494,912

Notes:

1. Data obtained from "The Oyster Industry of Virginia" 1930 by Corson.

* Exclusive of the James and the Potomac.

Virginia were not sufficient to police the public rocks and Corson also suggested that the cull law, which required the return of shell and oysters of less than three inches long to the water, was not enforced during the same period.

Lack of enforcement of the cull law could have had a major influence on the magnitude of landings prior to 1930. Had the cull law been enforced only three inch and over oysters would have been recorded in Virginia landings (2½ inch in some localities). However, if oysters of all sizes were tonged into the boat (no cull law), then many of the small oysters, which today would be classed as seed, could have been included in the data for market oyster production. Thus, in the early period "market" oyster production may in reality have been market oysters plus the undersized oysters and shell. From verbal reports of oystermen who operated during that period, it is evident that many small oysters and shell were included.

If in reality the early records included small seed-sized oysters as well as those 3 inches or larger, then the production of market or 3 inch oysters in the early period may not have been as high as suggested by Table 16.[3]

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[3] Table 16 showing early production is entitled Oyster Production and does not indicate if oysters were "market" size (3") or not.

It is not possible, however, to determine the degree to which this occurred from this vantage point in time.

Despite the imperfection of these early data the following quotes, and there are many of a similar nature, tend to support the concept that even higher production occurred during the mid-1800's.

1. . . .The natural oyster rocks of the York River are now insignificant compared to former days. . .(Ingersoll, 1881).

2. . . .The natural rocks in the Rappahannock are rapidly becoming destroyed, oysters are becoming scarce (Ingersoll, 1881).

3. . . .73% of the oyster rocks included within the Baylor Survey in the James may be said to be depleted. . .(Moore, 1910).

4. In the Mobjack Bay, the rivers of Mathews and Gloucester bordering on the Mobjack, the oyster is nearly extinct. . .(Comm. of Fish., 1912).

5. . . .In 1880 the natural (public) oyster beds in Virginia produced more than six million bushels of oysters. Today (1954) they produce not more than a third of that quantity. At least 65% of the oyster rocks in Virginia are showing some signs of depletion. . .(Marshall, 1951).

6. Great living oyster mounds, built up by nature through the ages, impeded ships in the James River. At high tide they were hidden so that unwary pilots struck them; at low tide they could be picked over by hand. They remained a threat to navigation until they disappeared under three centuries of harvesting (Wharton, 1957).

7. Marshall (1954) summarized changes in depths of oyster rocks in the James River from 1850 to 1948 to determine how depth of the bars may have changed due to activity of tongers or by natural conditions. Using data obtained from the U.S. Coast and Geological Survey he suggested that there had been a mean loss of about 1 foot in the 98 year period.

8. In more recent studies VIMS scientists have discovered that many of the oyster bars in the James River have been lowered by an average of two (2) feet in the last 35 years. Some are as much as five (5) feet lower (Nichols, personal communication).

Physical oceanographers have noted an increase in mean sea level of approximately 10 inches in the last 100 years. Some of the observed "lowering" of oyster bars is, therefore, related to a rise in the water level above those bars. However, there is no question that harvesting has reduced the levels of the oyster bars in the James. Other factors may also be involved, such as transfer of shells and cinder into the declivities between the bars in the culling process and slumping due to channel dredging.

It would be useful to show what part of this early production came from private plantings and what part from public bottom. Unfortunately, this cannot be done with any degree of accuracy. Data tabulated by Corson (1930) shows that total acreage leased in Virginia increased from 47,803 acres in 1900 to 59,436 acres in 1927. As explained previously, however, these records on leasing were incomplete.

It is probable that private plantings in the early period were vastly underreported.

Market Oyster Production from 1931 to 1975

State-Wide Production--Public and Private

Market oyster production will first be considered from the aspect of total combined production from public and private beds, then production from public and private grounds will be separated.

When collection of data was begun on a regular basis in 1931, total oyster production recorded from public and private grounds according to NMFS data was 2,848,477 bushels per year. Production slowly increased to 4,051,085 bushels in 1959 which represents a high for the period. Thereafter, total production trended downward and for 1972, the last year for which NMFS data are available, production was only 1,058,004 bushels[4] (Table 13; Figure 23). VMRC data based on tax records showed 895,597 bushels, a further decline, landed in 1975 (Table 12).

NMFS data separate public and private production over the 1931 to 1975 period. Production from private

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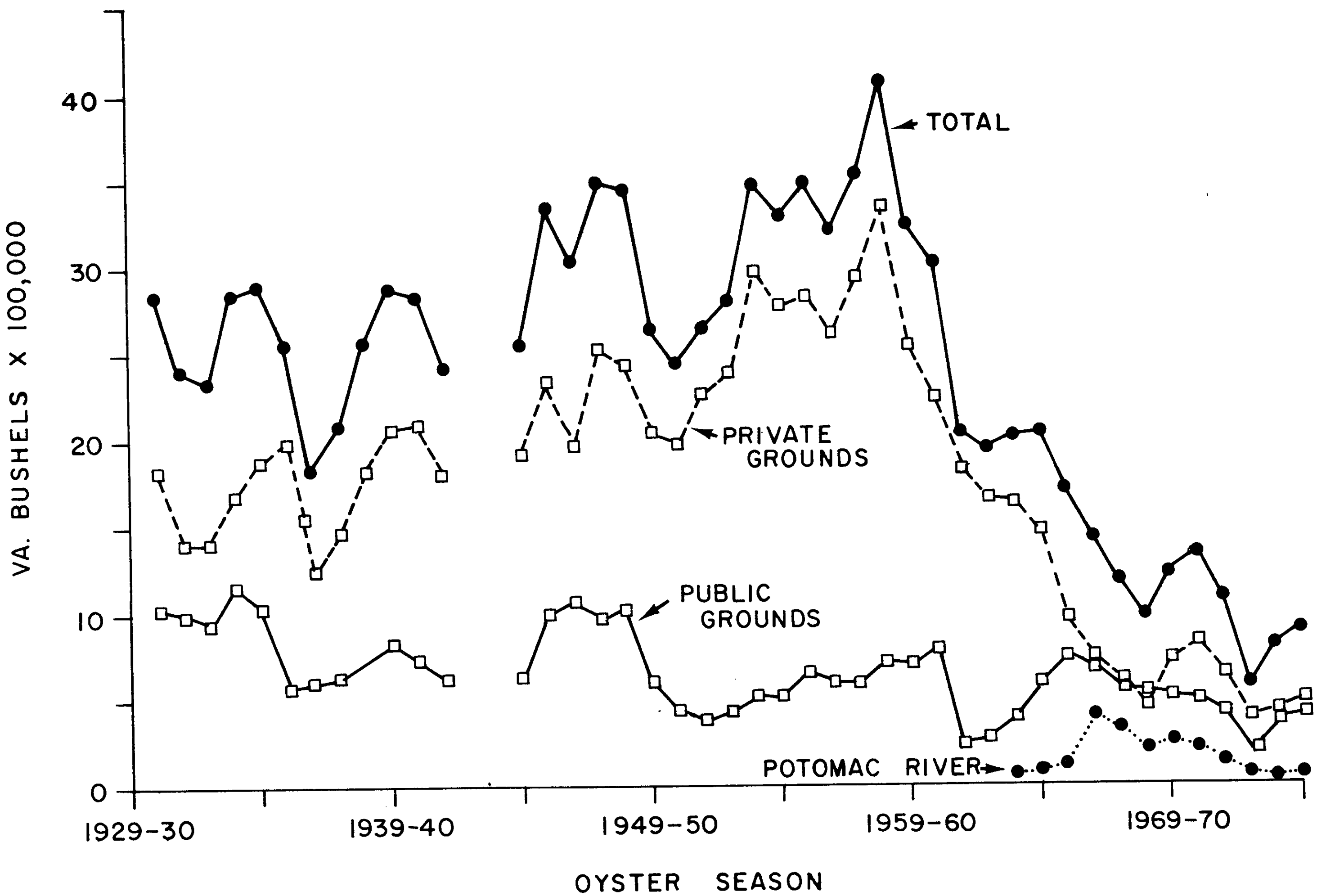
[4]If Potomac River landings (main stem) are subtracted, the total is only 918,387 bushels.

Figure 23

Virginia catch of market oysters 1930-1 thru 1974-5. Data for "Total", "Public" and "Private" thru 1971-2 from Fish. Stat. U. S. NMFS; other data from VMRC. The "Potomac River" curve shows the quantity which was taken from that river where the PRFC has jurisdiction and was credited to Virginia by NMFS.



VA. BUSHELS X 100,000
0
10
20
30
40
TOTAL
PRIVATE GROUNDS
PUBLIC GROUNDS
POTOMAC RIVER
1929-30
1939-40
1949-50
1959-60
1969-70
OYSTER SEASON

grounds accounted for about 69% of the total Virginia production from 1931 to 1950; about 83% from 1951 to 1960, and 69% from 1961 to 1972. VMRC data for 1973 to 1975 indicates a further decline in landings from private bottoms and in the 1974-75 season landings from those bottoms were 55% of the total (Table 12).

Production from public grounds from 1931 to 1975 shows evidence of an overall decline, but the trend is poorly detailed and change does not appear large. An inspection of data shown in Table 13 indicates that during 1931 to 1975 landings varied widely and shows a series of poorly defined peak years followed by years of slightly lowered production. Production from 1931 to 1960 ranged from 374,013 to 1,155,640 bushels; from 1961 to 1975 it ranged from 740,541 to 157,890 bushels.

The existence of a long term downward trend in landings is shown by five- and ten-year averages of production data, calculated from data shown in Table 13, as follows: 1931 to 1940--846,901; 1941 to 1950--823,580; 1951 to 1960--549,721; 1961 to 1970--524,557 (383,079 bushels if the Potomac River landings are subtracted); and 1971 to 1975--299,513 (if Potomac River data are subtracted).

In summary, production from public bottoms has declined during the last ten years. During the last five year interval production was about 56% less than it was during the 1931 to 1950 period. It is noted that production during the 1951 to 1960 period, before MSX, was only slightly higher than it was during many of the MSX years of 1961 and 1970 (Table 13).

Private production followed the same trend as total production. Based on NMFS data there was a peak year in 1959 when production was 3,347,170 bushels. After this it trended downward to only 639,090 bushels in 1972[5], or 19% of peak (Table 13). VMRC data (Table 12) indicated a rapid decline to 491,860 bushels in 1975 which is far below the peak year of 1959.

Trends in Market Oyster Production by District and from Private and Public Grounds

Market oyster production from all private grounds in Virginia has been reported from 1931 to 1972 from data gathered through the Virginia Inspection Tax receipts. It is now broken down by districts. However, this information discloses only the district in which oysters were purchased or processed, and not the river

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[5]The last year final NMFS data are available.

system or bottom where the oysters were grown. For example, oysters may be grown in the Rappahannock in any one of three districts and then shucked at Norfolk, Virginia, in another district. With full recognition of this limitation, production for the districts were summed into four major groupings which takes a large geographic area (Table 17; Figure 24). These were:

1. The Eastern Shore (Districts 24-29).
2. All of Virginia, less the Eastern Shore (Districts 1-22).
3. Virginia, less the Eastern Shore and Norfolk (Districts 1-20).
4. Norfolk (Districts 21 and 22).

Divisions were made in the preceding manner on the assumption that oysters harvested in these districts would tend to be marketed or processed in the same district. While the preceding assumption may not be entirely valid, it is nevertheless of interest to examine such divisions since economics of shipping would favor processing the oysters near their point of origin. For analysis 1931 to 1972 was subdivided into three periods:

1. 1931 to 1951--the early period of rising production.
2. 1952 to 1960--the period of peak production.

Table 17

Market Oyster Landings by Districts from Private Grounds in Virginia
1930-1 thru 1971-2[1]
in bu.

Season	Districts 24-29	Districts 1-22	Districts 21-22	Districts 1-20	Total for Virginia
1930-1	302,713	933,355	443,816	489,539	1,236,068
31-2	158,038	700,431	350,415	350,016	858,469
32-3	224,060	725,840	439,524	286,316	949,900
33-4	279,958	1,286,628	751,536	535,092	1,566,586
34-5	353,334	1,138,879	664,927	473,952	1,492,213
35-6	417,509	1,712,616	899,871	812,745	2,130,125
36-7	273,854	928,401	516,751	411,650	1,202,255
37-8	291,905	916,785	618,319	298,466	1,208,690
38-9	433,645	1,262,082	625,200	636,882	1,695,727
39-40	699,589	1,083,952	657,601	426,351	1,783,541
1940-1	525,894	1,131,075	702,010	429,065	1,656,969
41-2	434,911	1,083,991	684,808	399,183	1,518,902
42-3	394,580	1,462,741	661,689	801,052	1,857,321
43-4	335,540	1,003,063	468,917	534,146	1,338,603
44-5	536,490	1,088,572	361,281	619,655	1,625,062
45-6	666,920	1,400,344	470,136	930,208	2,067,264
46-7	655,509	1,524,033	550,710	973,323	2,179,542
47-8	472,464	1,498,953	594,219	904,734	1,971,417
48-9	403,079	1,413,753	532,339	881,414	1,816,832
49-50	542,730	1,652,471	571,003	1,081,468	2,195,201
1950-1	502,589	1,296,873	464,873	832,343	1,799,462
PER CENT OF TOTAL (1930-1 – 1950-1)	26	74	35	39	
51-2	587,313	1,273,919	381,149	892,770	1,861,232
52-3	969,475	1,377,016	422,153	954,863	2,346,491
53-4	1,035,867	1,719,275	459,703	1,259,572	2,755,142
54-5	903,544	2,153,357	615,079	1,538,278	3,056,901
55-6	668,537	1,714,920	489,351	1,225,569	2,383,457
56-7	820,002	1,729,527	571,018	1,158,509	2,549,529
57-8	838,333	1,609,490	580,993	1,028,497	2,447,823
58-9	603,631	1,933,339	548,959	1,384,380	2,536,970
59-60	557,808	1,639,043	358,262	1,280,781	2,196,851
(PER CENT OF TOTAL, 1951-2 – 59-60)	32	68	20	48	

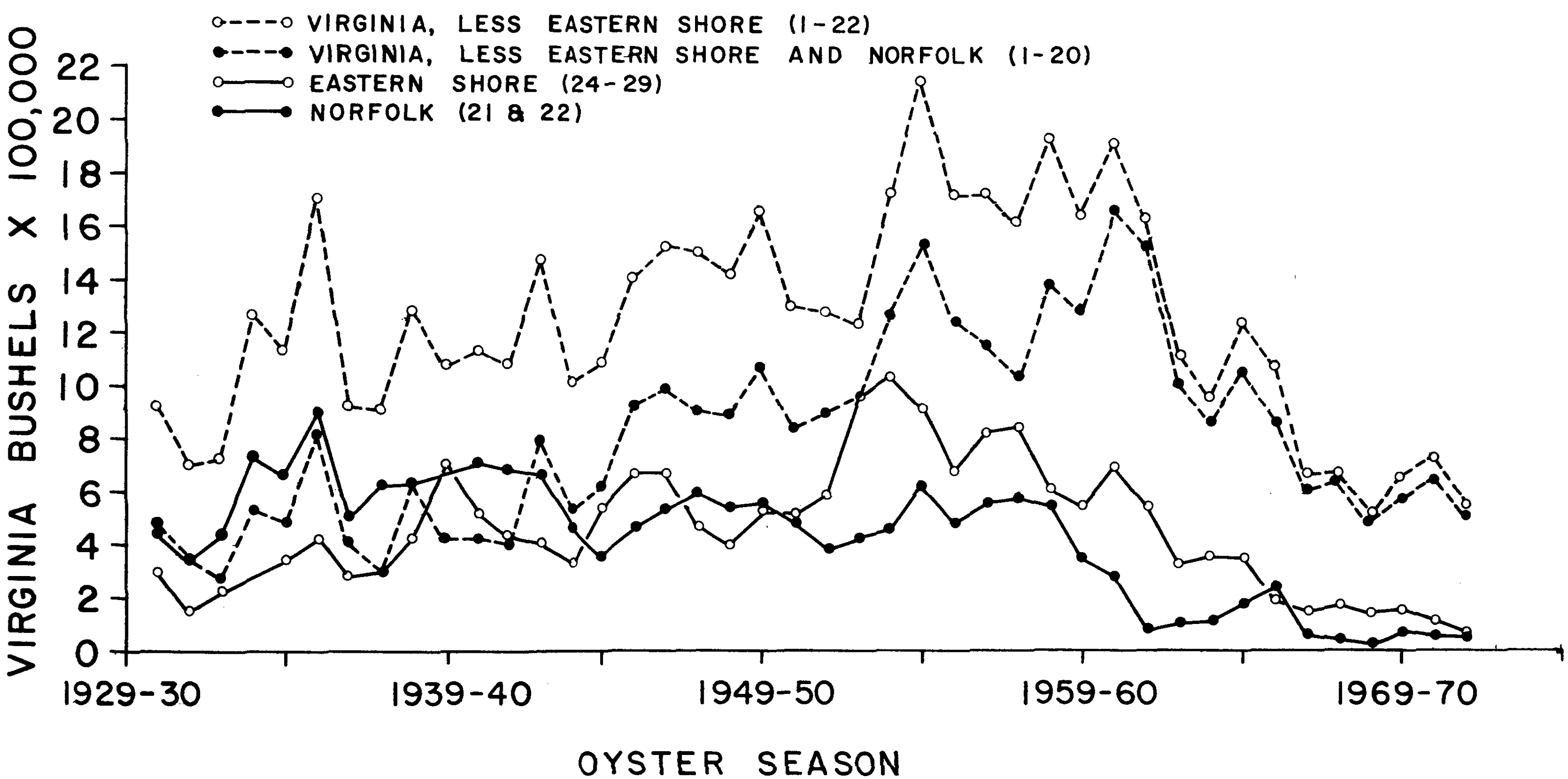
Table 17 (Contd.)

Season	Districts 24-29		1-22		21-22		1-20		Total for Virginia
1960-1	690,530		1,925,341		279,168		1,646,173		2,615,871
61-2	548,794	% of Total 23	1,618,845	% of Total 77	83,710	% of Total 9	1,535,135	% of Total 68	2,167,639
62-3	334,035		1,112,120		103,731		1,008,389		1,446,155
63-4	366,250		958,797		108,313		850,484		1,325,047
64-5	355,500		1,225,737		181,599		1,044,138		1,581,237
65-6	193,923		1,079,856		232,506		847,350		1,273,779
66-7	144,272				49,824		604,295		798,391
67-8	179,548		679,997		38,369		641,628		859,545
68-9	143,350		516,507		30,647		485,860		659,857
69-70	152,707		663,833		82,853		580,980		816,540
1970-1	110,254		719,461		69,399		650,061		829,715
71-2	68,224		568,076		63,807		504,269		636,300
Totals 61-72					1,323,926				15,010,076

1. Computed from tax receipts in annual reports of the VMRC and its predecessors; imports are included prior to 1962 but excluded since 1962. Not computed since 1972 because detailed figures needed for computation not published by VMRC.

Figure 24

Catch of market oysters from private grounds by districts in Virginia, 1930-31 thru 1971-72. Data computed from inspection tax receipts published in Annual Reports of the Commission of Fisheries and the Marine Resources Commission.



VIRGINIA, LESS EASTERN SHORE (1-22)
VIRGINIA, LESS EASTERN SHORE AND NORFOLK (1-20)
EASTERN SHORE (24-29)
NORFOLK (21 & 22)
VIRGINIA BUSHELS X 100,000
0
2
4
6
8
10
12
14
16
18
20
22
1929-30
1939-40
1949-50
1959-60
1969-70
OYSTER SEASON

3. 1961 to 1972--the time of declining production due to MSX and other causes.

Eastern Shore--Districts 24, 25, 26, 28 and 29

The Eastern Shore has contributed from 23% to 32% of the total taxable oyster production for the entire State from 1931 to 1972.

There are three possible inferences which may be drawn from these data:

1. The Eastern Shore was growing and processing about one quarter of the total State production of oysters during this long period.
2. Oysters were being shipped to that area to be processed or shucked.
3. Tax was collected with greater efficiency in those districts.

It is our belief that production was actually this high on the shore.

Norfolk--Districts 21 and 22

Totals from this area are most informative since two of the largest oyster shucking houses in the State and several small ones operated here from about 1930 to 1960. The two large firms had extensive oyster growing grounds in Mobjack and lower Chesapeake Bay in the areas which were later subject to MSX. These companies were the J.H. Miles Company and the Ballard Fish and Oyster Company. Total plantings of seed by the two firms sometimes exceeded 1,000,000 bushels annually. Most of the oysters taxed in District 21 and 22 undoubtedly were grown by these companies in Mobjack or in the lower Bay and not in the waters of the Norfolk District, per se.

The Norfolk area accounted for 35% of the State total from 1931 to 1951; from 1951 to 1960 it was only 20% of the total. This decline was not necessarily one of lower production, but represented a period of stable production for the Norfolk districts and an increase in production for other districts in the State. The massive drop in the 1960 to 1972 period to only 9% of Virginia landings represented the almost total abandonment of oyster culture in the lower Bay by the large Norfolk companies.

Virginia Minus the Eastern Shore and Norfolk--Districts 1 through 20

Tax revenues were collected from these districts, which include the Potomac tributaries and encompass the western shore of Chesapeake Bay from the Little Wicomico to the Nansemond and the James rivers. Production from the Nansemond River in the James basin from 1931 to about 1960 was negligible but, from 1962 to 1972 it greatly influenced total landings. Total landings in this major division from 1931 to 1951 were about the same as the Norfolk districts and amounted to 39% of the State production. Actual landings from 1952 to 1960 in the districts increased and accounted for 48% of the State total. Production dropped sharply from 1961 to 1972, but did not decline as rapidly as in other sections. Consequently, this region accounted for 68% of all production for that period.

These data show a drastic decline in production as shown by tax revenues in all major divisions of Virginia. This holds for the Eastern Shore, Norfolk, and for the region from the James to the Potomac. None of these divisions have maintained their former levels of productivity. Moreover, all regions show a decline. These data strongly suggest that no one region is declining significantly due to oysters being shipped from one region to another.

Market Oyster Production on Public Oyster Grounds By River System--1963 to 1975

Market oyster production presented previously using Federal and State data has not reviewed landings in respect to the river or place where the oysters were grown. For most of the period reviewed, such information is not available.

Beginning in the 1962-1963 season, however, the system of recording tax information in the Buyer's Reports made it possible to show the point of origin of market oysters, but from public rocks only (Table 18). Consequently, these VMRC data are treated by river system in the following paragraphs. These data clearly show, with the possible exception of the James, the productivity of Virginia's Baylor Survey Grounds for market oysters is low in comparison to that of leased bottoms. Average annual production on the public rocks of all areas from 1963 to 1975 was only 342,593 bushels. This was only 29% of the total State production.

Potomac River Tributaries in Virginia

There seems to be no trend in landings for the Virginia tributaries of the Potomac River basin. Total quantity landed for the 13 year period was 244,771 bushels (Table 18) or about 5.5% of the State production. This quantity of oysters was produced from 2,988 acres (Table 4). Calculations show this to be an average yield of about 6.3 bushels of oysters per-acre-per-year. Production declined sharply in this area during 1973, 1974 and 1975.

Little and Great Wicomico Rivers

For analysis, these two rivers are grouped together. The Little Wicomico has always been a market oyster producing area. Since 1963 the Great Wicomico has developed into a

Table 18

Market Oyster Landings from Public Rocks in Virginia Based on Data from VMRC in Bushels 1962-3 thru 1974-5.

Area	Season					
	1962-3	1963-4	1964-5	1965-6	1966-7	1967-8
Potomac	15,584	10,717	5,376	44,976	23,665	36,709
L. Wicomico	66	135	1,412	239	1,406	1,803
G. Wicomico	1,447	6,358	3,874	3,092	1,793	900
Rapp.	38,553	61,589	42,560	30,418	10,397	27,263
Piank. & Milford Haven	1,547	7,275	918	1,008	1,391	839
Mobjack	0	0	982	165	361	568
York	0	258	112	2,697	540	742
James*	175,695	417,375	449,971	487,937	116,989	182,020
Nansemond	17,893	60,709	65,099	25,008	11,227	3,517
Misc.	8,195	1,975	0	0	0	0
Total	258,980	566,391	570,304	595,540	217,769	254,361
Eastern Shore						
Bayside	0	409	1,000	1,843	3,178	5,974
Seaside	9,015	10,057	44,560	8,599	5,908	2,661
Total	9,015	10,466	45,560	10,442	9,086	8,635
STATE TOTAL	267,995	576,857	615,864	605,982	226,855	262,996

Table 18 (Contd.)

Area	Season 1968-9	1969-70	1970-1	1971-2	1972-3	1973-4	1974-5	Total	% of Total
Potomac	25,264	13,074	31,828	26,273	3,732	4,156	3,417	244,771	5.5
L. Wicomico	1,211	1,364	948	2,647	2,100	3,643	1,018	17,992	0.4
G. Wicomico	915	648	522	14,196	17,753	39,140	81,546	172,184	3.9
Rappahannock	29,402	23,698	65,949	81,711	95,583	110,933	203,331	821,387	18.4
Piank. & Milford Haven	75	983	280	261	649	1,575	11,676	28,477	0.6
Mobjack	1,088	338	70	323	532	3,722	4,529	12,678	0.3
York	204	360	716	131	1,091	535	1,233	8,619	0.2
James*	157,669	143,778	170,844	129,716	27,389	186,290	61,601	2,757,274	61.9
Nansemond	1,796	1,003	1,911	2,013	0	7,624	1,001	198,801	4.5
Misc.	0	94	292	278	160	644	15,173	26,811	0.6
Total	217,624	185,340	273,360	257,549	148,989	358,262	384,525	4,288,994	96.3
Eastern Shore									
Bayside	3,564	2,217	4,037	663	7,274**	14,666**	17,369**	62,194	1.4
Seaside	6,389	4,630	3,604	2,029	1,627	1,594	1,843	102,516	2.3
Total	9,953	6,847	7,641	2,692	8,901	16,260	19,212	164,710	3.7
STATE TOTAL	227,577	192,187	281,001	260,241	157,890	374,522	403,737	4,453,704	

* About 90% of these oysters are classed as soup oysters with an average size of about 2½ inches. See text for explanation under James River.

** Includes Tangier Island catch.

seed area producing 1,202,611 bushels of seed from its public grounds from 1963 to 1975 (Table 15). The Great Wicomico until 1973 was a poor source of market oysters having yielded only 33,745 bushels in the ten years. Total production of market oysters of both river systems from 1963 to 1975 was 190,176 on 24,438 acres (Table 4). This is an average production of about 0.6 bushels per-acre-per-year.

Rappahannock River

The Rappahannock from 1963 to 1975 produced a total of 821,387 bushels of market oysters from its Baylor Grounds or 18.4% of the State total. This quantity was produced on 55,185 acres of public ground (Table 4). Calculations show that average production over this entire period was only 1.1 bushels per-acre-per-year. This very low production on the Baylor Survey Ground is not surprising because the Rappahannock is not a high set area. It is, however, a good growing area largely free of drills and in most sections is not affected by MSX. Many of the market oysters harvested here may have come from seed planted by the VMRC. It is not possible to distinguish what percentage came from native set and what was planted. In general, production has increased in the Rappahannock River beginning in 1971. This increase may be associated with increased repletion activity and better than average sets during 1973, 1974 and 1975 in the lower river.

Piankatank--Milford Haven

Production of market oysters reported from Baylor Survey Grounds in these rivers was very low for the period 1963 to 1975 (Table 18). Total production over the 13 year period from these locations was only 28,477 bushels. This total was produced on 15,297 acres (Table 4). Calculations show it represents about 0.1 bushels per acre annually.

Up to 1972 the principal use of the Piankatank River was a seed source. However, it began producing significant quantities of market oysters in 1975. MSX and oyster drills are active in the lower part of the system.

York River and Mobjack Bay

The production of market oysters from the public rocks in this large region was very low. The 28,484 acres produced a volume of 21,297 bushels in 13 years (Tables 4 and 18). This averages less than 0.1 bushels per-acre-per-year. This low figure may in part be associated with MSX which is present in Mobjack Bay and in the lower York River where the public rocks are located. No long term trends are seen in the two systems. Production in 1975 was far above the 13 year average.

James River

The James River system, exclusive of the Nansemond and Elizabeth rivers, contains 23,245 acres of public ground.

This area produced a total of 2,757,274 bushels of "market" oysters from 1963 to 1975. This averages 9.1 bushels per-acre-per-year. Comparison of "market" oyster catch for the James with other regions is not entirely valid, however, since "market" oysters in the James may range from about 1" to 3" or more in length. There is no "cull-law" limit in the James. Those from the other regions must be 3" except in certain cases, i.e., Russ' Rock and Little Carter's Rock in the Rappahannock which may be 2½". The James River is different because it has, since the earliest times, been a seed area in which oysters were small and generally covered with small spat. Beginning in 1957 a large soup company began buying 1" to 2½" oysters for frozen oyster stew. These oysters came principally from the James and were steamed open at three locations. One of these is located in Norfolk, a second near Urbanna,[6] while the third is at Irvington, Virginia. These oysters are known as "soups" and could and probably should be reported separately. However, in the records of the VMRC they are classed as "market" oysters. After 1960 the James began to yield large 3" oysters which were sold to shucking houses in addition to producing soups. It is possible to estimate relative quantities of soups and large

[6] This company ceased operation in 1974.

oysters landed from the Buyer's Report. According to these data over 90% of the oysters sold in the James River under the term "market" were in reality "soups." In any event the James River produced 61.9% of all oysters classed as "market" oysters by the VMRC ("soups" as well as "shuckers") from the public rocks from 1963 to 1975. During this period production trended sharply downward.

It is of interest here to show that in the 13 year period from 1963 to 1975 the commercial harvest of seed from the James was 6,373,495 bushels (Table 15). This contrasts to 2,757,274 bushels of market oysters, 90% soups (Table 18). This is a total harvest of 9,130,769 bushels or 30 bushels per-acre-per-year which far exceeds the harvest from any other river system in the State for the comparable period.

Nansemond River

The Nansemond River system is a small tributary of the lower James River which produces market-sized oysters, 3" or larger. The 2,277 acres of Baylor Ground produced 198,801 bushels from 1963 to 1975 or an average of 6.7 bushels per-acre-per-year (Tables 4 and 18). During this period the catch trended sharply downward from 65,099 bushels in 1965 to zero bushels in 1972-73 season. Production has increased slightly during 1974 and 1975, but levels are still below those for 1965.

Eastern Shore

The Eastern Shore of Virginia contains 81,214 acres, or 33.3% of all Baylor Ground in Virginia (Table 4). This huge acreage produced a total of only 164,710 bushels in the 13 year period, and this was 3.7% of all Baylor Ground production in Virginia (Table 18). It amounted to less than 0.2 bushels per-acre-per-year. Catch has trended downward in the last 13 years from 45,560 bushels (0.6 bu/acre in 1965) to 19,212 bushels (0.2 bu/acre) in 1975.

Summary of Market Oyster Production from Public Grounds

In summarizing production from public oyster grounds from 1963 to 1975, it is evident that the overall productivity is very low. In this period all Baylor Grounds in the entire State produced only 4,453,704 bushels from 243,271 acres or 1.4 bushels per-acre-per-year (Table 16). Moreover, even this small figure represents a decline over the Baylor Ground production from 1950 to 1963 when a total of 6,506,918 bushels were produced or 2.3 bushels per-acre-per-year (Table 13).

This statistic is almost unbelievable when we consider that these same areas were set aside in 1894 as the naturally productive regions. These data admit but one conclusion. The Baylor Grounds as defined in 1894 were probably not on the whole very productive. While they undoubtedly contained highly productive regions, they also contained much barren or unproductive bottoms. Evidence supporting this view has been given here. We believe the low per acre production data as shown today may have existed even in 1894 due to the inclusion of vast areas of unproductive bottoms in the Baylor Survey. This discovery will be of value in development of remedial measures. It suggests that removal of some of the Baylor Grounds for leasing would have no significant effect on "natural" or unaided productivity.

Imported Oysters

Information on quantity of oysters imported into Virginia prior to 1963 is poorly documented. Records on imports have been kept by the VMRC since 1963. Most probably imports prior to 1960 were negligible since Commonwealth waters were providing enough oysters to satisfy Virginia processors. Very likely few Potomac oysters were landed in Virginia prior to 1960 because the Potomac was badly depleted. A major set in the Potomac in 1963, an extremely rare phenomenon for this river, provided the basis for an enormous stock of oysters which began to reach market size in about 1966.

Shortly after 1960 there was a sharp drop in production of oysters from Virginia bottoms which has been attributed primarily to MSX. To maintain their production shucking house operators began importing oysters in increasing quantities (VMRC, 1969). Basically the imports came from four locations:

1. Potomac River (main stem) oysters landed in Virginia (these are considered part of Virginia's production by the NMFS, Table 13).
2. Potomac River oysters landed in Maryland (these are considered part of Maryland's production by the NMFS).
3. Imports from elsewhere in the Chesapeake region other than those landed from the Potomac, that is, managed waters.
4. Imports from outside the Chesapeake region, mostly from South Carolina, the Gulf Coast of Florida, Louisiana, Alabama, Texas, and New Jersey.

An analysis of VMRC reports for 1969, 1970 and 1971 show that 1%, 3% and 0.4%, respectively of the imports came from locations other than the Potomac or Maryland. Consequently for presentation, all imports from locations other than the Potomac are totaled with those for Maryland. Imports to Virginia from the Potomac River are considered separately (Table 19).

Potomac River oysters landed in Virginia increased from 58,738 bushels in 1964 to 395,838 bushels in 1967. Thereafter, the quantity decreased to only 47,146 bushels in 1975 (Table 19; Figure 25). Calculations based on data in Table 19 indicate the Potomac catch to be from 40% to 25% of all imports from 1964 to 1968. This declined to where the Potomac furnished less than 4% of the total imports in 1975.

The decline in landings is because the Potomac has not received a good "set" of oysters since the major strike in 1963. Surveys in 1973, 1974 and 1975 show that most of the oysters on the bottom are now large. Those less than 3" long are scarce, and prospects for any increase in landings prior to 1978 are nonexistant. Unless another significant strike occurs in the next 2 or 3 years or seed is provided from elsewhere, future production from the Potomac will drop to very low levels.

While the Virginia imports from the Potomac have declined, Maryland imports, some of these were Potomac River landings credited to Maryland, into Virginia have increased since 1964 from 120,262 bushels to a high of 1,751,461

Table 19

Comparison of Harvest of Market Oysters in Virginia
With Quantity Imported 1962-3 thru 1974-5[1]

Season	Quantity from Public & Private Ground in Virginia (2)	Quantity Imported (Va. bu.) From Potomac River (3)	From Other Places (4)	Total	Total Production Virginia + All Imports Bushels	% of Imports in total
1962-3	1,174,238	(5)	300,800	300,800	1,475,038	20.4
63-4	1,864,950	58,738	120,262	179,000	2,043,950	8.8
64-5	2,263,509	74,662	110,938	185,600	2,449,109	7.6
65-6	1,879,870	109,976	234,424	349,400	2,229,270	15.6
66-7	952,308	395,838	896,762	1,292,600	2,244,908	57.8
67-8	1,103,745	328,571	971,696	1,300,267	2,404,012	54.1
68-9	878,022	220,022	1,127,436	1,347,458	2,225,480	60.5
69-70	1,011,130	266,275	1,274,612	1,540,887	2,552,017	60.4
1970-1	1,117,015	172,403	1,272,875	1,445,278	2,562,293	56.4
71-2	1,188,645	189,486	1,395,155	1,584,641	2,773,286	57.1
72-3	552,011	58,339	1,751,461	1,809,800	2,361,811	76.6
73-4	798,799	31,747	1,642,906	1,674,653	2,473,452	67.7
74-5	895,597	47,146	1,314,721	1,361,867	2,257,464	60.3

1. Imports not reported separately prior to 1963.

2. From publications of VMRC.

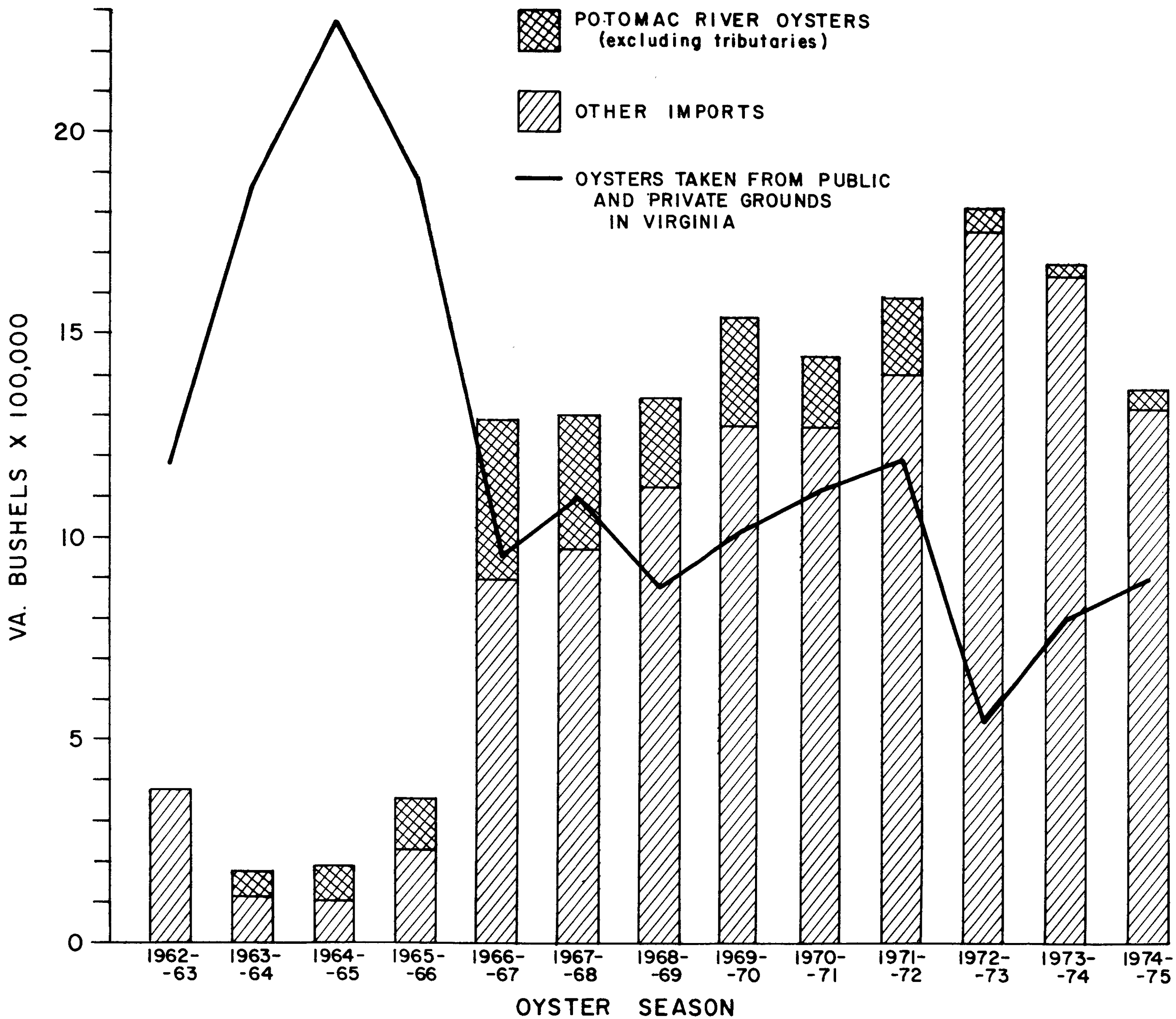
3. Data is the amount credited to Virginia oystermen by the NMFS from "Virginia Landings" for 1964 thru 68. Data for '69 thru '72 from VMRC reports. Data since '72 from NMFS.

4. Data for 1963 thru 1968 calculated from tax receipts contained in the annual reports of the Commission of Fisheries and Marine Resources Commission. Data for 69 thru 75 calculated from monthly VMRC reports.

5. No records available prior to inauguration of Potomac River Fisheries Commission in 1963; however, catch in the Potomac River was low prior to 1964; landings 1962-63 from other places may include some Potomac landings.

Figure 25

Comparison of harvest of market oysters in Virginia with quantity imported. 1962-63 thru 1974-75. Data for "Va. Oysters" is from publications of the VMRC. Data for "Potomac River Imports" is from "Va. Landings" NMFS; no data are shown prior to 1964 because Potomac River Fisheries Commission did not start operation until 1964; however, catch in Potomac River was negligible prior to 1964. "Other Imports" for 1962-63 thru 1968-69 calculated by subtracting "Potomac River Imports" from quantity of total imports calculated from tax receipts and reported in Annual Reports of the Commission of Fisheries and the Marine Resources Commission. "Other Imports" after 1968-69 calculated by subtracting "Potomac River Imports" from total imports computed from monthly reports of VMRC.



POTOMAC RIVER OYSTERS (excluding tributaries)
OTHER IMPORTS
OYSTERS TAKEN FROM PUBLIC AND PRIVATE GROUNDS IN VIRGINIA
VA. BUSHELS X 100,000
0
5
10
15
20
1962-63
1963-64
1964-65
1965-66
1966-67
1967-68
1968-69
1969-70
1970-71
1971-72
1972-73
1973-74
1974-75
OYSTER SEASON

bushels in 1973. In 1975 1,314,721 bushels were imported from Maryland (Table 19; Figure 24). This last figure exceeds the total Virginia landings, which were only 895,597 bushels for that year. These findings are significant and require emphasis. Over 50% of all oysters processed in Virginia were imported from the Potomac or from Maryland beginning in the 1966-67 season. Imports increased to 76.6% in the 1972-73 season, and 60.3% in 1974-75. This may be a conservative statement due to underreporting. A further indication was provided by T.D. Walsh, a NMFS statistician, who wrote, "The oyster plants in Virginia have to import about 75% of their shucking stock, usually from Maryland" (Walsh, 1969).

The net effect of these imports is clear when total imports are added to total Virginia production. When this is done total bushels processed in Virginia in the 1964 to 1975 period ranged from 2,043,950 to 2,642,645 bushels per year (Table 19). These ranges are similar in magnitude to Virginia production from 1950 to 1960 prior to MSX (Table 13). The industry was considered in satisfactory condition in this latter period. What the similarity in quantity of processed oysters in the pre- and post-1960 period suggests is that the demand for processed oysters from Virginia has been stable for many years. Obviously when production from Virginia's leased and public bottoms began to decline after

1960 the void was filled by the processing segment of the industry by importing Maryland oysters.

An interesting aspect of Virginia's oyster production is shown when Virginia imports from regions other than the Potomac (Table 19) are compared to total Maryland production (Table 20). These data show that for the period 1968 to 1975, Virginia imports have taken from about half to almost two-thirds of the entire output of the state of Maryland (Table 21). This is a very interesting point since it shows that the Virginia oyster processor benefits as much from the Maryland program as does the Maryland processor. It also suggests that Maryland harvesters may actually need the Virginia processors to help handle a significant part of their production.

Prices of the Virginia catch as contrasted to the Potomac harvest are shown in Table 22. These data are shown here only to suggest that the Potomac River catch sells for more than those harvested in Virginia.

Seed Oyster Production in Virginia

Introduction

Under present culture practices in the private production sector, a reliable supply of inexpensive seed

Table 20

Quantity, Value and Price of Maryland Market Oyster Catch

1949-50 thru 1974-5

	MARYLAND CATCH[1]			POTOMAC RIVER CATCH[2]		
Season	Quantity (Va. Bu)	Value in $1,000	Avg. Price per bushel	Quantity (Va. Bu)	Value in $1,000	Avg. Price per bushel
1949-50	2,065,591	5,386	2.61			
50-1	2,002,315	6,151	3.07			
51-2	2,123,062	6,720	3.16			
52-3	2,292,605	7,000	3.05			
53-4	2,752,093	8,798	3.20			
54-5	2,338,177	8,029	3.43			
55-6	2,269,603	8,210	3.62			
56-7	1,804,303	7,036	3.90			
57-8	2,015,899	7,012	3.48			
58-9	1,981,103	7,334	3.70			
59-60	1,928,265	8,271	4.29			
1960-1	1,603,537	7,630	4.76			
61-2	1,323,139	6,788	5.13			
62-3	1,163,732	5,816	5.00			
63-4	1,214,360	5,795	4.77	29,640	142	4.79
64-5	1,088,293	4,816	4.42	60,699	287	4.72
65-6	1,339,960	6,648	4.96	72,931	463	6.35
66-7	2,084,185	9,216	4.42	234,565	1,132	4.82
67-8	1,895,889	9,593	5.06	191,043	978	5.12
68-9	1,725,334	8,910	5.16	91,133	483	5.30
69-70	1,927,991	8,108	4.20	117,818	574	4.87
1970-1	2,051,351	9,789	4.77	54,049	265	4.90
71-2	2,249,516	11,740	5.22	24,496	168	6.87
72-3	2,649,138	11,903	4.49	9,366	42	4.48
73-4	2,715,664	14,053	5.17	189	0.79	3.97
74-5	2,065,987	9,712	4.70	308	1.7	5.52

1. Data for 1950 through 1972 from <u>Fish. Stat. U.S.</u> NMFS; data for 1973 through 1975 from "Md. Landings." NMFS. For easy comparison U.S. and Md. bushels were converted to Va. bushels and data was recomputed from calendar year to oyster season. Does not include Potomac catch after 1964.

2. Data from "Md. Landings". NMFS; oysters were caught in the Potomac River and credited to Md.

Table 21

Size of Maryland's Market Oyster Harvest which Was Exported to Virginia[1]
1963-4 thru 1974-5

Season	Quantity Harvested (Va. bu)[2]	Quantity Exported (Va. bu)[3]	Percent
1963-4	1,244,000	120,262	9.6
64-5	1,148,992	110,938	9.6
65-6	1,412,891	239,424	16.9
66-7	2,318,750	896,762	38.6
67-8	2,086,932	971,696	46.6
68-9	1,816,467	1,127,436	65.3
69-70	2,045,809	1,274,612	62.3
1970-1	2,105,400	1,272,875	60.4
71-2	2,274,012	1,395,155	61.4
72-3	2,757,197	1,751,461	63.5
73-4	2,715,853	1,642,906	60.5
74-5	2,066,295	1,314,721	63.6

1. Data extracted from Tables 19 & 20.

2. Data from "Md. Landings" for 1973-1975; prior data from Fish Stat. U.S., both publ. by NMFS. Includes Potomac catch credited to Md.

3. Data from 1964 thru 68 derived from inspection tax receipts in annual reports of the VMRC. Data for 69 thru 75 is from monthly reports published by VMRC. Data shows total Va. imports, other than Potomac River oysters which were landed in Va. almost all of which came from Md. (1% in 69, 3% in 70, 0.4% in 71 and 0.01% in 72 did not).

Table 22

Quantity, Value and Price of Virginia and Potomac River Market Oyster Catch 1930-1 thru 1974-5

Season	VIRGINIA CATCH[1] Quantity (Va. Bu)	Value in $1,000	Avg. Price per bushel	POTOMAC RIVER CATCH credited to Va.[2] Quantity (Va. Bu)	Value in $1,000	Avg. Price Per Bushel
1930-1	2,848,477	2,132	0.75			
31-2	2,396,287	1,315	0.55			
32-3	2,336,768	1,067	0.46			
33-4	2,845,500	1,217	0.43			
34-5	2,899,139	1,205	0.42			
35-6	2,559,242	1,186	0.46			
36-7	1,828,649	810	0.44			
37-8	2,077,715	962	0.46			
38-9	2,568,169	1,253	0.49			
39-40	2,881,654	1,485	0.52			
1940-1	2,819,105	1,853	0.66			
41-2	2,403,861	2,118	0.88			
42-3	3	3	3			
43-4	3	3	3			
44-5	2,540,679	5,170	2.03			
45-6	3,344,196	6,835	2.04			
46-7	3,013,302	6,516	2.16			
47-8	3,480,276	7,255	2.08			
48-9	3,438,482	6,656	1.94			
49-50	2,620,509	5,375	2.05			
1950-1	2,413,681	5,531	2.29			
51-2	2,633,983	6,552	2.49			
52-3	2,791,805	7,206	2.58			
53-4	3,461,791	9,558	2.76			
54-5	3,283,315	9,567	2.91			
55-6	3,470,651	9,933	2.86			
56-7	3,193,534	9,700	3.04			
57-8	3,513,054	11,699	3.33			
58-9	4,051,085	14,052	3.47			
59-60	3,232,695	12,098	3.74			
1960-1	3,019,519	13,781	4.56			
61-2	2,042,922	10,294	5.04			
62-3	1.931,710	9,077	4.70			
63-4	1,952,122	8,937	4.58	58,738	286	4.87
64-5	1,960,779	9,786	4.99	74,662	381	5.10
65-6	1,590,837	8,124	5.11	109,976	731	6.65
66-7	1,018,516	4,219	4.14	395,838	1,896	4.79
67-8	842,517	3,971	4.71	328,571	1,699	5.17
68-9	766,770	3,885	5.07	201,065	1,073	5.37
69-70	981,724	4,104	4.18	245,932	1,185	4.82
1970-1	1,110,919	4,694	4.22	210,989	1,074	5.09
71-2	918,387	3,944	4.29	139,617	748	5.36
72-3	604,805	2,487	4.11	58,339	276	4.73
73-4	708,887	3,102	4.38	31,747	171	5.39
74-5	691,727	3,702	5.35	47,146	337	7.15

Table 22 (Contd.)

1. Data for 1930-1 through 1971-2 from Fish. Stat. U. S. NMFS; later data from "Va. Landings." NMFS. Potomac River landings after 1963 subtracted in order to make figures comparable to area for which VMRC reports total Va. landings.

2. Data from "Va. Landings" NMFS; oysters were caught in the Potomac River and credited to Va.

3. Data for half a year only available.

oysters is indispensible to the operation of the Virginia oyster industry. This single fact cannot be overemphasized. Prior to 1963 most of the seed used by private growers came from the public grounds in the James River and, to a lesser extent, from public rocks on the Seaside of the Eastern Shore. The Great Wicomico and Piankatank rivers have come into the picture and supplied about 20% of all seed marketed in Virginia from 1963 to about 1971. There has been little if any seed harvested commercially from these two rivers since 1972.

Details of production of seed from private leases in Virginia are very poorly documented but an appreciable amount did occur prior to 1960 from the lower James. According to our data seed production from private leases has been low over the entire State since 1963.

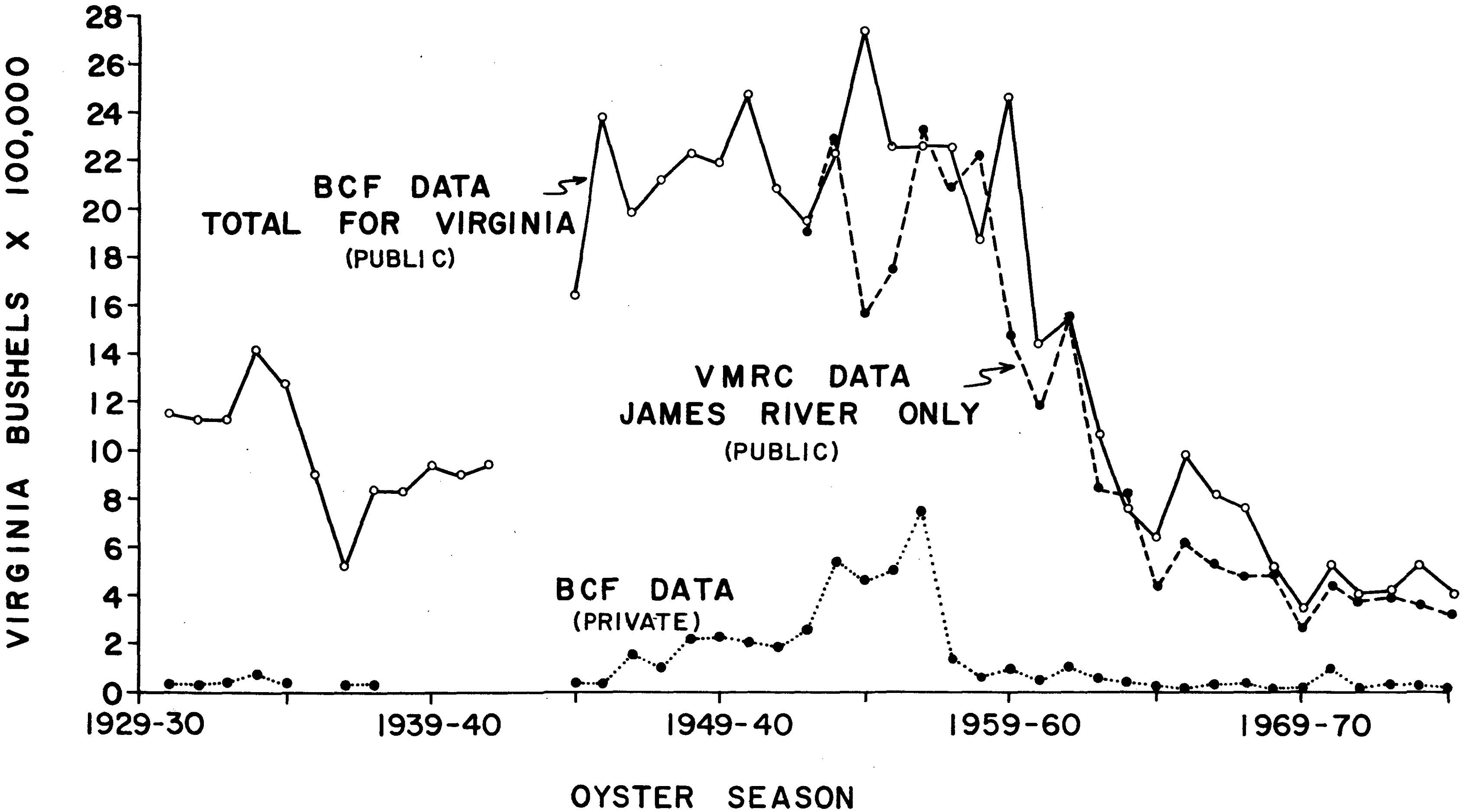
There is some private production of seed on leased bottom in other waters such as the Great Wicomico, but the amount is not known to us.

NMFS Data on Seed Production

Total seed oyster production in bushels based on NMFS data was tabulated for all rivers in Virginia for public and private grounds (Table 14; Figure 26). Prior to 1960 most of the seed oysters came from the James River with an

Figure 26

Catch of seed oysters from public and private grounds in Virginia. 1930-31 thru 1974-75. James River catch is shown for comparison; data from 1951-52 through 1961-62 were calculated from the public Repletion Tax receipts by Mrs. Lena Cosby at VMRC, while data from 1962-63 to 1974-75 are from reports published by VMRC. NMFS data for 1930-31 through 1971-72 are from Fisheries Statistics of the U. S. and, thereafter from "Va. Landings."



VIRGINIA BUSHELS X 100,000
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
BCF DATA
TOTAL FOR VIRGINIA
(PUBLIC)
VMRC DATA
JAMES RIVER ONLY
(PUBLIC)
BCF DATA
(PRIVATE)
1929-30
1939-40
1949-40
1959-60
1969-70
OYSTER SEASON

undeterminable fraction coming from the Eastern Shore. Statewide production was fairly stable at 1½ to 2 million bushels between 1931 and 1936. From 1937 through 1944 the record is incomplete, but a decline to 700,000 to 900,000 bushels is indicated. In 1945, when data were again available, 1,628,352 bushels were recorded. Production fluctuated erratically from 1945 to 1960 from 1,628,352 to 2,588,469 bushels per year with no definite trends. Beginning in 1961 production trended sharply downward and in 1975 only 392,504 bushels were landed. This amounted to a 88% reduction from the high point of 3,184,851 bushels in 1955.

The estimate of seed production from private beds shown by the NMFS in Table 14 seems far too low but there is no way of checking the accuracy of the data since the VMRC does not tax seed from private plantings. Probably these data were only partially reported.

<u>VMRC Data on Seed Production</u>

Data on seed production obtained from VMRC files are unreliable prior to 1963. Also, as explained earlier, the quantity of seed planted by VMRC is not considered part of the total seed production as reported by VMRC or NMFS.

VMRC data show total commercial seed production (VMRC harvest excluded) from public rocks for the State declining from 889,761 bushels in 1963 to only 336,891 bushels in 1975, or a decline of 62% (Table 15).

Table 15, based upon VMRC data, shows seed production for public grounds by region and also presents a total for commercial harvest. These data show several interesting aspects of seed production in Virginia.

Eastern Shore

Commercial production varied from 19,888 bushels to 122,806 annually during the period 1963 to 1975 with a definite downward trend since 1970. The area produced only 8.2% of all seed in the State during this 13 year period.

Great Wicomico

This seed source did not contribute significantly to the seed harvest of Virginia prior to 1963 since it was developed by the VMRC as a seed area only after that date. This small river produced 1,202,611 bushels or 13.1% of the State's harvest during the period from 1963 through 1975. This is a greater quantity than produced by the much larger public acreage of the Eastern Shore. Experience in the Great Wicomico serves to indicate what is possible under positive management.

Since 1971 production of seed has declined drastically. None was produced during 1973 and 1974. Production in 1975 was only 8,310 bushels.

James River

Prior to 1960 the James River was the source of nearly all seed planted in Virginia. Seed production from 1959 to 1963 (Table 14) declined sharply. Data shown in Table 15 indicate that production continued to decline in the James from 843,833 bushels in 1963 to only 317,003 bushels in 1975. This was a decline of 62%.

Production from the public rocks of the James accounted for 77% of the State's commercial seed oyster production from 1963 to 1975. While production is far below normal, the James is still the chief source of seed for the Virginia planter.

Due to the importance of this river, it is of major interest to carefully consider why harvesting or production of seed in the James has declined. Is the seed harvest down because there are fewer oysters on the bottom to be harvested, or is seed production down because of a lessening of demand, or are other factors responsible? Could a combination be involved? Partial answers to these questions may be inferred from the data presented here.

A Comparison Between Total Production of Market and Seed Oysters in Virginia

Market and seed oyster production have been discussed separately. They will now be contrasted to each other to show several interesting aspects.

Total market oyster and total seed oyster production for Virginia from 1931 to 1975, obtained from Tables 13 and 14, are shown in Figure 27. Market oyster production for public and private beds increased from 1931 to 1959 from 2,848,477 to 4,051,085 bushels annually. From the latter date it decreased by 78% to 895,597 bushels[7] in 1975. Production of seed followed a similar pattern declining from about 3,000,000 to only 400,000 bushels.

In respect to the relation between seed and market oysters, it was noted that if production of market oysters from public beds is subtracted from total production, the quantity of market oysters produced on private leases about equals the amount of seed oysters produced (Figure 28) indicating a 1:1 seed to market oyster production ratio.

Further examination of the data presented in the two graphs showed--if the curve for market oysters is advanced

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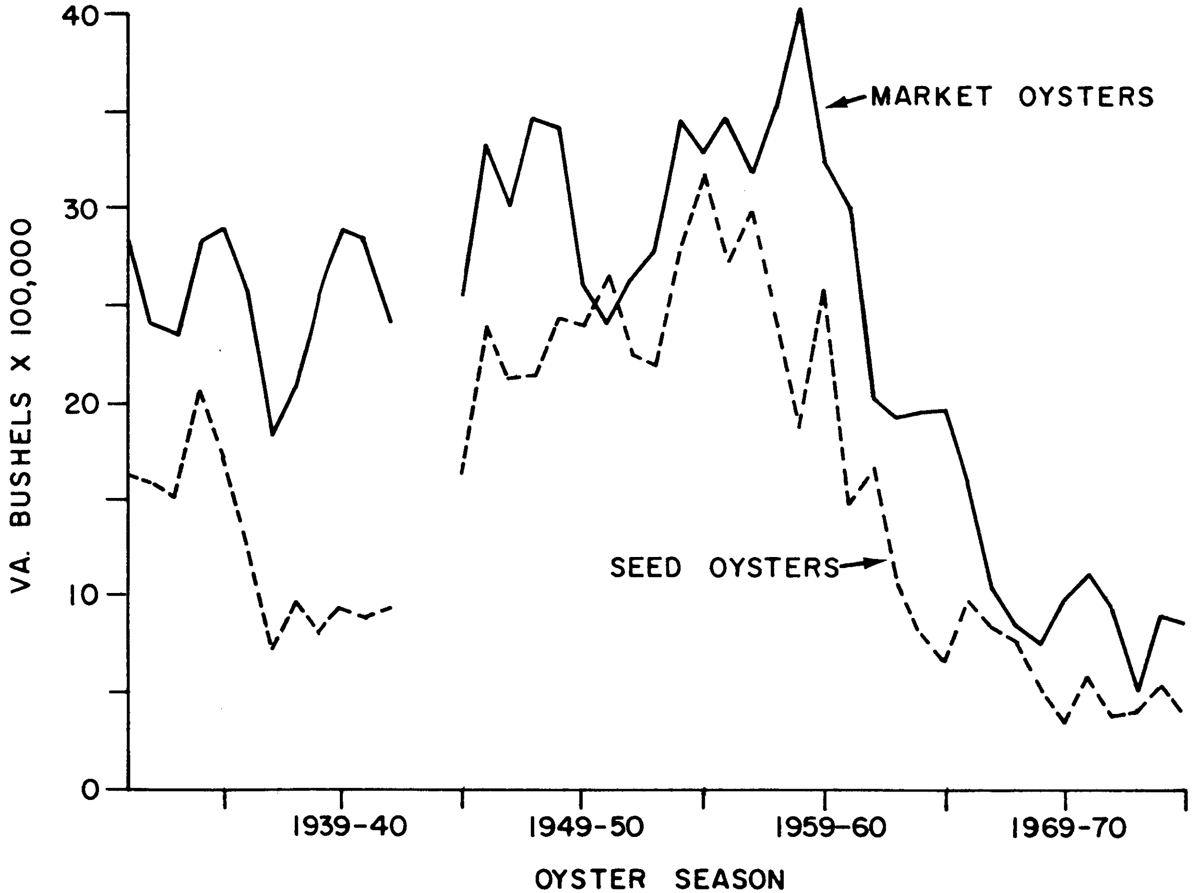
[7]Based on VMRC data--Data from NMFS not available for 1975.

Figure 27

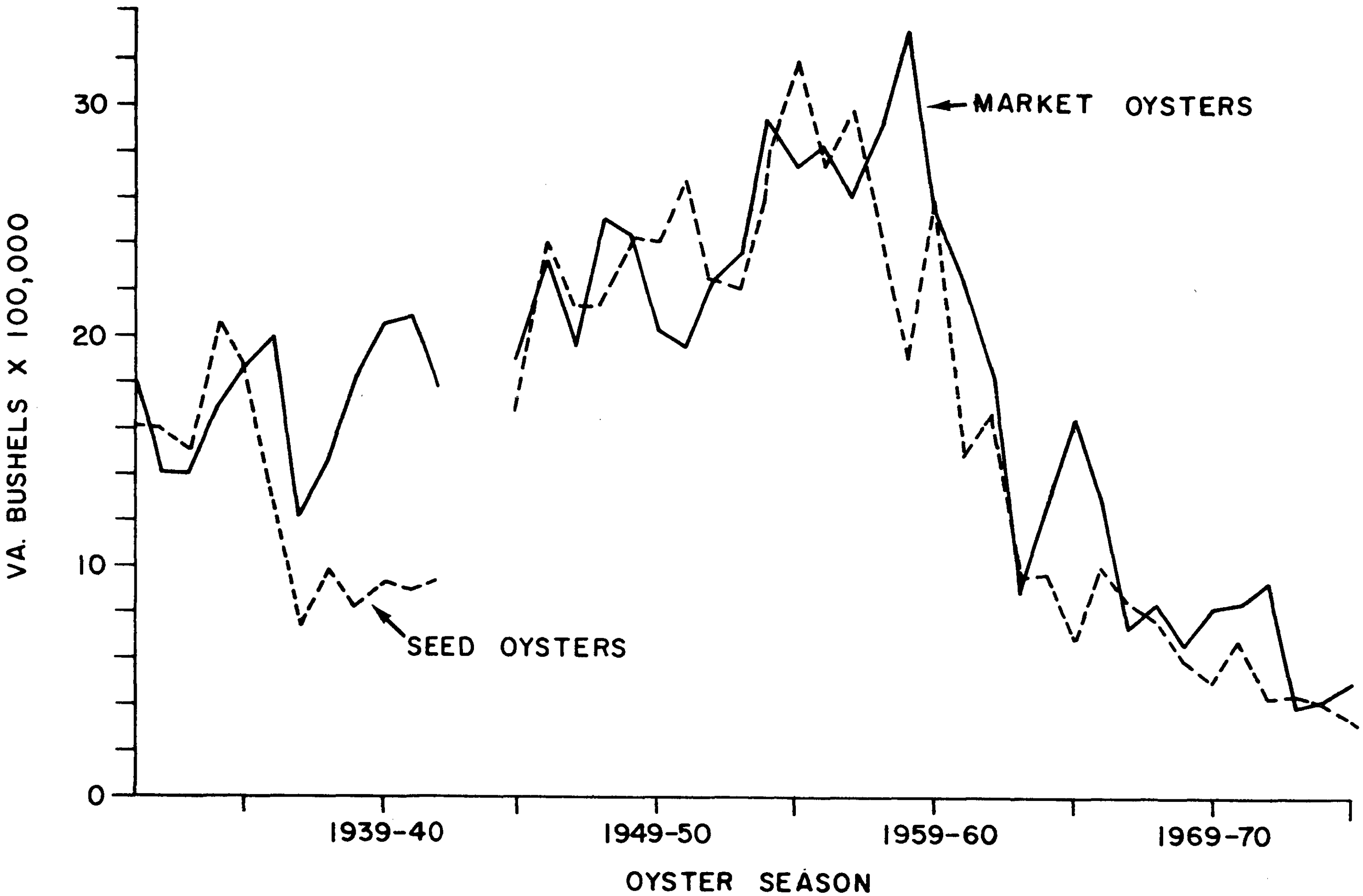
Market and seed oyster catch in Virginia from public and private bottoms. 1930-31 thru 1974-75. Data through 1971-72 are from Fisheries Statistics of the U. S. (NMFS). Thereafter seed data came from "Va. Landings" (NMFS) and market data from the VMRC.



40
30
20
10
0
VA. BUSHELS X 100,000
MARKET OYSTERS
SEED OYSTERS
1939-40
1949-50
1959-60
1969-70
OYSTER SEASON

Figure 28

Market oyster catch from private grounds and seed oyster catch from public and private grounds. 1930-31 thru 1974-75. Data for market and seed through 1961-62 from Fish. Stat. U. S. (NMFS); subsequent data for market catch from publications of the VMRC. Data for seed catch after 1961-62 are the sum of VMRC data for public and NMFS data for private.



30
20
10
0
VA. BUSHELS X 100,000
MARKET OYSTERS
SEED OYSTERS
1939-40
1949-50
1959-60
1969-70
OYSTER SEASON

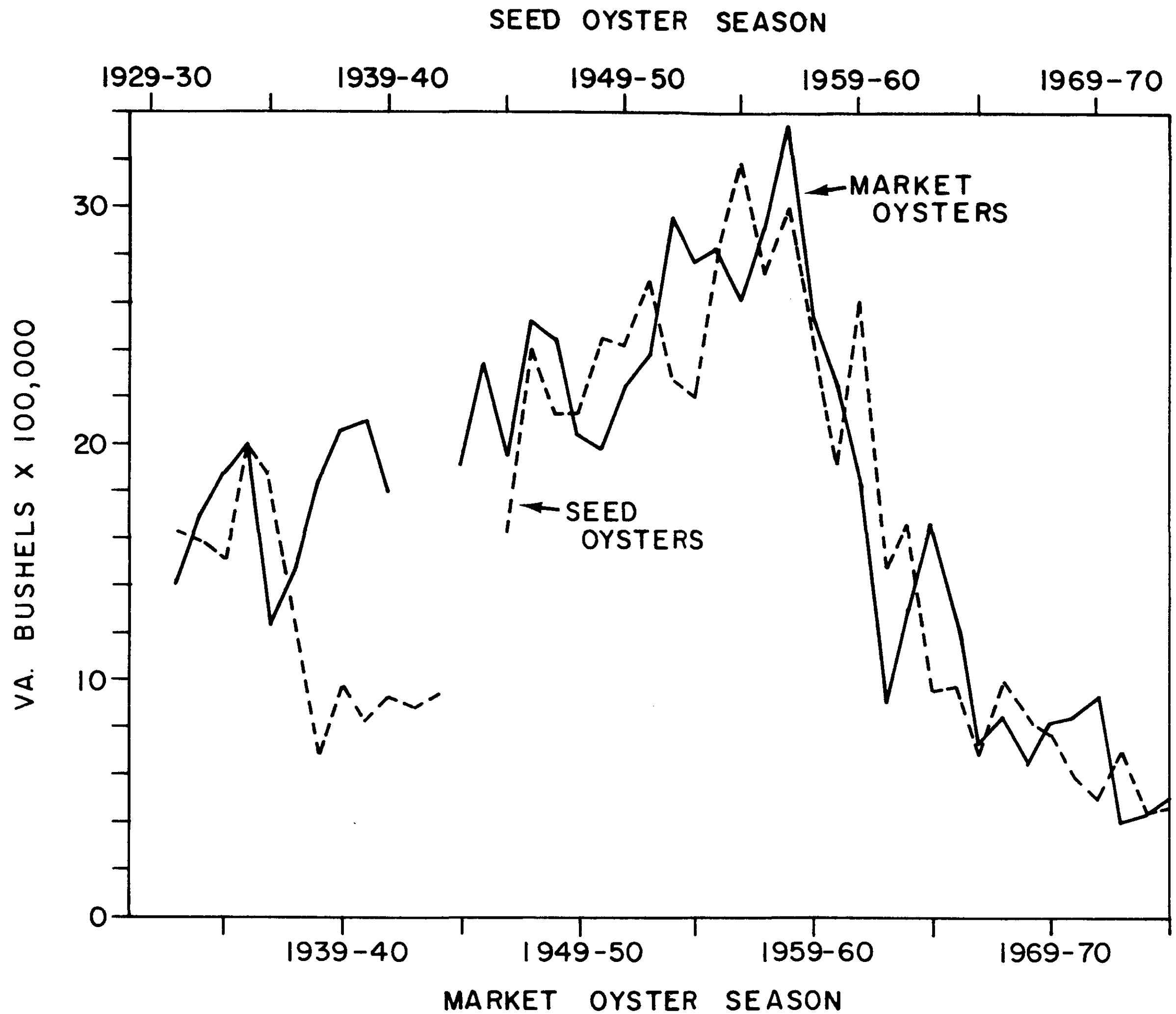
two years on the horizontal axis the amplitudes of the individual years coincide almost exactly (Figure 29). A similar but less exact fit was observed when the horizontal axis for market oysters was advanced three years. The biological justification for advancing the market oyster curve two or three years for comparison to the curves for seed production is that most private growers allow seed to remain on leased bottom two or three years prior to harvest. Ratios of seed to market oyster production two years later were calculated for 7 to 10 year periods from 1933 to 1960. The ratios ranged from 1.02 to 1.28. The ratio was 0.95 from 1961 to 1970. From 1971 to 1975 it averaged 1.17 (Table 9).

The relation between seed and market oyster production was evaluated statistically. For a two-year displacement from 1933 to 1975 there was a high degree of correlation ($r = .82$); for the 1946-47 to 1974-75 period correlation was higher ($r = .91$). This analysis clearly shows a very high degree of correlation between seed production and market oysters two years later.

In calculating the preceding correlation coefficients and ratios, we assumed that total seed production for the State from public and private grounds as listed in Table 14 was almost all planted on leased bottom in Virginia. This

Figure 29

Seed oyster catch from public and private grounds compared to market oyster catch from private grounds two years later. Data for market and seed thru 1961-62 from Fish. Stat. U. S. (NMFS); later for market catch data from publications of the VMRC. Seed data after 1961-62 are the sum of VMRC data for public and NMFS data for private.


SEED OYSTER SEASON
1929-30
1939-40
1949-50
1959-60
1969-70
MARKET OYSTERS
SEED OYSTERS
VA. BUSHELS X 100,000
0
10
20
30
1939-40
1949-50
1959-60
1969-70
MARKET OYSTER SEASON

assumption appears to be valid for 1931 to about 1963. An adjustment has to be made after 1963 for exported seed for the following reasons. In the decade of the 50's and probably before and in the early 60's, exports of seed from public rocks were banned due to the great demand by Virginia planters for seed. Most seed produced by private planters was used in-State during this period. The Potomac River Fisheries Commission (PRFC) was not active in seed planting until 1963. Therefore, prior to this year no Virginia seed went into the Potomac though it has since. In the early 60's exports were again banned due to the good demand by Virginia planters. Consequently, for the 1950's and up to 1963 the basic assumption is valid and the ratios shown in Table 9 are essentially correct.

Examination of data from 1963 through 1973 shows amounts bought by the PRFC and planted in that portion of the Potomac under its jurisdiction and the amounts of seed exported ranged from an estimated 3% to 24% (average 10%) of the Virginia seed harvest (Tables 23 and 24). Subtracting these exports from the total seed harvested gives the quantity planted by Virginia planters. This last figure was used to calculate new market-to-seed ratios for the 1965 to 1975 period (Tables 23 and 24) which are slightly higher than

Table 23

Quantity and Percentage of Virginia's Commercial Seed Oyster Harvest Which Was Planted in Virginia. 1962-3 thru 1972-3

Season	Total (Public and Private) Seed Harvested (Va. bu.)[1]	Seed Bought by PRFC (Va. bu.)[2]	Public Seed Exported (Va. bu.)[3]	Seed Planted in Virginia Quantity (Va. bu.)[4]	Seed Planted in Virginia Percent (%)
1962- 3	941,338	0	None	941,338	100
63- 4	959,148	0	30,329	928,819	97
64- 5	681,522	0	34,181	647,341	95
65- 6	997,744	70,447	84,498	842,799	84
66- 7	837,579	84,968	37,785	714,826	85
67- 8	764,088	29,364	20,592	714,132	93
68- 9	591,548	46,769	18,236	526,543	89
69-70	493,728	92,018	24,379	377,331	76
70- 1	673,001	101,326	21,811	549,864	82
71- 2	421,398	28,404	36,225[5]	356,769[6]	85[6]
72- 3	446,104	11,970	36,225[5]	397,909[6]	89[6]
Totals	7,807,198	473,082	344,261	6,997,671	
Average					90

1. From Table 9.

2. Data from the Potomac River Fisheries Commission (PRFC).

3. Data from files and published reports of the VMRC. Seed exported from the James, Piankatank, and Great Wicomico rivers only is shown. This gives a minimum estimate of exported public seed.

4. The result of subtracting seed exported and seed bought by the PRFC from total harvested.

5. Exact figures could not be obtained due to a change in the recording procedures; therefore, the average of the previous quantities was used as an estimate.

6. Estimated.

Table 24

Private Market Oyster Harvest Compared to Total Seed Planted on Private Grounds in Virginia. 1964-5 thru 1974-5

Season	Private Market Oysters Harvested (Va. bu.)[1]	Seed Oysters Planted in Va. Two Years Prior: Season	Seed Oysters Planted in Va. Two Years Prior: Quantity (Va. bu.)[2]	Ratio[6]
1964- 5	1,647,645	1962- 3	941,338	1.75
65- 6	1,273,888	63- 4	928,819	1.37
66- 7	725,453	64- 5	647,341	1.12
67- 8	840,749	65- 6	842,799	1.00
68- 9	650,445	66- 7	714,826	0.91
69-70	818,943	67- 8	714,132	1.15
70- 1	836,014	68- 9	526,543	1.59
71- 2	928,404	69-70	377,331	2.46
72- 3	394,121	70- 1	549,864	0.72
73- 4	424,277	71- 2	356,769[3]	1.19
74- 5	491,860	72- 3	397,909[3]	1.24
Total	9,031,799		6,997,671	
Average				1.29

1. From Table 9.

2. From Table 23

3. Estimated.

4. The ratio shows the average number of bushels harvested for each bushel planted.

those presented in Table 9. The corrected average ratio was 1.29 assuming a two year growing period.

It is suggested the return has been better (1.3 to 1) since 1970 than it was prior to 1970 (1 to 1).

Historically, the finding that there has been about a 1 to 1 or 1.0 to 1.3 relation between seed planted and market oyster landings from private beds is of major importance in considerations of management of the oyster fishery. If cultural techniques remain about the same we may now predict with a higher degree of confidence what Virginia's market oyster landings will be 2 or 3 years in advance! This, of course, will be done on the basis of numbers of bushels of seed harvested.

Relative Yields of Public and Private Grounds

Absolute Yields

Over the years private leases have always produced more oysters than the Baylor Grounds (Table 13). Ten year totals shown in this table were used to calculate ratios showing the magnitude by which private production exceeded that from public bottoms. These were: 1931-1940 = 2.0; 1941-1950 = 2.6; 1951-1960 = 4.8; 1961-1970 = 2.3; and 1971-

1975 = 1.5. Over the years the smaller acreage of leased bottoms have outproduced the 243,271 acres of Baylor Grounds.

Yield Per Acre

It is also of interest to compare the overall productivity of public and private oyster grounds in Virginia on the basis of yields per acre. For this purpose total acreage of public and private grounds on record from 1931 to 1975 were compared for each year with total market oyster landings.

In making this comparison several aspects must be kept in mind. The public bottoms set aside during the Baylor Survey were those presumed to be naturally productive. While some were actually barren and unproductive the best beds in Virginia, actual and potential, were included in Baylor Grounds. The areas set aside for leasing contained the less productive bottoms. In most cases it is necessary to plant oysters on these private beds to obtain production.

On both types of beds or bottoms, factors such as bottom type, depth, geographic location, diseases, and predators may cause productivity to vary. Consequently, the comparisons which follow may not be accurate in an absolute sense. They do indicate trends, however.

Yields Per Acre--Trend Prior to 1960

The total area involved for public grounds has been nearly constant over the past 45 years (Table 25). There was no obvious trend in yields per acre from 1931 to 1960 on these grounds. Production per acre was very low and fluctuated between 1.6 and 5.2 bushels per acre with an average of 3.2 bushels per acre. There was a decrease in yields from 1961 to 1975 when MSX appeared in the Bay. In this period it ranged from 0.6 to 3.2 bushels per acre with an average of 1.5.

Private leases from 1931 to 1960 were 7.6 times more productive than public grounds (Tables 5 and 25), yielding an average of 24.3 bushels per acre as contrasted to 3.2 bushels per acre for public bottoms. Yields per acre from 1961 to 1975 averaged only 8.2 bushels but private leases were still 5.5 times as productive. A most remarkable aspect of the data for production per acre from private grounds (Table 5) is its consistency in respect to yield per acre in relation to total acres under lease from the State during the period. Total production increased as total acreage leased increased. For example, from 1931 to 1960 total acreage of leased ground doubled from 63,442 acres to 130,107 acres. Over this same period oyster production nearly doubled from 1,830,836 bushels in 1931 to 3,347,170 bushels in 1959 (Table 5). Yields per acre in this 30 year period remained nearly constant averaging about 24.3 bushels per acre.

Table 25

Acreage and Yield of Public Oyster Grounds in Virginia
1930-1 thru 1974-5

Season	Total Public Acreage[1]	Market Oysters Harvested (bu)[2]		Average Yield (bu/acre)
1930-1	223,185	1,017,641		4.56
31-2	223,185	991,335		4.44
32-3	223,185	934,537		4.19
33-4	223,185	1,155,640		5.18
34-5	223,185	1,028,023		4.61
35-6	233,371	565,824		2.42
36-7	233,371	598,345		2.56
37-8	233,371	619,407		2.65
38-9	233,371	733,871		3.14
39-40	233,371	824,383	8,469,006	3.53
1940-1	233,371	726,241		3.11
41-2	233,371	606,498		2.60
42-3	233,371	N/A		N/A
43-4	233,371	N/A		N/A
44-5	233,371	634,179		2.72
45-6	233,371	997,843		4.28
46-7	233,371	1,060,147		4.54
47-8	233,371	962,284		4.12
48-9	233,371	1,015,035		4.35
49-50	233,371	586,412	6,588,639	2.51
1950-1	233,371	444,474		1.90
51-2	233,371	374,013		1.60
52-3	233,371	419,063		1.80
53-4	234,501	510,333		2.18
54-5	234,501	517,178		2.20
55-6	235,476	650,333		2.76
56-7	235,476	592,181		2.51
57-8	243,271	586,304		2.41
58-9	243,271	703,915		2.89
59-60	243,271	699,420	5,497,214	2.88
1960-1	243,271	781,783		3.21
61-2	243,271	227,921		0.94
62-3	243,271	267,995		1.10
63-4	243,271	576,857		2.37
64-5	243,271	615,864		2.53
65-6	243,271	605,982		2.49
66-7	243,271	226,855		0.93
67-8	243,271	262,996		1.08
68-9	243,271	227,577		0.94
69-70	243,271	192,187	3,986,077	0.79
1970-1	243,271	281,001		1.16
71-2	243,271	260,241		1.07
72-3	243,271	157,890		0.65
73-4	243,271	374,522		1.54
74-5	243,271	403,737	1,477,391	1.66

Table 25 (Contd.)

1. Data from Baylor Survey.

2. NMFS production figures were used to figure yield for 1931-1963; from 1963-1975 VMRC figures were used. This combination shows the most accurate figures.

N/A - Data was not available.

The almost stable figure for production per acre of 24.3 bushels from 1931 to 1960 deserves additional comments. A similar tabulation for the period 1935 to 1956 was made by Wheatley (1959) who calculated production in that period to be about thirty bushels per acre. This value is similar to ours which was calculated for a longer period. Galtsoff (1943) indicated thirty bushels per acre to be a reasonable objective of proper oyster management.

Yields Per Acre--Trend After 1960

Beginning around 1960 there began a decided change in the productivity, as shown by the data on the production per acre, for both public and private bottoms. For public bottoms this was due to MSX invading the formerly productive beds in the higher salinity waters. As a result, from 1961 to 1975 production averaged 1.5 bushels per acre within a range of from 3.2 to 0.6 (Table 25).

The change for leased areas was equally drastic. Private bottoms from 1961 to 1975 have produced only about 8 bushels per acre which was about one-third of the previous period (Table 5). In further evaluating the production per acre of leased ground the basic data expressed as bu/acre/ year may be misleading as previously outlined. In the first place, not all leased ground is actually put under culture. Some regularly used in production are fallowed, a technique used to reduce predators and, perhaps, diseases. Many leases are too small and scattered to be used in serious production efforts. Also some are leased for holding or "protection" of existing leases.

The extent to which leased ground is actually used is impossible to determine accurately. Data presented in the preceding paragraphs makes it possible to estimate use of leased grounds. If we assume: 1) that our data for Virginia production on private grounds (24.3 bushels per acre) is reasonably correct for the 1931 to 1960 period; 2) that our 1-to-1 estimates for yields is correct; and 3) that a Virginia planter may plant on the average about 750 bushels per acre. We may conclude that less than 4% of the land was in full use during that period. After 1960 estimates indicate 1% to be in full use.

A more important aspect of land use in relation to yield per acre, is--for sustained culture, a single acre is "productive" only once in two or three years. For example, let an individual, X, lease 100 acres. If the entire acreage is planted in the fall of 1970, production in 1971, 1972 and perhaps 1973 will be zero. Most planters wish a crop a year. Hence, plantings are made each year. In other words, on the average, under present methods of culture, it is possible for only about one-half to one-third of the individual's total leased acres to be productive each year on a sustained basis. Thus, in relation to the preceding production figure of 24.3 bu/acre/year, the actual production of one acre, once every three years, is probably closer to (3 x 24.3) or 72.9 bushels.

The stable production for bushels per acre from private grounds (Table 5) from 1931 to 1960 during the period when total leased acres was increasing suggests an important aspect of oyster culture during that time in Virginia. Increased production was accomplished by leasing and utilizing more land rather than by increasing yields on existing grounds. There is no reason to postulate that a great technological advance in growing oysters which might have increased yields per acre was adopted by growers in this period when in fact there was none.

A Decline in Licenses Issued

Above we have documented a sharp decline in oyster production. In order to develop an understanding of the factor or factors involved in the decline in oyster production, it is necessary to examine all of the possible causes.

One way of investigating the sharp decline in oyster production is to tabulate and study the number of persons who have been licensed to tong oysters. These data were obtained for the entire State from annual reports of the VMRC from 1931 to 1975. They are divided into numbers of patent tongers and hand tongers (Table 26).

Hand tongs (Figure 6) are the only type of gear permitted in Virginia on nearly all of the public grounds and, so, are responsible for most of its production, especially in recent years.[8] The number of permits to use hand tongs decreased erratically from 4,134 in 1931 to 2,640 in 1940, then remained stable during the 1940's. Numbers increased in the 1950's as did production. During the 1960's, when production was declining, hand tongers decreased sharply from 4,117 in 1960 to only 1,692 in 1970. The number of licenses issued from 1971 to 1975 has remained at about the 1970 level (Table 26).

Patent tongs are used today by fishermen to take oysters from public rocks in deeper waters in certain tightly restricted areas such as the lower Rappahannock and in the upper Chesapeake Bay (Code of Virginia 1950, 28.1-83). Fisheries statistics, until recently, did not separate the

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[8] See Appendix I for details on license fees for hand tongs and patent tongs.

Table 26

Number of Oyster Tongers in Virginia from License Records at VMRC

Season	Hand Tongers		Oyster Patent Tongers
1930-1	4,134		333
31-2	3,609		479
32-3	3,012		324
33-4	3,304		291
34-5	3,578		144
35-6	3,457		180
36-7	2,262		49
37-8	3,214		39
38-9	2,847		76
39-40	2,640	3,306 Avg.	181
1940-1	2,523		190
41-2	2,541		225
42-3	2,003		226
43-4	2,645		297
44-5	2,467		334
45-6	2,695		357
46-7	2,902		476
47-8	2,801		309
48-9	3,304		333
49-50	2,845	2,673 Avg.	229
1950-1	3,074		194
51-2	2,966		199
52-3	3,203		159
53-4	3,418		165
54-5	3,322		190
55-6	3,264		350
56-7	3,412		432
57-8	4,191		315
58-9	4,242		298
59-60	4,117	3,521 Avg.	306
1960-1	3,510		193
61-2	2,857		95
62-3	2,722		37
63-4	3,166		39
64-5	3,116		48
65-6	3,225		30
66-7	2,261		21
67-8	2,227		40
68-9	1,890		30
69-70	1,692		6
1970-1	1,690		5
71-2	1,181		8
72-3	1,248		7
73-4	1,557		34
74-5	1,703	2,273 Avg.	97

catches by fishermen using this gear from those made by shaft tongers. There was an erratic trend in the number of licenses issued from 1931 to 1960. After 1960 there was a sudden drop to only five licenses in 1971 and a partial recovery in 1975 to 97. The major reason for this decline after 1960 was that MSX appeared in the Bay system in that year and killed nearly all the oysters in the area where patent tonging was permitted. The partial recovery of patent tong productivity in 1975 was due to the return of some oysters to these areas.

The change in numbers of patent tong licenses issued since 1960 is thought to accurately reflect the major change in the fishery during this decade and a half. However, changes in the number of hand tong licenses as indicators of effort must be regarded with caution. For example, an unknown fraction of the tongers work steadily during the public oyster season while others may work for brief periods or for fewer hours per day due to the availability or competition of other jobs. Also, demand for oysters may be lowered so there is more incentive for watermen to seek other jobs.

Summary

Decline in Virginia Landings

A major fact established in this chapter is that all available sources of data from both NMFS and VMRC show a major decline in Virginia landings of seed and market oysters beginning in 1960. Moreover, this decline has occurred in all regions of Virginia. This holds for areas in the Chesapeake Bay where MSX was one of the major causes, as well as for the Seaside of Virginia where MSX is not a problem.

Decline in Market Oyster Landings

There has been a Statewide decline in market oyster landings as shown by the following averages (Table 13):

Production

Leased Bottoms	1951-1960 =	2,654,838 bu
	1961-1975 =	1,003,651 bu
Difference		1,651,187 bu
Decline		62%

Production

Baylor Grounds	1951-1960 =	549,721 bu[9]
	1961-1975 =	355,224 bu
Difference		194,497 bu
Decline		35%

The preceding tabulations emphasize the recent decline in total landings of market oysters in the State has largely been due to a lack of production from leased bottoms. Production of market oysters from Baylor bottoms has also shown a Statewide

[9]Potomac River landings subtracted (calculated from Table 13). If Potomac River landings are included the decline is only 14%.

decline, but total volume landed has always been lower than for the leased areas. Even if Baylor bottoms are restored to their pre-1960 levels, Statewide total production will still be low! Steps must be taken to encourage or enhance production from leased bottoms. As will be discussed in Chapters V and VII, Virginia has several options for increasing production.

Decline in Seed Oyster Landings

An exceedingly complex point documented in this chapter is--landings of seed oysters have declined in Virginia. Unlike market oysters, which may come from public and private bottoms in any area, seed is largely obtained from the James River. For example, in the James as shown in Table 14 and 15:

In 1931, 1,610,063 bushels were landed;

In 1945 to 1960 landings ranged from 1,622,950 to 2,743,479 bushels; and

In 1975, 317,003 bushels were landed.

Part of the decline in landings of seed are due to the absence of demand. Part is also due directly or indirectly to MSX. Another factor is the major decline in density of seed on the bottom of the James (Chapter IV). To counteract this reduction and decrease the dependence upon the James, which is Virginia's most heavily stressed wholly-owned tidal river, there has been a deliberate effort by VMRC to develop other seed areas in the Great Wicomico and the Piankatank rivers. Despite this effort and a serious drop in seed production, the James River still accounts for about 77% of all seed commercially harvested in the State from 1963 to 1975 (Table 15). This reduction from about 100% prior to 1960 to 77% is indicative of some success. However, the James seed area is still the key seed area!

Underreporting of Fisheries Statistics Data

Landings of Virginia oysters are published in Fisheries Statistics of the United States and in "Virginia Landings." They are based on tax data collected by the Virginia Marine Resources Commission. Collection of the basic tax in Virginia is on the honor system and evidence is that payment of taxes has been and is being avoided today. Accurate disclosure of production is not always practiced. Consequently, oyster production data for Virginia are probably underestimated. The State should attempt to determine the extent of such sources of error. Doing so will, if successful, allow an evaluation of the extent of the Commonwealth's losses.

The Higher Productivity of Leased Bottoms Over Baylor Grounds

Private leases have been and even today are the principal source of Virginia's market oyster production. This is not to say that the 243,271 acres of Baylor Grounds are of no significance. It is important to emphasize the importance of the private planters. It is principally the decline in their production which has contributed to the overall decline in landings from the State since 1960. Public grounds have not been very productive for many years.

Over the years private leases have always produced more oysters than Baylor Grounds. Ratios showing the amounts by which private ground production exceeded that from public ground are as follows: 1931-1940 = 2.0; 1941-1950 = 2.6; 1951-1960 = 4.8; 1961-1970 = 2.3; and 1971-1975 = 1.5 (Table 13). It is of major significance that in the 1951-1960 period when oyster production in Virginia was at its highest point production from leased bottoms was 4.8 times higher than total production from Baylor Grounds.

The annual production from 1931 to 1960 of all Baylor Grounds varied from 1.6 to 5.2 with an average of 3.2 bushels per acre. By comparison in the same period, private grounds were 7.6 times more productive with average yields of 24.3 bushels per acre. Since 1960, after MSX appeared in the Bay, the same general picture remains despite the depressing effects of the disease on total yields. Public bottoms production varied from 0.6 to 3.2 bushels per acre annually while leased bottoms produced about 8 bushels per acre.

The 1-to-1 Ratio Between Seed Oyster Production and Market Oyster Production

A very important point established above is a 1-to-1 ratio between seed production and market oyster production two years later! This ratio has prevailed for 46 years.[10] Total production from leased areas slowly increased from 1931 to 1960. The reason for this increase was that the private growers were leasing more bottoms and bringing them under culture. Per acre yields did not improve markedly! Over this period (1931 to 1960) the ratio between seed planted and market oysters harvested remained about the same. After 1960 landings declined as did the total amount of leased bottoms with the production ratio remaining at about 1-to-1. The perpetuation of this constant ratio over the years has led to the significant conclusion that there has been no improvement since 1931 in the efficiency of growing seed to market size! This absence of any improvement is incredible in the light of technological advances made in other industries in the last 40 years. These data indicate that strenuous efforts directed toward improving survival of seed are important for both public and private sectors of the industry and government.

This one-to-one ratio between seed planted and oysters harvested provides an accurate method of forecasting

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[10] From 1971 to 1975 the relation appears to be 1.3 bushels of market oysters to 1 bushel of seed.

yields two or three years in advance on the basis of number of bushels of seed planted.

Maryland Imports into Virginia

In this chapter we have also shown conclusively that Virginia oyster production has declined by about half with the resulting "void" being filled by the Virginia processor importing Maryland oysters so production of oysters for the market has remained at about the same level as it was prior to 1960. Virginia now takes about one-half of the heavily subsidized Maryland oyster crop. Evidence shows the demand for oysters processed in Virginia has been stable since about 1960.

CHAPTER IV

THE CONDITION OF THE PUBLIC OYSTER ROCKS IN VIRGINIA

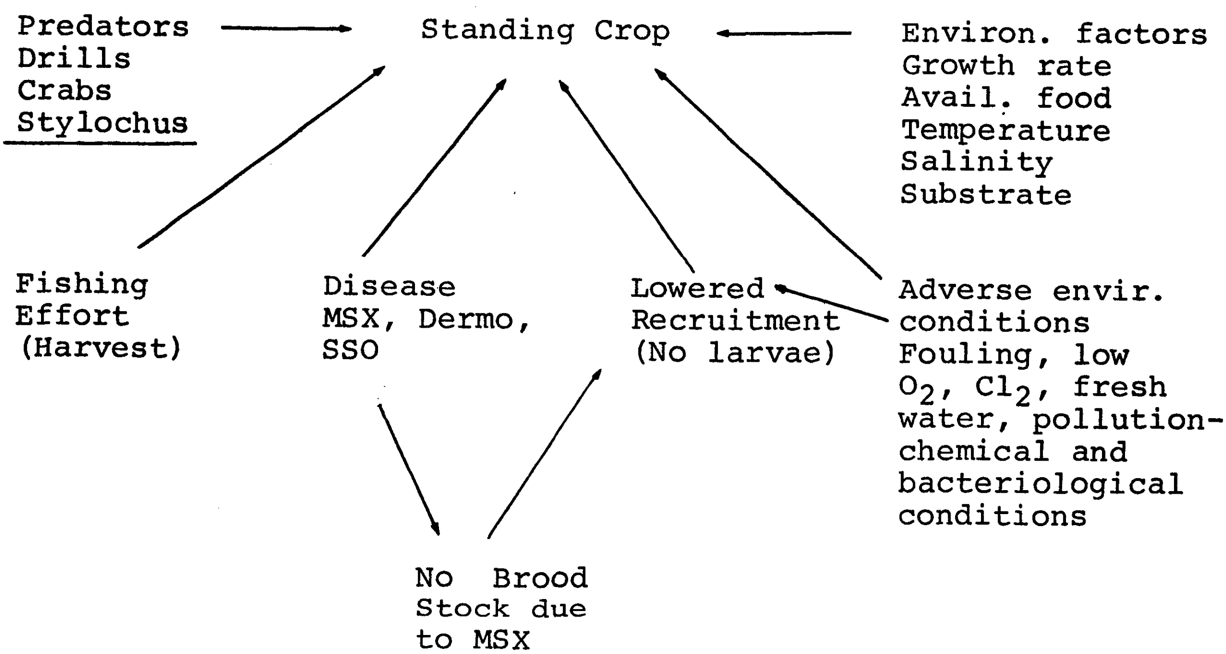
CHAPTER IV. THE CONDITION OF THE PUBLIC OYSTER ROCKS IN VIRGINIA

Natural Supply

Factors Influencing Abundance of Oysters on Public Bottoms

A majority of the public oyster rocks in all river systems in the Chesapeake Bay System in Virginia, for which data exist, are still producing oysters. However, most have suffered a reduction in numbers of oysters with a marked decline beginning in 1959-1960. The earlier reduction was probably due to continuous overfishing, in addition to environmental factors such as abnormal freshets or unusual disease-caused mortality coupled with predation. The recent decline has been most severe in the lower or higher-salinity portions of the systems. The size of oysters influenced (spat, small oysters or market oysters) differ with the river system. The decline in numbers of these three classes of oysters have been associated with declines in the levels of initial set for two or possibly three of the major river systems.

A simplified diagram of the interrelated factors of this complex problem follows:



A major question in considering this diagram is: What is the relative importance of the various factors affecting the standing crop and which have brought about the recent and dramatic decline in harvestable populations? For some of these factors there exist fair to good information while, for others, quantitative data are short or lacking.

This may seem like an extreme statement in light of the extensive studies on MSX and other diseases which have established the range of the diseases and mortality rates at selected locations. However, in the pertinent chapters which follow it will be seen that there is a lack of the type of data necessary to be sure what is occurring. For example, catch-per-unit-of-effort data for most areas have never been collected.[1] Numbers and density of oysters on the bottom of the various public Baylor beds from most areas may only be inferred from limited dredge samples. Until recently there has never been a meaningful study of population numbers and density of oysters on public seed rocks. Scientists from the Institute have begun an examination of this feature. Unfortunately, it does not cover a sufficient time span to show long-term trends.

The population dynamics of oyster bars have been studied only briefly for the Gloucester Point region. Until recently no one has collected the "effort" data in the form of numbers of active oyster boats per section of river per day or week which is necessary to establsih relative and comparable annual production (production related to comparable units of fishing effort) for any given area.[2] The cumulative effect on growth of various factors such as sublethal infections of disease and other causes has been only briefly investigated.

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[1]The VMRC has, since about 1966, collected effort data in terms of boat counts (numbers of boats working per day or observational period), but for the James River only.

[2]Since 1976 the VMRC has instituted a realistic program of evaluating effort.

Causes of Fluctuations

Oysters, being a living commodity, are subject to wide fluctuations in supply, much as agricultural crops. Both are affected by climatic changes, predators, disease and destructive acts of man. However, the oyster grower has less control over his crop than does the farmer since chemicals may be used to control diseases or stimulate growth and oyster growers have to rely on natural forces. For these reasons the supply of oysters is often unstable and unpredictable over the long term.

Characteristics of Seed Producing Areas

General Attributes

One of the first requirements of a natural seed-producing area is its waters contain significant quantities of oyster larvae which reach maturity. Also, it must have much exposed oyster shell or other suitable cultch material on the bottom to "catch" the setting oyster larvae. Additionally, the set of oyster larvae on the cultch must be in the "moderate" or "high" classification in terms of spat-per-unit of setting surface. The bottoms must be firm enough to support shells and oysters. Depth may range from the intertidal to about 25 feet below mean low water. However, it is not uncommon to find isolated small groups of oysters in deeper waters.

The largest and most important natural seed area within the Chesapeake Bay region is the James River with the Great Wicomico and Piankatank rivers also being productive. Scattered throughout Virginia are many small creeks and tributaries which are, at certain times, also highly productive. Many areas on the Seaside of Virginia between the Barrier Islands and the mainland may be classed as seed areas. However, Seaside waters differ so sharply from those in the Bay they must be discussed separately.

Salinity in Respect to Predators

A "set" of oysters may occur anywhere in Chesapeake Bay where salinities are higher than 5‰, the lower limit of their salt tolerance, and up to 35‰ sea water. Within this wide zone, however, the recently "set" oysters survive in significant numbers only where salinities average below about 15‰. The reason for this is not salinity *per se*, but because oyster drills and other predators, which kill developing spat and young oysters in large numbers, are limited to the high-salinity areas (about 15‰). Further, most of the serious diseases which kill older oysters are active in the same high-salinity areas.

The damage to spat is largely done by the smooth oyster drill, *Urosalpinx cinerea*. *Eupleura caudata*, the rough oyster drill is involved to a lesser extent (Chapter IX). The activities of these predatory snails (Mollusca, Prosobranchia) are confined to areas where salinities average over 15‰. The scarcity of spat and natural beds of older oysters in the lower Chesapeake Bay, the lower James and York, the Poquoson and Back rivers and other high-salinity regions has historically been due to the presence of these predators as well as other causes of mortality. Drills attack and eat oysters of any age, but are especially active in ingesting the meats of the younger, smaller oysters. Tropical Storm Agnes in 1972 killed or reduced to very low levels drill populations in the lower James and lower Rappahannock rivers, most of Mobjack Bay and in the Poquoson River. The survival of oysters setting in these areas will be much improved while drills are "down." Populations, however, are expected to return.

Other predators of spat exist whose exact roles have not yet been fully evaluated. Among these are the oyster leach, Stylochus ellipticus, the blue crab, Callinectes sapidus, and the xanthid mud crabs (MacKenzie, 1970a; Landers and Rhodes, 1970).

Additionally, the free-swimming oyster larvae, which are the precursors of the spat stage, are ingested by a wide variety of plankton-feeding organisms. Thus, the number of larvae in setting areas can be affected by plankton feeders such as menhaden, shad, herring, comb-jellies and other vertebrates and invertebrates. They can also be affected directly by disease, significant changes in breeding populations, whatever the cause, and by natural changes in the physical and other biological features of the environment. Pollution and heavy sedimentation also may affect survival of larvae, spat and young oysters. Adult oysters are generally more resistant.

The two oyster diseases MSX and Dermocystidium are active at salinity levels over 15‰. In the higher salinity waters of Seaside (32‰) MSX and Dermocystidium are not active, oddly enough, but SSO is. This aspect leads to delineation of another important characteristic of a natural seed area. Survival in a successful seed area is good because of the absence of significant levels of mortality-producing or endemic diseases. This allows accumulation of oysters over the years in the area, assuming that harvesting is not excessive, other environmental conditions are good and predation is not excessive.

Growth of Seed - Density

In most successful seed areas in the Virginia portion of the Chesapeake oysters grow slowly under normal circumstances. This seems to be a characteristic of good seed areas. The reason (or reasons) is only partly understood, but is probably associated with low salinity and/or crowding. Low salinity can cause slower growth though it may enhance survival. Crowding causes competition for available food supplies, and may also enhance setting. Growth has improved on certain bars in the James seed area where populations have been reduced. Seed areas are not normally satisfactory places to produce market-sized oysters because of slow growth, and for this reason small oysters are moved from the seed area to areas where growth is better.

Hydrographic Conditions

The occurrence or non-occurrence of mature larvae in an estuarine system or portion thereof may be the result of currents which retain or flush the larvae from suitable setting areas prior to setting.

Waters of abnormally low salinities (less than 0.5‰) have always been an important cause of mortality in the upper regions of all estuaries. Also, in times of excessive run-off almost all spat as well as the older oysters have been killed in these areas (Andrews, Haven and Quayle, 1959; Haven et al, 1976). However, fresh water may also have a beneficial effect in that it may control predators such as drills and disease (Andrews, 1964; Carricker, 1955; Haven et al, 1976).

Low dissolved oxygen values may be an important cause for the non-occurrence of larvae or survival of small recently-set spat. Laboratory studies at VIMS indicate that as oxygen falls below about 0.1 part per million (ppm) larvae will cease to swim and in about three days they will die (Haven and Bendl, 1975). Small spat will die in about one week but larger oysters can survive much longer. River systems like the Rappahannock and the Potomac frequently have dissolved oxygen values at or below the critical level in the deeper waters in summer. This is thought to be one of the reasons why they are such poor setting areas.

Absence of Brood-Stock

If mature, spawning oysters are not available in an area in sufficient numbers or strategic locations larvae will not be available.

Seaside of Virginia

On the Seaside of the Eastern Shore of Virginia most of the natural seed areas are located between the barrier islands and the mainland. Many Seaside seed areas are highly productive. They differ sharply from those in the Chesapeake since most of the natural rocks are intertidal.

The major differences between the two regions relative to survival of the sets to marketable size are: 1) on the Seaside of the Eastern Shore salinities generally range from about 25 to 35‰ and 2) the oyster drills (i.e., the "giant" subspecies unique to these high salinity waters, *U. cinerea follyensis*, and *E. caudata etteri*) are larger and more abundant than the smaller drills in the Bay. Still there is good survival of the seed on many rocks. Likely this is because the rocks are largely intertidal and the daily exposure of seed oysters on such rocks to air seems to inhibit predation, probably because the oysters can close and survive exposure better than the drills. Also, the magnitude of setting is moderate-to-heavy in many areas.

Fouling as a Factor in Preventing Setting or Killing Spat

Fouling organisms of various species may grow over shells and other setting surfaces to an extent sufficient to prevent or reduce setting. Also fouling may "over-grow" existing set and kill it. Among the most important fouling organisms in Virginia are algae, tunicates, barnacles, calcareous tube-building annelids (tube worms), and Bryozoa, (Manning, 1953; Chestnut and Fahy, 1953; Sieling, 1955, and others). Silting of shells may also be an important reason for the absence of an initial set, and it may also kill many small oysters, especially during winter (MacKenzie, 1970a, 1970b).

Industrial and Bacterial Pollution

Bacterial pollution *per se* does not appear to have impaired the survival of larvae. However, indirect effects such as high levels of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), naturally occurring low oxygen levels, algal blooms, and high nutrient levels, may be contributing factors to mortality of larvae.

In the summer of 1973 chlorine associated with the treatment of sewage sludge was shown to be lethal to fish and to cause developing oyster larvae to cease swimming (Haven, unpublished). Later VIMS laboratory studies found that levels as low as 0.005 ppm killed developing larvae (Roberts et al, 1975). Thus, chlorine or chloramines from the many treatment plants in the lower James River may be a reason for the continued reduction of oyster sets in recent times. Other toxic substances are known to occur in the domestic and industrial wastes which commonly flow from the outfall lines of sewage treatment plants.

Chemical substances originating from industrial and agricultural uses may kill developing larvae or impair setting and survival of spat. Among these substances are the chlorinated hydrocarbons such as DDT, PVC, and heavy metals such as cadmium, copper, zinc, etc. A study of those aspects should have high priority.

Poorly-Defined or Uninvestigated Causes

Many causes of spat mortality have never been fully investigated. Their role in causing significant fluctuations in Chesapeake Bay and its tributaries are unknown. Among these possible, poorly-defined causes of premature death are lack of adequate food and spat diseases. In heavily worked (tonged) seed areas, the constant mixing or raking by hand or patent tongs can kill small spat. Scraping and dredging also cause spat mortality by mechanical damage or covering. The extent of damage caused in this fashion has not been carefully evaluated by us although some earlier commentators tended to discount it. Some harvesting damage is unavoidable.

Fishing Mortality in a Seed Area

Fishing mortality, or the removal of individuals by harvest, is a significant cause of "mortality" in seed areas, but is an aspect which has never been carefully evaluated because of the lack of quantitative data. In 1972, 381,250 bushels of seed oysters were removed from the James River (Table 15--Chapter III). Later in this chapter we will show (Table 27) that average counts of spat per bushel from the James were about 158 from 1961 to 1971. Therefore, we do know that about 60,237,500 spat (158 x 381,250) were removed in that year by fishing effort (harvesting) alone. Data obtained in the preceding manner are not adequate to allow estimation of the impact of fishing mortality on James River seed oyster populations. Lacking are two important aspects:

1. We do not know whether the 60,327,500 spat cited as having been removed by harvest is a small or a large part of the total naturally-produced population.
2. Catch-per-unit-of-effort data are lacking. Another way of estimating the impact of fishing mortality is to determine changes in catch-per-unit-of-effort. Unfortunately, except for a limited series of data in the James obtained by the VMRC, numbers are non-existent.

Market Oyster Growing Areas

Diseases - Salinity

A market-oyster growing area cannot be delimited sharply from a seed area because one may grade imperceptably into the other. A prime requirement of a naturally productive market-oyster area is that it have some, but not necessarily all, of the previously described characteristics of a seed area. Among these are freedom or relative freedom from the oyster diseases, MSX and *Dermocystidium*, a firm bottom with sufficient shell substrate suitable for larval attachment, and an absence of oyster drills and other predators, adequate food, oxygen and salinity.

The lower limit of a seed area was given as $5^{o}/oo$ with an upper range of about $15^{o}/oo$. The minimum average salinity for a market-oyster rock is generally 6 to $7^{o}/oo$ for adequate growth. The higher salinity limit may be as high as $35^{o}/oo$.

Availability

For economic reasons a market-oyster growing area should be such that a full-time oyster tonger might realize a minimum catch of about five bushels of oysters or more per day.

Disease and Predators

The two oyster drills *U. cinerea* and *E. caudata* were the principal reasons prior to 1972 that productive natural oyster beds within the Chesapeake system did not occur where average salinity exceeded about $15^{o}/oo$. As a result of the fresh water flow caused by Tropical Storm Agnes in 1972 in the lower James, lower Rappahannock and in Mobjack Bay, drill predation has lessened and oyster populations are building up in many areas where salinities exceed $15^{o}/oo$.

Dermocystidium killed many of the older oysters prior to 1960 in high-salinity waters [over 15‰ (Andrews and Wood, 1967)]. The oyster pathogen, MSX, must be considered the principal factor since 1960, causing mortalities of young and adult oysters in the Bay where salinities average over 15‰ (Andrews, 1971a).

All the factors on the Seaside of the Eastern Shore which may be involved in limiting natural production are not known. However, the oyster drills, *U. cinerea follyensis* and *E. caudata etteri*, and the oyster pathogen, *M. costalis*, are certainly among the most destructive (Andrews et al, 1962).

Meat Quality

One of the attributes of a good market-oyster growing area is adequate meat quality or yields. A bushel of oysters should produce at least 5.5 pints of meats or more per bushel. However, a statewide average is from 6.0 to 6.5 pints per bushel. Yields above 7.5 pints per bushel are regarded as exceptional. Meat quality is not an important factor in a seed area.

Fishing Mortality in Market Oyster Growing Areas

There are almost no data available as to the impact of fishing mortality on numbers of market oysters. In 1972, for example, 81,711 bushels of market-sized oysters were harvested in the Rappahannock River (Table 18). If we assume 250 oysters per bushel, calculations show about 20,427,750 oysters to have been removed from that river system in that year. As outlined for spat, however, it is necessary to know the magnitude of the standing crop of the oysters on the grounds in order to evaluate the significance of taking such numbers.

Summary

The preceding discussion of disease, hydrographic conditions, and predators as limiting the occurrence of natural rocks is not exhaustive nor is it intended to be. These characteristics are briefly discussed only to demonstrate that the locations in the tributaries and in the Bay, itself, in which producing natural oyster rocks occur have an upper and lower limit imposed by natural environmental conditions.

It is generally the downstream limit which has, in recent years, fluctuated to the greatest extent as disease, predators or unfavorable hydrographic conditions changed. The lowermost public rocks in almost all rivers such as the York, James or Rappahannock are in a transition zone. Upriver from this zone average conditions are more stable. Representative public rocks above locations where oysters become scarce were selected for sampling for this study. The important point in evaluating numbers of adult oysters or spat in these representative areas is to demonstrate trends at specific places over the years. It is important to recognize the lack of productive natural rocks in the high-salinity regions in Chesapeake Bay is normal because it has been the case at least within historical times.

Surveys of Public Rocks Prior to 1947

The early history of productivity on public rocks in Virginia is known only from generalized descriptions with quantitative data almost completely lacking. The first quantitative survey, aside from those in the Tangier Sound region by Lt. Winslow and those that Brooks may have done (Brooks, 1891), was the Moore investigation of 1909 which estimated the numbers and density of oysters-per-unit-area in the James River (Moore, 1910). This was a careful and detailed study in which numbers of oysters per acre were established by samples tonged at 590 separate locations (Chapter II). Unfortunately this reasonably accurate method originally used by Moore was not continued by oyster biologists or repletion officers in later years. In almost all later studies of natural rocks, oysters were merely tonged or dredged and numbers per bushel of substrate recorded. This technique, while useful, yields results which cannot be related to a unit area of bottom.

Public rocks in Virginia were sampled in a limited way after Moore, as reported by Loosanoff (1932), Galtsoff et al (1947) and Mackin (1946).

Methods Used in Surveys of Public Rocks Since 1947

It was not until 1947 that public rocks were evaluated in a regular and systematic way by scientists from the Virginia Institute of Marine Science, then the Virginia Fisheries Laboratory. Collection of these data from 1947 to 1967 was under the supervision of Dr. J. D. Andrews and earlier scientists. It has been the responsibility of the Department of Applied Biology of the Institute since 1967. Several publications have resulted from this work (Loosanoff, 1932; Mackin, 1946 and Andrews, 1951). Additional information has been summarized for the 1947 to 1967 period by Andrews (unpublished manuscript). Since 1967 yearly and weekly summaries have been published by VIMS in the Marine Resources Information Bulletin supported jointly by the Office of Sea Grant Programs of the National Oceanographic and Atmospheric Administration and VIMS.

Bottom Cultch

Three methods of sampling have been used since 1947: 1) studies of samples of cultch taken from the bottoms; 2) shell-bags; and 3) shellstrings. The first consists of counting numbers of live oysters, spat and shell per bushel of substrate in a sample collected by tongs or dredges from representative oyster rocks. Numbers of live oysters per unit volume are counted and tabulated in the laboratory and placed in four categories: 1) large oysters (over three inches); small oysters (under market size, but over two years old); 3) yearlings (in their second growing season); and 4) spat which has set during the summer. Number of shells, empty boxes (recently dead oysters) and fouling are also recorded. Bottom samples are taken at least once a year, generally in the fall, winter or early spring. When an oyster rock is sampled more than once during the winter, results are averaged for presentation in this section.

Advantages and Disadvantages of Bottom Cultch

There are advantages and disadvantages in using bottom cultch for estimating the condition of public rocks. The principal advantage is that examination of the bottom material shows what is actually present on the oyster rocks at the time of sampling, i.e., what has survived of earlier sets. It reflects the results of the effects of all environmental conditions of water quality, disease and predation on all stages and classes of oysters. A major disadvantage of this method is that it may or may not disclose if oyster larvae capable of setting were present in the region in any specific year or lesser period. For example, if the bottom cultch is heavily fouled with silt, bacteria, fungi, algae, sponges, barnacles, mussels, tunicates or other plant or animal fouling organisms, there will be little if any suitable setting area for attachment of larvae on the substrate material. Samples based upon this method may not show conclusively whether or not larvae were available to set even though the samples show no spat, young or adult oysters. The oysters detected by this method represent those available for harvest at the time. However, by examining for scars or comparing sizes of oysters, it is possible to learn something of the history of the population sampled.

Another disadvantage of surveys made by collecting samples with a dredge and evaluating them on the basis of numbers of oysters per bushel is that they afford only quantitative approximations at best. Differences in numbers between samples must be great before they may be interpreted with confidence. Also, despite efforts to control the course, speed and sampling time of the dredge, the data cannot be used to show numbers of oysters-per-unit-area of bottom since it is not possible to tell how long or how far the dredge had been in actual contact with the bottom, or if it collected all the oysters in its path.

Tonged samples, if collected properly, may be used to obtain quantitative counts from bottom material (Moore, 1910).

This necessitates the anchoring of the boat, calibrating the opening of the tongs at various depths, and other standardizations. Since such sampling care was seldom the practice during most surveys in the past, much of the data collected by tongs to date embodies all of the disadvantages listed for dredged samples.

Despite these difficulties, samples collected in a consistent fashion by tongs or dredges over long periods of time are comparable.

Counts of large, small and yearling oysters and spat in bottom samples may be used in a general way to forecast the magnitude of the oyster supply in succeeding years. Comparison of the numbers of oysters of various sizes per bushel at a particular location over a period of years indicates possible changes in the availability of oysters. Information on spatfall and survival may be used to determine if a particular oyster bar can be self-sustaining. Biologists in several states were interviewed and asked for information about the magnitude of spatfall necessary for an oyster bed to be commercially productive. It was generally agreed that from 20 to 50 spat per bushel were required in the mid-Potomac and the mid-Rappahannock. Much higher initial sets are needed to cover losses and sustain populations in systems where drills and MSX are present.

A good oyster-growing area is one where large numbers of the spat which have set, survive and grow into yearlings and small oysters and then into market oyster sizes. Survival of year classes may be followed by watching spatfall as well as regularly conducting estimates of populations of adults.

Data from the extensive series of samples of bottom cultch collected by VIMS scientists are tabulated in the following pages. Most of them were collected by dredge.

Shellbags

A second method of monitoring spatfall and survival used in our study involves use of shellbags. This technique was put into use on a regular basis at VIMS in 1947 and is still employed. Chicken-wire bags of regular dimensions (12" by 28") are constructed and filled with about a quarter of a bushel of clean oyster shell three inches or larger in size. Such sampling bags when placed on oyster rocks have been used for two purposes: 1) to study weekly set and 2) to study seasonal set and survival.

The samplers for seasonal studies are suspended from stakes about one foot from the bottom at representative locations. They are placed in the water in late June just prior to the anticipated attachment of the oyster larvae and removed in late fall after setting has ceased. Following removal, they are carried to the laboratory where the spat, attached to both sides of the shell, are counted visually.

Seasonal shellbags do not necessarily disclose all of the oysters attaching to the shells within a bag during their period in the water. They do retain and hence reflect the numbers which have survived until the bags are removed from the water. This is a most useful parameter since it reflects natural production for the period which necessarily incorporates setting or recruitment and survival or natural mortality on the collectors. Numbers of spat surviving on shellbags are generally higher than on natural bottom cultch since the shells in the bags are free of fouling when they are placed in water. Natural bottom cultch is usually fouled to some degree and does not offer comparable setting opportunities. Furthermore, shellbags are off the bottom, eliminating much of the danger of smothering and bottom-bound pests and predators.

Shellbags were used to study the weekly set from 1946 to 1950. For this purpose the bags were exposed only one week. After exposure the spat attached to ten or twenty shells were counted. Results are expressed as spat-per-shell-per-day. Shellstrings came into use beginning in 1950 when the shellbags were discontinued as a means of studying weekly set.

Shellstrings

Shellstrings consist of ten or fifteen market-sized oyster shells with holes drilled in the middle strung on short pieces of wire. Shells are selected for uniformity in length and shape and range between three to four inches long. Strings are suspended at preselected sampling stations, smooth side down in the water, about one foot from the bottom. At the onset of setting season a shellstring is placed at each station. A week later it is removed and another substituted. Shellstrings are introduced prior to setting time and are regularly changed until setting has stopped, generally in mid-October.

Spat on the smooth surfaces of the shells are counted with the aid of a stereoscopic microscope. Results are expressed in three ways: 1) total spatfall-per-shell-face-per-season. This is calculated by summing all weekly averages for spat-per-smooth-shell-face (sometimes called total seasonal spatfall) for one setting season at a single station. In certain instances, which are duly noted, data are doubled to give values for spat per (entire) shell, i.e., to cover both sides of the shell; 2) tabulations of average weekly spat per 10 shell faces; and 3) the highest recorded average weekly set per shell face for one season at a single station and its time of occurrence.

Spat counted on weekly shellstrings or weekly shellbags measures the maximum spatfall possible for an area since shells are not fouled when they are placed in the water and offer optimum conditions for attachment. They also reflect available mature oyster larvae and, hence, effective spawning as well as survival of the spat for the first week. They do not reflect actual set or even survival rates which would occur on the less ideal surfaces offered by natural cultch. Nor do they incorporate the natural mortality factors involved with bottom cultch. Instead, they show the potential set in an area. Shellstring data also show, for a particular location, when setting begins, when it peaks and when it ceases. With such knowledge gathered over a number of years, one may forecast when, on the average, setting is most likely to occur. Generally, we are able to make such predictions a year ahead.

Analysis of Data

Effects of Planted Shell and Seed and Selective Harvest

VMRC planted a total of 41,352,237 bushels of shell from 1931 to 1975 on various public rocks in Virginia in its continuing Repletion Program. The purpose of these plantings was to provide cultch for attachment of spat and thereby increase production of seed or market oysters. In addition, from 1963 to 1975 this agency planted 886,974 bushels of seed on various Baylor bottoms to increase numbers of market oysters in areas being managed (Chapter VI). It would obviously be advantageous to know whether (and how) the addition of shell or seed may have influenced availability of oysters from the natural bottom samples from the various rivers which are discussed in this chapter.

One question raised about the State's shell and seed planting program in relation to our benthic sampling program is: To what degree have the VMRC plantings influenced the trends in availability of oysters, etc., revealed by our sampling program? If shells were planted, for example, on the natural rocks and they were sampled along with the natural populations then counts of living oysters per bushel would decline in that year due to dilution with these new shells. However, if they received a set, counts should increase over the surrounding natural bottom later on, assuming some survival. In contrast to the immediate diluting or augmenting effect of shell plantings then, counts per bushel of oysters would be increased if seed oysters were planted instead of shell.

The results of our sampling program in relation to this problem were unaffected by shell or seed plantings in the James and York rivers, since the VMRC, as an established policy, did not plant shell or seed on the productive natural rocks which we sampled in these two systems. Also, shells were not planted on the productive bars sampled by VMRC in the Rappahannock. Seed was planted on several productive bars in the Rappahannock. Usually, however, it was planted in discrete areas known to VIMS sampling crews, and samples were not collected from these locations. Moreover, the planted seed came largely from either the Piankatank or Great Wicomico rivers (see Chapter VI) and these oysters had a characteristic elongated shape. If samples containing this seed were inadvertently collected, they were discarded in order that our samples would be typical of oysters originating from a natural set in the area.

The Great Wicomico, Piankatank and Corrotoman rivers have in the past been "planted" with large quantities of shell on their relatively small acreages of public bottom, but with little, if any, seed. Because of the large volume of shells planted in a relatively confined area it is highly probable that our samples for the benthic studies in these rivers were taken where shells had previously been planted. Therefore, the data on numbers of oysters in bottom cultch collected in these systems must be considered in relation to this practice.

No attempt is made in this chapter to estimate what levels of oyster production on particular Baylor ground beds might yield on a sustained basis since, with the exception of very limited data obtained by the VMRC, catch per-unit-of-effort data have never been collected. Also, only limited data have been collected on rates of growth and the time required for populations to reach maximum biomass and this has been done for only one site--the lower York at Gloucester Point (McHugh and Andrews, 1955). There is a great need for these types of data and every effort should be made to develop a program to gather such data and allow regular and reliable evaluation of the population dynamics of oysters on the public rocks.

The normal practice of selective harvest of oysters further complicates analysis of size classes of oysters on the public rocks. In Virginia the law requires that on most public rocks oysters under three inches (two and one-half inches in some locations) must be culled out or separated and returned to the water. Thus, except in seed areas where all sizes may be harvested, the ratio of large to small oysters present in any area will be influenced or controlled by the selective removal of the larger oysters.

Tropical Storm Agnes

Tropical Storm Agnes struck Virginia on June 22, 23 and 24, 1972, and dumped from 6 to 12 inches in the water sheds of our estuaries. The impact of the resulting massive flows of fresh water on Virginia's oyster populations was enormous and has been fully documented (Haven et al, 1976).

Therefore, no attempt will be made to detail all the impacts here. The year 1972 is considered an atypical one for oyster production, and setting was zero or very low in all estuaries because of Agnes.

The Condition of the Public Rocks

Spatfall, spat survival, and numbers of spat, small oysters, yearlings and market oysters will be analyzed by individual rivers in this next section. For clarity, a brief review of each estuarine system will first be given. At the end of our discussion for each system will be a section which outlines the probable cause or causes for the distributions and changes noted. Locations of rivers, public grounds and oyster rocks discussed in this chapter are shown in Figures 2, 3, 4 and 5.

The James River

The James River is still one of the most productive areas in Virginia. Its supply of seed oysters remains an absolute necessity for the Virginia private oyster industry since even today it provides about 77% of all seed oysters sold in the State (Table 15). Additionally, in recent years its public rocks have produced 62% of all oysters classed as market oysters produced in the State (Table 18). Significantly, most of these oysters average less than three inches in length and not three inches or larger as do market oysters from other areas. These small oysters are used in the prepared soup oyster industry.

The productive Baylor Survey Grounds of the James River extend from just below the mouth of the Nansemond River on the southern side upriver to Deep Water Shoals near Fort Eustis on the northern side (Figure 2). Within this area a division exists termed the "cull line." It begins just off 60th Street in Newport News (about 1 mile below the James River Bridge) and extends across the river to Capper Creek on the south side which is about one and one-half miles below the bridge. Downriver from this line only oysters larger than three inches may be harvested. Above this line is the seed area where all sizes of oysters may be taken (Code of Virginia 28.1 1-126). In the lower river (Hampton Roads) are located the famous and once productive Hampton Bar and Willoughby Bay areas, once widely used by private planters as a growing area. These two areas contain no public rocks. Shell substrate is lacking in this region and prior to 1972 few small oyster spat survived to maturity because of drill damage. Therefore, this area had to be planted with seed to be productive.

Although this chapter deals almost exclusively with the public rocks, it will be necessary to briefly discuss oyster production from leased bottoms in the Hampton Roads area since changes in patterns of private oyster growing operations may have had an influence on the public rocks upriver.

Private growers before 1900 were using the lower James River to grow many hundreds of thousands of bushels of oysters. Actual production records are almost non-existent for the 1920's and 1930's, but conversations with dealers and watermen indicate it to have been heavily planted by local growers then. Bacterial pollution from sewage had become so serious that restrictions were placed on direct harvesting of shellfish from these waters. It was permanently closed to direct harvesting in the 1950's. However, oysters were still grown here and then transplanted to other beds for cleansing prior to final harvest for market. The added handling required resulted in increased production costs and, as a consequence, by the late 1950's the numbers of bushels of seed planted by private growers in the area began to decline. The next major change was the appearance of MSX in 1960 which killed most of the oysters on the planted beds in Hampton Roads. Additionally, there was a drastic reduction in set in the entire James after 1960.

Oyster drills prior to 1972 were a major cause of spat mortality below the cull line, and were largely responsible for the absence of natural seed beds below Nansemond Ridge. Almost all oyster drills were killed by Tropical Storm Agnes in the area and since 1972 have not returned in sufficient numbers to cause appreciable mortalities to the Baylor Grounds of the lower James. As a consequence, survival of oysters below the James River Bridge is greater than it was prior to 1972. The drills are expected to slowly return to this area.

Spat on Natural Cultch

The numbers of spat surviving from 1947 to 1960 in the James River until the late fall when the samples were taken were high (Table 27). Five-year averages for numbers of spat per bushel of bottom cultch for representative oyster bars showed the following ranges of numbers of spat surviving: Deep Water Shoal--468 to 1,744; Wreck Shoal--995 to 1,945; and Brown Shoal--412 to 1,030. Figures for individual years showed extreme fluctuations within this period. No well-defined pattern was evident except for the Point of Shoals bar. This station seemed to have consistently lower numbers surviving than other locations for those years for which data are available. There seemed to be no consistent pattern of spat abundance relative to whether the beds were in the upper or

Table 27

Live Oysters Per Bushel of Unculled Bottom Sample from the James River[1]

Season	LARGE OYSTERS Brown Shoal	Wreck Shoal	Point of Shoal	Horse Head Shoal	Deep Water Shoal
1947-8	16	56	N/A	0	74
48-9	137	33	28	N/A	7
59-50	120	13	24	0	9
1950-1	8	80	8	N/A	16
Average	70	46	20	0	27
1951-2	8	4	N/A	4	16
52-3	68	4	32	0	8
53-4	100	24	N/A	4	8
54-5	104	12	0	48	56
1955-6	32	4	N/A	N/A	32
Average	62	10	16	14	24
1956-7	132	12	N/A	0	3
57-8	52	0	N/A	8	16
58-9	N/A	8	N/A	4	N/A
59-60	118	6	N/A	0	0
1960-1	72	0	N/A	N/A	N/A
Average	94	5	N/A	3	6
1961-2	N/A	14	N/A	0	4
62-3	31	40	38	0	2
63-4	118	84	66	23	2
64-5	73	68	140	48	16
1965-6	106	38	N/A	84	83
Average	82	49	81	31	21
1966-7	101	53	76	22	100
67-8	108	35	N/A	10	2
68-9	68	88	N/A	94	45
69-70	25	30	60	9	39
1970-1	40	70	28	N/A	38
Average	68	55	55	34	45
1971-2	18	59	34	52	15
72-3	18	24	14	30	0
73-4	22	24	36	46	N/A
74-5	2	70	60	70	N/A
1975-6	10	78	16	0	0
Average	14	51	32	40	5

Table 27 (Contd.)

Season	SMALL OYSTERS AND YEARLINGS				
	Brown Shoal	Wreck Shoal	Point of Shoal	Horse Head Shoal	Deep Water Shoal
1947-8	24	966	N/A	784	320
48-9	241	1,648	1,412	1,999	334
49-50	469	1,603	1,156	1,416	331
1950-1	1,222	1,924	1,288	N/A	374
Average	489	1,535	1,285	1,400	340
1951-2	892	1,634	N/A	1,592	256
52-3	1,024	2,318	772	1,864	376
53-4	500	1,664	N/A	1,488	454
54-5	776	2,132	90	1,620	1,172
1955-6	620	1,372	N/A	1,158	814
Average	762	1,824	431	1,544	614
1956-7	1,380	1,284	N/A	856	867
57-8	840	1,748	N/A	1,446	784
58-9	N/A	1,404	N/A	1,056	N/A
59-60	158	531	N/A	2,732	1,692
1960-1	684	1,656	N/A	N/A	N/A
Average	765	1,325	N/A	1,522	1,114
1961-2	N/A	1,494	N/A	1,386	608
62-3	441	849	682	1,020	418
63-4	364	996	398	743	262
64-5	114	368	168	500	316
1965-6	45	1,363	N/A	888	233
Average	241	1,014	416	907	367
1966-7	76	766	996	732	148
67-8	78	798	N/A	924	937
68-9	78	795	N/A	549	568
69-70	10	340	530	776	734
1970-1	10	590	622	N/A	370
Average	50	659	716	745	551
1971-2	10	322	402	522	438
72-3	6	276	238	366	50
73-4	80	240	196	174	N/A
74-5	26	358	270	255	N/A
1975-6	88	750	136	166	104
Average	42	389	248	297	197

Table 27 (Contd.)

	SPAT				
Season	Brown Shoal	Wreck Shoal	Point of Shoal	Horse Head Shoal	Deep Water Shoal
1947-8	48	1,464	N/A	1,428	6,024
48-9	256	1,399	260	686	382
49-50	1,834	2,971	548	2,656	216
1950-1	734	1,772	348	N/A	354
Average	718	1,901	385	1,590	1,744
1951-2	1,836	2,754	N/A	1,460	928
52-3	1,460	1,502	336	1,084	132
53-4	356	1,540	N/A	4,312	2,468
54-5	104	877	336	508	796
1955-6	1,396	3,056	N/A	34	36
Average	1,030	1,945	336	1,494	872
1956-7	296	227	N/A	396	180
57-8	700	1,164	N/A	2,030	1,080
58-9	N/A	2,332	N/A	4,116	N/A
59-60	214	606	N/A	872	144
1960-1	438	644	N/A	N/A	N/A
Average	412	995	N/A	1,854	468
1961-2	N/A	132	N/A	68	10
62-3	113	201	42	8	20
63-4	166	157	0	7	10
64-5	83	937	364	234	500
1965-6	15	62	N/A	16	24
Average	94	298	135	67	113
1966-7	11	148	436	783	380
67-8	0	0	N/A	4	42
68-9	7	33	N/A	132	31
69-70	114	193	94	56	37
1970-1	5	65	216	N/A	1,181
Average	27	88	249	244	334
1971-2	108	69	224	38	143
72-3	0	18	26	0	0
73-4	12	26	8	5	N/A
74-5	34	670	150	110	N/A
1975-6	74	50	4	18	4
Average	46	167	82	34	49

Table 27 (Contd.)

1. Data for 1947-1948 through 1967-1968 from Andrews, J. D., unpublished. 1969-1970, 1971-1972 and 1975-1976 (spat) data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1968-1969, 1970-1971, and 1972-1973 through 1974-1975 and 1975-1976 (other than spat) from Haven, unpublished.

N/A Data unavailable.

lower river with the exception of Point of Shoals. The Deep Water Shoals and Horse Head areas did not consistently differ from the other two bars which are downriver in respect to the numbers of spat per bushel.

A drastic reduction in numbers of spat on bottom cultch occurred about the time MSX developed in 1960 at Deep Water Shoals, Horse Head Shoals, Wreck Shoals, Brown Shoals and Point of Shoals. Hardest hit was Wreck Shoals, formerly the most important seed producing oyster rock in the entire James River seed area.

Data shown in Table 27 were summed to give averages for the pre- and post-MSX period (Table 28) to show the extent of the decline. Calculations based on these tables showed the number of spat on natural cultch to have dropped to 12% of those occurring prior to 1960.

<u>Small Oysters and Yearlings</u>

Five-year averages prior to 1960 for numbers of small oysters and yearlings per bushel of cultch ranged as follows: Deep Water Shoal--340 to 1,114; Horse Head Shoal--1,400 to 1,544; Wreck Shoal--1,325 to 1,824; and Brown Shoal--489 to 765. The highest counts on the average were found at Wreck Shoal and Horse Head Shoal (Table 27).

Table 28

Comparison of Average Numbers of Oysters in Bushel Samples of Natural Cultch in Pre and Post-MSX Periods in James River, Virginia[1]

AREA	MARKET		SMALL & YEARLING		SPAT	
	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6
Deep Water Shoal	20	27	645	399	1,062	183
Horse Head	7	35	1,500	643	1,638	106
Point of Shoal	18	52	944	422	365	142
Wreck Shoal	17	52	1,563	687	1,593	184
Brown Shoal	74	53	679	102	744	53
Average	27	44	1,066	451	1,084	134

1. Computed from data in Table 27.

The numbers of small and yearling oysters between 1960 and 1965 began to decline at all five stations and from 1966 to 1976 five-year averages for numbers per bushel ranged from 42 to 745. The range (6 to 996) was large among all stations during this latter period. Table 27 indicates that in the fifteen-year period from 1960 to 1975 Brown Shoals, the seed rock farthest downriver, showed the largest decline, but at the four stations upriver it was less severe.

When all data for the pre- and post-1960 period (to 1975) were tabulated, the following decreases in numbers of small oysters per bushel were noted: Deep Water Shoals--38%; Horse Head Shoals--57%; Point of Shoals--55%; Wreck Shoals--56%; and 85% at Brown Shoals (Table 28).

With one exception, there did not appear to be any well-developed up or downriver gradient in the number of oysters or spat on samples of natural cultch at the stations sampled during the pre- and post-MSX years. Only at Brown Shoals was there a decrease in number of spat and small oysters after 1960.

The declines in numbers of oysters per bushel described above indicated a serious condition existed in the James and for all of Virginia since the James is the source of about 77% of all seed oysters planted each year in Virginia by private growers.

Market Oysters

Numbers of market-sized oysters (3 inches or over) in the 1947 to 1960 period at most stations in the James River never formed an appreciable quantity as measured in terms of number per bushel except in the lower river at Brown Shoals (Table 27). There appeared to be an increase in numbers at all stations, except at Brown and Deep Water Shoals after 1960. However, even in the post-1960 period, numbers of market oysters per bushel have never formed an appreciable percentage of the total catch. When market, yearling and small oysters were totaled in the Deep Water Shoals to Wreck Shoals area for the period after 1960, the market oysters on the average constituted only 5% of the total number. At Brown Shoals where all oysters were scarce they made up about 25% of the total.

Shellbags - Survival

The shellbag studies in the James showed similar results to the studies of spat on natural cultch. Both showed a drastic reduction in surviving set after 1960 (Table 29).

Average sets on shellbags expressed as spat-per-shell were high for the periods 1947 to 1953 and 1958 to 1961. Average counts had the following ranges: Brown Shoals--6.4 to 14.5; Wreck Shoals--11.3 to 13.8; and Horse Head Shoals--4.4 to 8.0. There was a major decline after 1960 in the numbers of surviving spat on shellbags. Average set-per-shell from 1961 to

Table 29

Seasonal Spatfall on Shellbags in the James River[1]

Spat per Shell

Season	Location: Brown Shoal	Wreck Shoal	Horse Head Shoal
1947-1948	4.5	14.4	8.7
48- 49	3.8	9.0	6.5
49- 50	12.0	17.0	3.6
1950-1951	5.2	13.3	1.7
51- 52	7.4	7.6	3.9
52- 53	5.7	6.4	1.8
Average	6.4	11.3	4.4
1958-1959	21.0	28.7	6.9
59- 60	N/A	9.6	N/A
1960-1961	7.0	3.0	9.2
Average	14.5	13.8	8.0
1961-1962	0.8	3.6	N/A
62- 63	1.6	1.2	0.5
63- 64	2.1	0.3	0.1
64- 65	1.5	2.7	1.5
65- 66	0.7	0.1	0.0
66- 67	0.6	0.4	0.4
67- 68	0.1	0.2	1.0
68- 69	N/A	N/A	N/A
69- 70	N/A	N/A	N/A
1970-1971	0.4	1.3	3.0
Average	1.0	1.2	0.9
1971-1972	31.0	0.2	0.6
72- 73	0.03*	0.1	0.0
73- 74	1.2	0.2	0.2
74- 75	7.3	5.0	3.8
75- 76	1.2	0.3	0.01
Average	8.1	1.2	0.9

1. Andrews, J. D., manuscript 1947-1948 through 1967-1968; data not available for 1953-1954 through 1957-1958, 1968-1969 and 1969-1970; 1970-1971 and 1971-1972 data from Haven, D. S., Marine Resources Information Bulletin, VIMS. Haven, D. S., unpublished data 1972-1973 through 1975-1976.

* Miles Watch House.

1976 were as follows: Brown Shoals--3.7; Wreck Shoals--1.2; and Horse Head Shoals--0.9. The percentage declines for all years prior to and after 1960 are: Horse Head--80%; Wreck Shoals--89%; and Brown Shoals--42% (Table 30). It is remarkable that in the 1961 to 1976 period there were only four years when the surviving set exceeded or even equalled (all at the same station) the lowest recorded surviving set prior to 1960 (Table 29).

Weekly Setting Pattern

Beginning around 1960 in all sections of the James River, data from natural cultch and shellbags both indicated a major decline in surviving spat and numbers of yearlings and small oysters per bushel of substrate. An analysis of data obtained from shellstrings indicates the principal reason for this decline is a decrease in the total seasonal spatfall which remains lowered.

Table 31 shows the typical total seasonal spatfall for the James River during the period from 1947 to 1953 when it was annually producing over two million bushels of seed. Typically, the total seasonal set disclosed by this method appeared to be highest in the lower river and to decrease in an upriver direction. During this period total weekly set averaged 128.2 spat-per-shell-face-per-season at Brown Shoals which was the highest for the river. Total spatfall averaged 99.5 spat-per-shell-face-per-season at Wreck Shoals.

Table 30

Comparison of Average Numbers of Spat per Shell on Natural Cultch, Shellbags and Shellstrings in Pre and Post-MSX Periods in the James River, Virginia.

AREA	NATURAL CULTCH[1]		SHELLBAGS		SUM OF WEEKLY SET SHELLSTRINGS[2]	
	1947-8 thru 1952-3	1961-2 thru 1975-6	1947-8 thru 1952-3	1961-2 thru 1975-6	1947-8 thru 1952-3	1961-2 thru 1975-6
Deep Water Shoal	2.1	0.4	-	-	11.6	6.0
Horse Head	3.3	0.2	4.4	0.9	14.4	10.8
Point of Shoal	0.7	0.3	-	-	-	-
Wreck Shoal	3.0	0.4	11.3	1.2	199.0	16.2
Brown Shoal	1.5	0.1	6.4	3.7	256.4	24.0

1. Assuming 500 shells per bushel.

2. Total spatfall per shell for entire season; data from Table 31; number per shellface doubled.

Table 31

Sum of Weekly Spatfall in the James River[1]
(Spat per Smooth Shellface)

Season	Type of Collector[2]	Duration of Setting	LOCATION Brown Shoal	Wreck Shoal	Horse Head Shoal	Deep Water Shoal
1947-8	SB	7/ 9 - 10/17		157.8		15.7
48-9	SB	7/ 1 - 10/ 7		84.9		
49-50	SB	6/28 - 11/ 2	155.6	107.2		4.7
1950-1	SB	7/11 - 10/19	140.4	108.6		2.9
1950-1	SS	7/11 - 9/20	132.8	157.4	7.2	2.4
51-2	SB	7/ 6 - 10/12		40.1		
52-3	SB	7/ 2 - 10/ 6	88.5	40.2		3.5
Average	SB		128.2	99.5		5.8
1963-4	SS	7/16 - 9/26	14.1	0.6	0.4	0.0
64-5	SS	7/28 - 9/29	6.8	4.7	2.1	1.3
65-6	SS	7/26 - 10/10	0.2	0.4	0.0	0.0
66-7	SS	7/ 5 - 10/14	6.9	3.8	3.3	2.9
67-8	SS	7/18 - 9/27	0.6	0.7	1.4	0.8
68-9	SS	6/13 - 11/ 9	2.1	9.2	6.4	11.6
69-70	SS	7/ 2 - 10/17	5.2	40.8	19.8	5.6
1970-1	SS	7/20 - 10/12	21.5	14.8	15.1	4.7
Average	SS		7.2	9.4	6.1	3.4
1971-2	SS	6/14 - 10/ 6	31.1	9.7	12.0	7.1
72-3	SS	8/ 1 - 10/ 2	0.7	3.0	3.3	0.9
73-4	SS	7/ 2 - 10/ 1	22.8	1.1	1.3	0.5
74-5	SS	7/ 2 - 10/ 8	16.6	4.1	3.2	2.2
75-6	SS	7/ 8 - 10/ 8	27.4	12.1	2.3	2.1
Average	SS		19.7	6.0	4.4	2.6

1. Andrews, J. D., unpublished data 1947-1948 through 1967-1968, data not available for 1953-1954 through 1962-1963; blanks indicate that data were not available. 1969-1970 through 1975-1976, Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1968-1969 Haven, D. S., unpublished.

2. SB=Shellbag; SS=Shellstring.

A major change in the seasonal set occurred between 1953 and 1963 (data lacking from 1953 to 1962) in the lower James River at Wreck and Brown Shoals. From 1963 to 1976 spatfall in this region averaged only 12.0 spat-per-shell-face-per-season at Brown Shoals and 8.1 spat-per-shell-face-per-season at Wreck Shoals. Calculations indicate that these values were only 8% to 9% of their former magnitude in the 1947 to 1952 period (Table 30). The data show less of a change in the upper river at Deep Water Shoals. At this upriver station average intensity declined only 48% (from an average 5.8 spat-per-shell-face-per-season prior to 1963) to an average of 3.0 from 1963 to 1975 (Table 30).

It is not possible to fix the time of decline more specifically from our weekly setting observations since those studies were not made between 1953 and 1963. They do show a decline in spatfall after 1963 as compared with pre-1952 levels. However, shellbag evidence indicates that the decline in total seasonal spatfall actually began about 1960.

The preceding shellstring data indicate the decline in the James in numbers of spat, small and yearling oysters on bottom cultch in recent years to be largely due to a decline in the total seasonal set. Corroborative evidence supporting this assertion is shown by a decline in the surviving set on shell-bags and on the bottom cultch which has paralleled the decline in the total seasonal set.

Survival of Spat

There was a definite pattern in the James in the survival of spat on natural cultch in relation to the total seasonal spatfall as measured on shellstrings. Survival on natural cultch was higher upriver (Table 30). Data extracted from Table 30 show the following survival before 1953: Deep Water Shoal--18.1%; Horse Head Shoal--22.9%; Wreck Shoal--1.5%; and 0.6% for Brown Shoal.

Numbers surviving on bottom cultch were reduced slightly but were still on the same order of magnitude after 1960 with a major decline in total seasonal set. These data suggest the decrease in numbers of oysters on bottom cultch after 1960 not to be associated with any decline in percentage of oysters surviving after setting (up to the time they were sampled during the first winter of their lives).

Timing of Sets

While the total seasonal set has declined in the James River in recent years, there has been no apparent change in the timing or season of peak set.

In 1931, studies by Loosanoff (1932) of the James showed setting from early July through late September with the peak set of about 30 spat-per-shell-per-week occurring in mid-September, with the heaviest set occurring mid-river. Andrews (1951) summarized setting data existing up to that time. His findings were:

1. Setting is continuous for about three months each year from the first of July to the first of October.
2. The most intense sets occur in late August or early September, while the July sets are relatively unimportant.
3. Since 1963, the time of setting seems to be the same as in earlier periods, from about the first of July through October, with the most intense sets occurring, as before, in mid-August to mid-September (Table 32).

Our studies covering the period from 1947 to 1975 agree with Andrews' findings (Table 32).

Table 32

Highest Weekly Spatfall on Shellstrings in the James River[1]
Spat Counted per Smooth Shellface Plus Week of Occurrence[2]

Season	Type of Collector[3]	LOCATION: Brown Shoal		Wreck Shoal		Horse Head Shoal		Deep Water Shoal	
1947-8	SB			40.5	S1			6.2	S1
48-9	SB			17.9	A5				
49-50	SB	32.6	A2	18.4	A3			2.6	A2
1950-1	SB	45.6	S2	39.0	S1			1.0	S1
1950-1	SS	99.2	S2	81.1	S2	4.4	S1	1.3	S1
51-2	SB			12.7	J4				
52-3	SB	23.0	S2	11.1	S3			0.7	A3
Average	SB	33.7		23.3				2.6	
1963-4	SS	4.7	A5	0.4	A5	0.2	S2	0.0	
64-5	SS	3.3	S2	1.8	S2	1.1	A5	0.5	A5
65-6	SS	0.1	A3	0.2*	O1	0.0		0.0	
66-7	SS	1.9	A1	1.1	A3	0.8	A1	1.1*	J4
67-8	SS	0.3	S1	0.5	S1	0.6	A4	0.3	A4
68-9	SS	0.4	A3	2.0	A3	1.5	A3	2.5	A3
69-70	SS	1.7	S2	21.1	S1	15.1	J3	2.4	J3
1970-1	SS	6.0	A1	9.2	A1	7.6	A1	2.8	A1
Average	SS	2.3		4.5		3.4		1.2	
1971-2		17.0	A4	3.4	A1	7.7	A1	3.2	A1
72-3	SS	0.3	S2	1.2	S3	1.1	S3	0.5	S4
73-4	SS	8.5	S2	0.3	J-S	0.2	J2	0.3	S2
74-5	SS	4.3	A2	1.1	A3	0.6	J4-A4	0.5	A2
75-6	SS	5.6	S1	4.0	S3	0.8	S1	0.6	S1
Average	SS	7.1		2.0		2.1		1.0	

1. Andrews, J. D., unpublished data 1947-1948 through 1967-1968; data not available for 1953-1954 through 1962-1963; blanks indicate that data were not available. 1969-1970 through 1975-1976 Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1968-1969 and 1971-1972 Haven, D. S., unpublished data.

Table 32 (Contd.)

2. Letters indicate the month of occurrence (J - July, A = August, S = September, and O = October). The digits following the letters indicate the week of the month.

3. SB = Shellbags; SS = Shellstrings.

* Shellstring was in the water two weeks.

A Discussion of Reasons for the Decline in Oyster Density and Setting in the James

Introduction

There has been a reduction in numbers of spat, small and yearling oysters per-unit-volume-of-bottom-cultch in the James beginning in the 1960-1965 period and extending to 1975. This has manifested itself as a decline in the number of oysters per-unit-area-of-bottom. The drop was most severe in the lower seed areas where numbers of small, yearling oysters averaged from half to one-third as abundant as previously. Spatfall on natural cultch from 1961 to 1975 at the same locations declined to levels ranging from 6% to 39% of those for the 1947-1960 period. An equally severe downward trend was observed for oyster spat upriver at two out of the three stations sampled.

Numbers of market-sized oysters per-bushel-of-bottom-cultch have increased at all stations since 1960. Because these large oysters are far less numerous than other sizes, the total numbers of oysters (counts) per bushel (small, yearlings and market-sized) have declined at most stations despite the increase in the market-sized animals. In fact, average numbers of oysters (of all sizes) per-bushel-of-bottom-cultch have declined from 2,177 in the 1947-1960 period to 629 per bushel from 1961 to 1976 (calculated from Table 28). This major change in number of seed per bushel is most important to the grower. Its significance is discussed in Chapter VIII.

The decline in quantity of seed-sized oysters on the bottom is most serious since the James River has been, and remains, the source of a large majority of the seed oysters planted on leased bottoms throughout the State. How much further natural seed production will decline in this river is unknown. It is obvious the disappearance of the James as a source of seed would be the end of the private sector of the oyster industry of Virginia as it now exists.

In evaluating the decline in numbers of spat, small and yearling oysters per-bushel-of-bottom-cultch after 1960, we concluded the major reason to be due to a decrease in the total seasonal levels of set as indicated by shellstring studies. Fewer oysters (in the form of spat) have been entering the population each year. The specific reason (or reasons) why the seasonal set has declined is (are) not entirely clear. A detailed discussion of all possible causes for the decline in numbers of oysters and the decline in the total seasonal set follows.

MSX and *Dermocystidium*

Dermocystidium was causing mortalities of oysters in high-salinity areas of the Bay for years prior to 1960 (Chapter IX).

It did not increase in incidence or intensity of infection during the late 1950's or early 1960's. Therefore, it cannot be considered as the cause of the recent decline in numbers of oysters in the James. In contrast, MSX disease, caused by *Minchinia nelsoni*, did "explode" around 1960 and swiftly killed oyster populations in the high and medium-salinity regions of the Bay and the tributaries. It is still present and a factor in mortalities.

There is no doubt MSX has been significantly involved in causing increased mortalities of oysters since 1960 at Brown Shoals and downriver since this region of the James is classed as a Type I MSX area, i.e., the worst in terms of prevalence and mortalities (Chapter IX). Above Brown Shoals, MSX has not been a significant, direct fact in causing excessive mortalities of oysters. Observed reductions in populations in these regions must be associated with lowered spatfall or other factors. MSX, however, has probably acted indirectly on populations on all of the James River seed beds by reducing the initial set, as discussed below.

Brood-Stock and Currents

One possible explanation for the decline in setting rates in the James in the 1960-1975 period is that there has been a reduction in brood-stock in that lower estuary caused by MSX. There is evidence to indicate that the sizeable oyster populations which existed on leased bottoms in the Hampton Roads area prior to 1959-1960 produced the larvae which later set in the mid- and upper-part of the James River oyster-growing area.

The reasoning behind this concept is that, prior to 1960, the lower James River at Hampton Bar and Willoughby Spit were sites of large-scale plantings by private growers. Due to MSX, these oysters died beginning about 1960. Shortly after that time populations in these areas declined to nearly zero. Since 1960 no plantings of any size have been made in the Hampton Roads-Willoughby Spit area.

Pritchard (1952) studied net river flows in the James in 1950 in conjunction with a study on distribution of oyster larvae conducted by the Virginia Institute of Marine Science. This study showed a net upstream flow of water below the level of no net motion on the north side of the James in the vicinity of Wreck Shoals. Pritchard postulated:

> The net movement of the deeper water provides a mechanism for this upstream movement of the (oyster) larvae.

He made a "key" statement in this report:

> There is not agreement as yet as to whether the oyster larvae which produce the profitable set of seed oysters in the James River originates from mature oysters in the immediate vicinity of the seed beds or whether the supply is from farther down the estuary, for example, from the mature oysters in the Hampton Roads area.

This question was investigated by Andrews (unpublished) who summarized all available information on setting derived from shellbags, shellstrings and natural cultch in the James River from 1941 to 1967. Andrews commented on the decline in initial strike since 1960 and the cause. On the basis of the number of oysters attaching to shell, which was generally highest in the lower river, he concluded that: 1) good sets in pre-MSX years were dependent on salt-wedge penetration of the seed area and 2) the populations of mature oysters present in the lower river at Hampton Roads and Willoughby Spit appeared to be the major source of spawn. He attributed the decline in set in the James to the death of oysters in Hampton Roads which were the "brood-stock" for larvae setting in the upper river. Andrews also suggested that prior to and after the severe MSX outbreak, larvae originating within the seed area also contributed to the spatfall; but this source was of less importance to the downriver populations on the important downriver bars than larvae originating in Hampton Roads.

Hargis (1966) reported on studies conducted in the hydraulic scale model of the James River located in Vicksburg, Mississippi. These studies consisted of placing dye in the model to simulate oyster larvae and observing its transport. In summarizing test results it was stated:

> ...In tests oyster larvae (as simulated by dye [ours]) made the voyage from release (spawning point) to Hampton Roads to end (setting area) points on the seed bed in times well within their life span times. Thus the areas of dye release may be considered as oyster larvae source areas and Pritchard's suggested scheme of upstream transport of oyster larvae is accorded some experimental support...

Extensive biological sampling was conducted in the James River in August and September 1965 in relation to the previously mentioned project. These studies were termed "Operation Kite" and "Operation Tail" (Hargis, 1966). A preliminary evaluation of the data indicated oyster larvae to be more abundant downriver than upriver. Also larvae appeared to be rather uniform in respect to vertical distribution.

A more detailed examination of the biological material collected in the "Kite/Tail" operations in September 1965 in the James was made by Wood and Hargis (1971), who indicated that in the channel in the lower James oyster larvae are indeed transported upriver. This study showed a net upstream transport of oyster larvae in the lower James River in the vicinity of Naseway, Brown and White Shoals. This movement occurred at all but two of the twelve stations sampled. In one area on the south side of the system a slight downriver transport was noted.

Wood and Hargis (1971) explained the observed transport of oyster larvae on the behavior of the larvae combined with transport by upstream currents and flood tides rather than on mere physical transport by water currents. Larvae were not being transported passively, but by a process of selective up and down swimming which contributed actively to their upriver transport by getting them off of the bottom (and not subject to transport) during ebb tide. Also, their data suggest this behavior to be correlated, not with increasing current speed, but with the increases in salinity accompanying the flood tide. In addition to their own data and conclusion, these authors cited numerous others who support the concept of selective swimming in synchronization with tidal cycles. Among them are: J. Nelson (1912), T. C. Nelson (1931), Prytherch (1928), Carriker (1951) and Kunkle (1958).

In contrast to these views, Korringa (1952) thought that the spread of oyster larvae upriver could be easily explained in terms of passive transport and that the oyster larvae themselves did not contribute significantly to this transportation.

It now may be concluded on the basis of these studies with considerable confidence that: 1) there exists a mechanism of transport of oyster larvae from the lower James to the seed areas and 2) private plantings in the lower James declined in the late 1950's and virtually disappeared by 1960.

Before settling on a theory of the cause of decline, there are other aspects that must be considered. Are we correct in assuming that the brood-stock in the lower river was more important in the past as a source of successfully setting larvae than the upriver populations? Probably this was the case, but we do not really know. It might be when the upriver populations of larvae mature (attain the eyed stage) they are largely flushed from the system. It is also possible only larvae originating downriver mature (in relation to transport by currents) at the optimum time to set in the river.

In ending our remarks on the impacts of declining brood-stock, we must conclude that while cause and effect have not positively been demonstrated, circumstantial evidence strongly supports the theory. That is, brood-stocks have been lacking in the lower James (on the north side) since 1950, and since 1960 recruitment with several minor fluctuations has been low. Hence, absence of strategically placed brood-stock has caused a decline in setting on the important bars in the James River seed area.

Industrial, Bacterial or Other Type of Pollution as Possible Factors in the Decline in Initial Set in the James

Many chemical substances which find their way into our estuaries may be damaging to developing oyster larvae or to adults. In a few cases their lethal or sublethal effects have been demonstrated in laboratory studies. Lacking in most instances is definite proof that they are occurring in sufficient concentrations to cause mortalities under natural conditions. This is not to say they may not be lethal, but rather it is difficult to demonstrate under natural conditions their presence or adverse effects.

We do not think bacterial pollution per se is responsible for the decline in set. The reason is that coliform counts were very high in Hampton Roads and elsewhere prior to 1960 when sets were high (Chapter X). Also, in some places, coliform organisms are diminishing, yet no sustained recovery of setting is indicated.

Evidence indicates that chlorine associated with sewage treatment plants may affect developing larvae adversely in nature. There was a major fish kill in the summer of 1973 centered around the Warwick River sewage treatment plant. An examination of water from the area showed chlorine and chloramines. In bioassay tests, using the water taken from a spot adjacent to the outfall, mature oyster larvae from the Institute's hatchery stopped swimming when placed in the water. Control larvae kept at similar levels of salinity but in York River water continued to swim (Haven, unpublished). Laboratory tests by the Department of Ecology Pollution at VIMS showed chlorine to be toxic to oyster larvae at concentration of .005 ppm

(Roberts et al, 1975). Hence, chlorine could be affecting spatfall in the affected part of the James by interfering with the larvae.

Chlorine pollution might have been adversely affecting larvae in the lower James even prior to 1960, and by 1960 it reached levels which could begin having an effect on the total seasonal set noted previously on shellstring. Possibly, chlorine and other toxicants also could have weakened the oysters making them more susceptable to MSX and other mortality-causing factors. While chlorine has been shown to be lethal to larvae in the laboratory, its actual concentration and impact in the estuary has yet to be evaluated.

A further examination of the possible role of sewage treatment plant effluents on oyster setting and production dictates a major research effort (by VIMS) into effects of chlorine and other additives on the biota in the immediate future. This study should include bioassay studies with water from the James accompanied by determinations on levels of chlorine or chloramines in the water. Laboratory studies started by VIMS in 1974 should continue to evaluate effects of known levels of chlorine and chloramines on larvae and recently set spat, as well as associated organisms in relation to levels found in the field. Information should also be collected as to the past history of the chlorine loadings of all sewage treatment plants on the lower James or on tributaries emptying into the lower river to see if the decline in set beginning in 1960 was accompanied by a major increase in chlorine.

Despite the possible involvement of chlorine, most convincing evidence to date indicates low brood-stock levels related to MSX to be the most significant probable cause of low sets in the James River seed area since 1959-1960. Also, chlorine or other debilitating contaminants could have been involved. Further study is necessary and warranted.

Effect of River Discharge on Set in the James

It was thought about 45 years ago that fresh water flow in the James influenced the setting of oysters. The quantity of fresh water flowing into the system greatly influences salinity and estuarine circulation patterns.

Loosanoff's (1932) observations showed good sets of young oysters in the James in summers which followed springs when stream flows were high. He attributed this to scouring action of the water on bottom cultch. Loosanoff was incorrect in this hypothesis since it is now known fresh water inflow, within limits, has only a minimal effect on the velocity of the flow of tidal currents in the seed area. Fresh water flow does, however, influence salinity as well as the net tidal current pattern over the seed area. Therefore, fresh water flows may indirectly influence distribution of oyster larvae which are transported by the net currents (Pritchard, 1952). Consequently, we decided to investigate the possible relation between fresh water input in the upper James and set on bottom cultch. Stream flow data for the river portion of the James were calculated by totaling data for two stations, i.e., 02037000, James River and Kanawha Canal near Richmond, Virginia, and 02037500, James River near Richmond, Virginia (U.S. Department of the Interior, Geological Survey Reports). Flow measurements for certain years from these stations were not available. When these lapses occurred, the flows for Cartersville (upriver from the locations) were substituted. Fresh water flow during the spawning season (July, August and September) were compared to spat counted on natural cultch for the Wreck Shoals area (Table 33). Results showed a correlation coefficient of only .137. Thus, less than 10% of the variation in numbers of spat counted was related to fresh water discharge for the summer months. A similar study for the months of April, May and June also yielded a low correlation. As a consequence of these negative findings, we must conclude that the variation in flow of fresh water since 1960 could not be associated with the lowered setting observed since then.

Table 33

Correlation of Oysters at Wreck Shoals in the James River and Freshwater Discharge in the Summer
1948 - 1976

Season	Freshwater Discharged[1] (cfs)	Oysters[2] (spat/bu)
1947-8	245,080	1,464
48-9	501,819	1,399
49-50	703,010	2,971
1950-1	535,418	1,772
51-2	258,356	2,754
52-3	403,365	1,502
53-4	145,892	1,540
54-5	131,424	877
55-6		3,056
56-7	155,707	227
57-8	185,453	1,164
58-9	272,020	2,332
59-60	207,525	606
1960-1	219,260	644
61-2	283,287	132
62-3	276,565	201
63-4	94,225	157
64-5	96,384	937
65-6	118,794	62
66-7	137,498	148
67-8	286,379	0
68-9	135,199	33
69-70	965,433	193
1970-1	149,266	65
71-2	291,820	69
72-3	672,275	18
73-4	266,908	26
74-5	447,272	670
75-6	712,242	50

Correlation Coefficient: 0.137

1. Data given are the sums of the mean daily discharges for the 92 days from 1 July through 30 September; discharge was reported in cubic feet of water flowing past the recording station per second. Most data were the result of adding flows recorded at two stations; one on the James River near Richmond and another on the Kanawha Canal. Data from a station on the James River at Cartersville are shown for 1949 and 1957 through 1960 because data for the first stations were not available. Data for 1955 were not available. All data from publications of the U. S. Geological Survey.

2. Data given are spat per bushel of a bottom sample - Wreck Shoal (Table 27).

Influence of Fishing Efforts

There was no evidence that an increase in fishing effort per se had been responsible for the documented decline in the productivity of Baylor Grounds in the James since 1959-1960. This was not to say that fishing effort had not acted to diminish populations in recent times as it had in the past. In fact, overharvesting of oysters on public beds had been responsible for general population declines in all Chesapeake Bay oyster growing regions over the last 100 years. It was also true that the James River was subjected to a major harvesting effort each year. However, such data, as were available on the subject, indicated that fishing effort on the James had not increased appreciably since 1966-1967. It had declined. Since fishing effort had not significantly increased (as far as we can tell) since 1958, it is highly unlikely that overfishing per se could have been responsible for the initial decline in numbers of spat, yearling and small oysters per-bushel-of-bottom-cultch.

Prior to evaluating more fully the information we had on fishing effort, we emphasized a point made earlier in this chapter. There was really no adequate data on fishing effort for oysters for any region of Virginia! Such data are badly needed for a complete understanding of changes in natural production, harvest and landings. We will evaluate what little information is available with this limitation clearly in mind.

Conversations with watermen, observations by the authors, and occasional organized surveys by VIMS suggested that prior to 1960 over five to six hundred boats worked daily in the James during the oystering season. Since 1966-1967, counts have been made by VMRC one day a week for each month from October through March or May. These data were used to calculate average numbers of boats per year (Table 34). They showed the number of boats working from 1966 to 1970 ranged from 116 to 177 per day. They declined still further from 1971 to 1975 with numbers ranging from 114 to 43. Thus, fishing effort (numbers of boats fishing) DROPPED by an estimated 76% from the pre-1960 period.

Other indirect evidence of a reduction in fishing effort came from a tabulation of tonging licenses issued. There was a 35% decline in numbers issued for the State from 1960 to 1975 as compared to the preceding 10-year period (Table 26).

We concluded from these data that there was no increase since 1960 in fishing effort for oysters in the James River, instead there was a major decline. This probably holds for other regions as well. Significantly, therefore,

Table 34

Average Number of Tong Boats in James River
October to May - 1966-7 thru 1975-6[1]

Date	Avg. Number Boats/Day
1966-67	141
1967-68	177
1968-69	116
1969-70	132
1970-71	114
1971-72	76
1972-73	65
1973-74	81
1974-75	43
1975-76	62
Average	101

1. Data based on figures from VMRC.

we cannot attribute the major decline in yields of oysters per-unit-area-of-bottom since 1959-1960 to an increase in fishing effort during this period. Obviously, overfishing can occur even where the number of boats fishing per day declines. Overfishing is related to the number of oysters available compared to the harvesting effort. When stocks have declined to low numbers, overfishing may easily occur even though harvesting effort has weakened. Under these circumstances, overfishing in the James, even at a reduced number of boats for the river, certainly must be considered as a major factor (along with natural mortality) in reducing existing populations. The point made here is that, prior to 1960, the system withstood a much higher fishing effort without demonstrating a marked adverse impact on numbers of oysters on the bottom. Therefore, we must conclude that productivity and general harvesting declines documented since 1960 are due to other reasons.

One way of looking at the problem today is to consider that beginning about 1963 the numbers of oysters naturally occurring in the James River seed area stabilized at a level based on the lower setting rate and the decreased fishing effort (number of boats). The question which needs an immediate answer is whether the present rate of harvest of seed and market-sized oysters will stabilize at the present annual (1975) level of production of about 317,003 bushels or 38% of its 1963 level (Table 15).

Drills and Stylochus

We find that drills were not responsible for the decline in numbers of spat-per-bushel-of-bottom-cultch after 1960. Drills were not found in significant quantities on Wreck Shoals and were absent above where most of the seed rocks are located and where the declines in spatfall and harvest were largest.

At Brown Shoals and downriver the decline in numbers of spat per bushel was maximal after 1960. Drills were present up to 1972 in this region but fall surveys of bottom cultch for drill activity (bored holes in the shell) did not indicate an increase in activity after 1960.

After Tropical Storm Agnes killed most (if not all) of the drills at Brown Shoals there was a slight increase in numbers of oysters observed. Moreover, we expect this trend to continue until drills return. The principal point made here is that the declines occurred largely where there were no drills.

The flat worm, Stylochus, kills small spat, and is found over the range of oysters in the James River. We know relatively little about the quantitative effects of this predation and can only state our opinion that Stylochus was equally abundant prior to and after 1960 and therefore cannot be held responsible for the recent decline. Probably, *Stylochus* had no significant effect on the decline of adult or seed oysters.

Other Possible Causes of the Decline

The James drains a vast basin, part of which is agricultural, wherein various pesticides such as DDT, Chlordane, Kepone and many others have been or are now being used and/or discharged (Chapter X). Many of these chemicals, if concentrated enough, are toxic in estuarine waters. Recently, long-lived Kepone was found in water, sediments, crustaceans and shellfish in that system. Additionally, heavy metals of various types have been detected (Chapter X).

Other changes have occurred in the James River over the past 30 to 40 years which are difficult to quantify, but are the result of man's ever-increasing impact on the environment. These aspects must be considered in looking for reasons for the decline in the productivity of the James. High BOD has resulted in oxygen sags over and above that which might occur naturally in many areas. Silt levels may have increased over the years due to widespread cutting of woodlands and numerous construction projects. Fresh water inflows have been modified and lessened due to dams and domestic and industrial use of water by rapidly growing populations and industrial activity. Marsh areas have also been depleted which has led to less nutritional organic matter entering the system.

An element needing study is how effects of the various contaminants and diseases present, such as MSX, may interact with one another. This process of interaction is called synergism. For example, the effects of MSX (or those of any other disease-producing agent) on oysters may be triggered or increased by the weakening effect of some pollutant.

What Did Cause the Decline?

In evaluating all probable causes for the decline in oyster production after the 1959-1961 period, it is not possible to absolutely state that any single factor was responsible. Indications are, however, that the absence of brood-stocks in the Hampton Roads-Willoughby Spit area and in the lower James River was the major, original cause. Other aspects are probably involved in keeping setting down, such as chlorine or perhaps other domestic or industrial waste products. We must also consider such factors as changes in river flow, silt loads and overfishing. The factors noted are additive and each contributes a part, in all probability, to the overall continuance or persistence of the reduction in natural production of the James River oyster beds.

One aspect becomes increasingly clear: The James River oyster populations are under continuing stress and further degradation of the environment will probably endanger the James-based industry to a point where it can no longer exist.

A Future Shortage

It is interesting to speculate what the seed catch might be were James River seed in as much demand today as it was in the past. If efforts were made to encourage seed planting and hence increase the demand for seed, could the James River seed area supply the demand without depleting the resource? Because both the numbers and density of seed on the formerly productive James River seed bars have decreased, it is likely that the supply would not be adequate.

A Recent Increase in Survival Rates in Type I MSX Areas

Since about 1972 there has been an increase in numbers of oysters on Baylor bottoms and in leased areas in Type I MSX areas in the lower James River, Mobjack Bay and the mouth of the Poquoson River. The initial reason for increased survival was Tropical Storm Agnes whose floodwaters killed drills or reduced population levels in those areas. However, many oysters setting in these areas reached market size in 1975 with very low levels of mortality. We believe that this high rate of survival is due to resistance to MSX as well as to reduced predation. Were some MSX resistance not involved, the adult oysters would have succumbed in greater numbers to the disease as they did earlier (Chapter IX).

The York River

The York River, the second major estuary up-Bay on the western shore, receives a moderate amount of fresh inflow, but less than the James. As a consequence of the low fresh water inflow, salinities change less rapidly and drastically and grade more regularly upstream. Red-water blooms are frequent and low dissolved oxygens frequently occur in the deeper portions of the river. Oysters occur in the York River from the junction of the Mattaponi and Pamunkey rivers all the way to the mouth. Today they are scarce on the public rocks in the lower half of the river largely due to MSX (Andrews and Wood, 1967). Drills are usually abundant in the lower third of the river extending upriver as far as Page Rock. Tropical Storm Agnes in 1972 did not eliminate the drill populations in the lower York as it did over much of the lower James, Rappahannock, Piankatank and Great Wicomico rivers. The York upland drainage basin is much smaller than the James. Because of drills, few spat setting on cultch survive in the zone from Gloucester Point to the mouth of the river. Also, because of the combined impact of drills, MSX, pollution and their impacts on young and adult oysters, productive oyster grounds today are restricted to a region in the upper third of the estuary from about Capahosic to Bell Rock (Figure 3). Prior to the outbreak of MSX in 1960, the lower river was used to a moderate degree by private growers for growing James River seed to market size. The Baylor bottoms below Gloucester Point have been unproductive for many years prior to 1960.

Before 1928 the York was said to produce up to 400,000 bushels of oysters annually (Galtsoff et al, 1947). However, since 1935[3] the York River has had a history of poor setting and low oyster production. Setting was first studied in the York in 1936 using wire shellbags. His study showed that numbers of spat per bushel of exposed shell decreased from the mouth to the head of the river. Galtsoff et al (1947) found mortality of spat on the bottom material to be greatest downriver. In his studies there was no material difference between numbers of surviving spat in the two sections of the

[3]Mr. Cranston Morgan, Weems, Virginia stated that from 1935 on there was only light and sporadic setting in the lower York. However, this area was heavily planted with seed.

river by the end of the setting season. They also found peak set occurred in the lower river in mid-September. Setting was spread over the period between July and September. In the upper river near West Point most of the set occurred over a shorter period from August to September. Calculations based on Galtsoff's data show maximum weekly set in the upper river per shell at about 0.1 spat and in the lower river at about 0.5 spat.

Spat on naturally occurring bottom cultch at nine stations in 1936 averaged about 100 spat per bushel and showed no difference in numbers up or downriver.

Spat on Natural Cultch

Data on spat counts on bottom cultch from the York from 1947 to 1976 were tabulated for four stations (Table 35).

These summarizations indicate the numbers of spat surviving on natural cultch from 1946 to 1976 to have fluctuated very erratically with five-year averages ranging from 6 to 154 spat per bushel.

There was a decline in numbers of spat-per-unit-of-bottom-cultch at all stations which seemed to start about 1960. These declines were: Bell Rock--88%; Aberdeen Rock--44%; Page Rock--43%; Green Rock (1956-1976)--59%; and 65% for all stations (Table 36).

Table 35

Live Oysters Per Bushel of Unculled Bottom Sample from the York River[1]

Season	LARGE OYSTERS Green Rock	Page Rock	Aberdeen Rock	Bell Rock
1946-7	N/A	72	N/A	92
47-8	N/A	71	60	64
48-9	N/A	N/A	N/A	N/A
49-50	N/A	61	37	92
1950-1	N/A	164	27	124
Average	N/A	92	41	93
1951-2	N/A	40	23	54
52-3	N/A	N/A	N/A	N/A
53-4	N/A	N/A	N/A	N/A
54-5	N/A	41	N/A	N/A
55-6	N/A	37	56	90
Average	N/A	39	40	72
1956-7	N/A	21	61	56
57-8	N/A	84	92	118
58-9	32	42	46	72
59-60	31	27	25	60
1960-1	10	15	27	12
Average	24	38	50	63
1961-2	3	16	30	24
62-3	5	16	19	32
63-4	N/A	50	52	39
64-5	15	27	91	78
65-6	9	57	57	50
Average	8	33	50	45
1966-7	9	50	35	20
67-8	N/A	39	28	11
68-9	N/A	24	36	47
69-70	6	6	20	67
1970-1	7	19	30	56
Average	5	28	30	40
1971-2	0	1	14	8
72-3	2	10	10	44
73-4	12	14	38	90
74-5	2	6	10	43
75-6	32	10	42	108
Average	10	8	23	59

Table 35 (Contd.)

Season	SMALL OYSTERS & YEARLINGS			
	Green Rock	Page Rock	Aberdeen Rock	Bell Rock
1946-7	N/A	156	2	100
47-8	N/A	116	104	107
48-9	N/A	N/A	N/A	N/A
49-50	N/A	40	23	76
1950-1	N/A	52	12	90
Average	N/A	91	35	93
1951-2	N/A	10	64	276
52-3	N/A	N/A	N/A	N/A
53-4	N/A	N/A	N/A	N/A
54-5	N/A	43	N/A	N/A
55-6	17	7	2	2
Average	17	20	33	139
1956-7	N/A	175	141	222
57-8	N/A	159	380	246
58-9	46	124	316	148
59-60	7	32	269	82
1960-1	9	8	50	63
Average	20	99	231	152
1961-2	0	41	81	106
62-3	0	15	22	139
63-4	2	47	24	75
64-5	1	5	91	85
65-6	6	360	109	374
Average	3	94	65	156
1966-7	1	13	36	114
67-8	N/A	66	71	443
68-9	N/A	25	99	178
69-70	3	7	34	203
1970-1	2	15	65	118
Average	2	25	61	211
1971-2	4	14	8	128
72-3	26	52	42	80
73-4	14	14	72	80
74-5	24	30	48	68
75-6	36	54	104	86
Average	21	33	55	88

Table 35 (Contd.)

Season	SPAT Green Rock	Page Rock	Aberdeen Rock	Bell Rock
1946-7	N/A	0	2	4
47-8	N/A	0	4	381
48-9	N/A	N/A	N/A	N/A
49-50	N/A	101	45	64
1950-1	N/A	8	13	170
Average	N/A	27	16	154
1951-2	N/A	4	67	54
52-3	N/A	N/A	N/A	N/A
53-4	N/A	N/A	N/A	N/A
54-5	N/A	0	N/A	N/A
55-6	90	113	2	2
Average	90	38	34	28
1956-7	N/A	210	230	326
57-8	N/A	21	95	294
58-9	1	40	1	1
59-60	11	1	3	12
1960-1	N/A	3	0	13
Average	6	55	65	129
1961-2	0	2	0	1
62-3	6	16	11	9
63-4	N/A	36	18	1
64-5	21	53	166	93
65-6	0	2	21	11
Average	7	22	43	23
1966-7	16	17	11	34
67-8	N/A	11	3	0
68-9	N/A	2	1	0
69-70	7	22	40	2
1970-1	16	12	1	0
Average	13	13	11	7
1971-2	6	64	4	10
72-3	4	4	8	0
73-4	30	4	2	0
74-5	36	28	58	26
75-6	20	94	268	36
Average	19	39	68	14

Table 35 (Contd.)

1. Data for 1947-1948 through 1967-1968 from Andrews, J. D., unpublished; 1969-1970, 1971-1972 and 1975-1976 (spat) data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1968-1969, 1970-1971 and 1972-1973 through 1974-1975 and 1975-1976 (other than spat) data from Haven, D. S., unpublished.

N/A Data not available.

Table 36

Comparison of Average Number of Oysters in Bushel Samples of Natural Cultch in Pre and Post-MSX Years in York River

AREA	MARKET		SMALL & YEARLING		SPAT	
	1946-7 thru 1960-1	1961-2 thru 1975-6	1946-7 thru 1975-6	1961-2 thru 1975-6	1946-7 thru 1960-1	1961-2 thru 1975-6
Bell Rock	76	48	140	152	124	15
Aberdeen Rock	46	34	139	60	73	41
Page Rock	55	23	77	51	42	24
Green Rock	21[1]	8	20[1]	9	34[1]	14
Average	50	28	94	68	68	24

1. Average for the period 1956-7 thru 1960-1.

Numbers of Small and Yearling Oysters on Bottom Cultch

In the York River five-year averages indicate from 1946 to 1976 numbers of yearling and small oysters were most numerous at the upriver stations. Over this long period at each of the four locations there was a downward trend in numbers which seemed to date to 1965 (about 5 years after MSX entered the Bay). When the 1946 to 1965 period is compared to the 1966 to 1976 period, the following declines were calculated from data shown in Table 35: Bell Rock--9%; Aberdeen Rock--45% and Page Rock--65%. Increases were noted at: Green Rock (1958-1965 to 1966-1975)--41% and Bell Rock--9%.

Numbers of market oysters at each station also showed a decline starting about 1965. The declines were: Bell Rock--25%; Aberdeen Rock--44%; Page Rock--64%; and Green Rock (1958-1965 and 1966 to 1975)--41% (calculated from Table 35).

Although the decline in yearling, small and market oysters began about 1965, it was of interest for comparison with the James to calculate the average changes in the York River since 1960 in all size groups of oysters. All stations, sizes and age classes showed declines with one exception. Average declines based on all stations for the pre- and post-1960 period were: spat--65%; small and yearling oysters--28%; and market oysters--44% (Table 36).

Shellbag Studies

Spat surviving on shellbags show no well-developed spatial survival pattern from 1947 to 1976 at the stations sampled (Table 37). There was no tendency for survival to be higher up or downriver from Clay Bank to Ellen Island (Table 37). Moreover, while data for the upper river beyond Clay Bank are lacking, the data available suggest that survival on shellbags in the lower York (from Page Rock to Gloucester Point) has not changed materially from 1947 to 1976.

Average numbers of spat surviving in the last 29 years on shellbags for various periods have averaged from about less than 0.1 to 7.2 spat per shell (stations with inadequate data not included).

Spat on shellbags for the pre- and post-MSX period (1960) were averaged for comparison with other estuaries (Table 38). These data indicate no decline but rather an increase for Gloucester Point.

An aspect emphasized concerning these shellbag studies is that stations in the lower river such as Gloucester Point still show a surviving set in regions of high salinity even though oyster populations on the public rocks are extremely low.

Table 37

Seasonal Spatfall on Shellbags in the York River[1]
Spat per Shell

LOCATION

Season	Ellen Island	Wormley Rock	Gloucester Point	Green Rock	Page Rock	Aberdeen Rock	Clay Bank	Purtan Bay	Bell Rock
1947-8			1.9						
48-9					0.3			0.1	0.0
49-50		1.1			1.3			0.7	0.2
1950-1		0.3			0.5	1.4			1.6
Average		0.7	1.9		0.7	1.4		0.4	0.6
1958-9			1.7						
59-60	0.9		0.1		0.1				
1960-1					0.4				
Average	0.9		0.9		0.2				
1961-2			0.5						
62-3				0.2	0.1		1.1		
63-4	0.5		3.8	0.5	0.4		0.2		
64-5	0.3	0.1	2.6	3.8					
65-6			0.4		0.4				
66-7	0.4		0.2	1.2	0.4		2.4		
67-8	<0.1[2]		<0.1[2]		0.1		<0.1[2]		
68-9									
69-70									
1970-1			2.3	<0.1[2]			0.4		0.0
Average	0.3		1.4	1.2	0.3		0.8		
1971-2			22.0	1.9	1.3		1.2	0.1	0.12
72-3	0.0[3]		0.0	0.01	0.01		0.03		0.0
73-4			0.7	0.01	0.1		0.2	0.0	0.0
74-5	1.0		6.1	0.3	0.6		0.2	0.0	
1975-6	2.4			0.1			0.1	0.03	0.05
Average	1.1		7.2	0.5	0.5		0.3	<0.1	<0.1

Table 37 (Contd.)

1. Andrews, J. D., unpublished data for 1947-1948 through 1967-1968; data not available for 1951-1952 through 1957-1958, 1968-1969 and 1969-1970; 1970-1971 and 1971-1972 data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1972-1973 through 1975-1976 from Haven, unpublished.

2. $<$ is the symbol for "less than."

3. Tues Light.

Table 38

Comparison of Average Numbers of Spat per Shell on Natural Cultch, Shellbags and Shellstrings in Pre and Post-MSX Periods in the York River, Virginia

AREA	NATURAL CULTCH[1]		SHELLBAGS		SUM OF WEEKLY SET SHELLSTRINGS[2]	
	1946-7 thru 1960-1	1961-2 thru 1975-6	1946-7 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1955-6	1963-4 thru 1975-6
Bell Rock	0.25	0.03	0.6	0.03		
Aberdeen Rock	0.15	0.08	1.4			
Page Rock	0.08	0.05	0.9	0.4		
Green Rock	0.07	0.03	0.8			
Gloucester Pt.			1.2	3.5	73.0	68.0

1. Assuming 500 shells per bushel.

2. Total spatfall per shell for entire season; number per shellface doubled.

Weekly Setting Pattern

Data from 1947 were collected from shellstrings exposed off the Yorktown Pier at Yorktown. When the Institute was moved to the Gloucester side the collection station was moved and from 1963 to 1976 data were obtained from strings suspended from the laboratory pier at Gloucester Point (Table 39). Data from these two places and two periods are not strictly comparable since data do not come from the same place. The data still show the lower York to be receiving moderate strikes. Intensity may have decreased in the last five years. Average spatfall from 1947 to 1955 was 36.5 per shell face; from 1963 to 1970 it was 38.7 which was higher than the previous period. Spatfall averaged 26.5 spat per season from 1971 to 1976--a decline of about 32%. Despite the above average spatfall for the period from 1963 to 1970, the decline probably began shortly before 1963, because from 1963 to 1976 the system produced about half the spat it had in the preceding 1947 to 1955 period. When data for 1964, an exceptional year, are eliminated average set on shellstrings from 1963 to 1970 was only 12.1 spat-per-shell-face which is about one-third that (36.5) for 1947 to 1955. The preceding discussion on a decline in total seasonal set is clearly labeled as speculation since the stations occupied prior to and after 1950 were on different sides of the river.

Table 39

Weekly Spatfall on Shellstrings in the York River Near Gloucester Point[1]; Sum, Maximum and Week of Occurrence.

Spat Per Smooth Shellface

Season	Duration of Setting	Sum of Weekly Spatfall	Max. Wkly Spatfall & Wk. of Occurrence[2]	
1947-8	7/ 7 - 10/ 7	28.5	5.8	A 5
48-9	6/28 - 9/27	11.0	2.7	S 2
49-50				
1950-1	7/12 - 9/27	36.8	13.8	S 2
51-2	6/27 - 10/10	44.8	11.8	A 4
52-3	6/23 - 11/17	51.0	21.4	S 2
53-4	6/12 - 10/ 7	56.7	19.5	A 4
54-5	6/28 - 11/ 8	28.5	14.2*	S 3
55-6	7/ 7 - 8/27!	34.7	11.1	J 3
Average		36.5		
1963-4	7/12 - 9/23	19.5	6.5	S 3
64-5	8/17 - 10/ 5	224.5	156.7	S 1
65-6	7/12 - 10/28	5.4	1.9	A 4
66-7	7/ 5 - 10/17	26.8	7.7	S 1
67-8	7/17 - 10/14	1.0	0.8	S 2
68-9	6/26 - 9/ 1!	0.4	0.1	J 4
69-70	7/ 2 - 10/13	12.2	0.7	S 3
1970-1	8/ 5 - 10/15	19.7	5.1	S 3
Average		38.7		
1971-2	7/20 - 10/19	87.2	53.2	S 2
72-3		0.3	0.3	S 1
73-4	7/19 - 10/ 4	17.7	7.0	S 4
74-5	7/ 7 - 10/ 3	14.6	8.0	J 1
75-6	6/30 - 9/26	12.7	5.0	E 4
Average		26.5		

1. **Andrews, J. D., unpublished data for 1947-1948 through 1968-1969; data not available for 1949-1950 and 1956-1957 through 1962-1963. 1969-1970 through 1975-1976 Haven, D. S., in Marine Resources Information Bulletin, VIMS. Data taken at Yorktown Fish Pier in the first two seasons and at VIMS' pier, Gloucester Point, in remaining years.**

2. Letters indicate the month of occurrence (J = July, A = August, and S = September). The digits immediately following the letters indicate the week of the month.

* Shellstring stayed in water about 4 weeks.

! Observations stopped on this date.

Time of Settings

Maximum strike in the York River from 1947 to 1975 sometimes occurred in August, but more often in mid-September (Table 39).

Discussions of Reasons for the Decline in Oyster Density and Setting in the York

The 65% average decline for all stations for spat on bottom cultch had a measurable impact on numbers of the older and larger size classes. This decline started shortly after 1960 as it did in the James.

The average declines for yearlings and small oysters (28%) and market-sized oysters (44%) were due primarily to several factors. The surviving spatfall was lower and fewer oysters were entering the fishery. That is, recruitment was lower. MSX entered the Bay and the York River in 1960. From the mouth to about Clay Bank, the York is classed as Type I and II for the disease. In years of high salinity it has caused excessive mortalities. That is, MSX plus lowered recruitment plus the usual attrition of natural and man-associated factors have been responsible for the declines noted in the lower two-thirds of the York at Green, Page and Aberdeen Rocks. At Bell

Rock, where MSX causes no mortality, small and yearling oysters did not decline in numbers.

Fishing mortality was not considered a significant factor in the decline of spat or yearlings and small oysters. The public rocks in the York are not classed as seed areas and only oysters 3 inches or larger may be harvested. Part of the decline in numbers of market oysters may have been due to harvest by man, but we do not believe it has been an important factor.

While we have offered an "explanation" for the decline in yearling, small and market-sized oysters, there still remains the question as to why numbers of spat-per-bushel-of-bottom-cultch declined after 1960 or 1965. We were able to show the reason for the decline in the James was due to a decrease in total seasonal set, but quantitative data to support the existence of a similar situation for the York are lacking. The basic reason for our failure to demonstrate differences is the absence of data on total seasonal set based on shellstrings. The two stations where total seasonal set was measured gave inconclusive evidence of a decline. Moreover, evidence based on surviving set on shellbags indicated a stable situation in the pre- and post-1960 periods. However, we must emphasize that shellbags measure the surviving set and not necessarily what has occurred over an entire season. While we cannot quantitatively document a decline in total seasonal spatfall, the fact that numbers of spat on bottom cultch have declined so drastically strongly suggests that such a decline has occurred.

There are three large industrial plants on the York. There is a pulp mill at West Point which has been in operation since the early 1920's; the large installation of the American Oil Company Refinery (AMOCO) at Yorktown which went "on stream" December 1956 and the Virginia Electric and Power Company (VEPCO) generating plant nearby installed about 1959. Several small sewage treatment systems discharge wastes treated to various levels into the river. Chlorine is used by VEPCO and AMOCO as well as sewage treatment facilities to kill living, fouling organisms on their condensing systems. Therefore, there is a possibility that a significant quantity of chlorine is being added to the York River from these industrial sources and also from the limited numbers of sewage treatment plants located along the length of the systems. In searching for a probable reason for the decline, it is more difficult to implicate chlorine associated with sewage treatment plants than it was in the James since the quantity of treated effluent entering the York is much less than in the James.

Spatfall may have declined due to the absence of brood-stock in the lower York as was proposed for the James.

Larval transport probably does occur in the York since the system is horizontally stratified and the bottom water has a net upstream flow as it does in the James. Populations of oysters in the lower river below Gloucester Point were never large in the decade prior to 1960. They were large, however, from 1935 to about 1950.

As outlined for the James, drills are present in the lower York and *Stylochus* are present over the range of oysters, but there is no evidence that these two animals were involved in the recent decline.

In conclusion, the York River, as was the case in the James, has suffered a decline in oyster density (numbers per bushel of bottom cultch). The factors involved in the decline are increased mortalities due to MSX and possible decline in total seasonal spatfall. The cause of this latter decline may be due to pollutants from industrial sources. However, as outlined for the James, long-term changes in environmental conditions such as increased silt loads, decreased levels of nutrition and modified salinity patterns may be involved.

The Piankatank River

Introduction

The Piankatank is a short system with a relatively narrow entrance and a small fresh water inflow. Average salinities during the summer months are slightly lower than in the York and range from 14 to 20‰ (Figures 9 and 10). For many years drills were present and were destructive in the lower quarter of the system in the vicinity of Milford Haven and Hills Bay. Since Tropical Storm Agnes in 1972 drills have been absent or scarce from that area. MSX probably caused mortalities in the lower river since 1960 and it is rated as a Type II area (Chapter X). However, the influence of MSX on survival of oysters in this area has never been adequately evaluated.

Since 1963 the Piankatank has been developed by VMRC as a seed area. A total of 4,394,731 bushels of cultch shells have been planted there from 1963 to 1975. Prior to 1963 (from 1931 to 1960) the area had received about one-half million bushels of shell. The State's shell planting program in this river has been generally successful because the system since 1963 has produced over 646,402 bushels of seed (Chapter VI).

Early History

The river was first studied in 1936 when spatfall on bottom cultch was examined over the length of the system

(Galtsoff et al, 1947). Spat count was highest in the lower river with 450 spat-per-bushel at Iron Point. It was lowest upriver at Ferry Point with 150 spat-per-bushel. Set on weekly shellbags was also highest in the lower river in this same study. The time of maximum set was in early September, similar to timing of the maximum set in the York. Maximum weekly set in 1936 in the Piankatank was about 450 spat-per-bushel or about 1 spat-per-shell-per-week. This was considered a good setting area by Galtsoff and his co-workers and was found to be about the same level in later studies of the Piankatank.

Natural Cultch

Data on number of spat surviving on natural cultch from 1948 to 1975 indicate a wide variability in set, but no years in which zero spatfall occurred. No samples were taken in the system from 1952 to 1955 and from 1968 to 1970. Five-year averages over the entire period ranged from 22 to 538 spat per bushel. During that time the upriver bars seemed to have as many spat as those downriver (Table 40).

Inspection of the data in Table 40 gives no clear impression of a declining trend in numbers of spat beginning in any period. This is due to the variability of the data. Because of this variability, the data were grouped, as were those for other systems, into the pre- and post-MSX years (Table 41).

Table 40

Live Oysters Per Bushel of Unculled Bottom Sample From the Piankatank River[1]

	LARGE OYSTERS			
Season	Burton Point	Middle Ground	Palace Bar	Ginny Point
1948-9	N/A	N/A	N/A	28
49-50	N/A	N/A	50	44
1950-1	N/A	N/A	N/A	N/A
Average	N/A	N/A	50	36
1951-2	24	N/A	88	32
1952-55	N/A	N/A	N/A	N/A
1956-7	N/A	N/A	144	60
57-8	N/A	N/A	N/A	N/A
58-9	73	40	96	64
59-60	N/A	N/A	16	60
1960-1	31	N/A	75	36
Average	52	40	82	55
1961-2	18	46	N/A	11
62-3	36	80	N/A	40
63-4	50	N/A	N/A	27
64-5	N/A	N/A	47	32
65-6	9	14	10	10
Average	28	46	28	24
1966-7	0	13	N/A	N/A
67-8	N/A	N/A	N/A	4
1968-71	N/A	N/A	N/A	N/A
1971-2	0	0[2]	1	0
72-3	14	4[2]	0	4
73-4	24	40[2]	N/A	58
74-5	N/A	N/A	N/A	N/A
1975-6	30	30[2]	14	22
Average	17	18	5	21

Table 40 (Contd.)

Season	SMALL OYSTERS & YEARLINGS			
	Burton Point	Middle Ground	Palace Bar	Ginny Point
1948-9	N/A	N/A	N/A	444
49-50	N/A	N/A	344	254
1950-1	N/A	N/A	N/A	N/A
Average	N/A	N/A	344	349
1951-2	72	N/A	488	546
1952-55	N/A	N/A	N/A	N/A
1956-7	N/A	N/A	370	544
7-8	N/A	N/A	N/A	N/A
8-9	241	389	N/A	188
59-60	N/A	N/A	317	52
1960-1	45	N/A	119	56
Average	143	N/A	268	210
1961-2	85	114	187	53
62-3	228	140	N/A	72
63-4	423	N/A	N/A	614
64-5	N/A	N/A	313	356
65-6	165	156	111	151
Average	225	137	204	249
1966-7	349	138	N/A	N/A
67-8	N/A	N/A	N/A	228
1968-71	N/A	N/A	N/A	N/A
1971-2	68	591[2]	226	596
72-3	198	106[2]	190	172
73-4	218	190[2]	N/A	156
74-5	N/A	N/A	N/A	N/A
1975-6	184	124[2]	100	120
Average	167	253	172	261

Table 40 (Contd.)

	SPAT			
Season	Burton Point	Middle Ground	Palace Bar	Ginny Point
1948-9	N/A	N/A	N/A	120
49-50	N/A	N/A	538	872
1950-1	N/A	N/A	N/A	N/A
Average	N/A	N/A	538	496
1951-2	864	N/A	464	294
1952-55	N/A	N/A	N/A	N/A
1956-7	N/A	N/A	344	122
57-8	N/A	N/A	N/A	N/A
58-9	26	12	N/A	7
59-60	N/A	N/A	607	44
1960-1	19	N/A	47	11
Average	22	N/A	332	46
1961-2	122	137	391	45
62-3	956	628	N/A	243
63-4	343	N/A	N/A	309
64-5	N/A	N/A	905	511
65-6	61	609	275	456
Average	370	458	523	312
1966-7	83	188	N/A	N/A
67-8	246	N/A	N/A	90
1968-71	N/A	N/A	N/A	N/A
1971-2	290	153[2]	615	284
72-3	4	4[2]	10	2
73-4	70	48[2]	N/A	124
74-5	N/A	N/A	N/A	N/A
1975-6	158	128[2]	308	68
Average	130	83	311	120

1. Data for 1948-1949 through 1967-1968 from Andrews, J. D., unpublished; data not available for 1952-1953 through 1955-1956 and 1968-1969 through 1970-1971. 1971-1972 data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1972-1973 through 1975-1976 data from Haven, D. S., unpublished. (Shells planted in most bars 1968-1971.)

2. Island Bar instead of Middle Ground.

Table 41

Comparison of Average Numbers of Oysters in Bushel Samples of Natural Cultch in Pre and Post-MSX Years in Piankatank River

AREA	MARKET		SMALL & YEARLING		SPAT	
	1948-9 thru 1960-1	1961-2 thru 1975-6	1948-9 thru 1960-1	1961-2 thru 1975-6	1948-9 thru 1960-1	1961-2 thru 1975-6
Ginny Point	46	21	298	252	210	214
Palace Bar	78	14	328	188	400	417
Middle Ground	40[1]	28	389[1]	195	12[1]	237
Burton Point	43	20	119	213	303	233
Average	52	21	284	212	304	275

1. Data from 1 year only.

Starting sometime after 1960, this grouping suggests there was a decline of 23% in spat-per-bushel-of-bottom-cultch only at Burton Point. There was a slight increase in numbers at the two upriver stations, Ginny Point and Palace Bar.

Numbers of yearling and small oysters from 1948 to 1976 showed two or five-year averages ranging from 143 to 349 per bushel (Table 40). As was the case for spat, an inspection of Table 40 suggests no well established trend due to extreme variability in numbers. There was a decline (Ginny Point--15%; Palace Bar--43% and Middle Ground--50%) when the data were divided into the pre- and post-MSX periods. There was an increase of about 79% in numbers at Burton Point, the station farthest downriver (Table 41).

From 1948 to 1976 market-sized oysters showed five-year averages ranging from 5 to 82 per-bushel-of-bottom-cultch (Table 40). Inspection of these data suggests a decline in numbers which began about 1960, but due to variability in annual counts, the trend is not clear. When the data are grouped into the pre- and post-MSX periods, the trends become apparent and the following declines are noted: Ginny Point--54%; Palace Bar--82%; Middle Ground--30% and Burton Point--53% (Table 41).

Shellbags--Survival

From 1963 to 1976 shellbag data were obtained at six stations from Milford Haven to Ginny Point (Table 42). Data from these stations represent a wider range in an up and downriver direction than those from bottom samples. Numbers of surviving spat, based on five and eight-year averages, ranged from 0.3 to 4.6 spat-per-shell-per-season, or about 150 to 2,300 spat per bushel from 1963 to 1976. There was a decided downward trend from 1971 to 1976 for surviving spat on shellbags compared to the average from 1963 to 1970. The percentage declines were: Milford Haven--90%; Three Branches--80%; Burton Point--39%; Palace Bar--40% and Ginny Point--74% (Table 42).

The average surviving set on shellbags from 1963 to 1971 was about twice those observed in the James River. Values for the Piankatank were about half those observed in the James from 1971 to 1976 (Tables 29 and 42).

Weekly Setting Pattern

Shellstring data have been collected for the Piankatank from 1964 to 1976. The sum of the weekly set shows extreme fluctuations from year to year with no one general area of the river consistently receiving the highest or lowest set. Average values for 1964 to 1976 ranged from 67.4 to 9.6 spat-per-shell-face-per-season (Table 43).

Table 42

Seasonal Spatfall on Shellbags in the Piankatank River[1]
Spat Per Shell

Season	Milford Haven[2]	3 Branch Shore	Burton Point	Palace Bar	Ginny Point
			LOCATION		
1963-4	8.3				11.1
64-5	1.4		1.3	1.7	1.6
65-6	3.1	3.6	2.6		5.8
66-7	1.4	0.8		1.4	
67-8		0.2	0.2	1.5	0.6
68-9					
69-70					
1970-1	1.1		2.9		3.9
Average	3.1	1.5	1.8	1.5	4.6
1971-2	0.2	0.2	0.2		
72-3	0.01	0.05	0.05	0.09	0.14
73-4	0.3[3]	0.7	0.08	0.8	
74-5	0.3[3]		2.6	0.2	0.2
1975-6	0.8[4]		2.6	2.7	2.5
Average	0.3	0.3	1.1	0.9	1.2

1. Andrews, J. D., unpublished data for 1963-1964 through 1967-1968; data for 1968-1969 and 1969-1970 not available. 1970-1971 and 1971-1972 data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1972-1973 through 1975-1976 data from Haven, D. S., unpublished. Blanks indicate data not available.

2. Hole in the Wall.

3. Lilly Neck.

4. Point Breeze.

Table 43

Sum of Weekly Spatfall on Shellstrings in the Piankatank River[1]
Spat Per Shellface

Season	Duration of Setting	LOCATION Milford Haven	3 Branch Shore	Burton Point	Palace Bar	Ginny Point
1964-5	7/ 6- 9/15	22.0				48.0
65-6	6/21- 9/ 6	115.8				190.9
66-7	6/23- 9/26	79.7				72.9
67-8	6/14-10/ 3	10.2		6.4	20.1	17.8
68-9	6/19-10/18	46.5	18.6	24.1	21.2	54.2
69-70	6/ 9- 9/22	3.7	3.8	4.5	12.1	27.7
1970-1	6/ 4-10/ 7	11.7	10.6	19.8		60.5
Average		41.4	11.0	13.7	17.8	67.4
1971-2	6/15-10/12	22.6	29.1*	8.7	11.4	71.2
72-3	6/20-10/ 2	0.1	0	0	0.1	1.2
73-4	6/19-10/ 2	17.2	15.5	35.6	34.4	39.2
74-5	6/10- 9/30	3.5	3.6	5.3	10.5	11.5
75-6	6/23-10/ 1	4.8	1.4	10.0	18.9	27.3
Average		9.6	9.9	11.9	15.1	30.1

1. Andrews, J. D., unpublished data for 1964-1965 through 1967-1968. 1968-1969 data from Haven, D. S., unpublished. 1969-1970 through 1975-1976, Haven, D. S., in Marine Resources Information Bulletin, VIMS. Blanks indicate that data were not available.

* Data to 9/7 only.

For further analysis, the data were divided into the 1964 to 1970 and 1971 to 1976 periods. A decrease in total seasonal spatfall was observed at the upriver stations as follows: Milford Haven--77%; Three Branches--10%; Burton Point--13%; Palace Bar--15% and Ginny Point--55% (Table 43).

Survival of Spat - Setting Season

The ratio between spat surviving on bottom cultch versus the total seasonal spatfall on shellstrings ranged from less than 1% to 3% from 1961 to 1975. These values were identical to those observed in the James River (with the exception of Deep Water Shoal) for the same period.

The setting season in the Piankatank begins in late June and extends into late September. The time of peak set occurred most frequently from mid-July to the first week in September (Table 44).

A Discussion of Reasons for the Decline in Oyster Numbers and Spatfall in the Piankatank

A decline started in 1960 in numbers of yearling, small and market-sized oysters in the Piankatank River, as was the case for the James and York to the south. There was only a slight indication of an accompanying decline in spat on bottom cultch in the Piankatank at one of the three bars sampled in the pre- and post-1960 period.

Table 44

Highest Weekly Spatfall on Shellstrings in the Piankatank River[1]
Spat Counted Per Smooth Shellface Plus Week of Occurance[2]

Season	Milford Haven	3 Branch Shore	Burton Point	Palace Bar	Ginny Point
1964-5	7.1 S1				11.6 S1
65-6	55.6 J3				85.6 J3
66-7	40.3 A5				23.2 A5
67-8	3.8 J4		2.8 J5	6.5 A2	10.4 A2
68-9	27.4 J3	10.3 J3	14.3 J3	9.5 J3	28.5 J3
69-70	1.1 S3	1.5 S3	1.1 J3	5.4 J4	9.5 J2
1970-1	1.5 S1	3.9 A3	7.3 J2		29.7 J2
Average	19.5	5.2	6.4	7.1	28.4
1971-2	12.3 S1	14.8 S1	3.2 S1	3.9 J1	13.5 A2
72-3	0.1 J3	0	0	0.1 E4	0.8 J2
73-4	4.5 J3	3.3 A2	15.4 A2	6.5 A4	11.7 A4
74-5	1.6 J3	1.7 J3	2.8 A1	3.2 A1	3.5 A1
75-6	1.8 J3	0.6 A2	2.2 S2	5.6 J2	9.6 A4
Average	4.1	4.1	4.7	3.9	7.8

1. Andrews, J. D., unpublished data for 1964-1965 through 1967-1968; 1969-1970 through 1975-1976, Haven, D. S., in Marine Resources Information Bulletin, VIMS; 1968-1969, Haven, D. S., unpublished. Blanks indicate that data were not available.

2. The letters to the right of the spat counts indicate the month (E=June; J=July; A=August; S=September; O=October). The digits immediately following the letters indicate the week of the month.

Shellstring and shellbag data were not collected in this system before 1960. However, we speculated that because the surviving spat on bottom cultch had not declined during the 1948 to 1975 period, that total seasonal set, as would be measured by shellstrings, had not declined. If we accept this point, it is difficult to attribute the documented decline in numbers of yearling, small and market oysters as being primarily due to lowered recruitment as we did in the James and York.

We believe the decline in numbers of larger and older size groups in the Piankatank may be attributed to MSX. The Piankatank is classed as a Type II area for MSX (Chapter II). Beginning in 1960, the timing of the decline indicates the possible involvement of this pathogen. That is, MSX added its impact to the pre-existing mortality producing factors, which includes drills, Dermocystidium, fishing effort and such other environmental factors operating in the system.

Possibly the absence of brood-stock was a factor in the decline, as it may have been in the James, but data were lacking to support this point. We do not believe pollution to have been involved in this system because there are no industries on the Piankatank and if sewage outfalls are located there, loadings are small in comparison to those entering the James.

This system received large quantities of shell and a heavy harvest of seed since 1963. Therefore, it is problematical if the trends in "natural" production in this system should be attributed to MSX or are more directly related to the repletion and harvesting activities of the Marine Resources Commission.

The Rappahannock River

Introduction

The natural oyster rocks (Baylor Survey grounds) in the Rappahannock extend from Russ Rock at the upper end of the mouth of the river (Figure 4). The public oyster bars in this system produce market oysters. It is not a seed oyster producing region due to its low setting potential and the Cull Law prohibiting harvesting of oysters less than three inches long. Production in the last ten years has been generally low, but it has increased slightly in the lower river since 1975 (Chapter III).

Despite the extensive public rocks, most of the market oysters produced in the Rappahannock come from the numerous and larger leased areas which are planted with seed oysters imported from the James, and to a lesser extent, up to 1972, from the Piankatank and Great Wicomico rivers.

The Rappahannock differs hydrographically from the James and the York. Changes in salinity over the length of the river are more gradual and extend over a larger area. Fresh water inflow is much lower in the Rappahannock than in the James, but greater than in the York. In the oyster-producing regions average salinity ranges from about 18 ‰ downriver to about 6 ‰ upriver (Figures 9 and 10). An oxygen deficiency develops during some years in the deeper portions of the lower river (20 to 30 feet) below Towles Point. The impact of this phenomenon on larval survival and setting has never been carefully evaluated, but it is thought to be of major importance in killing developing larvae.

Up to 1972 the oyster drill *U. cinerea* was present, extending to Towles Point causing considerable damage each year to young spat at Drumming Ground and below. Drill populations in this zone since 1972 have been reduced by flood waters associated with Tropical Storm Agnes to very low levels. It is expected that drills will gradually return to this area within the next four to five years and predation from this source will be resumed.

The disease-causing organisms, MSX and Dermocystidium, are present below Towles Point. This region is rated as a Type II MSX area. Areas above Towles Point below Morattico Bar are classed as a Type III MSX area with little or no mortality on the average (Andrews, 1968). In years of low rainfall, the area may bcome Class II with respect to disease because of increased salinity more favorable to MSX.

The Rappahannock River has always been noted for its high quality market-sized oysters and its poor sets. The following description of the river is taken from an early manuscript of Andrews and Haven (1952).

> The history of setting in the Rappahannock is vague. Old oystermen say that setting was never regular each year as it is in the James.
>
> In a single phrase, the Rappahannock can be described as a river where oysters grow fast but set poorly.

Setting on Natural Cultch - History Before 1947

Early studies in the Rappahannock by Menzel and Hopkins, as well as by others, were summarized by Andrews and Haven (op. cit.). Their data indicate that strike on natural cultch was above average in 1941. Set was again above average in 1944 and was heaviest downriver below Towles Point and decreased in the upriver sections. Average set in these areas was 303 and 103 spat-per-bushel-of-bottom-cultch, respectively.

Natural Cultch

When regular sampling of natural production began in 1947, spatfall on natural cultch followed a pattern similar to that suggested by the limited observations made in 1944. Drumming Ground in the lower river below Towles Point almost consistently had the highest numbers of spat. This appeared to be true for pre- and post- MSX periods (Table 45).

Prior to 1960 five-year averages for numbers of surviving spat-per-bushel-of-bottom-cultch at Drumming Ground ranged from 33 to 207 spat per bushel. These counts were several times higher than those obtained at the four upriver stations where the five-year averages ranged from 0 to 74 spat per bushel.

Individual years for all stations from 1948 to 1976 showed an erratic pattern of surviving spatfall with many values too low for an adequate commercial set, especially from Towles Point to Bowler Rock. Many stations showed zero spat per bushel for several successive years.

In 1965, five years after MSX invaded the area, there began a decline in numbers of spat on bottom cultch. It occurred river-wide with indications that the stations in the lower river were more strongly influenced than those at Bowler Rock and Morattico. Declines were noted when the 1966 to 1976 period is compared to previous years: Bowler Rock--39%;

Table 45

Live Oysters Per Bushel of Unculled Bottom Sample From the Rappahannock River [1]

	LARGE OYSTERS				
Season	Drumming Ground	Hogg House	Smokey Point	Morratico Bar	Bowler Rock
1947-8	16	72	N/A	44	40
48-9	36	56	92	52	20
49-50	55	52	27	24	6
1950-1	36	N/A	34	28	20
Average	36	60	51	37	22
1951-2	33	33	39	30	20
52-3	56	N/A	N/A	N/A	N/A
53-4	74	79	70	37	42
54-5	121	124	121	45	90
55-6	88	62	36	12	N/A
Average	74	74	67	31	51
1956-7	68	26	30	10	N/A
57-8	134	79	108	55	23
58-9	83	108	74	54	31
59-60	112	97	65	24	N/A
1960-1	23	45	37	18	38
Average	84	71	63	32	30
1961-2	24	38	49	19	29
62-3	38	70	40	21	N/A
63-4	53	81	48	47	N/A
64-5	43	81	41	28	67
65-6	38	31	50	38	N/A
Average	39	60	46	31	48
1966-7	41	10	44	22	N/A
67-8	32	37	109	56	N/A
68-9	24	52	64	81	42
69-70	13	21	22	40	24
1970-1	10	55	102	68	49
Average	24	35	68	53	38
1971-2	4	24	32	54	26
72-3	8	40	22	28	34
73-4	84	14	66	60	38
74-5	N/A	N/A	104	92	N/A
1975-6	46	16	64	50	18
Average	36	24	58	57	29

Table 45 (Contd.)

Season	SMALL OYSTERS & YEARLINGS Drumming Ground	Hogg House	Smokey Point	Morratico Bar	Bowler Rock
1947-8	0	340	N/A	30	32
48-9	108	72	28	18	92
49-50	91	56	29	6	2
1950-1	325	N/A	48	22	64
Average	131	156	35	19	48
1951-2	162	84	103	35	12
52-3	259	N/A	N/A	N/A	N/A
53-4	206	34	34	22	56
54-5	166	100	39	22	26
55-6	152	176	519	54	N/A
Average	189	99	174	33	31
1956-7	47	316	232	138	N/A
57-8	49	68	176	54	33
58-9	83	50	106	35	43
59-60	63	130	64	40	N/A
1960-1	60	27	24	6	15
Average	60	118	120	55	30
1961-2	57	19	9	10	10
62-3	65	21	49	27	N/A
63-4	144	141	69	50	N/A
64-5	280	76	105	39	17
65-6	61	28	153	98	N/A
Average	121	57	77	45	14
1966-7	112	35	240	334	N/A
67-8	197	18	249	196	N/A
68-9	81	78	150	101	29
69-70	13	70	91	132	82
1970-1	4	18	97	152	48
Average	81	44	165	183	53
1971-2	38	8	206	36	24
72-3	118	28	293	18	24
73-4	45	20	24	88	16
74-5	N/A	N/A	12	88	N/A
1975-6	88	6	110	34	20
Average	72	16	129	53	21

Table 45 (Contd.)

Season	SPAT Drumming Ground	Hogg House	Smokey Point	Morratico Bar	Bowler Rock
1947-8	166	140	N/A	N/A	16
48-9	132	8	0	0	8
49-50	346	12	10	8	12
1950-1	184	N/A	48	24	8
Average	207	54	19	11	11
1951-2	175	5	N/A	3	0
52-3	133	N/A	N/A	N/A	N/A
53-4	90	52	5	8	0
54-5	284	94	216	49	N/A
55-6	22	18	0	0	N/A
Average	140	42	74	15	0
1956-7	8	4	2	4	N/A
57-8	21	27	53	9	0
58-9	3	0	N/A	0	N/A
59-60	118	3	N/A	0	0
1960-1	17	6	0	0	0
Average	33	8	18	3	0
1961-2	12	0	0	4	0
62-3	156	35	28	1	N/A
63-4	227	89	29	4	N/A
64-5	125	82	254	53	15
65-6	227	60	112	52	N/A
Average	149	53	85	23	7
1966-7	68	21	42	28	N/A
67-8	5	0	0	0	N/A
68-9	29	5	0	4	5
69-70	5	9	15	6	8
1970-1	26	1	0	0	0
Average	27	7	11	8	4
1971-2	142	8	22	2	4
72-3	2	0	0	0	0
73-4	0	2	0	2	2
74-5	N/A	N/A	0	0	N/A
1975-6	34	20	0	0	4
Average	44	8	4	1	2

1. Andrews, J. D., unpublished data 1947-8 thru 1967-8; Haven, D. S., in Marine Resource Information Bulletin, VIMS, 1969-70 and 1971-2. Haven, D. S., unpublished data 1968-9, 1970-1 and 1972-3 thru 1975-6.

Morattico Bar--68%; Smokey Point--85%; Hogg House--80% and downriver at Drumming Ground--73% (calculated from Table 45).

If declines are calculated on the pre- and post-MSX years, as was done for the James River, the upriver public bars, Bowler Rock and Morattico showed no declines with downriver declines ranging from 11% to 37% (Table 46). The lesser rates of decline, using 1960 as a base year, were due to exceptionally high levels of spat from 1961 [illegible] [illegible]965.

Above-average years for spat survival from Bowler Rock to Hogg House were 1941, 1944, 1951, 1963, 1964 and 1965 or about six years out of thirty-five. Surviving set in the remaining years was barely sufficient to maintain the bars. For this reason this large area of the Rappahannock, where most of the leased bottom is located, is considered a poor "setting" area. The downriver sections below Towles Point had a more consistent record of survival in the last eleven years. 1971 was an exceptional year with 142 spat-per-bushel at Drumming Ground (Table 45).

<u>Small Oysters and Yearlings</u>

Small oysters and yearlings exhibit irregular changes in abundance from 1947 to 1976 which seem to reflect years of favorable spat survival during the preceding years (Table 45). A year of high spat counts, 1954, was followed in 1955, 1956 and 1957 by above-average numbers of yearlings and small oysters

Table 46

Comparison of Average Number of Oysters in Bushel Samples in Natural Cultch in Pre and Post-MSX Years in the Rappahannock River of Virginia.

AREA	MARKET		SMALL & YEARLING		SPAT	
	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6
Bowler Rock	33	36	38	29	5	4
Morattico Bar	33	47	37	94	9	10
Smokey Point	61	57	117	124	37	33
Hogg House	69	41	121	40	31	24
Drumming Ground	67	33	126	93	121	76
Average	53	43	88	76	41	29

at Smokey Point with counts ranging from 176 to 519. The years of higher-than-average numbers of spat in 1964 and 1965 were followed by a slight increase in yearlings and small oysters in 1966 and 1967 for Drumming Ground, Smokey Point and Morattico Bar.

Five-year averages at all stations for numbers of small oysters and yearlings from 1947 to 1960 ranged from 19 to 189 per bushel. Prior to 1960 oysters in these age groups were most available in the lower half of the river from Smokey Point to Drumming Ground. This difference was not apparent after 1960.

There was no obvious decline in numbers of small oysters and yearlings in the upper two-thirds of the river at Smokey Point, Morattico Bar and Bowler Rock after MSX manifested itself in the Chesapeake system around 1960 (Table 46). In the lower part at Drumming Ground and Hogg House after 1960 or 1965, the five-year averages indicated a decline in numbers. If 1960 is taken as the approximate year the decline began, the following declines were observed: Hogg House--67% and Drumming Ground 26% (Table 46).

Market-Sized Oysters

Five-year averages for numbers of market-sized oysters from stations in the Rappahannock varied from 22 to 84 per bushel from 1947 to 1976. Prior to 1960 market oysters were slightly more numerous in the lower half of the Rappahannock at Smokey Point, Hogg House and Drumming Ground, but the difference was not large. This gradient became even less evident after MSX in 1960 with irregular distribution throughout the river. A comparison of numbers of oysters at individual stations before and after 1960 suggests that the numbers of surviving individuals have remained unchanged in the upper part of the estuary from Bowler Rock and Smokey Point, but availability on the grounds decreased somewhat in the lower river. The percent declines were: Hogg House--40% and Drumming Ground--51% (Table 46).

Shellbags - Survival

From 1949 to 1965 data from seasonal shellbags in the Rappahannock were collected infrequently but the data permit certain conclusions over the 1947 to 1976 period.

Average levels of surviving set on shellbags based on intervals of 3 to 10 years were low except in 1965 and, with this exception, ranged from less than 0.1 to 1.6 spat-per-shell-per-season or from less than 50 to 800 spat per bushel (Table 47). The exceptional year (1965) showed 11.1 spat per shell at Drumming Ground or 5,550 spat per bushel.

Table 47

Seasonal Setting on Shellbags in the Rappahannock River[1]
(Spat/Shell)

LOCATION

Season	Parrott Rock	Orchard Point/ Drumming Ground	Hogg House Rock	Smokey Point	Morratico Bar	Bowler Rock
1949-50	1.4	2.5		0.2	<0.1[2]	
50-1	0.8	1.0		0.2	<0.1[2]	<0.1[2]
51-2		1.2				<0.1[2]
Average	1.1	1.6		0.2	<0.1[2]	<0.1[2]
1959-60			0.6		0.0	
60-1						
61-2						
62-3				<0.1[2]		
63-4					<0.1[2]	
64-5	0.4			0.8	0.2	
65-6	4.1	11.1	2.4	2.4		
66-7						
67-8	<0.1[2]	0.2	<0.1[2]	0.0		
68-9						
69-70						
1970-1			0.0	<0.1[2]		0.0
Average	1.5	5.6	0.8	0.7	0.1	0.0
1971-2	0.5	0.1	0.12	0.12		0.0
72-3	0.0	0.03	0.0	0.0	0.0	0.0
73-4	0.0	0.0	0.0	0.0	0.0	0.0
74-5	0.6	1.2	0.2	0.2	0.01	--
1975-6	1.4	--	0.01	0.02	0.01	0.1
Average	0.5	0.3	<0.1	<0.1	<0.1	<0.1

1. Andrews, J. D., unpublished data for 1949-1950 through 1967-1968. 1970-1971 and 1971-1972, Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1972-1973 through 1975-1976, Haven, D. S., unpublished data. Blanks indicate that data were not available.

2. < is the symbol for "less than."

Shellbag data confirm one of the observations made on bottom cultch: the number of surviving spat was highest downriver below Towles Point.

A point of non-agreement between the bottom cultch trends and that shown by shellbags is that the latter measure suggests no decline over the years in numbers of surviving spat; however, numbers of spat on bottom cultch declined after 1960.

In reconciling these two conflicting views, we are aware of the limited nature of shellbag data; moreover, the shellbag data are weighted by exceptionally high levels of surviving spat for 1965-1966. We conclude that available shellbag data suggest a stable situation, or one in which a possible decline is masked by extreme variability.

Weekly Setting Pattern

Shellstring studies were not made regularly in the Rappahannock. The limited data collected indicate that the total seasonal set has been very low over the years, especially in the upper sections of the oyster-producing regions. Earliest records were reported by Andrews and Haven (1952) at Monaskon Bluff where weekly shellstrings were placed in the river from 21 June to 30 October 1951. Only three spat were recorded in this entire period. Dr. Andrews exposed weekly shellstrings at seven stations in 1952 (Table 48). Set began in late June 1952 and extended into October with peaks during July and August. Total weekly set-per-shell-face for the season ranged from 4.6 to 31.7 below Towles Point; at Hogg House it was 8.6

Weekly shellstrings were set out again from 1969 to 1975 but the coverage of the system was not complete (Table 49). The total set in 1969 to 1970 for the area from Bowler Rock to Grey Point again showed the typically low seasonal set which ranged from zero to only 5.4 spat-per-shell-face-per-season. However, 1971 was an exceptional year and a count of spat per season was noted at Broad Creek of a total of 17.1 spat per season. This level resulted in a good surviving set on the natural bottom at nearby Drumming Ground where a count of 142 spat per bushel was observed (Table 45).

Shellstrings were set out from 1972 to 1975 only in the lower river below Towles Point. The seasonal set in 1972, 1973 and 1974 ranged from zero to only 1.4, but in 1975 it was above average with values ranging from 11.4 to 24.9 spat-per-shell-per-season.

Shellstring data are not complete enough for the Rappahannock to permit a conclusion as to why numbers of spat surviving on bottom cultch declined since 1960 or 1965

Table 48

Seasonal distribution of spatfall in the lower Rappahannock River and Corrotoman River in 1952. Counts per 10 shellfaces on weekly shellstrings.[1]

Dates	Butlers Hole	Broad Creek	Parrotts Rock	Drumming Ground	Hogg House Rock	Corrotoman Point	Island Bar
9-25 Jun	2	0	1	-	-	0	2
25- 2 Jul	6 (25 Jun	0	0	2	0	3	7
2- 9 Jul	-9 Jul)	4	3	4	1	23	121
9-16 Jul	3	46	37	27	2	25	31
16-23 Jul	11	12	11	10	34	15	50
23-30 Jul	2	16	10	11	14	9	11
30- 7 Aug	1	6	9	15	6	14	36
7-15 Aug	7	24	23 (7 Aug	144	26	42	45
15-20 Aug	5	9	-20 Aug)	14	2	3	5
20-27 Aug	1	6	1	19	-	4	8
27-15 Sep	3	4	-	10	-	0	0
15-26 Sep	5	0	5	-	1	2	1
26 Sep-27 Oct	0	2	1	0	-	1	0
Totals	46	129	101	256	86	141	317

1. Andrews, J. D., unpublished manuscript.

Table 49

Sum of Weekly Spatfall in the Rappahannock River[1]
(Spat Per Smooth Shellface)

Season	Duration of Setting	Broad Creek (inshore)	Grey Point	Corrotoman Point	Hogg House	Greenvale Creek	Bowler Rock
		Location					
1969-70	6/24 - 9/23	--	1.3	--	3.3	--	--
70-71	7/ 1 - 9/22	--	5.4	--	0.0	--	0.0
71-72	7/14 - 9/29	--	17.1	--	0.0	--	0.1
72-73	---	0.0	--	0.0	--	0.0	--
73-74	9/ 6 - 10/ 1	0.0	--	0.4	--	0.0	--
74-75	6/16 - 9/23	1.4	--	1.3	--	1.3	--
75-76	6/23 - 9/22	11.4	--	15.4	--	24.9	--

Highest Weekly Spatfall on Shellstrings in the Rappahannock River[1]
(Spat Counted per Smooth Shellface Plus Week of Occurrence[2])

Season	Broad Creek (inshore)	Grey Point	Corrotoman Point	Hogg House	Greenvale Creek	Bowler Rock
			Location			
1969-70	--	0.8 S3	--	2.7 J2	--	--
70-71	--	2.9 J1	--	0.0	--	0.0
71-72	--	5.4 S3	--	0.0	--	UNK
72-73	0.0	--	0.0	--	0.0	--
73-74	0.0	--	0.4 S4	--	0.0	--
74-75	0.6 A2	--	0.8 S3	--	0.9 A3	--
75-76	3.4 S2	--	4.8 A5	--	7.8 A3	--

1. Haven, D. S., in Marine Resources Information Bulletin, VIMS.

2. The letters to the right of the spat counts indicate the month (J = July; A = August; S = September). The digits following the letters indicate the week in the month.

seasons at Drumming Ground and Hogg House. These data do not show, as they did in the James, that numbers of spat which survived on bottom cultch, declined since 1960 or 1965 because the total seasonal spatfall (as shown by shellstrings) declined. The shellstring data are sufficient only to show that: 1) the total seasonal spatfall in the Rappahannock is typically highest downriver and is zero to very light upriver where most of the public oyster beds and leased areas are located; and 2) overall in the oyster-producing regions in the Rappahannock, total seasonal set is very light, with many years showing no set at all. Therefore, annual recruitment is typically low.

Time of Set

The fact setting is so erratic and spatfall levels are so low precludes an accurate evaluation of the setting period. Available evidence, however, indicated a setting period from July through September with peak sets occurring during August or September.

Survival of Spat

There are only limited data on this aspect for the Rappahannock, but when the total seasonal set on shellstrings is compared to numbers of spat on bottom cultch, the ratios suggest less than 3% survival (calculated from Table 50).

Table 50

Comparison of Average Numbers of Spat per Shell, on Natural Cultch, and Shellbags in Pre and Post-MSX Periods in the Rappahannock River, Virginia.

AREA	NATURAL CULTCH[1]		SHELLBAGS		SUM OF WEEKLY SET SHELLSTRINGS[2]	
	1949-50 thru 1951-2	1961-2 thru 1975-6	1949-50 thru 1951-2	1961-2 thru 1975-6	1951-2	1969-70 thru 1971-2
Bowler Rock	0.02	0.01	<0.1	0.1		
Morattico Bar	0.02	0.02	<0.1	0.1		
Smokey Point	0.06	0.07	0.2	0.4		
Hogg House	0.02	0.05	0.6	0.4	17	2
Drumming Ground	0.47	0.15	1.6	2.1	51	16[3]

1. Assuming 500 shells per bushel.
2. Total spatfall per shell for entire season; number per shellface doubled.
3. Data for Grey Point.
4. < is the symbol for "less than."

A Discussion of the Probable Causes of the Decline in Spatfall and Oyster Numbers in the Rappahannock

There were changes in the patterns of spatfall and oyster numbers on bottom cultch in the Rappahannock which agreed in some aspects with conditions observed in other systems discussed to date.

There was no decline in numbers of yearling, small and market-sized oysters-per-bushel-of-bottom-cultch after 1960 in the upper two-thirds of the Rappahannock, as was observed in the James, York and Piankatank rivers. Numbers of yearling, small and market oysters declined on bottom cultch after 1960 in the lower part as it did in the James and York rivers.

All four rivers experienced a river-wide decline of the number of spat per bushel. The decline seemed to begin in 1965 in the Rappahannock which was about five years later than the trend began in the James and York. Only a weak downward trend for spat on bottom cultch was observed in the lower Piankatank.

The decline in the Rappahannock in numbers of yearling, small and market oysters after 1960 in the lower third of the river was probably due to MSX. The lower Rappahannock is classed as Type II (Chapter IX) for the disease.

That is, MSX added its impact to the existing factors such as *Dermocystidium*, drills, other natural causes and fishing mortality to produce the decline in numbers. We believe the lack of an upriver decline in numbers of yearling, small and market oysters largely to be due to the absence of MSX in that portion of the system.

A portion of the river-wide decline in the James and York in numbers of yearling, small and market oysters was attributed to lowered recruitment (fewer spat being available on bottom cultch each year). This certainly was a contributing factor in the decline among the larger and older year classes in the Rappahannock. However, why it did not adversely influence numbers upriver as it did downriver is not known.

The reason for the recent river-wide decline in numbers of spat on bottom cultch each fall is not apparent. Prior to 1972, oyster drills in the lower river at Drumming Ground killed developing spat, but these predators are not normally present upriver from this station. Moreover, spat and oysters less than 3 inches long are not harvested in the Rappahannock since the cull law prohibits it.

We were able to show the decline in spat-per-bushel-of-bottom-cultch in the James was due to a river-wide decline in total seasonal spatfall. This relation cannot be seen in existing data from the Rappahannock. Spatfall has always been low and erratic and numbers are so sparse and variable that no trends or correlations are discernable.

While there is not quantative evidence to show a decline in the total seasonal spatfall since 1965, we believe it to be the only reasonable explanation for the decline in numbers of spat on bottom cultch. Predators are few, diseases are low and pollution is rare. If we accept this hypothesis, there are several possible causes of the decline, none of which can be "proven" at this time. Among the possibilities are low levels of dissolved oxygen commonly found in the deeper parts of the system which may have killed developing larvae. Low dissolved oxygen values are common to the lower Rappahannock, but not to the James, York[4] or Piankatank rivers.

We suggested chlorine or chloramines associated with treated sewage might be killing larvae in the James. This explanation does not seem logical for the Rappahannock since the system receives very little if any chlorinated effluent as

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[4]Until recently.

far as we are aware. We advanced the concept that an absence of brood-stocks in the James might be responsible for the lowered seasonal sets and there is good evidence to support this contention. The downriver populations below Towles Point in the Rappahannock was never large prior to 1960, therefore, this aspect is probably not a factor in the decline. However, overfishing has occurred in the Rappahannock.

There has been a decline in small oysters and yearlings since 1965 on bottom cultch in the lower Rappahannock and a decline in numbers of spat on bottom cultch for the entire system. We believe this latter aspect may be related to a diminished seasonal spatfall rather than to reduced survival of attached spat, but the cause or causes are not apparent. Possibly the changes are cyclic or related to some aspect related to increased sedimentation or changes in volumes of fresh water entering the system or to lowered recruiting potential caused by overharvesting of spawning-age oysters. Whatever the cause, it is not apparent and the problem should be studied.

The Corrotoman River

Introduction

The Corrotoman, a tributary on the north side of the lower Rappahannock, is a short system with little fresh water inflow. It has a restricted mouth, is weakly stratified and shows only a small salinity change over most of its range. Oysters occur widely. Average salinity during the warmer months ranges from about 10 to 17‰. Drills were present at the mouth of the Corrotoman up to 1972 when Tropical Storm Agnes killed most of them or reduced them to very low levels. Formerly they consumed significant numbers of spat and young oysters. Also, MSX and *Dermocystidium* probably cause mortality of undetermined numbers of older oysters in that region.

Early History

Observations were first made in the Corrotoman in 1931 and at that time annual set was high. Shellbags exposed at 15 stations in early spring and removed in late fall had counts ranging from 810 to 6,115 spat-per-bushel-of-shell (Loosanoff, 1932). Calculations based on 500 shells-per-bushel indicate counts of from 1.6 to 12.3 spat-per-shell for the entire setting season which was similar to levels observed in the James River from 1948 to 1961.

Natural Cultch

Studies on numbers of oysters in samples of natural cultch are available from 1947 to 1976 (Table 51). The five public bars, along with other locations in this river, have been planted with shell at irregular intervals. From 1963 to 1975, 692,527 bushels of shells were placed overboard (Chapter VI). The degree to which these plantings influenced our studies of numbers of oysters-per-bushel-of-bottom-cultch is not known. It is obviously difficult to compare production from "manipulated" or managed bottoms with those from natural bottoms.

Counts of surviving spatfall on natural cultch in the Corrotoman from 1947 to 1965 showed five-year averages ranging from 35 to 293 spat per bushel. In general, spatfall was characterized by wide annual variation. However, a year of zero spatfall was never recorded in this entire period and there was no well-defined trend in numbers between stations located up or downriver. Also, at any single station there appeared to be no upward or downward trend over the years (Table 51). There began a very poorly defined decline after 1965 in average counts per bushel. When data from the 1947-1965 period are compared with those from 1966 to 1976, the declines were: Corrotoman Point--46%; Black Stump--72% and Shelton Point--63%(calculated from Table 51). A similar decline was noted beginning about the same time in the adjacent Rappahannock system.

Table 51

Live Oysters Per Bushel of Unculled Bottom Sample
From the Corrotoman River[1]

	LARGE OYSTERS				
Season	Corrotoman Point	Middle Ground	Island Bar	Black Stump	Shelton Point
1947-8	80	32	76	68	60
48-9	28	N/A	59	36	10
49-50	54	62	35	38	44
1950-1	78	60	22	N/A	34
Average	60	51	48	47	37
1951-2	76	48	8	48	44
52-3	104	48	130	N/A	100
53-4	100	16	42	N/A	36
54-5	120	74	72	N/A	114
1955-6	84	46	46	N/A	44
Average	97	46	50	48	68
1956-7	52	46	36	42	44
57-8	68	54	124	18	N/A
58-9	74	30	38	N/A	58
59-60	N/A	56	41	34	26
1960-1	15	17	14	N/A	N/A
Average	52	41	51	31	43
1961-2	36	10	3	20	15
62-3	42	23	16	16	15
63-4	21	N/A	11	35	15
64-5	74	74	52	66	46
1965-6	30	50	40	N/A	14
Average	41	39	24	34	21
1966-7	64	30	28	18	12
67-8	N/A	N/A	36	34	28
68-9	-------------No DATA AVAILABLE-------------------------				
69-70	-------------No DATA AVAILABLE-------------------------				
1970-1	0	N/A	N/A	2	21
Average	32	30	32	18	20
1971-2	0	N/A	N/A	12	56
72-3	10	N/A	N/A	24	52
73-4	220	N/A	N/A	26	23
74-5	50	N/A	N/A	40	N/A
1975-6	34	N/A	N/A	40	34
Average	63	--	--	28	41

Table 51 (Contd.)

Season	Corrotoman Point	Middle Ground	Island Bar	Black Stump	Shelton Point
	SMALL OYSTERS & YEARLINGS				
1947-8	144	172	380	220	244
48-9	344	N/A	383	464	436
49-50	234	272	356	428	296
1950-1	296	290	376	N/A	194
Average	254	245	374	371	292
1951-2	352	296	306	568	452
52-3	202	268	316	N/A	196
53-4	184	104	222	N/A	150
54-5	146	272	268	N/A	148
1955-6	216	112	234	N/A	174
Average	220	210	269	568	224
1956-7	202	158	280	270	156
57-8	297	310	448	308	N/A
58-9	218	201	207	N/A	440
59-60	N/A	172	163	207	90
1960-1	82	105	114	N/A	N/A
Average	200	189	242	262	229
1961-2	160	92	112	72	102
62-3	52	87	93	50	40
63-4	234	N/A	256	68	109
64-5	286	242	250	42	136
1965-6	140	276	234	N/A	280
Average	174	174	189	58	133
1966-7	512	194	332	312	218
67-8	N/A	N/A	408	224	519
68-9	-------------NO DATA AVAILABLE-----------------------				
69-70	-------------NO DATA AVAILABLE-----------------------				
1970-1	5	N/A	N/A	26	74
Average	258	194	370	187	270
1971-2	22	N/A	N/A	108	170
72-3	126	N/A	N/A	94	144
73-4	101	N/A	N/A	137	100
74-5	112	N/A	N/A	76	N/A
1975-6	86	N/A	N/A	76	46
Average	89	--	--	98	115

Table 51 (Contd.)

Season	SPAT				
	Corrotoman Point	Middle Ground	Island Bar	Black Stump	Shelton Point
1947-8	300	164	360	324	368
48-9	56	N/A	232	268	244
49-50	328	140	290	288	340
1950-1	166	138	196	N/A	62
Average	212	147	270	293	254
1951-2	116	64	88	60	28
52-3	164	260	322	N/A	264
53-4	114	324	86	N/A	156
54-5	218	208	172	N/A	494
1955-6	152	38	56	N/A	96
Average	153	179	145	60	208
1956-7	74	200	382	260	68
57-8	59	80	92	84	N/A
58-9	5	12	18	N/A	24
59-60	N/A	34	16	3	12
1960-1	11	8	22	N/A	N/A
Average	55	67	106	116	35
1961-2	10	3	19	5	2
62-3	81	102	156	37	8
63-4	63	57	N/A	9	41
64-5	276	282	390	952	1,132
1965-6	500	344	546	N/A	124
Average	186	158	278	251	261
1966-7	324	142	264	146	74
67-8	N/A	N/A	160	67	128
68-9	-------------NO DATA AVAILABLE-------------------------				
69-70	-------------NO DATA AVAILABLE-------------------------				
1970-1	55	N/A	N/A	134	126
Average	190	142	212	116	109
1971-2	158	N/A	N/A	66	184
72-3	2	N/A	N/A	0	0
73-4	2	N/A	N/A	0	0
74-5	34	N/A	N/A	38	N/A
1975-6	74	N/A	N/A	24	20
Average	54	--	--	26	51

Table 51 (Contd.)

1. Data for 1947-1948 through 1967-1968 from Andrews, J. D., unpublished. 1971-1972 data from Haven, D. S., in Marine Resources Information Bulletin, VIMS. 1970-1971 and 1972-1973 through 1975-1976 data from Haven, D. S., unpublished.

N/A This indicates that data not available.

Years of very low or zero spatfall were recorded for the first time especially from 1971 to 1975.

While the decline in spatfall on natural cultch definitely began after 1965, we have calculated the change on the basis of before and after 1960 as we did in the James so changes may be related to the year MSX was noted in the Bay. Average declines for all areas were Shelton--15%; Black Stump--33%; and Corrotoman Point--1%. The average decline for all stations was 14% (Table 52).

For small oysters and yearlings from 1947 through 1970, the data showed no tendency for oysters to be more or less abundant at stations up or downriver. Over most of this period for single stations five-year averages showed no tendency for oysters to be more or less abundant from one period to the next up to 1970. There began a definite change in 1970 and the five-year averages showed a decline for all stations in numbers per bushel of small oysters and yearlings over previous periods. Differences in averages for the 1971 to 1976 period over the preceding five years were: Corrotoman Point--66%; Black Stump--48%; and Shelton Point--58%. Again there was no tendency for oysters to be more or less abundant at stations up or downriver from 1971 to 1976.

Table 52

Comparison of Average Numbers of Oysters in Bushel Samples of Natural Cultch in Pre and Post-MSX Years in Corrotoman River.

AREA	MARKET		SMALL & YEARLING		SPAT	
	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6	1947-8 thru 1960-1	1961-2 thru 1975-6
Shelton Pt.	51	28	248	162	180	153
Black Stump	42	28	352	107	184	123
Island Bar	53	N/A	389	N/A	167	N/A
Middle Ground	45	N/A	210	N/A	128	N/A
Corrotoman Pt.	72	48	224	153	134	132
Average	52	35	265	141	159	136

Numbers of yearlings and small oysters were averaged for comparison with other areas for the pre- and post-MSX years (1960). The following declines were observed: Corrotoman Point--32%; Black Stump--70%; and Shelton Point--35% (Table 52).

Numbers of market oysters showed little trend over the range studied from 1947 to 1976 and five-year averages ranged from 18 to 97 per bushel. There was a definite decline in numbers, however, which seemed to have begun about 1960. The declines were as follows: Shelton Point--45%; Black Stump--33%; and Corrotoman Point--33% (Table 52).

Shellbag - Survival

Only one series of shellbags has been employed in this river for an extended period. Spat per shell in four bags at Island Bar in 1948 varied from 2.9 to 3.8 spat per shell which equates to from 1,450 to 1,900 per bushel (Andrews, unpublished). These values are similar to those reported by Loosanoff (1932).

Weekly Setting Pattern

Only limited studies of weekly setting patterns have been made using shellstrings in the Corrotoman. Those made in 1952 (Andrews, unpublished) show it received a heavy set in that year. A peak set of 12.1 spat-per-shell-face-per-week occurred in late July or early August. Total weekly set-per-shell-face during the season was 14.1 at Corrotoman Point and 31.7 at Island Bar.

Probable Reasons for the Decline in Spatfall and Numbers in the Corrotoman

This system exhibited several but not all of the characteristics of the decline shown by the lower Rappahannock. Since 1963 about 692,527 bushels of shells were planted in this system. Therefore, for the same reasons as the Piankatank we must regard evidence of a decline or increase in this system with caution.

A point of similarity with the Rappahannock was a decline in numbers of spat on bottom cultch which began about 1965. Also, as was the case of the Rappahannock and all other systems discussed so far, there was a decline in numbers of yearlings and small oysters, but this decline was poorly defined and seemed to start in 1970 which was 5 to 10 years later than in the James, York, Piankatank and Rappahannock rivers. There was a decided decline indicated in the Corrotoman for numbers of market-sized oysters and in this respect the river was similar to all others reviewed so far except the James River which increased.

No shellstrings and only one series of shellbags were maintained in the Corrotoman so we cannot realistically evaluate probable causes for those declines. Possibly many of the environmental parameters outlined as probable causes for the decline in the Rappahannock also apply to the Corrotoman since the waters of the lower Rappahannock are contiguous with those of the Corrotoman.

The Great Wicomico

Introduction

The Great Wicomico has several points in common with the Corrotoman and Piankatank. It is a short tributary system with a narrow entrance and restricted fresh water inflow. Salinities are slightly lower than in the Corrotoman or Piankatank because it is farthest north in the Virginia system. Drills are present in the lower quarter of the river. The area is classed as Type II for MSX, but this pathogen probably causes only limited mortality in oysters in the lower part of the system except in years of high salinity. We have no data for high-salinity periods.

There are some special water quality problems in the Great Wicomico which are apparently due to low dissolved oxygen. This situation seems to be associated with fish processing operations in the area.

The Great Wicomico River has been under development as a seed area by the VMRC since 1963 with over five million bushels of shell planted on small areas of public rocks in the estuary (Chapter VI). In certain areas shells have accumulated large concentrations of oysters. Data on bottom cultch have not been collected on a regular basis because of the additions of large amounts of new shell each year.

Shellbags - Survival

Shellbag data were collected from 1965 to 1967 and from 1971 to 1976. Average counts of surviving spat for several representative locations from 1965 to 1967 ranged from 3.1 to 10.5 spat per shell or about 1,550 to 5,250 spat per bushel (Table 53). These quantities are several times greater than the number present on shellbags placed in the James after 1960. Values recorded for the 1971 to 1975 period were very low and the average surviving set ranged from 0.06 to 0.39 spat per shell. This was a major decline and it was apparently due to low dissolved oxygen in the deeper waters of the system. Data on dissolved oxygen levels were not collected in the Piankatank prior to 1971.

Weekly Setting Patterns

Weekly shellstring data collected for this river at ten stations showed heaviest surviving set in the upper-half of the river (Table 54). Averages of the total weekly set from 1964 to 1970 were very high ranging from 28.4 to 340.4 spat-per-shell-face-per-season or from 28,400 to 340,400 per bushel.

There was a major decline after 1970 in all sections of the system and from 1971 to 1976 total seasonal spatfall ranged from about 1% to 10% of their former values. Again, low dissolved oxygen values were thought to be responsible.

Table 53

Seasonal Spatfall on Shellbags in the Great Wicomico River[1]
Spat per Shell

	LOCATIONS					
Season	Dameron Marsh	Whaley Flats	Cranes Creek	Haynie Bar	Hundnall Dock	Glebe Point
1965-6	18.3	17.4	28.8	10.4	17.9	2.2
66-7	6.3	6.8	1.5	9.1	10.6	4.4
67-8	1.4	.9	1.9		1.6	2.7
Average	8.7	8.3	10.5	9.7	10.0	3.1
1971-2	.6	1.0	.5	.2	.5	.2
72-3	0.01		0.05		0.02	
73-4	0.00		0.01		0.01	0.00
74-5	0.2[2]	0.14		0.16		0.04
75-6		0.03[3]	0		0.02	0
Average	0.20	0.39	0.13	0.19	0.13	0.06

1. Andrews, J. D., unpublished data, 1965-1966 through 1967-1968. Data for 1968-1969 through 1970-1971 not available. Haven, D. S., in Marine Resources Information Bulletin, VIMS, 1971-1972. Haven, D. S., unpublished data, 1972-1973 through 1975-1976. Blank spaces indicate data not available.

2. Fleeton.

3. Shell Bar.

Table 54

Sum of Weekly Spatfall on Shell Strings in the Great Wicomico River[1]
Spat Per Smooth Shell Face

Season	Duration of Setting	Dameron Marsh	Mill Creek	Whaley Flats	Crane Creek	Eleet Point
1964-5	6/21- 9/21	407.7	-	-		-
65-6	6/14- 9/ 4	105.2	-	210.6	419.3	-
66-7	6/20- 9/19	-	-	33.3	-	-
67-8	6/12/ 9/27	8.4	8.8	29.4	25.7	-
68-9	6/17- 8/27[2]	48.5	36.0	142.3	250.2	-
69-70	6/ 9-10/29	9.6	39.7	64.8	75.8	26.9
1970-1	6/ 4-10/ 7	50.6	70.1	-	169.8	29.8
Average		105.0	38.6	96.1	188.2	28.4
1971-2	6/21- 9/24	4.4	2.9	2.0	4.0	0.2
72-3	6/19- 9/18	0	0		0	0
73-4	6/18-10/ 1	3.3	9.0	2.9	0.8	2.4
74-5	6/18- 9/30	0.2	-	3.3	1.2	6.2
75-6	6/16- 9/22	0.4	-	-	0.3	0.6
Average		1.7	4.0	2.7	1.3	1.9

Season	Duration of Setting	Cockrell Creek	Haynie Bar	Shell Bar	Hudnell Dock	Glebe Point
1964-5	6/21- 9/21	-	-	-	-	-
65-6	6/14- 9/4	-	491.1	-	240.4	133.8
66-7	6/20- 9/19	-	-	-	170.8	151.8
67-8	6/12- 9/27	-	79.3	-	91.1	266.1
68-9	6/17- 8/27[2]	-	48.8	-	204.5	181.9
69-70	6/ 9-10/29	51.5	189.8	226.7	151.1	67.2
1970-1	6/ 4-10/ 7	55.0	428.7	454.0	513.6	834.5
Average		53.2	247.5	340.4	228.6	265.9
1971-2	6/21- 9/24	1.7	8.1	11.7	17.4	46.3
72-3	6/19- 9/18	0.1	0	0.5	0.4	3.1
73-4	6/18-10/ 1	1.0	2.8	0.7	0	1.0
74-5	6/18- 9/30	-	1.5	13.0	3.0	11.7
75-6	6/16- 9/22	-	0.6	0.2	0.1	0.2
Average		0.9	2.6	5.2	4.2	12.5

1. Andrews, J.D., unpublished data 1964-5 thru 1967-8; Haven, D.S., in Marine Resource Information Bulletin, VIMS, 1969-70 thru 1975-6. Haven, D.S., unpublished data. 1968-9. Blanks indicate that data were not available.

2. Observations stopped on this date.

Time of Peak Set

The Great Wicomico differed from the James, York and Rappahannock in the time when peak setting occurred. In the Great Wicomico from 1964 to 1970 it occurred from late June through July, but typically during July (Table 55). After sets declined, peak set seemed to occur later in the season during August or September.

Reasons for the Decline in Oyster Set in the Great Wicomico River

No data were available on decline in set on shellbags or shellstrings prior to 1963. Also, no data existed for bottom cultch. Therefore, we cannot say if there had or had not been a decline in total seasonal spatfall here since 1960 as we did for the James and York rivers. However, there was no doubt a major decline in spatfall has occurred since 1970. This decline may be related to low values of dissolved oxygen noted in the bottom waters during 1972, 1973 and 1974.

The Seaside of Virginia

Annual surviving set on the bottom cultch on the Seaside of the Eastern Shore has always been higher than for

Table 55

Highest Weekly Spatfall on Shellstrings in the Great Wicomico River[1]
Spat per Smooth Shellface, Plus Week of Occurance[2]

Season	Dameron Marsh	Mill Creek	Whaley Flats	Crane Creek	Fleet Point
1964-5	239.9 E4	-	-	-	-
65-6	74.2 J3	-	129.2 J3	253.2 J3	-
66-7	-	-	17.8 J2	-	-
67-8	3.6 A2	5.0 A2	10.6 A1	11.5 A1	-
68-9	19.9 J4	17.2 J4	206.1 J3	119.1 J3	-
69-70	7.5 J1	28.1 J1	59.4 J1	71.8 J1	25.7 J1
70-1	34.4 E4	48.7 E4	-	132.7 E4	26.6 E4
Average	63.2	24.8	64.6	117.7	26.2
1971-2	3.1 A4	1.4 A4	1.5 A4	1.4 A4	0.8 S1
72-3	0	0	-	0	0
73-4	1.8 S2	8.2 S3	2.6 S3	0.6 S3	0.8 S4
74-5	0.2 A4	-	2.7 A1	0.4 J4	3.9 A2
75-6	0.4 S3	-	-	0.3 E4	0.6 S2
Average	1.1	3.2	2.3	0.5	1.2

Season	Cockrell Creek	Haynie Bar	Shell Bar	Hundnell Dock	Glebe Point
1964-5	-	-	-	-	-
65-6	-	250.2 J3	-	134.3 J2	67.8 J2
66-7	-	-	-	83.1 J2	49.9 J2
67-8	-	46.0 J4	-	60.3 J4	167.9 J4
68-9	-	19.7 J4	-	77.1 J4	66.4 J3
69-70	48.5 J1	175.3 J1	209.3 J1	134.7 J1	34.4 J1
70-1	50.0 E4	283.3 E4	290.2 E4	373.5 E4	530.7 J1
Average	51.8	154.9	249.8	143.8	152.8
1971-2	1.3 A3	3.5 A4	1.3 A3	2.2 A3	18.8 A3
72-3	0.1 S2	0	0.3 E4	0.4 E4	2.0 E4
73-4	0.6 S4	2.2 S3	0.2 S5	1.0 S4	0.2 S4
74-5	-	0.7 A2	8.9 J4	2.0 J4	8.8 A1
75-6	-	0.6 J4	0.2 J2	0.1 J2	0.2 J2
Average	0.7	1.4	2.2	1.1	6.0

1. Andrews, J.D., unpublished data 1964-5 through 1967-8; Haven, D.S., in Marine Resources Information Bulletin, VIMS, 1969-70 through 1975-6. D.S., unpublished data. 1968-9. Blanks indicate that data were not available.

2. The letters to the right of the spat counts indicate the month (E=June; J=July; A=August and S=September). The digits following the letters indicate the week in the month.

any other region in Virginia. An early reference to the intensity of the strike is that of Loosanoff (1932), who stated that in 1931 setting in these waters was quite heavy and regular. Shellbags placed at the low water level in that year averaged 1,600 spat per bushel; a maximum number of 12,760 spat per bushel was recorded. Setting in 1931 began in July and ended in October (Loosanoff, op. cit.). Mackin (1946) found: 1) strike varied with tidal level, with most set occurring between mean low and mean high water, and 2) in Burton's Bay maximum strike occurred in July and amounted to about 4,600 spat per bushel.

Available evidence showed strike is still heavy today on seaside. Studies by Haven and co-workers (Haven et al, 1966) showed an average strike of 981 spat per bushel of substrate in Machipongo Inlet in 1963. Castagna, Haven and Whitcomb (1969) found over 1,500 spat per bushel in three representative locations at Ames Shoals, High Shoals and Argyle Shoals (all in Hogg Island Bay) in 1966.

Studies based on shellstrings from 1972 to 1975 showed spatfall moderate-to-heavy in Conjur's Channel, Chincoteague Bay and many other places.

Areas Needing Study

The preceding areas were not the only ones which have been studied by VIMS. They were, however, the regions which received the most study and serve to show long-term trends. Only fragmentary information existed for other important regions. The most neglected locations needing study were the many creeks located between the Rappahannock and the Potomac rivers and on Bayside of the Eastern Shore. Other areas which should be examined are Lynnhaven Inlet, Back River and Poquoson River.

Seasonal and Regional Aspects of Setting

Setting occurs in Virginia largely between the last week in June and the first week in October. There was much variation between and within systems during this period. However, time of peak set in Virginia's estuaries occurred on the average at a progressively later date in a down-Bay direction. Peak set occurred in the Great Wicomico most often in July. To the south in the Piankatank River and in Milford Haven, peak set most often occurred during the fourth week in August or early September. Peak set generally occurred in the York River the first week in August to mid-September and in the James it peaked most frequently during mid-August to mid-September.

Spatfall in the James River often reaches its peak earliest in the lower reaches of the river. Data for other places are not adequate to detect any consistent pattern.

Ratios of Total Seasonal Spatfall to Surviving Spat on Cultch

One aspect is clearly indicated by the discussions on ratios between total seasonal set on shellstrings and the surviving set on the bottom at the end of the first growing season. The James River, regarded as being the most productive seed area in the State, has the highest rate of survival. In contrast, the Rappahannock has a much lower rate of survival and the annual production of spat on bottom cultch has, on the average, been low. The Piankatank, with a record of moderate production of spat, as measured by shell settings and numbers on bottom cultch, has rates of survival similar to the Rappahannock. These comparisons raise an important question: What is more important for a high surviving set--total seasonal spatfall as measured by shellstrings or survival rates? For example, if there was 100% survival of a total of 2 spat-per-shell-per-season, it would result in 2 spat per shell on the bottom cultch at the end of the season. In contrast, if there was 5% survival of 15 spat-per-shell-per-season, there would be only 0.75 spat per shell at the end of the season on the bottom.

Actually both were important and interrelated. Frequently, especially in the James since 1960, we saw examples of both situations. Spatfall on shellstrings in 1974 was quite low, however, there was an exceptionally high surviving set on bottom cultch. More often, a high total seasonal set results in a good set on bottom cultch as it did in 1969 and for most years prior to 1960 (Table 27). Regions having the highest total seasonal set generally are locations where survival of spat on bottom cultch is high. Regions having low or moderate levels of total seasonal spatfall generally have low-to-moderate levels of surviving spat.

Surviving Spat on Bottom Cultch as an Indicator of Producitivity

The best indicator of the productivity of any oyster-producing region is the number of spat per bushel of bottom cultch at the end of each growing season. This parameter reflects the initial set and survival under existing conditions of pollution, disease, siltation, fouling, nutritional levels and hydrographic conditions.

Numbers of spat on bottom cultch are subject to removal by fishing activity. However, most samples to evaluate bottom cultch are collected early in the fishing season; therefore, its impact is probably minimal. Moreover, the cull law in many areas prohibits the taking of this size.

Various areas in Virginia are classed as high, moderate or low in respect to their basic natural productivity on the basis of number of spat on bottom cultch at the end of each setting season, i.e., the number of spat on young oysters set during that season which have survived.

Highly Productive Areas

Areas classed as highly productive are defined as averaging regularly about 500 to 1,000 or more spat per bushel of bottom cultch. The James River was in this category prior to 1960. Five-year averages from 1947 to 1960 ranged from 336 to 1,945 spat per bushel with an overall average for all stations and all years of 1,080 spat per bushel.

The James River has the best survival rate of any system between total seasonal set and numbers of spat per bushel surviving on bottom cultch at the end of the season. Moreover, the James from 1947 to 1960 almost consistently maintained high levels of total seasonal set (40 to 158 spat per season) at Wreck Shoals, averaging 99.5, which was typical of most of the lower river (Table 31).

Numbers of yearling and small oysters were consistently high in the James from 1947 to 1960 and the yearly average for all stations was 1,080 spat per bushel (Table 56). This latter aspect, along with high survival and slow rates of growth, made the James River one of the best seed rivers on the East Coast.

Table 56

A Comparison of the Averages of all Bars in the James, York, Rappahannock, and Corrotoman Rivers for Numbers of Oysters in Bushel Samples of Natural Cultch for Pre-MSX Period (1947-8 thru 1960-1) and Post-MSX Period (1961-2 thru 1975-6).

	James	York	Rappa-hannock	Corro-toman	Piank-atank
			SPAT		
1947-8 thru 1960-1	1,080	68	41	159	304
1961-2 thru 1975-6	134	24	29	136	275
% Change	-88%	-65%	-29%	-14%	-10%
			SMALL OYSTERS AND YEARLINGS		
1947-8 thru 1960-1	1,066	94	88	265	284
1961-2 thru 1975-6	451	68	76	141	212
% Change	-58%	-28%	-14%	-47%	-25%
			MARKET		
1947-8 thru 1960-1	27	50	53	52	52
1961-2 thru 1975-6	44	28	43	35	21
% Change	+63%	-44%	-19%	-33%	-60%

Many areas on the Seaside of Virginia in the past and today are highly productive based on our definition. Spat counts as high as 3,600 per bushel of substrate were observed in 1946 (Mackin, 1946). Sets as high as 1,500 per bushel were recorded in 1963 (Haven et al, 1966). Studies based on shell-strings from 1972 to 1976 show total seasonal spatfall to be heavy-to-moderate in many locations.

While the surviving set is undoubtedly high on the Eastern Shore, comparatively little information has been published on this aspect. However, the oyster drill is, in all probability, the chief cause of deaths in that region during the first growing season.

Moderately Productive Areas

We define as moderately productive those areas which average from about 130 to 500 spat per bushel of bottom cultch at the end of the first growing season. Systems meeting this standard are the Piankatank, the Corrotoman and, since 1960, the James River. Data are lacking for the Great Wicomico, but limited studies indicate this system to be in the same class.

A decline was indicated in numbers of spat per bushel after MSX manifested itself in 1960 in the Chesapeake Bay in most of the preceding systems.[5] In presenting these data, however, it must be kept in mind that the changes did not all begin in 1960. On the basis of data summarized in Table 56, average counts per bushel for all stations and all years prior to 1960 were: Corrotoman--159; Piankatank--304; values for the Great Wicomico were not known. After 1960 average values for all stations were: Corrotoman--136; Piankatank--275; and the James River--134.

Levels of surviving spatfall at the end of the season resulted in the following average numbers of yearling and small oysters per bushel of bottom cultch. Prior to 1960 the levels were: Corrotoman--265; and the Piankatank--284. After 1960 levels were: Corrotoman--141; Piankatank--212; and James--451 (Table 56).

Data are lacking on ratios of total seasonal set on shellstrings to spat on bottom cultch. Those for the Piankatank indicate low survival to be ranging from less than one percent to three percent.

<u>Low Productive Areas</u>

The York and Rappahannock rivers are both classed as low productive areas where number of spat surviving on cultch

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[5]Counts will be given for the pre- and post-1960 period.

each season averages less than 100 per bushel (Table 56). Even since quantitative surveys were first made in 1930, the York, with exception of lower river, has never been considered as a good setting river. Average counts for all stations prior to 1960 was 68 spat per bushel and after 1960 it was only 24 spat per bushel (Table 56).

The Rappahannock with its diffuse salinity gradients, its wide stretches of low-salinity waters, and a deficiency of oxygen in its deeper waters in summer had the lowest levels of set for any of the major rivers in the State. The possible effect of low oxygen in the deeper parts of the Rappahannock on oyster set has never been evaluated but it may be a significant factor in killing developing larvae in years in which anoxia occurs. The low level of surviving set on bottom cultch in the Rappahannock is shown in Table 56 where the average pre-MSX spat count of small oysters and yearlings on natural cultch prior to 1960 was 41 spat per bushel. After 1960 it was only 29 spat per bushel (Table 56).

There are only limited data for low set areas on the relation between initial seasonal set as shown by shellstrings and the numbers surviving on natural cultch. Information obtained for the Rappahannock indicates a survival rate normally less than 3% (Table 50), which is less than in the James.

Mobjack Bay, Back River, Poquoson River and the lower half of Chesapeake Bay proper are considered moderate-set areas on the basis of very limited data. Scattered surveys suggest larval oysters may set in these areas but before 1972 few survived because of disease and predation including destruction from oyster drills.

Surveys are in progress in an attempt to locate high and moderate set areas in several small tributary creeks which might be developed into seed areas.

The Decline in Market Oyster Production From Private Leases

Obviously, the private segment of the Virginia oyster industry depends on an adequate supply of seed. About 77% of it comes from the James. The industry as it now operates would cease to exist without this seed. The private sector in the 1960-1971 period provided 2.3 times more market oysters than the public sector and, prior to this, from two to five times more (Table 12). Without seed, the private sector cannot operate--without the private sector, Virginia's oyster industry would founder.

Summary of Why Spatfall Has Declined Since 1960

The declines noted in this Chapter for numbers of spat and yearling, small and market oysters per-unit-of-bottom-cultch since 1960 or 1965 are due to the added impact of two factors not present prior to 1960. They are: 1) lowered rates of recruitment as measured by counting the numbers of spat on bottom cultch each fall (which gives surviving spat) and 2) mortalities due to the oyster pathogen, MSX.

While there is some evidence that the impact of MSX disease is declining due to acquired resistance of seed and young oysters, it still produces major mortalities (Chapter IX). Therefore, part of the declines (and their continuation) noted in numbers of oysters since 1960 in the yearling, small and market-oyster categories since 1960 are due to the added impact of this disease in the following Type I and II MSX areas: the James below Brown Shoals, the Rappahannock from Towles Point to the mouth, and the lower part of the York. Above these specific locations MSX causes only minimal mortalities. Therefore, MSX cannot be implicated as the direct cause of the declines noted above the previously cited zones. These upriver areas are:

1. The James River above Brown Shoals where most of the important seed producing areas are located.

2. The upper half of the York River.

3. The important market-oyster growing region of the Rappahannock above Towles Point.

There has been, since 1960 or 1965, in all three of these important upriver locations, a continuing reduction in numbers of spat-per-bushel-of-bottom-cultch (lowered recruitment). We believe this added factor, along with the typical mortality-producing factors already present (before 1960), is largely responsible for the continuing declines in numbers of yearling, small and market oysters noted in these regions. At the down-river locations and in the Piankatank and Corrotoman rivers lowered recruitment plus MSX have been responsible.

In respect to lowered recruitment, we consider it significant that the James River, farthest to the south and the most productive oyster-producing estuary in Virginia, showed the greatest decline, while the Rappahannock to the north showed the least. For example, the average declines in numbers of spat for each river for the pre- and post-1960 period were:

James River	88%
York River	65%
Rappahannock River	29%

The basic reason for lowered numbers of spat on bottom cultch in the James is due to a decline in the total seasonal spatfall and not due to changes in survival of spat after it set. The levels of set on shellstrings were only from 48% to 8% of the values observed from 1947 to 1952 (data from 1953 to 1959 not obtained). While there are gaps in the data, many observations by the senior author of bottom cultch during the spawning season from 1953 to 1960 amply confirm the high rates of attachment during those years.

Where annual total seasonal spatfall has always been low and erratic, there was no conclusive evidence (based on shellstrings) that total seasonal set had declined in the York and Rappahannock. Since numbers of spat-per-bushel-of-bottom cultch had diminished, we suspect the decline to have been due to lowered numbers of spat attaching to bottom substrate during the setting season.

There appeared to be a decline in oyster numbers beginning in the 1960 to 1970 period in the Corrotoman and Piankatank rivers where data on numbers of oysters on bottom cultch are available from 1947 to 1975. Since both systems receive large quantities of shell annually and are subject to very heavy fishing pressure, the declines noted cannot be separated from those associated with the possible direct impact of MSX and lowered recruitment as they were in the James, York and Rappahannock rivers. It would be highly speculative if we attributed the observed declines in these two systems to a lowered total seasonal spatfall or diminished survival. However, MSX undoubtedly is a contributing factor.

In respect to the question of why there has been a lowered total seasonal spatfall in many of the systems in Virginia, there appears to be no common denominator. We attributed it to the absence of brood-stock in the lower James caused by MSX-produced mortalities and acting along with other natural and man-made factors which affect larval and older oysters. There is much evidence to support this statement. There has been little brood-stock from 1960 to 1975 in the lower river to produce larvae to be transported upriver by the currents. Populations in the lower James since 1972, after drills were killed by Tropical Storm Agnes, have increased largely on bars on the south shore where net transport may be downriver (Wood and Hargis, 1971). While the serious drop in brood-stocks is due directly or indirectly to MSX and other mortality-producing factors and to harvesting by private planters in the early MSX period, we cannot ignore the possible additive effects of chlorine associated with the discharge of sewage from treatment plants or some industrial or agricultural product discharged into the river which is toxic to larvae, or which make oyster populations more susceptible to disease like MSX.

We believe the observed declines in spat on bottom cultch in the York and Rappahannock to have been due to lowered levels of spatfall as they have been in the James. It is true we cannot document this relation, but it appears to be the only explanation for the decline in surviving spat on bottom cultch. If we accept this hypothesis, we cannot explain the lowered rate of spatfall as we did in the James on the decline in brood-stocks in the lower parts of the system due to MSX. While both rivers have a net upstream flow of bottom water, neither the York nor the Rappahannock contained significant populations of oysters in their lower reaches prior to 1960.

Possibly the decline in the York might be associated with discharges from one or more of the three industrial plants located in the river or possibly from some unknown factor associated with changes in nutrient levels or fouling. Red-water has been prevalent in recent summers. The possibility of chlorine causing mortalities in the York must also be considered since several sewage systems discharge into the river. Also, chlorine is used by industry (the American Oil Company and the Virginia Electric and Power Company) to keep their seawater systems free from fouling.

There is still less evidence in the Rappahannock as to why spatfalls may have decreased. There are no industrial sites near the oyster beds and brood-stocks in the lower river are always low. Dissolved oxygen in the system may reach low levels each summer and this factor may be lethal to larvae and small spat if levels fall below 0.5 ppm.

Though no common denominator can be found for all systems, one aspect is clear. The James, with its numerous sewage outfalls (chlorine), its heavy concentration of industry, a system where declines in brood-stocks are highest, has shown the greatest decline in oysters on the bottom. In contrast, the Rappahannock, with no industry, has shown the least change (with no decline in small and yearling and market oysters in the upper two-thirds of the system). The York River is apparently intermediate.

Since there appears to be no common denominator, we assume the stresses oysters of the James, York and Rappahannock rivers are subject to are additive, and all factors are acting to reduce initial spatfall. The James with the greatest combination of natural and man-associated stresses has suffered the most and any further stress must certainly reduce levels of setting to still lower levels.

Countering the Decline

Introduction

The failure of sufficient numbers of larvae to set in the James River to maintain the rocks at their former level of productivity is one of the major problems facing the Virginia oyster industry. Every effort should be made to determine why this has occurred and to determine whether and how the cause may be corrected. A second approach to the problem is to develop new sources of seed in the event the present trend continues and cannot be reversed.

Recommendations

1. The Virginia Institute of Marine Science in conjunction with the Virginia Marine Resources Commission should actively find and develop new seed areas other than the James, Piankatank and Great Wicomico rivers.
2. Private planters should be encouraged to grow their own seed in specialized areas. A subsidy of some type might be indicated. Suggested methods might include remission of rent if proof of development is given. Others are to make reef shells available for planting at a low cost and encouraging the use of shellbags.
3. Development of hatcheries--Either private or State-owned hatcheries, or both, as need dictates, for producing seed should be developed if production on natural seed areas continue to deteriorate.
4. If seed numbers and density decline further in the James, conservation measures should be considered to preserve brood-stooks in the down-river sections. This might be done by making

the entire downriver area below Thomas Rock, a clean cull area where only oysters over 3 inches might be harvested.

5. At the same time, positive steps can be taken to increase brood-stock by planting seed from the natural beds in the lower James.

6. If demands from James River seed area increase, then the VMRC might consider other measures to conserve existing stock:

   a. Conserve seed by restricting the sale of soup oysters.

   b. Stop the sale of seed for export when the demand exceeds 20% of the previous year's production.

7. Develop methods to enhance survival of spatfall by control of fouling on shells or other means (see Chapter XI).

8. Improve existing cultural practices by planting shell, etc. in the proper season as indicated in this Chapter.

9. A four-year study has been completed to determine distribution numbers and density of oysters at representative areas in the

James, Great Wicomico and Piankatank rivers. This study should be repeated at intervals to determine future changes.

Field and Laboratory Studies

1. The first priority should be devoted to determining more adequately the characteristics and requirements of a good setting area and the actions required to maintain same. This would include cultch quality and condition, density and numbers of oysters of various stages, predation and disease tolerances, hydrographic characteristics, sustainable harvesting rates and other factors. Emphasis should be on known and important seed areas.
2. The second priority should be directed to determining if some chemical or environmental factor is killing oyster larvae in the lower James River seed area or earlier before they set. This should be a major research effort involving bioassay studies, testing water for levels of various chemical compounds and laboratory studies. Accompanying this program should be a survey of sewage treatment and industrial waste

treatment plants in the James and the other systems to show changes in loading since 1960. Also, a study should be made of industrial complexes in the area to determine types of chemicals being discharged into the river. The initial emphasis should be on chlorine and other toxic materials. Non-point sources should also be examined.

3. If chemical or environmental conditions are eliminated as the major cause of larval mortality (as might be the case), then emphasis might be to establish brood-stock areas in the lower James.

4. Evaluate larval populations in the James River on the north and south side in the vicinity to determine whether the net transport is upriver on both sides. This point has not been determined.

5. Begin to collect, in conjunction with the VMRC, data on boat counts or catch-per-unit-of-effort-data on all public rocks in Virginia. This might be done with weekly plane flights or by VMRC personnel from boats. Data should be tabulated and placed on punch cards for computer evaluation.

6. Begin population dynamics studies on representative public rock to determine optimum harvest time. This would involve determining and integrating recruitment, rate of growth, mortality and time of maximum biomass. Such studies are needed for any intelligent management program.
7. There was a set failure in the Great Wicomico River from 1971 to 1975. Low oxygen values occurred in the same years as the failure occurred. Located in the lower Great Wicomico on Cockrell Creek are several fish processing plants which are suspected of dumping soluble wastes into the water and thereby bringing about the low oxygen values. An immediate study is recommended to determine O_2, BOD and COD values of the water in Cockrell Creek and in the Great Wicomico. A plankton program should accompany this project.
8. The MSX program should be revised and enlarged to determine if sublethal infections may influence growth or spawning of populations.
9. SSO is the major cause of mortality on the seaside of the Eastern Shore. An immediate

study should be made of its life cycle to determine if control measures might be feasible based on its life cycle.

10. Other causes of mortality must also be investigated as contributing factors. Efforts to control them may have to be made in order to increase spatfall and survival.

CHAPTER V

ECONOMIC CONDITIONS OF THE VIRGINIA OYSTER INDUSTRY

CHAPTER V. ECONOMIC CONDITIONS OF THE VIRGINIA OYSTER INDUSTRY

The Virginia oyster industry, like many other marine resource based industries, is complex, and to make an effective analysis of economic conditions in the Virginia oyster industry requires the consideration of many factors basically associated with supply and demand. We will first consider the dollar value of the industry and factors which control the basic price.

Dollar Value of the Virginia Industry

The at-landing value of the 1974-1975 Virginia market oyster crop to oyster producers was $3,702,000 (Table 22). Quittmeyer (1957) stated as a conclusion of his study of the industry that the at-landing prices received by fishermen for all seafood in the 1940's were around one-third of the final retail price. The retail price versus at-landing cost figures found by Quittmeyer are not entirely accurate today since it was based on a determination made 25 or 30 years ago, but they are indicative and essential. A recent report on the Alabama oyster industry estimated oystermen in that state receive one-fourth of the final retail value (May 1971). This figure is likely more valid than earlier ones and probably comes reasonably close to the condition in the Virginia oyster industry. Using this more recent figure as a basis, we have calculated the retail value of the 1974-1975 catch to be approximately $14,808,000.

The many steps which oysters go through and the manipulations undertaken between the time they are purchased as seed for planting and the time they are prepared and/or sold to be consumed all add to the final cost.

The Consumer

Introduction

Demand is an essential element in the oyster industry as in any other industry. There would be no market without it. Consumers create the demand and, as Dr. Quittmeyer (1957) has said, "in the long run, it is primarily the consumer who, by exercising choice in the foods he or she buys and what he or she will pay for them, keeps the fishermen either in business or out of it." This is a fact which may be forgotten by the catchers or producers of oysters (tongers on public ground and private growers) who, like modern farmers, never come in direct contact with the people who consume what they produce. In former times many sales were direct from producers to consumers, and producers knew their ultimate market better. Some of the many factors involved in demand are shown in the following diagram:

DEMAND FOR OYSTERS

Consumer Demand

1. Seasonal food preference
2. Regional food preference
3. Religious beliefs
4. Confidence in purity of product
5. Long-term changes in food preferences
6. Availability of other seafoods
7. Income of consumer
8. Promotional activities, organizations and sales outlets
9. Food fads

Natural Supply

1. Natural mortality
   a. Disease
   b. Predators
2. Fishing mortality
   a. Number of fishermen
   b. Gear--effort
3. Hydrographic conditions
   a. Freshwater
   b. Temperature
   c. Levels O_2, H_2S
   d. Nutrients
   e. Others
4. Chemical pollution
5. Bacterial pollution
6. Meat quality
   a. Seasonal
   b. Regional
7. Rate of growth

Economic Factors

1. Costs of market oysters (wholesale/retail)
   a. Availability of market oysters
   b. Availability and costs of seed oysters
   c. Labor
   d. Transportation
   e. Insurance
   f. Taxes
   g. Ground rent

Consumer Demand

The belief among consumers that oysters are polluted or unfit to eat can cause disastrous reductions in demand which may be reflected in reduced oyster prices. Many consumers became afraid to eat oysters when they were implicated in some cases of typhoid in the early part of this century. Similar scares have caused like responses in recent years. Their fears were not confined to oysters from any one region. As a result, sales of oysters from all areas dropped drastically.

Fears about oysters continued to be widespread. A cooperative inspection program was set up in 1925 and 1926 by oyster-producing states and the U. S. Public Health Service to insure sanitary quality of market oysters and consumer confidence (Commission of Fisheries, 1928).

Today the Bureau of Shellfish Sanitation, Virginia State Department of Health, works cooperatively with the U. S. Food and Drug Administration which endorses the control program of any state meeting the standards of the National Shellfish Sanitation Program (NSSP). Virginia complies with these requirements and, in accordance with these plans, issues certificates to all approved shellfish dealers.

Many other factors, including different beliefs, influence consumption and demand. For example, in the summer of 1972, and outbreak of paralytic shellfish poisoning in New England depressed sales not only of northeastern oysters but those from many other producing areas. This indiscriminate, negative response was unnecessary and unjustified.

Demand for oysters at the retail level (and, thus, the wholesale level) normally declines in summer months due to a widely held belief oysters should not be consumed in months whose spelling does not include the letter "R." This belief was probably based in part on the fact that in the days of little or no refrigeration, oyster meats often deteriorated in the summer heat while they were on the way to the market. With the present methods of freezing, spoilage can be avoided and this factor need not be an obstacle to consumption in the non-"R" months. Another possible explanation is a belief which came from England and Europe where the European oyster grows. In this species, the larvae are brooded for a time on the gills of the adult. While still on the oysters' gills, the little oysters begin developing shells. For this reason, persons eating European oysters in the summer may find them "gritty" or "crunchy" due to the presence of developing larvae. Since our American oyster does not retain its larvae they are not gritty in the summer, but the effect of this belief persists. Another possible factor is oysters are poorest during the spawning season which is in late June, July and August in this latitude.

Increasing competition from other seafood commodities has lessened the demand for oysters. Shrimp, surf clams and crabs are three of the keenest competitors. Consumption of these species has increased greatly while consumption of oysters has decreased. Wheatley (1959) said:

> It may be noted that while the consumption of oysters (in the U. S.) was declining from 170,000,000 pounds (about 20,000,000 gallons of meats) in 1890 to 70,000,000 (about 8,235,300 gallons) in 1954, shrimp production increased from 4,000,000 pounds to 268,000,000 pounds and crabs from 7,000,000 to 141,000,000 pounds.

Possible reasons for the increase in the amount of shrimp and crabs consumed may well have been their availability or supply and the wide variety of ready-prepared products offered to the consumer. Where there is no tradition of consumption of oysters in the home or neighborhood, demand may not develop. Some may find oysters basically unaesthetic, unappetizing or difficult to prepare. Also, consumers may find "packs" displeasing or unattractive. Other preferential factors may be involved.

Religious beliefs have also influenced demand. This factor contributes to a rise in consumption of all seafood during Lent. Roman Catholics used to be denied meat on Fridays and traditionally fish were used on this day. The Thanksgiving and Christmas holidays are also times of increased demand for oysters because they are a regular part of the holiday menu for many people. This same situation is true in European markets. During these seasons oysters are traditionally used in stuffing for turkeys. Additional quantities are cooked in other ways or eaten raw. Oysters are eaten by some who believe them to favorably influence sexual activity.

A major factor influencing consumer demand is the income of consumers (Abrahamson, 1961). If the average income levels of consumers rise, so will purchases of oysters provided the price of oysters does not rise to discouraging levels. Changes in the size of the consuming population also affect the demand. Promotional advertising can also have a positive effect by making the consuming public aware of the availability and uses of oysters and by making oysters appear more desirable.

In summary, demand at the consumer level fluctuates for many reasons. These fluctuations are not felt as quickly by the men who produce the oysters (the tongers and the growers) as they are by retailers or even wholesalers, but, inevitably they are felt throughout the industry.

Economic Aspects

Introduction

Increasing quantities of oysters on the market can mean an increase in the gross value of sales for the industry, but not necessarily. Only if an increase in consumer demand accompanies an increase in supply will increasing dollars result.

Before undertaking to increase the supply of oysters, and we are confident it can be increased, Virginia growers, the VMRC and VIMS must ask, "What effect would increasing the supply have on the sales of oysters?" To answer this question it is necessary to know the nature of the demand for oysters or the elasticity of demand. If the demand for oysters is stable or inelastic, it means the consumption of oysters is static and cannot be stimulated by a lowering of the price. If the demand is elastic, the quantity of oysters consumed will increase with a decrease in price and there will be a greater demand for oysters at wholesale and retail levels.

Elasticity of Demand

Elasticity of demand can be determined by economists by examining market conditions. Several economists in recent years have indicated the demand for oysters to be elastic and, thus, would expand to consume an increase in supply. In a major economic study of the Virginia and Maryland oyster industry, Quittmeyer (1957) concluded the demand was elastic.

John D. Abrahamson (1961), assistant chief of the Bureau of Economics of the NMFS (then BCF) stated:

> The demand for oysters being elastic, the market can absorb a greater production.

He also said:

> The character of the demand is very important to producers of oysters. A small change in price or in spendable income brings about substantial changes in consumption of oysters. The significant fact is that with oysters, or any other product having an elastic demand, a lowering of price will bring about an increase in gross income up to a point. Hence, from the economic point of view, oyster production in the United States can be expanded from its current level, and in the face of possible reduction in prices, the industry can expect gross income to increase.

Producers and everyone else in the industry can lower their prices slightly and still the total or gross income from their sales will be greater due to a rise in consumption (with a larger quantity of oysters to sell).

In a study of the Maryland oyster industry, Christy (1964) stated, "demand since 1940 has been highly elastic." He pointed out as production is increased the total value of oysters sold will increase although the unit price will decline with an elastic demand. He went on to say most watermen "believe that a large increase in output will depress the price considerably so that total revenues will either remain the same or decline." This is probably a reflection of their own experience in terms of revenues per person and per bushel, rather than in terms of total returns, returns to the industry or the effect on retail prices. Recently Morse (1971), an economist studying the oyster industry of the Canadian Maritime Provinces, also concluded the demand for oysters is elastic.

Usually there are limits to elasticity on any commodity and, beyond a certain price level or a certain quantity of supply, demand and gross income will not rise. It is possible to estimate the limits of the elasticity of demand, but such an analysis is beyond the scope of this report. Estimates must be made to determine how much of an increase in supply the market can absorb without making prices tumble, and a qualified economist should undertake this task. After this is accomplished strategies may be devised by private and public management to achieve higher levels of production.

Supply and Demand

Axiomatically, supply and demand interact to govern the price of oysters. However, the details of how these interact in Virginia are not clear and should be carefully studied. One example will be sufficient to show the complexity of the problem.

Over half of the oysters shucked in Virginia in recent years came from Maryland. It might be suspected Virginia processors were buying these oysters in preference to Virginia oysters despite their higher costs because meat yields and, hence, saleable production were high. This does not seem to be the case since meat quality in both areas was satisfactory. We believe that the Virginia processor bought "Marylands" despite their premium price because he had to in order to satisfy customer demands and continue in business. Virginia oysters were not available in sufficient quantity to meet the demands. There is little doubt the increased cost was passed on to the consumer.

Types of Businesses

There are four types of oyster-processing activities recognized by the U. S. Food and Drug Administration which certifies such businesses for interstate shipment of oysters. In November 1975, the number and type of oyster-processing activities in Virginia were:

0	Reshippers
46	Repackers
54	Shell-stock Shippers
83	Shucker-Packers

It is emphasized these represent only the companies registered for interstate shipment. There are probably as many operating only in-state.

The way these businesses operate between and among themselves and in relation to other segments, their methods of setting price, and markets are largely unknown. Clearly, however, their operations play a significant role, perhaps the major role in determining final prices. These interactions and operations must be studied so appropriate management steps can be developed.

Seed Cost

Fluctuations in the supply and costs of seed influence the supply of market oysters. When seed oysters are scarce and their price is high, oyster growers tend to plant less. When a grower has to pay higher prices for seed he has several possible courses of action to offset the increased costs: 1) the asked price of his mature oysters can be increased sufficiently to cover the cost of seed; 2) he can keep his price the same and take less profit; or 3) he can institute practices to improve efficiency and thereby lower production costs. Probably a combination of these would occur.

If seed could be made more plentiful, either by increasing the supply in natural seed areas or by providing quantities of inexpensive and viable hatchery-reared spat, the price of seed per bushel would probably decline. This would allow a grower to plant more and, thus, increase production.

He could also reduce prices for the oysters when he harvests them, if that seems necessary or advisable. Should such reductions reverberate upwards in the processing, distribution and marketing system demand might be stimulated.

Supply Operations and Their Costs

Supply operations are those activities which must be carried out to get oysters to the retail market. They include planting, harvesting, shucking, trucking, processing, packaging, storing, marketing and other necessary operations. If the costs of any one or more of the supply operations can be reduced, then the retail price of oysters can be reduced giving the product an advantage over competing commodities, assuming other factors do not work against price reduction. On the other hand, a significant increase in any one of the operations listed above can cause producers and processors to stop handling oysters causing a reduction in supply.

Labor represents a significant cost of supply in all operations because so much of it is required under the current laws, regulations and by industry practices. Labor costs have been rising, thus, increasing supply costs. The reasons for the increase in wage rates are increasing minimum wage levels; growing fringe benefits and other costs of employing, competition from other employment, and declining availability of skilled workers. A reduction in the amount of labor required per unit of saleable product can be brought about by mechanization of the industry and by adopting new culture techniques (Chapter XI). This should be one of the main objectives of the industry.

Factors Affecting the Basic Price of Oysters

The price the processor will pay a grower for oysters is basic in determining whether the grower will realize a profit. It also determines whether the tonger who works on a public rock will earn a "day's pay." The price the shucker or processor pays depends on the complex interaction between supply, demand, consumer preference, labor costs, meat quality and transportation.

Processors or packers sell oysters by the 8 to 12-ounce can, pint, quart or gallon. The measure they get paid for is the volume sold. The grower, as well as the tonger working on public bottoms, in contrast, measures catches in bushels or occasionally in barrels.

All watermen, dealers and shuckers recognize the volume of meat a bushel of oysters will yield varies with the season and area. The overall range is from 4 to 8 pints per bushel. Consequently, when a processor buys oysters he evaluates what the oysters will yield in terms of pints or quarts of meat in setting the price. This yield will vary with season and river system and an experienced buyer knows, in general, when yields can be expected to be good or poor.

Yields per bushel are actually established by the buyer either by shucking a small sample before buying or by paying for the yield of the entire lot after the oysters are shucked, i.e., for actual yield.

Some oysters are shipped unprocessed to retail outlets for sale in the shell, i.e., the raw bar or half-shell trade. These oysters must be of regular shape and not clumped. The quantity sold in the shell is small compared to the annual harvest and to those sold in other forms.

After shucking, oyster meats are generally placed in large stainless steel tanks filled with fresh water where they are agitated by air jets for a period. Maximum duration is specified by State regulations. This process is beneficial to the consumer as well as the producer since it cleans the meats by rinsing mud, mucous and shell and extends shelf-life. Meats also take up 10-20% water during this process and thereby increase in volume. These facts are mentioned here only to show that yield may be measured at three points in the production cycle: 1) in the shell; 2) just after opening; and 3) after "blowing." Usually the processor bases his payment to the grower on oysters just after opening. However, he sells after "blowing," thus realizing the benefit of the increase in volume caused by this state in the processing cycle.

Shucked oysters are sold commercially either as standards, selects or counts, with the large sizes commanding higher prices. Ranges in numbers of oysters per gallon of each category (according to several packers) are respectively: standards--300 and up; selects--210 to 300; extra selects--160 to 210; and counts--160 or less.

Factors Affecting Private Grower Decisions to Plant and Harvest

The cost of raising oysters and the anticipated sale price at the wholesale level at the time of harvest are the basic parameters which determine whether or not a grower will attempt to raise oysters. The decision to raise oysters is made by the grower. He will not plant seed if he thinks he cannot make a profit from the market oysters from his leased beds. This decision to plant seed must be made two or three years in advance of the proposed sale of his mature oysters and requires all of his experience and knowledge. During this growing period there is a chance market conditions will change and turn an anticipated profit into a loss.

Furthermore, he may suffer crop losses due to problems beyond his control. If the grower is also a processor, he might have the option of foregoing the profit in the difference between sale price of market oysters and the cost of raising them and to make up the losses (or the reduced income) when he sells the processed product. Such an organization would be called an integrated business operation. Such an arrangement would enable a person to profitably market his crop when persons confined only to growing could no longer make a profit. There are, however, many individuals or companies which are basically growers.

Costs of oysters to processors are, of course, subject to the basic economic laws of supply and demand. However, as outlined in Chapter III, the Virginia processor in the last 10 years has been buying Maryland oysters because Virginia supplies have failed him, and he must maintain a stable level of production. Costs of these Maryland oysters have been on the average higher, a factor which has influenced profit margin.

Dollar Value of Oyster Harvest in Virginia - Source of Data

Published average, per-bushel (Virginia bushel) prices of market and seed oysters from public and private leases in Virginia are not available from other sources even though such information is necessary to any complete study of the industry. Therefore, considerable effort has been devoted to tabulating data from several sources. Sources were as follows:

1. NMFS Data - Data from the annual reports of the NMFS (and its predecessor, the BCF) were used to calculate average value of market and seed for each year from 1931 to 1975. Total catch from both public and private grounds was divided into dollar value (wholesale price at landing) and has been previously presented in Table 22.
2. VMRC Data - The Buyer's Report, which first became mandatory in 1963, was most useful in calculating price paid by processors for oysters from public grounds. A detailed analysis of reports available from the files of the VMRC was made and many thousands of individual records examined. Data on price per bushel of seed and market oysters as weighted averages were obtained from 1963 through 1975. The price recorded is regarded as being the "dockside" (wholesale) price.
3. Private Oyster Grower in the Upper Rappahannock - Records of the wholesale price of market oysters from private leases in the upper Rappahannock River were obtained from the files of an individual owner. These records covered the period from 1947 to 1975. To arrive at an average for the year, price per

bushel was weighted by numbers of bushels. Prices paid by the grower for seed were calculated in a similar manner. Calculated prices did not include cost of freight or tax unless specifically indicated.

4. Private Oyster Grower in Norfolk - Records of the price paid to tongers for seed by one Norfolk company from 1938 to 1961 were also made available to us. This price did not include freight or tax.

Dockside Price of Oysters from Public Rocks 1963 to 1975 (VMRC)

This analysis of the price structure reviews the dockside value (price paid to tonger) of market oysters from public rocks in Virginia for the period from 1963 to 1975. It is treated by geographical area for convenience. These data were based on buyers' reports on file at the VMRC (Table 57). Locations of areas mentioned are shown in Figures 3, 4 and 5. Data may be compared to catch data from public rocks shown in Table 18.

The at-landing prices, which harvesters received from buyers for market oysters from public rocks from individual systems, suggest the price from 1963 to 1971 either declined or, at best, remained about the same in the large regions of the Potomac, Rappahannock, James and Nansemond rivers which

Table 57

Average Price of Market Oysters from Public Grounds in Virginia. 1963-4 thru 1974-5[1] ($/bushel).

	Potomac River Estuaries							
Season	Machodoc, Nomini, Currioman	Coan River	Yeocomico River	Little Wicomico River	Great Wicomico River	Rappa-hannock	Corro-toman	Piank-atank
1962- 3	$ (2)	$ 4.41	$ 4.00	$ 5.39	$ 4.98	$ 5.10	$ 4.98	$ 4.00
63- 4	(2)	3.91	(2)	4.09	4.20	4.64	4.31	3.49
64- 5	3.88	3.81	4.25	3.25	4.23	4.45	4.20	3.50
65- 6	4.56	4.37	5.02	4.00	3.37	4.83	4.50	(2)
66- 7	4.80	3.73	4.94	3.47	4.19	3.94	4.00	(2)
67- 8	4.84	3.76	4.61	4.00	3.25	4.38	(2)	(2)
68- 9	4.75	3.85	3.98	3.00	4.07	3.90	(2)	(2)
69-70	4.17	3.57	4.05	3.81	3.60	4.24	(2)	(2)
1970- 1[5]	3.05	3.67	3.72	3.36	3.21	4.54	4.48	4.00[6]
71- 2[5]	4.98	4.24	4.71	4.13	3.80	4.95	4.95	4.96[6]
72- 3[5]	5.00	5.17	5.28	5.03	4.57	5.92	4.89	4.95[6]
73- 4[5]	4.93	5.45	6.03	5.09	4.97	5.40	4.81	4.96
74- 5[5]	6.83	5.73	(2)	2.60	4.63	5.18	5.33	4.35
Average	4.71	4.28	4.60	3.94	4.08	4.73	4.64	4.70

Table 57 (Contd.)

<table>
<tr><th></th><th></th><th></th><th colspan="2">James River</th><th></th><th colspan="2">Eastern Shore</th></tr>
<tr><th>Season</th><th>Mobjack Bay</th><th>York River</th><th>Lg Market Oysters[3]</th><th>Sm Market Oysters[4]</th><th>Nansemond River</th><th>Bay-side</th><th>Sea-side</th></tr>
<tr><td>1962- 3</td><td>$ (2)</td><td>$ 4.50</td><td>$ 3.33</td><td>$ 2.71</td><td>$ 3.56</td><td>$ 5.25</td><td>$ (2)</td></tr>
<tr><td>63- 4</td><td>(2)</td><td>4.41</td><td>3.41</td><td>2.56</td><td>3.85</td><td>(2)</td><td>(2)</td></tr>
<tr><td>64- 5</td><td>(2)</td><td>4.06</td><td>3.47</td><td>2.60</td><td>4.43</td><td>(2)</td><td>3.33</td></tr>
<tr><td>65- 6</td><td>4.42</td><td>4.10</td><td>3.76</td><td>2.72</td><td>5.32</td><td>(2)</td><td>(2)</td></tr>
<tr><td>66- 7</td><td>4.31</td><td>4.75</td><td>3.88</td><td>2.50</td><td>4.11</td><td>(2)</td><td>(2)</td></tr>
<tr><td>67- 8</td><td>4.66</td><td>4.40</td><td>3.39</td><td>2.32</td><td>4.08</td><td>4.88</td><td>5.00</td></tr>
<tr><td>68- 9</td><td>4.92</td><td>4.40</td><td>4.21</td><td>2.48</td><td>3.69</td><td>3.72</td><td>4.51</td></tr>
<tr><td>69-70</td><td>4.89</td><td>4.25</td><td>(2)</td><td>2.38</td><td>3.69</td><td>4.05</td><td>5.49</td></tr>
<tr><td>1970- 1[5]</td><td>4.21</td><td>4.58</td><td>3.38</td><td>2.43</td><td>3.50</td><td>4.16</td><td>4.70</td></tr>
<tr><td>71- 2[5]</td><td>5.27</td><td>4.74</td><td>3.57</td><td>2.75</td><td>4.00</td><td>5.00</td><td>5.49</td></tr>
<tr><td>72- 3[5]</td><td>5.54</td><td>4.44</td><td colspan="2">2.54</td><td>(2)</td><td>5.82</td><td>5.16</td></tr>
<tr><td>73- 4[5]</td><td>5.03</td><td>5.00</td><td colspan="2">2.57</td><td>4.64</td><td>5.85</td><td>6.21</td></tr>
<tr><td>74- 5[5]</td><td>5.20</td><td>5.09</td><td colspan="2">2.54</td><td>4.38</td><td>5.52</td><td>6.94</td></tr>
<tr><td>Average</td><td>4.84</td><td>4.52</td><td colspan="2">2.55[7]</td><td>4.10</td><td>4.92</td><td>5.20</td></tr>
</table>

1. Data computed from Oyster Buyer's Reports on file at the VMRC.
2. None reported.
3. "Clean Culls"
4. "Soups"
5. Data from tabulation of buyer's reports made by VMRC.
6. Milford Haven
7. Average for small oysters (prices after 1971-2 given for large and small oysters combined; however, catches were largely small oysters).

together produced about 90% of all public rock market oysters from Virginia. However, from 1972 to 1975, oysters from almost all regions except the James showed an increase in price. Notably, however, from 1972 to 1975, the increase over the previous period (1963 to 1971) was generally less than about 20%. This is relatively small in view of the strong inflation pressures in the economy.

In respect to the price of oysters from various geographic regions of Virginia, we originally surmised price per bushel of oysters from public rocks would vary over wide limits due to variations in meat quality. However, such a relationship between quality of meats and price was not evident when average values were considered. For example, for market oysters (3 inches in length or larger) the average price varied from $3.94 to $5.20, whereas yields varied much more widely. In fact, over the thirteen-year period oysters from the Potomac River tributaries, always noted for their high quality oysters, sold for about the same as those from the York where quality has always been considered marginal. The "small" market oysters from the James, sold mostly to the soup market and, selling for an average of $2.55 per bushel, are not considered in the comparison since they are produced only in the James and the prices are atypical. The reason for the absence of an apparent relationship between price and quality of oysters from public rocks is not apparent. It may mean people who want oysters, be they producers or consumers, will have them regardless of the quality of the meats, at least up to a point.

Price of Oysters from Public and Private Rocks 1931 to 1975 - NMFS and Other Data

The preceding analysis of the VMRC data for market oysters from public rocks from 1963 to 1975 indicated a stable price from 1963 to 1971 and then an increase in price for oysters from all systems except the James River (Table 57). Since the magnitude of the increase was so small, contrary to inflationary trends in other sections of the economy, it was considered necessary to evaluate other sources of data for the same and earlier periods.

For this purpose data on prices of market oysters from public and private grounds based on NMFS figures were tabulated for the period from 1931 to 1972. Unfortunately, the NMFS data in 1973, 1974 and 1975 do not separate private from public grounds (Table 58). To examine the extent of the change the price per bushel of oysters was converted to the 1967 dollar by multiplying actual values by a series of conversion factors obtained from Federal government statistics (Table 59). Prices adjusted to the 1967 dollar showed trends not directly related to inflation.

Table 58

Actual and Adjusted[1] Prices of Virginia Market Oysters From Three Different Sources.

	ACTUAL PRICES ($/Va. Bu.)				ADJUSTED PRICES ($/Va. Bu.)			
	NMFS[2]		VMRC[3]	PRIV.[4]	NMFS[2]		VMRC[3]	PRIV.[4]
Season	Public Va. Avg.	Private Va. Avg.	Public Rapp. River	Private Rapp. River	Public Va. Avg.	Private Va. Avg.	Public Rapp. River	Private Rapp. River
1930- 1	.73	.76			1.60	1.66		
31- 2	.52	.57			1.27	1.39		
32- 3	.40	.49			1.03	1.26		
33- 4	.38	.46			.95	1.14		
34- 5	.38	.43			.92	1.04		
35- 6	.42	.48			1.01	1.15		
36- 7	.41	.46			.95	1.07		
37- 8	.46	.46			1.08	1.08		
38- 9	.50	.48			1.20	1.15		
39-40	.48	.53			1.14	1.26		
1940- 1	.68	.65			1.54	1.47		
41- 2	.90	.87			1.84	1.77		
42- 3	(5)	(5)			(5)	(5)		
43- 4	(5)	(5)			(5)	(5)		
44- 5	2.00	2.05			3.70	3.79		
45- 6	1.96	2.08			3.35	3.56		
46- 7	2.15	2.16			3.20	3.22		
47- 8	2.14	2.06		2.00	2.95	2.84		2.76
48- 9	1.91	1.95		2.19	2.67	2.73		3.07
49-50	1.93	2.08		2.14	2.66	2.87		2.95
1950- 1	2.29	2.29		2.32	2.93	2.93		2.97
51- 2	2.41	2.50		2.84	3.04	3.15		3.58
52- 3	2.70	2.56		2.45	3.38	3.20		3.06
53- 4	2.62	2.78		2.26	3.28	3.48		2.82
54- 5	2.94	2.91		2.21	3.68	3.64		2.76
55- 6	2.74	2.89		(5)	3.37	3.55		(5)
56- 7	2.99	3.05		3.02	3.56	3.63		3.59
57- 8	3.46	3.30		2.75	3.98	3.80		3.16
58- 9	3.73	3.41		2.79	4.25	3.89		3.18

Table 58 (Contd.)

Season	ACTUAL PRICES ($/Bu.) NMFS[2] Public Va. Avg.	NMFS[2] Private Va. Avg.	VMRC[3] Public Rapp. River	PRIV.[4] Private Rapp. River	ADJUSTED PRICES ($/Bu.) NMFS[2] Public Va. Avg.	NMFS[2] Private Va. Avg.	VMRC[3] Public Rapp. River	PRIV.[4] Private Rapp. River
1959-60	3.74	3.74		3.19	4.23	4.23		3.60
60- 1	4.69	4.52		4.60	5.25	5.06		5.15
61- 2	5.25	5.01		5.55	5.78	5.51		6.10
62- 3	4.83	4.68	5.10	4.72	5.26	5.10	5.56	5.14
63- 4	4.76	4.48	4.64	4.45	5.14	4.84	5.01	4.81
64- 5	4.54	5.17	4.45	4.41	4.81	5.48	4.72	4.67
65- 6	4.63	5.65	4.83	5.14	4.77	5.82	4.97	5.29
66- 7	4.64	4.04	3.94	4.96	4.64	4.04	3.94	4.96
67- 8	5.18	4.54	4.38	4.68	4.97	4.36	4.20	4.49
68- 9	5.34	4.86	3.90	4.57	4.86	4.42	3.55	4.16
69-70	4.36	4.27	4.24	4.90	3.75	3.67	3.65	4.21
1970- 1	4.13	4.50	4.54	5.14	3.39	3.69	3.72	4.21
71- 2	4.09	4.66	4.95	5.51	3.27	3.73	3.96	4.41
72- 3	4.17		5.92	7.09	3.13		4.44	5.32
73- 4	4.42		5.40	(5)	3.00		3.67	(5)
74- 5	5.47		5.18	7.72	3.39		3.21	4.79

1. Actual prices were adjusted to eliminate the effect of inflation using figures contained in "Monthly Labor Review", U. S. Dept. of Commerce (1967 = 100).

2. Data computed from Fisheries Statistics of the U. S. NMFS. (1931 thru 1972), data for 1972-3, 1973-4 and 1974-5 computed from "Va. Landings". NMFS. Oysters taken from Md. waters of the Potomac and credited to Va. by the NMFS from 1964-5 thru 1974-5 are not included.

3. Data computed from Oyster Buyer's Reports on file at the VMRC. Data for the public grounds in the Rappahannock River only is presented; for prices in other areas see Table 57. Price data prior to 1963 is not available.

4. Data from records of an individual planter. Prices shown are what he received for oysters harvested from his grounds in the Rappahannock River. Data prior to 1947 is not available.

5. Data not available.

Table 59

Comparative Values of the U. S. Dollar. 1931-1975[1]
Values Used to Adjust Monetary Figures for Inflation.

Year	Comparative value of the dollar
1931	$ 2.19
2	2.44
3	2.57
4	2.49
5	2.43
6	2.40
7	2.32
8	2.36
9	2.40
1940	2.38
1	2.26
2	2.04
3	1.92
4	1.89
5	1.85
6	1.71
7	1.49
8	1.38
9	1.40
1950	1.38
1	1.28
2	1.26
3	1.25
4	1.25
5	1.25
6	1.23
7	1.19
8	1.15
9	1.14
1960	1.13
1	1.12
2	1.10
3	1.09
4	1.08
5	1.06
6	1.03
7	1.00
8	.96
9	.91
1970	.86
1	.82
2	.80
3	.75
4	.68
5	.62

How to use this table:

To find the value of the dollar in any year shown fill in the blanks in the following sentence:

The value of the dollar in <u>(any year)</u> when compared to the 1967 dollar was <u>(the figure in the column opposite the year desired)</u>.

For example:

The value of the dollar in 1950 in terms of the 1967 dollar was $1.38.

The value of the dollar in 1965 in terms of the 1967 dollar was $1.06.

To find the comparative value of any Price, value, cost or other monetary figure:

Simply multiply that figure by the figure shown in the column headed "Comparative Value of the dollar", omitting the dollar sign.

For example:

The actual price of shucking oysters from public ground in the Rappahannock River in 1970 was **$4.24** (From Table 58). The comparative price was **$3.65.**

[1] Based on the 1967 value of the dollar, and using the Consumer Price Index (compiled by the U. S. Department of Commerce) as the index of inflation.

Data for 1931 to 1972 show the unadjusted price of market oysters from the public rocks and leased bottoms (Table 58). Differences between prices of oysters from public and leased bottoms from 1931 to 1958 were slight and ranged from zero to sixteen cents with no group being consistently higher according to NMFS data. Differences from 1959 to 1972 were larger and ranged from 0 to $1.02 per bushel with no group appearing consistently higher or lower. The reasons for the preceding differences in price between the periods from 1931 to 1958 and 1959 to 1972 are not apparent.

The trends in unadjusted price of oysters from public bottoms based on NMFS data went from less than half a dollar a bushel in the mid-thirties to $5.34 a bushel in 1969. Thereafter, price declined to $4.09 in 1972 which is the last year NMFS data are available for the separate types of grounds.

There is a good possibility that beginning in 1957 and extending to 1972 (the last year for which adequate data are available), the NMFS information on price for market oysters on public bottoms may not really be representative of prices paid by processors for shucking stock (Chapter III). The reason is beginning about 1957 the NMFS data included the small "soup oyster" with the figures for the larger market oysters. Since the "soups" comprised about 64% of the State total landings, and since they sold for a lower price, it is obvious the price of market oysters in this period may be "weighted" downward each year in proportion to the quantity of "soup" oysters sold.

Based on this fact, one would expect the price of market oysters from public bottoms calculated using NMFS data to be lower than the price of oysters from leased bottoms. This is not the case and the reason why is not clear.

Fortunately, we need not attempt to evaluate these combined data to show a decline in price has occurred. We have just demonstrated (Table 57) that VMRC data from 1963 to 1975 (except for the James River) showed a decline in the price of market oysters to 1971 and then a slight recovery to 1975 when price was only slightly over the 1963 level. The only period we are not certain about in respect to price of market oysters (shucking stock) from public bottoms is from 1957 to 1963.

The price of oysters from private leases based on NMFS data showed approximately the same trends as that for public bottoms (Table 58). It went from less than fifty cents a bushel in the mid-thirties to $5.01 in 1962. Thereafter, with the exception of a slight "peak" in 1965 and 1966, prices remained the same until 1972. Final NMFS data for private leases after 1972 have not as yet been published.

Based on NMFS data, the adjusted price of oysters from public and private grounds paralleled that for the unadjusted price from 1931 to about 1962 showing an increase. However, the upward trend stopped in 1962 and from 1963 to 1972 there was a decided decline in adjusted price from both public and private bottoms (Table 58).

A third series of dockside price data was obtained from records of a private planter operating in the upper Rappahannock River from 1947 to 1975 (Tables 58 and 60). Prices and trends were similar to those indicated by NMFS data for private grounds over most of the period. Unadjusted prices rose from $2.00 a bushel in 1947 to $5.55 in the 1961-1962 season (Table 58). Unadjusted prices to 1971 remained at the same level but rose sharply to $7.72 in 1974. The adjusted price increased slowly from $2.76 in 1947 to a high of $6.10 in 1961, then trended downward to $4.79 in 1974.

For comparison, prices of oysters from public rocks in the Rappahannock presented in Table 57 are shown again in Table 58. From 1963 to 1975 adjusted price declined.

The preceding study of prices of market oysters from leased areas and public bottom utilizes information from three sources: VMRC, NMFS and a Virginia private planter. All sources indicate a general rise in unadjusted price from

Table 60

Economics of Planting James River Seed Oysters In the Upper Rappahannock River[1] 1947-1975.

Season	Sale Price Of Market Oysters $/Bu	Cost of Seed (No Freight) $/Bu	Cost of Seed as % Market Price	Cost of Seed, Including Freight & Tax	Net Difference $/Bu	Total Cost Of Seed as % Market Price
1947- 8	2.00	0.67	33.5	0.84	1.16	42.0
48- 9	2.19	0.50	22.8	0.69	1.50	31.5
49-50	2.14	0.50	23.4	0.69	1.45	32.5
1950- 1	2.32	0.58	25.0	0.77	1.55	33.2
51- 2	2.84	0.72	25.4	0.94	1.90	33.1
52- 3	2.45	0.62	25.3	0.84	1.61	34.3
53- 4	2.26	0.76	33.6	1.00	1.26	44.2
54- 5	2.21	0.63	28.5	0.87	1.34	39.4
55- 6			No Harvest			
56- 7	3.02	1.17	38.7	1.41	1.61	46.7
57- 8	2.75	0.89	32.4	1.18	1.57	42.9
58- 9	2.79	1.02	36.6	1.31	1.48	47.0
59-60	3.19	0.78	24.4	1.09	2.10	34.2
1960- 1	4.60	0.95	20.6	1.26	3.34	27.4
61- 2	5.55	0.88	15.8	1.19	4.36	21.4
62- 3	4.72	1.08	22.9	1.39	3.33	29.4
63- 4	4.45	1.50	33.7	1.86	2.59	41.8
64- 5	4.41	1.50	34.0	1.88	2.53	42.6
65- 6	5.14	1.09	21.2	1.49	3.65	29.0
66- 7	4.96	1.25	25.2	1.65	3.31	33.3
67- 8	4.68	1.25	26.7	1.65	3.03	35.2
68- 9	4.57	1.50	32.8	1.95	2.62	42.7
69-70	4.90	1.64	33.5	2.24	2.66	45.7
1970- 1	5.14	1.20	23.3	1.79	3.35	34.8
71- 2	5.51	1.85	33.6	2.38	3.13	43.2
72- 3	7.09	2.00	28.2	2.46	4.63	34.7
73- 4	No harvest due to Hurricane Agnes in 1972					
74- 5	7.72	1.95	25.2	2.62	5.10	33.9
Average			27.9			36.8

1. From a private planter's records. For an analysis of harvest costs for the same planter see Table 63.

the mid-thirties up to about 1962. Thereafter, depending on the source, it declined or remained at about the same until 1972. (The government has not as yet published final data after 1972.) Based on data from a private planter, the unadjusted price of oysters from 1972 increased. In all instances there was a downwarn trend in adjusted price starting about 1962. There has been a decline in the adjusted price of market oysters (shucking stock) in a period of inflated production costs, an affluent society, and increasing prices for commodities, labor and service. There was also an increase in production costs in the face of a decline in the availability of market oysters.

Price of Seed Oysters

Seed oyster prices were obtained from the same basic source as for market oysters; i.e., information published by the NMFS, from VMRC and from records of private planters.

Table 61, developed from the Buyer's Reports on file at VMRC, shows the average unadjusted price of seed

Table 61

Average Price of Seed Oysters From Public Grounds in Virginia 1962-3 thru 1974-5[1] in dollars per bushel

Season	James River	Piankatank River	Gt. Wicomico River	Eastern Shore Seaside
1962-3	1.29	N/A	N/A	N/A
63-4	1.48	N/A	N/A	1.25
64-5	1.49	1.03	1.24	N/A
65-6	1.23	0.97	1.00	N/A
66-7	1.25	1.00	1.04	N/A
67-8	1.26	1.00	1.04	0.88
68-9	1.49	N/A	1.00	N/A
69-70	1.62	1.00	1.05	0.71
1970-1[2]	1.51	(3)	1.02	0.68
71-2[2]	1.88	(3)	(3)	0.61
72-3[2]	2.04	(3)	(3)	0.90
73-4[2]	2.35	1.75	1.75	0.90
74-5[2]	1.88	N/A	(3)	1.00

1. Data from Oysters Buyers Reports on file at the VMRC.

2. Calculated from tabulations of Buyers' Reports made by VMRC.

3. No seed sold.

N/A - Data not available.

from 1963 to 1975 from the James, the Piankatank, the Great Wicomico and the Eastern Shore. In the James, which has always supplied a major part of the seed harvested in Virginia, the unadjusted price paid to the tonger showed no well-defined trend from 1963. Seed oysters sold for $1.29 per bushel in 1963. They sold for under $1.49 until 1969, but in 1970 there was a decided upward trend to $2.35 in 1974. The price fell to $1.88 in 1975. Therefore, the unadjusted price of James River seed has increased in the thirteen-year period between 1963 and 1975.[2]

Limited data from the Great Wicomico and Piankatank rivers and the Seaside of the Eastern Shore show no trends in price from 1963 to 1972 but a decided upward trend during 1973, 1974 and 1975. The preceding data demonstrate that, on the average, seed from these latter three locations sold for $0.61 to $1.75 per bushel or from 25¢ to $1.00, less than that from the James. Thus, James River seed is more valued by growers than seed from other locations in the State. There are several reasons for this higher valuation.

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[2]It is of major importance to note here that while the price of James River seed has risen only slightly on a bushel basis, there has been a major decline in numbers of oysters per bushel since 1960. For example, as shown in Chapter IV average total counts of oysters of all sizes was 2,977 in the 1947 to 1960 period; in contrast, from 1961-1976 the total was only 629. This aspect will be discussed in Chapter IX.

Eastern Shore seed oysters grow and survive well in high-salinity areas, but do poorly in the low-salinity regions in the Bay which comprise most of the growing areas. Therefore, the demand for this seed is limited.

The lower price of Great Wicomico and Piankatank seed is probably due to two related aspects. Growers have been planting James River seed for over a hundred years and its characteristics are well known. Growers "know" how many seed there are in a bushel, how fast it grows, and how many may die. In contrast, seed from the Great Wicomico and Piankatank rivers have been available only since 1963, and its growth characteristics and size are still largely unproven to many of the growers.

The adjusted price of James River seed, based on VMRC data from 1963 to 1975, showed peak price in 1964 and 1965 followed by an abrupt decline in 1966; from this date to 1974, the adjusted price increased again so that it was near its previous (1964-1965) peak (Table 62).

Data on unadjusted seed price tabulated from reports of the NMFS show a very gradual increase in price from 14¢ per bushel in 1932 to $1.97 per bushel in 1967 (Table 62). Thereafter, the price fluctuated irregularly up to 1975 between $1.33 and $2.48 with no indications of an up or downward

Table 62

Actual and Adjusted[1] Prices of Virginia Seed Oysters From Four Different Sources.

Season	Actual Prices ($/Va. Bu.)				Adjusted Prices ($/Va. Bu.)			
	NMFS[2]	VMRC[3]	PRIV[4]	PRIV[5]	NMFS[2]	VMRC[3]	PRIV[4]	PRIV[5]
1931- 2	.14				.34			
32- 3	.10				.26			
33- 4	.13				.32			
34- 5	.17				.41			
35- 6	.18				.43			
36- 7	.28				.65			
37- 8	.26			.22	.61			.52
38- 9	.22			.14	.53			.34
39-40	.23			.12	.55			.28
40- 1	.28			.18	.63			.41
41- 2	.28			.22	.57			.45
42- 3	6		.45	.29	6		.86	.56
43- 4	6		.40	.42	6		.76	.79
44- 5	.50		.43	.40	.92		.80	.74
45- 6	.39		.40	.24	.67		.68	.41
46- 7	.50		.58	.56	.74		.86	.83
47- 8	.56		.67	.75	.77		.92	1.04
48- 9	.51		.50	.56	.71		.70	.78
49-50	.68		.50	.49	.94		.69	.68
1950- 1	.83		.58	.71	1.06		.74	.91
51- 2	1.10		.72	.88	1.39		.91	1.11
52- 3	1.05		.62	.62	1.31		.78	.78
53- 4	1.18		.76	.76	1.48		.95	.95
54- 5	1.15		.63	.83	1.44		.79	1.04
55- 6	.99		.90	6	1.22		1.11	6
56- 7	1.22		1.17	1.01	1.45		1.39	1.20
57- 8	6		.89	.89	6		1.02	1.02
58- 9	6		1.02	6	6		1.16	6
59-60	.92		.78	6	1.04		.88	6

Table 62 (Contd.)

Season	Actual Prices ($/Bu.)				Adjusted Prices ($/Bu.)			
	NMFS[2]	VMRC[3]	PRIV[4]	PRIV[5]	NMFS[2]	VMRC[3]	PRIV[4]	PRIV[5]
1960- 1	.93		.95	.38	1.04		1.06	.42
61- 2	.88		.88		.97		.97	
62- 3	1.29	1.29	1.08		1.41	1.41	1.18	
63- 4	1.75	1.48	1.50		1.89	1.60	1.62	
64- 5	1.86	1.49	1.50		1.97	1.58	1.59	
65- 6	1.09	1.23	1.09		1.12	1.27	1.12	
66- 7	1.97	1.25	1.25		1.97	1.25	1.25	
67- 8	1.33	1.26	1.25		1.28	1.21	1.20	
68- 9	1.65	1.49	1.50		1.50	1.36	1.36	
69-70	1.66	1.62	1.64		1.43	1.39	1.41	
1970- 1	1.81	1.51	1.20		1.48	1.24	.98	
71- 2	2.18	1.88	1.85		1.74	1.50	1.48	
72- 3	1.51	2.04	2.00		1.13	1.53	1.50	
73- 4	2.48	2.35	2.12		1.67	1.60	1.44	
74- 5	1.88	1.88	1.95		1.16	1.16	1.21	

1. Actual prices were adjusted to eliminate the effect of inflation using figures from "Monthly Labor Review". U. S. Dept. of Commerce (1967 = 100).

2. Data computed from Fisheries Statistics of the U. S. NMFS (1930-1 thru 1971-2); subsequent data computed from "Va. Landings" NMFS. Prices are averages of all public and private seed; however, there has been very little seed from private ground (see Table 14).

3. Data computed from Oyster Buyer's Reports on file at VMRC. Data for James River only, where bulk of seed comes from, is presented; for prices in other areas(see Table 61). Price data prior to 1962-3 is not available.

4. Data from records of an individual planter in the Rappahannock who bought James River seed exclusively. Records prior to 1942-3 were not available.

5. Data from records of J. H. Miles and Company, Norfolk. Most of the seed planted came from the company's leased grounds in the James River; the rest was James River seed bought from tongers. Data after 1960-1 were not available.

6. Data not available.

trend. These prices are probably unreliable since they include data from all areas. That is, the price is weighted from 1963 on by the inclusion of low priced seed from the Piankatank and Great Wicomico rivers as well as the higher priced James River seed.

Adjusted prices for seed were calculated on the basis of the 1967 dollar (Table 62). The values for NMFS data on the basis of the adjusted dollar showed a slow but steady increase from 1931 to about 1967. NMFS data showed the adjusted prices for seed experienced an erratic drop after 1967 to $1.16 in 1975.

Information on seed price and other costs from the private grower in the Rappahannock River agreed in part with that obtained from the NMFS (Tables 62 and 63). The actual unadjusted prices of the Rappahannock grower slowly increased as they did in NMFS data from an average of 45¢ per bushel in 1943, to $1.50 in 1964 (Table 62). However, during half the years in this period the price of seed reported by the private grower was far under that reported by the NMFS for no readily apparent reason. Trends in unadjusted prices paid for seed by the private planter after 1965 trended irregularly upward to $1.95 in 1975.

Table 63

Economics of Planting James River Seed Oysters in the Rappahannock River. Data Obtained from the Records of a Private Planter at Bowlers Wharf. Averages Shown Are Based on Weighted Values.

Season	Avg. Price Seed/Bu.	Price Range/Bu.	Freight Costs/Bu*	Cost of Planting Seed/Bu	Tax/ Bu	Avg. Total Cost/Bu. Planted $	Price of Seed as % of Total Cost of Planting Seed
1942- 3	0.45	-0.45-	-0.15-	-0.02-	None	0.62	73
43- 4	0.40	-0.40-	-0.15-	-0.02-	"	0.57	70
44- 5	0.43	0.40-0.45	-0.15-	-0.02-	"	0.60	72
45- 6	0.40	-0.40-	-0.15-	-0.02-	"	0.57	70
46- 7	0.58	-0.58-	-0.15-	-0.02-	"	0.75	77
47- 8	0.67	-0.67-	-0.15-	-0.02-	"	0.84	80
48- 9	0.50	-0.50-	-0.17-	-0.02-	"	0.69	72
49-50	0.50	0.45-0.57	-0.17-	-0.02-	"	0.69	72
1950- 1	0.58	0.55-0.65	-0.17-	-0.02-	"	0.77	75
51- 2	0.72	0.65-0.80	-0.20-	-0.02-	"	0.94	77
52- 3	0.62	0.57-0.67	-0.20-	-0.02-	"	0.84	74
53- 4	0.76	0.67-0.90	-0.20-	-0.02-	-0.02-	1.00	76
54- 5	0.63	0.62-0.65	-0.20-	-0.02-	-0.02-	0.87	72
55- 6	0.90	0.80-0.90	-0.20-	-0.02-	-0.02-	1.14	80
56- 7	1.17	1.15-1.30	-0.20-	-0.02-	-0.02-	1.41	83
57- 8	0.89	0.80-1.00	-0.25-	-0.02-	-0.02-	1.18	75
58- 9	1.02	0.67-1.15	-0.25-	-0.02-	-0.02-	1.31	78
59-60	0.78	0.65-1.00	-0.25-	-0.03-	-0.03-	1.09	72
1960- 1	0.95	0.75-1.12	-0.25-	-0.03-	-0.03-	1.26	75
61- 2	0.88	0.60-1.14	-0.25-	-0.03-	-0.03-	1.19	74
62- 3	1.08	0.75-1.25	-0.25-	-0.03-	-0.03-	1.39	78
63- 4	1.50	-1.50-	-0.30-	-0.03-	-0.03-	1.86	81
64- 5	1.50	-1.50-	-0.30-	-0.05-	-0.03-	1.88	80
65- 6	1.09	1.00-1.35	-0.30-	-0.05-	-0.05-	1.49	73
66- 7	1.25	-1.25-	-0.30-	-0.05-	-0.05-	1.65	76
67- 8	1.25	-1.25-	-0.30-	-0.05-	-0.05-	1.65	76
68- 9	1.50	-1.50-	-0.35-	-0.05-	-0.05-	1.95	77
69-70	1.64	1.00-1.85	-0.40-	-0.10-	0.05-0.10	2.24	73
1970- 1	1.20	1.00-1.80	0.30-0.50	0.03-0.23	0.05-0.10	1.79	67
71- 2	1.85	1.50-2.25	0.25-0.40	0.03-0.25	0.05-0.10	2.38	78
72- 3	2.00	-2.00-	-0.25-	0.12-0.25	-0.10-	2.46	81
73- 4	2.12	2.00-2.25	-0.25-	0.25-0.40	-0.10-	2.64	80
74- 5	1.95	1.50-2.25	0.25-0.50	0.07-0.60	-0.10-	2.62	74
					AVERAGE		75.5

* Based on weighted averages for freight

The adjusted cost of seed to the private planter in the Rappahannock River trended gradually upward to 1964, and then declined to a low of 98 cents in 1971. Thereafter, it rose to $1.50 in 1973, which was slightly less than in 1964 and 1965, but it fell to only $1.21 a bushel in 1975 (Table 62).

Additional information on unadjusted seed oyster prices from 1938 to 1958 was obtained from the records of J. H. Miles and Company, Norfolk, Virginia. During this period the company was the largest planter of seed in Virginia and often planted in excess of 500,000 bushels of James River seed annually. Adjusted and unadjusted prices trended upward in this period and were remarkably similar to that reported for comparable periods (Table 62) by a planter in the Rappahannock River. Both were slightly lower than those cited by NMFS, especially from 1952 to 1960.

<u>Summary - Price of Market and Seed Oysters</u>

Data on price of market oysters, based on NMFS data for public and private bottoms, showed a slow increase in actual and adjusted price from 1932 to about 1962. Thereafter, actual prices remained at the same level or declined until 1973. For both areas the adjusted price declined after 1962. VMRC data on the price of oysters on Baylor bottoms for the Rappahannock, a typical area, showed the adjusted price declining from 1963 to 1975. Data based on the private grower in the Rappahannock from 1947 to 1975 indicated declines in adjusted price since 1962.

Based on VMRC data or those of the private planter in the Rappahannock River, costs of seed indicate a gradual increase in unadjusted price over the years to 1975. NMFS data indicate a rise in price from 1932 to 1967 followed by a stable situation. Data from all three sources indicate adjusted cost rose until 1964 and 1967 and then declined or remained stable to 1975, depending on the source of the data.

It is possible that the cost of seed listed by the VMRC or the NMFS data is not the actual price paid by the grower. Additional monies, up to 10% to 20%, may actually have been given the tonger by the buyer in the form of "gifts" or by some other arrangements. If this happened, then actual expenses of seed to the grower would have been larger than indicated. There is evidence this practice is common but, in the absence of actual data to show its magnitude, we can only use the best data available which are those based upon the tax collected by VMRC.

The values of seed and market oysters from the individual sources (Table 62) were averaged and mean prices obtained to show the overall trends and the ratios between them (Table 64). The average unadjusted value of market oysters from all sources showed a gradual increase in value from 1932 to 1962 followed by a "leveling off" through 1975. Adjusted mean price showed a similar slow increase from 1932 to about 1964, and then a definite downward trend to 1975.

The average unadjusted price of seed followed a different trend (Table 62). It slowly increased from 14¢ in 1932 to $1.13 in 1957. There was a dip in price from 1960 to 1962, but after this the trend was consistently upward to $2.32 in 1974. The average adjusted price of seed showed a slow increase from 1932 to 1964 followed by a leveling off from 1964 to 1975.

Costs of Harvesting and Planting Oysters

The preceding discussion of costs or prices of market oysters and seed at the primary levels of production was directed primarily toward showing trends in costs of those two products. There are many other expenses involved which have risen sharply, such as labor costs, freight and taxes. While information relative to taxes is available, data on other aspects may be obtained only from records of individuals or companies with few maintaining records over long periods.

Table 64

Comparison Between Mean Value for Price of Market Oysters and Seed from 1932 to 1975 with Values Expressed as Percent Seed Oysters Were of Market Oyster Price.[1]

Season	Market Oysters $/Bu.		Seed Oysters $/Bu.		Seed (as % Market)
	Actual	Adjusted	Actual	Adjusted	
1931-2	0.54	1.32	0.14	0.34	25.9
32-3	0.44	1.13	0.10	0.25	22.7
33-4	0.42	1.04	0.13	0.32	31.0
34-5	0.40	0.97	0.17	0.41	42.5
35-6	0.45	1.08	0.18	0.43	40.0
36-7	0.44	1.02	0.28	0.65	63.6
37-8	0.46	1.08	0.24	0.57	52.2
38-9	0.49	1.18	0.18	0.43	36.7
39-40	0.50	1.19	0.18	0.43	36.0
1940-1	0.66	1.49	0.23	0.52	34.8
41-2	0.88	1.80	0.25	0.51	28.4
42-3	(2)		0.37	0.71	
43-4	(2)		0.41	0.77	
44-5	2.03	3.76	0.44	0.81	21.7
45-6	2.02	3.45	0.34	0.58	16.8
46-7	2.16	3.22	0.55	0.82	25.5
47-8	2.07	2.86	0.66	0.91	31.9
48-9	2.02	2.83	0.52	0.73	25.7
49-50	2.05	2.83	0.56	0.77	27.3
1950-1	2.30	2.94	0.71	0.91	30.9
51-2	2.58	3.25	0.90	1.13	34.9
52-3	2.57	3.21	0.76	0.95	29.6
53-4	2.55	3.19	0.90	1.12	35.3
54-5	2.69	3.36	0.87	1.09	32.3
55-6	2.82	3.47	0.94	1.16	33.3
56-7	3.02	3.59	1.13	1.34	37.4
57-8	3.17	3.64	0.89	1.02	28.1
58-9	3.31	3.77	1.02	1.16	30.8
59-60	3.56	4.02	0.85	0.96	23.9
1960-1	4.60	5.15	0.75	0.84	16.3
61-2	5.27	5.80	0.88	0.97	16.7
62-3	4.83	5.26	1.22	1.33	25.2
63-4	4.58	4.95	1.58	1.71	34.5
64-5	4.64	4.92	1.62	1.72	34.9
65-6	5.06	5.21	1.14	1.17	22.5
66-7	4.40	4.40	1.49	1.49	33.9
67-8	4.70	4.51	1.28	1.23	27.2
68-9	4.67	4.25	1.55	1.41	33.2
69-70	4.44	3.82	1.64	1.41	36.9
1970-1	4.58	3.76	1.51	1.24	33.0
71-2	4.80	3.84	1.97	1.58	41.0
72-3	5.73	4.30	1.85	1.39	32.3
73-4	4.91	3.34	2.32	1.58	47.2
74-5	6.12	3.79	1.90	1.18	31.0

Average: 1931-2 thru 61-2 = 31.4%; Average: 1962-3 thru 74-5 = 33.3%

Table 64 (Contd.)

1. Mean computed from data appearing in Tables 58 and 62.
2. Data were not available.

Fortunately, the records of the Rappahannock grower are available and give an insight which we believe is typical. Seed cost is a major expense. Other expenses include freight, by boat or truck, from the James River to the planting ground, cost of planting the seed overboard, and tax paid on the seed to the VMRC (Tables 63 and 65). These data show that from 1943 to 1975 costs of all three items have risen. Freight increased from 15¢ to 25¢-50¢ a bushel; cost of planting went from 2¢ to 25¢-40¢, and tax escalated from zero to 10¢ a bushel. Calculations based on these data show the initial cost of the seed to the grower to have been from 67% to 83% of the total planted cost, an average of 75.5% (Table 63).

Pooled data on the relative prices of market and seed oysters is shown in Table 64. Seed oysters from 1932 to 1962, at the price paid to the tonger, averaged 31% of the cost of market oysters. There was a slight increase to 33% of the sale price of market oysters from 1963 to 1975. While these two values (31% and 33%) are close, an inspection of Figure 24 shows that from 1963 to 1975 cost of seed relative to that of market oysters has trended steadily upward. This condition is obviously unfavorable for the grower. It is even more unfavorable if the grower has had to pay an additional amount in the form of gifts or gratuities in cash.

Table 65

Value of market oysters per bushel and cost per bushel for harvest[1] (by dredge or tongs) as shown by records of a Rappahannock River oyster grower. Shown are values adjusted to a 1967 dollar (season: fall to spring) weighted value for costs.

Season	Sale price/bu.		Harvest cost/bu.		Harvest cost as % sale price of oysters
	Actual	Adjusted	Actual	Adjusted	
1947-48	2.00	2.76	0.37	0.51	18
48-49	2.19	3.07	0.42	0.59	19
49-50	2.14	2.95	0.33	0.46	15
1950-51	2.32	2.97	0.46	0.59	20
51-52	2.84	3.58	0.38	0.48	13
52-53	2.45	3.06	0.46	0.58	19
53-54	2.26	2.82	0.30	0.38	13
54-55	2.21	2.76	0.39	0.49	18
55-56	No Harvest Hurricane		--	--	--
56-57	3.02	3.59	0.41	0.49	14
57-58	2.75	3.16	0.37	0.42	13
58-59	2.79	3.18	0.44	0.50	16
59-60	3.19	3.60	0.51	0.58	16
1960-61	4.60	5.15	0.40	0.45	9
61-62	5.55	6.10	0.61	0.67	11
62-63	4.72	5.14	0.45	0.49	10
63-64	4.45	4.81	0.47	0.51	11
64-65	4.41	4.67	0.52	0.55	12
65-66	5.14	5.29	0.61	0.63	12
66-67	4.96	4.96	0.82	0.82	16
67-68	4.68	4.49	0.70	0.67	15
68-69	4.57	4.16	0.68	0.62	15
69-70	4.90	4.21	0.90	0.77	18
1970-71	5.14	4.21	0.78	0.64	15
71-72	5.51	4.41	1.29	1.03	23
72-73	7.09	5.32	1.62	1.22	23
73-74	No Harvest Due to Hurricane Agnes in 1972				--
74-75	7.72	4.79	1.39	0.86	18

[1]For an analysis of planting costs for the same oysters, see Table 60.

Additional data obtained from the same Rappahannock plant indicate harvesting the mature oysters (Table 65) to rank second to cost of seed (Table 63) as an expense in culturing oysters. This cost rose from 37¢ a bushel in 1948 to an average of $1.39 in 1975. Over the 1947-1948 to 1974-1975 periods harvesting by tongs or dredges cost from 9% to 23% of the sale price of the mature oysters. It is of major interest to re-emphasize one aspect shown in Table 65: in a period of rising production costs, the adjusted price of the market oysters "declined" after 1962.

The grower must meet other expenses in addition to those just outlined. The grower must pay boat operating expenses and bear the cost of the equipment and stakes used to mark grounds. There are also the expenses of financing boats, cars, shore-based facilities, capital outlay and operation costs. While all these expenses have not been analyzed, it is certain that most have increased during the past 15 years. As a consequence, it is obvious the oyster grower has been caught in a squeeze between a declining adjusted price for market oysters and a consistently increasing cost of producing it.

In preparing this paper it was not practical to take the time to send out questionnaires or interview persons to gain a full understanding of the expenses of a large number of the individuals or companies in the oyster business. Therefore, in the following pages we will show the major items of expense for the two principal types of operations: 1) tongers harvesting from the public rock and 2) growers who plant seed and harvest it.

Tonger Working Public Rocks

A tonger working public rocks basically earns as gross income what he is willing to accept for his day's efforts. He puts no direct effort into growing seed into market oysters he catches except that effort required to cull out the cultch and undersized oysters, depending on whether he is harvesting seed or market oysters. The tonger need not worry about the expenses of planting oysters. They are available to those who are willing to pay a minimal license fee, who can get out to the oyster rocks and are prepared to labor at tonging. The tonger needs to consider only his original investment in boat , tongs, gas and other operational costs. Then he must decide the level of "profit" (sale price of his catch minus his costs of doing business) he is willing to accept as his "wage." Information as to what "the watermen" are willing to work for in the way of "profits" is not available. However, expenses to operate his boat and cover costs of other equipment, goods and services will be outlined in the following pages.

Comparison of Expenses Involved - Tongers on Public Bottoms vs. Growers on Leased Bottoms

The oyster grower operating on leased bottoms must bear the costs of buying and planting the seed and growing and harvesting the resultant market oysters. In addition, money for this operation must often be borrowed and interest charges must also be added to costs. It is evident that the profit a private grower makes per bushel is much smaller than that made by the tonger working the public rocks. We may ask how the private grower continues to operate if his expenses are so much higher than those of the tonger? The answer is basically that the private grower makes his profit in volume sales.

An analysis of costs of operating vessels used in the oyster industry including fuel costs, maintenance and repair, and insurance would be highly desirable to a further evaluation of the impact of rising costs on the industry. Such a study while highly desirable is beyond the scope of this paper. However, we recommend that VIMS undertake such a study in the immediate future.

Comparison Between Costs of Maryland Imports as Contrasted to Virginia Stocks

It was stated in Chapter III that Virginia oyster processors were forced to buy oysters from Maryland in order to maintain their markets. Adequate supplies from Virginia waters were not available.

To show the basic price paid by processors for oysters from various sources we have summarized (Table 66) data on price of market oysters from all available sources (Tables 20, 22, 57 and 58) for the 1963-1964 through 1974-1975 period. An inspection of this table shows a complex array of prices, none of which seem to agree exactly. Part of the variation, however, may be explained. For example, column 1 of Table 66 shows NMFS data for combined public and private grounds presented as a weighted average with the values usually falling between NMFS data for public grounds (column 3) and private bottoms (column 4). The VMRC data for public bottoms (column 2) which excludes James River oysters is also a weighted average and is usually less than NMFS (column 3) which may include "soups" from the James River.

While these data are probably approximations, they do illustrate the major points we wish to establish, which are:

1. Price of Potomac River oysters landed in Virginia (column 5) and those landed in Maryland (column 6) show close agreement;
2. Oysters from the Potomac River landed in Maryland (column 6), in all but two years, were higher in price by 43¢ to $2.12 than oysters from Virginia's public rocks (column 2); in two years NMFS data were lower than VMRC's by 80¢ and $1.16;

Table 66

Dollar Value of Market Oysters from Various Sources

Season	Virginia				Potomac		Maryland
	1. Public & Private (NMFS)	2. Public (VMRC)	3. Public (NMFS)	4. Private (NMFS)	5. Landed in Virginia (NMFS)	6. Landed in Maryland (NMFS)	7. Public & Private (NMFS)
	Table 22	(1)	Table 58	Table 58	Table 22	Table 20	Table 20
1963-4	4.58	4.12	4.76	4.48	4.87	4.79	4.77
1964-5	4.99	4.07	4.54	5.17	5.10	4.72	4.42
1965-6	5.11	4.75	4.63	5.65	6.65	6.35	4.96
1966-7	4.14	4.27	4.64	4.04	4.79	4.82	4.42
1967-8	4.71	4.42	5.18	4.54	5.17	5.12	5.06
1968-9	5.07	4.05	5.34	4.86	5.37	5.30	5.16
1969-70	4.18	4.15	4.36	4.27	4.82	4.87	4.20
1970-1	4.22	4.17	4.13	4.50	5.16	5.09	4.74
1971-2	4.29	4.75	4.09	4.66	5.36	6.87	5.22
1972-3	4.11	5.28	(2)	(2)	4.73	4.48	4.49
1973-4	4.38	5.13	(2)	(2)	5.39	3.97	5.17
1974-5	5.34	5.09	(2)	(2)	7.15	5.52	4.70

Notes: 1. Weighted average calculated from Tables 18 and 57 (James omitted).

2. Data not published yet.

3. Prices of Maryland oysters (column 7) were mostly higher than those from Virginia's public rocks (column 2); differences ranged from 4¢ to $1.11 more in ten years; in two years, however, Maryland prices were 39¢ and 79¢ less than Virginia's;
4. And, in respect to the price of oysters from private leases in Virginia (column 4) during the period, prices in eight out of nine years have been less than prices for Potomac River oysters (columns 5 and 6) and less in six out of nine years than Maryland oysters (column 7).

These data indicate that the Virginia processor on the average has had to pay more for out-of-state and Potomac oysters since 1964 than for those grown within the State.

This finding lends support to a major point advanced in Chapter IV. That is, the Virginia packers or shuckers are not buying Maryland oysters for price advantage. One must conclude they are buying them because they must to satisfy their market due to the lack of sufficient Virginia supplies.

Our study shows the price will be even higher for the Virginia shucker who buys Maryland oysters when they are delivered to his place of business, due to the added transport charges. It is impossible to calculate what the exact added cost might be because of the many variables. An approximation, however, is possible which is based on the assumption that all taxes are paid, directly or indirectly, by the shucker.

1. For a Virginia shucking house operator who needs shucking stock, the additional cost for Virginia grown stocks in 1975 might approximate 73¢, calculated as follows:

a.	Transportation (maximum) from place of sale to processing point estimated on the basis of Table 63	50¢
b.	Virginia inspection tax	3¢
c.	Repletion tax on oysters from public grounds range 15¢ to 30¢ (average)	20¢
	Theoretical total cost per bushel	73¢

Note: The difficulty in arriving at the actual total cost a shucking house operator pays is that the relative amount he processes from public ground (where repletion taxes are required) and that processed from leased bottoms (no repletion tax) is not known. Therefore, the 73¢ just derived is maximal.

2. Similar calculations for Maryland oysters imported into Virginia follow:

a.	Transportation from place of sale to processing point (estimated)	75¢
b.	Maryland inspection tax	5¢
c.	Maryland export tax	10¢
d.	Virginia import tax	3¢
e.	Maryland severance tax for public rock oysters	20¢
	Theoretical maximum cost per bushel	$1.13

Note: In Maryland roughly 85% of the total harvest comes from the public rocks as contrasted with roughly 25% (from 1963 to 1975) in Virginia, but again there is no way of calculating how many oysters brought into Virginia come from public or private rocks. Therefore, the true amount of the severance tax to be added to costs can never be determined. The difference would probably be slight and make little difference to our conclusions.

3. Calculations for Potomac River oysters imported into Virginia for processing follow:

a.	Transportation from place of sale to processing plant	50¢
b.	Virginia import tax	3¢
c.	PRFC inspection tax	25¢
	Theoretical maximum cost per bushel	78¢

Summary

Trends in Price in Relation to Landings and Density on the Bottom

We must now analyze and integrate data on density of oysters, price and landings to account for the decline in oyster production for the State since 1960. Prior to attempting this, we will review again the pertinent information which is shown in synoptic form (Table 67) to aid in following the text. In this summary, we will first review the most important changes and then attempt to interrelate them.

Why Production of Market Oysters Has Declined on the 243,271 Acres of Baylor Bottoms

There is no doubt that one basic cause of today's low production of market oysters since 1960-1961 from the Baylor Grounds is MSX. However, economic conditions have played an important secondary role. MSX appeared in the Bay in 1959 and influenced 58% of the 243,271 acres of Baylor Ground and many productive privately-managed beds. Its impact was especially severe in the lower parts of the systems where salinities exceed about 15‰ (Chapter IX).

A most important factor concerning the impact of MSX is that locations of the Baylor Grounds which are reserved to the public are fixed in relation to the fluctuating range

Table 67

Synoptic Review of Landings, Availability, Price and Production In the 1959 to 1975 Period on Leased and on Baylor Grounds.

A. Market Oyster Landings
(Table 13)

Leased

1959-60 and 1974-75

2,553,275 bu.
- 81% ↘
491,860 bu.

Baylor

1959-60 and 1974-75

699,420 bu.
- 42% ↘
403,737 bu.

B. Market Oysters - Price
(Chapter V and Table 58)

Leased

1962-63 thru 1974-75

1. Unadjusted ↗ or →
2. Adjusted ↘

Baylor

1962-63 thru 1974-75

1. Unadjusted → ↘
2. Adjusted ↘

C. Market Oysters Density
(Chapter IV)

Leased

1960-61 thru 1974-75

1. Less planted oysters due to MSX
2. Oysters not planted.

Baylor

1960-61 thru 1974-75

1. Loss of oysters due to MSX.
2. Lowered recruitment.
3. Loss of growing areas.
4. Decline due to harvesting.

D. Production of Shucked Oysters
(Chapter III)

1. Little change in total volume produced from the State in pre-1960 and post-1960 periods.

Table 67 (Contd.)

E. Imports From Out-of-State
(Chapter III and Table 19)

Pre-1960	Post-1960
Nearly zero	(over 60% in 1975)

F. Seed Oyster Landings
(Tables 14 and 15)

Leased	James River
1962-63 and 1974-75	1962-63 and 1974-75
A major decline in landings but data unreliable	843,833 bu.
	- 62%
	317,003 bu.

G. Seed Oyster Density at Wreck Shoals-James River
(Table 27)

1959-60 thru 1971-72	1956-60 1971-75
1. Declined, but no good data	1325 small oyst.-yearling per bu.
	-71%
	389 small oyst.-yearling per bu.

H. James River Seed Oyster Price
(Chapter V and Tables 61 & 62)

1962-63 thru 1974-75	1962-63 thru 1974-75
1. Data suggests an increase in adjusted price from 1960-1964 and then no change to 1975	1. Unadjusted or 2. Adjusted or

I. Effort in Seed Area - James River
(Chapter IV)

Prior to 1960	1975
400 boats and over per day	less than 100

Table 67 (Contd.)

K. Annual Set - James River
(Chapter IV)

Prior to 1960	After 1960
A. About a 90% decrease in the lower river with a lesser decrease in the upper river.	↘
B. A decline in the Rappahannock and York also.	

of this pathogen. The pathogen can come and go as salinities fluctuate, but the Baylor Grounds and the oysters they bear cannot move. There are other Baylor Grounds elsewhere out of range of MSX or in low MSX areas and these can be used to grow oysters and in repletion efforts; however, these bottoms may not have the same growing characteristics as those forced out of production by MSX. In the foreseeable future, unless the severity of the disease declines, the public rocks in high-salinity areas will continue to be influenced with little prospect for improvement. [It appears as though there has been a decline in severity (see Chapter IX) but MSX remains a factor to be dealt with.]

Table 67 reviews the changes which have taken place on the public bars due to MSX, as well as economic considerations. Production of market oysters from 1960-1975 from public grounds declined from 699,420 to 403,737 bushels, a 42% drop. In the pre- and post-1960 periods the following average declines in numbers and density of market oysters per bushel were noted: York--44%; Rappahannock--19%; Corrotoman--33%; and Piankatank--60% (Chapter IV). In conjunction with these data, we must consider that the adjusted dollar value of market oysters increased until 1962 or 1969 and then leveled off in 1973. A single source indicated an increase from 1973 to 1975. According to all data adjusted price declined after

1962. That is, in a period of decreasing market-oyster production and availability, there also has been a decline in adjusted price. Logically, even if consumer demand remained constant, one might expect an increase in price with declining production which is what normally happens when a product becomes more scarce. The decline in adjusted market price which was experienced suggests a resistance on the part of the consumer to pay more for oysters.

This existence of a more-or-less fixed level of production of processed oysters from Virginia is quite significant, and its true meaning should be the subject of a further, more extensive investigation. It strongly suggests that there is a disinclination on the part of the consumer to pay a higher price for the final product. There is also the possibility that these processors having control over the market have set their prices too high for volume sales, but do realize a good profit at the present price level and volume of sales.

It is not clear how the economic factors have operated in relation to the lowered density of oysters in further reducing harvest, but they must certainly plan an important part. For example, there is no doubt that the standing crop of oysters has been reduced. What is not clear is whether the tonger is willing to work those rivers which have suffered from a "diminished" crop. In relation to this point, we have just shown that the adjusted price of market oysters in Virginia has declined in the period from 1960 to 1975 with costs of equipment and labor rising. We must conclude that there is less profit incentive for watermen to work the public rocks than formerly. The conclusion is: lowered availability and less profit are responsible for today's decline in landings. Unfortunately, data are lacking on catch-per-unit-of-effort so it cannot be determined which of the two variables is the most important.

At the start of this Chapter it was shown the demand for oysters is elastic and would expand to consume an increased supply if the price were lowered. If demand is to increase at the consumer level, there must be a lowering of the price. However, considering today's oyster supply, one aspect is clear. With today's lowered production and the lowered rates of recruitment, any major increase in effort (harvest) would shortly lead to severe depletion of the public rocks.

Seed Oyster on Public Grounds - The Decline and Its Probable Cause

Since 1960 there has been a major decline in seed oyster density on the Baylor Grounds in the James River. Average counts of small and yearling seed oysters-per-bushel-of-bottom-cultch at Wreck Shoals have declined 71%. Annual landings of seed in bushels have declined 62% since 1963 (Table 67).

The decline in seed oyster landings is indicative of an extremely adverse situation since the James supplies about 77% of the seed planted by private growers in the State. It is obvious seed not planted is seed not harvested. This means lowered production (landings) later on of market oysters on leased bottoms.

Factors involved in producing the major reduction in density of oysters on the bottom in the James River in relation to lowered landings of seed must be considered. Doubtlessly, MSX was partially responsible since it killed older seed oysters in the high-salinity portion of the system. The secondary major effect of this disease was that it wiped out the brood-stock oysters which provided larvae set in the seed area. In respect to decreased numbers of larvae, there is also the possibility pollution and other factors were involved. Whatever the cause, the net effect has been a major decline in numbers and density of seed on the bottom over most of the system.

In summary, the lowering in numbers of oysters on the seed oyster beds has been due to the combined impact of lowered recruitment (lowered spatfall), natural mortality and fishing effort. Both natural mortality and fishing effort amount to overfishing in the last analysis.

It is tempting to speculate that the decline in landings of seed is entirely related to the scarcity of seed on the bottom. There is no doubt that scarcity has caused a reduction, but it is likely not the only cause. Available evidence indicates that the problem is much more complex than this and that other factors are involved. For example, there is good evidence that lowered seed oyster landings are also partially the result of a reduced demand on the part of the grower. Reduced demand is also related to MSX and other biological problems, but economic factors have impacted upon the demand for seed. To comprehend this point, the following series of events are presented:

1. MSX (after 1960) was responsible for the deaths of millions of dollars worth of oysters planted on private beds in the lower Chesapeake Bay. These beds annually required about one million bushels of seed. Therefore, when these beds went out of production due to mortalities caused by MSX, this source of demand ceased. It has not been replaced. (Brood-stock for spawning was also removed, reducing spatfall in the seed area.)

2. For reasons which are only partly understood but were probably based on economic factors, the "voids" in production created by MSX in the lower Bay were not significantly compensated for by increased production in other regions of the State. The processors satisfied their demand for shucking stocks by importing oysters from Maryland and the Potomac even though these imports cost more than Virginia oysters. The added cost was passed on to the consumer.

A decline in demand for seed occurred in Virginia due to several factors which showed that the effort going into the harvest of James River seed has declined. For example, as shown in Table 67:

1. Prior to 1960 over 400 boats worked the river daily; from 1967 to 1976 daily number averaged only 100. Thus, the effort going into harvest has declined by three-fourths as measured in this fashion.
2. There has been a 35% reduction in numbers of licenses issued to hand tongers in Virginia since 1961, as compared to the 1951-1960 period. Many of these tongers "worked" the James River (Table 26).

3. There is indirect evidence based on price. If seed were becoming progressively more "scarce" and the demand remained the same or good, its price should have increased as it became progressively more difficult to catch. This was not the case since accompanying the decline in production of seed the adjusted price paid to the tonger remained stable or declined (depending on the source of data) from 1962-1963 through 1974-1975.

4. The point has often been advanced that many of the "troubles of the private grower in the last ten years have been due to the high cost of seed." The ratio of seed cost to dockside price of market oysters has remained nearly constant from 1932 to 1962 and increased only slightly from 1962 to 1975 (Table 64). Therefore, increased costs of seed relative to that of oysters do not appear to have been a major consideration in respect to why growers fail to make a more adequate profit. There is no doubt, however, since seed is one of the major items contributing to production costs,

a reduction in seed price would be of major benefit to the industry.

While scarcity of seed may have escalated the cost of seed above that which it might have been were it more abundant, the fact remains that both demand and fishing effort are far below pre-1960 levels. Virginia lacks an adequate system both for evaluating this important resource and the effort going into its harvest. Because of this lack we can only continue to speculate as to which is the dominant factor.

In maintaining that today's low seed production levels are due to lowered demand, we certainly do not imply that natural causes are not involved nor do we deny that fishing effort has removed many oysters. We find, however, that numbers and density of seed oysters have declined markedly since 1960 and the natural seed productivity of the James has stabilized at a much lower level than prior to 1960. If the present trend toward lowered set continues, even today's lowered level of fishing effort can easily lead to overfishing and a further decline in seed stocks. Most certainly, if demand increases (due to an increase in price) then many of the marginally productive seed areas will quickly become depleted to the point that overall yields from the James River seed beds will fall far below their present levels.

While the James is the principal souce of seed, lesser amounts have come from the Great Wicomico and Piankatank rivers. Evidence indicates that since 1971 these regions also have shown lowered levels of natural productivity.

Leased Areas - The Decline and Its Probable Causes

The decline in production from leased areas in Virginia is due to a number of factors. Due to MSX, over 3 million bushels of oysters died on private leases in the high-salinity regions of Chesapeake Bay in the area encompassed by Mobjack Bay, the lower York and James rivers, the Bay area off Back River and the Poquoson River in late 1959. An unknown number of oysters also died on Baylor Grounds in the same area. The general outline of the impact of MSX and its characteristics were given in Chapter II, and a full description of the effects will be given in Chapter IX. It is necessary here to anticipate some of the information contained in that discussion in Chapter IX in order to develop certain points. Since 1960 production has been eliminated on certain leased high-salinity bottoms. The three largest growers from 1949 to 1957 produced an average of 865,091 bushels of market oysters annually (Chapter IX).

In 1960, just before MSX began to affect oyster populations, market production from private beds totaled 2,533,275 bushels; but by 1975 it had declined to only 491,860 bushels, an 81% decline (Table 13). MSX had a major initial impact on natural production on leased bottoms immediately after 1960, but it is not the only cause of today's lowered landings. Locations of public rocks are fixed in relation to the range of MSX. Private growers can select the planting sites they will use and move to other, more favorable areas (lowered or no incidence of disease) to compensate for production lost to MSX. The Virginia grower is not forced to plant again in the high-salinity beds since it was within his ability to lease bottoms in the mid-salinity regions where MSX is not a problem. The question then becomes: Why didn't those growers affected by MSX relocate, and if they did not, why didn't other growers increase plantings in areas not infected to compensate for the lost production? Large tracts of underused leased oyster ground exist in districts where MSX is not significant (Chapter II). These areas include the upper parts of the York and Rappahannock rivers, the Virginia tributaries of the Potomac, those in the mid-James and extensive areas on the Seaside of the Eastern Shore. A considerable amount of unused acreage exists in these locations which are biologically suitable for oyster culture. Obviously, private industry has chosen not to try to maintain former levels of production from Virginia bottoms. The basic reason is the private growers cannot realize a suitable profit growing them locally.

There are several interrelated reasons involved, including economic ones and without a sound economic study it is almost impossible to determine which aspect has been the major cause.

Certainly one aspect of the problem is that as Virginia's production declined, Virginia shuckers or processors found a good alternative supply in Maryland. The question, then, is why did they use Maryland oysters instead of those that could have been grown in Virginia? Superficially, one would not at first consider price since it has been shown if the Virginia dealer wishes to purchase Potomac River or Maryland oysters, they will on the average cost slightly more than those grown in Virginia. The added cost for "Potomacs" is largely due to a higher dockside price and not for tax and transportation. For Maryland oysters, the difference is due largely to added transportation costs. On the basis of these findings, the Virginia processor could not be buying Potomac or Maryland oysters because of any price advantage. They do so to maintain a steady supply for their customers and to keep business operating at suitable levels in the absence of production from Virginia. The total volume of oysters handled by Virginia processors since 1964 (imports plus native oysters) has remained at the same level, about 2.5 million bushels (Table 20). As the Marine Resources Commission has said, "It was necessary for them (packing houses) to import 1,295,499 bushels of oysters in order to remain in business."

Why don't Virginia growers produce oysters to fill the void on their own bottoms? There are several possible reasons. The Virginia grower cannot afford to gamble by using low-yield grounds as he could have done formerly because of the high cost of seed, labor, supplies and services. Instead, he must farm only his best, most productive grounds where he knows yields are likely to be high enough so he can sell to the processor at an acceptable profit.

Another possibility is the Virginia grower does not plant because he feels he may be undersold at a later date by the Maryland imports which come largely from subsidized production on public rocks and where the harvesters' only expense, outside of his operating expenses, is a small tax. The possibility Maryland producers will be able to undersell Virginia competitors appears contradictory when it was learned, on the average, Maryland and Potomac imports cost the Virginia processors more than oysters grown in Virginia. However, one must recall that the Virginia grower must plan his plantings two or three years in advance of the selling date and is taking a significant risk in investing thousands of dollars in seed, planting costs and interest on loans in his venture. The mystery disappears when one realizes that the cost of Maryland imports, which the Maryland tonger largely obtains from the extensive public grounds (with little capital outlay), can be easily manipulated to undersell the Virginia grower. The

Maryland tonger has no real investment in the oysters from that state as contrasted to the Virginia private grower for oysters grown on leased bottoms in Virginia. The Maryland tonger must pay for only his boat expenses, tax and labor. Consequently, he could price his oysters to undersell those produced on private bottoms in Virginia.

Another possibility, interrelated with the preceding problem of imports, is the Virginia grower simply finds it profitable to farm only his best bottoms and that the availability of Maryland imports has little to do with his decision.

In conclusion, it is impossible to determine here which of the two possibilities (fear of being undersold or absence of a profit) is the primary cause of low production. Moreover, there is a lack of basic catch-per-unit-of-effort data information needed to analyze the problem.

The possibility also exists that the processors, having control over the market, have set their prices too high for volume sales, but do realize a good profit at the present level. This aspect of the economy should be the subject of a special study. Another possibility is while suitable bottoms exist, they are simply being held by those who do not wish others to use them for oyster culture (Chapter II).

One thing is clear, however--the dealer or shucker who processes or sells the oysters buys what is available at the time and pays what he must in relation to today's market. He generally cares little where his supply comes from as long as it is sufficient to meet his demand. Herein lies one of the major points resulting from our analysis. Virginia processors (shucker-packers) have suffered relatively little from the recent decline in oyster production since their volume is about the same as it was prior to 1960. Instead, their principal problems are associated with higher labor and processing costs.

The ones who have suffered the greatest loss are the oyster growers and those associated with growing, harvesting, moving seed and market stock for the growers (i.e., watermen, truckers and boat operators).

It is difficult to determine in detail why oysters produced in Maryland are not processed in that state. Evidence indicates shuckers are more available in Virginia than Maryland (Sutter, Corrigan and Wuhrman, 1968). At present it appears Maryland producers are dependent upon Virginia processors and vice versa. The Chesapeake Bay oyster industry is beginning to be a truly bi-state activity!

The Future - Public Bottoms

The future picture for oyster production on Baylor Grounds seems bleak when viewed in the framework of today's technology and from the present distribution of MSX, and other mortality-producing factors.

It is true that an unusually favorable year may allow a major improvement to occur in strike, or salinity patterns may vary so as to allow survival in a region otherwise troubled by excessive MSX mortalities. A good example of this is the recent decline in drill populations in the lower James, Rappahannock and Poquoson rivers due to Tropical Storm Agnes in 1972. However, the average picture is well represented by the past fifteen years. It is one of lowered yields.

There is hope, however, for the public rocks in Virginia. There is a possibility that oysters will gradually acquire resistance to MSX as outlined in Chapter IV. Another possibility is that production may be increased by the introduction of an accelerated repletion program aimed at the most productive areas and by other improvements. This must be a subsidized program which will "not pay its way" under present management practices unless changes in the rate of taxation or other factors are affected. Techniques for reviving production are already available and await only intelligent application and investments of money. Several of the techniques which can be applied have been used in the past and are being used today. Obviously, they are not working very well since production from public grounds is still very low in relation to the area available, and its presumed growing potential. In fairness to the existing program, it must be stated production might be down still lower if it were not for continuing improvements instituted over the last several years by VMRC. Despite these improvements, State efforts still fall far short of being able to bring the industry back to the pre-1960 period. Of course, neither VMRC nor anyone else can bring about a marked change in application of improved culture techniques and markedly improve production of the Baylor Grounds without additional funds. More money is essential. Also needed are changes in regulation and law. Whether or not the Commonwealth will choose to undertake and underwrite an accelerated repletion program remains to be seen.

Possible techniques for improving the public fishery will be discussed in Chapters VI and XI.

<u>The Future - The Grower</u>

In view of the unfavorable price situation for Virginia growers, it may be asked how the Virginia grower can survive.

A large part of the oysters which are harvested from private leases in Virginia are sold during the periods when the public rocks in Maryland and Virginia are closed. This is because a market demand exists or persists despite closure of public rocks. The processor must have oysters if he wants to supply his market demand. Consequently, the processor must pay whatever price the grower asks.

Another factor which enables the Virginia oyster grower to survive is by planting the grounds on which natural mortality is low, where yields of meats are high, where bottoms are firm, and where there is little disease and few predators. There may be other less desirable grounds where oysters might be grown, but if these are planted, the margin of profit would probably be lower. Large areas of ground where MSX does not cause significant mortalities exist on the Seaside of the Eastern Shore, and the upper parts of the York and Rappahannock. These grounds, while biologically suitable for oyster culture, are not planted because there isn't a sufficient margin of profit.

The best prospect for the private grower, therefore, is to reduce operating costs by utilizing the more efficient technological methods. Savings would make it possible to compete more successfully with the Maryland imports. Reduced production costs would also make it possible to plant higher risk beds and, thus, increase overall production with no serious reduction in profit. If enough did this, total Virginia market production would be increased. Also, the savings might be passed on to the consumer thereby causing an increased demand as outlined by Quittmeyer (1957). Research and methods of improving technology are major needs of the private grower.

The reassignment of unproductive Baylor Survey Grounds to private use would benefit the private grower by making available good growing areas and possibly seed areas where large-scale growing operations might be practiced (Chapter VIII). Thus, high yields could be anticipated, a reduction in operating costs would be possible and allow for competition against low cost imports. This would be done with private money. Currently unproductive grounds would be put into use and the entire industry would benefit.

In conclusion, it is stressed a major part in the statewide decline in landings has been due to the absence of production from leased bottoms. Therefore, if the Commonwealth chose to increase statewide production of oysters to the pre-1960 level, strong and deliberate encouragement for improvements must be given to the private as well as public sector.

CHAPTER VI

REPLETION

CHAPTER VI. REPLETION

Introduction

The Commonwealth has been interested in assisting the oyster industry for at least one hundred years. One noteworthy piece of evidence of this interest was the establishment of the Baylor Survey Grounds in 1894. At that time the leasing system officially began. Very little was done by Virginia with respect to active replenishment of the beds (repletion) for the next 35 years except for enforcement of applicable laws and regulations, collecting taxes and patrol activities.

Active repletion efforts have been undertaken by the State since the 1928 Oyster Repletion Act was passed by the legislature. Since then the Commission (now the Virginia Marine Resources Commission) has undertaken repletion activities. Early efforts consisted mainly of spreading or planting cultch in the form of oyster shells on public oyster grounds for the purpose of catching set and, thereby, increasing the supply of oysters. More recently seed has been transplanted for the same purpose. The effort, the quantity of cultch material planted and the cost increased significantly from 11,678 bushels costing $717 in 1931 to a maximum of 4,148,702 bushels costing $494,482 in 1965 (Table 68). Since 1965 volumes of

Table 68

Shell and Seed Oysters Planted by Virginia
The Cost and the Price[1]
1930-1 thru 1974-5

Season	SHELL Quantity Planted (in bu.)	SHELL Cost ($)	SHELL Cost ($/bu.)	SEED Quantity Planted (in bu.)	SEED Cost (4)	SEED Cost ($/bu.)
1930-1	11,678	717	.06	24,875	7,569	.30
31-2	158,170	12,002	.08	1,704	354	.21
32-3	280,549	12,944	.06	2,060	340	.16
33-4	372,382[2]	20,929	.06	0	0	N/A
34-5	486,462[2]	21,414	.04	29,260	4,754	.16
35-6	241,782	9,572	.04	6,610	1,235	.19
36-7	292,664	16,524	.06	11,520	2,490	.22
37-8	N/A	N/A	N/A	N/A	N/A	N/A
38-9	175,460	6,881	.04	18,100	1,730	.10
39-40	307,779	8,802	.03	5,000	500	.10
1940-1	301,421	9,856	.03	40,145	1,014	.10
41-2	272,618	10,047	.04	37,978	2,427	.07
42-3	87,398	6,647	.08	5,475	388	.07
43-4	264,310	22,666	.08	36,235	8,341	.23
44-5	378,421	30,238	.08	20,882	4,586	.22
45-6	227,551	19,304	.08	18,643	3,729	.20
46-7	369,078	33,431	.09	0	0	N/A
47-8	256,161	27,580	.11	0	0	N/A
48-9	326,823	35,192	.11	0	0	N/A
49-50	701,499	79,516	.11	0	0	N/A
1950-1	495,373	59,399	.12	0	0	N/A
51-2	504,290	71,008	.14	0	0	N/A
52-3	508,344	68,582	.13	0	0	N/A
53-4	509,534	76,471	.15	0	0	N/A
54-5	792,165	114,931	.14	0	0	N/A
55-6	775,034	112,271	.14	0	0	N/A
56-7	550,451	84,763	.15	0	0	N/A
57-8	987,555	151,450	.15	0	0	N/A
58-9	774,867	142,038	.18	0	0	N/A
59-60	889,697	164,889	.18	0	0	N/A
1960-1	950,106	152,005	.16	0	0	N/A
61-2	421,871	77,442	.18	96,460	93,999	.97
62-3	1,054,819	153,029	.14	23,408	15,244	.65
63-4	2,318,379	282,930	.12	82,350	28,772	.34
64-5	4,148,702	494,482	.12	9,577	2,067	.22
65-6	2,978,088	358,888	.12	95,425	32,122	.34
66-7	2,241,563	294,644	.13	37,500	9,750	.26
67-8	2,884,580	469,376	.16	53,418	27,285	.51
68-9	1,032,944	190,729	.18	57,366	39,309	.68
69-70	944,897	179,243	.19	114,613	87,447	.76
1970-1	1,488,494	288,589	.19	129,122	98,156	.76
71-2	964,826	190,156	.20	114,866	90,744	.79
72-3	1,885,718	413,769	.22	0	0	0
73-4	2,256,007	525,252	.23	118,950	106,407	.89
74-5	3,481,727	803,353	.23	50,379	48,508	.96

Table 68 (Contd.)

1. Data from reports of the Marine Resources Commission and its predecessors.

2. Figures given are for the calendar year only.

N/A. Data not available.

shell planted declined slightly, but costs have steadily risen to $803,353 for 3,481,727 bushels in the 1974-1975 season.

Detailed records showing quantity of shells or seed planted in various localities are available from 1931 to 1975 (Annual Reports of Virginia Marine Resources Commission, 1931-1975). Costs of shells and seed involved are available from these same documents. These costs represent the purchase price plus costs of transportation and planting. Also available from these same annual reports is information on costs of administration of the repletion program. Also on file at the VMRC office in Newport News are plots of shellplanting and seed planting areas and receipts showing when and where shell were purchased and planted.

One basic element of the State's shell planting program (Section 28.1-142 of the Code of Virginia) requires shucking houses in Virginia to sell up to 20% of their shell to the Virginia Marine Resources Commission unless those shells are to be planted by the owner in Virginia waters. After purchase the Commission's shells are planted in various locations generally in June, July or August, at rates of about 5,000 and, in some locations, 10,000 bushels per acre. This latter volume, seemingly large, in reality, is only sufficient to cover the bottom to a depth of two to three inches. When softer bottoms are shelled, the quantity of shell needed may be increased up to

15,000 bushels per acre. Those shells first planted serve to firm the bottom and provide a foundation to support those which will serve as cultch.

There seem to be three primary reasons why the VMRC plants shell:

1. To receive a strike of oysters on the shell to provide seed oysters for use by the VMRC and the public, i.e., harvest by watermen for sale as seed to growers or for use on their own growing grounds;
2. To receive a strike of sufficient intensity to provide a later catch of market oysters, and
3. Political considerations, which at times seem to require some plantings of shell in each oyster district.

The repletion program is supported in part by revenues collected by the Commission. Part of these funds are classed as "Special Funds" in the Commission budget.

Special funds are derived from various taxes on the oyster industry. Royalties from mineral products (i.e., sand, gravel, shell) and easements are collected and deposited with the State Treasurer and withdrawn on request by the VMRC. At times, funds from the Federal government provided for fishery improvements or disaster relief and recovery (also classed as special funds) are also available.

All revenue from the following sources goes into the Special Public Oyster Rock Replenishment Fund:

1. Public Oyster Rock Replenishment Tax (Repletion Tax)
2. Public Oyster Rock Export Tax
3. Royalties
4. Easements

The General Assembly has provided monies from the General Fund to support this program.

The aim of public repletion efforts in Virginia was stated clearly by the VMRC in its report to the Governor for fiscal years 1968 and 1969 (p. 18):

> ...an intensive rehabilitation program (was begun) in 1963 in an effort to assist the faltering industry. The program consisted of planting large quantities of oyster shells and transplanting seed oysters to public growing areas.

The goal stated in the preceding paragraph is in agreement with the purpose of the Special Public Oyster Rocks Replenishment Fund as contained in the law. That section of the Code of Virginia of 1950 and the 1974 Supplement read as follows:

S 28.1-94. Public Oyster Rock Replenishment Fund. All oyster replenishment taxes collected by the Commission of Fisheries[1] shall be credited and deposited to a Special Public Oyster Rock Replenishment Fund, to be used only for administration of the program, and for replenishment, planting, and replanting the public oyster rocks, beds, and shoals of this State with seed oysters, oyster shells, or other material which will catch, support and grow oysters. These funds shall be withdrawn and expended for such purpose on the order of the Commission of Fisheries.

Other repletion activities are conducted by VMRC apart from the Special Public Oyster Rocks Replenishment Program. These efforts we will call the regular repletion program. Precise details of the regular repletion program are not presented in the statutes, so we must conclude the Commission has freedom to use its own discretion in setting the policy and practices governing this program.

A recently stated objective of the Special Public Oyster Rocks Replenishment Program has been to develop supplies of MSX-resistant seed oysters. To accomplish this, large quantities of shell have been planted in areas where MSX occurs. Also, seed from these plantings have been transplanted to other public growing grounds (Commission of Fisheries, 1967). The resulting seed oysters grown in these MSX endemic areas will hopefully be

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[1]This reference to the old name of the Commission results from legislative or editorial oversight and should be corrected for consistency.

disease resistant which will enable them to survive. Implicit is the expectation that the progeny of these resistant oysters will inherit genetic traits to resist the disease. According to Andrews (1967) oysters resulting from larvae setting in MSX areas are more resistant to MSX than those setting in a non-MSX area. Reports indicate some of these experiments have been successful (VMRC Reports 1965, 1969 and 1971). Recently several areas planted with shell in Mobjack Bay and the Poquoson River (Type I MSX areas) have produced substantial quantities of market oysters.

Other repletion efforts since 1963 have been aimed at establishing new seed areas in the Great Wicomico and Piankatank rivers and on the seaside of the Eastern Shore as a supplement to the James seed beds. Seed raised from 1963 to 1972 by the repletion program in the Great Wicomico and Piankatank was largely purchased by private oyster growers or by the Potomac River Fisheries Commission.

Information relating to the VMRC shell and seed planting program is available in their annual reports under headings titled as follows:

1. Statement of Oysters and Shells Planted.
   Listed in these tables from 1931 to the present are total bushels of shell and seed planted, costs, and locations planted. The costs represent a total of purchase price, transportation and labor.

2. Repletion of Oyster Beds. These tables list from 1931 to the present the total annual administrative cost of the repletion program. Included are costs of transportation, labor, wages, cars, social security, etc. The costs of policing public grounds are not included. Also listed is a large item termed, "Other Expenses" or "Other Contractual Services." These monies are for planting shells and seed oysters.

3. Special Public Oyster Rock Replenishment Program. These data appear in annual reports of the VMRC from 1963 to the present. This is a special program and is in addition to the repletion effort reported in the above-mentioned table. To derive total expenses of the Commission for repletion from 1963 to the present costs shown in this item and in items 1 and 2 above must be added. That is, to secure data on total costs for seed and shell plantings for 1963 to the present the columns "Other Contractual Services" items 2 and 3 must be totaled. These costs are total expenses for planting shells and seed. They are generally higher than expenses shown in the "Statement of Oysters and Shell Planted."

The records of shell plantings made each year by the VMRC are on file at the Commission offices.

Locations are generally given in terms of recognized names of the various public bars, and by river system for each shell planting. A sales slip showing the dates shells were purchased and planted are also available.

An attempt was made in the early stages of this study to analyze plantings on individual rocks. This task proved impossible due to incomplete records, the large number of rocks and the scattered nature of plantings. Therefore, our analysis of the plantings of shell and seed deals with the data grouped by river system.

A major deficiency of the VMRC shell planting program is that there has been no regular program by the VMRC to evaluate production from the individual shell or seed plantings. Follow-up inspection of plantings has been casual with two notable exceptions with no attempt to document the results in a systematic matter so as to show the cause or reasons for success or failure. At best, success or failure of each year's seed or shell plantings are known only to the watermen and to those inspectors or supervisors who are directly involved with conduct of the repletion program and then only in a general fashion. It is probable that even these concepts are blurred or are forgotten in time.

There are several reasons for this. Prior to 1963 production data for public rocks, based on tax receipts, was reported by districts and it was not until 1963 that it became possible to separate production by river system (Chapter III). Knowing the production by river systems is no help in evaluating how individual plantings may have succeeded because the planted areas are generally small in comparison to large areas of adjoining Baylor Grounds which are not planted but which may themselves be productive. It is not possible to separate the induced or encouraged production resulting from seed and shell planting from that which would have occurred anyway. Therefore, except for a very few cases, an analysis of river-wide production tells little specifically about the actual productivity of a small planting located within it.

There could be two ways of quantitatively evaluating the success or failure of a shell or seed planting. One, which would be difficult, would be to determine the actual catch or harvest (in bushels) by tongers or dredgers from each planted area. A second would be to determine by a systematic, specially designed sampling program the numbers and density of oysters-per-unit-area-of-bottom. Up to 1975 VMRC has not used either technique with any degree of regularity or reliability.

There are only two river systems in Virginia for which it was possible (up to 1975) to evaluate shell plantings in terms of river-wide production. These are the Great Wicomico and Piankatank rivers. These two estuaries prior to 1963 produced no seed because their public rocks contained little suitable shell cultch. The VMRC began planting large amounts of shell in these estuaries beginning in 1963 and coinciding with this seed production (based on tax data) rose dramatically.

In conclusion, records on yields are vital to evaluating any repletion program. Existing records are, generally, inadequate for this purpose. Therefore, we recommend that the Institute or the Commission for management purposes begin immediately systematic, quantitative annual sampling on all areas planted with shell or seed to determine the numbers and density of oysters originating from these repletion activities.

Shell Planting Program

Quantity Planted

The total quantity of shells planted annually in Virginia gradually increased from 11,678 bushels in 1931 to 1,054,819 bushels in 1963 (Table 68), after which there was a major change in the repletion program. Following the recommendations of a Special Study Commission in 1962, the Virginia Marine Resources Commission (then Virginia Commission of Fisheries) greatly increased repletion efforts by creating a Special Public Oyster Rock Replenishment Program. Revenues for this program were obtained from taxes on landings from public rocks and from the Federal government. Other sources were developed and utilized including the General Fund. A separate office was created to manage the program and a Conservation and Repletion Officer was appointed. As a result of this new program, shell plantings increased on public bottoms to 4,148,702 bushels in the 1964-1965 season (Table 68).

Reef Shells

A large part of the shells planted under the new program from 1963 to 1968 were reef shells, which occur as subsurface deposits in many sections of the Bay. These deposits range from a few feet to many feet in thickness. Generally, they are covered with a foot or more of mud or sand, but in some instances they have no overburden of sediment.

The reef-shell program began in Virginia in 1962 when Radcliff Materials, Inc. dredged oyster shells in the vicinity of Craney Island in the lower James River under a five-year contract with VMRC. This contract permitted the company to dredge unlimited quantities of shell. Under the arrangement, as recorded in the October 1962 minutes of the Commission, Radcliff had to pay the Commission a royalty of 15¢ for every cubic yard of shell (there are 15.5 Virginia bushels per cubic yard) dredged, and they agreed to sell the State this dredged shell at 50¢ a yard. Thus, the VMRC obtained about one-third of

Radcliff's production at no cost to the public in terms of money (only the utilization of publicly-owned shell). However, the Commission had to pay the freight charges from the dredging site to the planting site. The VMRC planted 13,007,495 bushels[2] of reef shells. An additional undetermined quantity was purchased from Radcliff by private planters (VMRC, 1969).

Areas where Radcliff dredged in the lower James River were approved by VIMS with final permission given by the VMRC. Areas approved but never dredged were: various locations in Pocomoke and Tangier sounds, the lower Rappahannock near Parrot's Island, and a location in the upper James River just below Jamestown Island. Though Radcliff Materials, Inc. claimed to have made a detailed survey of reef shells in Virginia waters, the results were never supplied to the State. It was never possible for Virginia to agree in detail with the contractor about their claims as to the location, volume and accessibility of the reef shells. This was a great shortcoming of the contract and one that should not have existed. Unfortunately, the true extent of the reef-shell deposits in Virginia has never been determined by adequate survey by any governmental agency. This absence of a survey is a major lack, and one should be undertaken.

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[2]Of this total 503,531 bushels was obtained from a second company.

An agreement to dredge additional areas in 1968 could not be reached with Radcliff Materials. Therefore, Radcliff stopped operations and reef shells were no longer mined in Virginia. The exact reasons for the inability to reach an agreement were never clearly stated. However, VMRC, on the advice of VIMS, refused to give Radcliff access to certain new areas of the James which the company wished to exploit. VIMS specifically recommended against some of the sites the company said were vital to their operation. As a consequence, the total quantity of shells planted by the VMRC dropped to 964,826 bushels in 1972 (Table 68).

Tropical Storm Agnes hit Virginia in 1972 resulting in Federal disaster relief monies being made available to the VMRC. These funds were used by the VMRC in 1973 and 1974 to purchase reef shells from a Maryland company to supplement the supply available under their regular program. The result was the quantity planted rose to 3,481,727 bushels for the 1974-1975 season.

Where Has Shell Been Planted?

A comprehensive overview of shell planting in Virginia from 1931 to 1975 is presented in Table 69. It shows total numbers of bushels planted in the various river systems in relation to acres of public oyster ground in each system. Due to inherent weaknesses in the data a more detailed breakdown is not possible.

Table 69

Shell Plantings by Virginia in Bushels[1]
1930-1 thru 1974-5

Region	1930-1 thru 1939-40	1940-1 thru 1949-50	1950-1 thru 1959-60	1960-1 thru 1969-70	Acres[3] Public Rock
Rappahannock[4]	583,439	982,114	3,225,142	2,654,029	55,185
Eastern Shore Seaside	431,482	402,781	416,282	3,058,725	44,591
James[5]	478,499	532,708	406,629	4,136,782	27,841
Gt. Wicomico, Lt. Wicomico	181,516	273,274	246,033	4,663,350	24,438[2]
Piankatank	83,144	190,929	350,545	3,323,683	15,297
Mobjack Bay	158,566	168,396	645,835	396,056	24,634
Potomac	126,147	481,902	662,021	374,814	2,988
Eastern Shore Bayside	133,473	76,745	274,323	191,263	36,623
York	98,156	71,771	428,945	120,858	3,850
Poquoson	49,504	3,660	40,720	0	7,824
Misc.	3,000	1,000	90,835	56,389	0
Total for State	2,326,926	3,185,280	6,787,310	18,975,949	243,271

Table 69 (Contd.)

Shell Plantings by Virginia in bushels

Region	1970-1 thru 1974-5	Total to date	Bushels/ac 1970-1 thru 1974-5
Rappahannock	1,342,329	8,787,053	24
Eastern Shore Seaside	478,733	4,788,003	11
James	1,720,856	7,275,474	62
Gt. Wicomico, Lt. Wicomico	1,778,701	7,142,874	73[2]
Piankatank	1,188,036	5,136,337	78
Mobjack Bay	1,146,459	2,515,312	46
Potomac	262,943	1,907,827	88
Eastern Shore Bayside	989,862	1,665,666	27 27
York	506,013	1,225,743	143
Poquoson	447,728	541,612	57
Misc.	215,112	366,336	--
Total for State	10,076,772	41,352,237	41

1. Data from annual and biennial reports of the Marine Resources Commission (Commission of Fisheries).

2. This figure included ground in the Little Wicomico and Great Wicomico river and vicinity; relatively few shells were planted in the Little Wicomico (See Table 70).

3. From Table 4.

4. Includes 2,500 acres in Corrotoman.

5. Includes 2,277 acres in Nansemond.

Almost as much shell was planted in the Rappahannock and in the Mobjack Bay region as in the rest of the State prior to 1961. A total of 5,763,492 bushels for those years were planted in these two regions which was 47% of the State total of planted shell (calculated from Table 69). Quantities placed in the remaining rivers and embayments seem to have been about equal and were not related to the acreages of public bottoms they contained.

There also seems to be no relation during the 1931-1960 period between the quantities of shells planted in various locations and the receiving system's potential of yielding a good strike. The York River, one of the poorest systems with respect to setting potential, received almost as much shell as the Great Wicomico[3] which is a good setting area (based on the 1963-1970 record). The Rappahannock, also a poor setting system, received more shell than any other area. In view of the past history of low sets in these two rivers, it is difficult to understand the decisions to plant large quantities of shell there unless a desire to achieve geographical spread or other factors were involved.

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[3]The volume of shells planted in the Little Wicomico was very low.

The program was generally improved from 1961 to 1975 with greater emphasis being placed on planting shell in systems most likely to receive a good strike. This was done partially as a result of advice supplied by VIMS. During this period 16,811,408 bushels of shell (58% of the State total) were placed in the James, Great Wicomico and Piankatank rivers which were good setting areas. The poorer setting areas during this period (with the exception of the Rappahannock and Bayside of the Eastern Shore) received lesser quantitites of shell.

An inspection of Table 69 shows that VMRC planted more shells from 1961 to 1975 than it did in the preceding 30-year period.

Total Shell Planted Compared to Area of Public Bottoms Available

When the total volume of shells planted by the Commission is compared to acreages of public bottom available, it is seen that only a very small fraction received shell (Table 69). For example, if the amount of shells planted in the Piankatank River between 1971 and 1975 were spread over the total public acreage in the region, each acre would have received a total of 78 bushels over the five-year period or 16 bushels per-acre-per-year.

Each acre in the Great Wicomico River from 1971 to 1975 would have received 73 bushels or 15 bushels per-acre-per-year. These totals are far below the actual rate needed for good coverage which is from 5,000 to 10,000 bushels per acre for fairly firm bottom. This leads to the conclusion that only a small fraction of the total public acreage in the region of the Piankatank River (one of the most heavily planted in the State) was covered to adequate levels. If the quantity of shells planted in the Piankatank region between 1971 and 1975 (1,188,036 bushels) had been planted at a rate of 5,000 bushels an acre (as is usually the case), then only 238 acres (about 2% of the total available acreage) would have been adequately covered in the five-year period.

It is fully recognized in making the preceding comparisons that all Baylor Bottoms are not suitable for shellfish culture.[4] The extremely low values shown for the percentage planted, however, clearly illustrates that the shelling of bottoms, as now practiced by the VMRC, probably utilizes only a small part of the potentially productive acreage available.

Total Quantity of Shell Planted in Relation to Total Catch of Market Oysters

It is of interest to compare shell plantings with the total Virginia oyster production of 103,096,121 bushels of

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[4]A study started by VIMS in 1976 is now investigating how much Baylor Ground in each river system is suitable for shellfish culture. However, a shortage of funds threatens to terminate this important project.

oysters from private and public beds from 1931 to 1975 (Table 13). A total of 41,352,237 bushels of shell during this period was planted. If the total number of reef shells (12,503,965 bushels from Radcliff plus 503,531 bushels bought from another reef shell company in 1971, making a total of 13,007,495 bushels) are subtracted from the total shell plantings, we find 28,344,742 bushels of natural shells were planted in relation to a total catch of 103,096,121 bushels of market oysters. That is, about 27% of the oyster shells taken from the water were replanted by the Commission in Virginia waters. Section 28.1-142 of the Code of Virginia requires that each packer or shucker of oysters sell to the Commission at the prevailing market price up to 20% of his shells unless the shells are planted in Virginia by the packer or shucker. This is close agreement indeed between the quantity sold and that required by law. The remainder of the shells were used by private growers for planting or sold to Maryland oyster growers for planting or sold for road-building purposes.

Total Quantity of Shell Planted vs. Yields of Public Bottoms

Data on market oyster production from public bottoms from 1931 to 1975 (Table 13) were averaged for 10-year intervals and the values compared to volumes of shells (Table 69) planted in the same period. An inspection of these two tables shows production of oysters from the public bars in Virginia to have declined drastically even though shell-planting efforts have increased. Market oyster production from public bottoms fell from an average of 549,721 bushels yearly in the 1951-1960 period to an average of only 299,513 bushels in 1971-1975 (Table 13). In this same period shell plantings trended upward from an average of 678,731 bushels yearly in the 1951 to 1960 period to an average of 2,015,354 bushels annually from 1971 to 1975.

The preceding data should not be taken to indicate the VMRC shell-planting program has been of no value since one might argue quite properly that production would have been much lower had it not been for the program. These data show quite clearly that the present effort going into shell plantings has not been sufficient to reverse the downward trend in market oyster production from public bottoms for the State.

Time of Shell Planting

One of the most important considerations relative to the possible efficiency of the shell-planting program is the date (period) when shells are placed in the water. The optimum time for highest efficiency is when the maximum set or strike occurs. This time will vary from late June in the Great Wicomico River to mid-September in the James, but the approximate length of the setting period is relatively constant from year to year for every river system (Chapter IV). Depending upon the regional weather or climate in the drainage basin and factors such as runoff and temperature, yearly shifts of the setting period as great as three to six weeks are common. When unusual occurrences (such as Tropical Storm Agnes in 1972) take place large pertubations in hydrology may result, and even a complete absence of set. If shells are planted too early they will quickly become fouled and receive a much lower set. If they are planted too late sometimes no set will occur at all. Obviously, shell planting should be timed so it occurs in the early stages or just before the peak setting period.

Records obtained at the VMRC and from watermen, dealers and other sources suggest prior to 1963 the time at which plantings were made often was in May and early June -- a period which is too early and,hence,not optimum for most regions. The reason for early planting was that the packers had "help" during this time, whereas later their plants were closed and labor was not available.

More attention has been given by the VMRC in recent years to the correct timing of shell planting, and many areas now receive shells at the proper season.

Shell Planted by River Systems

We have previously outlined how data on production from individual plantings are almost completely lacking. We have also discussed the basic problems in attempting to evaluate public shell planting success or failure on the basis of river-wide production, the only continuous data available. We will now compare public production of seed and market oysters by river system from 1963 to 1975 (Tables 15 and 18) with quantity of shell or seed planted (Table 70). They are presented because they are the best estimates available and to illustrate the inadequacy of the present system (acreages from Table 69).

James River (a moderate set area)[5]

The 4,396,850 bushels of shell planted in the James was over half of the seed oyster catch (6,453,278 bushels) during the same period. Shells were planted on a few, but by no means all of the 25,564 acres of public ground. Since there is always a tremendous residue of natural shell or other cultch material on the bottom in the James, it cannot be assumed the planted shells alone caught this strike. Consequently, the value of shell planted in this system cannot be even estimated by the preceding method.

According to shell-planting records (Table 69) the amount of shell planted from 1961 to 1975 was over 10 times that of the preceding ten-year period. VIMS survey data reveal that in this period availability of small oysters per bushel of material on the bottom declined, as did landings (Tables 28 and 70).

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[5]Criteria for low, moderate and high set areas are defined in Chapter III.

Table 70

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	JAMES			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	175,695	843,833	98,016	0
63-4	417,375	840,675	870,926	0
64-5	449,971	424,234	621,059	0
65-6	487,937	629,442	293,709	22,875
66-7	166,989	555,069	549,050	22,500
67-8	182,020	483,690	243,234	0
68-9	157,669	486,536	0	0
69-70	143,778	264,203	0	24,148
1970-1	170,844	458,637	43,146	19,343
71-2	129,716	381,250	0	0
72-3	27,389	396,169	502,588	0
73-4	186,290	372,537	466,755	0
74-5	61,601	317,003	708,367	0
Totals	2,757,274	6,453,278	4,396,850	88,866

AREA	NANSEMOND			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	17,893	0	0	0
63-4	60,709	0	360,687	0
64-5	65,099	0	329,289	0
65-6	25,008	0	380,483	10,300
66-7	11,227	0	0	0
67-8	3,517	0	234,717	19,206
68-9	1,796	0	80,615	14,277
69-70	1,003	0	0	13,608
1970-1	1,911	0	0	5,315
71-2	2,013	0	0	9,271
72-3	0	0	0	0
73-4	7,624	0	0	16,665
74-5	1,001	0	0	3,000
Totals	198,801	0	1,385,791	91,642

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	YORK			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	0	0	0	0
63-4	258	0	0	0
64-5	112	0	0	0
65-6	2,697	0	0	0
66-7	540	0	120,858	0
67-8	742	0	0	0
68-9	204	0	0	0
69-70	360	0	0	0
1970-1	716	0	0	2,848
71-2	131	0	65,780	2,674
72-3	1,091	0		
73-4	535	0	0	0
74-5	1,233	0	237,049	10,676
		0	203,184	0
Totals	8,619	0	626,871	16,198

AREA	MOBJACK			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	0	0	0	0
63-4	0	0	0	0
64-5	982	0	396,056	0
65-6	165	0	0	400
66-7	361	0	0	0
67-8	568	0	0	725
68-9	1,088	0	0	0
69-70	338	0	0	5,136
1970-1	70	0	0	2,629
71-2	323	0	0	3,223
72-3	532	0	0	0
73-4	3,722	0	421,917	6,369
74-5	4,529	0	724,542	0
Totals	12,678	0	1,542,515	18,482

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	PIANKATANK			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	1,547	0	247,323	0
63-4	7,275	31,049	11,088	3,080
64-5	918	91,152	1,005,779	0
65-6	1,008	118,175	487,291	0
66-7	1,391	60,090	154,160	0
67-8	839	87,480	813,290	9,300
68-9	75	25,596	336,184	7,471
69-70	983	29,218	151,580	0
1970-1	280	27,024	56,914	4,449
71-2	261	40,113	171,810	6,540
72-3	649	0	236,628	0
73-4	1,575	102,236	279,080	5,165
74-5	11,676	34,269	443,604	0
Totals	28,477	646,402	4,394,731	36,005

AREA	RAPPAHANNOCK			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	38,553	7,942	147,215	7,942
63-4	54,303	0	0	27,969
64-5	37,925	0	308,580	0
65-6	30,209	19,150	0	54,950
66-7	10,397	7,500	333,260	15,000
67-8	27,263	0	526,252	2,700
68-9	29,402	0	35,139	6,716
69-70	23,698	0	27,888	50,657
1970-1	65,949	0	22,420	55,922
71-2	80,184	0	129,776	63,930
72-3	93,088	0	460,669	0
73-4	109,199	0	282,400	62,602
74-5	192,180	0	323,278	22,528
Totals	792,350	34,592	2,596,877	370,916

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	CORROTOMAN			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	0	0	62,478	0
63-4	7,286	0	105,772	0
64-5	4,635	0	38,313	0
65-6	209	27,600	56,358	0
66-7	0	7,500	124,966	0
67-8	0	21,955	50,245	0
68-9	0	0	67,381	0
69-70	0	0	63,228	0
1970-1	0	0	20,104	0
71-2	1,527	0	35,880	0
72-3	2,495	0	25,662	0
73-4	1,734	0	33,140	0
74-5	11,151	0	9,000	0
Totals	29,037	57,055	692,527	0

AREA	GREAT WICOMICO			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	1,447	11,725	204,352	10,850
63-4	6,358	38,550	386,264	1,595
64-5	3,874	109,296	902,155	7,280
65-6	3,092	244,239	1,092,955	0
66-7	1,793	146,103	552,184	0
67-8	900	104,200	577,662	0
68-9	915	86,394	302,584	0
69-70	648	170,099	491,494	0
1970-1	522	212,930	1,050,963	1,575
71-2	14,196	70,765	329,980	0
72-3	17,753	0	231,069	0
73-4	39,140	0	29,273	0
74-5	81,546	8,310	131,416	0
Totals	172,184	1,202,611	6,288,351	21,300

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	LITTLE WICOMICO			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	66	0	0	0
63-4	135	0	0	5,254
64-5	1,412	0	0	0
65-6	239	0	0	0
66-7	1,406	0	0	0
67-8	1,803	0	0	1,655
68-9	1,211	0	0	1,100
69-70	1,364	0	0	2,224
1970-1	948	0	0	14,070
71-2	2,647	0	0	13,235
72-3	2,100	0	0	0
73-4	3,643	0	0	0
74-5	1,018	0	0	8,310
Totals	17,992	0	0	45,848

AREA	POTOMAC			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	15,584	0	38,492	0
63-4	10,717	0	18,834	31,701
64-5	5,376	0	39,622	0
65-6	44,976	0	42,168	6,900
66-7	23,665	0	48,866	0
67-8	36,709	0	57,695	9,232
68-9	25,264	0	46,055	27,802
69-70	13,074	0	41,654	16,627
1970-1	31,828	0	59,747	20,254
71-2	26,273	0	89,670	12,845
72-3	3,732	0	98,980	0
73-4	4,156	0	14,546	9,491[2]
74-5	3,417	0	0	11,738
Totals	244,771	0	596,329	146,590

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings in Bushels[1]
1962-3 thru 1974-5

AREA	EASTERN SHORE, BAYSIDE			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	0	0	0	0
63-4	409	0	7,702	0
64-5	1,000	0	0	0
65-6	1,843	0	49,984	0
66-7	3,178	0	0	0
67-8	5,974	0	58,617	1,600
68-9	3,564	0	0	0
69-70	2,217	0	0	2,213
1970-1	4,037	0	0	2,717
71-2	663	0	62,370	3,148
72-3	7,274	0	330,122	0
73-4	14,666	0	203,064	2,551
74-5	17,369	0	514,181	1,006
Totals	62,194	0	1,226,040	13,235

AREA	EASTERN SHORE, SEASIDE			
	Catch		Plantings	
Season	Market	Seed	Shell	Seed
1962-3	9,015	50,544	256,943	4,616
63-4	10,057	95,268	557,106	12,751
64-5	44,560	33,414	507,849	2,297
65-6	8,599	45,789	575,140	0
66-7	5,908	79,313	301,830	0
67-8	2,661	100,022	322,868	0
68-9	6,389	45,949	164,986	0
69-70	4,630	122,806	169,053	0
1970-1	3,604	24,177	189,539	0
71-2	2,029	40,148	79,560	0
72-3	1,627	43,967	0	0
73-4	1,594	53,045	89,759	0
74-5	1,843	19,888	0	0
Totals	102,516	754,330	3,214,633	19,664

Table 70 (Contd.)

Public Rock Harvest Compared to State Plantings
1962-3 thru 1974-5

MISCELLANEOUS

Season	Catch		Plantings	
	Market	Seed	Shell	Seed
1962-3	8,195	0	0	0
63-4	1,975	0	0	0
64-5	0	0	0	0
65-6	0	0	0	0
66-7	0	0	56,389	0
67-8	0	0	0	9,000
68-9	0	0	0	0
69-70	94	0	0	0
1970-1	292	0	45,661	0
71-2	278	0	0	0
72-3	160	0	0	0
73-4	644	0	199,024	15,431
74-5	15,173	0	418,155	3,797
Totals	26,811	0	719,229	18,228

TOTAL

Season	Catch		Plantings	
	Market	Seed	Shell	Seed
1962-3	267,995	914,044	1,054,819	23,408
63-4	576,857	1,005,542	2,318,379	82,350
64-5	615,864	658,096	4,148,702	9,577
65-6	605,982	1,084,395	2,978,088	95,425
66-7	226,855	855,575	2,241,563	37,500
67-8	262,996	797,347	2,884,580	53,418
68-9	227,577	644,475	1,032,944	57,366
69-70	192,187	586,326	944,897	114,613
1970-1	281,001	722,768	1,488,494	129,122
71-2	260,241	532,276	964,826	114,866
72-3	157,890	440,136	1,885,718	0
73-4	374,522	527,818	2,256,007	118,950
74-5	403,737	379,470	3,481,727	50,379
Totals	4,453,704	9,148,268	27,680,744	886,974

1. Data on plantings from annual and biennial reports of the Marine Resources Commission and its predecessor. Data on harvest from publications of the MRC; harvest includes the quantity harvested commercially and the quantity harvested and transplanted by the MRC. (For a breakdown of the seed harvest according to the preceding categories see Table 15).

Table 70 (Contd.)

2. Plus 12 million hatchery seed planted.

Nansemond River (a moderate set area)

A total of 1,385,791 bushels of shell were planted in this system with no seed being produced. There was a total catch of 198,801 bushels of market oysters. This river contains 2,277 acres of public ground and is contiguous with the lower James. Natural cultch is abundant. Though shell plantings exceeded harvest of oysters by a factor of seven, landings in this system were high (Table 70). It is impossible, however, to state whether the shell were in any way directly related to the catch of market oysters.

York River (a low set area)

There are 3,532 acres of Baylor Survey Ground in the York. From 1963 to 1975, 626,871 bushels of shell were planted, or 13.6 bushels per-acre-per-year if all were planted equally. No seed was recorded as having been harvested. From the entire river, an average of only 663 bushels per year or 8,619 bushels of market oysters originated on the public rocks.

The great disparity between the magnitude of shell plantings and the market oyster harvest is striking. There is no apparent evidence that shell planting activity had any positive relation to availability of oysters in the York River system (Table 70). There is a strong possibility that harvest was underreported for this system. Unless it has been, however, shell planting efforts (almost 75:1) have had little effect.

Mobjack Bay System (a low set area)[6]

In this area 1,542,515 bushels of shell were planted on portions of the 24,952 acres of Baylor Survey Ground with no recorded return of seed and a production of only 12,678 bushels of market oysters or 0.04 bushels per-acre-per-year. It may be concluded from these figures that shell planting has been a most unproductive operation in the Mobjack Bay system. Possibly there was a set, but drills or diseases killed much of the spat, or young, before they grew to maturity. It is also possible that landings were not recorded.

Piankatank River (a moderate set area)

The Piankatank resembles the James as a moderate setting area, but differs in that it has little natural shell to serve as substrate--most of the shell which occurs there is planted. A total of 4,394,731 bushels of shell was placed from 1963 to 1975 on portions of the 15,297 acres of public ground in this system. This would be an average of 22.1 bushels per-acre-per-year if all the acreage had been planted evenly, but it was not. A total of 646,402 bushels of seed were harvested for a return of about one bushel of seed for every seven bushels of planted shell. The system produced only 28,477 bushels of market oysters.

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[6] Since 1972 moderate to high sets have been received in sections of this system.

We believe in this river, there is a direct relation between the quantity of planted shell and the subsequent increase in seed production. This is because there is little natural cultch in the Piankatank and because seed production increased after significant shell planting began. Heavy shell plantings beginning in 1973, as shown in Table 70, were followed by good seed harvests in 1965. Available records indicate no seed was produced prior to 1963 from this system. We assume seed harvested after 1964 was the result of shell plantings.

Rappahannock River (a low set area)

The 2,596,877 bushels of shells planted in the Rappahannock River from 1963 to 1975 were distributed over part of the 52,685 acres of Baylor Grounds. If evenly planted, which they were not, this would have amounted to a total of 49 bushels per acre or about 4 bushels per-acre-per-year. The area produced 34,592 bushels of seed and 792,350 bushels of market oysters in this period. Since natural cultch is abundant in this river, there is absolutely no way of determining what part of the seed or the market oyster production was derived from the planted shell. The harvest could also have been underreported, a not unusual event.

Corrotoman River (a moderate set area)

In this river 692,527 bushels of shell were planted from 1963 to 1975 on some of the 2,500 acres of public ground, or 21 bushels per-acre-per-year if planted evenly. During this time only 57,055 bushels of seed were produced and 29,037 bushels of market oysters. Natural bottom cultch is abundant in this system. There was little measurable effect of shell planting on oyster production. Again, there is the possibility of under-reporting of the harvest.

Great Wicomico River (a moderate set area)

This system, like the Piankatank, has been deliberately developed by VMRC as a seed area. It is similar to the Piankatank in that it is deficient in natural cultch. In the period from 1963 to 1975, 6,288,351 bushels of shell were planted and 1,202,611 bushels of seed harvested on 24,438 acres, or 20 bushels per-acre-per-year if all areas had been planted evenly. There was an average return of one bushel of seed for every five bushels of planted shell. The system also produced 172,184 bushels of market oysters.

Prior to the State's repletion efforts, the Great Wicomico produced little seed from its public bottoms. Therefore, we assume seed production in this system to have been the result of planted shells.

The set failed in this system in 1972 due to Tropical Storm Agnes, and failed during 1973, 1974 and 1975 due to low oxygen conditions. Unfortunately, dissolved oxygen values were not measured in this system prior to 1972 when sets were high.

Little Wicomico River (a low set area)

No shell was planted between 1963 and 1975 and no seed were harvested from public ground. Seed planted amounted to 45,848 bushels with 17,992 bushels of market oysters harvested.

Potomac River Tributaries (low set areas)

A total of 596,329 bushels of shell were planted from 1963 to 1975 on a portion of the 2,988 acres of public rocks in that area. No seed harvest was reported, but 244,771 bushels of market oysters were harvested. A downward trend in landings was noted from 1963 to 1975 (Table 70). Natural cultch is abundant in many sections of the system. It is impossible to evaluate the effect of shell plantings on market oyster production.

Eastern Shore, Seaside (a moderate to high set area)

On the Seaside, 3,214,633 bushels of shells were planted on 44,591 acres from 1963 to 1975. This is a rate of 5.5 bushels per-acre-per-year. In this period 754,330 bushels of seed and 102,516 bushels of market oysters were harvested. Again, the absence of quantitative data makes it impossible to even estimate how successful these shell plantings were. Natural cultch is abundant in many areas. SSO is active and oyster drills are present and most destructive.

Eastern Shore, Bayside (a low set area)

From 1963 to 1975, 1,226,040 bushels of shell were planted with no recorded commercial harvest of seed. In this same period 62,194 bushels of market oysters were harvested. Total acreage in this area is 36,623. It is impossible to establish or even guess what percentage of these oysters originated as spat setting on the planted shell. Very likely, only a small fraction originated from the shell since natural cultch was abundant in many areas. Obviously, shell plantings in the bayside areas have been unproductive.

Summary - Shell Plantings

In review, from 1962 to 1975 the VMRC planted 27,680,744 bushels of shells. Seed harvest Statewide was 9,148,268 bushels and market oyster catch was 4,453,704 bushels (Table 70). As stated previously, it is not possible to relate total harvest to total shell plantings with any degree of confidence.

Seed Planting Program

Introduction

Since 1963 the VMRC has been engaged in an accelerated program of seed planting on public rocks (Baylor Grounds) in selected areas of Virginia (Table 70). There have been two interrelated purposes of this program.

The first was to provide a source of market oysters for commercial oystermen in areas when the natural set was low or lacking. The second was part of the Commission's program, funded partially with federal monies, to develop MSX-resistant oysters. Under this last program the State raised oysters from spat in the Piankatank River which was an area subject to MSX. [Oysters raised in this type area are believed to be partially resistant to the effects of MSX (Andrews, 1968).] Subsequently, the VMRC began limited trial plantings of these presumed MSX-resistant oysters in various parts of the State. Unfortunately, due to lack of quantitative data, there is no way of evaluating conclusively the success or failure of this aspect of the repletion program.

The VMRC seed-oyster planting program was small from 1931 to 1946 (averaging about 17,000 bushels a year) and non-existent from 1947 to 1961. With the enactment of the Special Repletion Act in 1962, seed was again planted by the VMRC. Total seed plantings from 1963 to 1975 averaged 68,229 bushels per year (calculated from Table 70).

<u>The Statewide Impact of Seed Plantings</u>

One way of evaluating the seed planting program on public bottoms is to compare the total volume of seed (886,974 bushels) planted in all rivers from 1963 to 1975 with total harvest of market oysters (4,453,704 bushels) from the State for the same period (Table 70). The seed planted was 20% of the market oysters harvested. In the absence of quantitative data on survival and yields from the planted seed, we cannot assume that 20% of the harvest came from the planted seed, but the following considerations suggest that a large part of the seed planted may have been harvested:

1. As was shown in Chapter III, private planters obtain about one bushel of market oysters for every bushel of seed planted.
2. It is probable that the Commission obtained similar yields since their seed was planted over a range of habitats similar to those used by private planters.

<u>James River</u>

In the James 88,866 bushels of seed were planted over a possible 25,564 acres of Baylor Ground. This gives a planting rate of about 0.27 bushels per-acre-per-year over the 13-year period. A large percentage of this seed represents natural strike harvested from Deep Water Shoal and transplanted to the mid-James in the vicinity of Jail Island just above the entrance to the Warwick River. It was moved as part of an emergency program to relocate the upriver seed before it was damaged by freshwater. There is abundant natural cultch in the area and a moderate set. It is impossible to determine from available published data what the results of these plantings were. Probably most of the seed did survive since most diseases and predators are absent in the area of Jail Island.

Mobjack Bay

In this large area (24,952 acres) only 18,482 bushels of seed were planted, which is less than 0.1 bushel per-acre-per-year from 1963 to 1975. In this entire period 12,678 bushels of market oysters were harvested. It is not valid to assume the seed planted resulted in the observed production of market oysters since there is some natural production in the area. Furthermore, drills, *Dermocystidium* and MSX are problems in Mobjack as in other locations and the impact of the seed planting is impossible to evaluate. Undoubtedly, some did survive and were harvested.

York River

Seed was not planted in the York from 1963 to 1970. From 1971 to 1975, 16,198 bushels were planted on portions of the 3,532 acres of public ground there. This is a rate of 0.4 bushel per-acre-per-year. Harvests of market oysters for the period were 8,619 bushels. It is not possible to assess the significance of these recent plantings in terms of yield. Drills, MSX and *Dermocystidium* are present in this system. Consequently, the seed may have died or some or all of it may have been harvested and not reported.

Piankatank River

A total of 36,005 bushels of seed were planted on a portion of the 15,297 available acres (or a rate of 0.2 bushel per-acre-per year) from 1963 to 1975. Production of mature oysters in the same period was only 28,477 bushels. Again, available records are not sufficient to indicate how many planted seed survived. Probably most did reach maturity since drills and disease are not a major problem over most of this system. However, even assuming all of the market oysters originated from this effort, there was a yield of slightly over half a bushel of market oysters for every bushel of seed planted. Since this return is significantly less than that usually realized on planted seed, we conclude that catch in the Piankatank was underreported.

Rappahannock River

With few predators and little disease this river system has received by far the largest planting of VMRC seed in the State. From 1963 to 1975, 370,916 bushels were planted on selected portions of 52,685 acres.

Public rocks in the Rappahannock in the same period provided a harvest of 792,350 bushels of market oysters. If the planted seed survived, as it might have, and returned one bushel of market oysters for every bushel of seed, we may assume it provided a maximum of 47% of the oysters harvested in the river. We cannot say with any degree of certainty how many planted seed actually did survive. Many of the seed were planted in the vicinity of Smokey Point or Morattico where survival is generally good. We believe the seed planting did contribute significantly to the total catch from public rocks. Underreporting of the market oyster catch in the Rappahannock is always a possibility.

Corrotoman River

No seed was planted on public grounds here in the 1963 to 1975 period. The 29,037 bushels of market oysters harvested obviously resulted from strike on natural or planted cultch.

Nansemond River

A total of 91,642 bushels of seed was planted in this area from 1963 to 1975 where there are 2,277 acres of public oyster rocks. This gives a total planting rate of about 3 bushels per-acre-per-year over the 13-year period. Total harvest of market oysters from these rocks in this same period was 198,801 bushels. While this suggests a good yield ratio, one must consider natural production and the impact of diseases and predators which are present in this area. Without adequate records, it is impossible to evaluate the situation in an empirical sense.

Great Wicomico River

Seed plantings in the Great Wicomico were relatively minor since this area is itself a major seed producer in the

State. Almost all plantings of seed were made in 1963, 1964 and 1965. The impact of these plantings on production cannot be evaluated since any possible impact on landings or density on the bottom is masked by the tremendous quantity of seed already present.

Little Wicomico River

Over a 13-year period, a total of 45,848 bushels of seed was planted on 240 acres or about 14.7 bushels per acre. Harvest was 17,992 bushels of market oysters. Even if the rest of the river, independent of this seed, produced no market oysters (but it must have!), the yield of this planting would be about one bushel harvested to three planted. This is far less than the one-to-one average obtained by the State's private planters. Since there are few predators or diseases in this system, we must consider it possible that the harvest of market oysters was underreported.

Potomac River Tributaries (Virginia)

Virginia's Potomac River tributaries from 1963 to 1975 received large plantings of seed totaling 146,590 bushels over parts of the 2,988 acres available which is an average rate of about 4 bushels per-acre-per-year. The total market-oyster production from these same creeks and rivers was 244,771 bushels. The reported harvest was about 1½ times the quantity of seed planted. However, it is impossible to distinguish clearly what part of these were harvested from seed plantings or which originated from the natural strike. Survival of the planted seed (as reported by inspectors and tongers) was excellent in most years due to the absence of significant predators and disease. Hence, the seed probably contributed significantly to the market oyster harvest in the Potomac.

Virginia Seed Planted by the Potomac River Fisheries Commission

In 1966 the PRFC began a seed-oyster planting program in the Potomac River with most of the seed coming from Virginia waters. A total of 68,160 bushels of James River seed and 441,288 bushels[7] of Great Wicomico and Piankatank river seed were planted from 1965 to 1974. Seed from the latter two sources was bought by the Commission from local watermen at a cost of about $1.00 per bushel. Freight, hauling and tax added from 40¢ to 85¢ to this total (Table 71).

Probably most of this seed lived and was harvested.[8] Because it was scattered widely over producing bars, the contributions of this planting to the catches of harvested market oysters can never be estimated.

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[7]Of this total 145,838 bushels came from private leases in 1970, 1971, 1972 and 1973.

[8]In 1975, 1976 and 1977 the PRFC also transplanted 229,500 bushels of natural seed from the lower to the upper river.

Table 71

Summary of Seed Oysters Planted in the Potomac River, 1965 to 1974, from the Great Wicomico, Piankatank, and James Rivers by the PRFC. Price shown is total cost to the PFRC.

		Source - No. Bushels	
Calendar Year	Cost[1]	James	Piankatank and/or Great Wicomico
1965		0	0
1966	1.40	0	70,447
1967	1.43	0	84,968
1968	1.43	8,557	20,807
1969	1.78	19,559	27,210
1970	1.68 - 1.73	0	92,018 7,816[2]
1971	1.85	0	101,326[3]
1972	1.49 - 2.04	3,404	25,000[3]
SUBTOTAL		31,520	429,592
1973	1.88	274	11,696[3]
1974	2.82	36,366	
TOTAL		68,160	441,288

1. Of this, 10¢ is tax, the rest is payment to tonger, transportation, and planting costs.

2. Shellbags from private ground @ $1.73/bu.

3. These values came from private bottoms, the remainder were obtained from Baylor Bottoms.

Eastern Shore (Bayside)

The quantity of seed planted here has been small and amounted to only 13,235 bushels in an area where there are 36,623 acres of public bottoms. We cannot tell what this seed contributed to the 62,194 bushels harvested from 1963 to 1975.

Eastern Shore (Seaside)

Only 19,664 bushels of seed were planted by the VMRC from 1963 to 1975 on the Seaside of the Eastern Shore. This seed probably originated on the Eastern Shore but the reports do not indicate if this was the case. This total was planted on selected portions of the total available 44,591 acres or at the rate of less than 0.1 bushel per-acre-per-year for the period. As stated earlier, 102,516 bushels of market oysters were harvested in the same period. The Eastern Shore has abundant cultch in many places and a high natural strike. It is impossible with existing records to tell what part of the seed oysters planted lived until they could be harvested. Seaside oyster beds are subject to heavy predation of oyster drills. SSO disease also occurs there and there is also the problem of the likely under-reporting of the catch.

Costs of Planting Shells and Seed Oysters

Expenses of planting seed and shell in each year from 1931 to 1975 were obtained from the Annual Reports of the VMRC as outlined at the beginning of this chapter.

Total Cost of the Repletion Program

In representing the total cost of the repletion program, we must include expenses from the VMRC tables entitled Repletion of Oyster Beds and, after 1963, Repletion of Oyster Beds plus Special Public Oyster Rocks Replenishment Fund from the annual reports of the VMRC (first column of Table 72). These figures include salaries and overhead for personnel in the repletion program in addition to the direct costs of planting shell and seed, which have been mentioned in the previous section and are shown in the second column (headed Cost of Repletion Activities) of Table 72.

Total costs of the repletion program have increased from $14,035 in 1931 to a high of $533,628 in 1965. The cost in 1975 was $434,380. The bulk of this money has gone for the purchase and planting of shell and seed (VMRC Annual Reports for 1965, 1967, 1969, 1971 and 1974). In the 1974-1975 season, for example, $304,397 of the total went for these purposes (Table 72).

The total cost of the repletion program has remained about the same during the last decade. The total adjusted costs, adjusted to the 1967 dollar, declined over the period (Table 59).

Table 72

Cost of Virginia Repletion Program
1930-1 thru 1974-5

Season	Total Cost ($)[1]	Cost of Repletion Activities ($)[2]	Cost of Destroying Oyster Drills[3]	Administration and other costs[4]
1930-1	14,035	6,808	0	7,227
31-2	16,204	10,960	0	5,244
32-3	8,937	7,489	0	1,448
33-4	6,970	4,506	0	2,464
34-5	43,688	38,471	0	5,217
35-6	15,902	14,068	0	1,834
36-7	19,490	15,908	0	3,582
37-8	18,475	15,846	0	2,629
38-9	19,780	16,044	0	3,736
39-40	10,561	7,814	0	2,747
1940-1	10,554	6,354	0	4,200
41-2	24,250	11,326	892	12,924
42-3	12,469	6,696	1,452	5,773
43-4	35,099	29,351	1,966	5,748
44-5	39,189	34,122	1,048	5,067
45-6	21,438	19,304	737	2,134
46-7	45,933	39,313	1,636	6,620
47-8	50,677	43,924	380	6,753
48-9	42,633	35,234	1,344	7,399
49-50	85,840	79,569	1,025	6.271
1950-1	67,866	59,109	1,538	8,757
51-2	83,108	71,038	2,179	12,070
52-3	86,162	68,592	1,185	17,570
53-4	87,796	76,488	0	11,308
54-5	125,643	114,957	1,436	10,686
55-6	136,919	124,533	4,016	12,386
56-7	141,026	120,834	14,856	20,192
57-8	187,529	173,925	8,953	13,604
58-9	142,469	129,836	5,804	12,633
59-60	143,263	131,668	5,674	11,595
1960-1	N O T	A V A I L A B L E	8,102	
61-2	222,432	203,594	0	18,838
62-3	217,126	181,523	0	35,603
63-4	386,742	317,768	0	68,974
64-5	533,628	462,535	0	71,093
65-6	419,800	342,489	0	77,311
66-7	410,339	334,324	0	76,015
67-8	520,433	437,098	0	83,335
68-9	382,498	300,503	0	81,995
69-70	289,807	210,507	0	79,300
1970-1	396,173	314,684	0	81,489
71-2	366,818	283,603	0	83,215
72-3	511,844	412,993	0	98,851
73-4	408,245	301,301	0	106,944
74-5	434,380	304,397	0	129,983

Table 72 (Contd.)

1. Data from annual reports of the Marine Resources Commission and its predecessor, table entitled "Expenditures for Year Ending. . ." (usually Table 2.)

2. Data from above table(s), item usually entitled "Other Expenses"; the bulk of this expense is "for the planting of shell and seed oysters." (Annual Report for 1968 and 1969, p. 46).

3. Data from annual reports, table entitled "Statement of Oysters and Shells Planted" (usually Table 4.) Expenses shown in this column are probably included in column two.

4. Computed by subtracting the second column from the first.

5. Blanks indicate that data were not available.

Cost of Shell Per Bushel

A basic cost evaluation of the VMRC repletion program must include a discussion of expenses of planting seed and shells. One way of displaying or examining these data is to include costs of buying, transporting and planting shells and seed which are tabulated in the "Statement of Oysters and Shell Planted" in the Commission's Annual Report (Table 68). These data show costs of shell per bushel to have increased in a regular way from 6¢ a bushel in 1931 to 23¢ a bushel during the 1974-1975 season.

Data obtained from the records of one Rappahannock River planter agrees with these figures. Per bushel expenses from this latter source are: 1962--11¢; 1964--15¢; 1965--12¢; 1966-12¢ and 18¢ in 1967.

The preceding figures, both those for the private grower and those for the VMRC, include the purchase price plus cost of freight and labor for planting. They do not include other associated expenses or overhead. Some of the associated administrative expenses are time, travel and correspondence required to determine where to plant shells, arrangements for the purchase and planting of the shells, supervising the planting and regulating harvesting from planted beds.

Cost of the Shell Planting Program - 1962 to 1975

Another way to examine shell planting costs is to examine the total cost required to conduct the program from 1962 to 1975 when good data are available. Total cost is defined to include overhead or indirect costs, such as salaries, office communication and transportation expenses, as well as direct costs of purchasing, transporting and planting the shells.

The total costs from 1962 to 1975 of the VMRC's Repletion Program, which includes both the shell planting program and the seed planting program, was $5,277,833 (Table 73, Column 1). The direct cost, as defined above, of the State's seed planting program was $585,811 (Table 73, Column 2). This figure was subtracted from the total cost, $5,277,833, to get a result of $4,692,022 which represents the total cost of the shell planting program (Table 73, Column 3).

The figure presented immediately above represents the total cost of the shell planting program and includes overhead or indirect costs for the seed planting program as well as for the shell planting program for this reason: the Annual Reports of the VMRC contain two tables showing all costs for the two parts of the repletion program. These tables do not distinguish between overhead costs of the shell planting activities and those of seed planting.

Table 73

Average cost per bushel of shell & seed planted on public ground in Virginia with overhead included 1962-3 thru 1974-5

Season	Cost of Entire Repletion Program[1] ($)	Cost of Seed Planting[1] ($)	Cost of Shell Planting[2] ($)	Quantity of Shell Planted[1] (bu)	Quantity Of Seed Planted[1] (bu)
1962-3	217,126	15,244	201,882	1,054,819	23,408
63-4	386,742	28,772	357,970	2,318,379	82,350
64-5	533,628	2,067	531,561	4,148,702	9,577
65-6	419,800	32,122	387,678	2,978,088	95,425
66-7	410,339	9,750	400,589	2,241,563	37,500
67-8	520,433	27,285	493,148	2,884,580	53,418
68-9	382,498	39,309	343,189	1,032,944	57,366
69-70	289,807	87,447	202,360	944,897	114,613
1970-1	396,173	98,156	298,017	1,488,494	129,122
71-2	366,818	90,744	276,074	964,826	114,866
72-3	511,844	0	511,844	1,885,718	0
73-4	408,245	106,407	301,838	2,256,007	118,950
74-5	434,380	48,508	385,872	3,481,727	50,379
Total	5,277,833	585,811	4,692,022	27,680,744	886,974
Average Cost Per Bushel		66¢	17¢		

1. Data from annual reports of the VMRC shown in Tables 68 and 72.

2. This is the cost of the entire program less the cost of seed planting. This figure is, then, the cost of shell planting plus overhead for the entire Repletion Program. The justification for including all overhead costs with the shell planting phase of the Repletion Program is that the main purpose of the program was to plant shells rather than to plant seed. In other words, the seed planting part of the program was incidental.

Since VMRC reports show only a single figure for overhead, we could not separate or distinguish overhead costs of seed planting. It seems reasonable to us, when calculating the total cost of shell planting, to assign all the overhead expenses incurred by the Repletion and Conservation office to the shell planting program because the main activity of the repletion program has been shell planting (Commission of Fisheries, 1931 and 1967). The seed planting part of the program was a minor part of the whole.

This reflects the preference of the Commission for shell planting as an oyster repletion technique. Only in recent years has a VMRC officer publicly proposed the emphasis be shifted from planting shell to planting seed (VMRC, 1969). The emphasis, however, in the repletion program continues to be on planting shell.

The average cost per bushel of shell planted for 1963 to 1972 figured without overhead was 15.5¢ (Table 68, Columns 1 and 2). When the total cost of the shell planting program including overhead was considered, a higher average cost of 17¢ per bushel was obtained (Table 73).

<u>Cost of Seed Planting Program - 1962 to 1975</u>

From 1962 to 1975 the Commission harvested, transported and planted 886,925 bushels of seed from all public grounds, mainly from the Piankatank and Great Wicomico, which cost $585,811 (Table 73, Columns 2 and 5). Calculations show this to be an average of 66¢ per bushel. At this price it is logical to conclude that seed raised by the VMRC for planting costs very little per bushel. The same conclusion is apparent after looking at the same figures from 1931 to 1975 (Table 68). But this is only part of the expense for there is one more element to consider--the cost of the shell which the VMRC had to plant in order to get the seed.

The amount and cost of shell planted per bushel of seed returned cannot be determined for the whole State due to insufficient data, but it can be approximated for the Great Wicomico and Piankatank. Prior to 1963 there was not enough natural cultch in these rivers to catch a set sufficient for large-scale commercial production. Shell had to be planted. It may be assumed that most of the seed harvested from these rivers after 1962 can be attributed to the Commission's shell planting program!

The VMRC planted 10,683,082 bushels of shells in these two rivers from 1962 to 1975. During the same period 1,849,013 bushels of seed were harvested from these shell plantings (Table 74). For each bushel of seed harvested, 5.8 bushels of shell were planted. Earlier it was shown that each bushel of shell planted cost the Commission 17¢. Therefore, each bushel

Table 74

Comparison of Quantity and Cost of State Shell Plantings with Quantity and Value of Seed Harvested in the Great Wicomico and Piankatank Rivers
1962-3 thru 1974-5

Shell Planted		Seed Harvested	
Quantity	10,683,082 bu	Quantity[1,3]	1,849,013
Cost a) Total cost (bu x 17¢)	$1,816,124[2]	Value	
		674,449 bu[4] @ 66¢[5] =	$ 445,136
		1,174,564 bu[6] @ $1.00[7]	$1,174,564
		Total	$1,619,700

Comparisons:

1) Quantity of shell planted per bushel of seed harvested
10,683,082 of shell ÷ 1,849,013 bu. seed = 5.8 bu. shell per bu. seed.

2) Cost
a) Total cost of shells planted per bushel of seed harvested $1,816,124 ÷ 1,849,013 bu. seed = 98¢ per bu. seed.

Table 74 (Contd.)

1. Data from biennial reports of the VMRC (Table 70).

2. This figure includes other costs associated with the shell planting program such as salaries, administration and material upkeep as well as the direct costs of the shell which was planted. It was determined by dividing total cost of the repletion program (less cost of seed planting) by total shell planted to get an average cost of 17¢/bu. for shell planted (Table 73). Then the quantity planted was multiplied by the cost/bu.

3. Data from the VMRC (Table 15).

4. Quantity of seed transplanted by the VMRC from these two areas. Data from the VMRC (Table 15).

5. The average price paid by the VMRC for harvesting and transplanting the seed. Calculated from data in biennial VMRC reports (Table 73).

6. Quantity of seed sold by tongers on the open market (Table 15).

7. This is the price of most Piankatank and Great Wicomico seed as determined from VMRC reports and from buyer's reports (Table 61).

of seed on the bottom has cost the Commission an average of 98¢ over the 1963 to 1975 period (17¢ x 5.8).

To find the total cost paid by the VMRC for placing a bushel of seed raised in the Great Wicomico or Piankatank Rivers on the intended growing areas, one must add the cost of shell planting on seed beds (98¢/bushel) to the cost of harvesting, transporting and planting the seed which is 66¢/bushel (Table 73). When this is done it is apparent that the average total cost to the State from 1962 to 1975 of raising or developing and planting one bushel of seed from these two rivers was about $1.64/bushel (66¢ plus 98¢).

The shells which do not receive a "set" still remain on the bottom, and have some worth for repletion. The point still remains--from 1962 to 1975 the average return was only one bushel of seed to 5.8 bushels of shell. These shells will continue to firm the bottom and provide substrate for subsequent plantings or catches. If cleaned and turned over they can be made to catch more oysters, perhaps more than the first year that they were overboard.

Between 1962 and 1975, 1,849,013 bushels of seed were harvested from the Great Wicomico and Piankatank rivers. Of this total only 674,449 bushels were replanted by the Commission. The Commission utilized less than half of the seed it raised. The remainder, 1,174,564 bushels (Table 74), was tonged from the bottom by watermen and sold to private planters or to the PRFC for about $1.00 per bushel. Records of the PRFC show this bi-state agency purchased 295,450 bushels of this seed (from Baylor Grounds) from 1965 to 1974.[9]

The monetary return from 1963 to 1975 to the VMRC from the seed which was sold and planted on leased bottoms and on public bottoms in the Potomac River was the tax it levied on the seed when it was harvested by the watermen, and when the oysters were shucked. This amounted to a maximum of about 10¢/bushel when it was harvested or $107,797 (Table 75). There was the inspection tax of 1-1/2¢ a bushel when the oysters were processed (Table 9). Both taxes might have yielded a total return of about $125,415.

When the Great Wicomico seed was harvested in 1970 - 1971 by tongers they were paid about $1.00 per bushel by the buy boat or truck operators (Table 61). Freight to the Rappahannock cost about 40¢ per bushel in 1970. This brought the private planter's total cost to $1.40 per bushel. This can be compared to the 1962 - 1975 average cost of $1.64 to the VMRC. The cost

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[9]The PRFC purchased an additional 145,838 bushels from private planters in the Great Wicomico making a total planted 441,288 bushels.

Table 75

Revenue from seed harvested by tongers from public grounds in the Great Wicomico & Piankatank Rivers 1962-3 thru 1974-5

Season	Quantity Harvested (bu)[1]	Repletion Tax rate[2]	Amount of Revenue
1962-3	0	$ .03	$ 0
63-4	0	.05	0
64-5	193,168	.05	9,658
65-6	332,014	.10	33,201
66-7	206,193	.10	20,619
67-8	160,217	.10	16,022
68-9	54,624	.10	5,462
69-70	101,961	.10	10,196
1970-1	126,387	.10	12,639
71-2	0	.10	0
72-3	0	.10	0
73-4	0	.10	0
74-5	0	.10	0
Total	1,174,564		107,797

1. Data from reports of VMRC. (Also shown in Table 15).

2. Laws of Va. relating to Fisheries of Tidal Waters. Reprinted from the Code of Va. of 1950 and the 1962, 66, and 70 Supplements. The Michie Co. Charlottesville. (Also shown in Table 11.)

to the grower of the Piankatank and Great Wicomico seed, however, was not a true value which included the costs required to produce the seed as well as its harvest. The cost was simply what the tonger charged for his labor and operating costs. The growers, therefore, paid only the cost to harvest, transport and plant the seed but not to produce it.

The 674,449 bushels planted by the VMRC on public bottoms would yield additional revenues when they were harvested. The revenues are estimated as follows:

Repletion tax	- 20¢ x 674,449 =	\$134,890
Inspection tax	- 1½¢ x 674,449 =	10,117
	Total	\$145,007

Totaling \$145,007 plus \$125,415, we obtain a return in revenue of \$270,422 to the State which is about 15 cents on every dollar invested by the VMRC in planting shells in the two rivers.

It is not possible to estimate tax revenues obtained from shells planted in other regions where the spat were allowed to grow to maturity.

In conclusion, while the estimates presented in the preceding paragraphs are speculative they serve to illustrate one of the major points in this chapter. The costs of the repletion program are not paid back to the Commission although as will be shown the final value of the oysters derived from the program is larger than the original amount spent.

Other Purposes of Seed Planting Program

Shell plantings are not the sole source of seed planted by the Commission. In a few instances the VMRC obtains seed from natural rock in areas where setting is reasonable but growth is poor or where the seed is threatened, as by damage from freshwater. It has been found desirable to move freshwater threatened oysters from Deep Water Shoals in the James a short distance downriver where conditions for growth and harvest are more favorable.

The records of these specific "short distance moving" operations are sketchy, and data necessary to evaluate their success or failure are not available. Published information (VMRC Annual Reports for the period) shows from 1963 through 1972 a total of 88,866 bushels of James River seed (mostly from Deep Water Shoals) was transplanted downriver to Jail Island Bar and Days Point Shoal in the middle of the oyster producing region. The total cost of transplanting these oysters within the James is not known. Probably, it was somewhat less than the 66¢ per bushel average calculated for the whole seed planting program (Table 73), since the distances the oysters were moved was only about 8 miles.

In recent years VMRC has conducted experimental plantings in an attempt to increase the populations of MSX-resistant oysters. Seed oysters which set in areas where MSX is active (such as the Piankatank River) were transplanted to growing areas where MSX is present (such as the Nansemond River and Mobjack Bay) in order to observe their survival. Reports indicate favorable results were realized in some of the experimental seed plantings in MSX areas.[10] Data are not available to allow a quantitative evaluation. Between 1963 and 1972 an estimated 113,890 bushels of seed were transplanted to MSX areas at an estimated expense of $68,334.

The Repletion Program as a Subsidy

Since its beginning the Repletion Program has been a partial State subsidy for the entire oyster industry. It benefits the watermen who work the Baylor Survey Grounds and the processors, shippers, and private growers. The program has not been self-sustaining for the Commission since the costs for planting shell and transplanting seed exceeds the return in taxes.

Difficulty in Evaluating Total Impact

It is not possible to evaluate the total impact of the VMRC Repletion Program due to the absence of accurate and

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[10] Commission of Fisheries 1965, p. 14; VMRC 1969, p.22; VMRC 1971, p. 20 and 21.

specific information on yields from most shell and seed plantings. With the exception of the Great Wicomico and Piankatank rivers harvest data which might allow evaluation of the success or failure of individual plantings do not exist. Seed plantings may have been completely successful or they may have been killed by drills or diseases or smothered by silt deposits or some other calamity. The results were somewhere in between depending on whether the seed were properly handled and placed. Shell plantings may have produced high yields of seed or market oysters or failed due to one or more factors such as the absence of set, fouling or drills.

Prior to 1961 much of the shell planted in State waters was wasted since only about half was planted in areas which received marginal or better sets. Also, a considerable portion was planted at the wrong time to secure optimum set. There was a change in policy in 1962 with emphasis placed on planting shells in areas known to receive moderate or better sets. From 1962 to 1975 about 58% of the shells were planted in the James, Great Wicomico and Piankatank rivers with the VMRC spending $5,277,833 on planting shells and seed. During this thirteen-year period 27,680,744 bushels of shells and 886,974 bushels of seed were planted in Virginia (Table 73). This total for seed includes seed raised by the VMRC from the Great Wicomico and Piankatank rivers, Eastern Shore seed and seed transplanted from the upper to the lower James.

While we cannot estimate the returns from shell plantings for most areas we did analyze those for the Great Wicomico and Piankatank rivers. These data illustrate two major points: 1) the Repletion Program expenditures far exceed the income derived by the VMRC from the program; and 2) over the years the VMRC has realized only a small part of the benefit of its own program.

The combined data for the Great Wicomico and Piankatank rivers indicated the approximate cost of producing one bushel of seed to VMRC to have been 98¢ per bushel. Costs of raising, transporting and replanting a bushel of seed came to $1.64 per bushel. This latter figure was slightly higher than cost to private planters for James River seed in 1972 (Table 63).

Economic Benefits of the VMRC Repletion Program to the State

In terms of its value to the overall economy of Virginia, there is no doubt that the Repletion Program produces a definite net benefit. The value of the seed produced goes to Virginia tongers and processors who in turn pay out some of this for other goods and services. When the market oysters resulting from this seed are harvested and sold Virginia oystermen receive the at-landing value for them. Some of this value is paid out again for boat maintenance, gas, oil, provisions and repair parts. Most market oysters undergo some processing which further adds to their value and provides jobs for shuckers and other processing plant workers. The men who transplant the oysters and the wholesalers and retailers who sell them also receive money for their services, labor and costs.

Theoretical Wholesale Value of Oysters Originating from the Repletion Program in the Great Wicomico and the Piankatank

We may estimate a part of the wholesale value of oysters derived from Virginia's Repletion Program on the following basis (seed oysters only).

1. From 1962 to 1975, 1,849,013 bushels of seed oysters were harvested from the Great Wicomico and Piankatank rivers. Of this total, 674,449 bushels were planted on public bottoms in Virginia; 295,450 bushels were bought by the PRFC and placed on bottoms in the Potomac River; and the remaining 879,114 bushels were planted by Virginia private planters on their leased grounds.
2. We may assume, based on the experience of private planters, a return of one bushel of market oysters for every bushel of seed planted.
3. The approximate value of the marketable oysters (1962 - 1975 at the wholesale level in the shell) was $4.50 per bushel.
4. All of the oysters planted in the Potomac River were processed in Virginia.

Therefore:

a.	Planted by VMRC on public bottoms:	674,449 bu x $4.50 = $3,035,020 when grown and harvested
b.	Planted by PRFC and landed in Va.:	295,450 bu x $4.50 = $1,329,525
c.	Planted on leased bottoms in Va.:	879,114 bu x $4.50 = $3,956,013
	Total	1,849,013 bu $8,320,558

If we assume a yield of 6 pints of meats per bushel and a minimum wholesale price of $9.50 per gallon for "selects" (1970 value), then the meats from the 1,849,013 bushels would have a gross value of $13,174,218. If the price is calculated on the basis of "standards" at $8.50 per gallon then the meats would have a gross value of $11,787,458. Although we are discussing gross values and not separating the expenses or costs involved, it is obvious that the value of the product, even at the wholesale level, exceeds the original investment of the VMRC.

The Future of the Repletion Program

In view of the total economic value to Virginia shown for shell and seed plantings and in view of the continued lowered rate of setting in the James River the main objectives of the VMRC, if it decides to increase production, should be directed toward seed and shell planting to increase supply of both seed and market oysters. There is little doubt the industry would benefit economically by this increase. Of course, there is little direct return to the VMRC for its investment. Therefore, under the present management plan, at present level of taxes, fees and rentals, increased effort by the Commission will require increased funding from the General Fund or from special funds not derived from the oyster industry itself, i.e., federal monies or increased royalties for dredging, filling and mining activities.

The question might be asked: Why should VMRC make efforts to increase the supply of seed when there appears to be adequate supply in the James to meet present low demands? There are several answers to this question and while none are conclusive or final they do lend support to the original contention that efforts to produce more high quality seed would tend to lower costs of production and thus benefit the industry as a whole.

The stock of seed oysters in the State are on the decline due to a much lowered recruitment rate and while the present seed supply is marginally adequate to meet today's level of lowered demand, it would not be if demand were increased. Efforts to increase seed production to meet developed demand would have to be started several years ahead of the time when increased demand actually materializes. Shell plantings in the James (and the Piankatank) should be deliberately increased in order to meet anticipated increases in demand for seed as the industry picks up.

One of our major recommendations is that certain unproductive Baylor bottoms be made available for leasing. Such a measure, if adopted, will undoubtedly increase demand for seed. Moreover, if the VMRC continues at the present level or increases its seed transplanting to replenish public bars, then the supply of seed will clearly be insufficient without an increase in production.

The question of who should benefit primarily from the VMRC shell and seed planting programs (public tonger or private planter) has always been an unresolved problem. The public rock seed and shell planting program is controversial since private planters usually maintain that it acts to depress the price he will obtain for his own privately produced oysters by introducing competition from public sources. There may be some truth in this argument since an oyster shucker, broker or processor buying oysters does not care where his oysters come from as long as they yield well in terms of meats shucked-per-bushel and the costs to him are such that he can make a profit after processing. For these reasons he will purchase his shell stock from the source with the best combination of price and meat yield. Understandably, the private grower who finds or believes the State's seed planting program to be competitive with his own operations can be expected to view any attempt to enlarge the program with resentment.

Opinion favoring those who work on public bottoms says that all of the seed produced from State shell plantings should be replanted by the VMRC on public grounds in Virginia. One argument for doing so is any repletion undertaken by the State should be aimed at benefiting only the public bottoms (and the tongers) and not the private sector (the growers). According to this argument planting shell to provide seed for sale to private growers would be stopped. However, as presented in the statutes the purpose of the Special Public Oyster Rocks Replenishment Fund is not necessarily to benefit any particular segment of the oyster industry. Hence, the current use is entirely legal from this point of view.

It is possible to argue, in the case of the Special Public Oyster Rocks Replenishment Fund, that since it is supported entirely from public monies (or royalties and other fees extended from industrial activity) the plantings paid for by the fund should be directed solely toward the benefit of the public grounds, and public sector of the industry. Likewise, there is logic in the contention of some that since inspection tax revenues, ground rents, and other fees paid by private growers contributed to the support of the regular repletion program, this program should be aimed at benefiting private growers primarily. Others, more moderate, are content that both segments are benefited. In attempting to determine which course is most proper, if either is, we conclude that private growers and businesses are also citizens and should be eligible for public help. The public tongers, or tongmen as earlier specialists called them, will naturally benefit from any program directed at repleting the public rocks. As a consequence we see no reason to exclude either party from public help.

The VMRC appears to have exercised three options in the past in its use of the seed raised in its repletion program. These are:

1. Some seed has been moved by the VMRC to good growing areas at an approximate total cost of $1.64 per bushel. In these new locations, it has been harvested in 2 or 3 years as market oysters by the public tongers with a possible monetary return to the State of 10¢ to 30¢ Repletion Tax per bushel, plus the 1-1/2¢ per bushel Inspection Tax.
2. In other instances seed setting in an area may have been left for 2 or 3 years until it grew to market size, at an approximate total cost to VMRC of 98¢ per bushel. The monetary return to the State was a 10¢ to 30¢ Repletion Tax per bushel plus the 1-1/2¢ per bushel Inspection Tax.

3. Seed raised by VMRC may be harvested by watermen and "sold" to private growers at whatever price the tonger wishes and is able to charge for his efforts. The monetary return to the State was 5¢ to 10¢/bushel Repletion Tax when harvested while VMRC's cost was 98¢/bushel.

There is a fourth option which though not used has been suggested before. This is:

4. Seed raised by VMRC at an approximate cost of 98¢/bushel could be sold directly to the grower at cost or at a slight profit. Harvest would be by the buyer or grower.

Another option would be:

5. The grower could be allowed the use of Baylor Grounds, even in the James, (for a fee) for growing his own seed. (This option will be discussed in the next chapter.)

If seed is sold to private buyers at "cost" then another question arises: Shall the tonger who works the public rock be charged in a similar manner? The methods and questions just outlined are not resolved in this chapter. They are presented here only to indicate the numerous questions which arise and the many decisions which would be involved in an expanded repletion program.

One aspect basic to our entire repletion effort that must be fully realized is the relationship between the public and private sectors of the industry. As it is now constituted, the private sector is not self-sustaining. It is dependent on the public sector for seed.

The private sector has always been indirectly subsidized by the State with respect to its seed supply. Since the beginning of the industry many years ago the Baylor Grounds (managed and controlled by State funds and personnel) supplied all or most of the seed oysters planted on private bottoms. The James in 1972 provided about 77% while about 20% was furnished by the Piankatank and the Great Wicomico rivers, and private sources.

Today State beds are almost the sole source of seed for private growers and are a necessity rather than a choice of industry. One objective of the Baylor Survey was to set aside for public use all of the natural rock (where setting occurred so a rock could maintain itself). To a great extent this objective has been achieved. Good seed grounds outside the Baylor Survey are limited and available evidence shows that these valuable bottoms are underutilized. This waste of valuable potential for seed production should be stopped.

It would be possible to reduce the dependence of private growers upon publicly controlled seed production by making more seed-producing areas available to them for use at their own discretion and expense. This would make them self-sufficient and reduce costs of seed.

Recommendations to Improve the Repletion Program

Many steps may and should be taken by VMRC to optimize the set on the shell it plants and to improve the efficiency of their operations. Many have been made in the past and ignored (Appendix II). Among them are:

1. Shells should be planted only in moderate to heavy set areas.
2. Shells should be planted in quantities and on specific bars most likely to assure maximum spatfall.
3. The James River is still the best seed oyster producing region in the State, and if planted with more shell, would produce more seed than it does now. Many barren areas exist there. We suggest that shell be planted in these areas in far greater quantities than it is now.
4. Surviving set on shellbags and shellstrings varied in some river systems according to their up or downward location. More attention should be

paid to this setting pattern in planting shells. Shells planted in the upper half of the Great Wicomico would receive heavier sets than those planted downriver. The York and Rappahannock, which are largely low set areas, receive the heaviest set in the lower quarter of their length. In the Rappahannock this occurs below Towles Point; in the York, below Gloucester Point.[11]

If drills are a problem in these down-river areas and if the shells receive a set they can be moved to low salinity areas in late Fall or early Spring before drills kill the spat. If VMRC did not wish to move the spat then it might be sold to private planters who would be allowed to dredge the area for a predetermined fee arrived at by bids, or some other equitable means.

5. It is recommended every effort be made to have shells planted at the optimum time to receive a set. Peak set occurs in the various rivers at certain times, and it was pointed out

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[11]Shell plantings since 1972 (after drills were killed by freshwaters associated with Agnes) have been successful in this area.

shells planted too far in advance of setting often become too fouled to obtain a set. This single factor is undoubtedly the cause of most of the poor results of shell planting made in moderate or high set areas. It is probable more attention to this point would greatly insure successful setting on planted shells. In the past the price or cost of planting, nearness to shell piles, available "cheap" labor, etc. have largely dictated when shells went into the water. The concept of timing the planting to keep costs down which has motivated the Commission in times past is not reasonable. It would be better to pay up to twice the price for shells and have it successfully catch set, i.e., planted at the correct time.

6. More money should be invested in the repletion program. VMRC should consider increasing the tax on seed raised from shells planted by the State. This increase should be large enough for the repletion program to be more self-sufficient. For example, the tax collected from publicly reared seed from the Great Wicomico River is now 10¢ per bushel. This does not even cover the cost to the Commission of a bushel

of shell which is 17¢, and does not even approach the cost of 5.8 bushels, the average quantity of shell planted per bushel of seed harvested. A tax of 20¢ to 40¢ per bushel would be more realistic. Obviously, tax increases would be passed on to the consumer. Demand might be impaired. Should this be a likelihood, the State might have to forego such tax increases and continue the subsidy if it wishes to encourage the industry and guarantee to the people enough production on the Baylor Bottoms.

Other methods of raising funds for VMRC should be developed or expanded upon.

7. Unproductive Baylor Grounds should be reassigned by leasing to private growers under a system entirely different than now exists. Such a system should entail much higher rental fees and a more complete designation by the Commission of the locations available, longevity and size of the lease.

It is also suggested that if the State did not utilize certain high or moderate-set seed areas within the Baylor Survey Grounds, then these also might be leased for the purpose of growing seed or market oysters under a short-term lease of from 3 to 5 years. Dredging would be allowed on these bottoms. While this recommendation is not strictly a part of the current repletion program which stresses shell and seed it is included here since it relates indirectly to the seed program.

8. The reef shell program conducted by the Commission in cooperation with Radcliff Materials with advice from VIMS was successful in providing the State with large quantities of shell at virtually no cost. Undeniably, this shell was of benefit to the oyster industry. While we do not recommend a return of this shell-mining industry as it existed at that time Radcliff showed that reef shells suitable for cultch exist in considerable quantities in lower Chesapeake Bay and its tributaries.

During studies with an oyster harvester, VIMS scientists working in the lower York River and the Rappahannock River mined up to 750 bushels of buried shells per hour. Much of this shell was unbroken and in good condition for planting. VMRC should begin to utilize this resource for its repletion programs. A possible approach would be for VMRC to invest in a dredge designed specially to harvest shells. Such a machine need not be large or elaborate but might be constructed for less than $100,000. Use of reef shell by VMRC would enable the planting of shells at a much lower unit cost than presently. Moreover, it would enable shell to be planted at the optimum time since VMRC could by judicious use of mined shells be independent of the private planters needs and could plant and sell at the biologically optimum time.

9. In many instances shells planted by the State do not obtain a set. In almost all instances in a month or two these shells become fouled, and therefore, fail to "catch" a set of oysters even if the mature larvae are in the water. Thereafter, the shells may remain on the bottom for many years supporting fouling typical of the region without receiving a set. In some regions this fouling sometimes falls off or is scoured from the shells naturally, and a set of oysters is possible. However, in many localities silting or fouling is so heavy that no set is possible. Commercial growers and the Commis-

sion have recognized this fact and have often attempted to "harrow" the shells with a bagless dredge just prior to setting. This, in theory, is a good practice, but is time consuming, not too effective, and is not widely practiced.

It is recommended that VIMS be encouraged and enabled with appropriate funding to develop modern, efficient gear to "turn over" surface shells of old shell plantings. Such a device would be relatively easy to construct and would in our opinion be of tremendous benefit in renewing old shell plantings at a very low cost.

10. VMRC or VIMS should begin a regular and detailed system of evaluation of individual shell and seed plantings. Data collected should include: quantity planted, location by latitude and longitude, location in respect to shore marks, acreage, spat per bushel at the end of the first year, numbers of oysters per acre the second year, fouling, and final harvest of oysters. Information should be summarized in an easily retrievable manner to assist in management of the repletion program.

11. Since seed cost is the largest single item in the expense of growing oysters, any reduction in its cost would benefit industry. It is recommended that VMRC make every effort to produce more seed oysters at a lower cost to the industry. However, this effort will be of little value unless efforts are made at the same time to provide good bottoms for growing this seed.

12. Efforts should also be expanded and improved to increase demand for mature oysters.

To improve the productivity of the State repletion program and enable knowledgeable selection of public grounds for further State effort and for lease, additional practically-oriented research is necessary to enable comprehensive knowledge of the desirable features for productive oyster bottoms.

Careful and detailed surveys of the public bottoms, their nature, and actual and potential productivity are necessary. VIMS must be encouraged and funded to carry out the required surveys and assessments. This coupled with the improved productivity data gathering effort recommended above for either VIMS or VMRC is a necessary step for the State repletion program to be fully successful.

CHAPTER VII

METHODS OF MANAGEMENT OF VIRGINIA'S OYSTER RESOURCES

CHAPTER VII. METHODS OF MANAGEMENT OF VIRGINIA'S OYSTER RESOURCES

Introduction

Preceding chapters of this report have given a basic description of the nature and magnitude of Virginia's oyster industry, its value, and how it is managed and conducted. It is now possible to compare the present method(s) of management with others which have been suggested or can be developed.

The present method (wherein the State attempts to protect and replenish the most productive natural bars and allows or encourages private development on less productive bottoms) has persisted since the beginning of this century with very few changes. Preceding chapters, among other things, have described production, the methods of tax collection, the yield and the economic values for the oysters resulting from this system.

The Present Management System

The present program or system involves the management by the State of 243,271 acres of the best and most productive oyster "bottom," the Baylor Survey bottoms, in Virginia. Access to and use of these grounds is open to any resident paying a slight fee for a license. The time and method of harvest of oysters from these grounds is regulated by State law which is administered by the Virginia Marine Resources Commission.

In 1975 the total production of oysters from these Baylor or public grounds was 403,737 bushels of market oysters and 392,504 bushels of seed oysters (Tables 13 and 14). This present level of production (1975) represents a decided downward trend which began before the early 1960's. Cost of administering the entire State program in 1975 was $434,380 (Table 72). Of this total, $385,872 and $48,508, respectively, were spent to plant shells and seed (Table 73) in a Repletion Program aimed at increasing production.

The private oyster industry in Virginia is "encouraged" by the State in several ways. There are few restrictive laws to hamper operations. Annual fees required to hold and use leased land are very low (usually $1.50 per-acre-per-year) and private lease arrangements are most favorable. If the owner desires, oysters may be harvested on leased ground by dredge rather than by other less efficient or economical methods, such as tongs. There is no size limit on volume or size of the oysters in the catch and there are no seasonal restrictions. Most of the few restrictions imposed are health-related.

The total area leased in 1975 by private growers was 100,662 acres (Table 5), only about half the size of the Baylor Survey Grounds. This area produced 491,860 bushels (Table 5) which is greater by about 100,000 bushels than the volume of market oysters produced on the Baylor Grounds. This disparity in production between private and public grounds was even greater in earlier times. For example, private leases produced about 3 times more than the Baylor Bottoms before MSX in 1958.

The Baylor Grounds were originally selected to occupy most of those oyster rocks known to be naturally productive and, to a large extent, this objective was realized. Today Baylor Grounds still encompass most of the natural seed areas and a major portion of the better bottoms for growing oysters (where the bottom will support oysters and where diseases and predators are minimal). Private leases are located on less desirable grounds outside the Baylor Survey limits or boundaries. Few private leases are in areas which normally experience an adequate set. Many are located where predators such as drills and disease such as MSX and Dermocystidium kill significant numbers of growing oysters.

The James River seed areas on Baylor Bottoms provide over 77% of the seed planted on leased bottoms within the Bay. The remainder comes from a natural set or from seed located on private bottoms. On the seaside of the Eastern Shore, market oysters are grown from the local seed which does not do well in the Bay and its many tributaries. The history of the utilization of fisheries and of many other natural resources over the last several hundred years or more is full of examples demonstrating that unrestricted use of a public or common property resource eventually leads to its depletion and requires management of some type.

Characteristics of Public Use of Public Grounds From Christy (1964)

A great deal has been written about public use of natural resources such as fish, timber, range land and oysters.

One of the best and most inclusive discussions pertaining to oysters is by Christy (1964). This work is so important that pertinent aspects are given in detail in Appendix III. A brief review, however, of the more pertinent aspects follows.

A fundamental consequence of a common property natural resource (such as public oyster bottoms) is that it tends to become depleted due to overharvesting. There is no adequate incentive on the part of the harvester to reduce his harvests to leave a portion of the resource so it may replenish itself. The harvesters are rarely willing on their own to reinvest in the future of the resource even though its destruction affects their livelihood. Controls of some sort usually must be imposed on harvests of the fishing populations before they are economically or even biologically extinguished.

Industries based upon common property natural resources are inherently inefficient as soon as they reach a stage where use by one producer diminishes use by another. Therefore common property-based industries are generally marked by congestion. Moreover there are often undesirable fluctuations in landings based on seasonal access which results in sharp fluctuations in price and in inefficient processing and distribution.

For various reasons, including a general unwillingness to adopt "limited entry" as a management tool, management plans of common property natural resources are typically those which prohibit technological innovations, impose quotas on catch or establish closed seasons or areas. These methods frequently do not work out in the long run either economically or biologically.

Virginia's Common Property Oyster Resource

It is pertinent to compare what we have just outlined concerning management of a common property natural resource by Christy to the management of Virginia's common property natural resource, the Baylor Grounds.

There is no doubt that Virginia's public oyster grounds (especially those used to grow market oysters) are depleted. There is little doubt that decades of overfishing have contributed, but MSX has also been a major factor and there are a number of other causes.

As Christy (1964) indicated, controls of some sort are often established after depletion develops and becomes unavoidably apparent. This has been the case in Virginia. Laws exist and are enforced relating to the season of harvest and size of the oysters. Hand tongs are the only gear permitted on most natural public beds. More efficient gear such as patent tongs or dredges are allowed only in a few sharply restricted areas (Chapter II).

There are laws under which the Commission may restrict harvest by opening or closing certain areas as a management measure. Also, there are regulations controlling export of seed oysters from the State.

Little published information exists related to the problem of congestion in Virginia. However, it is popularly known but not documented that watermen do fish the best and most productive oyster areas first, leaving the poorer areas for later in the season. There is also good information that gluts and seasonal changes in price occur.

As we know further the "economic" rent (tax) derived from harvesting oysters on Baylor Grounds is insufficient to pay for the cost of the Repletion Program. For example, the tax on market oysters taken from public rocks varied from 10¢ to 30¢ a bushel and tax on seed is 5¢ a bushel for seed oysters from the natural rock in the James. Additionally, the State collects 3¢ per bushel tax when the oysters are processed. This is the only return or "rent" the public receives from the oysters harvested from the public rocks in Virginia. Most assuredly the State gets little back from the watermen from the resources they harvest.

Reallocation of Public Oyster Grounds to Private Interests

Because of the inherent inefficiences in attempting to culture and increase production of oysters on Baylor Grounds, and because private management of even the marginal land has been demonstrated to be more efficient in terms of yield of oysters per acre, the concept has been frequently advanced that some of the less productive public bottoms could be assigned to private management to increase production.

The concept of reassignment of barren or unproductive public rocks for use by private growers was first advanced shortly after the Baylor Survey was completed. Unfortunately, it has always been opposed by public oystermen (tongers) who regard the ability to work on the natural rock as a "right" rather than a privilege due them from the State. Most past attempts to change the "Baylor Survey" have resulted in loud and unyielding opposition from watermen, their hired legal representatives and frequently from their constitutional representatives from the Tidewater counties.

The first to advance this concept for the oyster industry of the Chesapeake was W.K. Brooks of The Johns Hopkins University. He advanced a series of arguments against unrestricted public use of natural rocks which are as valid today as they were about 100 years ago when first written (Maryland Oyster Commission, 1884).

In 1902, eight years after the Baylor Survey had been completed, the Virginia Board of Fisheries also recommended making Baylor Bottoms available to private interests.

> That it be empowered upon investigation to lease any bottom within the Baylor Survey found by it to be entirely barren of oyster rock or so barren as to be unprofitable to the public worker. Your Board finds that within the Baylor Survey there is a large acreage of most desirable planting ground, barren of oyster rock, much of which has never grown oysters, and a large acreage of which is so barren as to make it unprofitable for the public worker.

The same Board repeated the above recommendations in the two following annual reports, and in 1908 a bill was introduced into the General Assembly which would have directed the Board to determine barren ground in the James River and make it available for private leasing with provision to do the same in other regions later. This bill passed the Senate but was blocked by opposition in the House (Virginia Commission of Fisheries, 1908).

The controversy concerning leasing Baylor Grounds received additional attention in 1909 when Governor Claude A. Swanson of Virginia asked the U. S. Bureau of Fisheries to determine "fertile and barren areas in the James River, marking and plotting the same..." This work was completed during July, August and September 1909 under the direction of Dr. H. R. Moore. A report concerning this study showed that fifty-eight percent of the area within the Baylor Survey in the James consisted of barren bottoms, and that an additional fifteen percent bore oysters too sparsely scattered to be of commercial value (Moore, 1910). This same report presented effective arguments for leasing barren ground within the Baylor Survey boundaries.

Mr. Herbert F. Prytherch, assistant aquatic biologist with the U. S. Bureau of Fisheries, was called into the State in 1930 to study a large mortality of oysters in Mobjack Bay. Along with his biological findings he recommended, for the good of the oyster industry, that all public grounds be leased (Commission of Fisheries, 1931).

Mr. Victor L. Loosanoff (1932), while employed by the Virginia Commission of Fisheries, studied the oyster industry of the State. In a report dealing primarily with setting on public beds he stated:

> In Virginia the leasing of public bottoms will increase the supply of better quality oysters, furnish steady work for the people of coastal communities, and utilize thousands of acres of barren bottom, which at present are idle.

In 1951 the Virginia Advisory Legislative Council studied the seafood statutes and recommended changes which would aid the industry. One recommendation was "the State be directed to make a study of whether or not there shall be a resurvey of what should be set aside as the present natural oyster rocks."

In that same year (1951) the Committee on Fisheries of the Advisory Council on the Virginia Economy recommended:

> That State policy as to the leasing to private planters of public oyster rocks, as established by the Baylor Survey of 1894, be re-examined with a view of modifying it if such modification would better the economic position of the fishing communities and the State as a whole.

Several years later the Virginia Advisory Legislative Council appointed Dr. Charles Quittmeyer, College of William and Mary Economics Department, to make such a study of the Virginia oyster industry. Dr. Quittmeyer (1957) stated in his report:

> From a practical standpoint perhaps the best possible progress (toward increasing oyster production) would come from an easing of the restrictions on leasing (that is, to allow private leasing of barren public ground) yet at the same time keeping basically the dual nature of public and private oyster grounds.

Dr. Quittmeyer also outlined five possible policies to be followed by Virginia and Maryland for use and management of public and private oyster grounds which will be discussed later in this Chapter.

In the late 1950's Dr. John Wheatley of the University of Buffalo made a study of the oyster industry of the York River which was financed by the Chesapeake Corporation through the University of Virginia. Wheatley (1959) stated:

> With a view toward increasing productivity, the first recommendation of this survey is that a study be made of the public oyster ground... This proposal concerns itself with one of the basic economic problems facing the oyster industry in the Commonwealth. The barren unproductive public bottom represents a waste of resources. It is also ground which cannot possibly be brought back to its former productiveness except at very great cost to the State.

Wheatley recommended that grounds found to be barren by such a study be leased to private growers who would make them productive. Dr. Wheatley, like Dr. Quittmeyer, recognized that stiff opposition would meet any attempt to remove acreage from the Baylor Survey for leasing. His answer to this opposition was:

> There is no reason, however, to believe that the oyster tongers would have anything economic to lose if only barren ground were deleted from the area now outlined by the Baylor Survey. In fact, the availability of new and suitable bottom for growing oysters would have the effect of stimulating the demand for seed oysters which are

> taken primarily from public grounds. This increase in demand would, in turn, have a favorable effect on the price of seed oysters and furnish more work for the present tongers or call for services of additional tongers or some combination of the three developments.

In 1960 another study of the seafood statutes was made by a special study commission. This report stated:

> The Commission recommends no change in the Baylor Survey or the survey of the public oyster rocks of the State and it feels that where the lines of said survey shall have, because of time, become uncertain, they should be reestablished by the surveyor of the Commission of Fisheries (Comm. to Study and Revise Title 28., 1961).

A team from Old Dominion University studied the economy of the Eastern Shore in 1962 and concluded on the basis of a very brief discussion that it was necessary to greatly increase oyster production. The group considered leasing portions of public ground but discarded the idea because they thought it would deprive some people of income (Bowden, 1963).

A 1966 report to the General Assembly made no mention of changing the method or degree of management of oyster grounds (Virginia Marine Resources Study Commission, 1967).

A report to the Governor in 1970 advocated reducing the size of public oyster grounds (Governor's Management Study Report, 1970). Currently active scientists in Virginia and elsewhere have recommended increased private leasing as a means of improving production from Virginia waters for years.

Legal Aspects Related to Reassigning Public Grounds

Legal reference related to the transfer of Baylor Grounds appears in the Constitution of Virginia (Art. XI, no. 3). This Article contains the only limitation of the General Assembly relative to their power to regulate the use or exploitation of the beds of bays, rivers and creeks under the jurisdiction of the Commonwealth. It provides that:

> The natural oyster beds, rocks and shoals in the waters of this State shall not be leased, rented or sold but shall be held in trust for the benefit of the people of this State subject to such regulations as the General Assembly may prescribe, but the General Assembly may from time to time define and determine such natural beds, rocks or shoals by surveys or otherwise.

Thus, the Constitution does not precisely define or fix the terms or limits of the "natural oyster beds, rocks and shoals" but leaves this to the General Assembly. Therefore, the State can add to or delete from the "Baylor Survey" grounds and it can do so in order to facilitate leasing and increase oyster production or for other public purposes.

In reference to the point the courts have ruled:

> . . .the General Assembly may from time to time define and determine such natural oyster beds, rocks and shoals by surveys or otherwise. . . (Blake v. Marshall, 152 Va. 616, 148 S.E. 789, 1929).

The Commissioner of Marine Resources has been authorized by the General Assembly to reestablish, relocate and remark all lines of the Baylor Survey if these lines cannot otherwise be located because of loss or destruction of former marks (Section 28.1-101). The Commission cannot redefine the natural beds, rocks and shoals on its own authority outside of these conditions.

The General Assembly has from time to time declared certain bottoms originally excluded from the Baylor Survey to be a part of the natural oyster rocks of the Commonwealth (Section 28.1-149 through 29.1-159).

Our research has also indicated that the General Assembly has withdrawn from the public rocks certain areas in the lower James River. In relation to this point the courts have ruled:

> The power to withdraw the area here involved from the public use permanently includes the lesser power to withdraw it temporarily... (Blake v. Marshall, 152 Va. 616, 148 S.E. 789, 1929).

Regarding Article XI, the Virginia courts have also declared that other changes are possible:

> The reasonable and proper construction of the section is that it relates to private uses and not public uses and has no application to restrict the power of the legislature to authorize, permit or suffer tidal waters, including those over natural oyster rocks to be used for any public purpose to which they are at common law subject as the legislature may deem it to be for the benefit of the people to authorize or suffer (Blake v. Marshall, 152 Va. 616, 148 S.E. 789, 1929).

It is concluded from the preceding quotes that Article XI does not limit forever the use of these "natural oyster beds, rocks and shoals" to only public oystering because the General Assembly may redefine or direct a suitable executive agency to redefine their boundaries.

Economic Aspects of Leasing Baylor Bottoms

There are two interrelated problems which must be considered if Baylor Ground is to be leased to private interests:

1. Would there be sufficient economic incentive for the private grower to attempt oyster culture on the newly acquired bottoms?
2. Would there be a market for the additional oysters if private production was increased?

The failure of the private grower to increase plantings on existing (or available) leased bottoms after 1960 was probably due to economic factors. The Virginia grower finds it profitable to farm only his best bottoms (where yields are highest) since he is faced by rising production costs, increases in cost of money, and a stable or declining adjusted price for his final product. There is now less profit in growing oysters. The Virginia grower must plan his plantings two or three years in advance of his selling date. He is taking a significant risk involving thousands of dollars in seed cost, interest on loans, harvest cost and maintenance of equipment in a venture where he may be undersold by Maryland imports, oysters from the public bottoms in Virginia or imports from the Gulf region or elsewhere.

One might conclude from the preceding facts that it would be useless to make more grounds available to the private grower in the face of these economic problems. We do not agree! In the first place, there is a scarcity of good growing areas for persons not now holding leases who might or would like to go into the oyster business. Also, it must be recalled that currently leased bottoms are almost all marginal in that they were not included in the Baylor Survey as a naturally productive area. In the event Baylor Grounds were leased and the better, more productive bottoms were used, then a part of the economic problem might be alleviated. The Baylor Grounds generally are of high quality where returns of two or perhaps three bushels of market oyster per bushel of seed may be realized. Also, the tracts leased could be large enough to make large-scale and, hence, more economical production possible. These aspects would enable the grower to lower his costs of production and, therefore, his prices. This reduction in price could be passed on, and the reduced retail price would result in an increase in demand (Quittmeyer, 1957; Abrahamson, 1961 and Christy, 1964).

Problems in Reassigning the Baylor Grounds to Private Use

There will be problems in reassigning the Baylor Grounds to private use but with adequate study and preparation we believe they may be resolved.

There has never been a quantitative study of the density and distribution of oysters on the public oyster rocks in Virginia,[1] with the exception of the 1909 study in the James. Quantitative information is lacking as to the extent of marginally productive and unproductive grounds. There are many who would argue that a survey is not necessary, and that we already know enough about the various locations to make decisions concerning reassignment. The potential of certain areas like the mid-James and the Piankatank rivers are well known. Added to this fund of general knowledge is the knowledge of local watermen and other persons in the seafood business who base their conclusion on oyster distribution or on whether or not they might "make a living" oystering in a certain locality. There are, however, no data which would indicate productivity in real terms or affirm contentions of either watermen or inspectors.

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[1] A study of several representative seed areas was completed in 1975, but this study included less than 1% of the total Baylor Bottoms. A major project to study the potential productivity of Baylor Bottoms and their size was begun by VIMS in 1975. To date, the productive bottoms in the Rappahannock have been delineated. If funds are available, the remaining Baylor Bottoms will be surveyed during the next 2-1/2 years.

The existence of such a generalized fund of information in conjunction with that presented in this paper would make possible the reallocation of certain public grounds to private enterprise. For example, there would appear to be no question that most public bottoms on the northern side of the Rappahannock below Towles Point are clearly unproductive. However, in other locations decisions are more difficult since quantitative information does not exist as to what is now on the bottoms in respect to shells or living oysters. This is especially true in locations such as the Rappahannock above Towles Point, Pocomoke Sound, Tangier Sound, Mobjack Bay, the York River and in the lower James River. In these areas decisions to reallocate would be sharply contested by watermen who might claim that any areas suggested are in reality productive. In respect to these latter areas it will be necessary to establish limits or bounds on areas claimed as unproductive and/or productive which will remain public grounds, and those which would be designated as unproductive and be made available for reassignment.

Such a survey would be a major undertaking, but it should determine for each of the Baylor Grounds the approximate density of oysters and shell per-unit-of-bottom-area, where oysters set or strike, rate of growth and mortality, and the incidence of diseases and predators. This information in relation to bottom type and depth will be used as one of the criteria for defining grounds as being very productive, moderately productive, marginally productive or unproductive. Density will be determined by carefully dredged sampling using hydraulic patent tongs, and exact locations of the sampling stations will be determined by electronic ranging gear ("Raydist"). At each such station supplemental data will be obtained in bathymetry and type of bottom and such others as may be useful.

Activities Needed in Addition to Leasing or Reassigning Presently Unproductive Baylor Bottoms

The almost total dependence of the private sector on the public bottoms for its seed supply was outlined in Chapters IV and VI. It was shown that some 77% of the seed came from Baylor Grounds in the James and about 20% from the Great Wicomico and Piankatank rivers in the 1963 to 1972 period. Therefore, the following aspects are emphasized:

1. There is an ever-growing danger that the private grower's source of seed may be diminished so that supply is inadequate (Chapter IV).
2. Costs of seed total including tax and freight range from 21% to 47% of the sale price of market oysters in the last 30 years (Table 65).

3. It is evident, therefore, that anything which enhances the seed supply or diminishes its unit price would benefit the private sector.

The questions of where or how seed will be obtained to plant the unproductive (leased) Baylor Grounds are critical problems. As outlined previously, the Baylor bottoms took in the naturally productive bottoms even in seed areas by design leaving the marginal areas for leasing. Many of these latter areas have been or can be made to produce seed, but as previously outlined, they are not now available to those who might wish to attempt oyster culture. For example, in the lower James there are extensive areas of bottom outside the Baylor Grounds which could be used to produce seed if properly managed. Today, and for the last 30 to 40 years, most of these bottoms have been under lease by four or five companies. Prior to 1960 some were unused, a few were used to grow market oysters and a large part of them were used to grow seed for planting in the high-salinity regions of the Bay. After 1960, MSX made oyster culture unprofitable in these high-salinity regions (Chapter XII). Today, only a very small fraction of these grounds are used to their maximum potential for growing seed. In some cases the bottom is planted with shell and the set allowed to mature in place rather than being used for seed. Many bottoms, however, remain completely unused.

In the Piankatank, Corrotoman and Great Wicomico rivers (locations used by the VRMC to grow seed) there are many small leased areas which might be used to grow seed (Chapter III). To our knowledge only a few of these areas are used by growers for that purpose. We may only speculate as to the reasons. Some possible reasons are: 1) the leases are held in units too small to be worked economically; 2) it is still cheaper to buy naturally produced James River seed, and 3) the present leaseholders are not in the business of growing oysters and the owners are holding the bottoms for some possible future use. Undoubtedly, some leaseholders do not intend to produce oysters on them.

Possible Solution to Non-Use of Leased Bottoms

The long-term solution of the problem of non-use of leased bottoms would be to require proof-of-use of the bottoms for all existing and new leases or lease renewals. In this way, grounds suited for growing seed would be used to a greater advantage.

Use of Baylor Bottoms as Seed Areas

The best immediate solution would be for certain Baylor Grounds in moderate-to-high set areas to be leased to private growers to enable them to grow their own seed to supplement, if necessary, the diminished supply.

Management Plans for Virginia's Baylor Grounds

When faced with a rapidly declining production of oysters on the public and private bottoms, and with full realization of the inherent weakness in public management of the oyster bottoms, the question is: How can we manage the resource (public and private) so we may alleviate some of its problems? Quittmeyer (1957) made an excellent study in which he compared five management plans ranging from the complete control of all bottoms by private interests, to a situation in which the State controlled everything. The policies suggested by Quittmeyer follow:

> First Policy. The first policy would be to let all State aid and effort go, which would take both states (Maryland and Virginia) out of the oyster subsidy business. . .Such a policy would probably mean depletion of the public rocks. Raids on private leaseholds would probably be difficult to stop for awhile. Eventually, however, free oystering would be forced to the wall and leasing could come in. Such a policy is patently impolitic and not feasible.
>
> Second Policy. The second policy would be to turn the whole Bay and its tributaries over to private leasing. Such a plan has great merit from the standpoint of efficiency but lacks political reality. It would not work against the tradition of rugged independence of oystermen that has been so socially and politically powerful.
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> Third Policy. The third policy would be one of State controlled and managed public rock with large shellings for seed, large seed planting, and rigid reserve area control, and no encouragement to private leasing, such system to be supported by taxation on production or subsidized. Along with

such a program, as with present repletion programs, should be provision for adequate scientific study of the shell planting. Even if 90 percent of the funds were required for this purpose at first, the efficiency of shell planting that might result later would probably justify the strategy. A difficulty with this program is that subsidization might be necessary on a large scale, at least at first until tax revenues came in, and such federal financial subsidy would be most improbable and it should be noted that even with reference to federal agricultural subsidy, federal agencies do not plant the crop. Oyster tax support would come up against practical difficulties in the chronic aversion of oystermen to such a tax and in problems of the method of collection. The lure in getting the oystermen to pay the tax, however, is that some oysters salable at, say, $3.50 a bushel with revenue of $3.10 a bushel after a hypothetical 40¢ a bushel tax, is better than the revenue from no oysters after no tax. Also, with merchandising improvement market expansion would probably be able to absorb more Bay oysters without serious price disturbances.

Fourth Policy. The fourth policy would be similar to the third, except that encouragement of private leasing and culture would be added. With the large amount of poor but still usable bottom not in natural rock, it would seem that relaxed leasing requirements, such as on the number of acres leasable, might help more of this ground to be cultivated in oysters, provided better merchandising of oysters allows an expanded market, as would seem to be the case. Indeed, if a large effort of State management for the public rock came into being, political aversion to the encouragement of private leasing might lessen.

Fifth Policy. The fifth policy would be to continue present production policy as it exists in each state. A modest state program may have helped to stabilize the yield of oysters at 2.5 million bushels in Maryland with some production from the hamstrung private leaseholds, although stabilization of this sort could come about in the absence of subsidy, the equilibrium level depending on the balance between production and demand. Virginia has a declining production from the public rock which is apparently being arrested by subsidized repletion measures. However, Virginia's total yield has been stabilized at a higher level than Maryland's as a result of large production under its more lenient leasing laws. This fifth policy is feasible because it is working oystermen who actually do make a living under it. However, it is economically wasteful and causes political distress.

Summary. How do these policies appear weighted against developmental conditions? First of all the Bay oyster fishery meets well the conditions of magnitude of resource, prospects of demand (if the product is merchandised more carefully), regional competitive marketing advantage, and responsiveness to management. The Bay oyster fishery meets these requirements to a larger degree than any of the other fisheries of the Bay area, it should also be emphasized. Thus, it is the means of administration and public support which are the most critical conditions. Under this view it appears that the fourth and fifth policies of extensive state management and private culture, public support is feasible if it can be proved that large subsidization is only temporary. Means of administration would follow. Under the fifth policy, the present policy, both public support and means of administration have been forthcoming.

Author's Note: Please note, however, that Quittmeyer's proposals were made before MSX adversely influenced oysters growing in the high-salinity waters of Virginia and before Maryland began its expanded publicly-supported management program. At present (1977) Maryland production is slightly higher than Virginia's, reversing a century-long situation. In contrast to the trend of Dr. Quittmeyer's predicted production, the landings from both public and private oyster rocks of Virginia has dropped. However, this has been due to MSX and other factors, including competition from the subsidized production in Maryland. Another aspect not anticipated by Quittmeyer was that since 1960 there has been a major decline in setting in the James River seed areas and a decline in density of seed oysters there. A similar but less drastic change has occurred in other important seed areas.

Quittmeyer (1957) in his summary suggested that his fourth and fifth policies are the most desirable, that is, State controlled and managed public rocks with large shellings for seed, large seed plantings and rigid reserve area controls. He also recommended encouragement of private leasing with the addition of a more relaxed attitude toward leasing requirements such as the number of acres allowed to one person. We consider this latter recommendation of no value, since most of the "good" growing bottom are already held by others. However, the concept of allowing larger, more economical leaseholds is a good one.

Quittmeyer's summary (op. cit.) did not specifically advocate the leasing of Baylor Ground although he did make such a recommendation elsewhere in the report.

The following pages present our recommendations. Some are based on Quittmeyer's work, others are ours resulting naturally from factual information developed in preceding chapters. We believe that these measures or similar ones will be necessary if the oyster industry in Virginia is to attain its full potential or even if it is to return to its former level of production.

Recommended Management Policy

1. A major problem which will accompany any attempt to grow more market oysters (to increase production) will be a shortage of high-quality, low-cost seed. Virginia is presently faced with a combination of the lowered setting rate and a decline in seed density in the James and several other areas. A significant increase in demand for seed caused by a change in management policy or economic conditions will certainly lead to a seed shortage. The reversal of this downward production trend for seed (if possible at all) calls for the combined efforts of industry, the VMRC and VIMS. A major effort of VIMS should be to determine further the precise factors affecting setting in the James and other areas, especially those causing lowered setting

levels and, if possible, correct the situations responsible.

2. Virginia should maintain both its system of public oyster grounds and leased bottoms. However, there must be modifications in the use of Baylor Grounds. Baylor Grounds which are now producing seed or market oysters in significant quantities should largely remain in the public domain. Their productivity should be enhanced and maintained. Other grounds with high productivity potential might be added to the shell and seed planting programs and, once restored, maintained.[2] Unproductive areas as well as limited areas of seed-producing public bottoms should be made available for leasing by the State to private companies or individuals. The terms of leasing these unproductive or "surplus" Baylor Grounds should be realistic and sufficient to give strong support to the

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[2]The State must not be afraid to completely close off those areas which are being restored or which need respite from harvesting, despite pressures.

State's Repletion Program. On those grounds leaseholders should be required to use them for the purposes for which they were leased. The leases should stipulate automatic reversion to the State if the lessee does not vigorously pursue oyster culture. Private growers leasing such bottoms should be allowed to use any gear needed to harvest their oysters. No restrictions should be placed on size or season oysters may be harvested.

3. In the event portions of Baylor Grounds are made available for private leasing then the system of leasing should be different from the present system. It is recommended that:
   a. Areas to be leased should be determined by VMRC with the approval of VIMS and set aside in large blocks each with a minimum size of about 100 to 200 acres.
   b. Leases would be for ten years, at the end of which time they could be renewed. However, retention of the leases should be conditional on their use for growing oysters as substantiated by production

records which would be required of all lessees; this condition would be in addition to the stipulations in present leases. Without adequate proof-of-use, the lease should become void.

c. Right to lease an area reassigned from the Baylor Grounds should be obtained by public auction with a minimum fee of at least $50 per-acre-per-year. Proof-of-use should be required, as should records of effort and production.

4. Our recommendation for a long-term solution to the problem of non-use of currently leased bottoms is that the laws relating to leasing be changed so that proof-of-use of a lease will be a condition of continuing the lease. This solution would be of long-term value and would increase use and production in the non-Baylor areas. Probably, the conditions of existing leases could not be changed but as each 20-year lease expired it should be revised to include the new terms. That provision of current leases which stipulates that they are to be used for oyster culture should be enforced and monitored. The

preceding system of making currently leased bottoms available to those who wished to use them to grow oysters would take several years before its impact would have much influence.

5. On productive public bottoms, the State should carry out a balanced but expanded program directed toward:
    a. Increased production by controlled planting of shells.
    b. Market oyster production by planting shells to catch spat in areas where they might grow to maturity without being moved.
6. Seed (from seed areas) produced by the State should be utilized first by the State for its rehabilitation efforts in low set areas. The surplus should be sold at slightly over cost to private growers.
7. Oysters on public bottoms originating from natural cultch or planted seed or shell should be taxed at a realistic level which should probably be at least twice that of the present level of more. The tax should be realistic, and be such as to materially contribute to costs of raising the seed.

8. Management policies related to optimum time of planting shell and how it should be planted in moderate and high-set areas have been previously discussed in Chapter IV, and are outlined again in Chapter IX.

9. A major reform needed in the VMRC programs as well as for private planters is that they must adopt or develop new techniques for growing, harvesting and processing oysters. Many possibly useful techniques exist, others remain to be developed. These techniques will be discussed in full in Chapter XI. Among the items to be covered are use of the new and improved techniques for increasing spatfall, the use of hatchery-cultured spat and new methods of harvesting oysters.

10. A marketing study is needed to determine why the price of oysters has remained stable in a period of rising inflation. (Also, organized efforts are needed to develop consumer use and demand. This should be supported by industry if it can be persuaded to do so.)

11. New techniques related to production and harvesting should be developed and used to reduce costs of production and to develop new products.

Summary

Recommendations have been made to the oyster industry and to the relevant public bodies so that Statewide oyster production may be increased. This objective holds for privately leased bottoms as well as public bars. From a management standpoint, it is unfortunate but true that improvements in cultural techniques are more readily adopted by private industry than public management. The profit derived by private industry may be reinvested into recommended management practices. In the public sector, the profit goes to the harvester (tonger) and the State must constantly assign more monies as the public program is continued and expanded.

This is not to say that public management cannot be improved so more oysters will be produced. In fact, we are of the opinion that production can be increased even without the expenditure of more funds than are now allocated for this purpose. But with more money, production could be improved even further.

Those individuals or groups responsible for management of the public oyster fishery must decide on the magnitude of the subsidy they are willing to direct toward increasing production. That is, the degree to which production on public bottom is increased will, in the future, be dependent on expenditure of State funds. In contrast, the development of the private sector depends on the opportunity or the ability of growers to make a profit on their investment.

Many thoughtful and knowledgeable persons and study groups over a period of about 100 years have advocated leasing of the unproductive Baylor Grounds for private use as a step to increase production. We concur strongly with this view. The basic argument advanced is that private industry can do more with the bottoms (in the way of production) than can the public sector. As we read Article XI of the Constitution of Virginia, the General Assembly can arrange to allow use of bottoms by redesignating the area encompassing "natural oyster beds."

Also, it appears that, due to the present system of leasing and the fact that the Baylor Bottoms are the best area, the availability of the really good growing areas is probably a limiting factor today in Statewide production from private industry. Therefore, there is a need for making additional good quality growing areas available for leasing.

Leasing of presently unproductive bottoms must be accomplished by other remedial measures in order to be fully effective. Among these are providing more seed and reducing costs of production.

CHAPTER VIII

YIELD OF OYSTERS

CHAPTER VIII. YIELD OF OYSTERS

Introduction

Yield of oysters is a generalized concept which may mean many things. Growers or tongers measure their production or catch in bushels and may receive a price based on yields in terms of quarts or gallons. In another context, yield might indicate how many bushels of market oysters can be obtained from a bushel of planted seed or a certain number of individual oysters or that a volume of them may yield a specific volume of meats.

Number Planted and Number Harvested

On the average Virginia growers harvest slightly over 1 bushel of market oysters for every bushel of seed planted (Tables 9 and 24). Our discovery of this 1-to-1 yield[1] brings out two important aspects: 1) the 1-to-1 ratio has in the past been a yield which enabled the industry to operate profitably and 2) there has always been a large mortality between planting and harvesting of the market oysters. Due to many reasons these losses

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[1]In the past two large scale growers using efficient dredging techniques and other methods involving large scale culture integrated with processing realized a profit on a yield of about ½ bushel of market oysters for every bushel of planted seed (Chapter IX).

were fully discussed (Chapters III and IV). Losses are associated with damages occurring during the original handling, transporting and planting of the seed. Among causes of mortality at this stage are freezing, drying, silting, burial, mechanical damage in loading, off-loading and harvesting of both seed and market stages. In later stages of culture, while on the bottom, diseases, predators, and environmental conditions take their toll. Additionally, mechanical damage during harvesting and losses in transport and in the processing plant reduce final yields even further.

If we assume a 1-to-1 bushel return is economically profitable, which it appears to have been in the past, we can make several interesting theoretical comparisons. According to Table 28, James River seed averaged 1,066 small oysters (less than 3 inches long), 1,084 spat per bushel and 27 market oysters per bushel or a total of 2,177 per bushel from 1947 to 1960. Growers would harvest from this quantity two or three years later about 300 market-size oysters (3 inches or larger). There would be almost a 90% mortality of the original seed planted.

After 1960 when MSX became a problem, average yields for the State were still 1-to-1, but apparently in some cases survival rate of the seed was higher. A bushel of James River seed from 1961 to 1976 averaged only 495 small and market oysters and 134 spat per bushel, a total of 629 oysters per bushel (Table 28). Calculations show this to be about a 52% mortality.

The 71% decline in numbers from 2,177 to 629 seed oysters per bushel in the James has undoubtedly had a negative impact on the industry. We cannot evaluate exactly how much the impact has been without additional information which is not available. For example, it was just shown in Table 62 the adjusted price of seed rose until 1964 or 1967 and then declined or remained stable, depending on the source of the data, to 1975 (Chapter V). That is, in recent years the cost per oyster in a bushel of seed has increased, but this may have been at least partially compensated for (since 1960) by increased survival rates of the larger seed oysters. Certainly, this is a very complex problem and it merits a special study to determine the true economic "value" to a grower of seed oysters counting 2,177 per bushel with a mortality rate of about 90% as opposed to oysters counting 629 per bushel with a mortality rate of about 52%. Growth studies similar to those described below are clearly indicated.

The high mortality experienced between planting and harvesting was commented on by McHugh and Andrews (1955):

It is relatively simple to calculate the mortality that occurs between planting and harvesting. A bushel of seed from Wreck Shoal in the James River (prior to 1960) may contain as many as 3,000 oysters of various sizes (Table 28). If he counts a sample of seed, the planter will ignore the small spat, for he knows that these tiny oysters will not survive the planting operations, or if they do, will fall prey to oyster drills and other enemies shortly after, and hence cannot contribute to the harvest. The planter, therefore, will conclude that the viable seed in each bushel number perhaps 1,000 or 1,200 at the most. The market oysters that he harvests in an average period of three years will run about 300 to each bushel. Therefore, when the yield is 1-to-1, about 900 of the original 1,200 oysters, or 76 percent of the number planted, will have been lost. The true mortality, based on all the oysters in the original planting, is of the order of 90 percent, but the lower figure is more realistic from the oysterman's point of view.

Factors affecting growth and mortality include salinity, temperature, siltation, current, available food, diseases such as Dermocystidium and MSX, and predation from drills and other ecological conditions (Korringa, 1952; Galtsoff, 1964; Andrews, 1962 and others). Methods by which planters can determine growth and mortality rates from which net yields can be calculated were outlined by Hopkins and Menzel (1952). Similar calculations have been made for Louisiana waters (Owen, 1953).

McHugh and Andrews (1955) investigated time of maximum yields of tray-cultured oysters at Gloucester Point, Virginia. They concluded that a maximum yield of 2.8 bushels of market-sized oysters for every bushel of planted seed in their experiments was obtained 22 months after planting time (October). These findings, however, must be regarded with caution since these authors indicated it to be unwise to relate tray studies to growth of oysters on the bottom since drills and other factors which do not bother oysters in trays would cause lower yields on the bottom. For this reason they calculated theoretical yields based on mortality rates from 1.5 to 2.0 times higher than that of tray oysters. When this was done they found that a 1-to-1 yield is realized 19 months after planting. After this date yields in terms of bushels drops sharply. Additional studies on tray-cultured oysters were made by Andrews and McHugh (1957) to confirm the period when oysters held under almost ideal conditions at Gloucester Point, Virginia reached maximum yields in terms of bushels. They showed James River and South Carolina seed stocks both tended to reach maximum yields about 24 months after planting.

The preceding investigations were made prior to 1960 when Dermocystidum and drill predation were the principal causes of mortality of oysters within the Bay. The advent of MSX in 1960 with its large added mortality, causing much less than a 1-to-1 yield on infected grounds, has imposed a different pattern on time required to reach maximum yields at Gloucester Point (Type I MSX area) as well as the other areas influenced less drastically by this disease (Type II MSX areas). Since these original studies there have been no additional investigations in relation to optimum time to harvest. Studies have been made on mortalities in various locations but none show the time required for a planted stock to reach maximum biomass. Such studies are badly needed for representative oyster-growing areas of Virginia, especially in Type II MSX areas where growers avoid culture for fear of sustaining economic loss from MSX. Moreover, attention should be given to the increased size of James River seed (counts per bushel) in relation to survival. Such studies would aid materially in showing growers and management agencies where oyster culture is economically practical.

Meat Yields and Quality of Meats

Quality of oyster meats is of major interest to commercial growers since it often determines the margin of profit. High quality meats are plump with creamy white color and they generally fill the shell cavity. Meats of low quality, in contrast, are shrunken, have a high water content and a translucent appearance (Haven, 1962). Yield of meats from any bushel of oysters is directly related to quality. High-quality oysters are "high-yield" oysters.

Number of pints, quarts or gallons of meats which can be shucked from a bushel of oysters is the index or measure of "yield" used by most processors. This is not an exact measure since it is influenced by two major variables:

1. The number of oysters which may be packed into a bushel measure will vary widely depending on the size of the oyster and its shape. When oysters in shells are clumped or stuck together there will be more air space between them and, therefore, fewer per bushel than if oysters were all separate. Also, fewer oysters will be contained in a bushel if they are irregularly shaped rather than uniform.
2. The quality of meat enclosed within the shell cavity of the oysters will vary over wide limits. Here many factors are associated with variation in meat size and, hence, yield of meat per bushel of whole oysters or oysters in the shell. Among these are: disease, pea crabs, glycogen content and the physiological state of the animal as influenced by nutrients.

Oystermen know the general effects of many of these variables, but they seldom are able to attribute the variations to any single cause. Yields of meat in the

Chesapeake Bay area will vary from 3.5 to 9 pints per bushel after shucking but before blowing and washing. Oysters yielding 4.0 pints of meats per bushel in relation to this range are normally regarded as too poor to market since they are watery and unappetizing in appearance (Haven, 1962). Most oysters sold commercially in Virginia average about 6.0 to 6.4 pints per bushel.[2] Values between the latter two figures have been used by the U.S. Bureau of Commercial Fisheries to convert bushels to pounds of meats (Wheatley, 1959). Oysters which yield 7.5 pints or over are considered above average, and a yield of 9 pints or more per bushel is regarded as exceptional. The calculation of yield from the commercial aspect must consider changes in yield after shucking. Such changes are associated with soaking in fresh water (washing) and blowing to remove sand, mucous and bits of shell from the meats after the oysters are shucked. This treatment is legal and an accepted practice in the oyster industry. It does effect taste of the oysters and reduces the salt content which is undesirable to some consumers. It also reduces mud, dirt and mucous as well as bacteria and the probability of spoilage, allowing a longer time for shipping and extended shelf life. These qualities are important to

[2]A Virginia bushel (full).

the wholesalers and retailers. Usually it produces a 10% to 20% increase in the measured volume of meats over that when they are first removed from the shell due to absorption of fresh water by the oyster. Quantities absorbed or amount of free liquor have been studied and conditions governing absorption have been outlined (Kramer et al, 1962). Gains are not always predictable and much variation exists in quantity of water absorbed.

<u>Condition Index</u>

Number of pints of meats per bushel is a useful measure for commercial growers but it is of little use to the scientist who desires to compare changes in yield carefully from year to year or from one location to another. Biologists have designed a method of measuring relative yields which gives an "Index of Condition" for oysters (Higgins, 1938). It is calculated as follows:

$$\text{Condition Index} = \frac{100 \times \text{dry weight oyster meats in g.}}{\text{size of shell cavity in cc}}$$

Condition Index (C.I.) compares meats with their theoretical maximum size, that is, the volume of the shell cavity. The higher the numerical value for C.I., the greater will be the amount and quality of meats for any given bushel (Haven, 1962).

Factors that appear to lower C.I. are certain organisms associated with oysters: the mud worm, *Polydora websteri*, (Lunz, 1941); the coccoid *Dermocystidium*, (Ray et al, 1953); attached mussels, (Engle and Chapman, 1953); and the presence of the oyster crab, *Pinnotheres ostreum* (Haven, 1959).

Storage of reserve food, principally in the form of glycogen, and the Condition Index are both related to the spawning or the sexual cycle (Medcoff and Needler, 1941); Engle, 1958). Generally, along the Atlantic Coast, high Condition Indices occur in late spring and are associated with an accumulation of food reserves and developing gonads. Indices are low in summer after spawning, but improve again during a period of food storage in late fall. Age apparently has some effect on condition (unpublished data, VIMS). Examples of environmental conditions that may influence meat quality are: crowding and available food (Korringa, 1952); water depth (Nelson, 1933; Loosanoff and Engle, 1942); low salinity (Engle, 1946); and character of the bottom (Ito and Imai, 1955).

The Condition Index of oysters may be sharply increased by supplemental feeding with starch and lipids (Haven, 1965; Castell and Trider, 1974).

Aspects of Condition Index were investigated on public rocks in Virginia on an occasional basis from 1937 to 1947. Since then more information has been collected by the Virginia Institute of Marine Science which includes:

1. The Condition Index of oysters from representative public rocks from the York, James and Rappahannock rivers during winter from 1955 to 1971 (Haven, unpublished).
2. The Condition Index of oysters from representative public rocks from the York, James and Rappahannock rivers for each month from December 1969 to July 1971. This study has shown seasonal changes in Condition Index (Haven, unpublished).
3. The seasonal Condition Index of cultured-tray and "planted" bottom oysters was studied from 1955 to 1960 (Haven, 1962).

Information obtained in the preceding studies are summarized in Table 76 but, prior to understanding these data, one must be aware of the following scale of values for C.I.:

Condition Index	Yield Meats Per Bushel	Rating
3.0 to 5.5	5 pints or less	Below average - poor yield
5.6 to 7.5	5 to 6.5 pints	Average
7.6 and over	6.5 pints and up	Above average - good yield

Table 76

Summary of Condition Index of Oysters, Late Fall or Winter, 1955 to 1970, for James, York and Rappahannock Rivers.[1]

	1955-1956	1956-1957	1957-1958	1958-1959	1959-1960	1960-1961	1961-1962	1962-1963
James River								
Brown Shoal	5.2	NO RECORD	NO RECORD	4.9	4.7	6.3	5.3	
White Shoal	4.4					6.5		9.4
Point of Shoal								5.5
Wreck Shoal (shallow)	6.1			7.0	4.9	7.0	5.7	
Wreck Shoal (deep)								
Swash								6.6
Rainbow	5.5			6.3	4.9		3.5	
Horsehead				7.5	5.2		3.5	6.9
Deep Water Shoal	6.0			10.5	10.7			
York River								
Gloucester Point	6.2	7.4	5.7	6.6	5.6	6.7	7.5	10.9
Green Rock				7.1	5.2		5.6	5.9
Pages Rock	6.1	7.4	6.0	6.7	6.1	8.6	6.9	5.7
Aberdeen Rock	5.8	7.6	5.3	6.0	5.3	8.0	8.4	4.4
Purtan Bay			5.7			10.7		
Pig Rock	4.4		5.9			7.8		
Bell Rock (shallow)	5.8	5.7	6.3	7.0	4.6		6.9	
Bell Rock (deep)	5.7	5.2		6.7	4.4	9.2		6.0
Rappahannock River								
Rogues Hole	NO RECORD							
Broad Creek			9.0	10.0				
Parrotts Rock		7.6	7.6	8.1	8.1	10.3	11.4	7.2
Drumming Ground		8.5	7.5	8.5	8.6	6.8	10.9	8.8
Hogg House		7.0	9.4	8.3	7.8	12.3	9.9	11.3
Smokey Point		6.3	8.5	9.1	7.4	12.0	8.4	9.1
Punch Bowl		6.7						
Bluff Rock								
Morattico		7.7	9.3	8.6	6.2	9.8		8.1
Bowlers Rock			9.5	12.6	8.6	9.7		

Table 76 (Contd.)

	1963-1964	1964-1965	1965-1966	1966-1967	1967-1968	1968-1969	1969-1970	1970-1971
James River								
Brown Shoal	7.0	7.6	7.6			4.0	5.0	
White Shoal							6.1	
Point of Shoal							5.6	9.7
Wreck Shoal (shallow)	9.8	9.7	7.0			4.2	7.4	6.7
Wreck Shoal (deep)		6.1	7.7				4.9	6.2
Swash								
Rainbow	7.9					3.5		
Horsehead	7.4		9.3	5.7		3.5	4.6	6.9
Deep Water Shoal		10.0	10.5	7.1		4.6	5.6	8.6
York River								
Gloucester Point								
Green Rock	5.9	5.4					6.6	5.7
Pages Rock	4.8		4.2			4.0	6.4	5.4
Aberdeen Rock	6.6		3.9			4.6	7.0	6.1
Purtan Bay	7.7							
Pig Rock								
Bell Rock (shallow)	3.8		3.9	4.3		4.0		
Bell Rock (deep)	5.8						7.8	6.0
Rappahannock River								
Rogues Hole				7.6		4.5		
Broad Creek		6.1						
Parrotts Rock	8.1	7.9						
Drumming Ground	9.0	8.7				5.6	10.3	8.5
Hogg House	7.0	7.8	7.0			4.5	13.2	12.5
Smokey Point	9.4	7.4	7.9	7.5		3.8	10.2	10.6
Punch Bowl	9.0			4.8				
Bluff Rock	10.0							
Morattico	9.5	8.2	7.1	5.8		4.7	11.7	10.9
Bowler Rock						7.2	13.0	12.5

1. Data for 1955-56 through 1959-60 from Haven and Andrews (1962); data for 1960-61 through 1966-67 from Haven (unpublished); data since 1968-69 from Haven (in Marine Resources Information Bulletin, VIMS).

2. For Spike Ridge and Deep Rock at the entrance to the river.

Condition Index of Natural Rocks in Winter (During Harvest Period)

<u>James River</u>

Prior to 1957 the James River was classed as a seed area and meat quality was of minor consequence since few market oysters come from there, therefore, little attention was paid to the quality of the meats. Beginning in 1957 a major soup company began purchasing small oysters to be used in its frozen oyster stew.[3] These oysters are steamed open and meats packed in containers for shipment to the processing plant (Wheatley, 1959). Oysters used in this manner are known as "soups." Despite their different use and smaller sizes, the Marine Resources Commission lists them as "market" oysters and production was 2,352,228 bushels from 1963 to 1971. However, few exceeded 3 inches which is the legal size for market oysters in most areas. Most ranged from 1-3/4 to 2-3/4 inches in length (Table 27).

The extensive utilization of James River oysters as soup, market or food oysters instead of seed, which has developed since MSX has become prevalent, is of interest since the C.I. of these oysters is often the lowest

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[3]Since Kepone was found in the James River in 1976 oysters have not been processed as "soups" from that area.

of all systems studied from 1955 to 1971 when similar months and years are compared. No trend was noted in an up or down-river direction. Differences between years were especially marked. The periods of 1961-62 and 1968-69 were characterized by extremely low Condition Indices while those for 1965-66 appeared unusually high (Table 76). For all stations the average index for all years was 6.5 (calculated from Table 76).

The reasons for periods of low or high Condition Indices in the James are not fully understood. MSX and Dermocystidium act to lower the C.I., but the influence of these two diseases ends at Wreck Shoal (Andrews, 1967) where indices are as low as they are further upriver. The most probable reason for the lowered quality is related to nutrients.

York River

Meat quality of York River oysters has in the past been considered only average or below average with an all-station, all-years average of over 6.2. Galtsoff et al, (1947) described oysters in the upper York (above Clay Bank) in the winter of 1935-37 as poor and emaciated with a brownish or greenish discoloration of the mantle, gills and labial palps. Indices during this period in this upriver section averaged only 5.9, while in the lower river they were higher with an average of 8.3. Newcombe (1950) indicated an "average" condition of oysters in the midsection of the river and showed indices of 6.2 and 8.3 at Aberdeen and Page Rock, respectively, during the winter of 1947-48.

From 1955 to 1971 measurements of C.I. in the York during the winter showed conditions during that period (and presumably today) essentially unchanged from those described by Galtsoff in 1947. Over the years, oysters from any of the York's public rocks were average to below average; often they would yield about 6 pints per bushel or less (Table 76). No well developed trend was noted from 1955 to 1970. Condition Index was not consistently higher or lower in any one section of the York. Also, there was no indication that it was higher or lower in the pre- or post-MSX period.

Our evaluation of the poor quality of oysters from the York River was established principally from oysters grown on the public rocks. Private plantings were evaluated only to a limited extent. Sampling of private plantings in the vicinity of Clay Bank in 1953 indicated C.I. on these beds was low and similar to that on adjacent public rocks (Haven, personal communication). The condition is not river-wide. Areas in the mouths of several tributary creeks, such as Queens Creek, and especially the upper section, produce oysters of excellent quality. This was probably due to nutrients in the water which came from the upper reaches of each of these systems (i.e., from wetland contributed nutrients or perhaps the water from the creeks was of higher quality than main-stream water).

One possible cause of the poor quality of oysters in the mainstem of the York was studied by Galtsoff et al (1947), who attributed low quality to effluents from a large pulp mill at West Point which has operated there since 1919. His investigations failed to bear out the widespread suspicion. Later research has yielded the same results.

<u>Rappahannock River</u>

The all-years, all-season index for the Rappahannock was 8.7 which is considered above average.

It was superior to that observed in the York or the James rivers (Table 76). Quality from 1955 to 1960 was above average (6.2-12.6) with no trends in an up or downriver direction. Quality varied in this period annually with the winter of 1960-61 being exceptionally good. After 1960 quality was average or above-average for 6 out of 9 years for which data are available. Quality in the 1966-67 and 1968-69 seasons ranged from 3.8 to 7.5 which was below average.

Information obtained from growers indicates quality in these two periods to have been so low that few oysters from the region could be marketed. As far as we are concerned at this time, there is no information which might account for this low quality. No trend was noted in quality in the post-MSX periods (after 1960) in an up or downriver direction.

Other Areas

Condition Index studies have not been obtained in other river systems with any degree of regularity. The few measurements made in other oyster-growing regions such as the Eastern Shore, Mobjack Bay and the lower Chesapeake Bay were essentially average in respect to C.I. (Table 77).

Seasonality of Condition Index

Studies evaluating seasonal changes in C.I. in the York and the Rappahannock rivers were conducted from 1955 to 1959 and again from 1969 to 1975. The purpose of these studies was to determine the period when the oyster should be harvested to obtain maximum meat yields. In the earlier study, James River oysters were selected for uniformity in size and placed in trays in the York and Rappahannock rivers. Comparable groups were marked to aid recovery and placed on the bottom adjacent to the trays. Additional

Table 77

Condition Index of Oysters Taken from
Various Locations 1957, 1959, 1960
During the Winter Months

Location	1957	Year 1959	1960
Eastern Shore			
Wachapreague		8.4	
Machapungo		4.6 - 6.6	7.8
Cobb Island		8.5	
Onancock Cr.		5.8	
The Gulf		11.7	
Pocomoke Sound		7.0	
Potomac			
Machodoc Cr.			7.8
Coan R.			7.7
Ragged Pt.		9.2	
Chesapeake Bay			
Egg Island	8.4		6.3 - 6.6 - 6.8
Wolf Trap			6.7
Mobjack Bay	9.2		7.2 - 7.4 - 6.4
Hampton Roads			5.4 - 5.5

samples were collected monthly from representative public rocks in the same river (Haven, 1962). The study consisted of year-round, monthly samples of oysters of uniform size (3-4 inches) from public rocks from 1969 to 1975 (VIMS Information Bulletin). A summary of these studies follows.

Seasonality in the York River

Oysters cultured in trays and on the bottom from 1955 to 1959 showed similar trends in the upper and lower York (Haven, 1962).

1. Tray Oysters - In this five-year period oysters showed the maximum C.I. in May and June which ranged between 9.0 and 12.0. Condition Index decreased after this seasonal high and thereafter ranged between about 6.0 and 8.0 for the remaining months. The fall increase in Index, typical of oysters in other river systems, did not occur. A well-defined difference was noted in Index between oysters from the lower river at Gloucester Point and those grown in the upper river at Roane Point during the period from August through March. Upriver oysters in trays averaged about 2.0 C.I. units over those grown in the lower river.
2. Bottom Cultured Oysters - Oysters cultured on the bottom adjacent to the trays showed a similar

seasonal cycle to those grown in trays. Levels of Condition Index averaged about 1.5 units lower.

3. Oysters From Public Rocks - Oysters collected in winter from the public rocks at five stations in the York from 1955 to 1959 always had lower condition indices than those cultured in trays or those planted adjacent to the trays. Indices of these from public rocks collected monthly from 1969 to 1971 showed the same seasonal trends as did the cultured oysters studied from 1955 to 1959. There was a spring increase in quality following a lowered C.I. in July and August associated with spawning; there was no increase in C.I. after spawning. Condition Index of oysters from public rocks in winter ranged between 4.0 and 7.8 for the two-year period.

Seasonality in the Rappahannock River

The seasonal cycle of C.I. in this river differed from that in the York. In the Rappahannock there was a spring increase in C.I. followed by the usual summer decline after spawning. In the fall C.I. of the oysters again increased. Condition Indices at comparable seasons were much higher than in the York.

1. Tray Oysters - In the five-year period from 1955 to 1959 tray oysters from the upper and lower

river showed a major difference in C.I. In the lower river group the spring and fall peaks ranged from 11.0 to 13.0, while mid-winter indices averaged about 11.0. In the upriver section tray oysters showed the usual spring increase in C.I., which averaged about 11.0. In the fall and winter C.I. averaged between 13.0 and 14.0.

2. Bottom-Cultured Oysters - In the lower Rappahannock bottom oysters followed the same trend as tray oysters. Condition Indices were on the average 1.5 to 3.0 units lower than those grown in trays. In the upper river bottom oysters also followed the same trend as tray oysters, but differences between the two groups were always small and seldom exceeded 1.0 to 1.5 C.I. units.

3. Oysters from Public Rocks - From 1956 to 1960 oysters were collected from eight public rocks in the Rappahannock River during the winter months. Those oysters were above-average in Condition Index and, in general, far better than those from public rocks in the York River during comparable years. Quality, however, was lower than groups cultured in trays on adjacent bottoms.

Oysters collected monthly from the public rocks from 1969 to 1975 showed a seasonal cycle of Condition Index similar to that shown by tray and bottom-cultured oysters in the previous study.

Summary and Recommendations

Andrews and McHugh (1957) state James River seed oysters tend to reach maximum yields in terms of bushels or shell weight in June from 19 to 24 months after setting. Condition Index in the York River generally reaches a seasonal high during June and, consequently, yields and meat quality are highest during this month. Therefore, spring harvest of York River oysters is indicated if the harvester wishes to take his oysters at their best condition.

Data suggest in the Rappahannock that yields of meats per bushel and quality will be about the same during spring and fall. Oysters should be harvested in June because this season corresponds with maximum biomass. When harvest is delayed until fall then it should not be attempted before October. Although spring harvest of oysters is most practical for biological reasons, consumer demand is usually low in the spring when oysters are in peak condition. A possible solution to this dilemma would be to harvest and freeze or process oysters in June when they are at their best for consumption in winter when demand is high.

Oysters from the Rappahannock are clearly superior to those grown in the York and James in terms of Condition Index. These differences are not new but have existed since at least 1955 and been known since then. Studies by Haven (1965) suggest that differences may be associated with nutritional characteristics of the water, possibly carbohydrates. Studies relating to this problem have not been made and should be carried out. We must know more about the condition and oyster-growing characteristics of the various oyster waters.

Oyster quality in Virginia has not changed materially at the stations sampled from 1955 to 1971.[4] A drastic decline in oyster production and spatfall in Virginia has occurred during this period. Obviously, these declines cannot be associated with a decline in meat quality of oysters from the public rocks.

Studies are needed to show time necessary for seed to reach its maximum biomass in terms of shell growth and meat size in various regions. While informative, previous

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[4]Studies not summarized for this report up to 1976 corroborate this statement.

studies completed for the Gloucester Point area are limited in value since the data cannot be related to other regions where salinity, nutrients, predators and diseases impose different conditions on the oysters. Studies similar to those conducted at Gloucester Point are badly needed for other regions. They would tell oystermen where in each river he might expect to obtain an economically favorable ratio (above 1-to-1) between seed planted and yields. This information would help him determine where adequate or better yields could or could not be obtained and where he would probably lose money if he planted oysters.

Differences in the level of nutrients in the form of carbohydrates may be responsible for the differences in Condition Index between and within river systems. The basis for this hypothesis is that by adding starch (a carbohydrate) in minute quantities to water which is flowed over oysters, it was possible to obtain meats having a higher index than that found in the natural environment. Other substances which occur in natural waters such as protein, lactic acid and sucrose produced no effect. Lipids, however, may be important. There is much evidence to suggest that fluctuations in the level of carbohydrates do exist in the estuarine environment, since carbohydrates are part of the food reserve of green algae and also are found in decomposing plant materials derived from rooted plants on bottoms and in marshes. Details of the possible relations between levels of carbohydrates and like materials in the water and Condition Index must be evaluated carefully.

Density and numbers of oysters on specific areas of the bottom may be responsible for much variation in Condition Index since oysters are filter feeders and must compete for available food. In large groups (large numbers per area) they compete with each other to extract nutrient-bearing particles from the water surrounding them. Studies should be conducted to determine optimum planting density for maximum yield.

No significant long term trend in Condition Index were noted in the three rivers. That is, C.I. was about the same <u>in winter</u> prior to MSX (1960) as it was after. It is not possible to link factors (which might influence Condition Index) with the observed decline in spatfall and setting delineated in Chapter IV.

CHAPTER IX

PREDATORS AND DISEASES

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Introduction

Predators and diseases have always operated to reduce oyster populations and their detrimental influences on production have always been known to oyster culturists. Massive mortalities have occurred in the past sparking research and study of "pollution" or a search for previously unrecognized predators or disease-producing organisms. Prior to 1959 the commercial grower in Virginia often "lumped" mortalities due to disease and predators with those caused by environmental and cultural processes and accepted them as "normal." He often made no attempt to sort out individual causes. The only disease organism definitely known to cause significant mortalities prior to 1959 was the coccidium, *Dermocystidium marinum*, but others such as *Nematopsis ostrearum* were suspected. Important animal predators which were recognized included the species of drills, the voracious snails, *Urosalpinx cinerea* and *Eupleura caudata*, several species of fish, the blue crab, *Callinectes sapidus*, and possibly the oyster leech, *Stylochus ellipticus*.

Other animals known or suspected to interfere in varying degrees with the growth or metabolism of oysters are pea crabs, *Pinnotheres ostreum*; the trematode, *Bucephalus*, and the mud worm, *Polydora*. These organisms and numerous others have been around since historic times--most for millenia or eons. They will not be reviewed in detail since they have not been clearly associated with significant mortalities of oysters in the Chesapeake Bay Region.

Losses due to all factors between harvesting, transporting and planting of the seed and harvesting of the market oysters have always been large. Prior to 1960 a bushel of James River seed when planted might contain, on the average, 1,084 spat ranging up to one inch in diameter and, in addition, 1,093 small and market oysters from one to three inches long (Table 28). At harvest stage, two or three years later, the grower might typically obtain a single bushel containing about 300 small and three to four-inch oysters from this bushel of spat. This loss of over 1,877 potential market oysters is quite sizeable. If the loss could be reduced by a small amount, yields would be markedly improved.

Massive mortalities of oysters occurred in Delaware Bay in 1957-1958 and 1958-1959. The same phenomenon occurred in the fall of 1959 in oyster populations in the higher-salinity portions of the Chesapeake. These mortalities were traced to a microorganism known as Minchinia nelsoni, MSX. The onset of MSX disease added an additional mortality rate over that already existing. Consequently, after MSX began, James River seed could no longer be planted in areas classed as Type I MSX areas where large-scale operations were being carried out with any expectation of receiving a profitable crop of market-sized oysters. Only under specialized culture methods was it profitable to plant seed in a Type I area.

Hundreds of papers have been written on diseases and predators of oysters. Many were reviewed in preparing this Chapter and the review of those related to the Chesapeake Bay Region was as complete as possible. However, in the following detailed discussions, only those references necessary to confirm certain points and to show where additional material may be obtained are given.

Diseases

MSX Disease

Occurrence of the haplosporidian parasite, MSX (*Minchinia nelsoni*), in reservoirs of oysters (or other organisms) in higher-salinity waters of the Chesapeake system remains largely the reason why oysters may not now be profitably grown in those regions of the Bay. It is a systemic disease and occurs in all organs except nervous tissue. The plasmodial state, which is always present in the infected oysters, is usually from 4 to 30μ in diameter and may contain from 1 to 60 nuclei ranging from 1.5 to 7.5μ in diameter. Spores are very scarce but are occasionally seen in infected oysters (Haskin, Stauber and Mackin, 1966). The complete life history of the organism is not known even after twenty years of study. However, a tentative life cycle has been outlined by Farley (1968) and Perkins (1968, 1969a and 1969b).

History of MSX

The effects of MSX were first noted in the Spring of 1957 in New Jersey waters of Delaware Bay where by mid-summer a massive mortality had killed over half of the oysters on the beds where it occurred. Two years later nearly all oysters in this region died.

Its onset in Virginia was equally sudden though anticipated. Examination of oyster beds in February of 1959 in the Chesapeake Bay showed commercial plantings to be living with few deaths. Severe losses were reported by August of 1959 by Ballard Fish and Oyster Company, J. H. Miles Company and the J. S. Darling Company in the region extending down the western shore of the Chesapeake from Horn Harbor and Mobjack Bay to Hampton Roads (Figure 4). The sudden appearance in the Bay of MSX after bypassing the Seaside of Eastern Shore, where it had been anticipated to occur first, was unexpected. Monitoring by Dr. Andrews' group at VIMS followed the progress of the disease as it appeared in the Bay and the extent of its impact. Early losses within the Bay ranged from 30% to 50% of all the oysters on high-salinity beds except those planted in the Spring of 1959. The initial area of infestation in lower Chesapeake Bay included grounds which contained nearly all of the large-scale commercial operations--grounds on which over 3,000,000 bushels of oysters were planted. Mortalities continued and the disease extended its range into the lower sections of the James, York and Rappahannock rivers. By 1961 all plantings of seed oysters in the formerly productive lower Bay area and the lower reaches of adjacent tributaries had ceased (Andrews and Wood, 1967; Andrews, 1968). Public oyster bars in the lower estuaries were damaged.

In addition to its occurrence in the Chesapeake and Delaware bays where mass mortalities occurred, the disease organism has been found in oysters in Connecticut and in Long Island Sound, New York. In these high-salinity regions, for some unknown reason, the large mortalities associated with the disease in Delaware and Chesapeake bays have not been demonstrated (Haskin, Stauber and Mackin, 1966; Farley, 1968).

As an aid to the private sector of the industry certain areas in the lower Bay were declared disaster areas. Rents were remitted on 34,226 to 48,748 acres during the 1963 through 1967 period (Table 6).

MSX has not been successfully transmitted experimentally from an infected oyster to a healthy one. Failure to accomplish this basic step has seriously hampered experimental studies. It has also hampered efforts to discover and develop remedial measures. An additional severe shortcoming is that Koch's postulates have not been satisfied.

Areas Where MSX Occurs in Virginia in Relation to Salinity

MSX occurs in Virginia in living oysters over a very wide range which encompasses the middle and lower parts of Chesapeake Bay, the lower sections of the York, James and Rappahannock rivers, Mobjack Bay and the Bayside and Seaside of the Eastern Shore (Figure 30).

Two aspects of epidemiology and pathology are used by biologists to study the occurrence of MSX in oysters:

1. The prevalence of the disease organism in the oyster tissue, as determined by microscopic examination, and
2. The mortality rate associated with the disease (mortality).

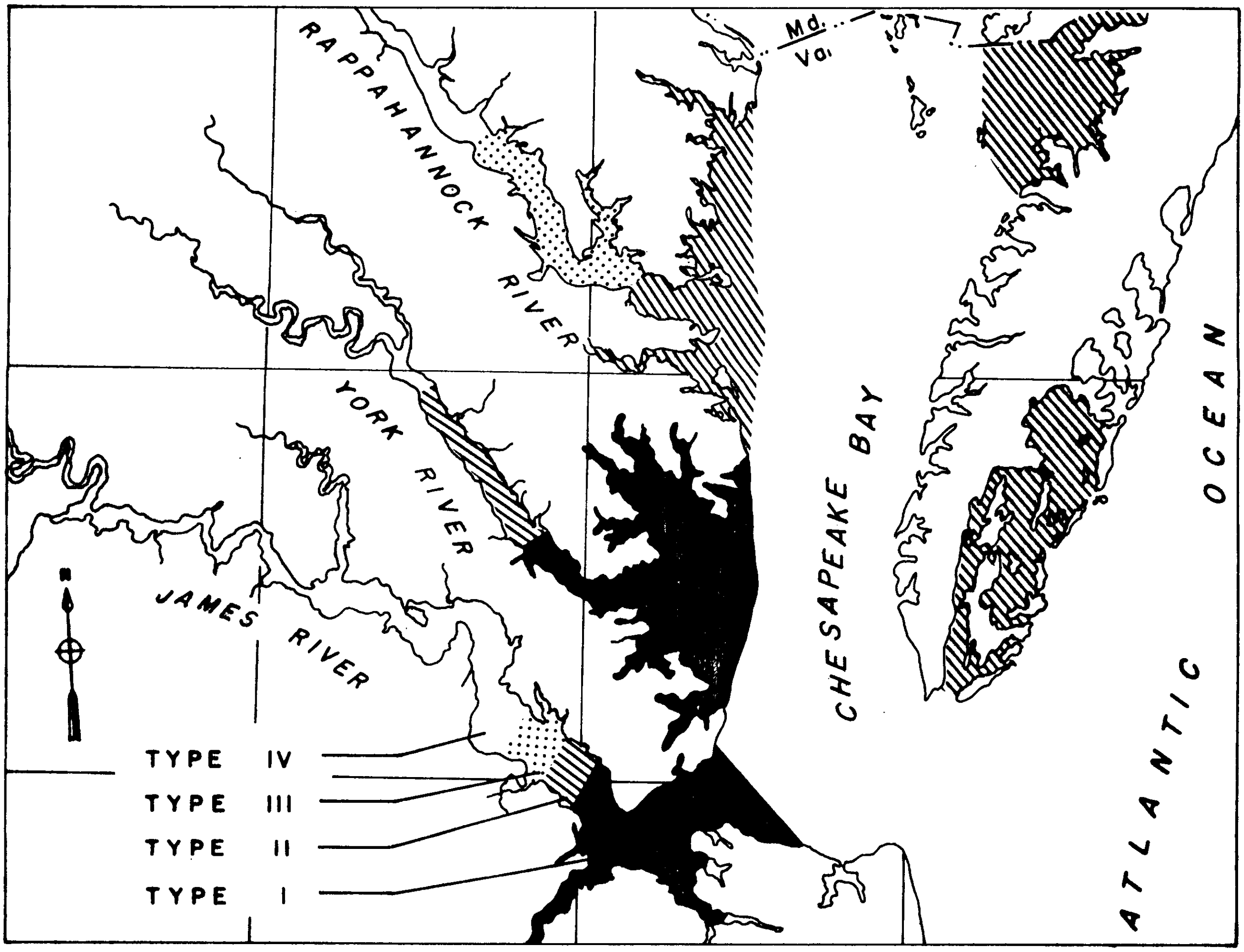
There is a positive relationship between the prevalence of the disease organism and the severity of mortality. Oyster populations showing low prevalence may exhibit little if any mortality. High prevalence is usually associated with high

Figure 30

Distribution of MSX in Chesapeake Bay showing Type I, II, III and IV areas.

The disease is most active in Type I and II areas.

From VIMS' Marine Resource Advisory Series, No. 1, September 1968.


Md.
Va.
RAPPAHANNOCK RIVER
YORK RIVER
JAMES RIVER
CHESAPEAKE BAY
ATLANTIC OCEAN
TYPE IV
TYPE III
TYPE II
TYPE I
N

mortalities (Andrews, 1968). Also, infected oysters demonstrate lower Condition Indices and yields.

Within Chesapeake Bay and its tributaries the average salinity of the water is related to the mortality pattern. The 15 ppt isohaline in late fall seems to divide a high MSX from a low MSX mortality area. Below about 15 ppt the organisms may be present in the tissue (low prevalence), but it is not associated with significant or extreme mortalities. On the Seaside of the Eastern Shore or Virginia where salinities exceed 28 ppt, the MSX organism, *M. nelsoni*, occurs in oysters at low levels (low prevalence). However, MSX (the organism) has not produced epizootics of oysters in this high-salinity environment (Andrews, 1968).

Only a few laboratory studies have been published on the relation between salinity and the occurrence of MSX in oysters, and those were of very limited scope. One study was conducted at the Chesapeake Biological Laboratory at Solomons Island, Maryland. It showed if oysters with a high incidence of infection (not stated) are exposed to 7.8 ppt for six months, then incidence of MSX was reduced to only 5.5%. Little reduction in incidence of the disease was indicated when oysters were held at 14 to 16 ppt (Sprague, 1961; Sprague, Dunnington and Drobeck, 1969).

Obviously, additional studies are needed to investigate the interrelation between salinity and MSX. Factors other than salinity may be involved. Possibly, some animal or plant vector or reservoir is involved which lives only in the salinity range of 15 to 28 ppt or the infection state only lives at this level. Other factors such as poor environmental conditions may cause debility and susceptability to MSX and contribute or result in development of epidemics.

For the purpose of classifying the intensity of MSX in the Chesapeake Bay, four types of areas based on mortality data and prevalence have been outlined [Andrews and Wood, 1967 and Andrews and Mason, 1968 (Figure 30)].

Type I MSX Area

MSX is fully active in all years and incidence of the organism in oysters varies from 36% to 72%. Annual losses in oysters planted in a Type I MSX region may be from 50% to 70% the first year.

Included in the Type I MSX category are:

1. All leased and public oyster grounds along the western shore of Chesapeake Bay from below the mouth of the Piankatank River to Lynnhaven Inlet (Figure 30).

2. The James River below the James River Bridge.
3. All tributaries of Chesapeake Bay between the York and James rivers with the exception of their extreme upper reaches.
4. Mobjack Bay and the East, North, Ware and Severn rivers with the exception of their upper reaches.
5. The York River from its mouth upriver to about Clay Bank.

Oyster culture is thought by most commercial growers to be economically impossible in Type I areas. Evidence supporting the absence of significant efforts at culture in Type I areas is overwhelming. To our knowledge, no oyster grower today is attempting to grow oysters from seed to full maturity (which requires two or three growing seasons) in such high disease areas. However, indications are limited use may be made of Type I areas if proper procedures are followed. One Norfolk grower plants nearly mature oysters on his beds in a Type I area in the lower Bay in fall or winter and harvests during the following spring or summer after they have fattened and grown slightly. This short growing period avoids the losses from MSX and other diseases which he would experience if oysters were left there for two growing seasons. This holding technique reportedly seems to be successful but production data are lacking. Other growers are not attempting similar use of their leased Type I grounds.

Type II MSX Area

Type II MSX areas are the transition zone between Type I areas where mortalities are considered by many to be too high for full-scale commercial oyster culture and Type III areas where mortalities are low enough to permit commercial production without special effort. Though poorly understood the limits of this zone fluctuate seasonally and yearly, but changes are associated with variations in salinity. These fluctuations make oyster culture in many Type II regions a gamble for the commercial grower. Oysters may be planted in a certain section of a Type II area when salinities are such that the disease is inactive, but a year or two of low rainfall may bring about an increase in salinity which will be accompanied by a return of the disease to the area. Since it generally takes at least two years for oysters to grow to full market size, this increase may bring about a rise in the disease level sufficient to kill enough of the seed so the grower does not realize a profit. In growing oysters in Type II areas it obviously is important for oyster managers to keep track of the late fall salinity to determine if they are averaging about 15%.

Approximate locations may be given for the lower limits of Type II areas as follows: Brown Shoals in the James River; mouth of the Rappahannock; mouths of the small creeks between the Rappahannock and the Little Wicomico and Clay Bank in the York. The upper limits of the Type II areas, in most of these systems, grade imperceptibly into the lower limits of the Type III areas (see description of Type III area, Figure 30).

All of the Seaside of Virginia's Eastern Shore is classed as Type II because of prevalence and mortality. However, the disease has not produced here the same severe epizootics as have occurred on the western shore (Andrews, 1968). Most of the Bayside of the Eastern Shore is also classed as Type II. Mortalities have occurred but rates have been poorly documented.

It is difficult to make a clear statement concerning oyster culture by private growers in Type II regions because in Virginia no record is required by the State as to the use of or production on leased bottoms. Only the individual grower knows where in a particular river system his oysters are planted and whether or not individual plantings succeeded or failed. Hence, neither VIMS scientists nor the State can determine which grounds are in use, how heavily they are planted and what their yields are. It seems as if a grower's unsuccessful plantings are discussed more frequently than those which do well. As a result, negative impressions predominate.

Perhaps the best statement which can be made about Type II areas is that oysters may be cultured to market size in the upper parts (lower salinity). The lower sections, where salinities might approach levels associated with excessive mortalities during certain years, are now avoided by growers. If growers so desired, many of the higher-salinity Type II areas could be more widely used to culture oysters for one growing season. Possible uses might be to grow soup-sized market oysters, holding oysters for depuration or to increase meat yields over short periods.

Type III MSX Area

Typically, the Type III MSX area is a zone where oysters strike and grow to maturity on natural substrate. Many of the natural rocks outlined in the Baylor Survey are located in such zones. Prevalence of the disease in these regions may be high in late fall but few deaths occur. Yields approach or exceed the average 1-to-1 ratio in many Type III areas. Typical Type III MSX regions include most of the James River seed areas, the Rappahannock bottoms above Grey Point, the upper York above Purtan Bay, and certain regions of the western shore of the Chesapeake Bay between the mouth of the Potomac and the Rappahannock. Salinities may range from about 8 to 15‰.

Type IV MSX Area

These areas are in the upper portions of the James, Rappahannock and Potomac rivers, in the upper reaches of several of the smaller tributary creeks and in most of the

Maryland portion of Chesapeake Bay. They are the low-salinity areas averaging from about 5°/oo to 12°/oo. MSX is seldom if ever found here with few or no oyster mortalities associated with this disease.

Mortality Pattern of MSX

The pattern of mortality, as monitored for seventeen years by Dr. Andrews and his co-workers at the Virginia Institute of Marine Science, has not changed appreciably since the disease first appeared. Oysters planted in winter or early spring in a Type I area exhibit only low mortality during the following spring months. A few may begin dying in May and June but deaths reach a peak during July and August. Mortalities decrease through October to less than 5% in December and January. A late winter kill of 10% to 20% may occur in late February and March. This pattern is repeated the second year. Death rates may reach 50% to 70% the first year and slightly less in the remaining population during the second year. Oysters planted in spring and early summer may begin dying during August, and the rate of kill is about the same as for oysters planted in fall (Andrews, 1968).

Type II areas exhibit the same timing of deaths as the Type I areas with levels of prevalence and mortality usually less than 20% for both. This is a transition zone and is characterized by wide variability in mortality ranging from those in a Type I to those in a Type III area.

It is regrettable that yields per planted bushel in Type II areas have not been defined in respect to more exact geographic limits and salinity ranges since much good oyster growing bottom exists in these locations. Trial plantings of seed should be made in Type II areas to determine whether or not the economically acceptable average of at least one bushel of market oysters to a bushel of seed might be obtained or exceeded. Research toward these ends should have high priority.

Impact of MSX on Public and Private Grounds and Sources of Data

A study was completed by VIMS in 1970 to show the percentage of leased and Baylor bottoms in Type I and II MSX areas and also the percentage decline in acres of leased bottoms in the same areas since 1960. This latter aspect initially proved difficult. The VMRC records of leased areas are updated each year to show only the current numbers of leases. They do not provide an accurate record for preceding years except when a special study exists.

While information on lease holdings for years prior to 1970 were lacking, a study had been made by the Marine Resources Commission for the State Water Control Board in 1967 showing the size of leases in various river systems. This was fortunate since in 1967 rent remission (Chapter II) was still in effect and most of the leases on record in 1960 (when MSX began killing oysters) were still being held by the growers.

That is, the 1967 study made it possible to show acreage and locations of the leases for 1967 (which is considered representative of the pre-MSX period), and to compare them with size of leases recorded for 1970 for similar areas when rent remission had been discontinued and when many of the grounds in Type I areas had been abandoned by the leaseholders because of MSX. Data for years after 1970 were not included, since after 1970 additional factors besides MSX strongly influenced acreage and locations leased.

The area actually influenced by MSX was calculated using the bounds of Type I and II MSX areas outlined by Andrews and Wood (1967). The acreage of public grounds in various regions was calculated in relation to the bounds of Type I and II areas using Baylor Survey charts and other sources of information. Calculations of areas of private leases in the Type I and II areas were made using the previously cited 1967 publication prepared in part by the VMRC and published by the State Water Control Board as well as the charts showing 1970 leases on file at the VMRC (Table 78).

Rent Remission on Leased Bottoms

The impact of MSX on the oyster industry was especially severe on growers who had to maintain their leases in Type I areas without any expectation of being able to grow a profitable crop. For these growers rent relief was provided in 1962 by the

Table 78

Location and Amount of Public Oyster Grounds on the Western Shore of Chesapeake Bay, in Type I & II MSX Areas.[1]

Location	Total in Locations	Amount (Acres) Type I	Type II
1. Potomac River Tributaries	2,988	0	0
2. Chesapeake Bay, Smith Pt. to Windmill Pt., incl. Little and Great Wicomico Rivers and Indian Creek	24,438	0	19,719
3. Rappahannock River	5[illegible],185	0	8,496
4. Chesapeake Bay, Stingray Pt. to Wolftrap, incl. Piankatank River and Milford Haven	15,297	0	15,297
5. Horn Harbor, Mobjack Bay & Chesapeake Bay off York River	24,634	24,634	0
6. York River	3,850		
Mouth to Cedarbush Cr.		1,555	
Cedarbush Cr. to Bells Rock			950
7. Poquoson River & Chesapeake Bay off mouth	7,824	7,824	0
8. Back River	0	No Public Ground	
9. James River	27,841		
a) Hampton Roads and James River below bridge		14,792	
b) Bridge to Blunt Pt.			4,478
10. Chesapeake Bay, Back River to Cape Henry	0	No Public Ground	
TOTAL	162,057	48,805	48,940
% of Public Ground on Western Shore of Chesapeake Bay		28	30
11. Eastern Shore - Bayside		0	36,623
Seaside		0	44,591

1. Extent of areas taken from VIMS' Marine Resources Advisory Series No. 1, September 1968.

Commission under authority of Section 28, 1-114 of the Code of Virginia (Table 6). Rent remission continued until 1967 for a period of about five years.

A brief review of the rent remission program follows. Rents were remitted in Type I and portions of Type II MSX areas from 1962 through September 1967. Acreage exempted varied from 34,226 to 48,748 acres. During this period relatively few growers abandoned leased land, even that infested by MSX. During 1967, the last season for rent remission, leased acreage in Virginia waters was at an all time high of 134,492 acres (Table 5). A resolution which discontinued rent remission was passed June 27, 1967 by the Virginia Marine Resources Commission (VMRC, 1967). This decision again made it costly for certain growers to hold all their leases in Type I areas. Consequently, many marginal grounds were abandoned beginning in 1968 in Type I areas, and there was a drop in total leased acreage in the State from 134,492 to 100,662 acres by 1975.

The Acreages of Leased Bottoms Influenced by MSX

Chesapeake Bay has been divided into three regions for analysis of changes in leased bottoms due to MSX: 1) all leased ground on the Eastern Shore on the Bayside; 2) on the Seaside; and 3) all leases on the Western Shore of the Bay.

On the Seaside of the Eastern Shore from 1967 to 1970, where 100% of the area is classed as Type II for MSX, there was no decline in leases. In fact, there was a small increase in leased acreage of about 1% (Table 79). This suggests that oystermen operating in this high-salinity, low MSX area were still optimistic about growing oysters in this region or they were holding the grounds for other reasons. In relation to this point, Andrews (1968) states that, "MSX has not caused enough deaths in eight years of monitoring tray oysters on the Seaside to produce a recognizable peak in mortality curves."

The Bayside of the Eastern Shore, also classed as Type II for MSX, showed a decline from 13,580 to 11,198 acres of leased bottom during the period from 1967 to 1970, a decrease of 18% (Table 79). It is noted that production in this area during the past 20 years has always been low.

On the western shore of the Chesapeake Bay, 18% of all leased bottoms was abandoned between 1967 and 1970 following the MSX-related mortalities in 1959-1961 and the end of remission. It was highest in Type I areas where there was a 33% decline in leases and less in Type II areas where 11% of the leases were abandoned. Areas where most bottoms were abandoned were in Chesapeake Bay where large-scale oyster farming was practiced by several large growers prior to the appearance of MSX, now classed as Type I for MSX. For example, there was a

TABLE 79

Location and Acreage of Private Oyster Ground in Virginia in Type I & II MSX Areas, 1967 and 1970.[1]

	Location	TOTAL ACREAGE IN LOCATION 1967[2]	1970[3]	Per Cent Change Area	TYPE I Acreage 1967[2]	1970[3]	Per Cent Reduction	TYPE II Acreage 1967[2]	1970[3]	Per Cent Reduction
1.	Potomac River	9,351	8,818	-6	0	0	-	0	0	-
2.	Chesapeake Bay, Smith Pt. to Windmill Pt., incl. Great & Little Wicomico Rivers	7,038	5,680	-19	0	0	-	5,069 65%	4,100 72%	19
3-a.	Rappahannock River	13,823	15,883	+15						
b.	Below Grey's Pt.				0	0	-	1,046 8%	1,046 7%	0
4.	Chesapeake Bay, Stingray Pt. to Wolftrap, incl. Piankatank River & Milford Haven	3,495	3,466	-1	0	0	-	3,495 100%	3,466 100%	1
5.	Horn Harbor, Mobjack Bay & Chesapeake Bay off York River	25,577	13,080	-43	22,980 100%	13,080 100%	43	0	0	-
6-a.	York River	14,803	15,165	-13						
b.	Mouth to Cedarbush Creek				5,712 38%	4,967 33%	13			
c.	Cedarbush Creek to Bells R.							9,588 55%	8,337 55%	13

TABLE 79 (Contd.)

	Location	TOTAL ACREAGE IN LOCATION 1967[2]	1970[3]	Per Cent Change Area	TYPE I Acreage 1967[2]	TYPE I Acreage 1970[3]	TYPE I Per Cent Reduction	TYPE II Acreage 1967[2]	TYPE II Acreage 1970[3]	TYPE II Per Cent Reduction
7.	Poquoson River & Chesapeake Bay off mouth	4,340	3,447	-21	4,340 100%	3,447 100%	20	0	0	-
8.	Back River	2,575	2,091	-18	2,575 100%	2,091 100%	18	0	0	-
9-a.	James River	16,174	14,813	-14						
b.	Hampton Rds., Nansemond R. & James R. below bridge				11,139 69%	8,966 60%	19			
c.	Bridge to Blunt Pt.							1,618 10%	1,618 11%	0
10.	Chesapeake Bay, Back R. to Cape Henry	5,848	2,545	-56	5,848 100%	2,545 100%	56	0	0	-
Total private ground on western shore of Chesapeake Bay		103,024	84,988	-18	52,594 51%	35,096 41%	33	20,816 20%	18,567 22%	11
11.	Eastern Shore-Bayside	13,580	11,198	-18				13,580 100%	11,198 100%	-18
	Seaside	17,456	17,644	+1				17,456 100%	17,664 100%	+1
Totals - Virginia		134,060	113,830	-15						

TABLE 79 (Contd.)

NOTES:

1. Extent of areas taken from VIMS' Marine Resources Advisory Series No. 1, September 1968. Preceding report indicates most of Eastern Shore is in Type II. However, effect of MSX is negligible on Eastern Shore (Andrews, 1968); therefore, Eastern Shore acreage, which was 28,842 acres in 1970, is not presented here.

2. Data from "Location of Oyster Beds in Virginia," State Water Control Board, 1967, Richmond.

3. Data from records at VMRC, 1 January 1970.

43% decline in leases from Horn Harbor to the mouth of the York River; from this area to Cape Henry there was a 56% decline in leased bottoms.

Leases in Type II areas showed smaller declines. These areas were the Great Wicomico, the Little Wicomico and the Bay area to the north of the Piankatank.

In the Rappahannock (Type II) there was a 15% increase in leased bottoms from 1967 to 1970 (Table 79). This increase indicated a move on the part of leaseholders to take up bottoms in growing areas where MSX was not a problem.

While the overall reductions in acres of leased bottoms in Type I and II locations seem impressive, growers in Chesapeake Bay in 1970 still held large acreages in areas influenced by MSX. As of 1970, 35,096 acres were still being leased in Type I areas and an additional 18,567 were located in Type II zones (Table 79).

Further analysis of the data for 1967 shows when MSX appeared in the Bay, 51% of all leased areas on the Western Shore of the Chesapeake Bay were in an area now classed as a Type I area. These went out of production. An additional 20% were in Type II areas and went partially out of production (a total of 71%). The once highly productive private grounds in the lower James River (Hampton Roads) showed a similar pattern with 69% of the leased bottoms in Type I area and an additional 10% in the Type II. All leased bottoms in the Poquoson and Back rivers, Mobjack Bay and Horn Harbor areas were in the Type I area.

Areas significantly influenced by MSX disease were fewer in the low-salinity regions of the upper Bay. No leased bottoms from Milford Haven to Smith Point were classed as being in a Type I area. The system least affected in the entire State was the Rappahannock River, where only 8% of the leased bottoms were classed in the Type II MSX category.

The tributaries' bottoms in the Potomac are classed as Type II or IV. The mainstream of the Potomac is not shown on Andrews' (1968) chart. However, MSX is occasionally found only in the lower reaches of the system and there it might be classed as Type III. The rest of the mainstream of the Potomac is Type IV.

In conclusion, on the Western Shore in 1967 some 73,410 acres of bottom were in Type I or II areas out of a total of 103,022 acres under lease for that year. Approximately 71% of all the leased bottoms were influenced to some degree by the disease.

MSX and Baylor Survey Grounds

Baylor Survey Grounds were not influenced by MSX to the same degree as private leases. This situation might be expected since these public grounds occupy most of the historically productive, natural setting areas where salinities are low or in the mid-range. For many centuries oysters have survived best on the lower-salinity bottoms where diseases and drills and other high-salinity related, mortality-producing factors were fewer. For the Western Shore of the Chesapeake Bay, 28% of all public grounds are in Type I MSX areas and 30% are in Type II (Table 78). This gives a total of 58% which is lower than the figure of 71% for private leases (Table 79).

The preceding table which indicated 58% of the State's Baylor Grounds on the Western Shore to be influenced by MSX is accurate but somewhat misleading. The reason is that a number of Baylor Grounds are located in high-salinity areas which never have produced significant quantities of oysters, even in the pre-MSX days. This was discussed in Chapter II where it has been shown that 6,170 acres of oyster ground were added to the Baylor Survey off the mouth of the Poquoson River in 1958 (Type I area). Also, 20,532 acres of unproductive Baylor bottom exists in high-salinity water (Type II) in Chesapeake Bay off the mouth of the Great Wicomico River. Other unproductive areas undoubtedly exist but by themselves the two locations described total 26,702 acres.

If the data in Table 78 are corrected by the total, then the amended figures would be:

Baylor Ground Acreage in Type I Area:

(44,606 - 6,170)	=	38,436 acres
% in Type I	=	24%

Baylor Ground Acreage in Type II Area:

(48,940 - 20,532	=	28,408 acres
% in Type II	=	11%
TOTAL		35%

While the new value of 35% is only our best estimate, it is far lower than the 71% estimated for private leases, and it confirms our original contention that the impact of MSX was more severe on leased areas than on productive Baylor bottoms.

Individual areas of public bottoms which were productive prior to MSX have been influenced by this disease in a pattern similar to that shown for private leases. Those located in high-salinity waters have been influenced to the greatest degree. The following values were calculated from Table 78. The James has 53% of its public bottoms in Type I and 16% in Type II. The Rappahannock region is favorably situated in relation to MSX since only 15% of all public bottoms is classed as Type II and none as Type I (calculated from Table 78). None of the Potomac River tributaries in Virginia or their leased or public bottoms are in Type I or II areas.

The Impact of MSX on Statewide Oyster Production

The catastrophic impact of MSX on oyster production was fully discussed in Chapter III. It is sufficient to repeat here only how large the decline was.

The average annual production on leased bottom s was 2,654,838 bushels from 1951 to 1960, and from 1961 to 1967, when rent remission was still in effect and growers had not released their bottoms, it averaged 1,413,437 bushels. This was a decline of 47%. This decline was due to the interrelated factors of a high death rate on Type I and II bottoms, and the absence of planting on the same areas because of MSX. The 47% decline occurred largely on the 97,745 acres of leased bottoms on the Western Shore classed as Type I or II for MSX (Table 78).

From 1951 to 1960 the overall State average for landings from leased bottoms was 21.6 bushels of oysters per-acre-per-year. It fell drastically from 1961 to 1967 to 10.6 bushels per acre (calculated from Table 5).

A Recent Increase in Oyster Number

There has been an increase since 1972 in oyster density on Baylor and leased bottoms below the James River Bridge on the south side of the river, in Mobjack Bay and in Back River. The principal reasons for this increase is probably due to mortality of drills by flood waters associated with Tropical Storm Agnes in 1972. However, of equal importance is the probability that these oysters have acquired resistance to MSX as will be discussed later in this Chapter.

Impact of MSX on Individual Growers

The impact of MSX on many oyster growers may be illustrated by production records of three of the largest companies in Virginia prior to MSX. Before 1960 the J. H. Miles Company and the Ballard Fish and Oyster Company, both of Norfolk, and the J. S. Darling Company of Hampton, grew about 28% of all oysters produced in Virginia. The growing grounds of these companies were in the lower Chesapeake Bay in the zone which later was classed as Type I for MSX and included Wolf Trap Light, Mobjack Bay, the area off Back River, Ocean View and Willoughby Spit (Figures 3, 4, 5 and 30).

For the J. H. Miles Company and the J. S. Darling Company, records were detailed but not always as complete as would have been desired.

For most years the J. H. Miles Company reported yields in terms of market oysters plus shells. This was the usual method of harvest for the larger growers. When the oysters matured everything was dredged from the bottoms and taken to the shucking house. Here shells and oysters were passed before the shuckers who removed and shucked living oysters; shells and "culls" went to the shell pile. In certain instances the Miles records contained data on actual yield of market oysters based on subsampling.

Records of the J. S. Darling Company contained detailed annual records of volume of seed planted in relation to yields of market oysters for several locations, and annual summaries for the combined operations of all areas. Records of the Ballard Fish and Oyster Company contained only annual production of shells and oysters.

The J. H. Miles Company planted more seed than any other company in Virginia prior to 1960 and maintained extensive growing grounds in Mobjack Bay and Ocean View (Willoughby Spit). Prior to MSX, from 1936 to 1960, annual seed plantings ranged from 106,405 to 1,004,528 bushels (Table 80). Total production of market oysters over this period is not available because of the company's system of recording catch in terms of bushels of living oysters plus shells. Typically, this company allowed seed oysters to remain two or three years (warm seasons) on a growing bed, and at harvest the dredged shells and oysters were transported to the processing plant in Norfolk for shucking. Yield of live oysters was determined by the company by recording volume of live oysters in 10 bushels of dredged material from a known quantity of material in a boat load. Catch of live oysters in the boat load was then calculated. Unfortunately,

Table 80

Total Oyster Production and Plantings of J.H. Miles & Co.
Before and After Culling

A. Before Culling | B. After Culling

Season Ending	Seed Plantings in bushels: Ocean View	Seed Plantings in bushels: Mobjack	Seed Plantings in bushels: Total	Oysters & Shells Dredged in bushels: Ocean View	Oysters & Shells Dredged in bushels: Mobjack	Oysters & Shells Dredged in bushels: Total	Oysters Culled in bushels: Ocean View	Oysters Culled in bushels: Mobjack	Oysters Culled in bushels: Total Bu.	% Culled ('49-'57)
1935-36	no data	227,102	227,102	no data	no data					
1936-37	168,388	81,088	249,476	no data	no data					
1937-38	111,083	309,198	420,281	no data	no data					
1938-39	260,628	317,788	578,416	no data	no data					
1939-40	220,502	506,558	727,060	no data	no data					
1940-41	351,240	383,036	734,276	no data	no data					
1941-42	202,145	802,383	1,004,528	359,597	760,258	1,119,855				
1942-43	86,839	674,851	761,690	no data	619,159	619,159				
1943-44	260,095	no data	260,095	no data	93,547	93,547				
1944-45	188,709	no data	188,709	no data	351,151	351,151				
1945-46	149,054	no data	149,054	no data	607,653	607,653				
1946-47	307,919	no data	307,919	no data	609,089	609,089				
1947-48	106,405	no data	106,405	no data	976,321	976,321				
1948-49	261,902	414,386	676,288	205,986	871,329	1,077,315	102,993	554,277	657,270	61
1949-50	190,882	809,236	1,000,118	265,527	798,662	1,064,189	119,487	440,344	559,831	53
1950-51	111,511	638,744	750,255	105,732	580,282	686,014	52,428	300,877	353,305	52
1951-52	171,887	538,773	710,660	361,649	279,036	640,685	164,138	124,842	288,980	45
1952-53	172,046	436,552	608,598	195,907	547,839	743,746	86,219	280,156	366,375	49
1953-54	111,511	524,003	635,514	201,238	311,829	513,067	118,565	157,353	275,918	54
1954-55	no plant	728,208	728,208	247,650	825,794	1,073,444	116,396	429,413	545,809	50
1955-56	116,067	350,074	466,141	509,838	564,656	1,074,494	163,138	258,425	421,563	39
1956-57	130,155	573,026	703,181	no data	761,950	761,950	no data	480,028	480,028	63
1957-58	143,943	583,836	727,779	no data	860,013	860,013	no data	no data	no data	
1958-59	125,812	656,226	782,038	96,925	599,209	696,134	no data	no data	no data	
1959-60	no plant	206,793	206,793	no data	1,125,473	1,125,473	no data	no data	no data	
1960-61	19,800	17,200	37,000	158,550	648,600	807,150	no data	no data	no data	
1961-62	NO SEED PLANTED AFTER 1961									
Total									3,949,079	
Average										52

data on numbers of bushels of live oysters produced are available only from 1949 to 1957 (Table 80). Our analysis of the data from this period showed that living oysters made up 52% of each dredge load on the average. In the pre-MSX period they obtained an average yield of about one-half bushel of market oysters for every bushel of seed planted.

Based on company records from 1949 to 1957, average annual landings of market oysters, based on subsampling the shells plus oysters, was 438,786 bushels. This production is considered representative for the entire pre-MSX period. Production of market oysters for periods prior to and after this time (but before 1960) may be estimated as 52% of the total catch of oysters plus shells.

The impact of MSX on this company's operation is evident since no seed was planted by the company after 1961 at Ocean View or Mobjack Bay. The large harvest of 1,125,473 (almost twice as high as the previous annual level, for 1960 (Table 80) was due to an attempt by the company to remove all oysters (i.e., those planted in 1959 as well as those planted in 1958) from their beds before they could be killed by MSX.

Apparently this company, in contrast to some others, listened to the warnings by VIMS scientists of the inception and impending spread of MSX and accepted the advice to harvest to avoid losses.

Records of the Ballard Fish and Oyster Company were less detailed than those of the Miles organization, covering only the period from 1949 to 1960. They were available only in terms of total quantities of shell and oysters harvested (Table 81). An estimate of the volume of live oysters harvested by the Ballard Company has been made using percent-culled data figure (52%) for the J. H. Miles Company (Table 80). While this is at best an approximation, it still provides the best industry data available. These data showed annual average production from 1949 to 1960 for the Ballard Company as 318,511 bushels. After 1961 a company official stated oyster culture in the Bay area was abandoned because of MSX. Limited culture was resumed on a very small scale starting in the mid-60's but total production in this area since then has never exceeded an estimated 5,000 bushels annually.

The Ballard Company also showed an increase in oysters produced in 1960 from 362,448 bushels the previous year to 471,635, the highest level ever in the 11 years of record (Table 81). They too may have heeded the warnings and harvested to avoid losses. In fact, it is 109,187 bushels higher than 1959 and 81,757 bushels higher than the highest year of record, 1955 (389,878 bushels), and 153,124 bushels higher than the 12-year average of 318,511 bushels.

Table 81

Oyster Production From the Grounds of
Ballard Fish & Oyster Company

Season Ending	Oysters & Shells Dredged in Bushels[1]	Percent Culled[2]	Oysters Bushel
1948-49	579,363	52%	301,269
1949-50	537,401	52%	279,449
1950-51	421,992	52%	219,436
1951-52	415,524	52%	216,072
1952-53	507,305	52%	263,799
1953-54	630,965	52%	328,102
1954-55	749,765	52%	389,878
1955-56	543,350	52%	282,542
1956-57	633,435	52%	329,386
1957-58	727,152	52%	378,119
1958-59	697,016	52%	362,448
1959-60	906,990	52%	471,635
Total			3,822,135
Average			318,511

Notes:

1. Data from records of Ballard Fish & Oyster Company
2. Percent culled is estimated on the basis of Table 80.

The records of J. S. Darling Company, now totally out of business, provided the clearest and most explicit documentation of the devastating impact of MSX on the private sector of the industry in high-salinity areas. The following is quoted directly from the conclusion of their record book, a copy of which was made available to VIMS, which documents their production and other aspects from 1941 to 1962.

> Mortality of Oysters - Lower Chesapeake and Mobjack Bays
>
> Mortalities increased over the years from 1947 to 1959. Some years mortality was no more than what has always been considered normal. But these years were followed by years of very high death rate.
>
> The season 1959-1960 proved to be by far the most serious of any known to anyone in the business. In the Summer of 1959 oysters began to die and by September approximately 80% of all three year old oysters were dead on our grounds. Two year olds were dead up to 60%. One year olds were alive and not too badly affected.
>
> Because of their mortality, we had a very small production in 1959-1960 and were also forced to stop buying seed in December 1959.
>
> In February and March 1960 a new and different mortality cause wiped out a great many more two year old oysters, but again did not kill many one year olds or newly planted seed.
>
> In the season 1959-1960 we used (harvested) beds that had been planted with 258,942 bushels (of) seed and took up (only) 66,413 bushels which was equal to 256 bushels for every 1000 bushels (of) seed planted.

The J. S. Darling Company of Hampton regularly planted James River seed in Chesapeake Bay off New Point Comfort, two places in Mobjack Bay, on Hampton Bar in the James River and during two years in the lower York River. Oysters were usually allowed to remain on the grounds for two seasons (two warm water periods) prior to harvest, as contrasted to two or three years for the J. H. Miles Company. Unculled loads of shells and oysters were transported to the shucking house where "bushels harvested" were regularly determined by the company on the basis of live oyster counts in subsamples of dredged material.

Data on total seed planted are available only from 1945 to 1961 (Table 82). During the pre-MSX years (up to 1960) the company planted annually from 106,622 to 304,398 bushels of seed (an average of 210,565 bushels). Most came from the public rocks in the James River. Smaller quantities came from leases owned by Darling as follows: Mulberry Island in the James River, Hampton Creek, Back River, Pagen Creek, the Elizabeth River and an area in the lower James about two miles above Newport News Shipyard (Figures 3, 4 and 5). In the 1960-1961 season (after MSX struck) planting dropped to a total of only 16,961 bushels.

Summaries of market-oyster production for 1941 to 1962 by the Darling Company are presented in Table 83. During the pre-MSX years (1941-1959) annual production ranged from 227,352 to 109,093 bushels with an average of 147,869 bushels.

Table 82

Total Seed Oysters in Bushels Planted by the
J. S. Darling Oyster Co.,[1] Hampton, Virginia
1945-1961

SEED PLANTING RECORD

Season	York River	Hampton Bar	New Point	Mobjack	James Ground	Total Seed (Bushels)	Total Market (Bushels)[2]
1945-46	0	155,973	64,727	44,218	35,665	300,078	173,214
1946-47	0	149,386	70,529	20,993	52,383	293,232	206,260
1947-48	0	110,085	47,147	45,895	17,872	220,999	188,784
1948-49	30,782	134,488	14,504	33,017	8,886	221,787	111,560
1949-50	0	209,784	94,614	0	0	304,398	133,672
1950-51	7,260	113,372	0	0	55,032	175,663	121,981
1951-52	0	110,618	43,557	0	33,245	187,420	123,690
1952-53	0	96,302	18,535	56,758	17,357	188,952	114,914
1953-54	0	76,116	57,223	61,784	0	195,123	116,852
1954-55	0	114,792	22,583	21,036	47,397	205,808	109,093
1955-56	0	78,522	62,144	0	31,801	172,467	120,636
1956-57	0	74,769	64,816	43,257	14,555	197,397	135,816
1957-58	0	60,144	24,114	65,336	40,710	190,304	66,413
1958-59	0	61,353	66,060	21,418	49,400	198,231	28,354
1959-60	0	27,956	63,325	0	15,341	106,622	10,899
1960-61	0	16,961	0	0	0	16,961	0
Totals	38,042	1,590,621	713,378	413,652	419,644	3,175,442	1,762,138
Average						210,565[3]	110,133

Market oysters as % of seed = 52%

Table 82 (Contd.)

1. These data are taken from summaries in company books. They do not agree exactly with data shown in Table 84 which are taken from the more detailed yearly records. The reason why is not known.

2. These data are from Table 83 but they are tabulated 2 years after the date shown in the table. The reason being that seed was allowed 2 years to grow by the J. S. Darling Company.

3. 1960-1961 excluded from average.

Table 83

Annual Market Oyster Production in Bushels from Grounds of Ballard, Miles and Darling[1] Contrasted to Total Virginia Production

Season Ending	Darling Company	Ballard Company	J.H. Miles Company	Total	Virginia Total[2]	Percent of Total Va. Landings
1940-41	130,411					
1941-42	135,089					
1942-43	227,352					
1943-44	175,076					
1944-45	136,050					
1945-46	146,098					
1946-47	202,962					
1947-48	173,214					
1948-49	206,260	301,269	657,270	1,164,799	3,438,482	34
1949-50	188,784	279,449	559,831	1,028,064	2,620,509	39
1950-51	111,560	219,436	353,305	684,301	2,413,681	28
1951-52	133,672	216,072	288,980	638,724	2,633,983	24
1952-53	121,981	263,799	366,375	752,155	2,791,805	27
1953-54	123,690	328,102	275,918	727,710	3,461,791	21
1954-55	114,914	389,878	545,809	1,050,601	3,283,315	32
1955-56	116,852	282,542	421,563	820,957	3,470,651	24
1956-57	109,093	329,386	480,028	918,507	3,193,534	29
1957-58	120,636	378,119	no record			
1958-59	135,816	362,448	no record			
1959-60	66,413	471,635	no record			
1960-61	28,354	no more	no more			
1961-62	10,899	produced	produced			
Totals '49-57	1,226,806	2,609,933	3,949,079	7,785,818	27,307,751	
Avg. '49-57	136,312	289,993	438,787	865,091	3,034,195	28

1. Data obtained from books of the companies.

2. Data from Fish. Stat. U.S. NMFS. See Table 13 .

The impact of MSX is clearly shown since harvest dropped to 66,413 bushels in 1960 and then to 10,899 bushels in 1962. Thereafter the company did not engage in oyster culture on any scale.

In the J. S. Darling records are summaries showing seed plantings in relation to bushels harvested. Their records are not always complete, but are sufficient to show percentage survival (Table 84). It is noted that the values shown for market-oyster production, if totaled, do not equal total production data shown in Table 83. The reason for this is data in Table 84 for certain years are not available from their records.

Prior to the appearance of MSX, before the 1960 harvest, there was an average of 40% to 140% survival of seed planted in the Mobjack Bay-New Point Comfort area. After MSX influenced oyster production (beginning with the 1958 seed planting), its impact is clearly seen. For these plantings only 12% to 24% of the planted seed survived to maturity.

The grounds leased by J. S. Darling in Hampton Roads received heavy use, and from 1945 to 1961 they were planted with a total of 1,615,718 bushels of seed (Table 84). These oysters were not harvested directly from the area, but were dredged along with shells and transplanted to the York River or Mobjack Bay for depuration. As a consequence, initial

Table 84

Oyster Production and Plantings of the J. S. Darling Oyster Company, Hampton, Virginia In Mobjack Bay and Off New Point Comfort[1]

Season	Mobjack Bay			New Point Comfort		
	Bushels Planted[2]	Bushels Harvested	Percent Survival	Bushels Planted[2]	Bushels Harvested	Percent Survival
1945-46	44,218	42,158	95	64,727	50,182	78
1946-47	20,933	29,435	141	70,529	47,849	68
1947-48	45,895	28,580[3]	-	47,147	41,389	88
1948-49	33,017	36,883[3]	-	14,504	9,926	68
1949-50	0	0	-	94,614	60,966	64
1950-51	0	0	-	0	0	-
1951-52	0	0	-	43,557	40,029	92
1952-53	56,758	42,129	74	18,535	7,462	40
1953-54	61,784	30,656	50	57,223	28,096	49
1954-55	21,036	15,482	74	22,583	12,340	55
1955-56	0	0	-	62,144	24,686	40
1956-57	43,257	22,918	53	64,816	43,906	68
1957-58	65,336	12,896	20	24,114	5,675	24
1958-59	21,418	3,265	15	66,060	8,213	12
1959-60	0	0	-	63,325	8,504	13
Total	413,652	264,402		713,378	389,223	
Average[5]			64			55

Table 84 (Contd.)

	James Ground - Mobjack Bay			Hampton Bar			
Season	Bushels Planted[2]	Bushels Harvested	Percent Survival	Source*	Bushels Planted	Bushels Harvested	Percent Survival
1945-46	190,765	65,256[3]	--	J.R., M.I.	156,073	182,600	117
1946-47	52,380	30,391	58	J.R.	167,313	59,900[3]	-
1947-48	17,872	7,925	44	J.R.	127,699	13,277[3]	-
1948-49	8,996	5,274	59	J.R.	122,326	77,035[3]	-
1949-50	0	0	--	J.R.	217,659	60,885[3]	-
1950-51	55,032	41,228	75	J.R., M.I.	113,097	Transplanted	-
1951-52	33,245	17,358	52	J.R.	103,018	Transplanted	-
1952-53	17,357	10,407	60	J.R.	96,302	Transplanted	-
1953-54	0	0	--	J.R.	75,966	Transplanted	-
1954-55	47,397	44,434	94	J.R., M.I.	114,792	Transplanted	-
1955-56	31,801	29,102	92	H.C., B.R., J.R.	88,739	53,005[3]	-
1956-57	14,555	11,489	79	J.R.	89,294	31,212[3]	-
1957-58	40,710	9,983	25	J.R.	90,356	9,083[3]	-
1958-59	49,400	6,932	14	J.R.	48,472	8,856[3]	-
1959-60	15,341	1,734	11	B.R., H.C., M.I., J.R.	40,612	2,630	6
1960-61	0	0	--	J.R., M.I.	16,665	Total Loss	0
Total	574,851	281,513			1,668,383	498,483	
Average[5]			56				-

Table 84 (Contd.)

1. Data from company records; harvest may be 2 years after planting date.

2. Almost all James River seed.

3. A portion transplanted--harvest less than indicated total.

4. Bushel includes shell plus oysters for Hampton Bar only.

5. Average percent survival prior to 1960 harvest for years with complete data only.

*Source: J.R.--James River
H.B.--Hampton Bar
H.C.--Hampton Creek
B.R.--Back River
M.I.--Mulberry Island in James River

survival data are not available. The company kept accurate mortality records of oysters transplanted for depuration to their two areas from 1943 to 1949. Data extracted from their records indicated only about 42% of the oysters transferred to Mobjack Bay were recovered after being on the bottom for a year or less.

The annual market-oyster production of these three companies in the pre-MSX period was examined in relation to the total market-oyster production for all of Virginia. Data on annual market-oyster production extracted from records of the companies are available for all three companies from 1949 to 1957. In this period they produced an average of 865,091 bushels, or 28% of all oysters marketed in Virginia (Table 83).

In examining the impact of MSX on these segments of the Virginia oyster industry, we considered what production might have been in the decade (1961-1970) following MSX if the three companies had been producing at the same rate as they were from 1949 to 1957 as shown in Table 83. Consequently, the average 865,091 bushels annual production for that period was added to average production from 1961 to 1970 (1,757,241) after MSX had become established. When this was done it was clear the average theoretical annual production would have been 2,622,332 bushels for the 1961-1970 period. This was nearly 89% of the previous decade's average annual production (2,938,445 bushels). These data suggest that about 73%

of the decrease (865,091÷1,181,204) in total Virginia oyster production in the decade after MSX could be attributed to the losses (and subsequent withdrawal) of the three large companies growing oysters in the high-salinity growing areas. The remaining decline might be attributed to losses on public grounds or to those of smaller companies not investigated.

We recognize that MSX is responsible for initiation of the serious decline in Virginia's oyster production and is partially responsible for its current condition and for the continuance of some of the reduction in productivity. We must at the same time, however, state clearly that we have already shown that economic conditions may also have limited production of oysters between 1960 and 1970 on public and private bottoms for a variety of reasons. Because of this economic involvement attempts at renewal of oyster cultures in the extensive high-salinity growing areas (managed by Ballard, Miles and Darling) which produced so well in the past, in all probability now would have difficulty in operating at today's level of inflated costs and decreases in wholesale price even if MSX was not present.

In respect to the role of VIMS as an advisor to industry, the Institute served a useful function when the disease first appeared. It warned of the impending spread of MSX and suggested oystermen operating in high-salinity areas harvest oysters there to avoid losses and it suggested transfer of their operations to low-salinity regions to allow continuance in business. It also suggested that those operating in low-salinity areas increase plantings so as to fill the market slack which MSX mortalities were expected to cause. Some did attend these warnings and suggestions thus directly benefitting from VIMS disease research and advisory services.

While economic conditions have adversely influenced oyster production in recent years and are still doing so, there is no doubt that if MSX could be controlled and the large expanses of the lower Bay (and Hampton Roads) were again planted, it would be of tremendous benefit to Virginia's oyster industry.

The Future of Type I and II MSX Areas in Relation to MSX Resistant Oysters

Oysters resistant to MSX have been developed in an extensive breeding program at the Virginia Institute of Marine Science (Andrews, 1968). Similar studies by Rutgers University have developed oysters resistant to that disease in Delaware Bay (Chapter XI).

The major questions are: 1) Can Type I and II areas be planted with MSX-resistant oysters? and 2) Can industry make use of all of these areas by planting shell for the attachment of cultch?

Andrews (1968; 1971b) demonstrated that the offspring (progeny) of oysters which have been selected from survivors in an MSX area are more resistant than those originating from areas where stocks have not been exposed. The former group suffer only a 10% to 20% mortality each year when exposed in MSX infested waters.

Andrews (1971b) also showed oysters, when grown in trays placed in MSX areas from the size of small spat, would develop a certain resistance to MSX and would also show only a 10% to 20% mortality. Oysters raised from spat growing in a Type I area would show about as much resistance as oysters which were bred from the survivors of the MSX kill. Resistance to the MSX pathogen acquired while the oysters are in their early development state is believed to be the reason.

Andrews also discussed the point that oysters setting in an MSX area (on natural cultch) also showed the same or even greater resistance.

The research by Andrews (1968) on resistance is regarded as fundamental to the problem of growing oysters at a future date in MSX regions. Therefore, his concepts are stated below:

1. Progeny of both susceptible and selected parents cultured in an MSX area....exhibit low levels of MSX activity and of mortality.... History and source of parental stock was less

> important for survival than early exposure to an environment where the disease was active....Survival of progeny and native oysters to market size in areas of intensive MSX activity where imported susceptibles had high death rates suggest that acquired resistance is involved.

Andrews drew a most significant conclusion from his data (i.e., one that needs to be followed in designing further research):

2. The immediate practical application of early exposure to reduce losses from the disease M. nelsoni makes it imperative that this aspect of resistance be explored and exploited fully. If effective in practice, it reduces the need for producing seed from genetically resistant strains.

Another significant point made by Andrews (op. cit.) was that seed oysters from the James River were still subject to extensive mortalities when planted in Type I MSX areas.

3. Most seed oysters originate in low-salinity sanctuaries where disease is absent or scarce, hence, sources of stocks exposed to MSX must be considered.

In relation to the preceding question, it has been shown in previous chapters that the private sector of Virginia's oyster industry is almost totally dependent on the James as a source of its seed. Over 77% of all seed oysters planted in Virginia came from James River seed beds which are in a low or non-MSX region, and will still die at extensive rates if planted in Type I locations. Today (1977) there is no evidence that this basic situation has changed (Andrews, 1967; Haven, personal observation).

James River seed will probably be as susceptible to MSX in the foreseeable future as it was in the early 1960's when MSX first appeared. The only apparent solutions to this problem are: 1) to plant Type I areas with MSX-resistant oysters raised in an hatchery; 2) plant with seed raised in a Type I area; or 3 plant shell to receive a set and make use of the phenomenon of locally acquired resistance.

Today (as will be discussed in Chapter XI) hatcheries capable of raising MSX-resistant seed oysters exist on the East and West coasts. Problems remain relating to culture of hatchery-reared seed on natural bottoms in high to medium-salinity waters (where there are drills and crabs) but 15 acres of hatchery-produced seed (raised in a low-salinity area in the Rappahannock) are now growing successfully in the Potomac River.

An aspect which must be fully evaluated in the near future is where hatcheries should be located. Oysters may acquire resistance to MSX by early exposure to this disease (Andrews, 1967). Therefore, if an hatchery were located in an area where MSX and other diseases were active, then oysters produced by the facility might have this resistance. A second problem raised by Andrews' research (1971a and b) is why oysters setting in the lower James in Type I and other Type I areas have not acquired resistance to the disease to the extent that there has been a gradual build-up in populations.

There is no doubt that oysters which set and grow in MSX areas die at a lesser rate than larger oysters imported from low-salinity regions. However, this resistance of locally grown spat obscures the evaluation of the progress of any breeding programs carried out in an MSX area. One cannot distinguish acquired resistance for oysters raised in an MSX area from genetic immunity.

Summary of MSX

About 71% of the acreage of private leases and about 58% of all total public bottoms are infested to some degree with MSX. The Rappahannock River and the Potomac tributaries are the least affected of all the areas in the Bay and offer the best opportunity for oyster culture in the future or until MSX wanes or significant MSX-resistant populations of oysters develop or are developed.

MSX has had a major impact on the oyster industry by eliminating oyster culture in the high-salinity regions (Type I and certain Type II regions). The elimination of oyster culture in Type I areas in the Bay on grounds owned by Miles, Ballard and Darling accounted for 28% of Virginia's total production. Grounds located in these regions were extensive and could be worked economically with large dredges and other mass production techniques greatly reducing the cost of culture. The companies made a profit even though returns were sometimes only one-half bushel for every bushel of planted seed, which is below the average of 1-to-1 or 1-to-1.3 rates for the entire State.

The Impact of the Coccidium *Dermocystidium marinum* on the Oyster Industry

Introduction

D. marinum, a coccidium infecting oysters, is found along the coast of the Western Altantic from Delaware Bay to Florida and on the coast of the Gulf of Mexico from Florida to Texas (Ray, 1952). It has been shown to be a major cause of warm-season mortality in the Gulf of Mexico and, until recently, was the principal cause of disease-produced mortality of oysters in Virginia (Andrews and Hewatt, 1957). The reason for its decrease in importance in Virginia is beginning in 1959 MSX eliminated almost all oysters in the zone where *D. marinum* was formerly the principal disease (Andrews, 1967). Even though *D. marinum* is now no longer a significant problem in many areas, it is pertinent to discuss the disease in detail since the possible return of oysters to the lower Bay and the high-salinity portions of the rivers would again subject extensive populations to its influence.

D. marinum has probably been in Chesapeake Bay for many years according to Andrews (1955) and Andrews and Hewatt (1957).

Large-scale mortalities of oysters have taken place in the past. These may have been associated with Dermo, but it is possible other organisms, even MSX, may have been responsible.[1] Heavy losses in the Chesapeake Bay in 1912 were attributed to low oxygen (Sale and Skinner, 1917). Later there was a large-scale mortality noted during the Winter of 1929-1930 which was attributed to *Nematopsis ostrearum* (Prytherch, 1931; 1940). These mortalities could have been caused by other diseases as well. Due to the lack of preserved specimens or epidemiological records, further clarification is impossible.

Life History

The coccidium (formerly considered a fungus), *D. marinum*, was first described in 1950 from material taken from Louisiana oysters by Mackin, Owen and Collier (1950). In that study only the spherical spores (hypnospores), 3 to 10μ in diameter, were described. This discovery was followed by the development of the thioglycolate assay method which gave researchers a rapid method for detecting the disease (Ray, 1952). Later stages involving hypnospores, sporangia and motile phases have been described (Perkins, 1969a).

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[1]It has never been clearly documented that MSX was not in the Bay prior to 1960 (and not causing extensive mortalities).

Dermocystidium in Relation to Oyster Culture

Oysters become infected during summer and fall by ingesting waterborne spores liberated from the disintegrating tissue of oysters killed by the disease. A possible second method of becoming infected is from ingesting feces voided by fish which feed on infected oysters (Andrews, 1957; Hoese, 1964). After the coccidium enters the oyster, its cells increase in the tissue and blood sinuses by multiple fission. The oysters become poor and their Condition Index drops. In one series of observations wet meat weight in heavily infected oysters dropped to about 33% less than controls. The magnitude of weight loss was related to season with losses in summer being larger than those of early spring (Ray, Mackin and Boswell, 1953). Also, *D. marinum* usually causes a slowing of growth of the infected oysters and finally complete cessation followed by death (Menzel and Hopkins, 1955).

Temperature and salinity have an important effect on *D. marinum*. The coccidium is inhibited and unable to establish infections below 20°C and proliferates readily only at salinities over 15% (Andrews and Hewatt, 1957). Consequently, losses from *D. marinum* in Virginia depend upon the levels of rainfall, season and annual (salinity), depuration of the warm season, coldness of the winter (temperature) and survival of cases through the winter.

Distribution Prior to 1960

The following was summarized from Andrews and Hewatt (op. cit.):

> The disease is intense in the lower part of the York River and its range extended over the entire oyster-producing areas of this river....Intensity of the disease is relatively low in the Rappahannock River although the fungus occurred throughout most of the oyster-producing areas....
>
> The western shore of Chesapeake Bay in Virginia showed substantial infections in the open Bay up to the Great Wicomico River, but a low level of infection at the mouth of the Potomac River. On the eastern shore of the Chesapeake Bay in Virginia, the occurrence of infections is somewhat variable with occasional negative samples in areas where other samples have shown numerous infections....
>
> Samples from Pocomoke Sound showed rather low levels of infections in 1954, but the weighted incidence was higher in 1955....
>
> In Maryland, the fungus extended up the western shore of Chesapeake Bay from the mouth of the Potomac River to the mouth of the Patuxent River....
>
> The most baffling fact about the distribution of Dermocystidium is the almost complete absence of infection along the Seaside of Virginia and Maryland.

The pattern of infection of acclimated oysters is fairly consistent in Chesapeake Bay. The first infections usually appear in June and may increase rapidly during the warm months of July and August. Infections remain high during these warm months and persist from September through November gradually declining with a fall in water temperatures in December.

By March or April of the following year most infections have disappeared. Levels of infection in fully acclimated oysters may range from 70% to 90% during late summers (Andrews and Hewatt, op. cit.).

Most of the local mortality data for _D. marinum_ are for tray-cultured oysters grown in the York River at Gloucester Point, Virginia. The annual mortality rate in 1952 of these cultured oysters ranged from 17% to 22% for oysters which had been acclimated to the area for six months or more (Hewatt and Andrews, 1954). A summary of these data follows:

> Death rates increased with age and varied with the year in patterns similar to those described for infections. In Chesapeake Bay oysters, yearlings had summer mortalities (June to October inclusive) of less than 10%, two-year olds from 17% to 26% and oysters three or more years of age from 26% to 67%.
>
> Oysters from the Seaside of the Eastern Shore died at a greater rate than those in the Bay. The latter group had summer death rates from 16% to 30% as yearlings. As two-year olds, mortality rates were 37% to 74% and in older oysters, 46% to 71%. In South Carolina oysters, mortalities like fungus infections, were usually low....Two-year olds had death rates of 10% to 12%, three-year olds, 26%, and four-year olds, 22%.

Mortality data obtained from tray-cultured oysters rarely represent what occurs on a natural bottom. This makes it difficult to develop an accurate estimate of the impact of _Dermocystidium_ on commercial and private oyster production from experimental tray data. The reason is that oysters grown in trays are more crowded than those grown on the bottoms and proximity to dying, infected oysters hastens the development of epizootics. That is, *D. marinum* is a density-dependent organism (Andrews, 1965). Stated in another way, it means that tray culture may result in greater cross-infections due to crowding which would cause excessively high mortalities when compared to mortalities among less crowded oysters growing on a natural bottom. Studies of mortality rates on natural bottoms in *Dermocystidium*-infested areas are needed, but are not practical today since deaths due to MSX tend to obscure results.

Distribution 1960 to Present

The range of *D. marinum* in 1977 is essentially the same as it was prior to 1960. Levels of infection today are low because there are few oysters in regions where *Dermocystidium* exists since they were killed by MSX. The coccidium is now detected only in oysters from narrow bands of beds in the fringe areas between high and low-salinity waters (Andrews, 1965).

Dermocystidium-like organisms are found in other molluscs, but little is known of their life cycles and whether or not the organisms may be transferred to oysters.

In investigating the interaction of D. marinum (Dermocystidium) and M. nelsoni (MSX) in infected oysters, it was found mortalities occur more quickly from D. marinum when M. nelsoni is also present (Andrews, 1967).

Careful consideration of existing information led to development of a series of recommended practices which, if followed, would result in decreasing the probability of mortality on planted oyster beds (Andrews, 1965):

1. D. marinum is a density-dependent organism which requires several years to develop an epizootic on an isolated, disease-free bed. Leasing oyster grounds in a growing area for a minimum period, followed by harvesting and then an intensive cleanup of beds will greatly limit damage by the parasite.
2. Planters in areas where D. marinum can survive and even persist should be very careful not to plant infected seed.

Prior to 1960 D. marinum was one of the principal causes of mortality of market oysters in high-salinity areas. Oystermen learned to "live" with it and were able in most years to realize a yield of one bushel of market oysters for every bushel of seed. The three largest oyster producers in Virginia were able to carry out their massive oyster culture operations where Dermocystidium was active. They had acclimated to it.

Obviously, while D. marinum was the major continuing disease problem prior to 1960, it cannot be considered as the major factor today since the populations it once attacked (those existing at salinity higher than about 15 ppt) have been eliminated by MSX disease. It is still, however, a disease to be considered in marginal areas where fall salinities range from about 12‰ to 15‰. When oyster culture returns to former levels in MSX Type I and II areas, Dermo undoubtedly will again become significant.

The Impact of SSO, or Minchinia costalis, on the Virginia Oyster Industry

The disease known as SSO, the seaside organism, was discovered on the Eastern shore of Virginia in the 1959-1960 period during early efforts to determine the range of MSX. This organism, later named M. costalis, turned out to be a new species of Minchinia which is characterized by small (3.1 to 2.6µ) operculated spores without projections (Wood and Andrews, 1962). SSO disease occurs primarily among oysters on the Seaside of the Eastern Shore of Virginia. It may cause mortalities on the Seaside almost as severe as those due to Dermocystidium and MSX in Chesapeake Bay. It is not a significant factor in causing mortalities in commercial plantings in the Chesapeake Bay.

The following, quoted from a paper by Andrews, Wood and Hoese (1962), gives general concept of the seasonal incidence and severity of the disease:

> Only a part of the life cycle of SSO is known. Experimental infections have not yet been attempted and nothing is known of stages and locations of the organism from July each year until it reappears in oysters the following March. Method and time of infections are unknown but field data suggest certain limitations. Oysters acclimated to Seaside, and thereby exposed to one SSO epizootic, die with high incidence of the disease the following May-June. Unexposed James River oysters brought in as early as February neither died or showed SSO the following May-June. James River oysters moved in mid-June 1959 experienced the full epizootic of SSO in 1960. No infections were found during the 1961 epizootic in James River stock transplanted as late as November 1960.

Losses among tray oysters native to Seaside in May and June during the 1959-1962 studies ranged from a low 12% to 14% in 1959 to 36% to 44% in 1960. James River oysters moved to Seaside showed higher losses than natives after a year of acclimation.

> The effects of age, source, and acclimation of oysters on SSO epizootics were only partly elucidated in these studies. All of these factors seem to be subordinate to the level of the epizootic in a particular year. The intensity of SSO in exposed populations of oysters seem to be similar at all stations in a given year, but rather large annual variations occur. In 1959, losses were low and uniform regardless of source, history and locality. In 1960, losses were high in all localities but only in native oysters over two years of age and imported oysters acclimated for six months or more. In native oysters, exposure at an early age and selection by SSO during each May-June epizootic makes analyses of age and exposure factors difficult.

> Oystermen on Seaside have been plagued by serious drill predation for so long that all other causes of losses have been ignored or have gone unnoticed. They have learned by experience that successful oystering requires planting the largest native seed available, and seed planted in fall, winter or spring is usually harvested the following year after 12 to 18 months of culture. Attempts to hold oysters longer result in heavy losses. It has been repeatedly said that James River seed will not survive on Seaside. Yet such oysters in trays lived 15 months with less than 10 percent losses; then an epizootic of Seaside disease killed over half in their second May-June period on Seaside. SSO appears to cause little trouble on Seaside if oysters are grown and harvested rapidly and if exposure to more than one May-June epizootic is avoided after one year of age is reached.
>
> Minor losses in young oysters and much heavier losses in older oysters are caused by SSO each year. Estimating losses on Seaside beds of heavily clumped oysters is difficult. Counts of dead oysters and talks to oystermen indicated only small losses on most planted beds -- probably not in excess of 10 to 15 percent -- but heavy losses on the very few beds of older oysters not harvested at the usual time.

Definite information is lacking concerning whether SSO is a "new" introduction, or whether it has always been present where it now occurs. Probably it has been there for a long time, since oystermen have always known oysters planted on the Seaside on the subtidal growing beds and left there for two or more years suffer excessive mortality. They avoided these losses by harvesting before these losses occurred. Consequently, the industry had in the past adjusted to only leaving seed oysters for a minimum time on the growing beds. That is, SSO is not considered responsible for the decline in production since 1961 as noted on the Seaside of the Eastern Shore.

In conclusion, it was shown in Chapter III that since 1960 there has been a drastic decline in landings of oysters on the Seaside of the Eastern Shore. While SSO has been in the area over this period there is no valid evidence to suggest that it was the direct cause of the decline in the sense that it is a recent introduction. SSO was probably in the area prior to 1960. MSX is a recent introduction but, as previously discussed, causes a minimal impact on oysters on the Seaside.

The Role of the Oyster Drills, *Urosalpinx cinerea* and *Eupleura caudata* in Reducing Oyster Production

The two species of oyster drills, *U. cinerea* and *E. caudata*, are small but highly successful predatory marine snails inhabiting the coastal waters of North America. Prior to their being transplanted by man to the West Coast, they occurred on the Atlantic and Gulf Coasts. They are especially abundant in the mid- and high-salinity oyster growing regions of Chesapeake Bay. Drills are known to have been present in Chesapeake Bay ever since oysters were cultured and even before European man came on the scene. They preceded the aboriginal American Indian by several million years. Areas infested by these drills include most of Chesapeake Bay below Smith Point Light, the lower parts of the York, Rappahannock and James Rivers, Back River, Poquoson River and the lower parts of the Piankatank and Great Wicomico Rivers (Table 85).

Floodwaters in 1972 associated with Tropical Storm Agnes killed or reduced drill populations to very low levels in the following areas: Mobjack Bay and in the lower reaches of the James, Rappahannock and Poquoson rivers. Drills are expected to return slowly to their former range over the next 5 to 10 years. If drills are reintroduced into these non-drill areas on seed, then their return will be greatly accelerated.

U. cinerea is more destructive of individual oysters than *E. caudata* because of its greater numbers and higher tolerance to low salinity.

When reviewing the extensive literature it is evident no practical, economical method of control has yet been developed and drills remain one of the actual (Eastern Shore), as well as potential (Western Shore), major problems of the oyster industry. Despite Tropical Storm Agnes, they will undoubtedly return as oyster production in the Bay increases. The development of an economical method of control would be of tremendous benefit.

Distribution and Impact

The downriver or downbay limits of significant spatfall survival on natural rocks before 1960 (before MSX) were determined

Table 85

Regions in Virginia Influenced by the Oyster Drills up to 1972*

River System	Extensive Damage	Region in River Where Damage Becomes Minimal**
James River	Below James River Bridge	Above Brown Shoals
Lower Bay	Smith Point to Cape Henry and Mobjack Bay	
Back River	Most oyster beds in lower reaches	
Pagan River	Most oyster beds in lower reaches	
York River	Below Page's Rock	Above Page Rock
Rappahannock River	Below Towles Point- most destruction on north shore	Above Towles Point
Eastern Shore Seaside	Almost all Bays and Inlets	
Eastern Shore Bayside	Lower half of the Peninsula	Tangier Sound

* Data obtained from field studies by VIMS.

** After 1972 drills were killed or populations reduced to low levels in the following locations: the lower Rapahannock, the lower James including Brown Shoals and the lower river, Mobjack Bay and the lower Poquoson River.

primarily by drill activity, and the damage in Chesapeake Bay to oysters by drills was frequently underestimated. Prior to 1960 only the larger James River seed survived planting in the drill infested, high-salinity waters of the lower Bay. It was common knowledge to growers that nearly all the small spat placed in areas of high salt content were killed by the "screw borers."

MSX made oyster culture impossible after 1960 in Type I (higher-salinity) areas, and marginal in certain Type II (lower-salinity) zones. Drills were still present in both areas; however, their importance in relation to other impediments to successful oyster culture had declined, eclipsed by other factors such as MSX and, perhaps, changing economic conditions.

This was largely the case in Type I MSX areas where culture of large and small oysters became economically unfeasible. In Type II MSX areas where conditions are marginal, losses by drills remain a serious hindrance to commercial oyster production. In regions where oyster culture is marginal because of MSX losses by drills may turn an otherwise profitable operation into one which loses money.

On the Seaside of the Eastern Shore two subspecies of drills occur which are much larger than those found in the Bay: *Urosalpinx cinerea follyensis* and *Eupleura caudata etteri*.

The range of drills in each river is determined by salinity. All are susceptable to low salinity but drills from different geographic areas differ in their salinity responses (Stauber, 1950; Franz, 1965). The lowermost salinity value necessary to kill drills varies according to where the drills grow and develop. Information on how low salinity must be to kill drills, obtained in other places, is not applicable to another area. As a result, only information obtained in lower Chesapeake Bay will be cited in this Chapter.

Since low salinities are lethal to drills the years when estuarine salinities are below average, they act to control the activities and range of this predator. Studies conducted in standing water indicate that at summer temperatures salinities below 10‰ are quickly lethal to York River U. cinerea after about 20 days. At 12‰ about 15% died after 40 days; at 15‰ mortalities are about the same as in the control groups. Therefore, 15‰ is usually given as the point when salinity may or may not influence drill populations (Haven and Whitcomb, 1965; Wood, 1964; Zachary and Haven, 1973).

While the standing water studies give useful information, they may be misleading if applied to estuarine conditions where salinities fluctuate with tidal cycles and with seasons. That is, salinity values based on standing water studies cannot be directly related to mortalities based on mean values in an estuary calculated over several tidal cycles (Zachary and Haven, op. cit.). It was shown that it was the length of time salinities are below mean lethal values which determines mortality rates; salinities ranging above these critical mean values delayed, but did not reduce, mortality rates.

Control

Possible control measures for oyster drills have been investigated by many authors. Most have been summarized by Carriker (1955). An abridged summary, principally from this source, is given below.

1. Capture of Drills and Egg Cases
   a. Hand Picking - On the Eastern Shore of Virginia, drills have been simply picked by hand from oyster rocks when they ebb bare. The Virginia Commission of Fisheries (VMRC) used to pay a bounty of $1.50 per gallon for the drills. This method is not regarded as efficient (Annual Report, Virginia Commission of Fisheries, 1944-45).
   b. Forks - Drills have also been shaken from oysters on the deck of oyster boats with oyster forks (Nelson, 1931; Galtsoff, Prytherch and Engle, 1937). Numbers of

drills recovered were not large. This was not an efficient control method.

c. Elevated Structures - Small concrete blocks or roofing tiles are placed on the beds. Drills crowd onto blocks which are later raised and drills collected (Nelson, 1931). No careful field tests on this method have been reported.

d. Oyster Dredges - The conventional oyster dredge has been employed to remove shells and oysters bearing drill egg cases in the New York and Connecticut areas (Glancy, 1954). The large amount of shell present on many Virginia beds made this method of control impractical.

e. Deck Screens - Oysters are simply shoveled over an inclined one-inch mesh screen prior to planting. The drills fall through the mesh (Stauber, 1943). This method is not efficient. Egg cases are not removed from the oysters and the shells of living oysters are often chipped or broken.

f. Rotating Screen - Oysters are passed through a rotating, perforated drum similar to that used in grading gravel. Large mesh wire screens are also used. While most live drills fall through the holes or interstices and are collected below, egg cases are not removed (Annual Report, Virginia Commission of Fisheries, 1947-48).

g. Special Drill Dredge - This method of capture utilizes a wedge-shaped dredge fitted on top with an inclined screen which when dragged over drill-infested bottom throws oysters over the dredge and drills automatically fall into the collecting bay (Galtsoff, et al., 1937). Results of tests with this apparatus were not considered satisfactory.

h. Drill Trapping - This system of control has been widely investigated. It consists of placing small, flat chicken-wire bags filled with oyster spat on the bottom. Bags are raised after a week or two and drills shaken from the bag. There is some evidence that drill populations may be reduced by this method. It is, however, labor intensive and, as a consequence, costly, and there is no published evidence that oyster production or spat survival has been increased by this technique (Stauber, 1938; Stauber, 1943; Newcombe, 1942; Andrews, 1957; McHugh, 1956).

i. Hydraulic Suction Dredges - These devices are perhaps the most promising of all methods (Glancey, 1954; Carriker, 1955). Using these dredges, vast quantities of shelly bottom material including drills are removed from the planting beds. Quantities as large as 3,750 cubic yards are moved at one time. This method of control is apparently successfully used today by Connecticut and New Jersey growers (MacKenzie, 1970b).

j. Escalator Dredge - Escalator dredges similar to (but larger than) those used to harvest soft clams might be used to raise drills and shells from the bottom but to date no one has used this gear for that purpose.

2. Destruction of Drills and Egg Cases

The possibilities of destruction of drills and drill egg cases by physical and chemical means as a control measure have been investigated.

a. Physical Methods - Physical methods include desiccation by heat in the form of hot water or flame on the exposed oyster rocks. Also investigated without much success have been ultrasonics, electricity and brine.

b. Chemical Control - The chemical control of oyster drills and drill egg cases has received the most attention in past years (Galtsoff, et al, 1937; Newcombe, 1942; Wood and Roberts, 1964). Substances investigated include magnesium chloride, copper sulfate, mercuric chloride, formalin, rotenone and Amox[R] and about thirty other insecticides, including DDT.

None of the above provided good control of drills or drill embryos.

In recent years much effort was exerted by the NMFS Laboratory in Milford, Connecticut in screening chemicals which might be useful in controlling drills. These studies disclosed that several chlorinated benzenes, if mixed with sand and placed on the bottom, formed a barrier to drill migration (Loosanoff, MacKenzie and Davis, 1960; MacKenzie, 1970b). The final

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[R]Registered trademark

mixture perfected at Milford was a mixture of chlorinated benzenes "Polystream[R]," and methyl carbonate (Sevin[R]). Laboratory studies at VIMS showed that Polystream[R] killed half of the test drills in from 5.5 to 6.8 days (Wood and Roberts, 1964). Field studies at VIMS and in Maryland, however, showed that these two chemicals alone or in combination were not effective in controlling drills under the conditions found in Chesapeake Bay (Haven, et al, 1966; Shaw and Griffith, 1967).

The reason it did not work was that treated sand "sank" into sediment and did not contact the drills (Haven, et al, 1966). Polystream[R] has other disadvantages. It deteriorates very slowly, and when applied to sand kills other benthic organisms. Also, the FDA regards it as a potential health hazard and in most locations it cannot be used without a special permit. However, as will be discussed in Chapter XI, if Polystream[R] is applied to shells set will be increased. This is regarded as the greatest potential

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[R]Registered trademark

use of this chemical in oyster culture.

A more detailed discussion on the use of Polystream[R] in oyster production is given in Chapter XI.

3. Irradiation with High-Frequency X-Rays

Scientists of the United States Department of Agriculture eradicated the screw-worm *Callitroga hominivorax* from Curacao by releasing X-ray sterilized males which competed with normal males. Experiments to test applicability of this method to control *U. cinerea* were carried out at VIMS (Hargis, et al, 1957). Preliminary results of this study suggest that the problem should receive further consideration and investigation.

4. Physical and Chemical Barriers

   a. *Fences* - Glude (1956) investigated the use of a copper fence several inches high as a barrier to migrating oyster drills. While this seemed effective in repelling drills in the laboratory, its use in the field has never been demonstrated to be effective.

   b. *Predators* - The possible occurrence of natural predators of drills was pointed out by Chapman and Banner (1949), especially in relation to embryos. This possible method of control has not been given enough attention.

[R] Registered trademark

5. Temporary Abandonment or Fallowing of Bottom

This control method was suggested by Stauber (1943). It has often been used by growers on the Eastern Shore of Virginia, who report that it is effective in controlling populations of drills (prior to the time seed is planted). It requires that growers using the technique have sufficient lease-holdings to allow fallowing of from 30 to 60 percent of his grounds at any one time depending upon length of fallowing time employed. No data exist which would support or refute the efficiency of this method despite its use by oystermen in the past. It is known (Hargis, unpublished results), however, that drills can survive on bottoms without oysters where they feed on other organisms including other snails as well as barnacles, clams, mussels and any one of the dozens of other shelled organisms living on the bottom. Likely, they can also feed on soft-bodied organisms.

Summary

Drill damage remains a significant factor in limiting oyster culture in Virginia but it has always been so. Therefore, it cannot be "blamed" for the recent decline in oyster production. It is still, however, a major problem which has never been solved and contributes significantly to the economic difficulties of the

Virginia oyster industry. At present, there is no tested, economically feasible control method for drills.

Since drills are a serious deterent to production in Type I and some Type II waters and would remain significant even if MSX and Dermocystidium were reduced, the search for effective control methods for these animals should be pursued. It is recommended studies to test existing control methods and develop new ones be reinitiated.

It is not difficult to suggest methods of control which have not been tried. Some would come under the general heading of repellents or chemical barriers to drills. Prior to planting small oysters might be coated with a substance which would be non-toxic but would repel drills or would inhibit drilling.

Another approach might be to use the bottom itself and natural processes to control drills. There are on the market today various industrial gums and gels. Possibly a thin coat of one of these substances could be spread over the bottom surface. Hydrogen sulfide, which is toxic, would generate under this coat thereby killing drills and other benthic organisms. Later, when the film had broken down, the bottom would again become aerobic and it could be planted again with seed oysters. It would be expected the cleared area would be reinvaded by drills. However, carefully selected and placed seed oysters could grow sufficiently before large numbers of snails returned so damage would not be great.

The irradiation sterilization technique (Hargis, et al, 1957) should be reinvestigated by laboratory and field studies. Additionally, the use of hydraulic suction dredges or escalation-harvester-screening combinations should be studied on the Seaside of the Eastern Shore where drills are still a major deterrent to successful oyster culture.

All possible techniques should be re-evaluated and the most promising examined by well-planned and executed studies.

The Possible Role of the Flatworm, *Stylochus ellipticus*, in Relation to the Recent Decline of Oyster Production

Certain evidence indicates that the polyclad flatworm, *S. ellipticus*, kills and ingests small oyster spat. Consequently, this animal must be considered when evaluating causes of declines in oyster landings and especially in relation to the decline in spatfall in the lower James River.

S. ellipticus is a small, flat, oval animal with a wavy margin. It ranges in length up to about 25 mm. Its color is generally light brown but shades ranging from dark brown to light pink are common.

The activity of this animal as a predator was investigated by Pearse and Littler (1938) and by Loosanoff (1956). Provenzano (1961), working in Martha's Vineyard, Massachusetts, found indirect evidence of predation. Webster and Medford (1961), in a study conducted in upper Chesapeake Bay, showed a relation between numbers of S. ellipticus in shellbags and spat survival, but evidence of kills by this flatworm was circumstantial.

Landers and Rhodes (1970) in a well-planned series of laboratory studies showed ten S. ellipticus from certain locations would kill from 0.14 to 160 spat per day under a temperature range of 5 to 22°C. An important aspect of this study, however, was their demonstration that when given a choice between oysters and barnacles, individuals from some localities exhibited a strong preference for barnacles. In support of this demonstration, Landers and Rhodes state:

> Attempts (by previous investigators) to induce S. ellipticus to prey on oysters in the laboratory have not always been successful.... Investigators at the Virginia Institute of Marine Science, Gloucester Point, Virginia, also failed to induce predation on oysters by S. ellipticus from some local areas, although the worms did prey on barnacles and several species of bivalves, other than oysters, common in Chesapeake Bay (Dana Eldridge, personal communication).

Landers and Rhodes (op. cit.) then state:

> Worms from Milford Harbor (in Connecticut) no matter what season observed, never preyed on oyster spat in the laboratory....

They observed a similar type of behavior for S. ellipticus from Cape Charles, Virginia, and from Bridgeport, Connecticut. However, worms from Martha's Vineyard, upper Chesapeake Bay and Bayville, Long Island, did ingest small spat. The selective feeding behavior of S. ellipticus was thought to be due to ingestive conditioning (Wood, 1968).

Shaw (1969) working in the Tred Avon River in Maryland observed an extensive mortality in suspended spat which he associated with Stylochus. Studies by Haven (unpublished) have shown S. ellipticus to be abundant in the James over the entire range of the oyster, and available evidence suggests that it has always been a part of the fauna of the Bay. It seems logical, therefore, that S. ellipticus did not contribute significantly to the recent decline in oyster productivity since 1960. It is evident, however, there is little information on this species and it may be more of a pest than was previously suspected. Clearly, research to examine the role of Stylochus as an oyster predator is necessary.

Fish as Predators

Cow-nosed rays, Rhinoptera bonasus, and drum, Pongonias cromis, often cause extensive damage to beds of oysters. This applies to recently planted seed as well as to large thick-shelled market-sized oysters. Little research has been done or published on this matter so quantitative data are lacking.

Beginning in the summer of 1970 growers in the mid-Rappahannock River reported to VIMS that many thousands of bushels of oysters were being killed by cownosed rays. Such reports had continued into 1977. Some of the damage consists of burial of oysters as the animals feed; more often the oysters were crushed by the teeth of the animals and the meats ingested. Damage to growing oysters was estimated by planters in the Rappahannock to be in the $100,000 to $300,000 range. Growers in 1976 and 1977 reduced seed plantings because of their fear of ray damage.

Drum and rays have for many years caused extensive damage to oyster and clam beds on the Seaside of the Eastern Shore. Frequently oystermen fence small concentrated plantings with wire netting. This method is too expensive for large-scale efforts.

Other Animal Parasites and Predators

The oyster is host for many other parasites and predators. While most of these do have undesirable effects on their hosts none have been implicated as a probable principal cause for the decline in oyster production since 1960.

1. Polydora - There are two species of annelids, *Polydora websteri* and *Polydora ligni*, which live in tunnels in the shells of oysters. Initially,

individuals of both species form a mud-coated tube on the inner surface of the shell of a living oyster which is later covered with shell. One or the other species is found in nearly all sections of the Bay (Galtsoff, 1964).

2. *Bucephalus* - This trematode is occasionally found in the gonadal tissue of oysters living in low-salinity regions. Infections block the ducts in the gonadal tissue effectively inhibiting spawning (Hopkins, 1957).

3. *Pinnotheres* (Pea Crabs) - Pea crabs are small crabs ranging up to one-half inch in carapace width. They live within the shell cavity on the margin of the gills, or, when very small, in the water conducting channels in back of the gills. Experiments have shown them to be responsible for significant reduction in the yields of oysters (Haven, 1959).

4. *Nematopsis* - Spores of *Nematopsis ostrearum*, a sporozoan, are often found in the tissue of oysters in Chesapeake Bay. This organism has a stage in mud crabs (Feng, 1958). It was suspected to be the cause of mortalities which

occurred in Mobjack Bay and the lower York in the late 20's and early 30's by Prytherch (1940). This suspicion has not been borne out by subsequent research.

Chapter Review

While there are many physical and biological causes for mortalities of oysters, there is little doubt that MSX was the initial cause of the major decline in oyster production in 1960. It appears that the impact will be persistent at least for Type I and II MSX areas. Ways that production in the affected zones might be increased would be: to plant MSX-resistant oysters in a major repletion program; and/or for the oysters setting there to develop natural immunity.

Pertinent to the recovery of oyster culture in MSX areas is a basic and highly significant aspect of MSX discovered by Andrews (1967) of VIMS. That is, oysters apparently develop a resistance to MSX if exposed to the disease when young. This important discovery needs further study since it may prove to be a basic principle in manipulating stocks of seed for planting in MSX areas. Also an understanding of the process may be of fundamental importance in determining if oysters, setting naturally in the Bay, may gradually develop resistance to the disease.

VMRC officials, VIMS biologists and watermen have observed very low mortality rates among two and three-year old oysters originating from shells planted in the lower James, Mobjack Bay and the mouth of the James River. This high survival rate gives strong support to the concept advanced by Andrews (1967) that oysters setting in Type I MSX regions develop resistance to that disease. Whether or not these populations will continue to show resistance to MSX remains to be seen. They should be examined for this feature.

As will be outlined in Chapter XI, techniques have been developed for growing large numbers of MSX-resistant seed in hatcheries which may be planted in Type I or II MSX areas. However, techniques have not been perfected as yet to plant and grow commercial quantities of this small seed to market size in areas infested with drills and blue crabs.

The prospect of raising seed oysters from the James River to maturity in Type I and II MSX areas in the immediate future appears bleak. Most leased areas, classed as Type I and II MSX bottoms and a few public bottoms, must be planted with seed if they are to produce. Unfortunately, over 77% of all seed available for use in Virginia comes from the James River. Andrews (1967) indicated mortality rates experienced when James River seed was planted in Type I and II areas to be about as high as they were in 1960. Andrews (personal communication) and many other sources indicate a similar situation today.

It is regrettable that definitive field studies have not been carried out by the Institute or anyone else to test survival rates of seed which has "set" in Type I and II areas and may have acquired natural resistance. Hampton Roads, the lower York and Piankatank and the Poquoson marshes are classed as a Type I area for MSX, and seed from these places should have some level of acquired resistance as indicated by Andrews (1967). It is recommended that such studies be started immediately. In recommending these investigations we are fully aware of the fact that, even if MSX can be controlled, spat setting in the high-salinity waters of the lower Bay in Type I and II areas will be subject to predation by the two species of oyster drills, *U. cinerea* and *E. caudata* (when the drills have recovered from the effects of Tropical Storm Agnes). They will also be exposed to *Dermocystidium marinum*-caused debility and losses as well as other factors but oyster culture can go forward despite these factors as it did before from a biological point of view.

We believe, however, that this problem may be overcome by proper management practices and the development of more efficient methods of drill control. For example, it may be possible to obtain a set in a Type I MSX (high-salinity) area where drills are a major problem, and to move it to Type II or III areas (lower-salinity) where drills are not a problem.

While MSX was the initial cause of lowered production from leased and public bottoms in high-salinity waters of the Bay around 1960 and is a factor in these same waters today it is not the sole cause of continued lower production. This aspect has been discussed in preceding chapters but pertinent aspects will be reviewed again in the context of the present chapter.

It would be logical to assume that the growers forced from the Type I and II areas might relocate on the Sea-side of the Eastern Shore or in the low-salinity regions (Type III and IV for MSX). The reasons why this has not occurred to any extent are interrelated and complex with socioeconomic aspects as significant as disease.

The probable reasons for the persistently low production from Virginia bottoms are:

1. Economic conditions relating to oyster culture seem to have changed since 1960 and growers do not choose to relocate to areas where mortalities can be avoided or reduced since there is no longer as attractive a profit margin to the grower as there was prior to 1960. Labor, operating costs, interest taxes, harvest costs,

etc. have increased while the adjusted wholesale price of oysters has remained nearly level since 1964. This has occurred during a period when the prices of other food products have risen by an average of 8% per year. Therefore, as outlined in Chapter IV, the Virginia grower appears to have operated profitably by farming only those bottoms that give him the highest yields and monetary returns (i.e., his best bottoms).

2. Also it is likely that production has been held down because of the large tracts of unused leased bottoms in the non-MSX areas not available to those who may wish to grow oysters (see Chapter VI). It costs only $1.50 per-acre-per-year to hold oyster grounds. Leases are for 20 years and are renewable; therefore, access to these grounds may be denied to newcomers. The remedy for this is to make leaseholders give up those leases (made for purposes of producing oysters) on which oysters are not under active cultivation.
3. Imports from Maryland have easily, until recently, filled the void created by the absence of production.

Large corporations, J. H. Miles & Co., Ballard Fish and Oyster Company and J. S. Darling, which once operated in the lower Bay, were put out of business when MSX in higher-salinity waters made oyster culture on their traditional planting grounds economically impractical. Prior to MSX they successfully operated when returns for transplanted seed were about one-half bushel of oysters per bushel of seed. This was far below the average of 1-to-1 for the State. The relatively low yield realized by these comparatively well organized corporations emphasizes the point that an integrated operation for growing, shucking and marketing oysters is often successful despite low yields since a loss, on one phase of the operation, may be absorbed in a more profitable phase. Thus, the oyster industry would seem to be amenable to this kind of an organization as much as other industries are.

Dermocystidium

The oyster disease, Dermocystidium, was the principal oyster pathogen in Virginia prior to 1960. It often caused a 17% to 22% annual mortality among acclimated oysters in high-salinity regions. Oyster growers, however, were able to operate successfully in spite of the presence of this coccoid.

MSX eliminated oyster culture over the range where this pathogen was once active, therefore, the disease is a problem today even in marginal areas where fall salinities range from about 12‰ to 15‰. If techniques are developed which enable the planting of large numbers of MSX-resistant oysters in the higher salinity areas, then Dermocystidium may again become a significant factor in the overall mortality pattern. Therefore, the disease resistance development program of the Institute should be broadened to include development of oysters resistant to Dermocystidium, SSO and other diseases as well as MSX.

SSO

While exact production data are lacking, it was shown that oyster tax revenues on the Eastern Shore dropped drastically since 1960 suggesting a drastic drop in production in that area. This fact has been confirmed by many interviews with dealers, oystermen and inspectors. Moreover, it has been shown that Dermocystidium and MSX are not the causes of significant mortality on Seaside. It is tempting to attribute the recent decline in oyster production to SSO which in 1960 produced mortalities up to 40% with typical mortalities ranging from 12% to 14%. Available evidence indicates, however, that SSO has been present in oysters on the Seaside of the Eastern Shore of Virginia for many years and oystermen have learned to "live with it." Losses to SSO disease have been avoided by planting large oysters and harvesting prior to the end of the second growing season.

SSO is now and has been in the past one of the two most important causes of mortality of oysters on the Seaside. Mortalities associated with this disease add greatly to the burden of the economic problems the Eastern Shore growers now face. Clearly, if some way can be found to minimize the impact of SSO, then operations could become more profitable with more growers attempting to grow oysters. A search of the literature indicates no significant studies of SSO have taken place since 1962. This lack is quite remarkable in view of the severity of the disease. Unknown is the life cycle of the organism and how it is transmitted. The following recommendations are suggested:

1. Studies should begin on the way this disease, as others, is transmitted from one oyster to another. If this aspect is known, then it may be possible by manipulating cultural techniques to control the impact of this disease.
2. Study effects of temperature and salinity on incidence of the disease.
3. Develop SSO-resistant oysters.
4. Monitoring for SSO should continue on a regular basis on Seaside.

Oyster Drills

The oyster drill remains a major actual or potential threat to economical oyster production in Virginia. A practical method of control would be of immense benefit to the industry.

Oyster larvae often set in areas where drills are abundant, but the small oysters resulting are nearly always killed by drills before the seed grows large enough to be moved. If drills could be controlled then the higher-salinity, down-river areas might become sources for inexpensive seed. Such seed (especially if it competes in price with James River seed) is badly needed by the industry.

It is recommended studies be instituted again on means of controlling oyster drills. Means of approach investigated should include:

1. Control by sterilization of males and introducing them back into the population as outlined by Hargis.
2. Development of chemical barrier coatings on the surface of oysters which will repel drilling oyster drills.
3. Studies on suction or other types of dredging of large areas to see if drill populations may be reduced.
4. Other methods or combinations of methods.

Other Predators

The oyster leech, *Stylochus elipticus*, is present in many of our oyster growing areas and has been known to kill newly set spat. The possible role of this animal as a predator in Virginia waters has never adequately been studied.

The cownosed ray and drum are fish which may occasionally destroy beds of mature oysters. Extensive damage often occurs on planted beds and natural rocks on the Seaside of the Eastern Shore and in the Rappahannock.

Oysters are also subject to many other predators such as the trematode (*Bucephalus*), Pea Crabs and *Nematopsis*. These organisms affect oysters and have been in Chesapeake Bay for many years. However, they did not play a major role in the recent decline in production.

Summary and Recommendations for Controlling MSX and Other Diseases, and Predators

1. Determine by laboratory studies how MSX is transmitted from one oyster to another. Questions such as: is the disease waterborne, or is there an animal vector involved? The solution of these and similar problems might lead to control measures if an animal vector is found to be involved.
2. Continue studies on developing MSX-resistant oysters, but expand them using strains from

Maine to the Gulf regions and other places (introduced under proper conditions).

3. Further evaluate the question of "acquired resistance" by field experiments in which seed grown in an MSX area is planted on the bottom in an half-acre plot with mortality and growth evaluated scientifically and quantitatively. If these seed do show resistance to MSX as indicated by laboratory studies, then immediate steps should be taken to develop seed areas in Type I or II areas such as the lower York, the lower James, Lynnhaven Inlet and off Poquoson.

4. Plant trial plots of MSX-resistant oysters raised from a hatchery in high-salinity areas (Type I) and evaluate survival. Mortalities of hatchery-reared MSX-resistant oysters should then be contrasted to mortalities of oysters which have "acquired" this resistance. In this phase, mortality by drills and blue crabs would be a problem. We recommend for this study that hatchery-reared seed oysters should be "set" on oyster shells or other "protective" materials rather than cultchless. This we believe will greatly minimize damage by crabs. The use of Polystream[R] (Chapter XII) of the type which does not sink into the

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[R]Registered trademark

bottom mud, or trapping or some other suitable measure may be necessary to control drills.

5. Continue and expand efforts to successfully and economically plant and grow hatchery-reared seed oysters with desirable characteristics such as rapid growth, predation resistance and disease resistance on growing bottoms.

6. Continue and expand efforts to assess the importance of the various predators and diseases in population of oysters and develop methods or techniques for combatting these problems.

CHAPTER X

BACTERIAL AND INDUSTRIAL POLLUTION AND THE OYSTER INDUSTRY

CHAPTER X. BACTERIAL AND INDUSTRIAL POLLUTION AND THE OYSTER INDUSTRY

Legal Aspects and Size of Condemned Areas

The Food and Drug Administration of the United States Public Health Service from 1925 until the present has exercised Federal supervision over the sanitary quality of shellfish shipped in interstate commerce. This control program is cooperative in nature with the State, the shellfish industry and the Food and Drug Administration, each accepting responsibility for certain procedures. The operational procedures, policies and recommended practices of the latter organization are outlined in its manuals of operation (Houser, 1965). Quotations extracted from these sources pertinent to management and industry follow:

1. Procedures To Be Followed by the State.

> Each shellfish-shipping State adopts adequate laws and regulations for sanitary control of the shellfish industry, makes sanitary and bacteriological surveys of growing areas, delineates and patrols restricted areas, inspects shellfish plants, and conducts additional inspections, laboratory investigations, and control measures as may be necessary to insure that the shellfish reaching the consumer have been grown, harvested, and processed in a sanitary manner. The State annually issues numbered certificates to shellfish dealers who comply with the agreed-upon sanitary standards, and forwards copies of the interstate certificates to the Public Health Service.

2. Procedures To Be Followed by the Public Health Service.

The Public Health Service makes an annual review of each State's control program including the inspection of a representative number of shellfish-processing plants. On the basis of the information thus obtained, the Public Health Service either endorses or withholds endorsement of health authorities and others concerned. The Public Health Service publishes a semi-monthly list of all valid interstate shellfish-shipper certificates issued by the State shellfish control authorities.

3. Procedures To Be Followed by the Industry.

The shellfish industry cooperates by obtaining shellfish from safe sources, by providing plants which meet the agreed-upon sanitary standards, by maintaining sanitary plant conditions, by placing the proper certificate number on each package of shellfish, and by keeping and making available to the control authorities records which show the origin and deposition of all shellfish.

The fundamental components of this National Shellfish Sanitation Program were first described in a "Supplement to Public Sanitary Control of the Shellfish Industry in the United States" (1925). This guide for sanitary control of the shellfish industry was revised and reissued in 1937 and again in 1946. It was separated into two parts by publication of Part II, "Sanitation of the Harvesting and Processing of Shellfish," in 1957 and by publication in 1959, of Part I, "Sanitation of Shellfish Growing Areas." The need for a specialized program of this nature was reaffirmed at the National Conference on

Shellfish Sanitation held in Washington, D.C., in 1954 and at the Shellfish Sanitation Workshops held in 1956, 1958, 1961 and 1964. The last workshop was held in Maryland in 1977.

Section A in Part I of the United States Public Health manual (Houser, 1965) outlines regulations which the State should follow in classifying growing areas. These are quoted below.

Approved

> Area I. The sanitary survey indicates that sewage from cities "A" and "B" (even with the "A" sewage plant not functioning) would not reach this area in such concentration as to constitute a public health hazard. The median coliform MPN of the water is less than 70/100 ml. The sanitary quality of the area is independent of sewage treatment at city "A."

Conditionally Approved

> Area II. This area is of the same sanitary quality of Area I; however, the quality varies with the effectiveness of sewage treatment at city "A". This area would probably be classified prohibited if city "A" had not provided sewage treatment.

Restricted

> Area III. Sewage from "B" reaches this area, and the median coliform MPN of water is between 70 and 700 per 100 ml. Shellfish may be used only under specified conditions.

Prohibited

Area IV. Direct harvesting from this area is prohibited because of raw sewage from "B." The median coliform MPN of water may exceed 700/100 ml.

Area V. Direct harvesting from this area is prohibited because of possible failure of the sewage treatment plant. Closure is based on need for a safety factor rather than coliform content of water or amount of dilution water.

Legal Aspects of Pollution in Virginia

Condemnation of oyster grounds in Virginia is by order of the Virginia State Health Department. The Bureau of Shellfish Sanitation of that Department has the direct responsibility of monitoring the State's shellfish resources for human health related contamination. The Bureau makes bacteriological surveys and also utilizes information provided by the Virginia Institute of Marine Science, the State Water Control Board, the U.S. Army Corps of Engineers, the National Marine Fisheries Service and other State and Federal institutions and agencies in its deliberations and determinations.

Once an area has been defined and declared polluted, it is the responsibility of the Virginia Marine Resources Commission and the State Health Commissioner to enforce legal regulations concerning possible oyster or clam culture within the area. Pertinent laws related to this subject are in the

Code of Virginia of 1950 and the 1974 Cumulative Supplement, Sections 28.1-176 to 28.1-181. Several of the regulations are quoted below:

> 28.1-176. Condemnation of Polluted Growing Area. When from examination of or analysis of the shellfish in a shellfish growing area, or the bottom in or adjacent to such area, or the water over such area, or the sanitary or pollution conditions adjacent to or in the near proximity to a shellfish growing area, the State Health Commissioner determines that the shellfish growing in such area is unfit for market, he shall, after notifying the Commissioner of Fisheries, cause limits or boundaries of such area upon which such shellfish are located or planted to be fixed, which area shall be condemned, and remain so until such time as the Health Commissioner shall find such shellfish or area sanitary and not polluted. The Commission of Fisheries, with instructions from the State Health Department, shall erect markers or signs designating condemned areas shall be supplied to the Commission of Fisheries by the State Health Department.
>
> A shellfish growing area and the shellfish located thereon may be condemned for the following periods:
>
> > (1) Condemned for an indefinite period, which shall remain in effect until some major improvement in pollution abatement occurs on the stream in question.
> >
> > (2) Seasonable (seasonally) condemned areas where recreation or certain other activities in or adjacent to the area may cause pollution of the growing area during certain seasons of the year.
> >
> > (3) Conditionally condemned areas which are sanitary and open under normal conditions, but which because of potential pollution hazards may be closed by the Health Commissioner at any time without advance notice or a prior hearing, provided that relative to said area there must be a hearing within thirty days after the area is condemned, unless it is re-opened within said period...

Designation of Areas as Polluted

The following is taken from the publication "Public, Leased and Condemned Shellfish Growing Areas in the Commonwealth of Virginia" (VSWCB, 1971). The publication in its entirety shows public grounds, leases, condemned areas and discusses them. Portions are quoted below since they give a good description of what a polluted area is under the regulations and what constitutes pollution according to the Virginia Department of Health.

> Shellfish growing areas are designated as approved when the area is not so contaminated with fecal material, industrial waste, radionuclides, pesticides, or heavy metals that consumption of the shellfish might be hazardous and the coliform median MPN of the water does not exceed 70/100 ml. Sewage or other pollutants reaching such growing areas must be so treated, diltued, or aged that it will be of negligible public health significance. This implies an element of time and distance to permit the mixing of waste with the receiving waters so that dilution or dispersion occurs.
>
> Considered judgment plays an important role in the evaluation of sources of actual or potential pollution to a shellfish growing area. Effectiveness and reliability of treatment, distances of pollutants from shellfish areas, the effects of winds, run off, stream flow, and tidal currents are important aspects of consideration. It must be recognized that all receiving waters are not equally efficient from the standpoint of dilution, dispersion, salinity, etc. and bacteriological standards are not indicative of relative safety. Each estuary receiving pollution must be considered as a separate case. Any variation in the pollution source will affect the sanitary quality of the water in the estuary. In the same manner, shellfish will rapidly reflect any deterioration in the quality of their environment but are slower to reflect improvement.

Shellfish growing areas near marinas, wharves, docks, beaches and population centers are often subjected to potential pollution hazards from small amounts of fresh sewage which are not ordinarily revealed by the bacteriological examination. It is also evident that the presence of people in an area creates certain pollution problems. This often is referred to as the effects of "people activity" and is associated with increased run off, sewage disposal problems, recreational facilities and other related requirements resulting from population expansions, all of which inadvertently affect the quality of adjacent shellfish growing waters.

In order to assure that shellfish harvested for direct marketing and possible consumption as a raw product are safe, it is often necessary to establish a "buffer or safety zone" around known or potential sources of pollution. Sources of pollution around which the establishment of a "safety zone" might be required are: sewage treatment plants, industrial waste discharges, marinas, docks, wharves, harbors, shipping channels, areas receiving animal discharges, recreational areas and those areas subject to "people activity." The "safety zones" allow for the mixing and diluting of the pollutants, give time for bacterial die-off and provide time for control agencies to take action to prevent shellfish harvesting from adjacent areas should a variance in established conditions make it necessary to do so. The pollution source is the dominant factor in determining the need for or the size of such a "safety zone" and is dependent upon a thorough evaluation of the overall situation.

As an example, these "buffer or safety zones" are necessary around sewage treatment plants due to the fact that mechanical failures and human errors often occur with a resulting interruption of treatment. Since pump stations often bypass sewage to shellfish areas, combined storm and sanitary sewers overflow; chlorination breaks down; plant design criteria is often not adequate; plant repairs or operational difficulties make bypass necessary; sewer outfalls are often unattended at various times; effectiveness of treatment varies with nature and quantity of sewage to be treated; sewage treatment is not absolute or complete for removal of all offensive materials; and there is considerable uncertainity regarding the effect of sewage treatment on viruses, a zone of safety around such installations is considered essential from the public health standpoint.

In addition, toxic materials, heavy metals, radionuclides, etc. from industrial waste require safety zones around such discharges as shellfish readily assimilate these materials. Likewise, the effects of pollution from marinas, harbors, animals, recreational areas, population centers, etc., while intermittent in nature, are nonetheless potential hazards to shellfish.

The State Water Control Board adopted the Water Quality Standards that became effective July 20, 1970. Paragraph 2.03 states: "Discharges of treated wastes, while not contravening established standards for shellfish waters may prevent the direct marketing of shellfish as a result of judgment factors employed by the State Department of Health." When the possibility of such condemnation arises as the result of proposals to discharge treated wastes, the Board will convene a public hearing to determine the socioeconomic effect of the proposal before reaching a decision.

It was pointed out by the United States Food and Drug Administration in 1975 that a serious condition or potential for conflict existed in some of the oyster growing regions of Virginia. This agency indicated that certain areas where oysters were grown and harvested, but were not listed as polluted, were reported to have coliform counts which exceeded the recommended federal standards for growing areas. This was in conflict with the then existing laws and regulations which provided that for interstate shipment median coliform counts of the water where oysters are harvested should not exceed 70 per 100 ml. This condition had apparently existed for several years or more with nothing being done about it at the State or Federal level.

The apparent reasons why these areas had not been closed up to this time were that the policy of the Bureau of Shellfish Sanitation of the Virginia Department of Health was to approve or condemn areas on the basis of known sources of pollution rather than the basis of actual observations on the coliform content of the water (SWCB, 1971). The foreward in this publication states the State Water Control Board obtained its information on locations of shellfish growing areas from the VMRC; the information on condemned areas was obtained from the Bureau of Shellfish Sanitation of the Virginia Department of Health. Review of the reasons presented in that publication for condemning areas indicates that areas were being condemned on the basis of distribution and presence of the following possible contaminating sources: marinas, subdivisions, swampy areas, marine railways, sewage treatment facilities, industrial dumps, animal populations, residential areas, boat pollution and other people-related activities and not primarily or even significantly on the basis of actual bacterial content of the waters themselves. Only in one instance in this publication was high bacterial count in the water given as a reason for closing an area!

The policy of the Virginia Bureau of Shellfish Sanitation has become more stringent since 1971 resulting in additional acreage of good oyster growing areas being closed. Closure since 1975 has been based on fecal coliform levels found in the water as well as on the potential pollution from known sources.

As a result of the alleged shortcomings of the management arrangements of Virginia and sister-states, the United States Food and Drug Administration found it necessary in June of 1975 to strengthen the National Shellfish Sanitation Program. The regulatory changes proposed by the FDA were intended to correct shortcomings where they existed by redefining the scope, requirements and responsibilities of involved state and federal government agencies. The proposed regulations required:

1. The individual states to develop a Comprehensive State Shellfish Control Plan (CSSCP) under which they would inform FDA of the measures to be taken to inspect shellfish harvesting and processing operations and of the resources to be provided to carry out such surveillance.
2. Strict enforcement of the current microbiological pollution and other quality standards for the waters.

3. A tagging and recordkeeping system for shipped shellfish that would enable FDA or State authorities to (a) determine within a matter of hours where shellfish found to be contaminated were grown; and (b) provide authorities with a definitive list of all producers and processors who may have handled them.

4. Establishment of specific control practices and sanitary requirements for both processors of shellfish and handlers of shell stock (unshucked shellfish).

5. That imported fresh or frozen shellfish meet the same sanitary standards as those applied to shellfish in the United States.

These proposals met with nation-wide opposition by industry and many state regulatory agencies. As of 1977, the proposed modifications had not been implemented.

Size of Condemned Areas - General

Condemned areas are often quite extensive and may even extend from one shore to the other. They frequently include many sites or locations which have never produced market oysters, hard clams, soft clams or brackish water clams. This fact must be considered when evaluating the impact of condemnation on the Virginia oyster and clam industry. Certain closed areas or portions of condemned areas do not produce oysters or clams and have not for a long time.

To evaluate the impact of pollution on the shellfish industry, it would be advantageous to estimate the size of public and private areas and their bottom depths and types. One should also consider distribution of diseases, predators and salinity patterns in relation to the size and location of the restricted areas and other factors. It is not practical to do so, however, because of the difficulty in establishing precise boundaries for the leases and for the various factors which affect oyster production.

While such a detailed analysis is not practical, it is possible to present a general concept of the location of polluted areas in relation to areas of actual or potential shellfish culture. For this purpose areas of polluted grounds, as indicated by condemnation or closure to direct harvesting of shellfish as of 15 December 1975, were tabulated by broad geographic regions showing total acreages of condemned ground using data from the Water Control Board and the Bureau of Shellfish Sanitation. These tabulations are presented in Table 86.

Table 86

Areas of Virginia Waters Where the Taking of Shellfish is Either Restricted or Prohibited, With Size of Leased and Public Oyster Grounds Shown For Reference[1]

POTOMAC RIVER - VIRGINIA TRIBUTARIES

Leased Acres	Public Acres
8,501	2,988

Area		Condemned Acres
Above Mathias Point		13,343
Upper Machodoc Creek		928
Monroe Bay		1,095[2]
Nomini Creek & Currioman Bay		670
Lower Machodoc Creek		269[3]
Rosier Creek		233[3]
Coan River		321[3]
Yeocomico River		366
Other Creeks		675
	Total	17,900
	Percent of State Total =	10.0%

CHESAPEAKE BAY - SMITH PT. TO WINDMILL PT.
Including the Little & Great Wicomico Rivers

Leased Acres	Public Acres
5,006	24,438

Area		Condemned Acres
Great Wicomico		1,117
Creeks tributary to Chesapeake Bay		520
	Total	1,637
	Percent of State Total =	0.9%

RAPPAHANNOCK AND CORROTOMAN RIVERS

Leased Acres	Public Acres
13,837	55,185

Area		Condemned Acres
Rappahannock River		
below Russ' Rock		1,249
Russ' Rock to Port Royal		20,472
Creeks tributary to the Rappahannock		2,933
Corrotoman River		534
	Total	25,188
	Percent of State Total =	14.1%

Table 86 (Contd.)

PIANKATANK RIVER AND MILFORD HAVEN

Leased Acres	Public Acres
3,343	15,297

Areas	Condemned Acres
Piankatank River	
Upper river, above Scoggins Cr.	1,328
Tributary creeks	269
Milford Haven	
Tributary creeks	547
Total	2,144
Percent of State Total =	1.2%

MOBJACK BAY AREA

Leased Acres	Public Acres
10,524	24,634

Area	Condemned Acres
Horn Harbor	42
Monday Creek	68
Severn River	57
Ware River	377
North River	43
East River	302
Total	889
Percent of State Total =	0.5%

YORK RIVER

Leased Acres	Public Acres
11,599	3,850

Area	Condemned Acres
River	
West Point to Roane Point	7,131
Naval Weapons Station & Cheatham Annex	1,259
Coast Guard Station	75
Gloucester Point	54
Creeks	2,328
Total	10,845
Percent of State Total =	6.1%

Table 86 (Contd.)

POQUOSON RIVER AREA

Leased Acres	Public Acres
3,959	7,824

Area	Condemned Acres
Creeks of Poquoson River	923
Percent of State Total =	0.5%

BACK RIVER

Leased Acres	Public Acres
1,679	0

Area	Condemned Acres
Back River	1,200
Percent of State Total =	0.7%

JAMES RIVER SYSTEM

Leased Acres	Public Acres
13,848	27,841

Area	Condemned Acres
James River	
Mulberry Point to Hopewell	58,792
Mulberry Point to bridge	2,433
Warwick River	2,123
Pagan River	1,748
Chuckatuck Creek	466
Nansemond River and tributary creeks	3,069
Hampton Roads and James River below bridge	35,942[4]
Total	104,573
Percent of State Total =	58.5%

SOUTHERN EDGE OF CHESAPEAKE BAY AND BEYOND

Leased Acres	Public Acres
2,361	0

Area	Condemned Acres
Chesapeake Bay	2,620
Little Creek	792
Broad Bay	45
Lynnhaven Bay	4,378
Ruddee Inlet	99
Total	7,934
Percent of State Total =	4.4%

Table 86 (Contd.)

Eastern Shore, Bayside

Leased Acres		Public Acres
8,840		36,623
Area		Condemned Acres
Pocomoke Sound		1,485
Tangier Island		739
Creeks		2,225
	Total	4,449
	Percent of State Total =	2.5%

Eastern Shore, Seaside

Leased Acres		Public Acres
15,227		44,591
Area		Condemned Acres
Chincoteague Bay		493
Creeks		557
	Total	1,050
	Percent of State Total =	0.6%

TOTALS FOR VIRGINIA, AS OF 15 Dec 1975

Condemned Area		176,079
Conditionally Condemned Area		1,923
Seasonally Condemned Area		730
	Total condemned	178,732

Notes:

1. Location and size of restricted and prohibited (condemned) areas from "Public, Leased, and Condemned Shellfish Growing Areas, " 1971, State Water Control Board, and Va. Bureau of Shellfish Sanitation; up to date as of 15 Dec. 1975. Data on leased areas from VMRC; as of 15 Dec. 1975. Data on public grounds from VMRC; as of 15 Dec. 1975 (Table 78).

2. 730 of these are seasonally condemned; that is, they are condemned between 1 April and 14 November.

3. Conditionally condemned (see Chapter X for definition).

4. 1,100 of these are conditionally condemned.

In 1975, 178,732 acres of bottom in Virginia were classed as Restricted for Shellfish Culture. We shall consider them by river system or area.

The James River

The James River encompassed the largest area of condemned bottom in Virginia. This system and its tributaries contain an estimated 104,573 acres of condemned grounds, or 58% of all condemned bottoms in the State.

For discussion, restricted areas of the estuarine James may be divided into: 1) the area below the James River Bridge; 2) the mid-estuary containing most of the public seed rocks; and 3) the upper part from Mulberry Point to locations further upriver toward Jamestown Island and beyond to Hopewell where oysters do not occur, but which does support the brackish water clam Rangia cuneata.

Below the James River Bridge

A large block of condemned bottom extends from the region of the James River Bridge to the mouth of the estuary. Included therein is Hampton Roads with 35,942 condemned acres. Several large sections of Baylor Survey Grounds are also encompassed by this restricted area. This section of the James was very productive prior to the condemnation of these shellfish growing areas, and before the heavy MSX-induced mortalities in 1960. Extensive leased areas and Baylor Bottoms existed in the Lafayette and Elizabeth rivers. On Hampton Bar, there were large private leaseholds belonging to the Ballard Fish and Oyster Company and the J.H. Darling Company.

Pollution began to be a problem about 1935, but as late as 1950 some of these leased bottoms were still used as direct-harvest growing areas. Harvesting of oysters was still permitted during periods when bacteriological studies showed water quality was within acceptable limits (Smith, 1953). Also prior to 1960, significant quantities of James River seed were still planted in the Hampton Roads area, despite permanent closure due to condemnation and when these oysters matured they were relaid in pollution-free areas for depuration (cleansing themselves of the bacteria) prior to shucking.

MSX manifested itself in the Hampton Roads area in 1960 and eliminated the practice of market oyster growing there. Today, even if the area were not polluted, it would not be economically feasible to grow oysters to market size using conventional culture techniques due to the added cost of depuration.

Two other tributaries below the Bridge, the Nansemond and Chuckatuck rivers, contain a total of 3,535 condemned acres. Baylor Grounds are located in the lower reaches of the two systems with both systems containing leased bottoms. Prior to 1960 (before MSX), leased bottoms in these two systems were extensively planted. Today many areas of bottom in sections where salinities are low enough so MSX is not a problem and which are not restricted are planted.

The Mid-James

This reach of the James extends from the James River Bridge to Mulberry Point and this area is almost free of MSX. It contains vast acreages of valuable Baylor Bottoms which contain most of the State's natural seed rocks. It also includes public bottoms in the Warwick and Pagan rivers, as well as productive leased bottoms located inshore of the public bottoms. In this section 6,304 acres are condemned. Much of this restricted bottom lies in or just outside the Warwick and Pagan rivers. In addition there are about 2,433 restricted acres on the north shore above the James River Bridge.

While the Hampton Roads area is restricted and plagued with MSX, it still produces about one-third of the hard clams harvested in the State. Each year during

July and August many clams are taken from the area and transplanted to unpolluted zones so they may be cleansed and later reharvested for marketing.

Bacterial contamination in the mid-James has begun to influence market and soup oyster production and zones of condemnation are beginning to encroach upon highly productive areas. Such condemnation forces relaying of oysters for depuration which raises costs of production even if the soup companies would buy relayed oysters. The potential for damage to the oyster industry in this section is greater than in any other region of the State. The reason is that from 1963 to 1975 public bottoms in this section of the James produced 2,757,274 bushels of oysters sold for processing or 62% of all those produced in the State. Most of these small market-sized oysters were used as "soups."

A further encroachment of polluted zones on the unpolluted oyster growing area could be disastrous. If the mid-section of the James becomes totally polluted, the seed from this section planted freely in the various systems would technically be considered polluted. Under these circumstances, the planting of polluted seed would theoretically come under the restrictions related to harvest and relaying of polluted oysters since there is the possibility of some of the larger oysters among the seed (and there are now more of them than formerly) being sold for immediate consumption (or as soups) rather than for seed. This would mean that under present State law, oysters from condemned bottoms might well have to be moved under the supervision of an inspector and planted in areas marked by yellow flags, as outlined in Section 29.1-179 of the Code of Virginia to be sure that condemned oysters would not get into the marketplace directly after harvest from the contaminated area. Of course, for oysters actually used for seed, the State would have to monitor these plantings until the time required for depuration had passed.

The Upper James River

In the upper reaches of the James from Mulberry Point Shoal area to Hopewell there are 58,792 acres of restricted bottoms. It was restricted mostly because it supports an extensive population of the brackish water clam, Rangia, which, even though it is edible, has had limited use as a food item. Except for the immediate area around Deep Water Shoal, the Baylor Grounds included do not produce oysters due to the low salinity (less than about 5‰). A few leased grounds occur in this region of the river. There is little effect on the oyster industry, public or private from this condemnation though by law direct marketing is not allowed.

The Rappahannock River

The second largest accumulation of polluted areas is the Rappahannock River where 25,188 acres were condemned, or 14.1% of the State total. It must be noted that 20,472 or 81% of these condemned grounds are located above Russ Rock where oyster culture is not possible due to fresh water.

As in the James, this restricted area was established because of the presence of the brackish water clam, Rangia.

In the mainstem of the Rappahannock, only one small productive area of Baylor Ground off Urbanna is effected by condemnation.

Many of the small tributary creeks containing leased bottoms, which are highly suitable for oyster culture, contain condemned areas.

The Chesapeake Bay

Along the southern shore of the Chesapeake Bay, both in the Bay and in the tributaries, there were 7,934 acres of condemned bottoms or 4.4% of the State total. Most of this acreage is marginally productive today because of MSX and other factors. Areas influenced are all in tributaries such as Little Creek, Broad Bay, Linkhorn Bay and Lynnhaven Inlet.

The York River

The third largest agglomeration of condemned areas in the State is in the York River comprising 10,845 acres or 6.1% of the State total. The biggest piece, consisting of 7,131 acres (or 66% of the York's total) extends from West Point, seven nautical miles downriver, to about Roane Point. It contains a large quantity of potentially valuable non-Baylor ground for shellfish culture as well as some Baylor Grounds. The second largest area, 1,259 (or 12% of the York's total) is located around the U.S. Naval Weapons Station pier. This is in a Type II zone for MSX.

The Potomac River

The Virginia tributaries of the Potomac River contain 17,900 acres of condemned ground or about 10% of the State's total. However, 13,343 acres above Mathias Point are restricted because of the occurrence of the brackish water clam, Rangia. Only 4,557 acres, or 2% of the State's total, are in oyster growing areas! This latter acreage is considered a highly potentially productive area for market oysters since MSX is not a problem and there are few predators and no known other significant disease. Much of the polluted (restricted) ground is otherwise quite suitable for oyster culture. It should be very attractive as an area to grow market oysters.

Other Areas

While the preceding locations comprise most of the restricted areas in Virginia, there are additional, but localized areas on the Eastern Shore and other places where productive bottoms have been lost due to pollution.

Oyster Culture in Condemned Areas

Even though an area may be condemned, oysters (and clams) may still be cultured there and relaid in unpolluted areas. After 15 days at temperatures over 50°F, they may then be harvested for human consumption. Laws in Virginia regarding use of oysters (or clams) from polluted grounds are specific and a few of the rules are quoted below from the Code of Virginia in Section 28.1-179.

> No person, firm or corporation shall take, catch, transport, sell, offer for sale, remove, receive, keep or store shellfish from condemned areas, or relay shellfish taken from such areas, until a special permit has been obtained from the Commission, which must be carried in his possession when engaged in such operation...
>
> Shellfish removal, and/or relaying, from condemned areas shall be under the supervision of the Commission of Fisheries and the Department of Health.
>
> The season for the removal, and/or relaying of shellfish from private grounds shall be from April first to November first.
>
> The season for the removal, and/or relaying of shellfish from public grounds shall be from May first to August fifteenth...

> The above dates for the opening and closing of said seasons may be changed by the Commissioner, and the Commissioner may refuse to grant permits for removal of shellfish from any and all condemned areas of the State...

Unfortunately, this section (28.1-179) of the Code of Virginia does not include one additional important condition of harvest of oysters from condemned areas which is imposed by a regulation of the Virginia Bureau of Shellfish Sanitation. Oysters or clams may be transferred to unpolluted water only when water temperatures are over 50°F (10°C) and they must remain in water above this temperature for a minimum of 15 days before sale.

Several of the regulations or statutory requirements related to relaying and harvest of oysters (and clams) should be re-examined and modified as necessary, since they seem to be based on ease of administration or enforcement rather than on biological or health-related reasons. For example:

1. Regulations related to harvest of oysters from restricted areas only during certain seasons might be amended to permit the initial harvest and relaying at any season or at least over longer periods. The only necessary restriction needed is oysters must be subject to water temperature over 50°F (10°C) for 15 days prior to reharvesting for consumption as a food item.

If such a change were initiated it would enable watermen to plan their year-round work more effectively and they could work longer periods in restricted areas. We recommend that the appropriate State and Federal regulatory agencies consider such a change.

2. The 15-day period required by law for relaying oysters may be longer than necessary and might be shortened. Studies recently completed at VIMS show if, provided conditions of temperature, salinity and oxygen are at sufficient levels oysters will depurate fecal coliform bacteria in only 2 days. Studies should be undertaken by VIMS to determine if 15 days is actually required under field conditions or if a shorter period is sufficient.

Economic Aspects of Oyster Culture in a Condemned Area

As recently as 1959, the J.S. Darling Company grew James River seed to maturity in restricted (condemned) sections of Hampton Roads. Prior to marketing substantial quantities of oysters were transplanted to the lower York River and other locations in Mobjack Bay for depuration. Other companies utilized other areas for similar purposes. This practice was successful at the time in the sense that a profit was made (and by several prominent companies) despite the extra steps and costs required. Such a cultural technique is seldom attempted today because it has proven economically unprofitable.

Data presented in Chapter V on the culture, practices and experiences of a private Rappahannock River oyster grower make possible several basic calculations based on 10 bushels and based on a presumed one-to-one yield.

1.	Average sale price of Rappahannock River oysters from private grounds	@ 7.72 bu. =	1975 77.20
2.	Average cost seed (1975)	@ 1.95 bu. =	19.50
3.	Average freight and planting	@ 0.56 bu. =	5.60
4.	Harvest cost (dredge) approximate	@ 1.00 bu. =	10.00
5.	Gross return (1 minus 2, 3, and 4)		$ 42.10

Out of the $42.10 net (77.20 - 35.10), company operating expenses must be deducted. If we assume the 10 bushels of oysters are replanted and reharvested instead of being marketed, the net becomes much smaller. There are two reasons for this: 1) when oysters are replanted and reharvested only about 75% are recoverable due to mechanical injury, some are lost (i.e., not alll can be recovered), and some may be covered by silt in planting, and 2) there are the additional costs due to labor and freight which are a part of operations during relaying.

If the 10 bushels of oysters were harvested and only 75% were recovered, the probable cost and balances would be as follows:

6. Expense of moving and planting oysters a second time 10 bu. x .56 = $5.60

7. Harvest of oysters the second time 75% of 10 bu. = 7.5 bu. x $1.00 = $7.50

8. Value of oysters reharvested 7.5 bu. x $7.72 = $54.00

The total value of oysters would be $54.00 with estimated expenses of 48.20 (Total 2, 3, 4, 6 and 7). This is a net of only $5.80 in 10 bushels.

Relaying as presently practiced is becoming economically impractical. Due to losses, it may already have become uneconomical for many. It is possible relaying techniques be improved so the 25% loss is minimized. Oysters may be depurated under controlled conditions in tanks in only 2 days as will be discussed later in this chapter.

Way of Using Oysters Grown in Restricted Areas

As the condemned areas encroach further into valuable shellfish areas, there are possible ways of utilizing oysters from these regions other than the uneconomic technique of controlled depuration or relaying in the field.

For example, we believe that oysters from restricted areas might be harvested if they are canned with heat sterilization. At present, Federal law does not permit the canning of oysters harvested from areas where total coliform in the water average over 70 per 100 ml. Crabs and fish taken from these same restricted areas may be sold for human consumption and large numbers are harvested for sale from lower Hampton Roads and other restricted areas.

A possible reason for this law is that oysters (and clams) are consumed both raw and cooked and it would be difficult to regulate harvest to prevent oysters from restricted areas being sold for raw consumption. However, this provision of law seems to be more for the convenience of the law enforcement agency (who may not wish to have the "bother" of enforcing the law) rather than being based on public health.

Many foods are handled in this fashion. It is difficult to see why oysters which are steam sterilized when canned may not be sold in a similar manner. There is no reason that we can see why the industry should not be allowed to harvest oysters from condemned areas provided they are properly canned. It is recommended that steps be taken to review this problem and, if possible, to amend the law so as to allow canning.

Depuration Under Controlled Conditions

There has been extensive research on holding oysters in tanks of circulating seawater so they may rid themselves of harmful bacteria. This process is termed depuration. Experimental plants have been constructed in the following places: Alabama (Hartley and Hammerstron, 1971); Canada (British Columbia) (Devlin, Eng and Neufeld, 1971); and New York (Bennett, 1969). Much of the pertinent material dealing with the subject has been reviewed in the manual, "Depuration Plant Design," by Furfari (1966).

The process consists of holding baskets of oysters in shallow rectangular tanks constructed of concrete, wood, fiberglass or a similar inert substance. Water is run through this system at a rate which depends on the number of oysters being held. Water may be simply flowed through the system on a once-through basis after being sterilized by passage under an ultraviolet light or it may be recycled after being sterilized by ultraviolet light.

The details of the operation of plants of various sizes are shown in Tables 87 and 88. An inspection of these data show considerable equipment and cash is needed to operate a small plant processing 400-600 bushels daily. The present cost of depuration is fairly high. At an estimated daily output of 400 bushels the cost would be about 44 to 55

Table 87

Designing Factors for Depuration Plants[5]

Plant Capacity Bushels	Floor Area of Building Without Lab.[4] Sq.Ft.	Total Tank (1) Capacity Cu.Ft.	Flow Rate Sea Water GPM	No. of Purdy UV Units	Controlled Storage Volume Cu.Ft.	Wash (2) & Cull Machines	Total Person-nel (Mini-mum)	Sea Water (3) Heating Requirements Lbs. Steam Per Hour	Approximate Daily Output Bushels
50	500	400	50	2	80	0	3	570	20- 25
100	800	800	100	3	155	2	3	1100	35- 50
200	1500	1600	200	6	310	2	3	2300	70-100
400	3000	3200	400	12	630	2	4	4600	130-200
800	5700	6400	800	23	1250	2	4	9100	270-400
1200	8500	9600	1200	35	1900	2	5	13600	400-600

1. For Quahogs and Oysters: Use 62.5% of these values for Soft Clams.

2. The type designed by Marine Department of Conservation. For small plants see text.

3. Open system. (Multiply these values by 940 (for 35 psi saturated steam) to obtain BTU/hour).

4. Larger plants may require more than 200 square feet of laboratory space.

5. From "Depuration Plant Design." 1967. U.S. Dept. Health, Ed. & Welfare.

Table 88

Price Difference Per Bushel -- Buying -- Selling
To Break Even -- Running At Capacity[3]

Total Plant Capacity Bushels	(1) Expected Daily Output Min. Bushels	(2) Expected Annual Output Bushels	Annual Cost Without Mortgage $	Annual Cost With Mortgage $	Break-Even Cost Per Bushel Without Mortgage $	Break-Even Cost Per Bushel With Mortgage $
50	20	5,000	19,840	20,680	3.98	4.15
100	35	8,800	20,370	21,670	2.32	2.46
200	70	17,500	21,590	23,940	1.23	1.37
400	130	32,500	29,150	33,250	0.90	1.02
800	270	67,000	33,930	41,560	0.51	0.62
1,200	400	100,000	43,930	54,930	0.44	0.55

1. See Table 87.

2. Assumes 250 days/year.

3. From "Depuration Plant Design." 1967. U.S. Dept. Health Ed. & Welfare.

cents per bushel (Furfari, 1966). This would be from 65 to 82 cents when adjusted to the 1975 dollar (Table 59). Costs will probably be reduced by further study and engineering development.

Five depuration plants, which are State funded or privately operated, have been built and are now operating to depurate soft clams, *M. arenaria*, and hard clams, *M. mercenaria*, in Maine, Massachusetts, and New Jersey. Details and costs are not available.

A three year study has recently been completed at VIMS on depuration and depuration plant design (Haven and Perkins, 1976). This study concluded that oysters contaminated in nature depurated fecal coliform bacteria with a consistant and high degree of predictability in 48 hours or less over a wide range of environmental conditions typical of Chesapeake Bay. It was shown that temperature, salinity and dissolved oxygen levels should be between certain limits for the process to be effective. These limits were as follows: temperature, 12 to 32°C; dissolved oxygen, above 1.7 ppm; and salinity, above 10 ppt. Several commercial-sized tanks were developed each holding 6 to 8 bushels. A flow of water of 1 gallon per-minute-per-bushel of oysters was the minimum recommended flow to these units. Oysters infected with *Dermocystidium* and MSX were able to depurate as quickly as those not afflicted with these diseases.

Costs of constructing and operating a depuration plant were not made in this study, but such research is recommended.

Guidelines for depuration plant design and operation have not been formulated at the State level. It is suggested appropriate agencies formulate such laws or regulations in Virginia so a depuration plant might be constructed and operated.

Depuration in tanks will probably not become an established aspect of oyster culture on a widespread scale in the <u>immediate</u> future for the following reasons:

1. While many good growing areas are restricted, the availability of suitable growing bottom due to pollution does not at present appear to be limiting, except in localized areas like Chincoteague Bay and Lynnhaven Inlet. The availability of high yield bottoms was discussed fully in Chapter VII. There it was shown that certain potentially high yield but uncultivated bottoms in unpolluted areas were not available to all who might want them. It may also be shown that the problem might be partially solved by making certain Baylor Grounds available for leasing.

2. The cost is high in relation to today's sale price of market oysters.

Still, there are foreseeable circumstances where depuration may be adopted. For example:

a. If the price of Virginia oysters were to rise to a level as high as it already is in some sections of the country, as for example in the Northeast, the expense of depuration would be proportionally reduced and depuration would become economically feasible. In New England, oysters for the raw bar trade now sell for as high as $21 per bushel, and the 65¢ to 82¢ cost of depuration is only a small fraction of the total.

b. If industrial or domestic pollution increases substantially beyond what is now, and the amount of uncondemned oyster growing bottom diminishes notably.

c. If laws relating to bacterial standards are upgraded thereby reclassifying as restricted many bottoms which are not condemned.

d. If regulations were adopted to require all shellfish to be depurated regardless of source. Such a practice would help assure a more standarized (bacteriologically) product. It has been threatened. For example, for many years, all milk (except that produced under strict supervision and used for special purposes) has had to be pasteurized. Milk remains a staple for families with children.

e. In special growing areas oysters have a "name" which often commands a price 50% over those grown in other areas. Lynnhaven Inlet is such an area; Tom's Cove near Chincoteague is another. Since they often command a premium price, oysters from such areas might be depurated at a profit.

Depuration in tanks may become an integral part of production in the Chesapeake area in certain small areas today and on a wider basis at some future date.

Problems Associated With Non-Bacterial Pollution

There are more types of pollution other than those associated with bacterial levels in water and seafood. These are the chemical wastes resulting from industrial activities and processes. In addition, materials which are toxic or debilitating to oysters or which affect other biological processes or the physio-chemical environment itself may be introduced by agriculturists, homeowners, businesses, governmental facilities, transportation organizations and industry. Such wastes may have lethal or sublethal effects on adult oysters as well as their larvae. Laboratory studies have shown that heavy metals such as mercury, lead, zinc and cadmium not only accumulate in adult oysters, but may at certain levels cause emaciation of tissue and finally death (Schuster and Pringle, 1969). Soft detergents which are found in household and industrial waste water at concentrations as low as 0.025 mg/l reduced development of fertilized oyster eggs (Calabrese and Davis, 1967). Common agricultural pesticides may inhibit the activity and growth of oysters at concentrations as low as one part in 100 million after only 24 hours of exposure. Butler, Wilson and Rick (1962) and Butler (1961, 1965, 1966 and 1967) have shown effects of many chemicals on growth and development at various stages of molluscan development. Lowe et al (1971) showed growth of oysters to be affected and pathology produced in animals reared in seawater containing about one part of DDT, toxaphene or parathion per billion parts of water. Many other references similar to the preceding exist. Kepone has recently added its unknown impact to the environment.

There is now a growing body of evidence that chlorine and chloramines at concentrations of about 0.005 ppm or over kill larvae of many marine species including oyster larvae (Roberts et al, 1975). Such concentrations have been found to exist in the vicinity of outfalls of several sewage treatment plants in the James. Levels of chlorine from treatment plants have increased sharply since 1960. Therefore, chlorine is now suspected as a contributing cause of low set which has plagued the James River since 1960 (see Chapter IV).

The Virginia Marine Resources Commission in 1973 and 1974, supported by the Virginia Institute of Marine Science, recommended that chlorine levels used to treat sewage in the James at several plants be reduced to as low levels as possible (and still be in the recommended range). This was done. No change in oyster setting was noted in 1973. The set on shellstrings (weekly set) was low in 1974, but the surviving set in the James at Wreck Shoals and below reach an 8-year high. Though this is encouraging, we are unable at this point to demonstrate a cause and effect relation. However, we do recommend this problem as a major topic for research.

During the late 1960's one industrial firm in Virginia began producing Kepone, a long-lived organic pesticide. Its production continued until 1975. Soon after manufacture of this toxicant began, it started to reach the environment. The oyster industry of the James River felt its effect in 1975 when its presence finally became known. It still persists in sediments and organisms although it is not now manufactured. The results were disastrous to the entire fishing industry in the area.

Immediately after discovery of its presence in humans working around the plant, scientists from the Virginia Institute of Marine Science and the U.S. Environmental Protection Agency, among others, began searching for it in the environment. As a result Kepone was found in nearby fresh waters and in the waters, sediments and biota of the James estuary and its tributaries.

Scientific work showed oysters were able to rid themselves of Kepone until it was below the established Temporary Action Tolerance Level. Management authorities were able to allow sale and transplanting of James River oysers, thus minimizing the economic damage to this segment of the fishing industry. However, the major canning companies are no longer buying soup-sized oysters for oyster stew.

Unfortunately, we do not know what the long term effects of Kepone on oyster populations might be. Further investigation of Kepone effects and other toxic chemical substances is required.

Another fact demonstrated by the Kepone disaster was that the elaborate apparatus which had been established to prevent such occurrences did not work. Its failure was unfortunate because much social, economic, political and personal turmoil followed. We must develop scientific knowledge with adequate standards and new and more effective management procedures. We have no clear idea of the role that non-point source pollutants play in oyster culture.

Extensive sampling by VIMS and other State and Federal institutions and agencies has shown the presence of heavy metals such as zinc, mercury and cadmium in oysters and other marine animals in Chesapeake Bay. Sampling has also shown that chlorinated hydrocarbons such as DDT, DDD and similar pesticides occur in the same groups of animals (Bender, Huggett and Slone, 1972). Many similar references exist. A summary of this information is beyond the scope of this paper.

While there is a considerable body of information on the effects of these chemicals on oysters in the laboratory and about the existence of these same substances in tissues of oysters, there are still two large voids in our knowledge.

1. We do not understand what possible effects these metals and pesticides actually have on natural populations. For example, can the decline in set in the James River be attributed in any way or degree to the lethal effects of heavy metals or pesticides on developing larvae? This should be investigated by conducting bioassay studies using water from various sources.
2. What chemical species occur in Virginia's oyster producing waters and what is their origin? What industrial and/or WTP sites are releasing what chemical? What wastes are being introduced by agriculture and other non-point sources? In respect to these questions, the State Water Control Board has accumulated much information. The new Toxic Substance Reporting Act may help considerably. A systematic summary of this information should be compiled by VIMS in a preliminary effort to establish those molecules and complexes which may be or are entering into our oyster-growing

waters so the screening be orderly. Recently studies along many different lines were instituted by the Department of Ecology-Pollution of the VIMS Division of Environmental Sciences and Services and other departments on effects of heavy metals and oils on various groups of animals. These studies should go a long way in answering many questions. Much more work is needed and badly.

Summary

The areas classed as restricted for shellfish harvest for direct sale into the market have increased sharply in recent years, and as of 15 December 1975, 178,732 acres were classed condemned or restricted. Not all of this was productive,but much of it was. Many of the once productive tributaries in the York, James, Rappahannock and Potomac contain acreage classed as restricted and are essentially "out of production." While the loss of these areas is a serious matter, causing economic damage to the oyster industry, condemnation because of pollution has not been the principal cause of the major decline in oyster production which took place in Virginia from 1960 to 1975. Hampton Roads is the only area now condemned where oysters were grown in any quantity prior to 1960 and this location was producing only a small fraction of the total market landings just prior to the start of the major decline. However, the recent condemnation of many new areas and the ever-increasing use of our estuaries as outlets for sewage treatment plants indicate that bacterial pollution will be a major problem in the future. Additionally, certain chemical species formerly thought not to produce problems in estuaries are now being implicated in oyster deaths. For example, chlorine and chloramines from treated WTP effluents are believed to cause mortalities among populations of mollusc larvae in nature. It is definitely and clearly established that they kill oyster larvae and juveniles in extremely low concentrations, .005 ppm. In laboratory experiments other species are affected also. There is no reason to suspect them not to be as toxic in the natural environment.

The relaying of oysters from restricted areas is an expensive process and is seldom practiced today. Depuration in tanks under controlled conditions is practical in 2 days. None of the oysters are lost, but the process is costly for routine use. However, in certain situations where oysters are priced above average, it may be practical today. If pollution continues to increase or if oyster prices increase, depuration under controlled conditions may become a more widely used technique.

Research to delineate the roles and importance of biological contaminants (i.e., bacteria and viruses) is badly needed. Also necessary are studies of contaminants of all types from point and non-point sources. Depuration needs to be perfected and its possible uses clearly established. Much research and especially development is needed.

CHAPTER XI

PRODUCTION, HARVESTING AND PROCESSING

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Introduction

The Lack of Innovation

The public and private sectors of the oyster industry on the East Coast of the United States have practiced forms of oyster culture which have remained essentially the same for over 110 years. The public sector still depends largely on the uncertain bounty of "natural production" with some assistance from repletion programs. Most of the private sector, while slightly more advanced, still uses cultural techniques for growing, harvesting and processing which have remained unchanged since the 1880's.

In view of the almost complete absence of innovation in the Virginia oyster industry and in view of the recent catastrophic decline in landings since 1960, it has often been stated that the oyster industry might be revitalized if it adopted or developed "new" culture practices or if more efficient gear were developed to harvest or process oysters (Wheaton, 1972). It has been advocated by many others. We share this view strongly.

Wheaton (op. cit.) conducted an analysis of the oyster industry in Chesapeake Bay and commented on its inefficiency and the rising costs of operation. His solution to these problems was mechanization. His analysis of some of the problems follows:

1. Hand labor dominates the industry.
2. Oysters are handled many times between spat and market.
3. Rising labor costs are placing the industry in a cost-price squeeze.
4. Shortage of skilled shuckers is a major problem in the industry.
5. Young people are not entering the oyster shucking trade.
6. An oyster processor can afford to pay about \$30,000 for a shucking machine which can shuck 60 oysters a minute and be operated for \$5.00 per hour.

There are many other aspects to the problem than those cited by Wheaton. Many already have been mentioned.

The purpose of this chapter, however, is to review: 1) the wide range of cultural and technological practices not in general use in Virginia, but which have been studied and tested by State or federal agencies; 2) those which have been adopted by commercial companies only in certain locations and 3) those techniques which are needed but not as yet developed. All of these when added to those described earlier, cover a range of possibilities for improving Virginia's oyster industry.

Some of the needed reforms relate to improving repletion activities in the public sector. Recommendations have been made for improving production where setting conditions were moderate to heavy and by planting shell cultch at the proper season. Other suggested improvements relate to utilizing mechanical devices or other techniques to enhance setting.

Techniques of Oyster Culture

No attempt will be made in this Chapter to comprehensively review the many diverse and ingenious techniques used throughout the world for growing oysters. Instead, a few widely used techniques will be briefly discussed. Attention then will be focused on those which may be used to grow *Crassostrea virginica* in the United States.

The first question addressed is why cultural practices vary throughout the world. Major reasons are the extreme range over which oysters grow and the many species and genera involved. The family Ostreidae consists of a large number of edible and non-edible species whose range extends in coastal waters from about 64°N to 44°S (Galtsoff, 1964). Over this extensive range each commercial species may have different ecological requirements, be subject to varying incidence of pathogenic diseases and predators and to differences in consumer demand. Consequently, methods of harvest and culture, suitable for one area and species, may not be applicable in another location.

As an example of the large number of species involved, Galtsoff (1964) lists 11 species of oysters, either native or recently introduced, in the continental United States and Hawaii. Of this total two are harvested commercially in large quantities. Two others either have limited commercial value or there are or have been attempts to culture and market them.

1. Crassostrea virginica - This is the only species of oyster cultured commercially in volume on the East Coast of the United States. Its range extends from Canada to the Gulf of Mexico. It grows best in temperate waters and is tolerant of a wide range of salinity and turbidity.
2. Crassostrea gigas - This species, which probably originated in Japan, occurs in Portugal and nearby coastal waters. Imported to the United States from Japan, it is now the principal species grown commercially on the Pacific Coast. Some attempts have been made to grow this mollusc in New England, but commercial production, if any, is low.

3. *Ostrea edulis* - This is the native European oyster once widely distributed in England and northern Europe. It was introduced into Maine in the 1940's where it is now cultivated to a limited extent. The quantities sold commercially are extremely small.

4. *Ostrea lurida* - This species, known as the Olympia oyster, inhabits tidal waters from north Alaska to lower California. It is extensively cultivated in the Hood Canal in Washington, but *Crassostrea gigas* still accounts for most of the West Coast production.

Costs of labor and supplies needed to culture oysters vary worldwide and even in the United States. Hand labor, for example, is cheap in Asiatic countries and, therefore, certain cultural techniques using hand labor are profitable. However, the same techniques because of labor costs might well be unprofitable in the United States.

The technological level of a country or an area may determine or limit the degree of development of the industry.

Local laws or regulations made for conservation, economic or aesthetic purposes prohibit certain cultural practices. For example, the most cost-effective way to harvest oysters is with a mechanical device or a dredge. However, many localities permit only hand tongs. Local customs of industry and work habits of watermen often are resistant to change. There may be competition between the oyster industry and other industries or activities. For example, rafts for growing oysters may interfere with boat navigation or recreational activities.

The Artificial Propagation of Oysters

As an introduction to this subject there will be a brief review of the cultural techniques used in other countries. Its purpose is only to show that many ways of growing oysters considered by some to be "new" have, in reality, been in general use in other countries for many years. In no sense should this review be considered to be comprehensive since such a discussion is far beyond the scope of this paper.

The Off-Bottom Culture of Oysters in Other Countries

Off-bottom culture of oysters has been widely practiced throughout the world for several hundred years. Many effective ways for raising *C. gigas* were developed in Japan. These techniques in the original or modified form have been widely copied elsewhere to grow *C. gigas* or other species, but many utilize much hand labor.

Oyster culture in Japan began several hundred years ago and Yonge (1960) tells how bamboo branches were placed in the water as spat collectors. The Japanese began to experiment with off-bottom culture in the late 1920's developing three basic techniques (Engle, 1969). These are described in detail since the same or similar methods are used in other countries.

1. Floating Raft - Shells, strung on wires or ropes up to 14 m (46 feet) long, are suspended from floating rafts which may be as large as 6.5 to 16.0 m (21.3 to 52.5 feet). Oyster larvae attach to suspended shells and grow to maturity.
2. Long Line - Glass or plastic floats connected by ropes are arranged in rows resembling the skeleton of a large raft. The floats are anchored in place and the long lines between the floats support a series of vertical ropes which hold collecting shells on which oysters are grown (in the twist of the rope).

3. The Rack Method - The rack method is simply a shallow water adaptation of the hanging culture method. The racks are supported from rows of stakes driven into the bottom.

Shaw (1967) summarized off-bottom culture in Japan and one of his most pertinent summaries follows:

> Now over 90 percent of the oysters harvested in Japan are grown off-bottom (Glude, 1964). Rows of rafts carrying either strings of shells to catch seed or strings of oysters being grown to market size are found in many of the inlets and bays of Japan.

Techniques similar to those developed in Japan have been modified and are in use in Korea, Australia, New Zealand, France, Canada and many other locations (Engle, 1969; Quayle, 1969; Watkinson and Smith, 1972; Curtin, 1973 and Korringa, 1976.

Several additional cultural methods, widely copied, were developed in France. Beginning about 1853, bundles of sticks suspended from rafts were used to obtain an initial strike. Later, depleted beds were shelled and seed obtained from the bundles of sticks planted on the surface. Even later roofing tiles were used to obtain an initial spat strike. To facilitate removal of spat, tiles were coated with a friable mixture of lime and sand. When the small oysters reached about 1/2 inch (12 mm) they were flaked off by hand.

After small spat were removed from the tile they were especially subject to predators so in the early days they were cultured in wire-covered trays to keep predators away. Later this practice was discontinued and a net or wooden fence was used to keep out predators. Today screens made of plastic are used.

Pond culture of oysters was a feature of French oyster culture for many years. The following, which describes the process, is taken from Yonge (1960):

> A distinctive and very old feature of oyster cultivation around Marennes is the presence of shallow ponds or "claires" dug out of the clay soil and connected by shallow canals with the sea. Drained in the early spring, the ponds are then filled with seawater at high tide. Ideal conditions of high temperature and salinity and abundant food develop in the stagnant water of these fattening ponds. In them, oysters may double their weight in six months and acquire a creamy consistency and often the diatom Navicula, which gives them a very high market value. Imported flat oysters (Gryphea angulata) are normally so treated, although Portuguese oysters may also be put into claires for greening.
>
> The final stage for all oysters, either from the parcs or from the claires, is compulsory treatment in a brick-lined storage basin or "degorgeior" filled with clean seawater where the oysters expel their pseudofeces, after which the shell is washed and the oyster graded and packed for dispatch, usually by rail. From over 700 oyster establishments in the Charente Maritime come some 30,000 tons of oysters, over half the total produced in France.

Many of the French oyster grounds are exposed at low tide and at one time they were intensively worked by hand labor to separate small oysters and to remove predators such as crabs and starfish. Frequently, oyster-growing bottoms were studded with short stakes to protect the more valuable oysters from attack by rays.

In recent years techniques have been evolved for collecting spat on bundles of lime-coated plastic rods. When a set has been collected the bundles are separated and the spat knocked off by a specially designed machine. The spat are planted on natural bottom, and later harvested by a dredge.

Off-Bottom Culture in the United States

Off-bottom culture has been conducted in the United States in a variety of ways. Recent studies have utilized one or more of the following techniques:

1. Oysters are grown in trays held off the bottom by short legs made of steel or wood.
2. Styrofoam blocks, wooden logs or steel drums are used as floats. Strings of shells are hung from these (strung on plastic rope or wire) on which spat set. The resulting set of oysters is allowed to grow to maturity, on the shell, or the set is sold as seed.

3. Oysters are grown in trays suspended from fixed structures driven into the bottom.

4. Trays are suspended from floats.

Shaw (1969) and Hidu (1971) summarized State and Federal studies relating to off-bottom culture in the United States. Material in the following paragraphs, unless specially noted, is taken from these sources.

1. Maine - Since 1963 the Maine Department of Sea and Shore Fisheries has studied seasonal oyster catches (*C. virginica*) on strings of scallop shells suspended from rafts. At the end of the 1964 season, spat counts ranged from 3 to 10 spat per shell--a commercially acceptable number (Shaw, 1969).

   More recently, in conjunction with hatchery studies, *O. edulis* spat set in the laboratory have been cultured in screened cages suspended from floats or held in floating lobster pounds (Hidu and Richmond, 1974).

2. New Hampshire - Studies have been conducted on seed oysters collected on strings of shells suspended from rafts. Also, hatchery-raised seed were grown in suspended trays and this showed excellent growth (Shaw, 1969).

3. Massachusetts - As reported by Shaw (1962), early studies in this state extended from about 1956 to 1960 were conducted in the vicinity of Chatham. They demonstrated oysters can reach market size in 2-1/2 years when suspended from a raft. It was estimated that raft culture was commercially feasible.

Mattiessen and Toner (1966) investigated off-bottom culture in Massachusetts using rafts 9 x 22 feet to suspend strings of shells. Results showed that oysters grown on these shells reached market size in slightly over two years after the date of setting, with all reaching market size in three years. In contrast, in that same area, four to six years were required for bottom oysters to reach market size.

In 1966 the cost of a 9 x 22 foot raft including styrofoam blocks was estimated at $80 and this raft was capable of suspending 100 eight-feet strings of shells with each costing 40¢. The total cost of the raft including anchors, ropes and shellstrings was estimated at $120. This would be about $199 adjusted to the 1975 dollar (Table 59). It was also estimated that each raft in two or three years would produce about 50 bushels of oysters. At $20 per bushel (Massachusetts price) this type of culture may be profitable. However, in Virginia at $8 per bushel (1975 Virginia price) this would be a gross return of about $400. Subtracting the production costs of $199, we obtain a return of $201 for three years. This does not include costs of maintaining the raft, cleaning the shells or marketing expenses. In view of these added but undefined costs, this gross does not seem to be an adequate return on an annual basis.

Mattiessen and Toner (op. cit.) concluded that raft culture offered a promising technique for oyster culture in that area. They cited, however, disadvantages such as the high cost of capital investment, failure of spatfall, and loss of gear and oysters due to ice and storms. Additional disadvantages not cited are laws and regulations which may prohibit the anchoring of rafts in navigable waters, fouling of the shellstrings and natural mortality.

4. New York - The New York State Conservation Department tested the feasibility of catching seed oysters off-bottom for several years.

Shellstrings were suspended from racks and preliminary results yielded counts ranging from 2.6 to 25.6 spat per shell. Later studies investigated setting on shells suspended from rafts in Oyster Point, East Hampton and Long Island (Shaw, 1969).

5. Maryland - Extensive studies have been carried out at Oxford, Maryland by the NMFS (Shaw, 1967, 1969 and 1971). Strings were suspended from floats or fixed structures. Sets as high as 25 per shell on suspended shellstrings were obtained in 1965, 1967 and 1968. Other studies investigated growth of oysters cultured on suspended strings of shells in the Tred Avon River. These studies showed over 90% of the oysters were marketable 2 years after setting. Yields as high as 2.9 tons of meats per acre per year were postulated using rack culture.

The Maryland Department of Chesapeake Bay Affairs at Solomons Island, Maryland tested off-bottom seed production. Successful sets were collected on oyster shells enclosed in chicken wire bags suspended from rafts in the St. Mary's River in 1966 (Shaw, 1969).

6. _Virginia_ - Studies were started at the Virginia Institute of Marine Science in 1954 using strings of oyster shell strung on wire as spat collectors (Haven and Andrews, unpublished). The study showed that if the strings were placed in the water at the time mature larvae were present (July and August), the shells would collect excellent strikes of small oysters. However, if the strings were placed in the water a month or so before this period (too early), they would become too fouled to obtain a set. In the Virginia study, the strings, with the attached spat, were allowed to remain in the water for two years. It was found that, unless the strings with the attached oysters were removed and cleansed three or four times a year, fouling by barnacles, bryzoans and tunicates became so dense that many spat were killed. Also after about one year, yellow boring sponge, _Clinona_ sp., caused the collector shells to soften and many growing oysters fell off. From this series of experiments it was concluded that: 1) the shellstring technique could be used to collect a set, but it was more expensive than conventional techniques;

2) fouling was more a problem than for shell placed on the bottom and 3) the technique could not be used to grow oysters to maturity unless boring sponge was controlled and an effective, economic way could be found to control or deal with fouling.

7. North Carolina - The North Carolina Division of Conservation and Sport Fisheries experimented with suspended cultch and concluded that this type of culture showed little promise unless airing (exposure to air presumably for the purpose of controlling fouling) could be economically adopted.

8. Georgia - The University of Georgia Marine Institute has experimented with off-bottom culture near Sapelo Island since 1966. In their studies, the shells became heavily fouled with barnacles, bryzoans and tunicates (as did those at Gloucester Point, Virginia). Oyster setting was limited to a one foot band about five feet below the surface. The suspended oysters suffered serious mortality from predation by fish and crabs, and growth was retarded. Moreover, the strings became heavily fouled by tunicates and barnacles.

9. <u>Florida</u> - The U.S. Bureau of Commercial Fisheries in 1967 studied raft culture of spat in Tampa Bay. A set was obtained but a heavy set of barnacles hindered further studies on growth.

10. <u>Alabama</u> - Rafts constructed of lumber and styrofoam and racks of creosoted posts and lumber were used to support oysters off-bottom. Oysters falling off the strings was a serious problem. Growth of oysters was rapid. It was concluded that in Alabama, this technique was not economically feasible (May, 1969).

11. <u>California and Washington</u> - Studies carried out in these states will be discussed in the section dealing with commercial aspects of off-bottom culture below.

<u>Commercial Production of Oysters Using Off-Bottom Culture</u>

Information on the success or failure of large-scale commercial off-bottom operations is difficult if not impossible to obtain. Understandably, many companies regard their techniques, costs and data as "trade secrets." In some instances operators have failed to keep records and do not know themselves the results of planting, however, limited information is available from a few published sources and from conversations with hatchery operators and others.

The following summary, therefore, is not complete nor is it intended to be. Its purpose is to illustrate that large-scale culture has been attempted in many areas.

1. New York - The largest off-bottom production of seed oysters on the East Coast of North America occurred at Fishers Island, New York. In 1968, 55,000 strings of scallop shells were suspended from 130 rafts in a 20 acre salt pond (Shaw, 1969). Matthiessen (1965) estimated that 25 million seed oysters were harvested from this pond annually. Much of this seed was sold to Long Island oyster companies (Shaw, 1969). Data on production of market oysters from these plantings are not available.

   At least five Long Island oyster companies who have operated oyster hatcheries have attempted at some time or other to grow hatchery-reared seed in floating trays to a size (about 3/4 inch) where it will survive on natural bottom. Information is lacking on the results of their attempts but in general the process was biologically feasible. No data are available on costs, etc.

2. Rhode Island - In Bristol, Rhode Island, the F.B. Blount Oyster Company constructed a raft 80 ft

(25 m) by 32 ft (10 m) using styrofoam floats. In April 1968 some 3,800 strings containing 28,000 scallop shells bearing oyster spat were suspended from the raft. It was predicted that 800 bushels of oysters could be harvested in 1970 (Shaw, 1969). The actual results of this project are not known.

3. Washington - Seed oysters were caught in 1967 in Dabob Bay, Washington. Rock structures and off-bottom floats were used in 1967 to suspend about 200,000 strings of shell. The set that year of *C. gigas* was of good commercial value. Growing oysters off-bottom to market size was studied at Henderson Bay and Grays Harbor but the results of the studies were not discussed (Shaw, 1969).

4. California - In California in Elkhorn Slough, Monterey County, seed oysters (*C. gigas*) were attached to ropes hung from floats. In one year a reported 9,000 gallons of oyster meats were harvested. No data were given for number of bushels harvested. However, the company involved in this operation had difficulty in marketing the oysters and the operation was discontinued.

In 1969 the major center for commercial off-bottom culture was Humboldt Bay where strings of oysters were suspended from racks in approximately 2 acres of the Bay. Recent information (1977) indicates that this company is no longer involved in off-bottom culture.

Smaller commercial-sized operations existed in Morro Bay, Drakes Estero, Tamales Bay and in Aqua Hedionda Lagoon. It is not known if these operations survived at these locations.

5. Western Canada - In 1967 the biggest operation on the West Coast was located in Pendrell Sound, Vancouver Island, British Columbia. During that year 200,000 strings (6 feet long with 100 shells per string) were suspended from log rafts. The seed was sold to commercial planters. Operations continued until at least 1969 (Shaw, 1969). The magnitude of operation there today is not known.

Shaw (1967, 1969 and 1971) summarized some advantages and disadvantages of shellstring culture. The advantages were:

1. Spatfall is higher on rafted substrates.
2. Growth is almost twice as fast as on the bottom.

3. Areas unsuitable for growing because mud or other unsatisfactory bottom characteristics are usable.

4. Oysters are segregated from most predators.

5. More oysters may be grown per unit area of bottom.

The disadvantages were:

1. Many of the waterways where oysters could be grown from rafts are presently being utilized for recreation and navigation and are not available for raft or shellstring culture. To solve this problem it would be essential for certain waters to be zoned and set aside exclusively for off-bottom culture. In many states this apparently would require legislative action.

2. Additional disadvantages not listed by Shaw are based on the results of the author's experience and that of other investigators on growing *C. virginica* in Chesapeake Bay. These are:

   a. Rafts and the construction of shellstrings are expensive and require much hand labor and there is always the danger of loss due to wind, storms or ice. None to date have actually demonstrated the method to be cost effective for commercial operations.

b. In Virginia and to the south, fouling by barnacles and tunicates are major problems. It strings become covered with fouling early in the season, then they may not obtain a set. Also, excessive fouling after setting may kill attached spat. Fouling may be controlled with Polystream[R] (Castagna, Haven and Whitcomb, 1969). However, use of this chemical has not been approved by regulatory agencies. Other methods for control of fouling are by salt dip or drying but all treatments increase operating costs.

Tray Culture

It is entirely possible to culture oysters in trays elevated by short legs a foot or so off the bottom or suspended from a fixed structure. Among the first to attempt this type of culture in Virginia was the Chesapeake Corporation which in 1936 began to grow oysters in trays supported off the bottom by short wooden stakes. This operation took place in Queen's Creek where it empties into the York River (Andrews, 1971a; Dill, 1968). Over 11,000 trays stretched over 3 miles (4.8 km) each holding about one half bushel of oysters were in use at one time, and large numbers of high-quality oysters were produced and

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[R]Registered trademark

sold commercially. This program was discontinued about 1942 and it is not known if the operation was economically practical. It did serve the company which sponsored it. Oysters were successfully grown in an area alleged by company critics to be polluted. The late Mr. Garland Evans, long a principal in this venture, indicated to one of us (Hargis, personal communication) that the high cost of labor to maintain the racks and trays and handle the oysters caused its abandonment as a commercial venture.

Studies by Haven (1962), using the same type of tray, showed oysters cultured by this method grew much faster than those grown on adjacent bottoms. Selected James River oysters about 2 inches (4 cm) long reached market size in about a year as compared to two years for similar oysters cultured on the bottom. Quantity of meats obtained from tray cultured oysters was also 10 to 30 percent higher than from oysters living directly on the bottom. While tray culture will actually produce a well-shaped, high quality oyster in a year less than required for bottom culture, there are certain faults which make tray culture economically impractical at this time. These are:

1. Metal mesh trays with plastic coatings similar in size to those used by the Chesapeake Corporation

hold only about one-half bushel of oysters. Today (1975) they cost about $60 each. If the value of oysters produced after two years is a maximum of $10 (Virginia price) it would require about 12 years of use to amortize the cost of the tray. Less expensive trays could be constructed of wood or plastic coated wire mesh, but the same factors would likely operate. Over a long period of time, tray costs would exceed the value of the oysters cultured in them.

2. Oysters in our elevated trays fouled more quickly than bottom cultured oysters. This necessitated expensive maintenance to remove fouling and prevent food competition and smothering.

3. Tray culture removes oysters from bottom predators, thus eliminating this source of mortality. However, oysters cultured in trays in high-salinity areas are subject to excessive mortality from the fungus, *D. marinum*, due to the crowding (Andrews, 1967).

Pond Culture

Pond culture has been practiced for many years in France to condition oysters, but only recently has it been investigated in the United States. In a review of pond culture, Shaw (1965) states:

> ...One of the first was on the shore of Chincoteague Bay, Md. (Ryder, 1933). A 50-square yard pond was excavated in a salt marsh and connected to a bay by a trench 10 ft long, 2 ft wide and 3½ ft deep... The experiment proves, in Ryder's estimation, that ponds or enclosed areas of water may be used readily for culturing oysters along the Eastern Coast of the United States.

Robert Lunz (1956) was among the first in modern times on the Eastern Coast to investigate pond culture. Initial results were successful but heavy mortalities, believed to be caused by D. marinum, terminated his studies. Carriker (1959) conducted studies on pond culture of Gardiner's Island, Long Island Sound, New York, and concluded this method had commercial potential.

Subsequent studies on "pond" culture were carried out in Massachusetts (Shaw, 1962; Shaw and McCann, 1963; and Shaw, 1963). These studies utilized rafts in large semi-enclosed natural salt ponds. They showed seed oysters utilizing raft and string culture could be grown in these locations.

Studies carried out in Oxford, Maryland in quarter-acre artificial ponds, each supplied with 80 gallons per minute of water from the Tred Avon River, were not successful.

These ponds, because of their low flows, were unsatisfactory for growing market oysters; they were useful in propagating seed.

The term "pond" has been used loosely in literature on pond culture. Some impoundments or containments referred to as ponds were constructed from concrete and supplied with piped-in water. Others were dug or constructed from dirt, either with pumped water or tidally-controlled gates, while others were large, natural, salt ponds or embayments with a natural connection or manmade entrance to the main estuary. The critical aspect of pond culture is the ratio between numbers of oysters and the volumes of water entering into and flowing through the system. Every body of water, whether manmade or not, has a carrying capacity. This aspect has not been considered sufficiently in most pond culture studies. For example, oysters filter up to 11 liters of water per-hour-per-oyster at about 20°C (Galtsoff et al, 1964) to obtain their food. Thus, to make pond culture economically feasible for growing market-sized oysters, extremely large volumes of water are required to meet the nutritional needs of the oysters. When volumes are restricted, growth or development is restricted. Studies at the Virginia Institute of Marine Science show about 7.5 liters of water per-oyster-per-hour are required to facilitate growth and meat development for 25 oysters comparable to that obtained in the estuary (Haven, 1965). To hold 30,000 oysters (100 bushels) flows of 225,000 liters (59,440 gallons) per hour would be required. Costs of this operation using a 50 horsepower pump would be about $300 per month (Dupuy, personal communication). Obviously the costs of such a pump and its maintenance would far outweigh any profits.

When oysters are first spawned their size is small, as is the volume of food required. Consequently, several million larvae can be successfully cultured in a cubic yard of water if the water is changed daily and supplemental algal food is provided. This fact has been demonstrated repeatedly, as evidenced by the success of oyster hatcheries in producing seed, especially small seed. Difficulties begin when the oysters reach about 1/2 inch (12 mm) in length, since their food requirements begin to exceed the capacity of most algal culture laboratories or most totally "enclosed" ponds. When this occurs water must be pumped into the "pond" or container from an outside source. The expense of pumping may quickly become prohibitive for the ordinary commercial production of oysters under the market conditions existing in most sections of the United States.

Growing oysters in enclosed ponds has a second disadvantage. When oysters feed they deposit quantities of feces and pseudofeces which quickly accumulate and form deposits on the bottom of the holding ponds. These deposits may actually smother oysters in the manner outlined by Lund (1957) or accumulate on and contaminate the bottom and adjacent waters (Ito and Imai, 1955). Haven and Morales-Alamo (1966) have shown an oyster will deposit, on the average, 1.6 grams of solids (dry weight) weekly in feces and pseudofeces. Translating these data to the 100 bushels mentioned previously, the oysters will deposit 2,496 kg (5,503 lbs or over two tons) annually in the small space needed to hold the 100 bushels. These deposits may be removed, but their removal adds to production costs.

Regardless of the current economic disadvantage of raising seed in such restricted waters, ponds might be of value in growing seed oysters for experimental purposes. Pond culture (getting the spat to seed-size) seems an essential step between the hatchery and the field in developing oysters with MSX-resistance, or other desirable genetic qualities. Studies should be carried out on the most efficient way of maintaining large numbers of small oysters in ponds or similar enclosed waters, isolated from "wild" populations, until they reach the size of about 3/4 to 1 inch (18 to 24 mm) and the time when they may be placed in the estuary.

Shellbags

Shellbags are wire bags containing about a half bushel of shells, which may be placed in areas of high set in order to obtain seed (Prytherch, 1930).

Shellbag culture of seed oysters is a practical cultural technique which may be used to obtain seed oysters. In 1970, 100,000 bags of seed were produced in the Piankatank River, Virginia by commercial growers. This type of mariculture should be encouraged, especially as an export item to the Potomac or Maryland waters.

The technique of constructing shellbags and setting them out in the estuary has been known to growers and scientists for many years. Twenty years ago a few growers were experimenting with them. A number of laboratories have data on intensity of set on shellbags in various regions. Only in the last 8 years has the demand for this type of seed increased to such an extent this method of culture has become practical for the commercial grower. Mr. Earl Cockrell, a commercial oyster grower in Virginia, has supplied the following information: shellbags are constructed of 1-1/2 inch hexagonal mesh chicken wire by twisting the edges of the wire together with the aid of a special tool. In 1971, it cost 30 cents to construct and fill a bag and an additional 10 cents to plant it (this would be a total of about 53 cents in 1975).

In Virginia, bags are placed in the water just prior to the period of maximum set. They are removed in September or October and planted on a growing area (Haven and Garten, 1972). Sale price depends in significant measure upon the "set" which occurs on the shells. A half-bushel bag containing 1,000 small spat sold for $1.00 in 1972 while bags with 400-500 spat brought 75 cents. Its approximate sale price in 1975 would be 98 cents.

The Virginia Institute of Marine Science has experimented with plastic mesh as a substitute for chicken wire. Plastic is easier than wire to work with and lends itself to mechanization of filling the bags. Moreover, the bags may be reused. There are disadvantages to using plastic since it does not disintegrate. The oysters may grow around the plastic filaments and several years later, when they are harvested, the bags will remain and catch in the tongs or dredge and interfere with harvest. On the other hand, chicken wire disintegrates and allows the oysters to spread over the bottom (Haven and Garten, op. cit.). Other substances such as coarse, mesh burlap bags could probably be used but these have not been tested.

Another technique for collecting spat is a newly developed "French system," Spat are set on lime-coated plastic rods fixed in a box-like structure. The "boxes" are set out in the river for early growth.

Oyster Hatcheries

Introduction

In England the artificial culture of oysters in hatcheries began in the mid-thirties (Orten, 1937) and was later carried along by Cole and Knight-Jones (1949). Walne (1956) further perfected the art of raising oysters in hatcheries and oysters hatcheries now exist in several other European countries.

Studies on raising oyster larvae in the laboratory were begun in the United States by Wells (1920, 1926 and 1927) and Prytherch (1924). They were successful in raising *C. virginica* larvae to setting. Their studies were discontinued and it was not until 20 years later they were resumed by the U. S. Fish and Wildlife Service at Milford, Connecticut (Loosanoff, 1945; 1971). Further studies at Milford and elsewhere resulted in the development of techniques for reliably producing spat at any season under laboratory conditions (Loosanoff and Davis, 1952 and 1963; Davis and Guillard, 1958; Hidu et al, 1969; Dupuy and Rivkin, 1972; Dupuy, 1973 and 1975; Dupuy, Windsor and Sutton, 1977; and others).

A review of hatcheries and their operation has been published under the title, Artificial Propagation of Commercially Valuable Shellfish (Price and Maurer, 1971). This book contains reviews by several prominent biologists and much of the material in the following pages is taken from this source.

There are now three basic ways of successfully growing spat from the fertilized egg to time of attachment (Loosanoff in Price and Maurer, op. cit.):

1. The Wells-Glancy method spawns oysters by conventional techniques and the resulting larvae are fed as follows: water from the natural environment is centrifuged or filtered so as to remove particles larger than about 10μ. This water is then held in large tanks in a heated greenhouse so blooms of the natural algal population may occur. This culture is fed to the developing larvae.
2. The Loosanoff-Davis method was perfected at Milford, Connecticut by the National Marine Fisheries Service. It attempts a more rigid control of all phases of larval rearing than the Wells-Glancy method. The oysters are spawned in the usual manner but the larvae are fed algal

"foods" composed of species which have been selected as producing fast growth and good survival. The algae are cultured in the laboratory in specially designed systems. This technique is more reliable than the Wells-Glancy method.

3. The Hidu method spawns oysters in the usual manner, but the resulting larvae are fed water filtered through a 32µ filter bag to remove the larger plankton organisms. The filtered water is fed to the larvae daily.

Ukeles (in Price and Maurer, 1971) and Ukeles, 1976 discussed the species of algae used in feeding oyster larvae and techniques for their culture. Larvae will survive and grow if fed many different species of algae with certain types being clearly superior as food. Hidu and Ukeles (1964) tried dried algae as an artificial food for oyster larvae and found it suitable as food for clam larvea but not for oyster larvae.

Early hatcheries set larvae on oyster shells or on a similar cultch material such as scallop shells. Many hatchery operators, however, reported problems with this type of culture. Attachments of larvae to the cultch were not uniform and shells proved bulky, thus difficult to handle and expensive. Furthermore, spat set on shell are fixed in place and if too thick, must be forcibly culled to allow growing room. Later they must be separated for sale or processing or shucked in clumps. Additionally, the shapes of the shells of the developing oysters are not always regular.

Several techniques were developed in the late 1960's for producing cultch-free spat. The French were the first to use this technique when spat were set on lime-covered tiles and then scraped off to provide small oysters separated from each other. It was noted in this country, as early as 1958, oysters which set on sheets of smooth plastic dropped off at the size of 1/8 inch or more (Loosanoff, 1958). It is sufficient to note several different techniques were developed by commercial companies as well as federal and state laboratories. [Recent publications on the subject are by Andrews (1971a) and Dupuy, Windsor and Sutton, 1977.] Basically, the process still consists of obtaining a set of oysters on smooth plastic. Spat are removed after growing to varying size by flexing, scraping or by means of a water jet.

There have been many improvements in recent years in rearing oysters in hatcheries. Hidu et al (1969) and Hidu (1971) perfected techniques of using filtered water and cultured algae at Solomons Island, Maryland. Dupuy, Windsor and Sutton (1977) now colleagues at VIMS, and others have developed new techniques for conditioning and causing oysters to spawn year-round and also for holding newly set oysters in flowing water in the laboratory.

<u>Where Hatcheries Are Located</u>

MacKenzie (1970) reported five hatcheries in the Long Island region. Hidu (1971) reported nine state, federal or private laboratories in the Chesapeake Bay and Delaware Bay area engaged in oyster culture activities as follows:

1. Rutgers, the State University, New Jersey Oyster Research Laboratory on Delaware Bay.
2. Snow Hill Field Station of the Natural Resources Institute, University of Maryland on Chincoteague Bay. (This facility is now closed.)
3. University of Delaware Marine Laboratory at Lewes, Delaware.
4. Wachapreague Field Station of the Virginia Institute of Marine Science, at Wachapreague, Virginia.
5. Virginia Institute of Marine Science at Gloucester Point, Virginia.
6. Chesapeake Biological Laboratory of the University of Maryland at Solomons Island, Maryland. (This facility is now at Horn Point, Maryland.)

7. Frank Wilde - private hatchery at Shadyside, Maryland.

8. The Windmill Point Oyster Company (EDA affiliated) at Urbanna, Virginia. (This company closed in 1974.)

9. U.S. Bureau of Commercial Fisheries Laboratory at Oxford, Maryland. (The hatchery portion of this operation has been discontinued.)

Others were located on the Gulf and Pacific Coast.

Published information related to numbers of commercial hatcheries and their operations since 1971 are lacking. However, the information which follows on activities on the East Coast of the United States up to 1975, was obtained by interview (Castagna, 1976 - personal communications).

1. Massachusetts
    a. Cultured Clam Corporation

        This company operates a hatchery for hard clams.

2. New York
    a. Shelter Island Oyster Company

        This company operates an oyster hatchery at Greenport, Long Island. Unialgal cultures are fed developing larvae which set on plastic sheets. The spat are removed from the sheets and grown to about 1 inch (2.54 cm) in floating trays; after this, they are planted on a shelled bottom. This company has published no information on the magnitude or details of its operation.

b. Long Island Oyster Farms

This company is located at Northport, Long Island. It operates an oyster hatchery using the unialgal system. A set is obtained on chips of oyster shells; later the small set is held in trays and then planted on the shelled bottom. The company is said to be successful in growing oysters to market production.

c. Frank M. Flowers Company

This is a Long Island company which cultures oysters using the Glancy Method, and also the unialgal system. Oysters are set on chips of shell, and the small spat held to a size of about 1-1/2 inches (3.8 cm) in floating trays. Later, the oysters are grown to maturity on shelled bottoms.

The company is said to be successful in raising oysters to market size in commercial quantities. Again, no data are available on costs, etc.

d. Blue Point Oyster Company

This company is located at Sayville, Long Island. It maintains a hatchery largely for the production of hard clams but occasionally produces oysters.

e. Radel Hatchery

This commercial facility is located at Sayville, New York. It is a low-volume hatchery which occasionally produces oysters.

3. New Jersey

a. The state of New Jersey is preparing to establish an oyster hatchery for the purpose of growing seed oysters.

b. Mariculture Industries

This small commercial hatchery for hard clams is in Oceanville, New Jersey. It utilizes a modified Glancy method for culture.

c. Earl Huskie

This is a small hard clam hatchery also located in Oceanville, New Jersey. The culture methods used are similar to those employed in 2., above.

d. Cape Horn Company

Similar to 2. and 3., above, in New Jersey.

4. Maryland

a. Frank Wilde

This is a small oyster hatchery at Shadeyside, Maryland. The hatchery utilizes a modified Glancy cultural technique. Some seed is sold.

b. The State of Maryland

Maryland has an operating hatchery at Horn Point. This facility produces cultchless spat as well as spat on oyster shell. Oysters have been planted on an experimental basis on public oyster bars. No data are available on production or costs.

c. Chesapeake Sea Farms Inc.

This was a large hatchery established at Ridge, Maryland for the culture of cultchless oyster spat. It utilized unialgae culture to feed oyster larvae and the spat were set on plastic sheets. The oysters were grown to about 1-1/2 inches (3.8 cm) in trays held in troughs of flowing seawater. This company recently went out of business.

5. Virginia

a. Greer Derrickson

This small company in Chincoteague operated a hatchery for hard clams and oysters. It utilized trays to raise the cultchless spat to market size. The resulting product was sold at a premium price as barrel stock. This company no longer produces seed.

b. Johnny Warren

This is a small hatchery on the Eastern Shore specializing in the culture of hard clams using the Glancy Method. The output of this enterprise is unknown

6. North Carolina

a. A commercial hatchery is located at Beaufort and is designed to produce hard clams and oysters. It operates as Marine Resources Enterprises.

Volumes of Seed Produced by Hatcheries

It is evident from material discussed in the preceding pages there is no biological reason today why hatcheries cannot produce almost unlimited numbers of small seed oysters. Many private, state and federal agencies have done so. Published estimates of the output and profitability of existing hatcheries are, however, difficult to obtain. The few which are available follow:

1. Dupuy (personal communication) states that one of the large hatcheries in the Long Island area could produce, on a sustained basis, one million spat daily.
2. A large California oyster hatchery advertised that it would sell cultchless spat and quoted the price for lots of ten million or over.
3. The Windmill Point Oyster Company at Urbanna, Virginia (now out of business) supplied the Potomac River Fisheries Commission with two million seed 3/4 inch (18 cm) long in 1972; in 1973 it sold the Virginia Marine Resources Commission 12 million spat with an average size of 3/4 inch (18 cm).
4. The Wilkerson Hatchery at Colonial Beach, Virginia began in 1973 did not produce commercial quantities of seed. It was located where salinities were too low. The company went out of business in 1975.
5. Prior to its closure, Chesapeake Sea Farms at Ridge, Maryland, produced five million 3/4 inch (18 cm) spat each month (Dupuy, personal communication).

Growth of Hatchery Seed on Natural Bottoms

While spat can be set on plastic sheets or shell and raised by the millions in hatcheries, there is still the problem of raising the progeny to maturity in sufficient numbers and at a cost to be profitable under prevailing market conditions. A most critical phase is during the early period of growth from about 1/2 inch (12 mm) up to about 3/4 inch (18 mm). Experience has shown cultchless spat less than 1/2 inch (12 mm) suffers extensive mortalities when planted on natural bottoms. The cause or causes of this mortality has not been fully determined, but it is related to natural predation, silting, or transport from the growing area by currents.

To avoid mortalities it is necessary to hold the developing spat for a period in flumes of flowing seawater or in trays suspended from rafts until they reach an average length of about 3/4 inch (18 mm) or larger. However, it is seldom economically practical to hold them to a size larger than 3/4 inch (18 mm). At about this size the bulk volume of the spat makes it impractical to handle them in trays. If cultured in flumes, space and the economics of pumping sufficient water for adequate feeding are limiting factors.

There exists only limited information on techniques for growing hatchery seed to maturity in an estuary. Hidu

(1969) states that month-old hatchery seed (about 5 mm long) raised at Solomons Island, Maryland, were placed in trays at five locations in the Patuxent River. Survival ranged from 73% to 98% through the first season. Aside from this, and a few other vague references, there is almost no published information relating to the success or failure on growth of hatchery-developed seed to maturity.

No quantitative information is available concerning the success or failure of the Long Island companies.

The operator of the Windmill Point Oyster Hatchery two miles above Urbanna in the Rappahannock River indicated that its operations showed complete mortality of some lots and "success" with others when the spat was planted in the estuary (Haven, personal communications).

The Windmill Point Oyster Hatchery (see above) also supplied the Potomac River Fisheries Commission in 1972 with over two million cultchless spat. The size range was 1/2 to 1 inch (12-25 mm) with the average size about 3/4 inch (18 mm). These small oysters were planted in the upper Potomac River off Morgantown, Maryland, in a cooperative program involving the Virginia Institute of Marine Science, the Chesapeake Biological Laboratory and the Potomac River Fisheries Commission. The average salinity in the area at the time of planting was about 7°/oo. Only 50% of the spat had died by November 1974. Survivors ranged from 3/4 to 2 inches (18 to 51 mm) with a mean of about 1-1/2 inches (38 mm). Most of the initial mortality was due to the death of spat less than 1/2 inch (12 mm); the cause of the mortality was not determined (Haven, unpublished).

A second large-scale planting took place in 1973 when the Windmill Point Oyster Company sold the Virginia Marine Resources Commission over 12 million cultchless spat ranging from 1/4 to 1-1/8 inches (5 to 27 mm) with a mean of about 3/4 inch (18 mm). These spat were planted in Lower Machodoc and Nomini creeks in the Potomac by the Commission in October and November 1973 where they were monitored by the Virginia Institute of Marine Science. In Nomini Creek where seven million spat were planted, 27% were alive two years later. In the Lower Machodoc Creek 20% of the spat remained two years later in September 1974.[1] Average size was about 2-1/4 inches (57 mm) in both areas. It was noted 3% of the cultchless spat had reattached to shell substrate. Again, mortality was highest in the group less than 1/2 inch (12 mm) long (Haven, unpublished).

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[1]At the end of the first year about 50% were alive in both areas. The higher death rate the second year was thought to be due to harvesting (and not due to predators or disease).

While the preceding mortalities may have been excessively high, they still resulted in densities of 5.2 and 2.8 oysters per square foot, respectively, in Lower Machodoc and Nomini creeks at the end of two years. Calculations based on the cost of seed (0.2¢ each) and a sale price of $7.00 per bushel (300 oysters) for mature oysters indicate, if all these oysters matured, their wholesale price would exceed the cost of the seed. This estimate did not include labor or harvest costs.

Cost of Constructing a Hatchery

There are only a few estimates on the costs of constructing and operating commercial-sized hatcheries since most private corporations have not made this information available.

Matthiessen and Toner (1966) working in Massachusetts projected costs of a small hatchery producing 40 million oyster spat annually. The following quote is from that source:

> ...The cost of constructing and equipping a hatchery, including cost of land, would approximate $60,000....Annual operating expenses, as outlined, would be estimated at a maximum of $19,200; if the hatchery was operated for 180 days during the year, annual salaries would approximate $17,500. Therefore, once the hatchery was constructed and equipped, the annual operating budget would approximate $36,700 per year.

Cost of Hatchery Seed

The Windmill Point Oyster Company at Urbanna in 1972 and 1973 sold 3/4 inch (18 mm) average, cultchless spat for $2.00 per thousand. The adjusted price for 1975 would be about $2.42 per thousand (Table 59).

In a 1974 report to the VMRC by Davis, Dupuy and Haven, the cost of hatchery-raised seed was estimated at $5.00 per thousand (the adjusted cost for 1975 would be $5.48).

Hidu and Richmond (1974) stated that Pacific Mariculture, Inc., Pigeon Point, California, offered cultchless spat in the following price ranges:

Quantity	Price
3,000	$ 60.00
10,000	100.00
50,000	200.00
100,000	330.00
1 million	2.75 per 1000
10 million	2.00 per 1000

The adjusted cost per 10 million for 1975 is calculated to be $2.20 per 1000 (Table 59).

International Shellfish Enterprises, Inc., Moss Landing, California, advertised three species of hatchery-raised seed for sale in Fishfarming Incorporated, Volume 3, No. 3, 1976. The species listed were: C. gigas, C. virginica and O. edulis. The cost of the latter species for 1/2 to 1 inch (10 to 25 mm) cultchless spat was $14 per 1000. This price is not a cost of production price, but one which includes a profit to the company. It appears to be much higher than other companies and is not regarded as typical.

Mattiessen and Toner (op. cit.) indicated in 1966 that costs of producing 15 million seed would be $2.40 per thousand. This cost was arrived at by dividing the annual yearly cost of operating their hatchery ($36,200) by 15 million to determine individual costs and calculating from there. Considering inflationary factors, we estimate cost of this seed in 1975 at $3.98 per thousand (Table 59).

Dupuy, Windsor and Sutton (1977) indicate that on the East Coast C. virginica seed, 3/4 inch (18 mm) long, could be sold commercially for 3/4¢ each or $7.50 per thousand.

Costs of Hatchery Seed vs. Natural Seed

Estimates of the present economics of hatchery-raised cultchless spat versus natural seed discussed below indicate the latter to cost much less. A bushel of James River seed in 1975 sold for a maximum of $2.25 a bushel. Studies by VIMS showed an average bushel contained about

800 oysters. Based on this value it was calculated that cost for 1,000 was $2.81. These seed oysters were large (1½ to 2½ inches, 38 to 64 mm) at planting and were expected to grow to marketable size in one or two growing seasons. Because they were large, to start with their resistance to mechanical damage and predation would be better than for smaller hatchery seed. In contrast, 1,000 cultchless spat from a hatchery would cost from $2.20 to $7.50. These would be about 3/4-inch (18 mm) long and would take two to three years in the field to mature depending on the areas where they were planted. Mortality could be as high as 50% by the end of the second year and perhaps more at maturity.

Other examples indicate naturally produced seed to be less costly than that produced in hatcheries. Information obtained from a Virginia grower shows oyster shells planted in shellbags in favorable localities, such as the Great Wicomico River, may obtain sets of 3,000 spat-per-bushel. Two bags totaling 1 bushel in volume, sold in 1969 (wholesale) for $2.00 (Haven and Garten, 1972). Calculations show this to be 67 cents per 1000 spat which is less than cost estimates for hatchery-produced seed.

There are still advantages to hatchery-reared cultchless seed, however, which may make them profitable when industry is ready for them. A major advantage is that it is available on demand. Other advantages are: singleness, separation from cultch, uniform shape and size. Moreover, they may yield more and be easier to shuck. All are qualities which will be important when machine-handling becomes possible and/or economically useful. Hatchery seed has other desirable features such as rapid growth, thick shells, deep cup and disease resistance. These features will be especially useful, even necessary, to some growers or to public management agencies.

Possible Areas Where Cultchless Spat Might Be Grown

There are many areas in Virginia similar to those in the Potomac where cultchless spat might be planted and in which mortalities would probably be 50% or less.

1. York River - Bells Rock to Almondsville.
2. Rappahannock River - Bowler Rock to Jones Point.
3. James River - Deepwater Shoals to Point of Shoals.

The Future of Hatcheries - A Summary

Hatcheries can produce seed in almost unlimited quantities at costs ranging from $2.20 to $7.50 per 1,000 and this "seed" can be grown for a year, and perhaps two, with an estimated 50% mortality in low-salinity regions. These costs average higher than that of natural seed obtainable today in the James. We believe hatchery seed is fast approaching the point where it can compete with natural seed in low-salinity areas for the following reasons:

1. The James is the source of 77% of the seed planted by private growers, with most of the remainder coming from the Great Wicomico and Piankatank rivers. Without these sources the Virginia oyster industry (especially that of the James River) as we know it would cease to operate.

2. There is now good evidence that seed oysters from natural rocks are becoming less available, and in the foreseeable future the supply may not be sufficient to meet the demand. The reason for this is that since 1960 there has been a catastrophic decline in setting of oyster larvae in the lower James River seed area which has resulted in a decline in numbers or density of seed over much of the lower estuary. The same thing is true in other active seed areas. In 1972, 1973, 1974, 1975 and 1976 the set of oysters in the Great Wicomico has been nearly zero or far below normal. Clearly, the Virginia oyster grower faces a problem as do public managers who plan to plant seed. If the trend of decreasing setting continues, we must plan for alternate seed sources if we are to

survive. Hatcheries appear the only feasible solution should these problems continue.

3. Despite the higher costs of hatchery production over natural seed, hatchery seed might well be used profitably today by a private company with integrated operations. That is, a company which raises its seed oyster in its own hatchery, grows them to maturity, processes the meats and markets them. In such a company, the added costs of the seed might be absorbed in profits derived from other stages. In this case, the advantage of using hatchery seed over the "natural seed" would be: a) availability on demand; b) disease resistance; c) superior growth rates to meet special needs of the growers and his planting grounds and d) thicker shells.

4. Developing full production on the 243,271 acres of Baylor Grounds is another problem. Some of this acreage can be used to grow seed if conditions are proper. However, a large percentage is designated as market oyster producing area. Because of low recruitment (low set) in recent years the productivity of Baylor Grounds in certain areas has been very low (Chapter III). If the trend

is continued, then we may expect even lower levels of production. It was shown in Chapter VII that the trend might be reversed by a subsidized seed planting program. However, if "naturally produced" seed for this purpose becomes unavailable, then hatcheries offer the only possible solution.

5. There remains one major problem for which hatcheries offer a possible solution. Many of the leased areas in high salinity regions are out of production due to MSX. Here hatcheries offer potential for major benefit and soon. As explained previously, Andrews (1967) and others have developed MSX-resistant seed, and if techniques of protecting hatchery seed against predators in these high salinity regions is perfected, then these areas might once again become productive. It is recommended that trial plantings of MSX-resistant seed begin immediately using spat on shell where mortality by crabs must be minimized.

A major research effort is recommended for decreasing costs of producing hatchery seed, development of hatchery seed with special characteristics, reducing losses experienced overboard, growth of seed with acquired resistance and growth of MSX-resistant seed in Type I areas. A reliable and up-to-date experimental hatchery is necessary for this work. It will probably have to be supplied by the State (VIMS).

The type of hatchery described above would require the attention of one full-time person available for duty 12 months of the year and three men part-time for the same periods. Anticipated yields would be 15 million newly-set spat during a six-month period. In these calculations, it was assumed that about 20% of them would attain maturity with a final yield of 10,000 bushels.

A hatchery feasibility study submitted to the Virginia Marine Resources Commission by the Virginia Institute of Marine Science by Dupuy, Haven and Davis (1973) estimated costs of a hatchery capable of producing 60,000,000 3/4-inch (18 mm) oyster spat annually would be $180,000 for the first year and $90,000 yearly thereafter.

Dupuy and his associates at VIMS have recently published a comprehensive manual on hatchery design, construction and operations (Dupuy, Windsor and Sutton, 1977).

They calculate that a hatchery capable of producing 44 million 3/4-inch (18 mm) spat annually would have an initial cost of $313,000. This would include land, building, plumbing and equipment. Annual operational costs after the initial period of adjustment were about $207,000. This cost estimate was rather comprehensive including salaries, interest on loans, insurance, supplies, etc.

Selective Breeding of Oysters

Studies on oyster genetics are being carried out by Longwell and Stiles at the National Marine Fisheries Service Laboratory at Milford, Connecticut (Longwell et al, 1967; Longwell, 1969 and Longwell and Stiles, 1972 and 1973). Longwell has reviewed the beneficial results which come from out-crossing and cross-breeding the American oyster. These were increased reproductive capacity, increased environmental range and greater uniformity among individuals, disease resistance and hybrid vigor.

Work at Milford has included studies on possible mutations induced by radiation and possible chromosome doubling. Their experimental efforts have not progressed to the point where data have been produced on variation in the growth or size as the result of crossing or breeding.

Menzel (1971) also reviewed desirable objectives for a selective breeding program for *C. virginica* and other species such as: faster growth of shells or meats, as well as a uniform *rate* of growth; thick shells to resist shell-boring pests; resistance to the principal oyster diseases such as *M. nelsoni* and *D. marinum* as well as *M. costalis*, and resistance to physiological stresses.

Menzel stressed the possible advantages of hybridization and stated in terrestrial organisms hybridization between species or varieties often results in the desirable characteristics of both parents being bred into succeeding generations. Working in Florida, Dr. Menzel attempted to cross six species of oysters: *C. commercialis*, *C. angulata*, *C. gigas*, *C. iredalei*, *C. rhizophorae* and *C. virginica*. Several of these crosses were successful: *C. angulata* x *C. gigas*; *C. gigas* x *C. angulata*; *C. angulata* x *C. virginica*; *C. gigas* x *C. virginica*; *C. rhizophorae* x *C. angulata*; and *C. rhizophorae* x *C. virginica*.

More recently Dr. John Dupuy at VIMS has successfully crossed *C. virginica* x *C. gigas* (recriprocally), and back crossed the second generation (Dupuy, personal communication).

Since 1964 Dr. Andrews and his colleagues at the Virginia Institute of Marine Science have done extensive work in a genetic program with the goal of developing oysters resistant to MSX. These studies have been successful and seed which is resistant to MSX has been produced. The program involved extensive testing of progeny in trays in Type I MSX regions.

An extensive breeding program begun about 12 years ago is still in progress under the direction of Dr. Harold Haskin at Rutgers University, New Jersey. The results of these studies have not been published. However, it is known to us that Bayshore seed (Bayshore is on the New Jersey side just inside Delaware Bay) exposed while young to MSX is now being planted in Delaware Bay.

The Closed System of Oyster Culture

Various persons have proposed growing oysters from spat to maturity in closed systems. Some have tried it, but these studies suggest this aspect is not practical today from a commercial aspect. A recent publication along this line is by Yentsch, White and Richardson (1969). Based on their calculation, algal production from one acre will produce about 10 pounds of shellfish per day. These authors also suggest the closed system is a realistic approach and that a pilot plant be constructed.

Goodrich and Wainright (1968) published on the feasibility of growing oysters in a closed system from the larval stage to maturity. Among the advantages of their proposed system they cite oysters may be produced at a steady rate throughout the year, and quality control is possible. This report is long and detailed and contains documented cost estimates. They state that the favorable economic potential of the factory concept warrants the immediate undertaking of some definitive scientific and developmental studies.

A careful reading of the report indicates that much remains to be done before we are able to raise commercial quantities of market oysters under completely closed conditions. The cost of a plant to raise 200,000 bushels a year was estimated to be from 11 to 12 million dollars. Costs of raising the oysters ranged from about $40 to $72 per bushel. Other problems were raising sufficient algae to feed the spat or oysters and the accumulation of metabolites and high energy costs for heating or pumping water.

Six species of bivalve larvae including _C. virginica_ were recently cultured in a closed recirculating system. These studies at Newark, Delaware were conducted using cultured algae as food. The water was recycled over a carbon filter and over a second filter composed of silica gravel and shell. Growth of the molluscs varied according to the species of alga but *C. virginica* grew about 2 inches in 125 weeks. While these studies utilized recycled water, fresh seawater containing food elements less than 5μ were occasionally added. The accumulation of metabolites was cited as a major problem (Epifanio et al, 1973; Epifanio, Logan and Turk, 1976).

We conclude the "closed" culture of oysters to market size while extremely desirable has no application in the immediate future of the Virginia Oyster Industry. However, closed culture techniques may be used to advantage in culturing spat if the desired size is not too large.

Artificial Foods

As indicated above one of the major problems (other than accumulation of metabolites) in developing techniques for closed-culture systems of oysters, pond culture work and raising oysters under laboratory conditions in flowing water is an adequate inexpensive food supply. To date we are far from a solution to this basic need. Techniques exist for culturing algae sufficient for laboratory use and for most hatchery needs and some artificial foods exist (Ukeles, 1971, 1976; Epifanio, Logan and Turk, 1976). However, techniques do not exist as yet for mass culture of algae at a price which enables commercial growers to raise oysters to market size or for supplemental feeding with artificial foods at a cost competitive with those available under natural environmental conditions. If such mass cultural techniques or artificial foods were developed advantages would be:

1. Oysters might be grown in the laboratory or in ponds at rates which might exceed that of the natural environment.
2. Oysters could be grown in the laboratory in artificial media with a known chemical composition. Then it would be possible to study more exactly the effects of predators, heavy metals, pesticides and other factors on this important species.
3. In developing and growing oysters with known genetic traits it is desirable to isolate them from waterborne diseases and from contamination with wild "sets" of oysters. Closed system culture would make this possible, but it depends upon food availability.
4. Oysters might be held in ponds or tanks and fattened prior to marketing.

While artificial foods sufficient for completely closed conditions have not been developed for growing oysters to market size, various artificial supplemental foods for partially closed conditions have been developed. Early attempts at developing artificial supplemental foods were not successful. Mitchell (1915) tried glucose and later Gavard (1927) and Martin (1928) investigated ground algae, detritus, ground fish and ground invertebrates. Haven (1965) showed that if hydrolized starch was added to flowing water where oysters were being held that dry meat weights increased due to glycogen accumulation. This work was later confirmed by Gillespie, Ingle and Havens (1966) and Dunathan, Ingle and Havens, Jr. (1969). Subsequent studies by Turgeon and Haven (in press) showed about 5 ppm hydrolized starch would double meat weight in about two months under laboratory conditions. Starch increased meat weights in the Japanese oyster (Kuwatani, 1968).

A variety of artificial foods including vitamins, cellulose, caseine, cod liver oil and cornstarch were recently evaluated as foods for adult oysters in Canada (Castell and Trider, 1974). In this study high levels of dietary carbohydrates resulted in greater glycogen production. It was also shown that the type and level of lipids in the diet was important.

In summary, particulate carbohydrates (starch) offer a definite potential in the future for increasing meat yields of oysters. Carbohydrates might be incorporated into slow release pellets for application to growing areas in the open river. Another technique might be to increase quality of oysters by holding them for periods in flumes of running water to which starch has been added.

Clearly, while accumulation of metabolites is a major problem in culturing oysters in a closed system, the development of a satisfactory artificial food ranks equally in importance. If the problem is to be solved, both aspects need further study.

Bottom Cultch For Natural Oyster Production

Reef Shells as Cultch

The use of reef shells for cultch in Louisiana was described by St. Amant (1959). Results of a study indicated reef shells were quite suitable for oyster cultch provided they were greater than one inch in size. When compared to oyster shells obtained from a steam plant, it appeared reef shells were about 10 percent less effective in catching a "set" of oysters than shucking house shells.

Maryland makes extensive and effective use of reef shells. Between 1960 and 1966 they planted annually between three and four million bushels at the cost of about 1-1/2 cents a bushel (Manning, 1966). This practice continues today, but the cost of reef shells has increased so much that it now approaches that of natural shells.

Virginia began to use reef shells, mined in Virginia, in 1963 under a cooperative agreement with Radcliff Materials, Inc. In this program over 13,000,354 bushels were planted from 1963 to 1968 at relatively low cost to the State. This program was terminated by the VMRC in 1968. From 1968 to 1972, however, Virginia planted about one million bushels of reef shells annually which they obtained in Maryland.

Oyster beds were devastated in many areas of the State in 1972 by Tropical Storm Agnes and as a result federal monies were made available to the VMRC. A portion of this money was used to fund an expanded reef shell planting program throughout Virginia.[2] Since that time annual reef shell planting rates have averaged about two million bushels annually.

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[2]This shell originated in Maryland and was dredged by a Maryland company.

Clearly, reef shells are a useful and needed supplement to the natural supply of shell which is limited. Therefore, it is logical to assume a continuing demand for reef shells may increase. To meet public demand at lower or at least comparable costs the VMRC might consider increasing its capacity to plant shell by utilizing again, as the sole user, the supply available in Virginia waters. If such a program was developed by the VMRC, shell might also be made available to private planters.

It is emphasized the development of Virginia's reef shell resource by the Commission should be made only after the magnitude and location of Virginia's available shell resources have been carefully established. Though recommended many times, this has not been done to date. Deliberate research is necessary for this problem.

Types of Cultch Other Than Reef Shells

There is a possibility other less costly substances may be substituted where necessary for oyster shells obtained from shucking houses or reef shells.

In 1933 fifty tons of slag were planted by the VMRC as a substitute for shell. Results of this trial were never reported (Commission of Fisheries, 1934). The North Carolina Division of Commercial and Sport Fisheries used marl as a substrate to catch seed. Again results have not been reported. Gravel was employed by growers in New England in the 1880's (Ingersoll, 1881).

Surf clam shells are now being used in large quantities in Maryland and on the Seaside and Bayside of the Eastern Shore. Several such plantings were examined by VIMS personnel. Attachment of spat was good and reports were the shells "broke down" later on so oysters were not clumped. We advise a wider use of this type of cultch in Virginia.

Oysters will set on nearly any firm surface, and the possibility of developing an artificial cultch has occurred to many persons. One West Coast company has patented a process for producing small curved discs of clay (about 2 inches in diameter) for artificial cultch. Costs of this substance is not known nor is its effectiveness.

Further tests should be made in Virginia using slag, shell-marl, surf clams and possibly other substances less costly than shell. Moreover tests utilizing the recently developed "French System" of spat collecting should be tested.

Use of Seed Oysters From Other Sources

Seed oysters originating from one area do not always grow well or survive when transplanted to other areas. This fact has been known in a general way by oystermen for many years. Ingersoll (1881) discussed imports from Chesapeake Bay into New England, New Jersey and Delaware in the period prior to 1880. A summary of his findings follow.

As early as 1845 Virginia oysters were sent to Wellfleet Harbor in Massachusetts (on Cape Cod) and by 1850 100,000 bushels were planted annually. Oysters were largely "bedded." That is, they were planted in spring and sold during the following fall or winter. It was reported that many would perish if carried on through the winter.

To the south of Cape Cod in the 1860's, the large natural beds of Massachusetts were not sufficient to supply seed for the demand and Virginia seed was imported for "bedding." It was reported, however, that the seed did not always do well around Sandwich.

During the late 1800's in Rhode Island over 500,000 bushels of Chesapeake Bay oysters, largely from Tangier Sound, were bedded annually. It was reported by Ingersoll (op. cit.) that those from Saint Mary's and the Potomac did not "do well."

Growers in Connecticut and New York during the same period imported similar quantities of "Chesapeakes" for bedding. It is difficult in these reports for these two states to distinguish between the true seed and those used as bedding but indications were that no matter what the purpose of the imports was, Virginia oysters did not survive well during the winter.

Seed from the Rappahannock and York rivers were preferred by oystermen in the vicinity of Staten Island, New York.

Ingersoll (op. cit.) reported large quantities of seed from Chesapeake Bay were being imported into Delaware Bay in the late 1800's. For example, in the 1879-1880 season, 287,760 bushels were planted from Virginia and 651,840 from Maryland. Ingersoll reported that this seed was left to grow on the bottom only one year as it was risky to leave it there longer in that it might not survive for longer periods.

Ingersoll (op. cit.) described how the James River seed area was the principal source of oysters planted at Chincoteague, the lower James and York rivers and in Hampton Roads. It is emphasized again the James was in those days as it is in the present, the source of most oysters planted in Virginia. Seed transplanted from the James to those regions still grow well and annual mortalities (except those due to known diseases and drills) are low. Seed from the Eastern Shore of Virginia, although abundant, was not employed by growers in the lower Bay, but was used on the Eastern Shore and in Delaware Bay.

The James River met most of the demands of the private planters in Virginia prior to 1960 but, even in that period, growers were always looking for new sources of low-cost, high-quality seed. Consequently, seed from Delaware Bay, Long Island, the Seaside of Virginia and from South Carolina was occasionally planted as early as 1953. Results of these plantings were seldom documented in publications, but the conviction developed among growers that seed from other states and the Seaside of the Eastern Shore did not do well in most parts of Chesapeake Bay.

Beavin (1949) compared growth and survival of seed from several other locations in the upper Bay with that occurring at Solomons Island, Maryland where the salinity averaged about 15 ppt. In preliminary trials he found oysters from a low-salinity area in North Carolina showed only a five percent mortality. The highest mortality of fifty-eight percent was in a group of Long Island oysters from a high-salinity area. Additionally, groups from the James River in

Virginia, New Jersey and Eastern Bay, Maryland had second-year mortalities ranging from 13 to 23 percent. Seed from a low-salinity area in the upper Bay showed a very low first-year mortality of 5.0 percent when planted in a high-salinity area of Chincoteague Bay.

During 1950, 1951 and 1952 mortalities of South Carolina seed were evaluated in the upper Bay and in the York River at Yorktown, Virginia (Beavin, 1953). Extensive damage was done to several of these groups by oyster drills but results were evaluated in terms of non-drill mortality. South Carolina seed experienced decidedly poor survival in the upper portions of Chesapeake Bay, good survival in the lower Bay and excellent survival in Chincoteague Bay on the Eastern Shore of Maryland. Seed from South Carolina survived best in high-salinity waters.

Hewatt and Andrews (1954) reported rather high death rates of South Carolina seed the first year with low mortality during the second summer. Andrews and McHugh (1957) provided additional information on the use of South Carolina oysters grown at Gloucester Point. This seed had a lower incidence of the fungus Dermocystidium than native oysters. Their results also showed South Carolina oysters to have poorer survival during colder-than-average winters than did native stocks. Meat yields of South Carolina oysters was much lower. Further study by Andrews and Hewatt (1957) confirmed these observations. The cause of the winter mortality was not stated but it was concluded that colder water temperatures of this latitude were responsible. It was also concluded that the planting of South Carolina seed in Virginia was fraught with excessive risk.

Seed oysters from Seaside Virginia did not do as well as local oysters when planted in the lower-salinity waters of the York River at Gloucester Point, Virginia (Andrews, 1955; Andrews and Hewatt, 1957). Seaside oysters had a summer death rate of 16 to 30 percent as yearlings and mortality rates of 37 to 74 percent for two year olds. Tissue from the two groups showed a much higher incidence of the fungus Dermocystidium in those from Seaside as compared to natives.

Shaw and McCann (1963) showed the source of seed to be important when they grew seed from various localities in Taylor's Pond, West Chatham, Massachusetts. In that experiment seed from Wareham River grew more slowly than those from Mill Creek, Massachusetts or from Long Island Sound. They reported no reason for these differences.

The preceding paragraphs clearly illustrate one point. Oysters native to one area, which are moved to another location may (but not always) show differences in susceptibility to various controlling or limiting factors of their new environments. Probably, as suggested by many competent biologists, there are a number of physiological races of oysters along the Atlantic and Gulf Coasts, each adapted to regional differences in disease resistance to existing ranges of salinity and temperatures. There is, of course, ample evidence for the existence of these races as shown by the recent research in genetics and MSX studies which have just been reviewed. As previously outlined by Andrews (1967) there is a possibility that small spat may acquire resistance to disease (MSX) in their early growth stages in addition to resistance developed by breeding MSX-resistant oysters.

We recommend studies be started soon to evaluate growth and mortality of seed oysters from various sources in representative growing regions of Virginia.

The Use of Chemicals or Biological Techniques to Increase Spatfall on Natural Cultch

Techniques exist for increasing set of oysters on natural cultch.

One of the most interesting is related to the phenomenon of gregarious setting. That is, there is a tendency for oyster spat to settle on cultch where there are pre-existing spat rather than on similar substrate lacking spat.

Early oyster culturists in this country may have unknowingly taken advantage of this phenomenon. Long Island oyster culturists in the 1860-1880 period often planted from 30 to 50 bushels per acre of oysters among newly planted shells to provide "spawn." Their "error" in thinking larvae would tend to remain close to where they were produced may be excused. They may, however, have been seeing the results of gregarious setting without recognizing it. The presence of the oysters may have encouraged or contributed to securing a set on the planted shells.

There is additional evidence to support this early practice. Cole and Knight-Jones (1949) found oyster larvae set in greatest numbers on shells already containing spat. They suggested some chemical was secreted by the newly set spat which encouraged others to set. Crisp (1967) suggested oyster larvae may respond to chemicals such as conchiolin, matrix protein and tissue extract. Hidu, et al (1970) showed the larvae of C. virginica demonstrate gregarious setting patterns and suggested a water soluable pheromone may be involved.

This tendency to gregarious setting by C. virginica may be used in mariculture to increase set on shell plantings and also those of private growers. It is strongly recommended these promising leads be tested in the field under suitable experimental conditions on plots of appropriate size.

Keck et al (1971) demonstrated that three naturally emitted substances, i.e., feces, pseudofeces and shell liquor, when applied to oyster shells, induced significantly higher spatfall than on control shells.

Chemicals may be used to increase the set or survival of spat on oyster shells. Studies begun at Milford, Connecticut (Loosanoff, 1961) suggested shells dipped in the chlorinated benzene Polystream[R] had almost three times as many spat as untreated shells and that spat on the treated shells were larger. These results were confirmed by Shaw and Griffith (1967) in upper Chesapeake Bay. Similar results were reported for Chincoteague, Virginia (Castagna, Haven and Whitcomb, unpublished; Haven and Whitcomb, unpublished). These last two studies suggest the method might be used commercially. An experimental fault of all studies using Polystream[R] was none of the studies showed whether the higher set obtained at the end of each experiment was the result of a higher initial set or merely better survival on

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[3]Polystream[R] remains on treated shells for over a year as evidenced by a strong odor after a year's immersion in water (Haven, unpublished).

[R]Registered trademark.

the treated shells. However, whether it was set or survival, the results showed that seed production could be increased by this technique.

Chemical Control of Fouling to Increase Set

Oyster shells placed in an estuary at the wrong time may become so covered with fouling organisms that oyster larvae cannot attach (Chapter II). MacKenzie (1976) has advocated the use of two tons of lime (CaO) per acre to control fouling. Tests using this new technique were reported as successful (MacKenzie, 1976). Experiments along this line should be conducted in Chesapeake Bay.

Inhibition of Disease By Chemicals

The fungus disease, *D. marinum*, was once a major problem in the lower Bay, and several investigators have decided that it might be controlled by chemicals the same way agricultural crops are protected on land. In laboratory studies cyclohexamide, an antibiotic, prolonged the life of oysters naturally infected with *D. marinum* (Ray, 1965). This method of disease control was suggested (Ray op. cit.) for use in closed systems. Unfortunately, Ray (op. cit.) did not discuss the possible application of his technique to oyster culture in the field. Likely effective concentrations of the antibiotic could not be maintained in the open estuary.

It might, however, be used in pond culture as well as in laboratory situations.

Any proposal featuring the use of chemicals in estuaries and in the ocean must contend with the problems of dilution, chemical change, currents, adsorption, absorption, and other factors of the environment. Additionally, they must not kill or harm other species and they must be acceptable to those government agencies responsible for water quality and product control.

Chemical Control of Oyster Drills

Tests conducted by the Bureau of Commercial Fisheries Biological Laboratory at Milford, Connecticut, disclosed the mixture of several chlorinated benzenes known by the trade name of Polystream[R] to act as a barrier to drill migration (Loosanoff et al, 1960) when mixed with sand and applied in an appropriate pattern on the bottom. Subsequent studies at Milford suggested that Polystream[R] mixed with the insecticide Sevin[R] reduced drill populations on Long Island oyster beds by as much as 99 percent (Loosanoff, 1961). Further studies at Milford suggested that chemical mixture might be used commercially to control drills in oyster-

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[R]Registered trademark.

growing regions. Studies by Wood and Roberts (1964) in standing water at VIMS evaluated Polystream[R] and Sevin[R] in the laboratory and found the combination killed half the drills in four to seven days.

Field studies by Haven et al (1966) and Shaw and Griffith (1967) indicated Polystream[R] and Sevin[R] or Polystream[R] alone were ineffective in controlling drills in those portions of Chesapeake Bay which were tested. The chemical did not kill the drills. It did not even come in contact with them. The treated sand grains sank below the surface or they became covered with silt. MacKenzie (1970b), in reporting on the use of Polystream[R] in Long Island Sound, obtained different results from those tests in Chesapeake Bay. He suggested Polystream[R] absorbed on clay granules and applied at 1,600 pounds per acre killed up to 85 percent of the drills. Cost of treatment per acre was estimated at $200.

To our knowledge, the use of Polystream[R] on the East Coast was never certified by Federal agencies, and the chemical is no longer used by commercial oyster companies.

[R]Registered trademark.

Improvements in Methods for Shucking Oysters

Introduction

Oysters are still opened with shucking knives and, from all reports, persons willing to perform this work are becoming increasingly scarce. The unwillingness of persons to engage in this work is probably due to unfavorable working conditions, tedium, low pay and the seasonal nature of the work.

Wheaton (1970) has summed up the necessity for the industry to mechanize shucking.

> Rising labor costs, shortage of skilled shuckers and onerous labor requirements make it necessary for the oyster industry to consider mechanization for lowering costs and solving labor shortage problems. Since very little operations research has been done in the oyster industry, a study was conducted to identify operations that might be mechanized. Information collected from literature review, oyster processing plant visits, time study data, and personal contacts with oyster processors and biologists were used to construct an operations-process chart of the oyster industry and to identify several processes where mechanization is needed. Since shucking is a major problem data necessary for estimating the initial cost of a processor could afford to pay for the shucking machine were assembled. Under the assumptions made in this paper, an oyster processing plant could afford to pay about $33,000 for a shucking machine capable of shucking 60 oysters a minute.

Wheaton (1970) also conducted extensive studies on the economic aspect of processing oysters and on the engineering aspects of opening and processing oysters. They fall into four classes: 1) time and effort studies on processing oysters; 2) developing and investigating techniques for "gaping" oysters so they are easier to shuck; 3) developing techniques and machines for breaking the bond between the oysters' adductor muscle and the shell; and 4) developing a machine, utilizing concepts outlined in 2) and 3) above, for commercially shucking oysters.

Wheaton (op. cit.) reviews 47 approaches to opening and shucking oysters which are divided into eight categories. A partial outline of the techniques and methods he investigated follow.

1. Acceleration - Tumbling, centrifuge, droppling and vibration.
2. Shock Waves - Fire crackers, gas explosions, etc.
3. Chemical - Acids, O_2, enzymes, dehydration, etc.
4. Mechanical - Hammer, hand-opening, shears, piercing, cutting, pinching hinge, etc.
5. Vacuum - Pulling valves apart, drying, etc.
6. Pressure - In pressure chamber.
7. Heat - Water bath, microwave, propane flame, infrared, etc.
8. Freezing - Slowfreezing, dry ice, etc.

He concluded that most of the concepts tested, while good in theory, were not practical. In some instances, energy requirements were too high or the technique resulted in an inferior final product. In other cases the process simply did not work.

Several techniques which appeared promising were the use of infrared heat to break the bond between the adductor muscle and the shell, and techniques for shucking oysters by mechanical means (Wheaton, 1973 and 1974).

Steam Shucking

Steam shucking of oysters has been practiced in Virginia since 1860. However, the meats are cooked in the process and the product cannot be used in the raw bar or cocktail trade or as breaded oysters or other preparations requiring raw oysters.

A brief description of the process as it exists in the modern plant follows. Oysters are thoroughly washed in rotating steel drums to free them of clays, silts or other detritus. They are then steamed in large retorts each holding 10 to 15 bushels of oysters. The steamed oysters are next tumbled in a second drum which retains shell but allows meats to drop out onto a moving conveyor belt. Meats and bits of shell on the conveyor go into a brine flotation tank which floats meats and allows shell particles to sink. A second conveyor scoops up the floating meats and after a fresh water wash, the meats pass before inspectors who remove shell and other materials not eliminated by the floating process. The processed meats are then packed and frozen and shipped to processing plants.

Virginia Seafoods in Lancaster and the Ballard Fish and Oyster Company in Norfolk are large steam shucking plants operating in Virginia. They pack for a large soup company which uses the oysters to make frozen oyster stew. These companies require smaller-sized animals with shells ranging from 1-1/2 to 2-1/2 inches (36 to 61 mm) long for the stew.

The steam shucking industry might be greatly expanded to make use of clustered Seaside Eastern Shore oysters and small oysters grown in MSX areas.

Heat Shock

One method which was proven highly successful for opening clustered oysters is the "heat shock" method developed by Somers B. Pringle of the Shellfish Section of the South Carolina State Board of Health (Pringle, 1964). Oysters to be shucked are first washed and then simply immersed in hot water (145-150^{o}F) for up to three and one-half minutes. They are then quickly cooled. Completion of this short procedure makes the oyster easier to open. Laboratory studies in South Carolina showed that this heat treatment reduced coliform and fecal coliform bacteria at all percentile levels.

Heat treatment has been an established practice in South Carolina since before 1965 and, at present, the process is used on clustered oysters in both North and South Carolina.[4]

Recently several Virginia oyster shuckers have began to use steam to cause oysters to gape prior to shucking. A temperature of 160°F for 3 minutes is required to gape oysters. This technique is highly successful and should be more widely utilized.

<u>Gaping Oysters by Shock</u>

A machine was developed by Prytherch in the early 1940's to shake unopened oysters in a rotating drum. This treatment caused them to gape so facilitating opening. There were many faults to this technique. Not all oysters opened, shell liquor was lost, and fragments were mixed with meats. Consequently, it cannot be recommended.

A preliminary study showed <u>C. virginica</u> may be caused to gape for mechanical shucking by use of shock-wave

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[4]Aspects of heat treatment along with recommended practices are outlined in Part II "Sanitation of the Harvesting and Processing of Shellfish" by the U.S. Department of Health, Education and Welfare (Hauser, ed. 1965).

energy (Paparella and Allen, 1970). General Electric hydraulic system and the PHR Air Gun were examined as devices available for producing shock-wave energy. From 33 to 86% of the total number of oysters subjected to treatment were gaped at a rate of 67 oysters per minute. While the preliminary attempts were partially successful, treatments by the Electrohydraulic System produced damage to the meats (shattered tissue). Maintenance of equipment was a major problem since the electrodes used to produce the shock eroded rapidly.

The equipment necessary to accomplish this process is expensive and, while theoretically practical, the process needs further research and development before its use could be recommended.

<u>The Mechanical Oyster Shucker</u>

The obvious need for a better way to open oysters has given impetus to development of mechanical ways of opening oysters and extracting their meats. A mechanical oyster shucker has been under development by Wheaton (1973) for several years. This machine is designed to clasp oysters tightly near their bill end while a saw cuts off the hinge, thereby exposing the shell cavity. Next, steel blades cut the adductor muscle and force the shells apart and the meat falls into a container. This machine has not yet been developed to the stage where it is used commercially. Its major faults are: 1) it cannot shuck clumped or irregularly-shaped oysters; 2) it damages the meats; 3) the current version is expensive and cannot be maintained except by a skilled mechanic; and 4) its output is low.

A similar shucking machine has been developed by Mr. Sterling Harris (1971).

The Use of Infrared Heat to Open Oysters

Infrared heat was applied to unopened oysters by passing them on a conveyor belt under a propane flame. At 300°C for 121 seconds, 68% of the oysters showed a broken bond between the shell and the adductor muscles; at 300°C for 162 seconds, 95% of the muscles detached from the shells (Wheaton, 1974). Wheaton concluded the process had major problems due to the uneven transfer of heat through the shells of oysters. The process resulted in the cooking of some oysters while others having the same dimensions remained unopened.

Gear Improvement

Many possibilities exist for developing or adapting mechanical gear to reduce costs or improving efficiency in the planting, growing and harvesting of oysters.

Improvements in Techniques of Planting Oysters

Techniques of planting oysters have changed little in the last 100 years. Seed oysters are still shoveled from the bottoms of the tong boats into bushel measures and the filled iron container (one Virginia bushel) is dumped onto the deck of the buy boat or onto a conveyor belt which dumps the oysters in a truck. If loaded onto a truck, they are transported to another shore site, reloaded onto a barge and shoveled or washed off onto the planting ground.

Mr. Garrett, a Rappahannock River planter, has developed a barge equipped with a moving rubber conveyor belt. Oysters are loaded onto the sides of the barge next to the conveyor belt. Later, as the loaded vessel is moved over the planting site, oysters are shoveled onto the belt which transported them toward the front and over the side. There a slowly revolving disc (moved by a hydraulic motor) about 3 feet in diameter spreads the oysters as they fall off the end of the belt. This apparatus works very well and could be adopted by other growers to reduce the high cost of hand labor. It speeds operations and spreads the oysters more evenly than can be done by hand or by a water jet.

<u>Mechanical Harvest of Oysters</u>

Tongs and oyster dredges have been the traditional equipment used for harvesting oysters since the 1860's and up to 1950 there was little change, i.e., one or two tongers operated from each boat. Dredge boats usually towed one dredge at a time. Oyster dredges were dumped by hand on the deck of the boat and the oysters shoveled into a pile. Beginning in 1950, the Ballard Fish and Oyster Company of Norfolk, Virginia began using large-capacity dredge boats each equipped with four dredges. Two of these dredges worked while the other two were being raised, emptied and lowered. Dredged material was put into large rectangular baskets for transport to the shucking house. Shells and oysters were emptied from the baskets at the shucking house directly onto a conveyor belt which carried the material past shuckers who removed and shucked live oysters. Empty shells simply passed by and fell into the shell pile. This technique was suitable for harvesting and processing production from large-scale operations such as were formerly practiced in the lower Chesapeake Bay.

After MSX developed, harvest with these large, efficient boats was stopped since oysters disappeared from the extensive leased beds upon which they had been used so productively and economically. Why they were no longer used is not apparent, but perhaps the cost of operations and upkeep of these large vessels was too much and their efficiency was reduced when they were employed on the smaller tracts not affected by MSX.

There have been many improvements on the operations and types of dredges used in harvesting oysters in Long Island

Sound (MacKenzie, 1970a). Dredge boats owned by a large corporation (Long Island Oyster Company) are equipped with hydraulically operated booms from which dredges are towed. The dredge is a large rectangular basket with a bottom which opens by means of a "catch." The dredge is lowered, raised and dumped into containers on deck without being touched by hand. This apparatus is most efficient, but whether or not it would be cost-effective in Chesapeake Bay is unknown.

Other efficient methods of harvesting oysters exist. One method is to use a modification of the Maryland type hydraulic soft clam dredge which was developed by Fletcher Hanks in Maryland. This device jets the soft clams from the bottom and then transports them on a moving belt to the surface. This rig was adopted for harvesting oysters (MacPhail, 1960 and 1961) by directing the water jets horizontally. The MacPhail dredge operates satisfactorily where bottoms are soft or where there is no crust of shell material below the sediment surface. However, if shells are embedded in the bottom, as they are in many oyster growing areas, the bottom scoop or blade of the dredge becomes "hung" or embedded in the substrate and the device becomes very inefficient.

Recently the Virginia Institute of Marine Science developed a mechanical oyster harvester which eliminated one of the basic faults of the MacPhail harvester. It does not stick or become embedded in crusty or hard bottoms. The harvester utilizes the basic escalator system employed on all soft clam rigs, but the water jets and scoop are replaced by a special head. This head consists of a rectangular steel box with an approximate inside width of 36 inches and an overall length of about 36 inches. The box narrows to a width of 18 inches where it attaches to the escalator.

Inside this box are rows of flexible steel tines affixed to two steel cylinders which are rotated by an underwater hydraulic motor. As the box slides on steel runners over the bottom, the tines rake oysters and shell from the bottom. A horizontal jet of water washes them onto the escalator which carries them to the surface.

Since the mechanical harvester can be operated by two persons, it represents a savings in manpower over the conventional harvester which requires three workers. Also, unwanted shell falls directly back to the bottom which eliminates the need to hand cull on deck or shovel it overboard. The dredge causes no apparent significant damage to the bottom since it harvests only the top two or three inches.

Tests indicate a harvest rate of oysters on planted bottoms of up to 138 bushels per hour. Oyster shells were raised at a rate up to 775 bushels per hour. The depth to which oyster harvesters might work is limited by the length of their escalator system. Escalators 50 feet long which could harvest oysters from a depth of about 16 feet are practical. This depth would include most (but not all) of the oyster-producing regions in Virginia.

At the present time, hydraulic escalators may be legally used on private grounds to harvest soft clams upon receiving a permit from the VMRC. They may also be employed for soft clam harvest on public grounds with the permission of the VMRC, which could issue a permit to do so, but only after a public hearing.

Since this device damages the bottom less than a soft clam harvester there appears to be no biological reason why its use should be prohibited. However, it needs to be carefully assessed. The results should be reviewed by the VMRC before taking action.

"Suction" dredges are in use on the West Coast of the United States to harvest oysters. One of the most successful is the Bailey harvester, which is covered by U.S. Patent No. 2,508,087. The principle of the Bailey dredge is the use of water in motion to lift the oysters from the beds with a mechanical conveyor to bring them to the surface. The harvester is well suited to the West Coast where there is usually little shell on the bottom along with the live oysters.

However, its use in Virginia would be limited since the device would lift shells and oysters; it has no provisions which would allow culling of the unwanted shells. Moreover, the device probably causes extensive bottom modification of soft bottoms. Regardless of these limitations, the device might be useful in Virginia if it were modified. Consequently, trials should be made.

"Cleansing" Oyster Shells to Obtain Higher Natural Sets

Spike-tooth harrows or bagless oyster dredges have been used to "cultivate" the bottom to enhance setting. When a dredge or harrow is dragged over old fouled shell beds, unfouled surfaces are exposed where larvae may set. For example, Sayce and Larson (1966) reported on the use of the English pasture harrow (spike harrow) in oyster cultivation on the West Coast of the United States to break apart and scatter clusters of the Pacific oysters. They reported dragging distributed oysters more evenly, raising them out of the substrate and increasing spatfall three to five times.

Long Island Sound growers have also used bagless dredges to accomplish the same objective. Used in that area is the "Flower Silt Board" which scours silt off shells so they will obtain a good strike (MacKenzie, 1970a).

Virginia oyster growers, as well as the VMRC, have for many years used the bagless oyster dredge to "work" old shell plantings to increase strike. Many of the oyster growers in the state report that "harrowing" helps. The VMRC reported a three to five-fold increase in set on a harrowed area on Brown Shoals in the lower James River in 1973.

Studies in 1956 at the Virginia Institute of Marine Science were conducted with an underwater spike-toothed harrow (Haven, unpublished). This harrow was operated at Hampton Bar and also in the Chesapeake Bay in a series of tests to distribute newly planted James River seed. Examination of the bottom before and after harrowing indicated clumped seed was spread evenly over the bottom with little if any burial or breakage to the live oysters. A second test by the Institute in 1970 in the Great Wicomico River showed that cleansing and reordering of an old oyster bed by "harrowing" resulted in doubling of the set.

A large New England oyster company has constructed a suction dredge mounted on a barge named the "Quinipiac." This vessel is capable of quickly raising (by suction) several thousand bushels of buried shell daily. The shells are cleaned of silt and are stored in a large bin on the deck of the vessel. The shells are then replanted (MacKenzie, 1970a). An added bonus of this treatment is oyster drills are often buried and many are killed.

Gear suitable for the Chesapeake Bay area may be designed or developed to clean or renew old shell plantings more efficiently than the techniques or devices now in use. The oyster harvester developed by VIMS is capable of raising up to 775 bushels of shell an hour. A device harvesting larger quantities of shell could easily be developed. Also, techniques might be developed for turning or mixing shells (to enhance spatfall) without raising shells to the surface.

Dredges of the types described here could be integrated into other units or be used for multiple functions such as harvesting, bottom rebuilding, drill control, shell cleaning, replanting to bring about more economical operations or more effective culture techniques. We recommend that such gear be developed.

Oyster Depuration

Techniques have been developed for cleansing oysters of undesirable species of bacteria especially those in the coliform group. This aspect has been discussed fully in Chapter X.

Summary

Many sophisticated as well as simple ways exist to improve the growing, harvesting and processing of oysters. Many of the methods of improving the fishery such as off-bottom culture, while biologically feasible, are not cost effective in Virginia at the present sale price of oysters. Other methods of culture such as closed-system culture are still beyond the present state of technicial development. There are, however, many possible ways of culture which might be adopted with advantage by the Virginia oyster industry.

Toward this goal, emphasis today should be toward enhancing natural production. There are several promising areas but one of the most important is to increase natural spatfall on public as well as leased areas. Increasing the quantity and quality of bottoms available for lease is also important.

A method of improving set on natural bottoms includes the use of the underwater harrow or similar techniques to bring silted-over shells to the surface and to "turn" those on the surface. Here the need to develop mechanized gear is evident since towing an underwater harrow from a boat is inefficient. The use of lime to control fouling should also be investigated. Both of these techniques, while promising, need further research before they are fully evaluated. It is suggested they be given high priority in future research plans.

Oyster shells have been the conventional cultch in Virginia, but substances like marl and surf clam shells offer promises of reducing seed costs. Another technique which would help reduce seed costs would be a further increase in the use of reef shells. Steps should be taken to develop this latter resource in Virginia for the sole use of the oyster industry. This could be done by subcontracting to a dredger or by the construction of a dredge (owned by the VMRC) to dredge this shell.

Another promising approach toward raising seed by a commercial grower or others, and one which is already in use to a limited degree, is the use of shellbags. This technique should be encouraged by every means possible.

Available techniques to control drills and other predators of newly set spat are not adequate or broadly applicable. Some are so inefficient they are virtually worthless. Research is badly needed to perfect new and useful control measures.

Cost of harvest of oysters by dredges or tongs is a major part of the cost of growing oysters (Chapter V). Gear exists in the form of the harvester developed by VIMS which would greatly decrease harvest costs. The more expensive Bailey harvester should be tested and modified if necessary on private leases to promote efficiency.

Shuckers are becoming increasingly scarce and are also a major cost in producing oysters for the market. As long as economics and social attitudes and practices remain the same, dependence of industry on labor will be reduced. This applies not only to the shucking operation but also to other phases. The use of the Pringle heat shock method of gaping oysters should be encouraged among Virginia processors. Other techniques should be developed, modified and/or tested by industry and by the government.

At this time we do not advocate the use of hatchery-raised seed to rehabilitate public bottoms since the emphasis today should be directed toward enhancing natural production. However, we believe that an experimental hatchery capable of producing large quantities of seed should be established to study aspects of developing resistant seed, etc.

Most privately-owned hatcheries in the area have either failed outright or have not yet returned a profit. However, we believe that there soon will be a place for hatcheries operated by private interests. Our reasons for this follow. There is no doubt hatchery seed can be raised and planted on bottoms where salinities are low with the expectation of about 50% survival. According to present techniques this process is still more expensive than planting seed from the James River. We believe as techniques are developed costs can be reduced thereby making costs more competitive. Even if this is not practical, there is the strong possibility that even today a properly organized and managed vertically interpreted company with an intergrated operation might operate a hatchery, plant and then market its oysters with a profit. The high costs of hatchery seed might be absorbed by profits from the overall operations.

The future of hatchery seed seems especially bright in growing oysters on leased bottoms in MSX areas. However, problems of drill and crab predation must be overcome before this will be practical since small hatchery seed is especially vulnerable to these causes of mortality.

We have described cultural practices which are generally not used by the Virginia industry but which might be used to its advantage at present or some future date.

Many of the presently used techniques or practices are still good. Others must be improved or replaced. For example, it was recommended in Chapter IV that the State shell planting program might be expanded, and that shells should be planted by the VMRC only at optimum times and in moderate to high set areas to receive a set and not in low set areas at times as has often been the case.

Another method for improving oyster production is the reassignment of blocks of unproductive, yet useful, public grounds to private owners (Chapter VII).

Some of the mechanization discussed in this chapter is feasible only when the volume of operations is large enough to justify it. Some will work best when individual seed and larger oysters of similar size and shape are available. It may be difficult or impossible for a small grower, shucker or processor to make the capital outlay required for certain types of mechanization. In order to make the desired changes possible, it may be necessary for a number of growers to group together in a cooperative association.[5] Shucking house operators, other processors and packers could also form cooperatives. Such cooperative associations could perform marketing functions as well.

Many improvements can be made in the system, procedures, equipment and arrangement which will result in

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[5]For more discussion of the benefits and disadvantages of COOPS, see Quittmeyer, 1957.

increased yields of oyster from public and private grounds. Application of available techniques for producing useful seed, harvesting, shucking and processing can enhance production and reduce costs of developing and raising marketable oyster products. Marked improvements in production of raw oysters and other marketable oyster products are possible now, even without the development of special new technology. We urge immediate action by industry and government!

CHAPTER XII

SUMMARY OF LAWS IN ATLANTIC AND GULF STATES RELATED TO OYSTER MANAGEMENT

CHAPTER XII. SUMMARY OF LAWS IN ATLANTIC AND GULF STATES RELATED TO OYSTER MANAGEMENT

The intent of preparing this review of laws pertaining to oyster management was not to review all laws of the Atlantic and Gulf States, or even all seafood related laws of Virginia, but to reveal how Virginia stands in comparison to other states in respect to several important management practices. Such a review is badly needed, but is far beyond the scope of this paper. A collection of laws from thirteen states has been assembled with very short summaries including the legal aspects of taxes, harvesting season, gear, leasing and use of public grounds. They are as follows:

Alabama (as of 1975).

A. Public Sector:

1. Management:

Open Season: 1 September - 31 May, normally.
Cull Size: 3".
Gear Permitted: Hand tongs only. Dredging of seed allowed with special permit.
Daily Catch Limit: None.
Statistical Collection Methods: State depends on NMFS.
Licenses required for: Harvesters, boats, dredges, shippers, processors.
Repletion: Shell planting.

2. Taxes Levied:

In lieu of money each wholesaler or processor must replant on public beds and at his expense a quantity of shell equal to 50% of the oysters which he buys.

The tax on seed exported is equal to the value of equal quantity of shells plus the cost of replanting them.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: Any.
Statistical Collection Methods: Done by NMFS.
Licenses Required For: Harvesters, dredges, shippers, processors.

2. Taxes Levied:

3¢ per bushel.

3. Leasing:

Ground Available: All but public reefs.
Annual Rental Rate: $1 per acre for most.
Minimum Production Requirements: Lessee <u>must</u> plant 200 bushels of oysters or cultch per acre over 25% of his lease within two years of obtaining the lease and varying amounts thereafter or forfeit the lease.
Period of Lease and Size: 12 months for first lease of plot; renewable for 4 years.

<u>Connecticut</u> (as of 1975).

A. Public Sector:

1. Management:

Open Season: 20 September to 20 July.
Cull Size: Size limited by restricting mesh size in dredge bag.
Gear Permitted: 30 lb. hand dredges and tongs only.
Daily Catch Limit: None in effect although Shellfish Commission has the power to enact one.
Statistical Collection Methods: For public seed harvest only.

License Required For: Boats, harvesters
Repletion: Shell and seed planting (curtailed at present).

2. Taxes Levied:

None.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: All.
Statistical Collection Methods: None.
Licenses Required For: No one.

2. Taxes Levied:

Property tax on ground leased: 2% of valuation.

3. Leasing:

Ground Available: All but some natural beds.
Annual Rental Rate: $1 per acre and up (prices determined by bid).
Minimum Production Requirements: None.
Period of Lease and Size: No lease granted for a period of less than three years, none more than ten years.

<u>Delaware</u> (as of 1975).

A. Public Sector:

1. Management:

Open Season: 30 September - 30 April.
Cull Size: 3".
Gear Permitted: Patent tongs, hand tongs, hydraulic patent tongs, dredges not permitted, vacuum or suction devices expressly prohibited.
Daily Catch Limit: 15 bushels harvesters voluntarily.

Statistical Collection Methods: Harvesters report quantity. Failure to report can lead to revocation of license annually. Shellfisheries personnel estimate seed harvest.
Licenses Required For: Harvesters.
Repletion: Shell and seed planting.

2. Taxes Levied:

$0.50 per bushel plus $0.15 per bushel for seed.

B. Private Sector:

1. Management:

Open Season: 20 August - 1 July.
Cull Size: None.
Gear Permitted: All.
Statistical Collection Methods: "Producers" report quantity weekly with inspection tax. Lessees report each Spring the bushels of seed planted past year, extent of cultivation and amount of seed planting proposed.
License Required For: Dredge boats.

2. Taxes Levied:

None on oysters from leased ground.

3. Leasing:

Grounds Available: Parts of Delaware, Rehoboth and Indian River bays. (No natural beds.)
Annual Rental Rate: $0.75/acre.
Minimum Production Requirements: Lessee must "plant and cultivate" his lease (no minimum figure set). Beginning no later than two years after leasing or forfeit lease; lessee must report use annually.
Period of Lease and Size: No limit.

4. Imports from the James River in Virginia and oysters with "fungus" prohibited.

Florida (as of 1975).

A. Private Sector:

1. Management:

Open Season: 1 September to 31 May in most places.
Cull Size: 3".
Gear Permitted: Hand tongs (other require special permit).
Daily Catch Limit: None.
Statistical Collection Methods: Dealers and processors report monthly the quantity handled. (No penalty is specified in the statutes for non-reporting.)
Licenses Required For: Non-resident harvesters, canners, dealers and boats.
Repletion: Shell and seed planting. Department of Natural Resources has authority to take shells from processors to plant on public bottoms.

2. Taxes Levied:

None.

B. Private Sector:

1. Management:

Open Season: Year-round in most places.
Cull Size: 3".
Gear Permitted: Hand tongs (special permit required for others).
Statistical Collection Methods: Dealers and processors report monthly the quantity handled. (No penalty is specified in the statutes for non-reporting.)
Licenses Required For: Non-resident harvesters, boats, canners, dealers.

2. Taxes Levied:

None.

3. Leasing:

Ground Available: Only that ground which is currently leased.

Annual Rental Rate: $5 per acre.
Minimum Production Requirements: Lessee must effectively cultivate lease (defined as planting at least 800 bushels of shell or seed per acre on at least one-fourth of lease) every year or forfeit lease.
Period of Lease and Size: Size usually limited to 25 acres. Greater acreage may be leased when prior acreage is in cultivation. No limit on period.

Georgia (as of 1971).

A. Public Sector:

1. Management:

Open Season: 1 September to 30 April.
Cull Size: 3".
Gear Permitted: Tongs and dredges under 150 pounds.
Daily Catch Limit: None.
Statistical Collection Methods: Processors and harvesters submit records monthly; failure to report is a misdemeanor.
License Required For: Harvesters.
Repletion: Processors required to plant up to 1/3 of their shells each year.

2. Taxes Levied:

2¢ per gallon; 5¢ per bushel.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: Tongs and dredges under 150 pounds, processors and harvesters.
Statistical Collection Methods: Processors and harvesters submit records monthly; failure to report is a misdemeanor.
License Required For: Harvesters.

2. Taxes Levied:

2¢ per gallon; 5¢ per bushel.

3. Leasing:

Ground Available: All but natural bars.
Annual Rental Rate: Not less than 25¢ per acre.
Minimum Production Requirements: Lessee required to plant annually a quantity of shell equal to 25% of the quantity of oysters taken from his lease or forfeit lease.
Period of Lease and Size: 20 years, 1000-acre size limit.

<u>Louisiana</u> (as of 1975).

A. Public Sector:

1. Management:

Open Season: Labor Day to 20 May or before.
Cull Size: 3".
Gear Permitted: Any, with exception of one area which the State cultivates.
Daily Catch Limit: None, with exception of one area.
Statistical Collection Methods: Dealers pay tax monthly based on quantity; from them NMFS works up landings data. State personnel estimate seed harvest.
Licenses Required For: Boats, buyers, shippers, processors and dredgers.

2. Taxes Levied:

Severance: 3¢ per barrel (barrel = 3 bushels).

3. Repletion:

Some shell planted.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: Any.
Statistical Collection Methods: Dealers pay tax monthly based on quantity; from them NMFS works up landings data. State personnel estimate seed harvest.

2. Taxes Levied:

Severance: 2-1/2¢ per barrel (barrel = 3 bushels).

3. Leasing:

Ground Available: All.
Annual Rental Rate: $1 per acre.
Minimum Production Requirements: Lessee must cultivate (by planting "sufficient" shell) at least one-tenth of his lease annually or State may revoke lease.
Period of Lease and Size: 15 years. Size limit is 1,000 acres with provision for canning plant owners to lease up to 1,000 acres more.

<u>Maryland</u> (as of 1975).

A. Public Sector:

1. Management:

Open Season: 1 September to 1 April.
Cull Size: 3".
Gear Permitted: Tongs and sail dredges (dredges can operate under power two days a week).
Daily Catch Limit: 25 bushels/man; 75 bushels/tong boat; 150 bushels/dredge boat.
Statistical Collection Methods: Buyers report weekly the quantity bought, boat and location. Failure to report is a misdemeanor with penalties ranging from $500 and/or 3 months to $1,000 and/or 1 year. In addition, license may be revoked.
Licenses Required For: Harvesters, buyers, processors.
Repletion: Shell and seed transplanting.

2. Taxes Levied:

25¢ per bushel, plus 10¢ per bushel if exported in the shell.

B. Private Sector:

1. Management:

Open Season: Year-round.

Cull Size: None.
Gear Permitted: Tongs and dredges in the Bay; tongs only in Bay tributaries.
Statistical Collection Methods: Buyers report weekly the quantity bought, boat and location reporting is spot checked. Failure to report is a misdemeanor, with penalties ranging from $500 and/or 3 months to $1,000 and/or 1 year. In addition, license may be revoked.
Licenses Required For: Harvesters and processors.

2. Taxes Levied:

Inspection: 5¢ per bushel for those harvested plus 10¢ per bushel if exported; 1¢ per bushel for imported seed.

3. Leasing:

Ground Available: On a very limited basis if it is not public oyster, clam or crab ground. (Leasing suspended during Bay Bottom Survey.)
Annual Rental Rate: $2.00 per acre.
Minimum Production Requirement: Only in Charles County where lessees are required to plant seed oysters within 3 years, or relinquish lease.
Period of Lease and Size: Size limits (for one lessee) in acres follow: Chesapeake Bay - 500; Tangier Sound - 100; Worchester County - 50; all other counties - 30. Lease for 20 years.

New Jersey (as of 1972).

A. Public Sector:

1. Management:

Open Season: 1 September to 30 June.
Cull Size: 3" in estuarine areas, none off coast.
Gear Permitted: Hand tongs only for market oysters; dredge for seed (dredges limited to 190 pounds).
Daily Catch Limit: None.

Statistical Collection Methods: Shucking house operators and shell dealers report monthly. Failure to report can lead to revoking of license and a fine of $100 to $500.
Licenses Required For: Boats, harvesters, processors, dealers.
Repletion: Shell planting.

2. Taxes Levied:

Shuckers must provide State with 40% of their shells or pay the current price for shells.

3. Seed Exports:

No out-of-State export permitted.

B. Private Sector:

1. Management:

Open Season: 1 September to 30 May.
Cull Size: None.
Gear Permitted: Any (dredges limited to 190 pounds).
Statistical Collection Methods: Shucking house operators and shell stock dealers report monthly. Failure to report can lead to revoking of license and a fine of $300 to $500.
Licenses Required For: Planters, processors, harvesters, boats, dealers.

2. Taxes Levied:

Shuckers must provide State with 40% of their shells or pay the current price for shells.

3. Leasing:

Ground Available: To residents of New Jersey only. In Delaware Bay only around mouth of Maurice River and along the ocean coast.
Annual Rental Rate: Delaware Bay - 50¢ per acre; Atlantic Coast - $1.50 per acre.
Minimum Production Requirements: None.
Period of Lease and Size: Period of lease flexible but not to exceed 30 years.

North Carolina (as of 1975).

A. Public Sector:

1. Management:

Open Season: 1 October to 31 March.
Cull Size: 3" in northern half of State; 2-1/2" in southern part.
Gear Permitted: Dredge restricted to 100 pounds permitted in some places; tongs in remaining locations.
Daily Catch Limit: 75 bushels.
Statistical Collection Methods: Sellers report monthly all transactions showing quantity sold, location, name and license number of harvester. Failure to report is a misdemeanor.
Licenses Required For: Harvesters, boats and processors.
Repletion: Shell and seed planting.

2. Taxes Levied:

8¢ per bushel.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: Same as public bars during the open season; oysters sold during the closed season do not have to be culled.
Gear Permitted: Any which does not damage surrounding bottom.
Statistical Collection Method: Sellers report monthly all transactions showing quantity sold, location, name and license number of harvester. Also, each leaseholder must report annually the amount of material planted, amount harvested and disposition of the harvest. Failure to report is a misdemeanor.

2. Taxes Levied:

8¢ per bushel.

3. Leasing:

Grounds Available: All but natural beds.
Annual Rental Rates: $1.00 per acre for first two years, then $5.00 per acre.
Minimum Production Requirement: Harvest after 1 year 5 bushels per-acre-per-year or plant according to accepted standards and practices. Lessee must also report annually plantings and harvest; non-use or non-reporting will cause forfeiture of lease.
Period of Lease and Size: 20 years; 200 acres per lessee in Pamlico Sound; 50 acres per lessee in rest of State.

<u>Potomac River</u> (as of 1976).

A. Public Sector:

1. Management:

Open Season: 1 October to 31 March.
Cull Size: 3".
Gear Permitted: Hand tongs only.
Daily Catch Limit: None.
Statistical Collection Methods: There is a dual reporting system. Required reports of quantity and location are mailed in weekly by boat operators. Also, buyers are required to submit similar weekly reports. Failure to report is a misdemeanor and can result in a fine up to $1,000 and/or one year of confinement.
Repletion: Shell and seed planting.

2. Taxes Levied:

Inspection: 25¢ per bushel.

B. Private Sector:

There is no leasing to private interests allowed.

<u>South Carolina</u> (as of 1975).

A. Public Sector:

1. Management:

Area of Public Bottom: As of 1975 there were only 75 acres so designated.
Open Season: 15 September to 30 April.
Cull Size: Set by regulation.
Gear Permitted: Tongs (dredges restricted to water over 12 feet unless permitted in writing).
Catch Limit: 4 bushels per-week-per-man.
Statistical Collection Methods: Shellfish dealers submit monthly records. Failure to report can bring fine of $25 to $500 or imprisonment for 20 days to 6 months.
Licenses Required For: Shellstock shippers, boats, processors and buyers.
Repletion: Division of Marine Resources plants shell and seed.

2. Taxes Levied:

1-1/2¢ per bushel. 10¢ per bushel for market oysters exported in the shell. 2¢ per bushel for seed exported.

B. Private Sector:

1. Management:

Open Season: 15 September to 30 April.
Cull Size: Set by regulation.
Gear Permitted: All (dredges restricted to water over 12 feet unless permitted in writing).
Statistical Collection Methods: Shellfish dealers submit monthly records. Failure to report can bring fine of $25 to $500 or imprisonment for 20 days to 6 months.
Licenses Required For: Boats, processors, buyers and shellstock shippers.

2. Taxes Levied:

1-1/2¢ per bushel. 10¢ per bushel if exported in the shell for market oysters. 2¢ per bushel for seed exported.

3. Leasing:

Ground Available: All but about 75 acres of public ground.

Annual Rental Rate: $1.50 per acre.
Minimum Production Requirements: Lessee must market oysters from the leased area. In addition, he must plant 65 bushels of shell or seed per acre each year or forfeit lease.
Period of Lease and Size: 1000 acres per lessee; 5 year period.

Texas (as of 1975).

A. Public Sector:

1. Management:

Open Season: 1 November through 30 April (other times allowed only by special permit).
Cull Size: 3".
Gear Permitted: Tongs or dredges whose width shall not exceed 36", nor capacity exceed 2 bushels with one dredge per boat.
Daily Catch Limit: 150 bushels per boat per trip.
Statistical Collection Methods: Amount of oysters is specified in permit to harvest seed. Dealers in market oysters make monthly reports; failure to report is a misdemeanor and carries a fine of $10 to $50.
Licenses Required For: Each dredge used, harvesters and boats.
Repletion: Shell and seed planting.

2. Taxes Levied:

None.

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: Any.
Statistical Collection Methods: Dealers make monthly reports of market oysters; failure to report is a misdemeanor and carries a fine of $10 to $50.
Licenses Required For: Harvesters, planters, dealers and boats.

2. Taxes Levied:

2¢ per barrel (barrel = 3 Texas bushels).

3. Leasing:

Ground Available: All except natural reefs.
Annual Rental Rate: $1.50 per acre after 5 years.
Minimum Production Requirements: Lessee must produce oysters within five years from the time lease is granted and annually report the volume harvested or lose lease.
Period of Lease and Size: 100 acres per lessee.

Virginia (as of 1976).

A. Public Sector:

1. Management:

Open Season: 1 October to 1 June (except 1 Nov. to 1 Apr. on Seaside of Eastern Shore).
Cull Size: 3" (most places).
Gear Permitted: Hand tongs only most all locations except patent tongs and dredges allowed in restricted areas.
Daily Catch Limit: None.
Statistical Collection Methods: Licensed buyers report quantity and location at least monthly. They also report price and repletion tax collected for the State. Reports are spot-checked. Failure to report can cause revoking of license and is a misdemeanor.
Licenses Required For: Harvesters, dealers and processors.
Repletion: Shell and seed plantings; up to 20% of shells must be sold to Commission.

2. Taxes Levied:

Repletion Tax - 5¢ to 30¢ per bushel.
Inspection Tax - 3¢ per bushel.
Export Tax - 20¢ per bushel (if exported unshucked).

B. Private Sector:

1. Management:

Open Season: Year-round.
Cull Size: None.
Gear Permitted: Tongs or dredge (there are certain restrictions on dredging).
Statistical Collection Methods: Processors report monthly, no reports required of leaseholders. Reports are spot-checked. Failure to report can cause revoking of license and is a misdemeanor.
Licenses Required For: Dredge boats, dredges, dealers and processors.

2. Taxes Levied:

Inspection tax - 3¢ per bushel.

3. Leasing:

Ground Available: Any except public ground.
Annual Rental Rates: $1.00 and $1.50 per acre.
Minimum Production Requirements: None.
Period of Lease and Size: 20 year period; 3000 acres per lessee.

Summary of Laws

The review just presented merely touched on a few of the major laws utilized in many states. It does deal with those aspects which are of comparative importance to Virginia's management efforts.

Even a casual inspection of the laws shows there are wide differences in the public policies relating to shellfish culture among several coastal states. It is impossible, in most instances, to determine their reason for being or discern the rationale behind them. Nevertheless, a few aspects of Virginia's laws will be reviewed along with recommendations for improvements or future study.

Tax on Leasing Private Grounds in Virginia

The annual rent on most private leases in Virginia is only $1.50 per acre. Of the twelve states reviewed, only three, Florida, Maryland and North Carolina, have maximum leasing fees which exceed those of Virginia (Table 89). Other states have similar or lesser rates. The rate paid in Virginia is an extremely small amount, particularly in light of the strong property rights and long-term economic benefits transferred by the State to the leaseholder and of the potential natural and economic productivity. There is strong evidence that low fees encourage misuse or lack of use of leased lands including occupancy without intent to grow oysters and occupancy for the purpose of excluding those who might wish to grow oysters. Some leaseholders appear to make more money in law suits and property settlements than in oyster production. At times public agencies must pay considerable amounts to leaseholders in order to be able to use leased grounds for public projects.

It is recommended that the rent or tax on leasing bottoms be reviewed by the appropriate State agencies or study commissions with the view toward establishing use requirements and making the rent commensurate with the rights and production potential imparted. It seems certain that the rent should be established at a significantly higher level. Advantages of such action would be: 1) to provide more income to the State for repletion activities; 2) to discourage leaseholders who are

Table 89

A Comparison of Sub-tidal Leasing Practices in Atlantic and Gulf Coast States. (Information current as of February 1975).

State	Leasing Permitted	Annual Fee ($/Acre)	Period of Lease (Yrs)	Use of Bottom Required to Maintain Lease	Penalty Non-Use	Acreage Limit	Dredging Permitted	Tax on Landings ($/Bu)
Ala.	Yes	1.00	5	Plant 200 bu. shell/ac Over 25% lease by 2nd year & every yr. thereafter.	Forfeit Lease	Not Stated	Yes	.03
Conn.	Yes	BID[1]	3-10	NONE	NONE	"	Yes	None
Del.	Yes	0.75	No Limit	"Cultivate" within 2yrs.	Forfeit Lease	"	Yes	None
Fla.	Yes	5.00	No Limit	Cultivate at commercial density (800 bu/acre/yr)	Forfeit Lease	"	Yes	None
Ga.[a]	Yes	0.25	20	Plant shell (25% of oysters grown).	Forfeit Lease	1,000	Yes	.02/gal .05/bu
La.	Yes	1.00	15	Shell 1/10 lease/yr.	"	1,000-2,000	Yes	.02-1/2[7] /bbl.[6]
Md.	Yes[2]	2.00	20	In Charles County lessees are required to plant seed.	Forfeit Lease	30-500	Yes	.05
N.J.[b]	Yes	0.50 1.00	Up to 30	NONE	NONE	Not Stated	Yes	.10[5]

Table 89 (Contd.)

State	Leasing Permitted	Annual Fee ($/Acre)	Period of Lease (Yrs)	Use of Bottom Required to Maintain Lease	Penalty Non-Use	Acreage Limit	Dredging Permitted	Tax on Landings ($/Bu)
N.C.	Yes	5.00	20	5 bu/acre/year (harvest or plant)	Forfeit Lease	50-200	Yes	.08
Pot. R.	No				--	---	--	--
S.C.	Yes	1.50	5	Market oysters and plant 65 bu/acre/year shell or seed	Forfeit Lease	1,000	Yes[3]	1½
Tex.	Yes	1.50	Not Stated	Produce oysters in 5 years	Forfeit Lease	100	Yes	.02/bbl[7]
Va.	Yes	1.00 1.50	20	NONE	NONE	3,000	Yes	.03

a - current as of 1971

b - current as of 1972

1. $1.00 minimum; final price established by bid.
2. Leasing, while legally permitted, is most difficult.
3. Dredging is permitted where depths exceed 12 feet.
4. There is a property tax of 2% of the value of the lease.
5. 40% of the shell from oysters produced by the lease or equivalent monetary value.
6. A La. barrel (bbl) contains 3 La. bushels.
7. A Tex. barrel (bbl) contains 3 Tex. bushels.

holding grounds with no intention of using them; (this practice denies the use of those potentially productive bottoms to those who might wish to grow oysters on them); and 3) to compensate the State for increased administrative costs which have risen sharply due to inflation.

Changes in the leasing arrangements are important to the future well-being of the private oyster industry in Virginia and to the public which owns those bottoms. However, care must be taken to consider the needs and rights of the public, the oyster grower and other users. Some buffering and fallowing lands should be allowed. The public's right-of-use for projects in the greater public good, the needs and rights of tenure and other factors must be considered.

Open Season

The open season for market oysters on public rocks extends from 1 October to 1 June in Virginia for all areas except the Seaside. The VMRC can, by regulation, close the season earlier. On the Seaside of the Eastern Shore, it extends from 1 November to 1 April. Maryland's season opens 1 September, but closes two months earlier on 31 March. Public rocks in the Potomac open the same time as in Virginia and close the same time as Maryland.

All states have restrictions of some sort on fishing seasons for their public grounds, but no seasonal restrictions on leased areas. The closed season corresponds to or encompasses the local spawning season. There is little evidence from a biological viewpoint to support the concept of a closed season if the crop is to be harvested at the time of maximum biomass or even at the point of maximum economic yield. The reasons follow:

Oysters in the York River and other systems are often in peak condition (maximum biomass) in July, during the closed season (Chapter VIII). A possible advantage of harvesting during the spawning season would be to increase the potential for spatfall. During harvesting, shells on the bottom would be turned over and stirred up, thereby exposing more fresh surfaces for oyster larvae to set. There might have been a desire to conserve brood stocks at levels sufficient to provide adequate numbers of larvae. This aspect, however, (if needed) may be accomplished by placing an annual limit on harvest at any time or season.

The concept of closure during the spawning season has probably evolved for a variety of reasons: In the past, oysters harvested in summer were subject to development of higher levels of bacterial contamination than during the colder months. During certain summer months, after spawning, yields of oysters decline because oysters become poorer ("exhaust" themselves) during the spawning process. Consumer preference is associated with the lack of market during the warmer months. Other economic and unknown sociopolitical reasons may have played a part. In summer when the public rocks are closed, the private grower sells his oysters without competing with lower costs of oysters from the public rocks.

There are many other complex and interrelated aspects to the pros and cons of a closed season. Restricting the harvesting period as a method of conserving oyster populations is a widespread practice. Closure may be useful in some instances. The length of the Virginia season should be reviewed to establish its utility and justification.

Size at Which Harvest is Allowed

All states examined have laws requiring oyster harvesters on public bottoms to cull through their catch (i.e., separate the young from the mature) and making it illegal to sell young oysters, except when the oysters are sold for replanting. The cull laws in all states mentioned define legal and illegal oysters in terms of length. Length is defined as the longest measurement from the hinge-end to the bill or sharp end. The minimum size is three inches in Virginia and many other states.

The most powerful and perhaps valid reason for the three-inch cull law is that it is wasteful in terms of biomass to harvest an oyster when it is growing rapidly and on the average, three inches is the time when growth begins to "level off." However, the concept of harvest at the point of maximum biomass might not be as valid as harvest at the point of maximum economic return. An example of this concept is partially illustrated in the harvest of "soup" oysters in the James River where the three-inch cull law does not exist. The soup industry provides a good market for oysters less than three inches. The problems of when to allow harvest of oysters in each area of the State should be studied in detail with the view of modifying the legal size to permit maximum economic return where there is the most reasonable goal.

Harvesting Gear Permitted

Virginia allows only hand tongs to be used on most of its public rocks, but patent tongs are permitted in the lower regions of the Rappahannock, Piankatank, James and Corrotoman rivers and Chesapeake Bay. The regions where patent tongs are permitted are usually too deep for hand tongs and the oysters are too scattered to be worked economically with that device. Dredging on public rocks is permitted in limited areas of Tangier Sound in December, January and February, the only place where it is allowed in the entire State.

Maryland and the Potomac River Commission have laws similar to Virginia for hand tongs. They are the only gear permitted in taking market oysters in most regions. Alabama and New Jersey permit hand tongs for market oysters and dredging of some seed areas. Other states, such as Connecticut, allow dredging on public rocks. Some of these states impose limitations on dredge size.

The restrictions on dredging on public bottoms might be liberalized to permit dredging on a wider scale than is now permitted. Unfortunately, most of the public rocks already suffer from overfishing. To allow harvest by dredging on such bottoms without controlling total "take" in a reasonable fashion to prevent overfishing would be irresponsible. However, something must be done to make harvesting more efficient and less intensive so that economic pressures may be met. We suggest a review of the problem by the VMRC or by a special commission composed of the appropriate agencies.

Use of Leased Bottom as a Condition for Holding Title to the Lease

Anyone who has received a lease and pays the rental fee in Virginia may hold his private lease for twenty years, barring condemnation or the taking of an easement by the State. The leaseholder also has option of renewal. The State has the power to condemn leases, but this has seldom, if ever, happened. Lessees are supposed to use the land to cultivate and produce oysters, but there are no regulations or laws requiring such activities. Most states have laws making it necessary for the lessee to cultivate the lease to keep it in effect upon penalty of losing the lease. Among these states are Alabama, Delaware, Florida, Louisiana, South Carolina, North Carolina and Texas.

It is recommended that the Marine Resources Commission and other appropriate groups study the possibility that Virginia adopt similar regulations.

Taxes Paid on Oysters Harvested

The Repletion Tax in Virginia for oysters from public bottoms ranges from 5¢ to 30¢ per bushel. An Inspection Tax of 3¢ per bushel is levied on all market oysters when they are shucked or processed. The Export Tax on public oysters is 20¢ per bushel. Some states, such as Connecticut and Texas, have no tax on oysters from public rocks, but do on those from private leases. Other Atlantic and Gulf Coast states have taxes of some kind which are equal to or less than those of Virginia.

While tax rates in Virginia are equal and even larger than many other states, they fail by a wide margin to pay for repletion activities. It is recommended that this aspect be considered by the appropriate State agencies or a study commission.

Standard Bushel

Various standards of measurement are used by the oyster industry of various states. Though all states in the Eastern United States use the bushel as a standard unit for buying and selling and for levying tax, not all define the bushel in the same fashion. Some bushels are different than others (Table 90). The maximum difference is between states like New York, which defines the bushel as having 2,150.4 cubic inches (a standard U. S. bushel) and Georgia, where the bushel is 5,343.9 cubic inches. The Virginia bushel is defined

Table 90

Measures of Oysters

State		Capacity of State Bushel Cubic Inches
Maine		2,150.4*
Massachusetts		2,150.4*
Rhode Island		2,150.4*
Connecticut		2,150.4*
New York		2,150.4*
New Jersey		2,257.3
Delaware		2,257.3
Maryland		2,800.7
Virginia		3,003.9
North Carolina		2,801.9
South Carolina		4,071.5
Georgia		5,343.9
Florida, East Coast	(4 bu = 1 bbl)	3,214.1
Florida, West Coast	(4 bu = 1 bbl)	3,214.1
Alabama	(2 bu = 1 bbl)	2,826.2
Mississippi		2,826.2
Louisiana	(3 bu = 1 bbl)	2,148.4
Texas	(3 bu = 1 bbl)	2,700.0

* U. S. Standard Bushel.

as having 3,003.9 cubic inches and a Maryland bushel has only 2,800.7 cubic inches.

Obviously, the Atlantic States Marine Fisheries Commission should be asked to standardize the oyster bushel.

Conclusion

This brief review of the laws applying to the oyster industries of several states emphasizes the need for an indepth study of the oyster-related laws of Virginia and their impact on the oyster industry. The goals in modifying those in Virginia should be compatible with the biological and environmental as well as socioeconomic factors. Effort should be made to secure compatibility between states in those areas where uniformity is useful or necessary.

Efforts must be made to develop laws and regulations for Virginia which will result in increased realization of the natural potential for oyster production, sustain a viable and profitable industry, provide employment to as many individuals and firms as possible, and to perpetuate the resources and their productive potential.

CHAPTER XIII

SUMMARY AND RECOMMENDATIONS

CHAPTER XIII. SUMMARY AND RECOMMENDATIONS

Introduction

Historically the oyster industry of Virginia has passed through six phases. The first started over 200 years ago and was characterized by underutilization of a huge population of oysters existing throughout most sections of Tidewater. Beginning in the mid-1800's the second phase began.[1] It was characterized by increasing demand and production caused by the increasing growth of our population, especially along the Eastern seaboard. Production, generated in response to this demand, grew eventually reaching a plateau during the third period lasting from 1894 to about 1912 with annual harvesting ranging from about 5 to 7.5 million bushels.

A gradual decline in landings was associated with overharvesting of the public beds which fell to a low in the fourth period from 1931-1932 when annual production from the State declined to 2,396,287 bushels. The fifth phase began shortly after this as landings increased to about 4.0 million bushels in the 1958-1959 season due largely to production from leased or private bottoms. The sixth phase, which we are now

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[1]According to Brooks (1891) demand for Chesapeake Bay oysters increased markedly around the time that the oyster packing business began in Baltimore in 1834.

experiencing, has been characterized by a catastrophic reduction in production which began when MSX entered the Bay. This last decline has been continued by a complex and interwoven series of events in which MSX and other diseases, pollution and socio-economic aspects have all interacted. During the 1974-1975 period annual production from private and public bottoms totaled only 895,597 bushels!

In the preceding twelve chapters we have described the most important individual facets of the activities of nature and man affecting the production of oysters. The scope of matters analyzed can be reviewed by reference to the Table of Contents.

The drastic reduction in landings of oysters since 1961 has been associated with several factors. MSX caused the initial decline. Afterward, an additional and continuing reduction occurred not only in waters of higher salinity affected by the disease, but also statewide in disease-free low-salinity beds, and even on Seaside of the Eastern Shore in those high-salinity waters where MSX is not a problem. The drop has taken place on Baylor Grounds and on leased bottons.'

This seventeen-year decline in oyster production from Virginia waters has occurred and persisted not only because of biological and environmental problems such as mortalities due to diseases or predators, lowered brood-stock levels, lowered setting rates or pollution, but also for economic causes. Rising production costs, stagnant dockside prices, consumer resistance, failure of the industry to adjust to modern production methods, inadequate management by industry and by the public sector, and competition from growers and harvesters outside of the State, have all contributed.

With so many factors operating it is difficult to separate or rank them completely and, in fact, some can never be evaluated separately because of their intertwined nature, yet clarification is possible. Admittedly, all facets of the problem are not equally understood and further study and analysis is needed but one point is quite evident: to bring production of oysters from Virginia waters back to their pre-1960 levels, or even to pre-1900 levels, whichever goal is selected, several of the pressing problems, biological as well as economic and sociopolitical, will have to be solved. To remedy or obviate the biological and environmental problems without correcting the essential elements of public and private management practices or improving the economic or technological restrictions will do little to rectify the present deplorable state of the oyster fishery. Problems of all phases of the industry will have to be addressed concurrently--or at least close upon one another. It will not be easy!

Despite the difficulty associated with this complex task, it is our conviction that marked improvement in production at all levels within a reasonable period is possible and every effort should be bent toward revitalizing the public and private sectors of the industry. We intend to review the major causes of the reduction in oyster production from Virginia waters and recommend remedial measures. To do this it is necessary for clarity that definitions of the various words and phrases describing the oyster industry and the factors affecting it be clearly understood (Chapters I and II). For example, one cannot use the phrase "oyster production <u>from</u> Virginia waters" to mean "oyster production <u>in</u> Virginia" since many oysters processed by the Virginia oyster industry are grown in out-of-state waters and are merely shucked, processed and packaged here. They are products of the Virginia oyster industry but not of Virginia waters. Obviously, both bring money into the Virginia economy and create employment. One must also separate actual <u>production on the bottom</u> from those harvested <u>as</u> seed, soups or markets and also characterized as <u>production</u>.

The Decline in Production

The major factors involved in the decline in production of oysters from Virginia waters are as follows:

The Impact of MSX

MSX was the cause of the initial drop in production on public grounds and leased bottoms in the Chesapeake Bay and the lower ends of its tributaries where fall salinities average about 15 parts per thousand or above. It struck oyster populations in these areas in 1959 and caused severe mortalities in all age groups, except newly-set spat.

The Magnitude of the Decline on Baylor Bottoms and on Leased Acres

A major point established in this report is that it has been largely the drop in harvested production from leased bottoms since 1960 (after MSX) which has been responsible for the catastrophic decline in Virginia's total landings. The 100,000 to 130,000 acres of bottoms under lease from 1951 to 1960 produced nearly 5 times more oysters than the 243,000 acres of Baylor bottoms. Average production from all leased acres from 1951 to 1960 was about 2.6 million bushels. This declined to about 556,000 bushels annually in the 1971 to 1975 period (79%). On Baylor bottoms, for the same periods, annual production went from about 550,000 to 370,000 bushels (32%).

Lowered Setting Levels

While MSX caused a decline in the numbers and densities of seed, soup and market oysters on the beds in high salinity locations, it also indirectly influenced landings in lower-salinity regions by impairing setting. The cause of this indirect damage has been a reduction of the brood-stocks of adult oysters which produce the larvae that set in regions often far removed from where the parent stocks are living. The consequence of this reduction in brood-stocks has been far reaching. It has resulted in fewer larvae in the water, which has meant lowered setting levels of oysters. This has resulted in fewer seed to transplant and fewer soup and market-sized oysters to sell at maturity.

In the lower James seed area this effect has been especially severe, since it has resulted in a 50% decline in the numbers of seed oysters in the vicinity of Wreck Shoals from 1965 to 1972.[2] Similar declines in setting and of numbers and density of seed and other young oysters have been noted in other areas during the same period.

While strong evidence points to MSX as the cause of reduction in brood-stocks in the James River area and hence of larvae which can set and develop into spat as the major factor responsible for lowered setting in that river, other factors may have contributed. For example, chlorine and chlorine

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[2] In 1974 there was an unusually high set of oysters in the lower James River beginning at Wreck Shoals and extending to Nansemond Shoals. While this set may have temporarily reversed a trend which started in 1960, there is no evidence that it will be repeated in the near future, and in fact, the 1975 set was much lower.

derivatives once thought harmless under estuarine conditions have been found to be extremely toxic to oyster larvae at very low levels (i.e., 0.005 parts per million) and concentrations exceeding these levels have been found in parts of the James seed area. The sources of chlorine are sewage treatment plants, refineries and power plants, or other chlorine users.

It is also possible that MSX is synergistic with increased pollution level. However, set has also declined and mortalities have occurred in areas which are not (as far as we know) affected by chlorine or other detectable or known pollutants. While chlorine may be implicated as a cause for lowered setting, other chemical substances as yet unidentified may be responsible as exemplified by the recent finding of Kepone in the James River.

Whatever the cause or causes (and they may vary from place to place and time to time), the lowered level of setting is one of the major problems needing further attention by both science and management because seed is vital.

The Importance of an Adequate Seed Supply

Without a reliable source of high-quality, low-cost seed the private oyster industry as it exists today, with its dependence upon seed from natural waters, will cease to exist. The public beds (those which derive their populations naturally and replenish themselves) also need an adequate set for their survival. Those with diminished levels of setting will continue to decline in productivity and then stabilize at much lower levels of production (provided fishing pressure stabilizes, which it will when economics dictate).

Different Problems Face Leaseholders and Those Working or Managing Baylor Grounds

The problems facing private growers who operate using leased grounds are not the same as those facing the public managers (VMRC) and users (the tongers) of the public or Baylor Survey grounds. Though individual private growers or private oyster companies are or have been bound to specific regions or areas, the private segment of Virginia's oyster growing industry has greater flexibility than those dependent upon Baylor Grounds with their fixed locations and boundaries, and their patent dependence on a natural set, and on public monies.

Failure of Leaseholders to Relocate After MSX or for Others to Increase Production in Non-MSX Areas

Undoubtedly, MSX was the immediate cause for the severe declines in oyster landings in Virginia which began in 1960 in that it killed millions of bushels of oysters on leased beds in the higher-salinity, downriver beds and in the lower Chesapeake Bay. This eventually caused catastrophic economic problems for at least four major oyster-producing companies and severely dislocated many others. With the advanced warning provided by concerned marine scientists (from VIMS, Rutgers, and NMFS among others) as well as by oystermen from the Delaware Bay region (which experienced mortalities first) some companies were able to harvest and dispose of their oysters before mortalities became severe, thus reducing their losses. Some did nothing and suffered severe economic disruption. Some even perished. In no case has either one of the four major companies then occupying leases in the lower Bay area been able to resume former levels of productivity. Two have gone completely out of business.

Interestingly, neither of the four largest companies relocated in non-MSX areas to continue production at high levels despite suggestions of scientists to do so. We have pondered their failure to do so ever since. Perhaps good low-salinity beds were not available to them.

After this initial negative impact of MSX other factors began to operate. Most of the remaining oyster growing companies operating in lower-salinity waters, where MSX was not a factor in survival, did not increase production materially to fill the market void left by the withdrawal of the major lower Bay producers (Chapter IX), though a few did increase harvests immediately after the disaster. Instead the needs of the oyster packers (that stage or segment of the industry which packs and/or processes for dispersal in the marketing network) in Virginia have been increasingly satisfied by imported oysters produced on the public rocks in Maryland.

The reason or reasons why the oyster growers of Virginia failed to increase oyster culture activities in regions less prone to MSX damage and thus maintain production in Virginia waters are complex and still only partially understood, but they are largely based upon economic factors related to increased costs of production, transport, processing, marketing and other operational aspects of oyster culture. Discussion of the major economic factors involved follows.

Stable Wholesale Prices and Consumer Resistance to Higher Prices--Less Profits to the Growers

Since about 1964 the demand for oysters at the consumer level seems to have reached a plateau. Apparently, the reason for this has been associated with consumer resistance due to the high price of the marketed product. The effects of these stable demand levels have rebounded down the chain of supply and demand through the various middlemen to the processors and packers who, themselves, have resisted increases in prices paid to the growers or market tongers selling oysters at dockside. The net effect of this stable or declining wholesale price (adjusted for inflation) during this whole inflationary period has been especially severe on the grower operating on leased bottom.

The private grower has been faced with major escalations in costs of labor, plant and marine equipment, vessels, supplies and money in a period of stable dockside prices. This circumstance has reduced the margin of profit. As a consequence surviving growers find it economically advantageous to plant seed and culture oysters only on their best bottoms where they may expect the highest and most reliable yields. In quantitative terms, these are the beds on which a grower might hope to secure an average of two bushels of market oysters for every bushel planted.

The beds on which the historically profitable average yield of one-to-one could still be easily realized are no longer being utilized to the same extent because costs no longer warrant the effort, time and cost.[3] These and many lower-yield beds are still, however, held by lessees. In relation to this point, our study showed that about 40% of the leased beds are being held in units of a size inadequate for use as the sole source of full-time income for a person or a corporation. This aspect definitely needs the attention of VMRC.

Increasing Statewide Oyster Production

Statewide oyster production may be increased by appropriate action but the approach must be to remedy several aspects simultaneously.

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[3]If the cost-of-production to price relationship could be improved, either by lowering the former or increasing the latter, planting on average-yield bottoms might be renewed.

Leasing Unproductive Baylor Bottoms to Increase Statewide Oyster Production

Since economic factors have driven the grower to discontinue use of beds whose productivity is marginal and the existing economic situation seems unlikely to change in the immediate future, the State could provide incentives for growers merely by making more high-quality bottoms available so that more oysters could be grown per acre or unit of time or cost and at a profit--even at current stable dockside prices.

Many of Virginia's best growing areas, however, are within the Baylor Survey boundaries. Most are not being effectively used and hence are not very productive. A large percentage is unproductive. Among the possible remedies for the unavailability of good bottoms to leaseholders would be for the State to arrange to make unproductive Baylor grounds which it does not now use, or does not plan to use, available for leasing. Conditions of leasing these newly available bottoms should be such that active efforts at culture must be pursued upon them within a reasonable period of time or they automatically revert to the State. Furthermore, fees should be sufficiently high as to discourage "idle leasing." It is not our purpose to develop details of such lease arrangements here. That can be left to the management agency. We are confident, however, that suitable legal terms can be developed which will assure that the State's (the peoples') goals in making such leases of publicly-owned bottoms available are met and, at the same time, made attractive to potential private oyster culturists. Furthermore, this will not damage the State's own repletion efforts in any way but, on the contrary, will enhance them.

Altering Terms of Leasing Bottoms to Prevent Holding Without Use

To remedy the situation in which firms or individuals hold potentially productive currently leased or leasable grounds, but do not use them to produce oysters, conditions of leasing should be altered so as to prohibit acquisition or holding of leased grounds for purposes other than oyster culture--or such other productive uses as are in the interest of the State.

Using Leases for Purposes Other Than for Oyster Culture

Of course, there are other "legitimate" goals for leasing public bottoms to private entities or non-state public or semi-public bodies, such as other private or public uses or protection of amenities; for example, marl or shellmining, fishing, clam culture, diving, historical preservation, archaeological activities, etc. The potential use for usch leases should be identified and leasing conditions appropriate to the use arranged.

There is no question the current system of leasing shellfish-growing bottoms has allowed publicly-owned bottoms to be used for purposes other than shellfish production. Some of the uses have been questionable, such as to deliberately interfere with industrial and public construction projects. In fact, some shellfish beds have been more valuable for use in business or legal contests than in shellfish production. Often such suits have been contrary to public interests. There also have been "legitimate" uses other than oyster culture. Our primary purpose here is to consider the ills of the oyster industry and to suggest public and private remedies for those ills. We must leave detailed consideration of other uses of public bottoms for a later time. There is no question, however, that the entire matter of uses of the bottoms of tidal waters of the Commonwealth must be carefully reconsidered and revised. Current leasing arrangements, which incorporate the fractionated and ill-considered conditions of the past, are no longer sufficient to encourage economic development of and conservation (where necessary) of the valuable bottoms of Virginia. There is also no question that a new system of leasing is required, one geared to identified purposes for such leasing.

Consumer Demand May be Enhanced by a Reduction in Retail Price

Demand on the part of the ultimate consumer may be enhanced by a reduction in retail price since several competent economists have expressed the belief that demand for oysters is "elastic." That is, if the retail price is lowered then demand at the consumer level for the oysters will likely increase.

This increase in demand will help stimulate a higher level of production by the processor, and perhaps by the oyster grower or the tonger who catches market oysters, as well as by seed tongers.

A reduction in retail price, however, would be possible only if productivity is increased at no increase in costs of production or if production costs are decreased. These are critical issues. It has not been possible for us to evaluate seriously the possibility of increasing consumer demand by other methods such as increased efforts at advertising, improved processing or packaging and otherwise encouraging use by food vendors, restaurants, institutions, government agencies and housewives.

Management Steps Necessary If Demand for Market Oysters is Stimulated

If the demand for market oysters is stimulated as suggested above, without improvememts in the basic seed supply, there is a very real possibility that supplies of seed from currently productive public seed beds of the Commonwealth will not equal the demand, especially in light of the monetary limitations now applying to the seed-oyster repletion program of the Commonwealth. Ways of increasing seed supply include:

1. The encouragement of the development and successful operation of oyster hatcheries by private business and by public institutions

or agencies as necessary. Work along these lines is already well underway at VIMS and elsewhere by others, but it should be increased;

2. Making a reasonable number of areas where natural seed production may be expected or where such production can be undertaken or available for lease to private growers;
3. Increase the State's repletion activity;
4. Introduction and utilization of new technology to improve setting and increase utilization of existing levels of spatfall, and
5. Increasing brood-stocks with desirable traits in strategic locations so as to increase levels of larval production and spatfall.

Increased efforts are needed by scientific groups to understand details of the natural mechanics of natural seed production. It is especially important to identify the principal factors involved in setting and its ups and downs. Methods of improving setting should be developed and then, through this research and engineering development, the conditions that are identified should be remedied.

The State Repletion Program

The Repletion Program, carried out by VMRC, is supported by funds generated by State and Federal sources. Through this program the Commission assays management of the common-property oyster fishery resource. Historically, in Virginia and elsewhere, this has proven to be a very difficult accomplishment.

Virginia's Repletion Program, like those of many other states, is largely financed by State subsidy and it is not self-supporting. The returns to the State in direct taxes or fees from production resulting from the program, itself, never equal the costs of the State's efforts to maintain or increase the production of seed or market oysters on Baylor bottoms.

It must be quickly rejoined, however, that the economy of the State as a whole benefits from the program, probably far in excess of original expenditures. These are largely self-renewing resources which, like agriculture, if handled properly, produce considerable yields in relation to cost of production. Economists have calculated that a dollar developed at the basic level is enhanced about five times as it passes through various levels of the economy.

Unfortunately, the efforts of the State have not succeeded in reversing the serious downward trend of production from public ground (Baylor) which began many years ago.

Increasing Production

There are ways that the State can increase production on Baylor bottoms at little extra cost. Instead of being planted throughout the oyster-growing regions of all of the tidal waters of the State, as has been done for many years in the past, shells intended for cultch should be planted only in those known setting areas which may be classified as moderate to heavy by the standards described in Chapter IV. Furthermore, they should be planted only at those times which are most propitious biologically.

If additional funds can be secured, other improvements in repletion technology are possible. For example, the State's resources of buried or unused "reef shells" might be utilized to increase cultch planting. Also, hatchery activities which will contribute seed or brood oysters of desirable characteristics could be supported. A full list of the possibilities is presented later in this summary.

Failure to Follow Recommendations for Improving Repletion Activities

It has been remarked above that many recommendations which would have helped increase production have been made numerous times since the Civil War period. Unfortunately, most have been partially or totally ignored (see Appendix II). Deliberate avoidance of professional advice is not a new phenomenon but began in the last century when Dr. W. K. Brooks (1891) made many of the same recommendations as VIMS' scientists and others have since. Sad to say, resistance to scientific and engineering advice and to modernization has been true of all fisheries, not just those based upon shellfish. However, it is particularly unfortunate that public and private shellfish culturists have been so refractory to sound and useful advice since shellfish are the most readily susceptible to deliberate management of all marine animals.

Management Problems - Modifying Laws and Regulations

Four major public management problem areas are offered as examples in addition to those suggested above. They are:

1. Need for adoption of clear and consistent policies and goals to guide programs;
2. Need for more adequate and responsive management controls;
3. Need for laws and regulations which will allow management flexibility and meet these goals and fulfill policy; and
4. Need for adequate resource and production data which can be utilized by public management.

The present policy, as interpreted from explicit statements of policy (i.e., the Constitution of Virginia and, more specifically, Title 28 of the Code of Virginia and VMRC regulations), seems directed toward deliberate encouragement of oyster (and other fishery) production from Virginia waters and bottoms, as do other laws and implicit elements of law, various legislative and executive attitudes and actions, and other relevant regulations. Judging from both the explicit documentation and from the implicit evidence, it is intended that this production is to be ultimately handled by private individuals or companies as well as by individual tongers harvesting from the public rocks. In other words, established public policy is to enable and aid both the public and private sectors of the oyster-based industry.[4]

Many believe the public tongers to be the only recipients of State help. In actual practice, State effort is expended in the maintenance of both phases of the industry. Of course, the individual public oysterman is more directly dependent upon State expenditures for a larger percentage of his gross and net income than are the growers operating on

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[4]We have assumed that this policy, which is based upon 350 years of legislative and executive activity in Virginia, will be continued at least for the foreseeable future. Hence, recommendations are largely based upon this assumption. Different policies would require different combinations of the remedies suggested herein.

leased bottoms who are directly engaged in a more sophisticated approach to oyster production which requires a higher order of management activities. An analogy between oyster growers and oyster tongers in estuarine waters can be drawn considering the differences between farmers and husbandmen as against herb and root gatherers and hunters on land.

Also the oyster grower, the processor, and the survival of the extensive oyster-producing potential of the private sector are dependent upon State-supported efforts such as the Repletion Program (resource management), policing, environmental control, marketing development, research and engineering developments and other activities of the State.

As an example, the private oyster growers of the Commonwealth presently obtain 77 percent or more of their seed from James River beds managed by the State. There has been considerable discussion, much of it philosophical or political, over which segment of the oyster industry is most productive at least cost to "the people" and whether it is reasonable or wise to continue to support the "hunters" (the tongers) or to provide help to the entrepreneurial activities of the oyster growers and processors. Our investigation has shown that both elements are benefitted significantly by public management and research activities. There is no question, therefore, that the "private sector" of Virginia's oyster industry as it is carried out today is almost as dependent upon the public seed oyster rocks as are the tongers. Without publicly encouraged seed production the industry as it operates today would almost cease to exist. There is also no question that it could be made less dependent if the State were to alter its management practices and allow and encourage private growers to produce a much larger percentage of their own market oysters from their own seed. This objective would be possible if certain high-setting Baylor bottoms were made available for leasing.

Many of the oyster related laws and regulations of Virginia are outmoded. In fact, some were of little or no value when they were adopted or established. Many of the rest have lost their utility and meaning. Survival of obsolete or counter-productive laws and regulations help maintain production costs at higher levels than are necessary. For example, the requirements of the use of tongs on public bottoms when dredges are most effective. As another illustration, it is highly doubtful that the three-inch cull law where it is applied allows oystermen to harvest oysters at the most favorable sizes, if we wish to maximize yields (in terms of meats) or economic returns (in terms of possible uses). As an example of the latter, the soup markets prefer smaller oysters, many of which must be thrown back under the cull law.

Furthermore, present seasonal limitation on the taking of oysters is not realistic and should be changed to allow harvesting over longer periods to take advantage of favorable market conditions. Other questionable, inappropriate, inadequate or archaic laws or regulations are reviewed elsewhere in this paper.

A Need for Reliable Statistical Data on the Fishery

In our efforts to identify problems of the oyster industry and seek remedies, a major difficulty in evaluating the status of the oyster industry today (as of 1975-1976), as in the past, has been the almost complete lack of: 1) reliable, quantitative data on numbers and densities of oysters on and taken from the public beds (Baylor grounds); and 2) production figures from and inventories on leased bottoms. Additionally, reliable data related to fishing effort expended, catch-per-unit-of-effort, costs of production (public and private) and recruitment are generally not available. Socioeconomic data are extremely sparse.

Naturally, lack of important data has limited our study to a considerable degree. Continuation of the lax and irresponsible attitudes of the past which disapprove requiring and encouraging availability of all of the necessary data will seriously hamper efforts at improvement of oyster productivity (as it does with other fisheries). No businessman could work effectively without accurate records and an adequate knowledge of all costs and results including effort, inventory, productivity and profit. It is important to recognize that if deliberate efforts are made to rehabilitate the Virginia oyster industry by suggesting changes in public management policies, it will be necessary to have cost, effort and productivity data relating to all phases of the public and private sector of the industry. This information will be needed to allow evaluation of the effectiveness of those programs (or efforts) and to decide on changes, if and when necessary. We are encouraged that the Marine Resources Commission is now taking steps to secure more adequate data. It needs help and encouragement in this effort.

The Need for Research and Engineering Innovations

Research and engineering are essential supplements to effective management. Much scientific and engineering effort has been directed at the oyster fishery, especially since World War II. Despite the considerable research and engineering effort (mostly the former) directed at learning more about oyster-based economic and social activities, considerable ignorance remains about key aspects! Scientists, for example, still cannot transmit MSX from one oyster to another even though they understand the epidemiological aspects fairly well and can identify and induce disease resistance in selected oyster populations. On the Seaside, SSO is a major deterent to oyster culture but its life cycle is only partially known. We do not understand the phenomenon of acquired resistance versus genetic immunity to MSX or other diseases. Effective control of oyster predators remains elusive. We do not have yet a firm grasp of the normal and abnormal cytology and histology of oysters and their associates. Many of the aspects of the nutritional and environmental requirements of oysters are still mysterious. Many aspects of the oyster's ability to deal with toxic or damaging materials such as oil, pesticides and heavy metals must be learned in order that Federal, State and local management of wastes and water quality can be fully conducive to oyster cultivation.

Of major importance is the existence of considerable technological or engineering inadequacy. Reliable growing systems must be planned and arranged and more adequate mechanization must be installed to increase productivity and reduce costs for the industry. Additional discussion of needed research and the engineering developments and socioeconomic investigations which should be carried out is presented elsewhere in this Chapter.

Detailed Recommendations for Increasing Oyster Production

Following this introductory assay of some of the highlights of the detailed chapters presented above, it is now our purpose to consider each finding and recommendation in greater detail.

Leasing Unproductive Baylor Bottoms

We have clearly recommended the leasing of some of the presently unproductive grounds within the Baylor Survey in order that private growers can grow more marketable oysters on grounds which are likely to be more highly productive than those available to them now. Oyster production can be increased quickly with little or no direct cost to the Commonwealth by utilizing this promising management strategem.

Private growers, who have historically produced the major part of the landings, would benefit since their ability to produce marketable oysters in larger volume and at lower cost per acre would be enhanced.

If seed oysters continue to decline in numbers, it will be necessary to enhance seed production. This can be done at no cost to the State by making some of the seed-producing acreage within Baylor Grounds or other publicly-controlled bottoms in seed-producing rivers and reaches of rivers available for leasing to induce and enable the private growers to produce seed. It would also be possible to develop a seed-ground leasing plan which would allow persons who are now tonging to grow seed for their own use or for sale to growers. Such a move might make leasing of Baylor Ground more practical for tongers. A similar arrangement, with preferential treatment for tongers--at least in the beginning, might be made to encourage market oyster leasing of Baylor Grounds.

There will be some resistance to leasing of Baylor Grounds by tongers or by traditionalists in the industry or State government, but it should not be allowed to eliminate this highly useful management alternative. There are no good reasons to abstain from such an highly promising practice. All significant objections can be met. To do so would not lower the productivity of those Baylor Grounds retained under State management and would enhance overall oyster production. Neither will it damage the independent watermen. In fact, if oyster growers are successful, there will be additional opportunities for the independent watermen in that there will be greater demand for seed and more work on the water. Jobs for tongers, boat operators and others who work directly for the growers or processors, including shuckers, would be increased. Improvement in these sectors will encourage supporting businesses. Clearly, it is in the public's interest to encourage private oyster culture by all reasonable means.

Until very recently beds under management by private growers have historically out-produced those cultivated by the State for harvest by independent watermen from 2-to-5, this despite leases being limited to bottoms having little if any natural set and which are generally of much poorer quality and producing potential. There is little question that private enterprise, using its own money to produce seed and market oysters, can do as well as the State. In fact, it can do better in many ways, especially where control of shell and seed planting and harvesting is concerned. (The State is frequently forced by political and financial pressure to plant shell or seed in the wrong places and at the wrong time. Also, the State is usually prevented, by political pressure, from keeping areas closed or from limiting harvest. This, too, must change!) For decades many competent study groups, including government-sponsored commissions, and fishery scientists have recommended this action. Lt. Baylor, himself, urged emphasis on private enterprise in 1894 as have many scientists and even a number of State fishery commissioners. It will be to the State's interest to encourage this improvement.

Accordingly, we recommend that legislative action be taken as quickly as possible to allow the Marine Resources Commission to make selected, currently unproductive Baylor Survey Grounds available for private leasing and use. The Commission, working with the Institute, must determine which acreages should be leased first and which should be retained for State use. It has been established that such action can be taken by the General Assembly. We urge prompt action!

It would be worthwhile at this juncture to reiterate that quantitative information of the detail and accuracy that science and management should have concerning which of the public grounds are most productive or potentially productive is sparse or lacking. This shortcoming must be eliminated quickly! To do so careful surveys are needed, as will be discussed in more detail later. However, it is now possible to identify a sufficient number of currently unproductive bottoms to get this phase of the program going based upon existing knowledge and experience. As soon as the General Assembly makes leasing possible, the following should be done:

1. Areas to be leased should be determined by the Marine Resources Commission with assistance of the Institute of Marine Science. Those so identified should be subdivided into blocks, each with a minimum size of 50 to 100 acres. The larger the better!
2. Rights to lease such areas should be established by public bidding, perhaps with some preference given to individual watermen presently employed as tongers. There should be a minimum rental fee set at a sufficient level to prevent "frivolous" bidding and to help defray costs of public management.

3. Leases could be for a sufficiently long term to encourage private growers and yet short enough to protect the public's interest.

Ten years seems reasonable for such purpose. They should be renewable, but all should be quickly recoverable by the State on a reasonable and fair basis. Of course, the lessees' interests should be considered, but potentially productive public bottoms should not be leased without protecting the public's rights, interests and future alternative use options.

4. Proof of "use" should be required or the lease would become void at the end of the fifth year.

To assist in establishing proof-of-use, we recommend a law, or better, a regulation (since the Commission should be given more latitude in regulations and to do so laws should be reduced to a minimum), to require leaseholders to submit a sworn statement of use of the bottoms during the preceding year when payments for annual rental fees are submitted. Data required should involve yields, estimates of oysters on the ground and amounts of shell or seed planted. Failure to supply the required information should be established as prima facie evidence of lack of genuine intent to use and cause the lease to automatically become void. The Commission could be given the power to continue the lease should legitimate mitigating circumstances be established by the leaseholder and at his or her expense. Not infrequently, bad growing periods occur, and it is also conceivable that adverse economic periods would act against reasonable use.

Recommendations to Improve Seed Production

While the preceding recommendations for State action are intended to facilitate an increase in market oyster production by private oyster growers, it is also clear that steps must be taken gradually to increase seed production both at public and private expense. To assist in achieving this goal we recommend that a reasonable but limited quantity of Baylor Ground, known to have the potential of producing consistently good sets, be assigned to leasing by private growers.

Leasing requirements for seed-producing grounds would be more stringent than those suggested above for the currently "unproductive" market oyster producing grounds. Annual fees might be as high as $50 to $100 per-acre-per-year or higher (or a percentage of the seed yield for State repletion activities or a percentage of the profit--this arrangement would be more flexible than a fixed-fee rental and would allow for bad years) and proof-of-use should be required as a condition of lease retention. Shorter terms for leases and for the proof-of-use period should be arranged. It should be easier for the State to recover these beds, if the leaseholder does not use them for the purposes for which they are leased. The reasoning behind this set of recommendations is that seed areas would be established on the basis of their known success at receiving sets and their high survival rates for very young oysters. Furthermore, these grounds are most amenable to public improvements and they are now widely used by seed tongers. The market beds from the Baylor Survey Grounds mentioned above do not have these valuable characteristics. The higher fees and resulting increased revenues should be used to increase seed production on those Baylor Grounds retained for use "by the public," i.e., the individual, non-leaseholding tongers.

Those unleased, but non-Baylor Grounds which are in the James River setting (seed) area should also be made available for private leasing. Seed production is so vital that it should be encouraged in any reasonable manner!

Recommendations for Improving the Public Repletion Program

The Baylor Survey Grounds in the James River, and to a lesser extent the Great Wicomico and Piankatank Rivers, have produced almost all of the seed oysters planted by private planters (over 90%). Without seed from these three sources, the Virginia oyster industry as we know it would cease to exist!

Grave danger now faces the Commonwealth's oyster industry since there has been a decline over the past eighteen years in setting intensity in all three rivers with a resulting decrease in numbers and density of seed oysters. The exceptional 1974 season in the James is regarded as atypical for the period 1961-1975[5]; it is not a reversal of a trend. Even though it was a good set for the period, it did not compare with average 5-year sets of the pre-MSX period. As was pointed out earlier, the lower demand for seed may now be in equilibrium with the lower annual rate of production of seed. However, if demand increases or if the supply of seed itself declines, then natural seed stocks will clearly become inadequate. Therefore, we

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[5]Seasonal sets in 1976 were below average. In 1977 annual set was high in relation to the preceding 17 years, but was still less than the average set for the 1947-1960 period.

recommend that the main objectives of the Public Repletion Program be:

1. To increase the production of low-cost seed in existing, productive public areas such as in the James and Piankatank rivers;
2. To develop new seed areas in Virginia waters;
3. To identify new sources of seed outside Virginia;
4. To encourage private planters to develop their own sources of seed to augment seed from public bottoms, and
5. To encourage development and adoption by industry (and by the State, if necessary) of new techniques for producing and cultivating hatchery-reared seed.

Assuming that environmental factors such as pollution, predation, disease and other pests do not change markedly from their present patterns, the objective of more seed at a lower cost cannot be attained by the system of management presently employed by the State. Such a goal, however, may be attained by more efficient management as outlined below.

1. Shell-planting practices should be modified as follows:

It is recommended that shell not be planted in areas which historically receive low sets until those areas which do receive moderate-to-good sets have been completely replenished (Chapter IV). Shell should be planted only in known moderate-to-high setting areas, or in those moderate-to-high setting areas which might be discovered by the surveys which are also urgently recommended.

Areas which, according to present knowledge, should receive shell-plantings for the purpose of growing seed are listed in order of their importance:

a. The entire James River from Wreck Shoals downriver, especially the seed beds which are producing at this time--Traditionally, much of this valuable area has not been shelled due to the complaints of tongers who believe that planted shell "dilutes" the catch and makes culling more difficult. It obviously does, but this effect may be eliminated by planting shells on barren bottoms which will be located by surveys. Furthermore, shelling of currently productive bottoms may well be necessary to keep them productive! In such cases the need for full productivity must outweigh convenience to the harvester. Therefore, it is recommended that shell be planted in the James over those wide areas which do not have harvestable quantities of seed or anywhere where shell is obviously needed regardless of complaints. The seed beds must be maintained at all costs! Without them there will be no oyster industry or no tonging activity. Old, partially buried shell reefs could be located and restored since the presence of such reefs indicate potential for use. This would have to be done carefully and deliberately because such reefs may have "died" because oysters could no longer survive there.

b. The Piankatank River and the Great Wicomico River--In the latter case, however, shell should not be planted until the problem of low oxygen levels is thoroughly investigated. It has been reported that the low dissolved oxygen condition in the Great Wicomico results from residual and continuing contamination from wastes generated by the menhaden fishery and associated processing plants. The validity of these reports should be investigated.

c. In the lower York and Rappahannock rivers where shellbags and shellstring studies have disclosed areas of moderate setting--Beds recommended for shell-planting are those below Towles Point in the Rappahannock and those extending from Gloucester Point to Tue Marsh Light in the lower York. Seed raised in these areas might show acquired resistance to MSX. If drills come back in these areas, then the seed could be moved prior to its being eaten as will be outlined. Drill levels must be monitored in all areas!

d. On the Seaside of the Eastern Shore where many bottoms receive moderate-to-high sets.

e. Recent studies, outlined in Chapter IV, indicate that shells planted by VMRC in the Poquoson River area and in Lynnhaven Inlet have received moderate-to-heavy sets during the past two or three years and that survival has also been good. These sites seem to offer great potential as seed areas, and they should continue to receive trial plantings of shells especially in the tidal creeks around Plum Tree Island in Poquoson. Seed grounds in each might have to be delineated and set aside.

2. It is even possible to utilize drill-infested beds to increase seed production, especially where the setting potential is high. If a set of oysters is obtained on shells in an area where the oyster drills are active, it should be transplanted in October or November of the first growing season to a drill-free area. Areas where drills are or may become a problem are

the Piankatank, the lower Rappahannock, the Bay between the Rappahannock to the York River, including Mobjack Bay and the lower York, off the Poquoson River, off Plum Tree Island and in Lynnhaven Inlet. Drill abundance varies with time and space. Recently, Tropical Storm Agnes killed many drills in these areas. If surveys disclose that drills here are scarce or doing little damage, then the seed oysters should be allowed to remain where set, provided they are not too dense for proper growth. Settings that are too dense should be thinned in accordance with guidelines provided below. Monitoring of natural conditions, drill activity, oyster condition and survival would be necessary.

3. It is further recommended that decisions to move seed from the areas where the set is obtained for planting elsewhere or to allow it to remain and grow to maturity should be based on the following considerations:

   a. High-density seed (over 500 spat-per-bushel) could be used where predation will take a toll, but where sufficient numbers will survive to allow a 2:1 yield. Contrariwise, low density seed should not be exposed to predation.

b. Moderate-density seed (130 to 500 spat-per-bushel) could be transplanted to suitable growing areas so oysters will not be unduly crowded as they reach maturity.

c. Shell with counts of about 130 or fewer spat-per-bushel should be allowed to remain in place where the small oysters will grow to maturity or perhaps even receive an additional set in the next setting season.

d. Seed setting in Type I or Type II MSX areas should be allowed to remain in place to help build brood-stocks, or it should be transplanted to other growing areas where MSX is a problem since such seed may have acquired resistance to MSX. However, if drills are abundant in the prospective growing site within Type I or Type II MSX area, the seed should be moved to other sites where drills are not a problem. In any case, the probable disease-resistant qualities of such seed should be recognized and considered.

4. It is recommended that the Marine Resources Commission review its policy regarding the use of seed developed in the Repletion Program. Other things being equal, the least costly use of seed resulting from a "strike" on planted shell is to allow it to remain in place to grow to maturity providing that the area is one which will produce marketable oysters in reasonable time with minimum loss and maximum market-to-seed ratio (Chapter VIII). Unavoidable mortalities due to mechanical damage and stresses occur each time oysters (especially young ones) are taken-up, exposed during transfer, moved around in transfer and replanted. Further, each relocation requires labor and costs money, increasing production costs. For example, seed production in the Great Wicomico and Piankatank costs 98¢ per bushel. If the seed is left in place to experience only the normal mortalities during growth, no further costs

or unexpected losses are involved. If it is dredged, moved and replanted, seed costs rise by 66¢ or more to at least $1.64 per bushel and deaths due to damage and stress usually reduce productivity.

5. It is recommended that the Commission carefully review the percentage of its annual seed oyster production derived from its repletion activities (outside the James) which will be allocated for its own use, i.e., for replenishment of retained Baylor Grounds. In the future the Commission should utilize a higher percentage of this seed in replenishing brood-stocks or in growing market-sized oysters (for the soup and chowder, shucking or half-shell trade) on the Baylor Grounds. If it sells to private interests the price should be more realistic in respect to the cost of raising the seed.

6. We recommend that the Commission take all possible steps to optimize set on the shells it plants. Certain historical practices will have to be revised to do so. We are encouraged that steps along these lines are already being taken by the Commission. However, further useful changes can be made and shell-planting can be even more fully directed to

good setting areas and suitable times. It must be noted, however, that there will be certain sociopolitical costs in changing some of the traditional practices. The tongmen, industry and some of their supporters may object. However, the benefits to be gained should not be overlooked, denied or avoided merely because of political pressure. Tongboats and oystermen are, by and large, mobile, and eventually all (including the tongers and processors) will realize the wisdom and necessity of such management actions as they share in the benefits, the value of more realistic and productive repletion practices. Where superannuated oystermen or vessels exist which the political system decides must be served, i.e., a "senior citizens program," special arrangements can be made. Likely, necessities for such arrangements will be few.

In the past, costs of planting, proximity of shell piles, availability of cheap labor and the sociopolitical pressures to have shell planted "in our district" have largely dictated where and when shell were to be placed into the water. If the objective is to secure maximum sets-per-bushel of shell planted as it properly should be, the concept of timing shell plantings to keep costs down or positioning them to respond to pressures is not appropriate and should be abandoned. Shell at 40¢ a bushel which obtains a set because it is clean when placed overboard and arrives on the bottom when larvae are ready to "strike" is inexpensive when compared to one or even two plantings of 27¢-per-bushel shell put overboard at the wrong time or place which receives little or no strike! We recommend that the Commission adopt a policy of paying the price necessary, even a seasonable premium, if required to achieve this end, to have the shells planted at the optimum time and place.

7. We recommend that gear and techniques be developed which will efficiently prepare beds to catch maximum spatfall. On many beds, shells become heavily and quickly fouled with a scurf of small plant and animal forms as well as mats of colonies of bryozoans, tunicates, sponges, barnacles, etc. Even new shell plantings which are mistimed (and there will be some even under the best shell-planting program) quickly become fouled in summer. Oyster larvae cannot strike effectively on shells in

this condition and the cultch is of little value for seed production.

In some regions or unusual years, fouling is reduced naturally due to changes in environmental conditions, usually by abnormal flows of fresh water which reduces salinity, and higher oyster sets are made possible. In many localities, however, such conditions do not exist and fouling and silting is so heavy that setting is regularly or frequently interferred with or even prevented. And it is these areas which would require regular attention. Shell cleaning programs, of course, would have to be based upon detailed historical and current knowledge of specific beds. Two approaches to cleansing cultch are suggested below.

Commercial growers, the Institute, and the Commission have long conducted casual experiments or made occasional efforts at cleaning the shell beds by "harrowing" them with a toothed (and bagless) dredge just prior to historical setting time for the area. The limited tests conducted by the Institute and the VMRC of those "experimental" treatments indicate that it works if properly timed and conducted in moderate set areas (Chapter XI). Unfortunately, "harrowing" in this manner is time-consuming, inefficient, and at times of limited effectiveness. Possibly, as a result of these limitations, it is not widely practiced.

Considering several relevant engineering developments of the last decade, it seems likely that efficient gear to agitate and turn the shell operated by mechanical or hydraulic power can be produced.

These aspects will be discussed elsewhere when research and development needs are examined.

8. It is recommended that the Commission investigate the advisability of resuming the use of reef shells harvested from Virginia waters as a means of reducing costs of the State's Repletion Program.

The reef-shell program conducted by the Commission in cooperation with Radcliff Materials of Norfolk, Virginia, with occasionally-followed advise from the Virginia Institute of Marine Science, from 1962 to 1967 was successful in providing the State with large quantities of shell to be used for cultch at little cost.

In this program Radcliff Materials used (or sold) a portion of the shells as a raw product for cement production. Royalties to compensate the public were provided to the Commission, usually in the form of planted shells. While there were problems associated with this particular arrangement (and we do not recommend a return to the shell-mining industry as it was originally conducted) the operation effectively demonstrated that shells suitable for cultch now lie buried beneath the surface of the bottoms of our rivers in many locations.

In the past few years (since 1973) the Commission has imported several million bushels of reef shells annually from Maryland. Comparable shell available in Virginia might well cost less than that from the Upper Bay.

We recommend that these possibilities be examined carefully by the Commission in concert with VIMS. Part of the examination should involve a thorough survey to determine the magnitude, potential and conditions of availability and use of reef shells in Virginia. At the same time, the cost and potential of securing reef shells or other suitable cultch materials elsewhere should be carefully investigated to enable a fair comparison of costs, availability and promise. Should the Commission decide to proceed with a local reef-shell program, which might well be done prior to or during the studies described above, mining could be done on a regular contractual basis for the Commission by an established dredging company.

Should shell mining by contract be resumed, adequate surveys of shell resources must be arranged. Realistic knowledge of the resource is necessary for proper management!

9. We recommend that the Commission, working with VIMS, undertake a comprehensive program of monitoring the State's Repletion Program. Improvements in monitoring and data acquisition have been made in recent years by the Commission and this progress is commendable but more should be done. The data which must be secured should be: 1) quantities of shell or seed planted; 2) nature of shell or seed planted, i.e., size, condition, mortalities, and 3) final yields. The areas involved should be accurately and precisely known, as should effort and costs.

10. We recommend that experiments devoted to evaluating, developing and utilizing hatchery-produced seed be

more actively pursued by the State. It is already possible to rear seed of known parentage and predictable characteristics, i.e., features, shell shape and thickness, disease-resistance, in large quantities under controlled conditions. Further, we can determine time of spawning and the speed of passage of the larvae through the juvenile stages to maturity. As with agriculture and animal husbandry, controlled and predictable developments seem most promising.

While laboratory production of seed is now a technical reality, problems remain regarding assurance of the survival of such seed in nature so that it will reach market size. We should discover how to economically rear seed to market size under more tightly controlled and predictable conditions. The promise warrants the costs and efforts required.

Preliminary tests show up to 50 percent survival of laboratory-reared, cultchless (and uniform) spat in low-salinity regions. This compares favorably with survival of naturally-produced seed. Unfortunately the price per oyster of cultured seed is about twice as high as that of James River seed of much larger size, but we believe that the unit price may be reduced through research on improvement of the technology. If price can be reduced, or survival increased or other advantages which change the economic picture are developed or discovered, hatchery-produced seed will be most useful in improving the State's (or industry's) Repletion Programs.[6] The advantages possible in hatchery-produced seed are:

a. Disease-resistant seed can be produced for planting in areas where disease agents are prevalent. Seed, resistant to MSX, is now available as a result of research done by VIMS scientists. Resistance to different diseases such as SSO (on Seaside), <u>Dermocystidium</u> and others will

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[6] or if costs of natural seed production increase or natural seed is no longer available

undoubtedly be developed with further research.

b. Seed with other characteristics, such as rapid growth, high meat quality, good flavor, uniform shell shape and fast-growing, thick shells (for predator resistance), can be produced in quantity.

c. Additionally, there is a need to increase survival rates of hatchery seed on high-salinity growing beds through research. Even with this need, it is our opinion that hatchery-reared seed can be planted and reared successfully on many large areas of bottom where salinities are low and where predation by drills and even crabs is reduced.

11. Natural seed is a valuable product of natural setting beds. An adequate seed supply is the foundation and keystone of the oyster industry. It seems likely to us that revisions in current regulations and laws governing the James River seed beds would result in more efficient utilization of this valuable resource. Hence,

we recommend that current laws and regulations regarding the James River seed area concerning such factors as season of harvest, leasing bottoms, openings and closures of beds, etc. be reviewed by the Commission and the Institute and revised as necessary. (This may require legislative as well as executive action.)

Evaluating the Resource and Improving Utilization

Virginia does not know the extent of the resources available to it for growing oysters or other shellfish from its tidal waters. Furthermore, current practices and arrangements for leasing the public's bottoms, for raising money for replenishment and conservation, for related research and development activities and for gathering data for management are inadequate. Eliminating these weaknesses is of major importance to improving the management and utilization of this self-renewing, economically and socially valuable resource. Steps required are as follows:

1. We recommend that a thorough and careful survey of the extent and quality of the Baylor Grounds, including the numbers and density of oysters present in each area,

spatfall, setting potential, survival potential and other factors, be conducted.[7] While there have been some efforts along these lines by the Institute, and we have some knowledge of numbers and density on a few specific sites and, understanding the setting and growing potential of most areas, there has been no evaluation of a large proportion of the acreage incorporated within the limits of the Baylor Survey since a study was made in the James River in 1909. This can be hardly considered as being current or all inclusive and we should move quickly to fill this sixty-five year gap. Possible plans for conducting such a comprehensive survey have been discussed in Chapters V, VI and VII, and will be repeated here.

2. We recommend that the Commonwealth take steps to determine the extent to which potentially productive public bottoms, ostensibly leased to private persons and companies for purposes of culturing oysters, are actually being used

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[7]A beginning attempt at developing and carrying out such survey is now in progress by VIMS. As of 1977 it was about one-third completed. It will be very useful but requires improvement. Additional time and funds are required to refine and complete these important efforts.

for that purpose. This suggestion is based upon our findings, described more fully in Chapters II and XII, that many leases are not now employed to produce oysters. Some have never produced quantities of oysters for lack of cultivation. Some have been actively cultivated, but only rarely. Some have been used regularly.[8] Since leases under the current scheme may be held for 20 years with an option for renewal at very little cost-per-acre and little financial risk to the leaseholder, lack of cultivation of such lands is probably quite extensive. Where potentially productive bottoms are involved in unused leaseholds, it amounts to lost oyster production for the State.

The recommended study should determine whether the bottoms are not being used because of being: a) actually unsuitable for oyster culture; b) only marginally productive; c) economically inadequate; d) affected by disease or predators; e) used in rotation (a reasonable practice); f) employed as a margin

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[8]Of course, some were never productive, having been unsuited for oyster culture for many years--or never.

or barrier (also a reasonable practice), and g) held to block other uses for purposes of law suits or whatever. These data should be used to: a) evaluate current leasing arrangements, b) determine the parameters for a new one, and c) recover for the State for reassignment for re-use those lands which are being held under false pretenses.

As has been noted previously, there are other reasonable uses for bottoms than oyster culture, such as clam culture, establishment and maintenance of fishing stands, or mineral production, which are also in the interest of the State to encourage or facilitate. Such uses should be considered in any revision of the leasing arrangement.

3. We strongly reiterate the recommendation that the system of oyster-fishery statistics be further improved. Major improvements over former practices have been recently instituted by the Commission, but they must be enhanced considerably with other data which would allow more detailed knowledge of productivity, effort, potential productivity, etc. Modern data-handling methods should also be used.

4. The need for more adequate knowledge of the fishery, itself, has been noted. Among the significant data gaps is knowledge of the location and area involved in repletion or harvesting activities, effort expended to harvest specific catches, and the total catch. The Marine Resources Commission should acquire "catch-per-unit-of-effort" for specific well-defined areas.[9] Such data along with data on numbers and densities of oysters occurring naturally on a specific bed or area of the bottom would help answer questions such as: Are seed production and availability increasing or decreasing in the James River or elsewhere? Are market oyster numbers waxing or waning? Is fishing pressure too heavy for the level of replenishment and the rate of growth of the resource, etc. [Basic or verification data (and verification of written reports by independent means must be involved) could be acquired by daily boat counts, including--for example, determination of locations fished, numbers of tongers or units of gear in operation, and number of

[9]The VMRC is now collecting some of these data.

bushels harvested, which could be determined with periodic counts from the air or from patrol boat or both.] Aerial observations, even with photography, as necessary for accurate counts and records would also be utilized for counts or for checks.

5. We recommend that the system of fees and taxes currently applied by the State be re-examined with a view toward updating the system and making the income from oyster production match, more nearly, the actual costs of maintaining an adequate public oyster management effort. The entire tax and fee system should be involved in this review.

   A special study commission, including a variety of capable and experienced representatives from the major interests involved (a mechanism that has been employed in earlier fishery studies and improvement efforts), could be convened for this purpose.

   Whatever the outcome of this recommendation, it is clear that VMRC should introduce a system for objectively determining whether or not the various yield or production data and the taxes paid for same are accurate. Some type of check or audit is obviously needed.

Availability of a plentiful supply of seed which can be produced and sold or purchased at a reasonably relative cost to that of market oysters is crucial to the oyster-growing industry. To encourage growers to plant more seed in these times requires efforts to see that such seed is available at a relatively stable and low cost. To maintain such a supply of seed while numbers and densities of seed decline will require: a) increases in productivity (mentioned above) or b) conservation efforts--perhaps both.

Our studies indicate that the supply of seed from Virginia seed areas is generally adequate to meet present levels of demand from the growers. Additionally, the demand for soup oysters (which are smaller than either standard shucking oysters or half-shell oysters) can be met from these same bottoms. However, should demand increase, the production of our seed areas, especially the James River, would be insufficient. If a significant increase in demand from private planters (or by soup houses, for that matter) develops or is anticipated, several alterations in the management system would have to be considered. A possible course of action would be to:

a. Restrict use of oysters produced on public seed grounds in the James to sale and use as seed.[10] We must remember, however, that the utilization of oysters in making oyster soup or stew, which has grown considerably in the last decade, is a legitimate use. They are being used as food and the use is profitable, aiding the entrepreneur, the workers, the harvesters and the State. The demand it creates does absorb natural productivity of a renewable resource and sale of oysters for the soup trade meets a market demand which might not otherwise be available to oysters. Jobs and income

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[10] Since about 1975 soup companies have not utilized James River oysters because of Kepone. Since Kepone is no barrier to employment of small oysters as seed, because they cleanse themselves quickly, the elimination of their use in the soup trade is likely the most serious damage done by the Kepone incident to the James River-based oyster industry.

are provided to tongers and growers (especially the former). Ways should be sought and found to allow both seed and soup demands be met.

b. Encourage Virginia oyster growers to increase the productivity of Virginia waters. To do so, the Commission should be prepared to restrict the sale of seed to the export trade to meet internal demands.

As a suggested conservation measure we recommend stopping the sale of seed for export when the Virginia export exceeds 15 percent of the previous year's production. We must note here, however, the need for caution. As has the "soup" market, export demand for seed has helped maintain a market for the output of individual oyster tongers. In the face of declining demand for Virginia seed (if the trend is not abated), it would be unwise to cut off or reduce this source of demand for our oysters and income for tongers.

It would be worthwhile developing and considering other strategies for accommodating the several purposes presented above, i.e., enhancement of seed production, enhancement of soup production, increase in market-oyster production and conservation and continuation of this valuable renewable resource.

Research Recommendations Which Will Benefit Both Public and Private Participants

Both public and private segments of the oyster industry are dependent upon ready and inexpensive access to sufficient quantities of palatable oysters which are or will be safe to eat whether for shucking or for the half-shell trade for the "soup" market, or merely for seed. There is a direct relationship between the quality of the oyster beds, the sediments under and around them and the water above them. If there are predators or disease, oyster population levels are affected. If the waters or the sediments are contaminated, the oysters may be killed, their life cycles may be interrupted, or they may become unsafe to eat or genetically damaged or whatever.

We must give consideration to maintenance of water quality suitable to growing oysters which can be eaten.

Consideration must also be given to biological and physical factors as well as to economic and technological aspects.

For public and private management to be able to operate effectively it must have adequate scientific and engineering assistance and advice. Much scientific knowledge of environment and biology exists. Expertise and engineering and other useful skills abound and more effective management is possible. Much remains to be learned and done, however, before we will be able to effectively manage the oyster industry with assurance and continuing profit.

It is to these investigatory requirements that the following is addressed. It is our purpose to use the list of needed research and technological study to develop research and advisory projects for the near, mid- and long-term research programs of the Institute. There are also tasks that the Marine Resources Commission and others must participate in or conduct by themselves. Though some of these recommendations for research and engineering studies have been presented before, they are repeated here in order that all may be arranged and available in this section.

1. The James River has received only one adequate spatfall (in 1974--about 500 spat per bushel) in over 17 years. Indications are that sets have failed in at least two other river systems,

i.e., the Great Wicomico and the Piankatank rivers, in the last three to four years. A continued trend toward low setting will seriously damage the Virginia oyster industry as it is now conducted.

Lack of brood-stock, caused by natural mortalities and overfishing, is implicated. However, other factors such as contamination from chlorine and its derivatives, Kepone and other pesticides acting by themselves or synergistically with other causes of debilitation may also be involved. Also, low levels of dissolved oxygen which develop in many places in late summer have gained added importance as probable causes. Only additional, carefully-done research can answer the numerous questions involved. Among the problems to be approached are:

a. Laboratory studies utilizing bioassay techniques should evaluate survival of laboratory-reared spat and the plankton used by larvae as food in water from the major river systems to determine the possible existence of lethal or sublethal factors in the water--for example, chemical contaminants in red-water blooms. If the existence of such substances is demonstrated, then an extensive effort by VIMS should be directed toward determining what substance or substances are involved. These initial tests might concentrate on chlorine and chloramines, Kepone, PCB's and others. Additional financial support to do the extensive field and laboratory studies required is necessary.

b. Oyster set has failed for the past four years in the Great Wicomico River (as previously stated) and oxygen has been demonstrated to be deficient in the bottom waters and sediments of this system during the spawning season.

A direct relationship between low oxygen concentrations in summer and early fall and low setting seems likely. Nearby fishmeal and oil processing plants may be the source of organic matter which causes the O_2 depletion, but natural conditions related to circulation of Bay water may also be responsible. This area should be studied carefully to determine what the basic causes are and what steps may be taken, if any, to remedy the situation. Field studies should evaluate BOD, COD, O_2 and H_2S values in that system to see if levels are low or high enough to kill oyster larvae or the plankton on which they feed (see additional recommendations for laboratory studies).

c. There is a possibility that fouling of shells on the bottom has increased over the past ten years due to increasing nutrient enrichment of the water (see Chapter IV). If this has occurred it might be one of the reasons for the decline in setting of oyster larvae on shell substrate in the James, Great Wicomico and Piankatank rivers.

2. The oyster disease MSX continues to be the second major problem needing further study. All related signs indicate that it still remains the major reason why growers cannot raise oysters effectively

on their down-Bay or downriver high-salinity beds. It is the reason why Baylor Grounds in Type I and II areas are producing less. Many unanswered questions, which if answered could lead to possible control measures, remain. We, therefore, recommend:

a. Determine by laboratory studies the mechanism of transmission of MSX from one oyster to another. We must find out if the disease is waterborne or whether there are vectors or reservoir hosts involved.

b. To accomplish these objectives, experiments will require controlled production of MSX infections by exposing experimental oysters to MSX cultures of known purity. But MSX has not as yet been cultured. Hence, renewed effort should be devoted to development of pure cultures of the MSX disease-producing microorganism.

c. A study should be done to determine the effect of low salinity on oysters infected with MSX. That is, do freshets caused by storms like Tropical Storm Agnes eliminate MSX from oysters or reduce their incidence or virulence?

d. Studies on breeding MSX-resistant oysters should continue, but a change in emphasis should occur. Effort should be now shifted toward evaluating present stocks on suitable experimental plots in MSX regions. The possibilities of restoring oyster production in Type I and II MSX areas in all rivers in Virginia should be tested by making trial plantings, perhaps one acre in extent or more (as required), of James River, Piankatank and/or laboratory-raised resistant seed.

The purpose of this program would be to determine if it is possible in these locations to realize the "break-even" point of a bushel of marketable oysters to one bushel of seed yield and how long it takes oysters to reach maximum biomass or the size of maximum economic yield. These would be long-term studies.

e. We should make every effort to determine the exact nature of MSX resistance. Is it genetically determined or is it related to acquired resistance? Research along these lines should be started immediately.

f. Similar studies should be made of Dermocystidium marinum (Dermo) and other disease-producing organisms.

3. The third major problem needing further research and development effort in Virginia is development of practical methods of controlling oyster drills. While drills have become less of a problem, relatively speaking, in Chesapeake Bay in the last six years because of Tropical Storm Agnes and MSX, they remain the major problem on the Seaside of Virginia. Furthermore, drills will again become significant when oyster culture is resumed in full throughout the areas where it has been reduced, especially if MSX-resistant oysters are planted in high-salinity areas (see Chapters IX and XI). We recommend, therefore, the following possible lines in research:

a. Control of drills by sterilization of males and introducing them back into the population as outlined by Hargis et al (1957).

b. Development of chemical barrier coatings on the surfaces of oysters which will repel oyster drills.

c. Utilization of suction-dredging or other mechanical techniques to clear large areas of drills.

d. Study possible means of killing drills over large bottom areas using "gel" coats on the bottom which will allow hydrogen sulfide to generate below it so that it will kill all drills.

e. Oysters often set in an area where drills are abundant, but the small oysters are nearly always killed by drills before the seed grows large enough to move. If drills were controlled, then the down-river areas might become sources for inexpensive seed. It need not be added that this seed (especially if it competes with James River seed in price, survivability and growth) is bably needed by the industry.

It has been shown that oysters raised from the spat in MSX regions would be more resistant to MSX than older seed matured in non-MSX areas. If seed were cultured as outlined in the preceding paragraph, then there would be the added bonus that it might be profitably grown to maturity in MSX areas (see Chapters IX and XI).

4. The oyster pathogen, SSO, and the large oyster drills, _Urosalpinx cinerea folleyensis_ and _Eupleura caudata etteri_, are the major biological problems facing oyster growers on the Seaside of Virginia. Since the discovery of SSO-disease, its mortality pattern in respect to season and part of its life cycle have been described. However, nothing is known about how it is transmitted or possible effects of temperature and salinity on the organism. Knowledge of these factors might enable growers to manipulate their culture practices to minimize the severity of this disease. We recommend:

   a. Continued monitoring of the incidence of this disease on the Seaside.

   b. A series of laboratory studies to determine how SSO is transmitted from one host to another.

c. Laboratory studies to investigate the effects of low salinity on SSO to determine if low salinity *per se* is the reason why SSO is not a problem in Chesapeake Bay (see Chapters IX and XI).

d. Efforts must be made to induce genetic or acquired resistance, or both, to SSO disease in oysters.

5. An adequate supply of inexpensive seed oysters is vital if the Virginia oyster-producing industry is to survive and compete with imported oysters from Maryland, and with those from other oyster-producing regions in the nation (or enable independence and survival should outside sources fail). Therefore, every effort should be made to improve the quantity and supply of seed oysters. We recommend:

a. Assurance of an adequate supply of low cost seed in the future. To do so new sources of seed must be developed. Particularly desirable are sources which do not involve as much labor to harvest as is required by tonging. Some possible sources are spat collectors (such as the wire bags of oyster shells which are used by some private seed growers today) and hatchery-reared, cultchless spat.

b. Efforts to develop an efficient method of cleansing cultch in place should be vigorously pursued. One possibility is development of an efficient underwater harrow to turn up or uncover buried shell so it may be available to receive a good strike of small oysters. A possible gear design would include a strong "A"-frame which would be towed from a boat. Affixed to the base of the "A"-frame would be a steel cylinder to which are affixed flexible steel "tines." These would be rotated by an underwater hydraulic motor.

c. The use of marl and surf clam shells or other materials as possible cultch for spat attachment should be studied.

d. Lime (quicklime) has been said to control fouling on oyster shell so that oyster larvae may attach. Studies should be conducted along this line to establish its utility. Many other possibilities for improving setting can be developed.

e. To locate or develop alternate sources of seed, we recommend systematic, careful evaluation of growth and survival of small oysters from outside the Bay system. For example, Seaside seed is available in quantity but limited tests suggest it does poorly in low salinity areas of the Bay. Seed from Lynnhaven is abundant but has never been tried elsewhere (see Chapter XI). Perhaps the Lynnhaven River can be developed as a seed area. In a similar way, South Carolina seed, while abundant, is said to die extensively during colder winters in the Bay. However, these tests were, at best, limited and further studies should be made.

6. It is strongly recommended that the State, through VIMS, continue and expand its controlled oyster breeding program with the following purposes:
   a. To determine if an acquired resistance exists apart from resistance which has a genetic basis.
   b. To develop oysters resistant to SSO and *Dermocystidium* as well as to MSX.

c. To develop oysters which show a fast rate of growth as well as high-meat yields.

d. To evaluate the results of a., b., and c. above with a well-designed, statistically-sound program.

7. Hatcheries likely have a definite place in the future of both the public and private sectors. It is recommended that the State continue to encourage development of private hatcheries in Virginia. Toward that goal, we recommend that experiments and engineering developments designed to increase production and quantity of hatchery-reared seed, including validation of economics of hatchery and hatchery-based oyster culture, be vigorously pursued by the government, VIMS and industry.

8. It is recommended that research be conducted in Virginia on the use of ponds for experimental shellfish culture especially in connection with raising hatchery seed (see Chapter XI). Initial studies should concentrate on the use of ponds 12 x 40 feet with plastic liners and dyked "earch" sides. It might be necessary to experiment with ponds in different areas. These ponds might be

used to raise large numbers of small oysters for trial plantings in MSX studies. In respect to this last recommendation, it is recommended that initial trials be made using spat set on oyster-shell cultch. However, other studies might concentrate holding cultchless spat until it grows large enough to resist predators. Newer type predator-resistant collectors, such as the "French collectors" now being used by Dr. DuPuy at VIMS should be carefully tested.

9. An evaluation of material presented in this report and of the work being done at VIMS and elsewhere shows a dearth of research efforts in the fields of engineering development and in food technology. That is, while answers to biological problems are of use to industry, it is apparent that many of their economic problems can best be solved by new marketing methods, new ways of packing and selling their product, and new processing techniques. Also, oyster growers as well as tongers working the public rocks may be helped if machines are constructed to harvest oysters, to turn buried shell to increase spatfall, to open oysters, etc. Among a possible list of projects which may be of value would be:

a. Working with industry to determine its needs for new methods of food processing, marketing, etc.

b. Development of gear to process oysters mechanically, which would include machines to plant, culture, harvest, open and process oysters.

c. Investigate and evaluate the Pringle Heat Shock Method of gaping oysters and other opening machines and methods.

d. Determine ways to keep cownosed rays and other predators away from oyster grounds. Such things as fences and electrical fields should be considered and promising leads or variations examined.

10. There is a major need to study and understand the economics of the seafood industry. Questions which should be answered include:

a. Why have the wholesale market prices of oysters remained stable in the last ten years? To what extent would a drop in retail prices stimulate an increase in demand for oysters?

b. What is the consumer demand for oysters? How does it develop and change? Can consumer demand be increased significantly and for reasonable lengths of time? Can we capture a larger percentage of the market for Virginia?

c. Has promotion by advertising such as that now practiced by the Virginia Seafood Council resulted in increasing sales? If the study shows sales to have been increased, this activity should be expanded.

d. Would new and better processing help demand and sales and/or reduce production costs sufficient to create useful markets or increase economic profit?

11. It is recommended that studies of the lethal and sublethal effects of heavy metals, pesticides and other pollutants on all stages of the oyster's life history be more vigorously presented. The recent oil spill, chlorine and Kepone problems are excellent examples of why this work is vital. Included in such research would be consideration of the phenomena related to routes and pathways for toxicants in nature, uptake, distributions in the organisms, and duration of self-cleaning by the young oysters.

12. A pilot-scale depuration plant should be constructed and evaluated for its production in controlled studies on cleansing of bacteria or other polluting substances from oysters.[11]

13. Studies should be made in the James River at stations in mid-channel at 15 feet (4.6m) during September at Brown Shoals and Wreck Shoals to determine if eyed-larvae are present and the relative numbers at each station.

14. It is recommended that the effect of low oxygen and hydrogen sulfide on oyster larvae and their planktonic foods be studied in the laboratory since these two factors may be a major reason of the consistent set failures in the Rappahannock, the Great Wicomico and elsewhere in the Chesapeake Bay. Other aspects such as availability of broodstock, larvae, etc. should be studied in the field.

15. Every effort should be made by State and Federal officials to encourage expansion of the oyster-canning industry. We recommend that Federal laws be modified to permit canning of oysters from condemned areas. This is not unreasonable since crabs taken from these same waters may be canned.

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[11] Plans for this are underway but funding is doubtful (see Chapters X and XI).

APPENDIX I

APPENDIX I

License Fees

To help pay for the many functions it performs for the oyster industry and to keep track of the number of persons working in the fishery, the Marine Resources Commission must levy license fees on individuals and companies who work in the industry. These license fees must be paid annually before a person or company can legally harvest or process oysters.

The fee for each person harvesting oysters with hand tongs is $7.50. This applies only to people working on public or unassigned ground. Those working on leased or private grounds are not required to have licenses. Each person using patent tongs to catch oysters must pay a fee of $17.00. This, too, does not apply to people working on private grounds. The number of people licensed to harvest oysters by these two methods are shown in Table 65.

Provision is made in the seafood laws for licensing people to dredge on public ground (Code of Va. of 1950 and 1975, Supplement, Section 28.1-128), but it is very restrictive. Dredging on public bottoms may be authorized by VMRC only on certain oyster rocks in Tangier Sound and then only during December, January and February.

No fee is required of people harvesting oysters on private grounds with hand or patent tongs or by hand. A fee of $1.00 per boat is required for every boat engaged in dredging for oysters. People harvesting oysters from public grounds must pay more tax than those operating on private grounds. This can be understood when one remembers VMRC performs many more functions for the public harvester or worker than it does for the private planter.

Individuals who buy oysters harvested from public grounds must pay fees of $25.00 for each place of business which they maintain plus $15.00 for each boat or truck which they use to transport the oysters from the place of sale to the place where they will be processed. For example, one buyer who operates out of Menchville and has a fleet of ten trucks pays the State $175.00 a year. No buyer's license fee is required for a person to buy oysters from private grounds.

Each individual or company shucking or packing oysters is required to pay an annual license fee which is graduated according to the quantity of oysters handled. The fee schedule is presented below.

1. For any number of gallons under one thousand 3.00

2.	For ten thousand gallons or over, up to ten thousand	8.25
3.	For ten thousand gallons or over, up to twenty-five thousand	15.75
4.	For twenty-five thousand gallons or over, up to fifty thousand	30.75
5.	For fifth thousand gallons or over, up to one hundred thousand	46.00
6.	For one hundred thousand gallons or over, up to two hundred thousand	75.75
7.	For two hundred thousand gallons or over	150.00

We consider none of the license fees discussed above to be excessive. Most were enacted with acquiescence of industry representatives. Neither they nor any of the other monies collected have been sufficient to cover the full costs of regulation and administration of the oyster fishery over the last decade.

APPENDIX II

Suggestions For Improving the

Virginia Oyster Industry

APPENDIX II

This Appendix contains a compilation of many of the suggestions and recommendations made since 1900 to improve the oyster industry in Virginia. They include suggestions and recommendations made by the Virginia Fisheries Laboratory, later the Virginia Institute of Marine Science, and the Virginia Commission of Fisheries, later the Virginia Marine Resources Commission. Also included are studies by outside agencies as well as those made by special legislative advisory commissions.

Reports of the Virginia Commission of Fisheries

<u>1900 and 1901</u>

1. Proposed uniform rental law.

<u>1910 and 1911</u>

1. Proposed that a moderate use of "scrapes" is not injurious to some bottoms.
2. Asked for straightening Baylor Survey Grounds.
3. Advanced concept that "some states to the North have their planting beds subdivided, square plots taking in good, bad and indifferent grounds and the planter has to take no less than a square, paying from $5 to $10 per-acre-per-year (as in R. I."

1915 and 1961

1. This report suggests a repeal law prohibiting taking seed out of State.

1919 and 1921

1. Repletion was proposed and the Commission proposed replacing shell taken from natural rocks.

1926 and 1927

In March 1927, Gov. Byrd appointed a commission of seven to investigate every phase of the seafood industry. This was known as the Spratley Committee. It was composed of the following members:

J. C. V. Spratley (Hampton)
G. W. Lineweaver
J. W. Bowdoin
C. Hardin Walker
Col. J. E. Healey
O. A. Bluxom
W. A. Ballard

Report of J. J. Corson in Richmond News-Leader

1930

In 1930, J. J. Corson, writing for the Richmond News-Leader wrote as follows:

If the constitutional provision that the natural oyster rocks shall be maintained for the public benefit is to be obeyed, provision should be made immediately for the replanting of barren areas with shells and the closing of such areas until oysters have matured. If this is to be done it should only be attempted after accurate, scientific study has shown in which areas such planting may prove profitable.

Reports of the Virginia Commission of Fisheries

1931

The Commission recommended to the Legislature in 1931 the following:

1. Recommended that the State adopt a constructive program for the repletion of the natural oyster rocks of the State which are now productive, by the planting of shells thereon, and if such a program is adopted that a fund of $100,000.00 per year be provided for the purpose; and if any repletion program at all is to be pursued that a sum be provided sufficient to purchase and plant on said rocks at least 500,000 bushels of shells each year.
2. Recommended that the Commission be authorized to cause an examination of the public oyster rocks of the State as defined by the Baylor Survey, and after examination and surveys thereof to lease

such portion of said area as may be barren or incapable of self-rehabilitation in such manner and on such terms as the Commission considers will promote the interests of the State and the oyster industry.

3. That the Commission be given authority, when it deems it expedient, to make more than one assignment of 250 acres of oyster planting ground to one person.

4. That the Commission be authorized to cause a resurvey, according to fact, of the natural oyster rocks in those localities in which the original Baylor lines cannot be accurately established.

5. That the Commission be authorized to examine the new areas included in the waters of the Commonwealth by the definite establishment of the Potomac River boundary line between Maryland and Virginia; to cause the productive natural oyster rocks located within said areas to be surveyed and set aside for public use; and to lease the residue of said bottoms for oyster planting purposes in such manner and on such terms as the Commission may deem best for the promotion of the industry.

1935

In this year suggestions were made to develop seed areas other than the James River. Note: the Virginia Fisheries Laboratory (VIMS) had not as yet been established at this time and biological advise to the Commission was obtained from the U. S. Bureau of Fisheries and from the University of Maryland. The following is quoted from their report.

> Realizing that these beds (James River seed beds) which supply nearly all the seed for planting in Chesapeake Bay and its tributaries, may at any time be seriously affected if not totally destroyed by pollution from trade wastes, every effort is being made to build up a seed supply in other rivers...

1940 and 1941

The Commission recognized the need for scientific recommendations.

1942 and 1943

In the 1942-43 report by the Virginia Fisheries Laboratory to the Virginia Commission of Fisheries, it was suggested that a unit be formed for the collection of statistical data. This report also outlined several of the laboratory's long range objectives. These were:

1. To provide a sound basis for replenishing depleted oyster rocks.

2. To show how shell may be used economically for getting a high production of marketable oysters per acre.
3. To determine best locations for seed areas and for fattening.
4. Late summer and early fall suggested as a possible optimum planting time for shell.
5. This study achknowledge the damage done by drills.

<u>1944 and 1945</u>

In the report for 1944-45 the Virginia Fisheries Laboratory while not making specific recommendations to the Commission did point out several possible means of improving the oyster industry, and several objectives of the laboratory. These suggestions were largely the efforts of Drs. Menzel and Mackin.

1. Study setting in the York River and to see if fouling and drills might be controlled.
2. Study James River seed rocks and to determine how to prevent continued depletion.
3. The laboratory suggested that the Rappahannock River had the most important public rocks for the production of market oysters directly from strike. It pointed out that all rocks would produce more oysters if adequate cultch was properly planted.

4. The report suggested that the Corrotoman would support a sizable seed industry.

5. The report commented on the depleted condition of the Eastern Shore rocks and on the drill problem.

Virginia Fisheries Laboratory in the Report of the Virginia Commission of Fisheries

1946 and 1947

In this year the objectives of the laboratory program was outlined by Dr. Andrews. They were:

1. When during a spawning season a commercial strike might be expected.
2. Which of these strikes has the best chance of survival.
3. Why an effective set is not obtained in July.
4. When is the best time to plant shells.

1948 and 1949

A summary of several of those recommendations made in this report were:

1. That a large portion of available shells be planted in seed areas (good setting areas) rather than growing areas (poor setting areas).

2. That no shells be planted on soft bottoms or drill infested bottoms at present since large areas of more suitable ground are available for repletion now.

3. That we strive to get shells planted as late as the month of June -- provided shells are not lost to the State by such time limits.

4. That the most effective way of growing oysters on certain bars ("growing bars") is to transplant seed oysters.

5. That an accurate evaluation of repletion work will require careful marking of areas and data on the production of these areas.

6. The entire Corrotoman should be immediately developed as a seed area because of its good sets and poor growth. The resulting seed should be replanted in the upper Rappahannock above the limits of Dermo and drills.

7. In the lower Rappahannock seed should be planted rather than shell.

8. The Commission of Fisheries should remove the young oysters at Deep Water Shoal each winter before the spring rains and plant them on good growing bars.

9. Any seed taken from Brown Shoal after April be planted in low salinity waters due to the abundance of drill egg cases there at that time.

1949

Report mailed to oystermen by Dr. J. D. Andrews. In this report the Virginia Fisheries Laboratory recommended:

1. Shell be planted on good growing bars to provide market oysters, but that most of the shell be planted on good setting bars to provide seed.
2. No shell should be planted on muddy bottoms.
3. As a general policy shells should be planted in June.
4. Seed oysters should be planted on good growing bars which are devoid of drills.
5. Plan early where to plant shells so that State can get best bargin when buying shells.
6. In order for the laboratory to evaluate plantings, each planting be marked by surveyor and a record of bushels and acres planted and counts per bushel be given to laboratory.
7. The choice of where to plant shell and seed be made by a team composed of the oyster biologist, oyster inspector and the surveyor.

8. Planted areas should be closed until they show good yields.
9. Increasing shell plantings in the James; plant them on stiff bottom near the middle of the river (ex. off Mulberry Island) to avoid necessity of clearing off inshore bars.

<u>1950 and 1951</u>

In this report it was recommended the Corrotoman River be opened for seed oystering. It was hoped that this would initiate a practice of freeing more and more such areas for seed harvest while sustaining their good condition by continued shell repletion. The laboratory report written by Dr. Andrews recommended:

1. Plant shells in good setting areas.
2. Do not plant on soft mud or drill infested bottoms.
3. Transplant seed to good growing areas.
4. Open more localities to seed oystering.
5. Plant shell as late as June, if possible.
6. Mark repleted areas accurately and obtain reliable information on production.

The Advisory Council on the Virginia Economy

1951

The report of the Council Committee of Fisheries (E. A. Kincaid, Chairman), after citing the importance of the public grounds to all segments of the Virginia oyster industry, their decline, and the demonstrated ability of planted cultch to rehabilitate grounds, proposes that a complete survey program of public grounds be made, "to get adequate information for management of all the public grounds." They list the following types of information which the study must obtain:

1. Information of bottom types and depths, similar to that obtained by Moore in the James in 1910.
2. Data on annual set and oyster populations in order to estimate quality of oysters available.
3. Data on the growth and condition of oysters in all locations in Virginia.
4. Sufficient statistical data to allow computation of such essential management figures as catch per man per day.

The preceding report was part of a longer report made for the Advisory Council on the Virginia Economy. The larger report strongly recommended that a continuing statistical data collection program which would be sufficient for proper management.

The Virginia Advisory Legislative Council
to the Governor, (DeJarnette, Chairman)

1951

A separate report from the preceding one. This group recommended:

1. Public grounds must be policed around the clock if the oysters on them are to be conserved.
2. That shucking-house operators be required to reserve 20% of their shell for sale to the State at the State's option.
3. That "a determined program of shell planting... be gotten under way."
4. That a tax be imposed on all oysters taken from public rocks and that the tongers should pay the tax. Revenue should go to an oyster repletion fund.
5. That $150,000 should be appropriated from the general fund to go to an oyster repletion fund.
6. That the Virginia Fisheries Laboratory should study the effects of removing oysters from deep water on quantity of oyster spawn.

7. That no additional grounds in the James River be leased. (This would prevent any more individuals from leasing ground in the James and selling the seed to out-of-state growers.)

8. The power of the Commissioner of Fisheries to prevent the sale of seed oysters (from public rocks) for transportation outside the State should be abolished. Rather, the export tax should be increased 10 to 20 times as a deterrent to out-of-state shipment.

9. Dredging should not be permitted (on private grounds) of the James River during the open season for taking oysters except on a special permit from the Commissioner.

10. The Virginia Fisheries Laboratory should devise ways to combat the drill and should tell those in the oyster industry.

11. The Virginia Advisory Legislative Council should be directed to make a study whether or not there should be a resurvey of what should be set aside as the present natural oyster rocks.

Virginia Fisheries Laboratory

1952

A mimeographed report by Andrews and Haven recommended:

1. Plant seed.
2. Develop new seed areas near the Rappahannock.
3. Control drills by trapping them.
4. That shell-plantings should be limited to the lower Rappahannock, the Corrotoman and Piankatank rivers.
5. Determine density of oysters on public bottom in terms of density per unit area.
6. Inaugurate an adequate statistical program.

Virginia Fisheries Laboratory in a Report to the Virginia Commission of Fisheries

1952 and 1953

In this report, the Virginia Fisheries Laboratory recommended:

1. Open additional areas for seed oystering.

1954 and 1955

This year the Virginia Fisheries Laboratory made a series of suggestions:

1. Shell plantings can not improve production much.

2. Seed should be transplanted from Corrotoman or Piankatank to Rappahannock.

3. More study of public grounds.

4. More study of shell planting by Commission.

1957

In a mimeographed report of the Virginia Fisheries Laboratory, Andrews and Haven recommended:

1. Plant shell in Rappahannock.

2. Develop new seed areas.

Advisory Council on the Virginia Economy

1957

Dr. Quittmeyer lists five policies for possibly increasing production. These policies are quoted below.

> First Policy. The first policy would be to let all State aid and effort go, which would take Virginia out of the oyster subsidy business, to the extent of around $100,000. Such a policy would probably mean depletion of public rock. Raids on private leaseholds would probably be difficult to stop for a while. Eventually, however, free oystering would be forced to the wall and leasing could come in. Such a policy is patently impolitic and not feasible.

> Second Policy. The second policy would be to turn the whole Bay and its tributaries over to private leasing. Such a plan has great merit from the standpoint of efficiency but lacks political reality. It would not work against the tradition of rugged independence of oystermen that is so socially and politically powerful.

Third Policy. The third policy would be one of State controlled and managed public rock with large shellings for seed, large seed planting, and rigid reserve area control, and no encouragement to private leasing, such system to be supported by taxation on production or subsidized. Along with such a program, as with present repletion programs, should be provision for adequate scientific study of the shell planting. Even if 90 percent of the funds were required for this purpose at first, the efficiency of shell planting that might result later would probably justify the strategy. A difficulty with this program is that subsidization might be necessary on a large scale, at least at first until tax revenues came in, and such financial support by the State would hardly be politically feasible. Federal subsidy would be most improbable and it should be noted that even with reference to federal agricultural subsidy, federal agencies do not plant the crop. Oyster tax support would come up against practical difficulties in the chronic aversion of oystermen to such a tax and in problems of the method of collection. The lure in getting oystermen to pay the tax, however, is that some oysters salable at, say, \$3.50 a bushel with revenue of \$3.10 a bushel after a hypothetical 40 cents a bushel tax, is better than the revenue from no oysters after no tax. Also, with merchandising improvements market expansion would probably be able to absorb more Bay oysters without serious price disturbances.

Fourth Policy. The fourth policy would be similar to the third, except that encouragement of private leasing and culture would be added. With the large amount of poor but still usable bottom not in natural rock, it would seem that relaxed leasing requirements, such as on the number of acres leasable, might help more of this ground to be cultivated in oysters, provided better merchandising of oysters allows an expanded market, as would seem to be the case. Indeed, if a large effort of State management for the public rock came into being, political aversion to the encouragement of private leasing might lessen.

Fifth Policy. The fifth policy would be to continue present production policy as it exists in each state. A modest State program may have helped to stabilize the yield of oysters at 2.5 million bushels in Maryland with some production from the Hamstrung private leaseholds, although stabilization of this sort could come about in the absence of subsidy, the equilibrium level depending on the balance between production and demand. Virginia has a declining production from the public rock which is apparently being arrested by subsidized repletion measures. However, Virginia's total yield has been under its more lenient leasing laws. This fifth policy is feasible because it is working and oystermen actually do make a living under it. However, it is economically wasteful and causes political distress.

Summary

How do these policies appear weighted against developmental conditions? First of all, the Bay oyster fishery meets well the conditions of magnitude of resource, prospects of demand (if the product is merchandised more carefully), regional competitive marketing advantages, and responsiveness to management. The Bay oyster fishery meets these requirements to a larger degree than any of the other fisheries of the Bay area; it should also be emphasized. Thus, it is the means of administration and public support which are the most critical conditions. Under this view it appears that the fourth and fifth policies are most likely. Under the fourth policy, that of a mixture of extensive State management and private culture, public support is feasible if it can be proved that large subsidization is only temporary. Means of administration would follow.

Under the fifth policy, the present policy, both public support and means of administration have been forthcoming.

Recommended Policy for Private Interests

The basic policy recommended for the private interests in the fisheries of the Bay area is to increase emphasis on the production and marketing of shellfish products. As has been indicated, shellfish products meet best the developmental conditions established in this study. Yet at the same time such a policy should be flexible enough to take advantage of seasonal production and the favorable fluctuations in the supply of all seafood, with careful thought to the amount of investment that would be most profitable for such a flexible approach.

Emphasis should be put on greater attention to market demands in the way of a merchandised product. Increasing attention should also be given to the intensification and extensification of the supply of oysters from both public and private grounds, with careful regard to the possibility of expanding the production of leased ground, especially in the more favorable leasing climate of Virginia. In this latter regard, the leasers and leaser-dealers should try to work as closely as possible with the small oystermen to assure them that their small enterprises will not be willfully depressed.

In view of the brighter prospects of the shellfish industry of the Bay area, but not discounting the local opportunities for fresh fish, the seafood fishermen, as well as dealers and processors, should shift gradually toward shellfish. Not to be overlooked is that some fishermen may find better opportunities outside the fishing industry, a point that some of the more marginal dealers might also consider. It is recognized, however, that there are strong sociological frictions to occupational mobility in the Bay area.

The Public Fishery

Dr. Quittmeyer lists as one possible course of action to increase public oyster production would be to embark on a greatly increased program of shell and seed plantings and strict management and control of planted areas.

Virginia Fisheries Laboratory in a Report
to the Virginia Commission of Fisheries

1958 and 1959

This report recommends:

1. Monitoring of disease (MSX).
2. Begin breeding MSX resistant oysters.
3. Wait until month prior to set to plant cultch.

4. Harvest oysters in May and June for York River, Rappahannock during spring and fall.

1960 and 1961

This report recommends:

1. Plant shell in areas heavily infested with MSX to catch spat which will have MSX resistance - and increase funds for this.
2. Empower Commission to control imports of marine organisms.

Commission to Study and Revise Title 28 of the Code of Virginia Related to Fish, Oysters and Finfish to the Governor and the General Assembly (House Document No. 14).

1961

A review of many laws is given and recommendations given for updating them.

Virginia Institute of Marine Science in Report to the Virginia Commission of Fisheries

1962 and 1963

The Virginia Institute of Marine Science recommended:

1. Do not plant imported oysters in Virginia waters.
2. That a full-time Conservation and Repletion officer be placed in charge of repletion work.

3. That the weight of patent tongs be limited to 100 pounds.

4. That the Commission of Fisheries be given more authority in managing the public rocks.

5. That repletion tax be greatly increased in order to increase repletion efforts.

6. That people buying oysters from public rocks be licensed and required to file the reports which are the main part of a new statistical data collection program.

Report of E. V. Bowden

<u>1963</u>

In this report, it was suggested that a coop be established on the Eastern Shore which would plant great quantities of shell and seed.

Report on the Potomac by Beaven and Andrews

<u>1964</u>

In this mimeographed report, the authors recommended:

1. Utilize limited good-setting areas to a maximum as seed areas by planting shells and quickly moving out each spatfall of seed quality.

2. Growth and survival are not serious problems and should not be used as grounds for transplanting oysters from the upper river unless they are definitely threatened by flood waters or accumulate in great quantity.
3. Avoid importing foreign stocks which may interbread and reduce the valuable characteristics of the Potomac oyster race unless laboratory studies have demonstrated them as superior stock under Potomac conditions.
4. Keep as large a brood stock as possible in the river. This can be done by harvesting only mature oysters and by encouraging private planting. Retain as brood oysters the limited stocks close to channel in water too deep for harvest by hand tongs for their position near the bar may facilitate utilization of larvae from them.
5. Initiate an independent survey for buried shell available for dredging and use in repletion programs.
6. Find sources of seed oysters from public and private grounds in tributaries adjacent to the lower river.
7. Actively seek support for an enactment of legislation that will encourage private planting of oysters to provide stability of setting and pro-

duction and an increased efficiency of operation through use of private capital.

8. Adopt a bushel tax of not less than 10% of market value for financing the Commission program.

9. The Potomac River should be operated as a unit biologically without any division by states. The area of oyster grounds and the amount of setting are greater by far on the Maryland side, hence, most of the shell and seed planting should be on that side.

10. Work for political decisions which provide more flexibility in managing the river and its tributaries.

11. Insure that enforcement is adequate to close and protect beds of young oysters until maximum yield can be obtained.

12. Institute a recordkeeping system which tells what was planted where and how much it yielded.

13. Provide funds for an increased program of joint research by the Maryland and Virginia laboratories and a management biologist working in cooperation with them.

Virginia Institute of Marine Science
Biennial Reports

1964 and 1965

The laboratory recommended:

1. That private individuals and companies build hatcheries and ponds to breed and raise MSX-resistant spawn which VIMS would supply.
2. Establish a 3-inch cull law in the James.
3. Amend Potomac River Compact to allow PRFC to move good seed from Potomac tributaries to bars in the river.

1968 and 1969

1. Recommended that changes in laws be made.

APPENDIX III

APPENDIX III

A summary of Christy's (1964) views concerning the operation of a common property natural resource is quoted as follows:

I. <u>Effects on the Resource</u>

A. The fundamental consequence of common property natural resources is that they tend to become depleted. The individual producer, who shares the resource with others, has no incentive to reduce his rate of use, and no incentive to invest in the future of the resource by cultivation or management techniques. Any restraint on the individual's part represents loss, not postponement, of harvest. And there is no assurance that the individual will be able to capture any return from investment in cultivation or management practices.

B. Since each producer operates under the same conditions, each trying to obtain the greatest share for himself, the total use rate is unrestrained by the usual economic forces, and the producers operate at the point where average costs just cover average revenues. With continued, or increasing demand, the net effect is inevitably an "over-rapid" rate of use. For non-renewable resources, the consequences may be a glut on the market and a rapid consumption of the stock. For renewable resources, the reproductive capacity will be diminished and the resource will become extinguished or depleted, depending upon its vulnerability and the incentive to use.

C. It has been frequently stated, and is commonly believed, that a fish stock (oysters) cannot be extinguished because, as density of the stock decreases, the costs of catching the remaining individuals increases, and these costs lead to higher prices and diminished consumption. This theory, however, neglects the changes that can, and do, occur in the supply and demand curves. Improved technology can shift the supply curve downward and to the right, while growing demand moves the demand curve away from the origin. These shifts increase the incentive to the producer and at the same time make it economically feasible to harvest stocks of lower and lower densities.

D. Whether or not the resource will be extinguished may be academic, because controls on the rate of use are likely to be established well before that point is reached. However, it is not an academic consideration to emphasize and anticipate the inevitable depletion of the resource. If it is society's desire to maintain the resource (at some level), then the controls should be established well before that level is reached.

E. It is usual that if controls are established, and it is most often the case, that these are established after the depletion, and its effects, have become severe. The objective of the controls is usually stated as the "maximum sustainable yield," meaning the maximum physical quantity of the resource that can be harvested periodically over time. This objective has several shortcomings, and should be replaced by the objective of maximizing the net economic revenue. However, property resource is made specific in ownership, or if entry is restricted, as will be seen later. In the absence of such appropriation of use rights, maximizing sustainable yield may be a useful "second-best" objective....

F. The definition of the yield is also the source of some disagreement, although decisions can usually be reached. Here is the question of what is to be maximized: Is it the number of animals to be harvested or the number of animals of a certain size? Is it the total poundage of meat or meat of a certain quality? There are, for example, strong disagreements among nations as to the size of fish that is preferred. As for oysters, maximizing total pounds of oysters may not be so important as maximizing the output of glycogen which is richest in November and December and poorest in September when the season opens....

G. It is to be expected that common property renewable natural resources will tend to become depleted. This will occur because the users will do nothing voluntarily and unilaterally to restrain their catch or invest in cultivation and management. It is to be expected also that the course towards depletion will be interrupted by the institution of controls and that these controls will generally have as their objective the maintenance of a maximum physical yield.

II. Economic Consequences

A. A common property resource industry is inherently inefficient, as soon as it reaches a stage where use by one producer diminishes use by another. There is an excessive application of productive factors with the consequence that the share of the return captured by each factor is diminished, or is lower than it would be if the property were under sole ownership. The producers tend to operate at the level where average costs are just covered by average returns. Differences in fertility between beds, banks, or grounds are eliminated as each season progresses since they cannot be appropriated by individual producing units. Common property industries are generally marked by congestion which creates interference and further reduces efficiency. There is frequently a seasonal maldistribution of production, accompanied by sharp fluctuations in price and inefficient uses of processing and distribution facilities. Furthermore, these problems are generally compounded, rather than alleviated, by the kinds of controls and regulations that are established to prevent the depletion of the resource, although this does not have to be the case. In short, there is considerable economic waste attached to the exploitation of a common property natural resource....

B. Dissipation of economic rent: Another reflection of economic inefficiency in a common property resource industry lies in the fact that economic rent to the resource tends to become dissipated. In agriculture, rent to land is indicated by differences in quality, and accrues to those lands that have higher fertility, longer growing seasons, closer proximity to market, etc. For common property renewable resources the qualitative differences are reduced to zero and the quality of all acres in production are equal to that of the last area brought into production.

C. In fisheries and shellfisheries, the higher quality areas are those with the denser populations, close to port, and in places where harvest is facilitated because of favorable shelter, currents, winds, etc. Where no ownership is permitted, it is these areas that are brought into production first. But the output from these areas diminishes the density, and congestion, if it occurs, increases the difficulty of harvesting the product. Both of these factors lead to rising cost curves which will induce a shift of the producers to lower quality areas. This will continue throughout the season, until the average cost curves for all areas are equal and are as high as those of the last area brought into production. In other words, there will be no qualitative differences in any of the producing areas at the end of the season and economic rent will have been dissipated....

D. Congestion and interference: There is frequently a physical manifestation of economic inefficiency of a common property resource....Congestion and interference will occur in any commonly-owned fishery but, like the eventuality of depletion, the speed with which it occurs depends upon the incentive to use the resource and the density of the resource. Certain types of gear lead to congestion and interference more rapidly than other types.

III. Maldistribution of Production

A. The output of common property resource commodities is generally very uneven, marked by gluts at certain periods and shortages at others. For such resources newly brought into production, the initial output levels rise rapidly because each producer is anxious to obtain the greatest share of the output for himself. For resources with seasonal elements, the opening of the season tends to be accompanied by high output levels, because density of the stock is usually greatest at this period and harvest is easiest....

B. ....This concentration of catch over a short period of time has significant implications for the marketing and processing of the commodity as well as for the price. Price to the producers will tend to drop during the period of heavy output. There is likely to be a strain put upon the storage and processing facilities and upon the distribution facilities if the storage life is short. Furthermore, during the balance of the year, the production and processing units may be unemployed; or ineffecently employed if the commodity requires special equipment.

IV. Technological Innovations and Restrictions

A. It was noted above that common property natural resources tend to become depleted. As depletion becomes severe, the most common occurrence is the establishment of some form of "conservation" measure. This frequently serves, directly or indirectly, to restrict technological innovation.

The threat of an efficient harvesting machine or technique coalesces the users of old equipment into a forceful body of opposition....

V. Public Costs of Common Property

A. For common property resources that are unmanaged, depletion, while inevitable, is not necessarily a bad thing for society. If the resource becomes extinguished the market place may be temporarily poorer. But substitutes will appear quickly and society will soon forget. If the output of the unmanaged resource becomes stabilized at a low level, there will be a chronic misallocation of productive factors. But it may be, in some situations, that the costs of the misallocation are borne by the producers rather than by society. A more rational allocation may lead to higher prices for the commodity because of output and more control of output. (On the other hand, it should be pointed out that lower prices may result because of increased incentives to make technological innovations and because of increased density of the stock resulting from controlled output.) A more rational allocation may also mean higher wages to the productive factors that remain in the industry and higher wages eventually for those that are forced into alternative forms of employment. The point is not that these conditions will occur, but that, as yet, there is no absolute proof that society will be better off by managing the common property resource.

B. This may be an academic rather than a realistic viewpoint, however. In almost all cases the depletion of a common property resource is accompanied by the adoption of some form of management; and the question for society is not whether to manage or leave alone, but what form of management to adopt. In the past, the form of management that has been adopted has almost always been one that perpetuates, or actually aggravates, the economic inefficiencies.

In fisheries the typical forms of management are those that prohibit technological innovations; impose quotas on catch; or establish closed seasons and closed areas. While these regulations may be effective in helping the stock to recover, they are also effective in increasing the costs of supply. The economic consequences, described above, remain in effect for all such forms of management.

C. Alternative forms of management are those that restrict the number of producers or that actually establish exclusive use rights for individual producers. Such forms, for various reasons, have seldom been adopted. One of the major reasons for this is that the transitional problems are quite severe. For a depleted fishery, the first stage is reduction of entry, not just restriction, and this obviously imposes hardship on the producers who are forced into other forms of employment. The producers themselves view the resource as free, and fear any restrictions on their freedom or any costs that they may be asked to bear. Furthermore, there are difficult problems in achieving equitable administration of such programs. Consequently, public management of common property fisheries may be expected to take the form of restrictions on technology, output, areas, or seasons.

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