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The Imperilled Oyster Industry of Virginia: A Critical Analysis with Recommendations for Restoration

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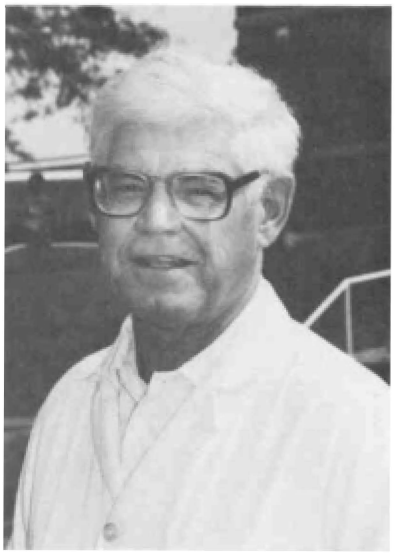
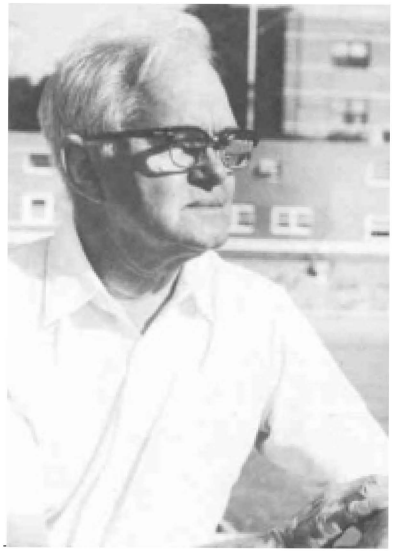


A native Virginian, William Hargis received his Ph.D. from Florida State in 1954. He joined the research staff of the Virginia Fisheries Laboratory (predecessor of VIMS) and teaching faculty of the College of William and Mary in 1955. He was Director of VFL and VIMS from 1959-1981 and founder and Dean of the School of Marine Science from 1961-1981. His research efforts have been devoted primarily to parasites and diseases of fish, fish pathology, oyster predators and the oyster industry. Dr. Hargis has served as a scientific advisor to numerous state and federal councils and committees, and has authored or co-authored some 200 research and scholarly publications, essays, hearing statements and reports.



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"To the end that the people have clean air, pure water, and the use and enjoyment for recreation of public lands, waters and other natural resources, it shall be the policy of the Commonwealth to conserve, develop and utilize its natural resources, its public lands...."

Excerpt from paragraph 1, Article XI, "Conservation" of the Constitution of Virginia.

ACKNOWLEDGMENTS

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The authors appreciate the reviews of Jay D. Andrews, Herbert Austin, Michael Castagna, William D. DuPaul, John DuPuy, Roger Mann, Cranston Morgan, William Shaw, and others on this report or earlier versions thereof. In addition to these general reviewers N. B. Theberge examined that part pertaining to legality of leasing of Baylor Bottoms and M. H. Roberts, Jr. provided certain information on toxicity. The efforts and suggestions of all reviewers have improved the report considerably. However, any errors of inclusion, exclusion, interpretation or logic, should such exist, are the responsibility of the authors. We have attempted to be selective, inclusive, consistent, reasonable and logical. We believe the conclusions to "save the facts" and that our conclusions and opinions are sound and worthy of attention.

We thank Ms. Gloria B. Rowe who assisted in typing earlier editions of this report. Ms. Shirley O. Sterling deserves our special gratitude for patiently and competently preparing most of the many drafts required to bring this edition into suitable form. We are grateful to Ms. Ruth A. Hershner and Ms. Janet G. Walker who prepared the final versions of the report and to Ms. Christine M. Plummer and Ms. Nancy J. Chartier who saw it to press.

The views expressed in this report are those of the authors, as they indicate with their acknowledgements, who take full responsibility for the report content. Fishery management is a complex activity requiring continual evaluation of complex, changing situations and the latest data and technology. Consequently, the views expressed herein should not be taken to relfect the official position of the College of William and Mary, Virginia Institute of Marine Science.

FOREWORD

In 1978 we finished a comprehensive study of Virginia's oyster industry from 1931 to 1976. The prime objective of that report (Haven, Hargis and Kendall, 1978a) was to examine the history and status of the oyster industry of Virginia, once the largest in the world. We also investigated the catastrophic and continuing decline in oyster landings since 1960, determined most probable causes and suggested remedial measures. The revised edition, prepared and issued in 1981, updated the landings data and reiterated the recommendations.

The full report was very long (116 tables and figures and over 1,000 pages) since it presented details on all known aspects of the oyster industry, all analyses, all references employed, and all of the findings which were the bases for the extensive recommendations. Because that book was too lengthy for easy perusal, a condensed version also was prepared (Haven, Hargis and Kendall, 1978b). It, too, was revised in 1981.

Since appearance of these two documents in 1978 some of their recommendations have been adopted; however, most have not. In the meantime the decline in harvests of oysters from the waters of Virginia's lower Chesapeake and its major tributaries continues. Production is at an all-time low - far below its normal potential. Due to drought conditions during 1986 and 1987 in the Chesapeake watershed the major oyster diseases affecting Bay oysters, MSX and "Dermo" (Perkinsus) have moved into populations hither to free from their scourge. During harvest year (1986-87) most market oysters grown in Virginia came from those James River beds which have supplied the bulk of seed oysters used by planters for the last 100 years. Further, most of the public watermen of Virginia's Chesapeake Bay have concentrated on the James, placing additional pressures on those critical seed beds, already severely stressed. This unfortunate occurrence which continued into the 1987-88 season, makes the future appear even more bleak. Both public and private sectors of the Virginia oyster industry are in desperate need of proper management and effective renewal!

Because of the continuing problems of the Commonwealth's oyster industry, we determined to again review its conditions and prepare a completely revised report on its status and problems, including recommendations for its rehabilitation. Extensive revisions have been required to reflect recent changes in the resource and the industry. Landings data for public and leased bottoms have been updated to include the 1985-86 and 1986-87 harvest seasons; therefore, the continuous statistics utilized herein now cover a span of over 55 years. Revised data were obtained largely from publications or computer records of the Virginia Marine Resources Commission (VMRC) Newport News, Virginia and are for the "biological" or harvest year (1 October to 30 September). Oyster fisheries yield or harvest data are sometimes reported to cover two other periods: 1) the calendar year, 1 January to 31 December; and 2) the fiscal year, 1 July to 30 June. Confusion to the uninitiated often results when data are presented by various state and federal agencies in the three different ways. By using the harvest year consistently herein we hope to reduce this

confusion. Further, our data are given in Virginia bushels (3003.9 cu.in.). This is larger than the U.S. standard bushel (2150.4 cu.in.), commonly used in statistical summaries.

In summary, the present report has been extensively revised from earlier editions! In most instances, however, our original basic analyses based on data from the 1931 to 1978 period remain valid and current, and many of the remedial concepts included in this new report are based on the work published in 1978. Others are new. All should be attended!

Prior to presenting the revised report we must briefly recognize some of the recent positive steps already completed or underway.

1. The survey of the Baylor grounds called for in our 1978 summary report was completed by VIMS in 1979 and published in 1981. This detailed study, requiring two volumes (Haven, Whitcomb and Kendall 1981a and b), presents the outlines and locations of Baylor bottoms, and acreage of productive and potentially productive and non-productive bottoms on 53 large-scale charts. In addition, it summarizes the best use for various sections (reaches) of the Baylor Grounds in all major tributaries. It will be useful in developing the new approaches to leasing public bottoms recommended below.

2. A major research program by VIMS, called the James River Initiative Study, was begun in late 1983. It is directed toward developing a more complete understanding of the hydrographic and ecological conditions which regulate setting of seed oysters in the James River and may help to provide additional insight as to why setting declined in the James River after 1960; and especially reasons for continuing setting problems. It may assist in improved management of the lower James and its valuable and essential seed beds.

3. New studies are now in progress at VIMS directed toward understanding the life cycles of disease-causing MSX and SSO and how they are transmitted. These important but difficult disease studies should be expanded and hastened. Disease monitoring, so important (indeed <u>critical</u>!) to effective understanding and management, must be continued, even improved, but research must be pressed as well. Both are vital to help assure the short- and long-term future of the Virginia oyster industry. The rapid spread of MSX and <u>Perkinsus</u> into previously uninfected "low-salinity" populations during the 1986-87 drought reinforces the importance of this research - and monitoring.

4. In 1984, culminating some 15 years of experimental work, VIMS began construction of a modern production-level oyster hatchery at Gloucester Point to provide larvae to industry and to develop other aspects of the culture of hatchery-reared seed. This facility is now producing eyed-larvae and small seed oysters in limited quantities for trial by industry. Perhaps it will assist in rehabilitation of seed and market oyster beds depleted by decades of overharvesting and disease.

5. In the field of technology, a mechanical device has been developed by VIMS to harvest oysters. One version has been built and tested by the State of North Carolina and a slightly modified design has been constructed by a Virginia company. In addition, special gear has been designed to renew old shell plantings; but to date this gear has not been built. Resistance to mechanization continues in Virginia.

6. Since 1981 there has been improvement in the VMRC shell and seed oyster planting programs. Both are now being planted in more favorable times and places. Also, plantings of seed and shell are now being examined more carefully than before; but, as will be shown below, much additional effort is needed for the program to be truly effective!

7. Another recent development which may help restore Virginia oyster production has been the establishment by the VMRC of an Advisory Group to assist with its shell and seed planting programs. We do not know how effective it has been or will be. Early signs are discouraging. The Advisory Group appears to be operating in a "business-as-usual" mode and seems to ignore many scientific and engineering findings. Reportedly its operations are confused. Without assiduous incorporation of proper scientific information and advice, in addition to other essential management efforts outlined below, any improvements in shell planting programs which may be accomplished by the Advisory Group will not reverse the long-term downward trend of production of oysters from Virginia's waters!

8. A Fisheries Management Advisory Council authorized under Public Law 28.1-23 has been established to formulate long-range objectives and goals for all aspects of Virginia's marine fisheries. A preliminary management plan for the oyster industry is being formulated; but to our knowledge no adequate formal plan has been completed or implemented as yet. If current indications hold true, the plan will be another case of "too little, too late". Certainly, if present public and private attitudes and trends continue, and, sad-to-say there seems no reason to assume that they will not, oyster production from Virginia waters will continue to decline, and when it bottoms-out biologically, economically and sociologically, remain at very low levels despite the efforts of Councils, Advisory Groups, and Committees and the availability of a Management Plan.

9. Some improvement has been made in the VMRC data acquisition program related to the repletion program and to acquisition and treatment of harvest data. Greater improvements are badly needed. Available data are inadequate for careful, effective management!

10. Fisheries management activities at VMRC have recently been reorganized. We hope that this promising step results in improved management leading to recovery of the oyster industry. The next several years will tell...

In summary, some progress has been made since our original reports on the status of the oyster industry in Virginia appeared in 1978. However, harvesting (and natural production) of oysters from our seed and market oyster beds continue the long-term trend of decline; and much more remains to be done before oyster production is restored to pre-MSX (1960) levels, much less to the higher yields experienced around 1900! Yet we are convinced that both are possible!

The entire process of planning for and managing the oyster industry remains much too susceptible to political pressures at all executive and legislative levels. Expediency, driven by those pressures, has prevented adoption of the measures necessary to halt over-harvesting and bring about renewal of oyster production from Virginia's waters to the higher levels possible. No management plan, no matter how well-framed, and no public management agency, no matter how well-intentioned and vigorous, can succeed if the overall resource and environmental management system (public and private, executive and legislative) will not let them for whatever reasons. Unfortunately such appears to be the case! The oyster industry of Virginia is <u>in deepening peril</u>. Effective and rapid remedial action is needed, badly!

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INTRODUCTION TO THE REPORT

Since the beginning of governmentally-supported research into the fishery resources and the environments which sustain them, the primary objectives of that research have been to improve management of those resources and environments and to increase the productivity and profitability of the fishery activities dependent thereon. Though modern efforts at fishery science by the Commonwealth of Virginia may be said to have begun with the hiring of biologist Victor L. 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 back at least to the activities of William Keith Brooks, pioneer marine scientist of the Chesapeake Bay who served as a Maryland Oyster Commissioner in 1883, and published on the oyster and its fisheries (1891 and 1905). Also active in the period was Lt. Francis Winslow of the United States Navy, on loan to the U.S. Coast and Geodetic Survey, who studied oyster production in Tangier Sound.

Technical or engineering 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 with Lt. Baylor.

Organized research into the biological resources and the fisheries of the Maryland portions of the Chesapeake Bay were undertaken much earlier by various groups such as the old U.S. Commission of Fisheries and persons like Dr. W. K. Brooks of Johns Hopkins University and Lt. Francis Winslow, U.S.N., and later Reginald V. Truitt, C. Francis Beaven and other scientists of the Chesapeake Biological Laboratory at Solomons, Maryland. In the thirties 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 1940 this latter organization was physically replaced by the Virginia Institute of Marine Science (then officially named the Virginia Fisheries Laboratory), which continued the work on oyster biology and other aspects of estuarine ecology. Through the years a number of competent marine scientists have worked on oyster-related problems of Virginia: Jay D. Andrews, Walter A. Chipman, James B. Engle, Paul S. Galtsoff, Willis G.

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[1] In his report to the Governor of Virginia describing his efforts and findings, Lt. Baylor urged, among other things, encouragement of the leasing and private planting activity. Thus, the man whose name is synonymous with the Commonwealth's 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).

Hewatt, Sewell H. Hopkins, Victor C. Loosanoff, John A. Mackin, Nelson Marshall, R. Winston Menzel, Malcolm H. Owen, Curtis L. Newcombe, Donald W. Pritchard, Herbert F. Prytherch and Daniel B. Quayle are among them.

Though this historical account is brief, it serves to indicate that efforts to improve or preserve the oyster fisheries of the Chesapeake by scientific and technical means have been underway for over a century. Early marine biologists recommended improvements which have not as yet been adopted, but are still valid and being urged. These voices from the past should be heeded!

For most of this long period, investment of money, facilities and manpower in scientific endeavors was sparse! Only in the last twenty to twenty-five years have allocations to marine research been significant in Virginia. This is far too short a period to allow development of an understanding of the complex natural and socioeconomic problems involved in the many fisheries (and environmental phenomena) important to the lower Chesapeake. Much remains to be learned, even about the oyster and its fisheries; the best understood of all estuarine animals and biologically-based marine industries.

In carrying out such research one must be concerned not only with the complex nature of the species involved and the many ecological factors affecting them, but also of the fisheries dependent upon them. Especially important is an understanding of the impacts upon these resources and fisheries by environmental factors, by commercial harvesting operations and by other users. It is a difficult and many-faceted subject not easily or quickly fathomed.

Despite the gaps in our knowledge of the oyster and the oyster fishery, more detailed scientific understanding and technical capabilities have been developed than put to use! There are many reasons for this lack of effective application of available knowledge and manipulative capability to increase yields and economic benefits of the oyster resources of Virginia. Some are: 1) continuing archaic attitudes and practices within the oyster industry, itself, especially its public components; 2) continuing socioeconomic and political conflict between segments of industry, and between industry and other users; 3) continuing resistance to installation of best-management practices by segments of industry; 4) lack of a clear, firm and consistent long-range policy for cost-effective management of the resource; 5) continuation of legal restrictions and economic practices which do not help increase oyster production, but actually mitigate against and prevent improvements in the fishery; and 6) lack of consistent and strong public interest and, yes, <u>public</u> <u>will</u> to make the changes necessary for marked improvement.

Perhaps part of the failure in achieving control over the fishery resources, and of the industry based thereon in the past, has been due to the lack of comprehensive review and analyses of the problems of the fisheries industries and of existing knowledge related to fisheries stocks,

environmental conditions, socioeconomic aspects and of fishery technology.[2] Convinced of the necessity for such analyses of public and private oyster fisheries, we determined to undertake a careful study which began in 1971 and continued through to publication of this report. This study is intended to assist in the development of comprehensive, yet detailed, management recommendations to the Virginia Marine Resources Commission and other relevant elements of the Executive Branch, and to the General Assembly (i.e. the groups constituting the public managers) and to the various segments of the oyster industry. The goals are: 1) to increase understanding of the oyster and its history; 2) to stop and ultimately reverse the trend of diminishing yields from public and private oyster grounds of Virginia; 3) to bring about increased productivity from Commonwealth waters and bottoms; 4) to increase related economic activity; 5) to increase use, income and profit at all essential stages in the fishing industries involved; and 6) make the fullest use of those resources and resource-producing potential which are owned by the Commonwealth and all of its citizens and posterity - and not just a favored few![3]

Whether all or part of these goals will be attained is for the future to tell. However, we are determined that lack of careful, complete and candid analysis and development of clear management, scientific and technical recommendations, and communication to industry and to the State will not be valid excuses should natural and managed oyster production continue to drop and industry decline still further, as <u>they certainly will</u> if current practices are not changed, markedly!

We intend that these recommendations will enable Virginia's public oyster managers and citizens involved in the oyster industry to review and revise their policies, rules and practices in order that 1) the Commonwealth can resume her position as a (hopefully "the") leading oyster producer in the region and Nation; and 2) the Virginia oyster industry can be restored and prosper. Also, this study should enable development of a more efficient, economical and productive program of research, engineering, and advisory services for the oyster fisheries of the Commonwealth and the Chesapeake region.

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[2]Unfortunately, these same problems are shared by most other fisheries of the Chesapeake region and even those operating offshore in the U.S. Fishery Conservation Zone. Truly effective management of most estuarine and marine fisheries is not yet a reality.

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[3]Our goal is not to find fault or fix blame but to identify and locate problem areas and recommend remedial action. Blame-fixing is a traumatic and generally unproductive public activity. The persistent troubles of the oyster industry occur at all levels, with all segments, public and private, and in all organizations involved, including industry, the executive branch and the General Assembly.

To provide an understanding of the complexity of Virginia's oyster industry and its problems, a brief general review of the catastrophic decline in Virginia landings is given first (Section I). Section II presents the pertinent facts about the oyster resources of Virginia and the commercial activities which they support. A review of the status of the Virginia oyster industry and its problems appears in Section III, while recommendations for their correction are presented in Section IV.

The Review (Section III) and Recommendations (Section IV), are complete and free-standing and may be read and used by themselves. Section V presents a very brief summary and conclusions.

SECTION I

THE CATASTROPHIC DECLINE IN LANDINGS OF OYSTERS FROM VIRGINIA'S WATERS

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 late 1950's. Middens from prehistoric periods in the Bay demonstrate wide use of oysters by American Indians (Wharton, 1957). Similar shell piles attest continued consumption in pre- and post-Revolutionary periods. Soldiers, sailors and civilians from all periods of U. S. military history through World War II and in times of peace have left remains of ordinary meals and feasts containing millions of shells around the shores of the Bay.

During the mid-1800's millions of bushels of oysters from Chesapeake Bay were consumed locally each year or sold to markets in New England and even as far away as California and England. According to 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 Chesapeake was recorded as having yielded 6,954,500 bushels of oysters in 1865. Ten years later, in 1875, annual harvests had more than doubled to 17,000,000 bushels and continued to increase "year after year up to the last few years" (Brooks, 1891). If Maltby's and Brooks' statistics are accurate, and we see no reason to challenge them, oyster landings in the Chesapeake Bay and its tributaries may have reached 20,000,000 bushels or more per year in the period between 1875 and 1885![4]

Based upon these figures, Brooks calculated that during the 56-year period after 1834 when the business of packing oysters for shipment to the interior was established in Baltimore, Maryland, the average annual harvest from the Bay was 7,000,000 bushels per year; or 392,000,000 bushels for the period. This massive yield was almost entirely wild or natural production; little culture was involved.

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[4]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 now is the larger of the two, i.e. Va. bushel = 3003.9 cu/in, Md. bushel = 2800.7 cu/in. Any error would tend toward conservatism, i e. there would be a conservative bias in Virginia's earlier production figures. Actual production would have been higher than stated.

Sometime during or after this period, Maryland's market oyster harvest dropped below that of Virginia. This loss in comparative productivity may have been due to the development of the private leasing system in Virginia in the late 1800's, growth of power-dredging in Virginia, to overfishing and/or increasing destruction of the public bottoms in Maryland, or (most probably) a combination of the four. Undoubtedly, growth of production from privately-leased beds in Virginia played a role. The early 1900's saw the Commonwealth become the largest producer of oysters in the Chesapeake Region and on the entire Atlantic seaboard. She remained so until the advent of MSX in 1959. (See Tables I and II).

To enable readers to understand the data on which this study is based it is necessary to provide a few explanatory remarks relative to Tables II and III. We have reviewed the various sources of landings data for market and seed oyster production (harvests) employed in the large original report by Haven, Hargis and Kendall (1978a) and the 1981 revision. As a result we have revised the data for market oyster production in Tables 12 and 13 from that document and have presented them here as Table II. Table 14 in the earlier publication for seed oyster production is given here as Table III. The reasons for these revisions are:

1. To update harvest or landings data.

2. To update earlier "provisional" data which now do not agree with the more current published information; and

3. To establish clearly the sources of the numbers shown in Tables II and III and the manner in which our data (in Virginia bushels) were obtained and derived in order that others can understand, interpret and continue these data sets in comparable fashion.

Use of data from several sources has been necessitated by the following:

1. Data on Virginia landings is published in Fisheries Statistics of the U.S., but publication of this annual report is not current as it is usually 4-5 years behind.

2. The method of reporting employed in Fisheries Statistics of the U.S. (i.e. pounds of meats per U.S. bushel) makes it difficult to reconvert to Virginia bushels, which must be done if comparisons are to be made in this unit of measure.

3. Data published as Virginia Landings were formerly reported by the U.S. N.M.F.S. but are now published by the VMRC. Often these VMRC data are provisional and may be changed after the first report.

4. Footnotes to Tables II and III provide further details of the sources of the data presented therein.

By the early 1900's Virginia's public production (harvest) had decreased somewhat as the natural oyster beds became depleted to the point that annual yields were down to 4 to 7 million bushels. Though a decline,

° Table I

Recorded Oyster Landings in Virginia[a] from 1880 to 1925 for Certain Years

Year	Bushels	Pounds of Meats
1880	6,837,320	47,861,240
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

[a]From Table 16, Haven, Hargis and Kendall (1978a as modified from Corson, 1930). This revision excludes the harvest report for 1887 included in Haven, Harper and Kendall (1978a), because data for that year did not include James River clean culls or market-oysters harvested from the Virginia tributaries of the Potomac River.

Table II

Virginia Market Oyster Landings from Public and Private Bottoms, and Total Landings, in Virginia bushels for the Harvest Years 1930-31 through 1986-87[a,b]

	Public[a]	Private[b]	Total
1930-31	1,017,641	1,830,836	2,848,477
31-32	991,335	1,404,952	2,396,287
32-33	934,537	1,402,231	2,336,768
33-34	1,155,640	1,689,860	2,845,500
1934-35	1,028,023	1,871,116	2,899,139
35-36	565,824	1,993,418	2,559,242
36-37	598,345	1,230,304	1,828,649
37-38	619,407	1,459,308	2,078,715
38-39	733,871	1,834,298	2,568,169
1939-40	824,383	2,059,271	2,883,654
1940-41	726,241	2,092,864	2,819,105
41-42	606,498	1,797,363	2,403,861
42-43	749,410	1,857,321	2,606,731
43-44	845,721	1,338,603	2,184,324
1944-45	634,179	1,906,500	2,540,679
1945-46	997,843	2,346,535	3,344,378
46-47	1,060,147	1,953,155	3,013,302
47-48	962,284	2,517,992	3,480,276
48-49	1,015,035	2,423,447	3,438,482
1949-50	586,412	2,034,097	2,620,509
1950-51	444,474	1,969,207	2,413,681
51-52	374,013	2,259,970	2,633,983
52-53	419,063	2,372,742	2,791,805
53-54	510,333	2,951,485	3,461,818
1954-55	517,178	2,766,137	3,283,315
1955-56	650,333	2,820,314	3,470,647
56-57	592,181	2,601,353	3,193,534
57-58	586,304	2,926,750	3,513,054
58-59	703,915	3,347,170	4,051,085
1959-60	699,420	2,553,275	3,252,695

Table II (continued)

	Public	Private	Total
1960-61	781,783	2,237,736	3,019,519
61-62	227,921	1,815,001	2,042,922
62-63	278,830	1,652,880	1,931,710
63-64	576,857	1,223,549	1,800,406
64-65	615,864	1,605,759	2,221,623
1965-66	605,982	1,188,633	1,794,615
66-67	226,855	587,105	813,960
67-68	262,996	790,483	1,053,479
68-69	227,577	621,463	849,040
69-70	192,187	818,943	1,011,130
1970-71	281,001	836,014	1,117,015
71-72	260,241	928,404	1,188,645
72-73	157,890	394,121	552,011
73-74	374,522	424,277	798,799
74-75	403,737	491,860	895,597
1975-76	397,209	475,159	872,368
76-77	312,539	320,711	633,250
77-78	512,687	394,692	907,379
78-79	590,533	441,082	1,031,615
79-80	608,880	465,896	1,074,776
1980-81	704,848	472,465	1,177,313
81-82	464,280	326,809	791,089
82-83	329,492	361,792	691,284
83-84	241,517	285,777	527,294
84-85	341,757	316,922	658,679
1985-86	328,338	386,665	715,003
1986-87	273,811[c]	265,695[c]	539,506[c]
	(476,050)[c]		(741,745)[c]

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[a] Public Harvests: Landing data for 1930-31 to 1962-63 and 1975-76 through 1976-77 are from NMFS Fisheries Statistics of the U.S. Essentially, they are the same as shown in Table 13 (Haven, Hargis, Kendall 1978a).

Data for 1965-66 to 1976-77 were obtained from the annual summaries of the VMRC. They are mostly the same as shown in Table 12 (Haven, Hargis and Kendall 1978a).

Data for 1977-78 to 1986-87 were calculated from Virginia Landings (VMRC Newport News, Virginia.

Table II (continued)

[b] Private Harvests: Landings data for 1930-31 to 1962-63 were from NMFS Fisheries Statistics of the U.S.. They are the same as shown in Table 13 (Haven, Hargis and Kendall 1978a) and are the best available despite certain shortcomings.

For 1965-66 to 1974-75 they were obtained from the annual summaries of the VMRC, Newport News, VA.

Landing data for 1975-76 to 1976-77 were calculated from Va. Landings NMFS (on the basis of pounds landed).

Data for 1977-78 to 1985-86 were calculated from Va. Landings VMRC, Newport News.

[c] During the 1986-87 harvest year the James River seed bed area became the major source of market oysters (called "clean'culls" there) and Virginia Landings showed that a total of 476,050 Va. Bu. had been taken from public bottoms in Virginia. This figure is shown in parentheses for emphasis! This was a marked increase (147,712 Va. bu., or some 44%) over the 1985-86 records for 1986-87 (i.e. VMRC computer files on 2/4/88) show that many of the publicly taken market oysters for that harvest year (some 202,239 Va. bu., or 42.5%) had come from the James River, mostly from the traditional seed beds. Since harvest of large quantities of market oysters from these beds was unprecedented, any comparison of the market oyster yields of 1986-87 (and 1987-88, when finally in) with earlier harvests must take this into account to be as accurate and realistic as possible!

Actually, the most comparable market yield datum for the 1986-87 harvest with those of previous years was 273,811 Va. bu. (i.e. the first number presented in the table for harvest year 1986-87) since the clean cull (market) harvesting from the James River seed had not begun in earnest before 1986-87 (though up until the Kepone incident of late 1975 soups, which may have been recorded as market-oysters or clean-cull, had been taken from some beds in the lower James). Compared with the 1985-86 yield of 328,338 Va. bu. of market oysters from public bottoms this represents a reduction of some 54,527, or 16.6%..

Total non-James market oyster production of 539,506 Va. bu. represents the second lowest yield of record since the 1930-31 harvest year when more-or-less "careful" recording of harvest first began, 57 years previously. It was exceeded only slightly (12,212) by the 1983-84 harvest of 527,294 Va. bu., which was the lowest! Compared with the total of 715,003 from 1985-86 this is a drop of 175,497, or 24.5% - nearly a quarter. This remarkable reduction, related mostly to the inroads of disease, previous over-harvesting and transfer of most of the hand-tonging harvesting effort to the James River seed beds continues the dismal story of decline of yields from the non-James public bottoms.

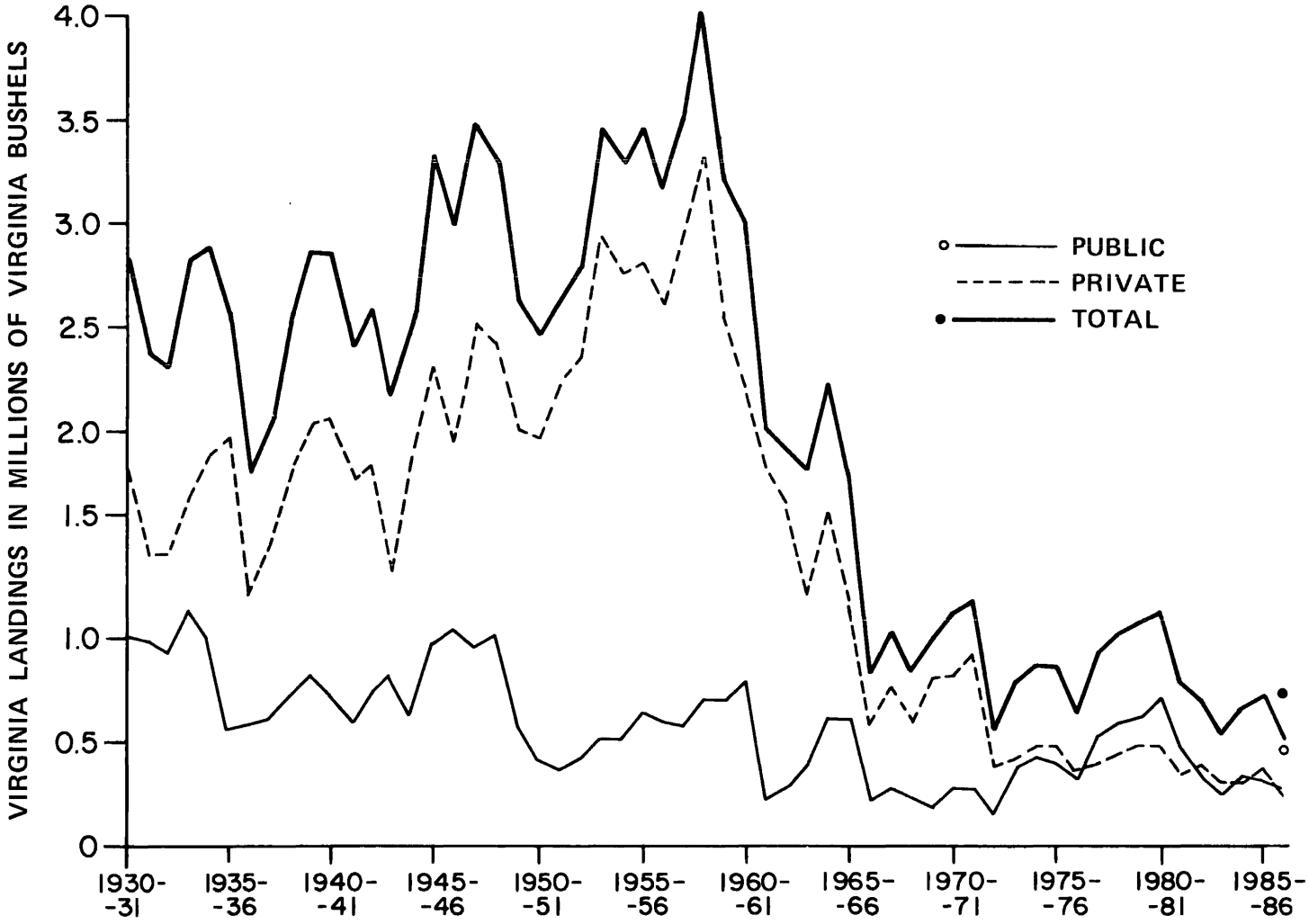

Figure 1

Graph showing recorded Virginia market-oyster landings for the 1930-31 through the 1986-87 harvest years in millions of Virginia bushels. (Total seed-oyster harvest by harvest year are included for comparison.)

this amount was large by national, even worldwide, standards and Virginia continued to out-produce all other East Coast states.

According to the record, this level was maintained up until 1925 when a drastic decrease in landings began (Table I) and in 1931 only 2,848,477 bushels were harvested. This was a reduction of from two-thirds to one-half - not insignificant! Probably, diminished demand from outside the Chesapeake Bay region during the Depression years was responsible for a portion of this decline, but other factors may have been involved. After 1931, production slowly increased to 3.5 million bushels in 1954, mostly due to private culture; it remained at this approximate level through 1959 (Table II and Figure 1). Harvest year 1958-59 saw the highest production of the post-1925 period at 4,051,085 Va. bushels.

The recent catastrophic decline in market oyster landings began in 1960, and by the 1976-77 season total Virginia harvests from leased and public bottoms had fallen to 633,250 Va. bushels. During the 1984-85 season oyster landings from leased bottoms were lower (316,922 Va. bushels) than for public bottoms (341,757 bushels) for a total of only 658,679 bushels (Table II and Figure 1). In 1985-86 total landings increased by some 50,000 Va. bu. while public harvests dropped about 14,000 bu. In 1986-87 total landings from private leases and non-James River public grounds dropped to 539,506 Va. bu., the second lowest year of record since 1930-31. During 1986-87 non-James public "rocks" out produced private grounds by 8,116 Va. bu. as private production declined by 120,970 bu., or 31,390 bu. less than 1985-86. Clearly the prevailing downward trend has continued through 1984 and since 1976-77 public rocks have produced more than private leaseholds in 7 of the last 10 years. That the slight movement upward in private and total production in 1985-86 (715,003 Va. bu.) is merely another minor perturbation in the continuing downward trend, unfortunately appears to be the case. In 1986-87 the total market harvest from public and private rocks was (741,745 Va. bu.) up even more than 1985-86; however, of that total 476,050 bu. were from public bottoms. Of these oysters, 202,239 Va. bu. (or 42.5%) of market oysters for the shucking and shell-stock trade were taken from the James River seed area! Except for "soups" taken prior to Kepone years and, perhaps, a few clean culls this use of the James River seed area to produce market oysters is unprecedented! If we subtract these James River market oysters from the total of those taken from all public bottoms in 1986-87, as we must to make 1986-87 yields comparable to earlier years when <u>substantial</u> "market oyster" harvests from the James did not take place, the total harvest from "other" public bottoms would be 273,811 Va. bu., a reduction of 52,527, or 16.6% of the 328,338 Va. bu. taken in 1985-86. As Table II shows, and we have explained in detail immediately above and in footnote c to Table II, harvests from all public grounds increased in 1986-87 to 476,050 Va. bu., mostly due to the unprecedented harvest of large quantities of "market" oysters from the <u>James River seed beds</u>. This practice was renewed at the beginning of the 1987-88 harvesting season and the total of market oysters from these seed beds likely will be even higher than that of 1986-87. This ill-advised occurrence probably will be regretted by all concerned as hydroclimatological conditions became normal and demand for seed is renewed!

Especially noteworthy is the fact that in 1904 total Virginia market oyster landings reached a recorded high of 7,612,289 Va. bushels. Since then, with perturbations, harvest levels have dropped (Table I). The 1924-25 harvest year produced over 300,000 Va. bushels more than the highest peak since 1930-31. This is significant because, as Table I shows, only two comparable recorded years prior to 1925 were lower than the harvest in 1925. The lower production record of 1887 of 2,921,140 Va. bu. is not included in Table I because the records for that year were not complete, lacking production from the James and the Virginia tributaries of the Potomac.

Accompanying the decline in market oyster landings from leased bottoms has been a reduction in seed oyster harvests from the State's seed producing areas (Table III and Figure 2). Some 80-85% of this seed has been tonged from the James River each year. Part of the lowered seed landings was due to reduced demand for seed oysters as lease holders stopped planting their grounds. Other important factors responsible for the decline in seed production are discussed later.[5]

To determine the reasons for the reduced yields from market and seed areas alike we have conducted a detailed study of the oyster industry for the period 1931 through 1987. This period was chosen because sufficiently reliable and comprehensive information exists in the literature concerning the fishery to support such an analysis. Data from earlier in this century and before are not complete.[6] This report examines production or yield trends and the major problems facing the industry. Emphasis is placed on determining the reasons for recent major reductions in oyster yields (and natural production) from Virginia estuarine waters 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

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[5] In 1986-87 and the early part of the 1987-88 season, market oysters harvested from the James River seed beds brought prices in excess of $15.00/bu. Not surprisingly, watermen concentrated on these oysters and ignored seed which brought $3.50-$5.00/bu. This, too, does not augur well for the future.

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[6] Even now (1988), truly adequate data on natural production and yields of sufficient quantity and quality for effective management are lacking even though sufficient information exists to allow our analytical efforts and support the conclusions derived. Timeliness of data availability is poor. Often such data as are presented are labelled "provisional" and remain so for long periods. Furthermore, the data which are obtained are neither carefully verified, nor complete (hence, not accurate) nor do they indicate details of place of harvest, fishing effort or other information so important to proper analysis and effective management. This allows for confusion and, as far as we are concerned, further indicates the uncertain nature of the data-acquisition system and of the data.

Table III

Seed Oyster Landings in Virginia from Public and Private Grounds for the Harvest Year 1930-31 through 1986-87[a,b]

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	(c)	729,401
37-8	983,681	2,400	986,081
38-9	814,979	(c)	814,979
39-40	930,860	(c)	930,860
1940-1	890,592	(c)	890,592
41-2	932,699	(c)	932,699
42-3	(d)	(d)	(d)
43-4	(d)	(d)	(d)
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	2,230,229
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[e]
57-8	2,321,954	150,258	2,472,212[e]
58-9	1,850,231	60,980	1,911,211[e]
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	828,008
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

Season	Public Ground (Va. bu.)	Private Ground (Va. bu.)	Total (Va. bu.)
1971-2	391,172	0[f]	391,172
1972-73	401,067	5968	407,035
1973-74	524,818	2500	527,318
1974-75	372,504	0[f]	372,504
1975-76	532,023	90,679	622,702
1976-77	415,024	40,698	455,722
1977-78	466,887	74,914	541,801
1978-79	477,054	119,002	596,056
1979-80	287,765	18,637	306,402
1980-81	330,890	71,228	402,118
1981-82	444,040	94,852	538,892
1982-83	475,874	47,490	523,364
1983-84	371,412	32,078	403,490
1984-85	391,512	30,813	422,325
1985-86	290,473	69,788	360,261
1986-87	200,917[g]	58,761	259,678[g]

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[a] Data from 1972 to 1974-75 are from Fisheries Statistics of the United States (NMFS) and have been converted to Virginia bushels. Data are the same as shown in Table 14 (Haven, Hargis and Kendall, 1978a). Data from 1975-76 to 1977-78 are from Virginia Landings (NMFS). Data from 1978-79 to 1984-85 are from Virginia Landings (VMRC).
Most of the public ground seed production (80-85%) came from the James River.

[b] A small amount of the total seed harvest (about 1% or less) was Maryland harvest from 1943-44 through 1959-60.

[c] No data available.

[d] Data available for a half-year only.

[e] Computed from data shown in Fisheries Statistics of the United States.

[f] 0 = no reported production.

[g] During the 1986-87 harvest year seed oyster landings declined to their lowest level since before the 1930-31 season (55 years - data on landings of seed from public bottoms were incomplete or lacking during two years of the World War II period). Data from Virginia Landings showed 200,917 Va. bu. from public grounds, mostly the James River seed beds, and 58,761 Va. bu. from private grounds. The total seed oyster harvest of 259,678 is the lowest of record since 1930-31, 57 years ago. In comparison, VMRC computer records indicated (2/4/88) that of the 206,850 Va. bu. of seed produced from all public seed areas in the Commonwealth 198,908 Va. bu. (or 96.1%) were taken from the James River. Seed production from public grounds in the James River very likely will be much lower in 1987-88 than previously. If this happens

it will be due primarily to concentration by harvesters on higher priced "clean-culls" or market oysters from the "seed beds" and, perhaps, to reduced demand by planters.

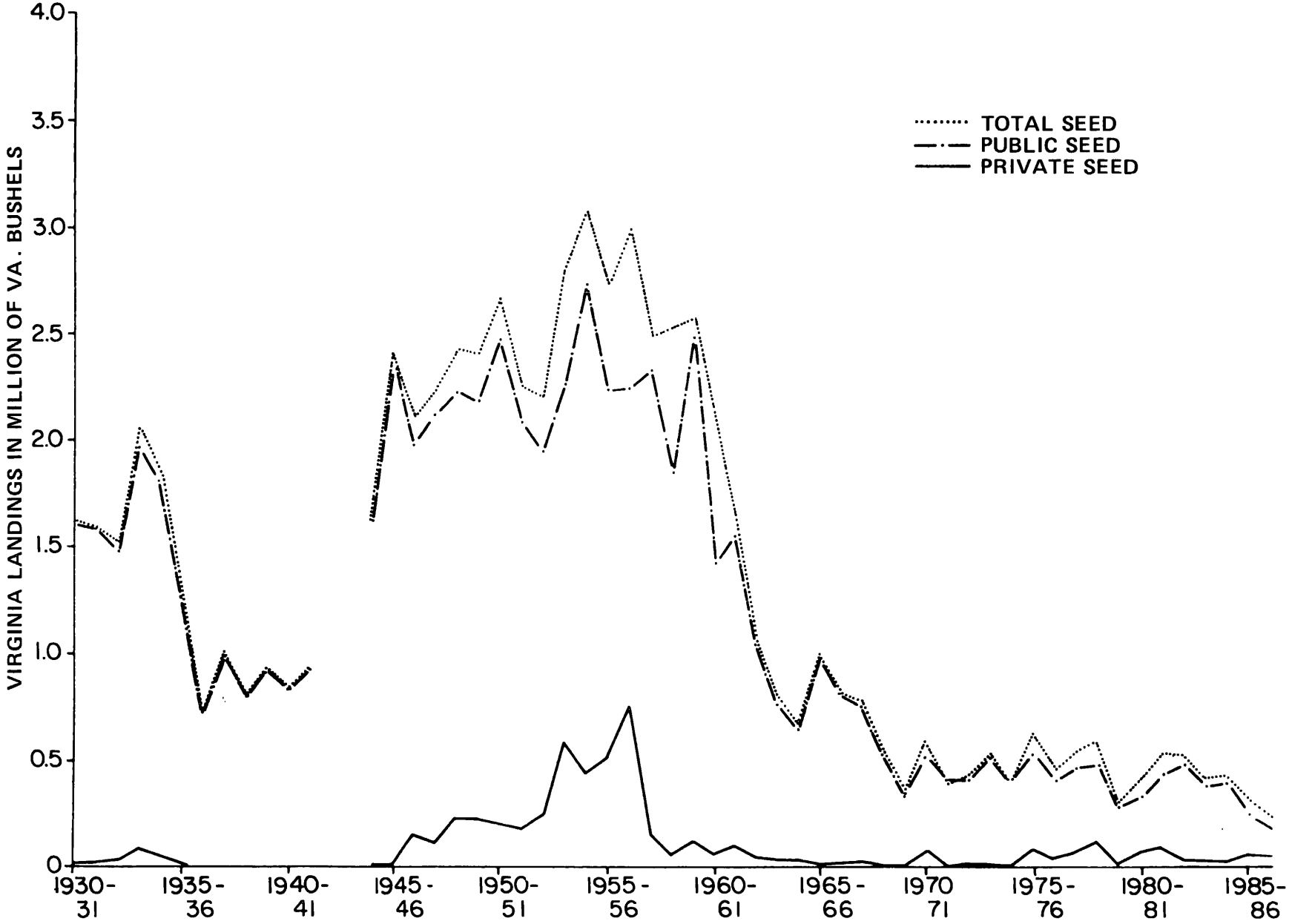

Figure 2

Graph showing recorded Virginia seed-oyster production for the 1930-31 through the 1986-87 harvest years in millions of Virginia bushels.

file at the Virginia Marine Resources Commission, records from several private oyster producers and information from interviews with oyster growers, dealers, inspectors, planters, packers and processors which provide details not available in the "official" records. The geographical area emphasized is the lower Chesapeake Bay and its tributaries, including the Virginia tributaries of the Potomac as well as the Seaside of the Eastern Shore.

Before our first review was undertaken in 1971, little was known in detail about the Virginia oyster industry as a whole. Many papers and articles on various aspects had been published, but until our major report of 1978 appeared little of the available information had been synthesized. Many persons had generalized knowledge; a few knew many or most details of specific portions of the industry; but almost no one had details of all segments. This situation persists.

For our analysis, the factors and phases of the oyster industry, both public and private, have been divided into several categories. These are: 1) oyster production on public and leased areas, 2) the condition of the public rocks, 3) economics of the industry, 4) possible methods of management, 5) predators and diseases, 6) pollution, 7) oyster culture, 8) laws and regulations, and 9) recommendations.

For greater detail than provided herein the reader is referred to our major work (Haven, Hargis and Kendall, 1978a). No matter which document is consulted, the poor situation of Virginia's oyster resources and the industry they undergird is clear. A crisis exists: It is deepening! Public and private elements are both in peril. An emergency situation prevails and state officials and the industry should be made aware of its serious dimensions. Emergency action seems justified, and even required.

SECTION II

OYSTER CULTURE AND HANDLING IN VIRGINIA - PAST AND PRESENT

A general discussion of where and how oysters are grown, methods of harvest, processing techniques, management efforts, diseases and predators and other aspects is necessary to provide a framework against which later details may be considered

The Resource

Magnitude and Value of the Resource

Puantity and value of oysters landed and processed in Virginia are summarized yearly by the United States National Marine Fisheries Service (NMFS), formerly the U.S. Bureau of Commercial Fisheries (BCF). According to statistical data for the period 1880 to 1925, the Virginia harvesting industry was producing large quantities of oysters, ranging from 4 to 7 million bushels annually (Table I).

During depression years, from about 1929 to 1940, recorded landings diminished or remained constant as outside demand slowed. After this period, total reported oyster harvests trended slowly upward, peaking from 1955 to 1959 (Table II). During this latter period annual statewide landings ranged from about 1.3 to about 4.1 million bushels. As shown later, most of this yield originated from leased bottoms while production from the public bottoms showed annual fluctuations throughout this 30-year period (1929-1959). During most of the period the trend in landings from public bottoms was downward.

Beginning in late 1959 the Virginia industry began a catastrophic decline in State-wide harvests (and production on the bottom) and during the 1972-73 season less than one million bushels were landed. The latest available data for 1984-85 and 1985-86 showed total landings from leased and public bottoms of only 658,679 and 715,003 Virginia bushels, respectively (Table II). This same table also shows that the comparable total landings for 1986-87[7] were 539,506 Va. bu., the second worst of the 57 harvest years of record.

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[7] Total landings from all sources public and private were 741,745 Va. bu. but this included 202,239 Va. bu. of "clean culls" from the lower James - largely from the James River seed area which had not been heavily harvested for market oysters in previous years. Removal of the seed-bed "clean-culls" from the total harvests from all public bottoms leaves 273,811 Va. bu. which can be compared to tabulated yields of previous harvest years. Total harvest data had to be adjusted likewise to make them comparable!

The relatively low catch of 1984-85 was worth about 6.9 million dollars at dockside. The value of the processed meats from the oysters (shucked, raw, steamed or breaded) is usually considered to be 4-5 times more than at-landing prices. Thus, despite recent declines in landings the oyster industry remains a multi-million dollar business activity contributing significantly to the economy of the State. It is even greater considering that oysters, like other species employed by the fisheries, are capable of being partially or wholly self-renewing. If the resource and the habitat on which it depends are properly managed, production on the bottom and yields can not only continue indefinitely; but, with a little help from man, increase markedly.

Many persons, unfamiliar with the details of the Virginia oyster industry, regard it as a simple business of harvesting Nature's bounty directly from the bottom with little preparatory effort or expense or, at most, planting some seed oysters and dredging up marketable oysters after a few years. Actually, the oyster industry is very complex, consisting of many segments, all of them interrelated. Consequently, something which influences one part usually will ultimately affect the many other segments and economic repercussions may be widespread. Participation in the oyster industry and nurture of the resource on which it is based can be costly. A box chart model showing the industry in all of its organizational and operational complexity is shown in Figure 3.

Natural History

The American oyster, Crassostrea virginica, occurs along the Atlantic and Gulf Coasts of North America. This mollusc has been a desirable and nutritious seafood from early times, when it was consumed by Indians and later by colonists[8] (at first somewhat reluctantly by many), until the present. Middens and refuse pits and shell piles from all ages and stages of human habitation support this statement. Oysters were used for other purposes as well. Many of the older roads, alleys and driveways of Chesapeake Bay country once were entirely paved with oyster shells. In addition, until the mid-1900's many oysters were harvested merely for lime-burning and as an ingredient in cement: The meats were wasted.

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 the gills by the action of small cilia. The quantity of water pumped by mature oysters is large and may amount to as much as 15 liters (3.963 gallons) per hour. In a 24-hour period the volume pumped and strained by a bed bearing thousands of oysters would be tremendous. For example a 50 x 50 ft area with 10,000 adult oysters would move 150,000 liters or 39,630 gallons per hour of pumping. During a 24-hour period the volume pumped, assuming activity for three quarters of the day,

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[8] Early reports mention that in Colonial times, around 1700, some oyster reefs were awash at low tide and constituted threats to navigation (Hedeen, 1986).

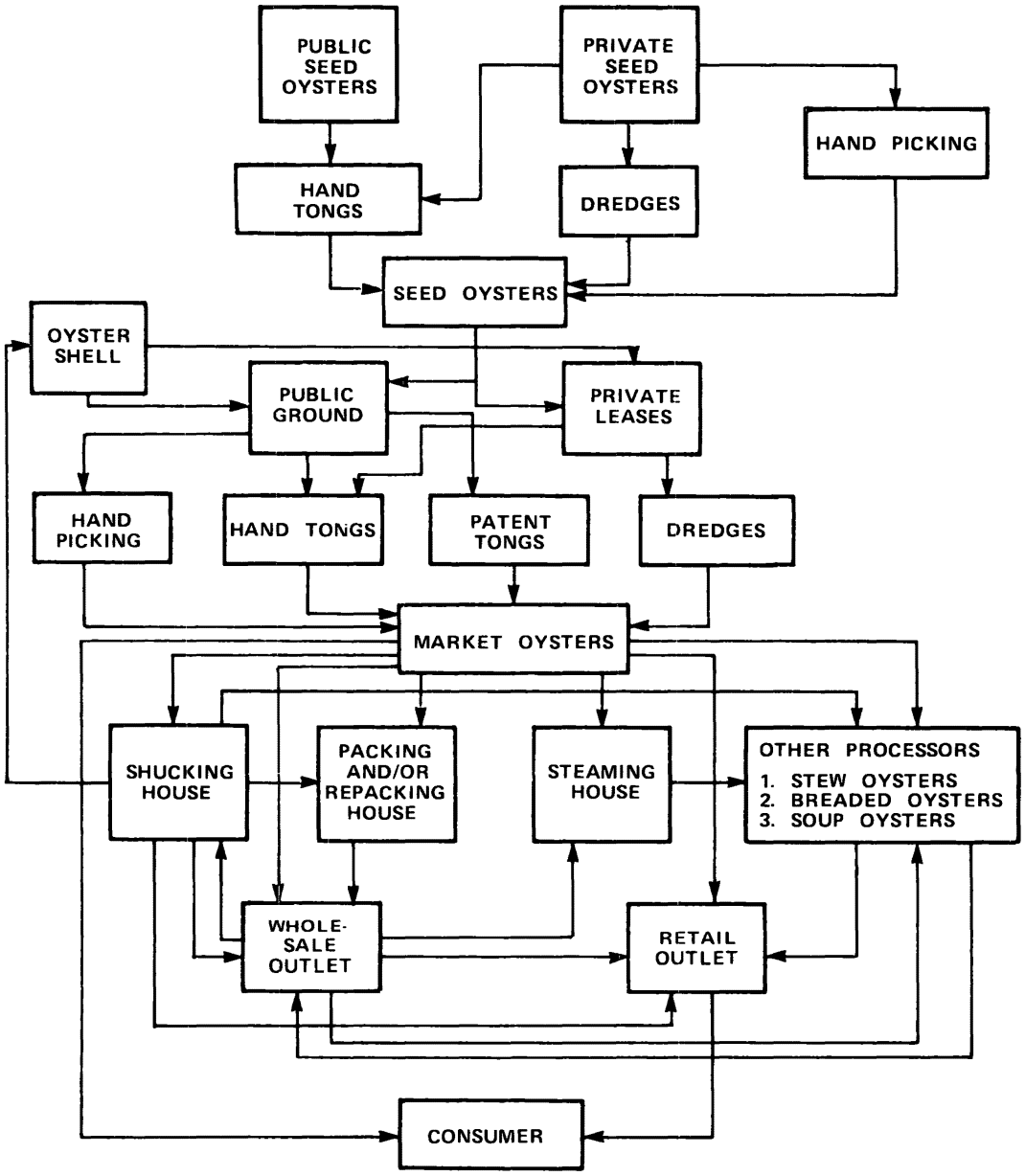

Figure 3

A box model showing the key elements in the harvesting, processing and distribution of seed and market oysters in Virginia.

(From Haven, Hargis and Kendall 1978a, revised and updated)

would be about 2,700,000 liters or 713,340 gallons of estuarine water - an amazing volume. Material retained by the gills is transported by ciliary action to the mouth and then to the oyster's digestive system where absorption of nutrients takes place. Waste products passed through the gut are voided as feces. Materials brought into the shell cavity but not taken into the gut, which have been selected out - or rejected and segregated from the water 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." Ejected in this fashion are large amounts of silt and other unsuitable and presumably undesirable particles. This adaptation enables the oyster to survive in many coastal and estuarine waters whose silt burdens are extremely high. Turbid waters are characteristic of the shallow bays, lagoons and estuaries in which oysters do best.

Though sex may reverse in individual oysters, the sexes at any one time are separate. Fertile and fecund individuals of both sexes must be available so that a suitable mixture of sperm and ova results at spawning time. Spawning may occur during an extensive period from late June to October. However, in Virginia waters most takes place during July, August and September. The ova, often called eggs, are released into the water from the female and then fertilized by sperm released by males. Fertilization of the female gamete and the early stages of blastulation and gastrulation (embryogenesis) 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 10 to 22 days before attaching (setting) on an oyster shell or any other firm object whose surface is sufficiently clean and clear to receive them. It has been shown that their swimming ability is useful in moving the larvae to ultimate setting places. Embryonic shells begin to develop even before the larvae attach.

After setting, or attaching to the final substrate, the small oysters are called spat. Their growth varies with salinity and location. For example, in the James River seed area an average length of from 1/4 to 3/4 inch is achieved by November-December when growth ceases due to lowered water temperatures. In the Rappahannock River, average length may reach 3/4 to 1 1/4 inches over the same period. On the Seaside of Virginia's Eastern Shore spat commonly grow from 1 to 2 inches during their first growing season.

The growth of oysters to market size (3 to 4 inches) also varies according to the salinity of the water and the nature of the estuary or region in which they occur. Historically, each area has characteristic patterns of growth which are generally well known to oyster growers and scientists. For example, in the James River growth typically has been slow and many oysters 4 to 5 years old range from about 1 1/2 to 2 1/2 inches long. This slow growth coupled with suitable setting rates and low mortality normally results in large populations of small oysters called seed oysters once widely planted by private growers on their leases. They have also been used to replenish public bottoms. The importance of the James River to the oyster industry and the decline in setting in the seed area are discussed below. In the upper reaches of the Rappahannock oyster-producing area where salinities are low, oysters may require 4 to 5 years to reach

marketable size. In the lower portion of this estuary, 3 to 4 years is usually sufficient. This latter growth rate is typical of many other oyster-growing areas.

According to data gathered by VIMS scientists over the last 40 or more years, each estuary has a characteristic pattern of spatfall (or setting pattern) both in timing and quantity of set. On the Seaside of the Eastern Shore, the set of oysters has always been high, with 20 to 50 spat commonly attaching to a shell 3 to 4 inches long during a season. These extremely heavy sets usually 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"; many are stunted.

On the Bayside of the Eastern Shore, the set of oysters generally is lower than on Seaside and, in many regions, such as Pocomoke Sound, too few small oysters attach during a season to maintain the yields of natural oyster rocks at recent harvesting rates. Low setting levels on Bayside do not seem to be a recent development, because the limited records available suggest little change in setting intensity in the areas examined over the past 25 to 30 years.

On the Western Shore of the main portion of the Bay proper and in the York, James, Rappahannock, Great Wicomico, Piankatank, and Corrotoman rivers and other primary and secondary tributaries, the set of oysters varies widely. Historically, the James River has been the best setting area in the State. However, since 1960 there has been a serious decline in numbers of larvae setting and numbers of spat surviving on bottom cultch at the end of the setting season (Table V). This decline has resulted in fewer spat setting and surviving each year on the bottom, leading to lowered levels of natural production.

Lowered natural productivity of the James River is regarded as one of the most serious problems facing the industry, since historically the James River has supplied 75% or more of the seed oysters planted each year on leased bottoms by the private sector. Without this source of seed, private sector market oyster production would be seriously restricted; permanently! More important, efforts to restore private and public production and yields to pre-1960 levels would be thwarted.

The impact of the decline in spatfall in the James River since 1960 has not been obvious because there has been a major reduction in the demand for seed since 1960. However, if the demand for seed oysters was to increase, to the immediate pre-1960 level for example, the James River would not be able to supply the necessary seed at present levels of recruitment and natural production. The situation is worsening since harvesting sizeable quantities of market oysters (clean culls) from the James was allowed in 1986-87 and is now occurring during the 1987-88 harvest year.

The Great Wicomico and Piankatank Rivers are seed-producing areas, but their productive (or potentally productive) acreage, singly or together, is

not sufficient to produce volumes of seed comparable to the James River seed area.[9]

The Industry - Public and Private Use and Management

Where Oysters Grow - Public and Private Grounds

The business of packing Bay oysters for shipment seems to have developed around 1834 (Brooks, 1891). After this, 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 shipped by sea to New England for use as seed and "bedding" (overboard storage in the water for later recovery and consumption).[10] Great quantities were also consumed locally or packed for shipment to California and England (Ingersoll, 1881) where they often went overboard. Also, large numbers went inland.

Baylor Survey Grounds

The depletion of the naturally productive oyster-producing areas in the late 1800s aroused the concern of the interested public and legislators, leading to a survey, completed in 1884, which set aside thousands of acres of naturally productive oyster bottoms, as well as many unproductive ones, for public use. This survey was conducted by Lt. Baylor, USN, who worked for the U.S. Coast and Geodetic Survey. Other surveys, conducted later, have added to the original acreage. Currently, about 243,000 acres are classified and set aside as Baylor Survey or public bottoms.

When completed in 1894, Lt. Baylor's survey included most of the natural oyster producing regions in Virginia as well as other, non-productive bottoms. That is, it incorporated areas where oysters set and grew naturally without assistance from man: It also encompassed extensive barren areas where oysters did not grow naturally! Certain selections of bottoms for inclusion within survey boundaries seem to have been chosen or made somewhat arbitrarily or capriciously by the local groups assisting Lt.

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[9] In 1987 they were found to be infected by Perkinsus marinus (Dermo). Therefore, transplantations from these sources must take this factor into account.

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[10] Oysters transplanted in such fashion usually carried a full complement of associated flora and fauna. Alien competitors, diseases, pests and predators were frequently transplanted with their hosts to infest new waters and plague local oyster culturists.

Baylor. Bottoms inside the Baylor Survey boundaries cannot presently be leased but are held "in trust" for public use.[11]

Areas of tidal bottom below mean low water, and outside the Baylor Survey Grounds, are also under State jurisdiction.[12] Some of these non-Baylor public grounds are leased to private oyster growers and today about 110,000 acres are under lease. Also, some of the non-Baylor bottoms are assigned to nearby riparian owners and others are designated as public clam grounds. Others are unassigned. All publicly-owned "bottoms" in Chesapeake Bay and its tidal tributaries are administered by the VMRC. Occasionally the General Assembly enacts special legislation allowing access to or use of specific public bottoms, even Baylor Grounds, for purposes other than mollusc culture as for example powerlines, cable crossings, pipelines, bridges and tunnels.

In most instances plots leased to private planters are not "natural oyster bottoms" since they are not "self-perpetuating"; most probably never were. Rather, they are areas where oysters normally would not occur in numbers without intervention by man. Often these leased bottoms must be improved by "hardening" or firming the bottoms (usually by shells) at considerable cost and effort. The great majority must be seeded as well.

The Baylor Survey Grounds (or public oyster rocks) are scattered throughout tidewater Virginia in the principal tributaries and in the Bay

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[11] Under Article XI, Section 3 of the Virginia Constitution, natural oyster beds may not be leased, rented or sold, but the General Assembly may periodically **define** (and redefine, nobis) and **determine natural oyster beds**. Our interpretation of this provision is that redefinition and redetermination by the General Assembly could result in modification of the boundaries in such a way as to allow leasing of the bottoms currently excluded by such legislative action.

Also, it has been held that this section of the Virginia Constitution does not prevent the General Assembly from **infringing** on **natural oyster rocks** by authorizing other uses that are in the public interest (Commonwealth v. City of Newport News, 158 Ba. 521 1164 S.E. 689 1932). An example of the General Assembly's authority to infringe upon public oyster grounds can be found in Sec. 28.1-101.2 of the Code authorizing the State Highway Department to cross Baylor grounds. Such changes in use patterns have been permitted for many other projects and for other purposes.

Such "flexibility of use" provisions seem relevant to the objective of improving leasing arrangements for the private sector of industry in order to restore native oyster production, revive public and private elements of the oyster industry, improve Virginia's seafood-based economy and benefit the entire citizenry of our Commonwealth.

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[12] With the exception of those bottoms explicitly assigned to individuals or organizations by early Colonial charters or patents.

(Figure 4). The naturally productive rocks within the Baylor Survey Grounds often have a firm sand-clay or shell bottom on which oysters occur. However, the Baylor Grounds also include areas of shifting sand or mud bottom or deep water unsuitable for oyster culture as currently practiced. In some locations, deeper waters cannot be used regardless of the type of bottom or culture methods because of other factors, such as seasonal hypoxia (low oxygen). 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 passed down for many generations (Figures 5, 6 and 7).

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 (and spawning) size. Generally, oysters may be harvested only when they reach 3 inches, except for a few low-salinity regions where growth is slow and the legal size is 2-1/2 inches, or in seed areas. Specific 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 ranging from recently-set spat to those of the largest size may be harvested from those places. In the past, oysters from the James River in the 2 to 3 inch size range were harvested and the meats steamed from the shell. These meats were sold to soup companies to use in canned stews. Consequently, this size range was commonly called "soup oyster". In 1986-87 large quantities of "clean-cull" or market oysters for shucking, shell-stock, or direct marketing, were taken from these seed beds, contrary to past practices. Harvesting of market oysters from the James River seed beds has been continued into the 1987-88 season.[13]

Opening or Closing Public Rocks

Certain laws and regulations govern the harvesting of oysters in Virginia. However, with the exception of the Great Wicomico and Piankatank rivers, they are seldom used to maximum advantage.

Under those laws the Commission (VMRC), or the Commissioner with the approval of the Commission, may, whenever it is deemed 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. Also it may establish seed beds, plant shells and other cultch thereon, transfer seed thereto, or take any other restorative measures which it considers suitable.

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[13] As may be seen in Table II and the discussion derived from that compilation, actual determination of the exact source of harvests within the lower James River, i.e. the traditional seed beds as well as those downriver, cannot be determined. This makes careful separation of the harvest production of clean-culls (soups or markets) from seed oysters in the lower James impossible. This undesirable situation must be corrected before production figures will be accurate and fully useful!

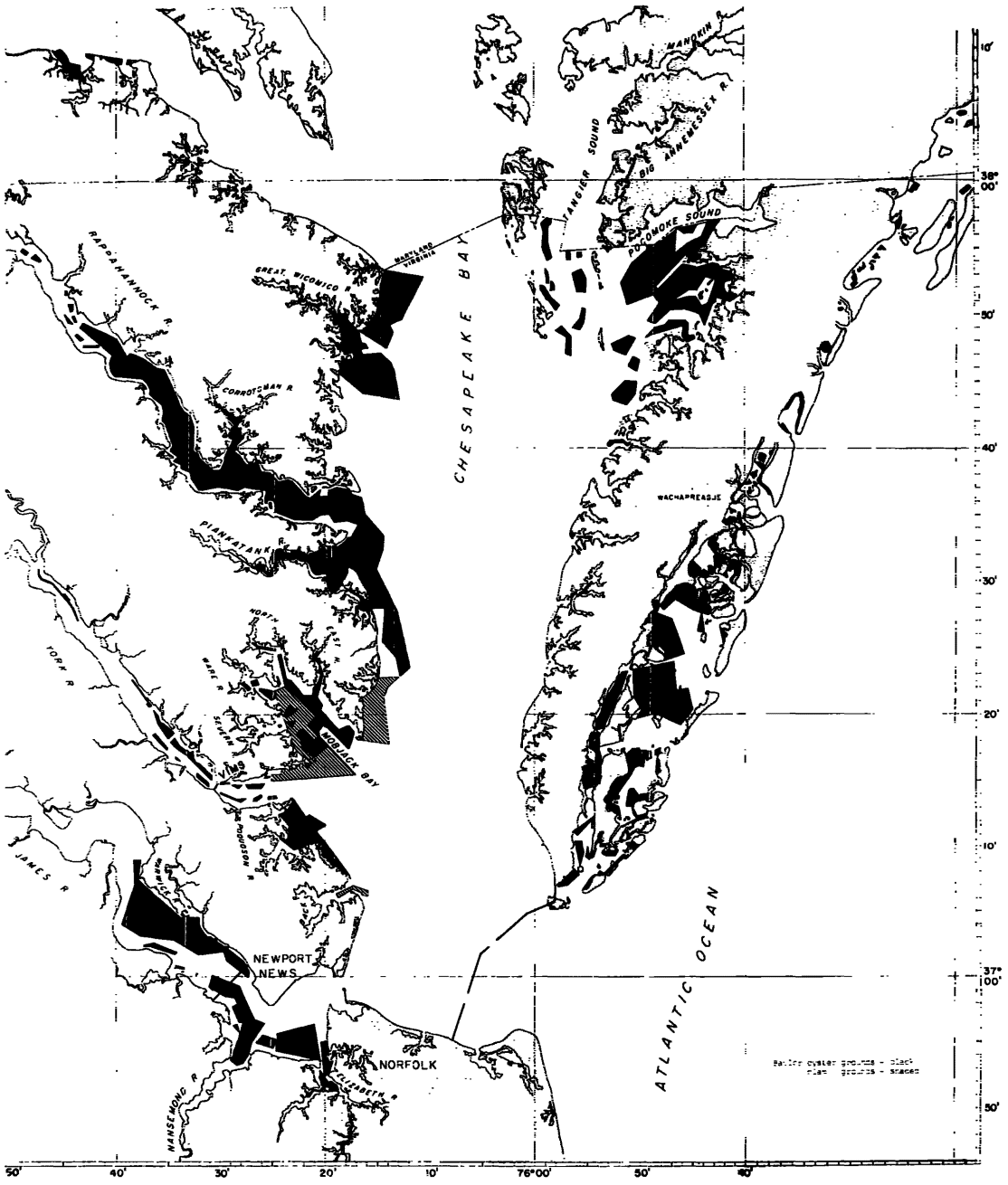

Figure 4

Map of tidewater Virginia showing public oyster ground(s) and public clam ground(s). The public oyster ground(s) (Baylor Bottoms) are in black; public clam bottoms are shaded. (From charts on file at VMRC.)

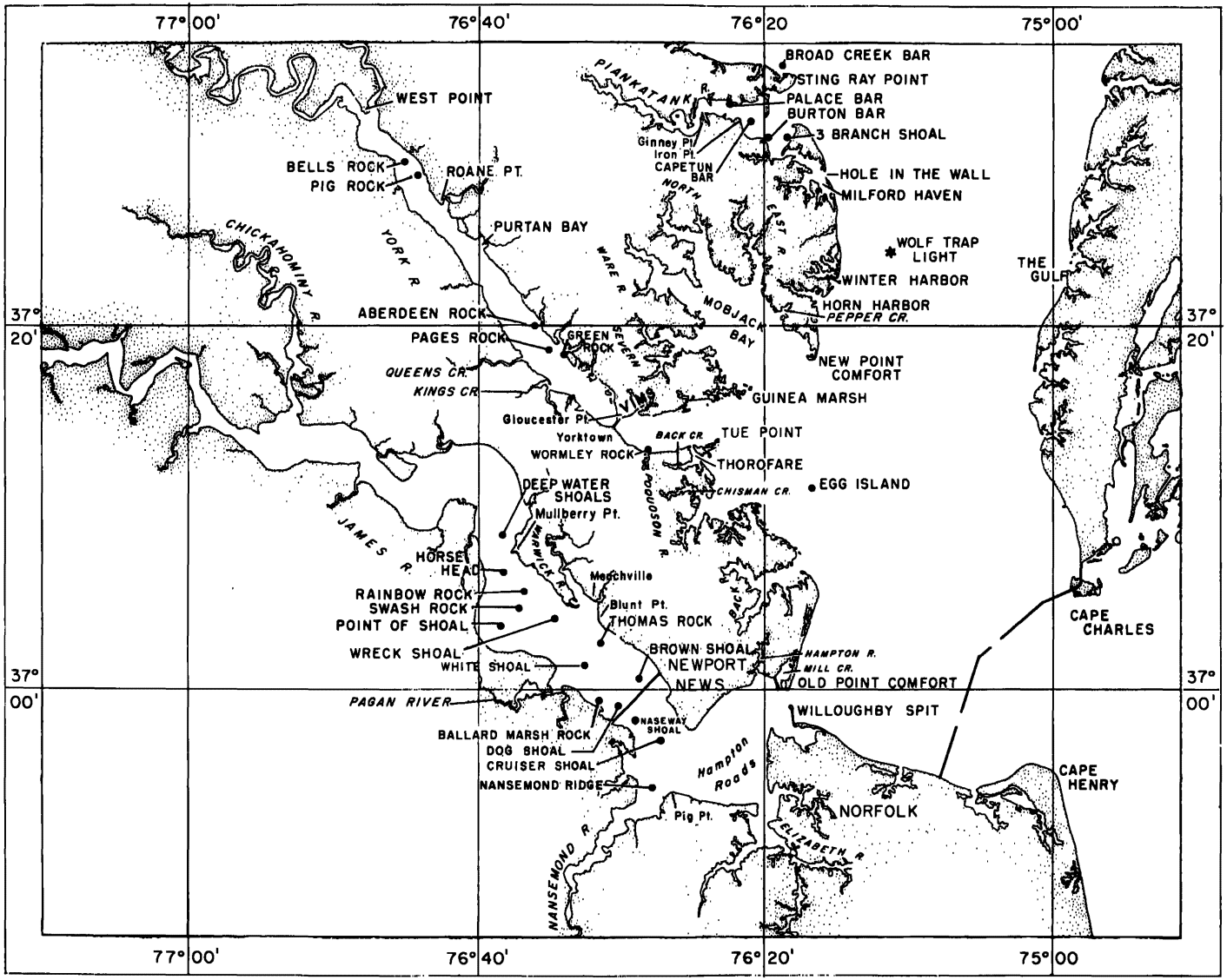

Figure 5

Names of oyster rocks, geographical points, towns and bodies of water in James and York rivers.

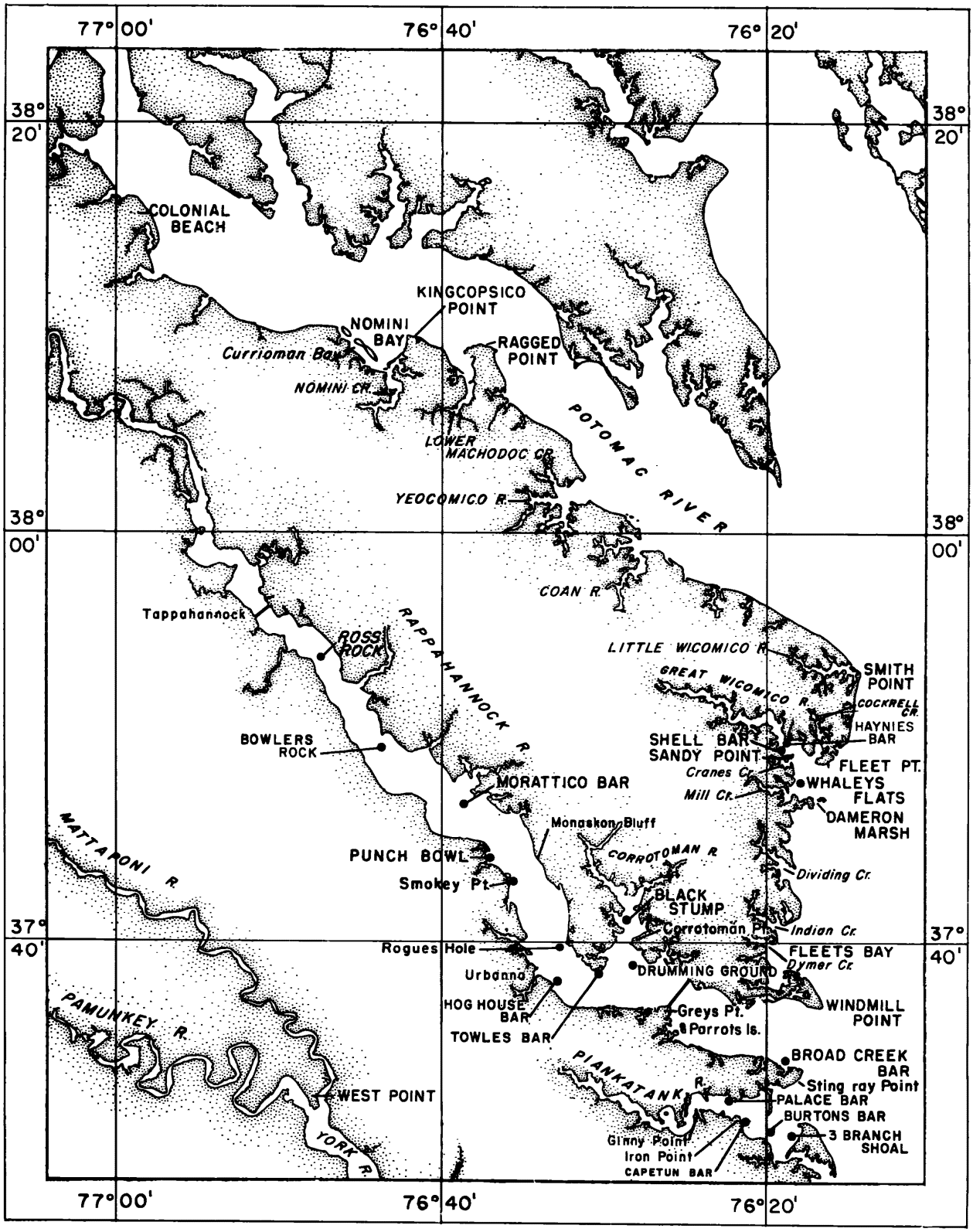

Figure 6

Names of oyster rocks, geographical points, towns and bodies of water in Rappahannock and Potomac rivers.

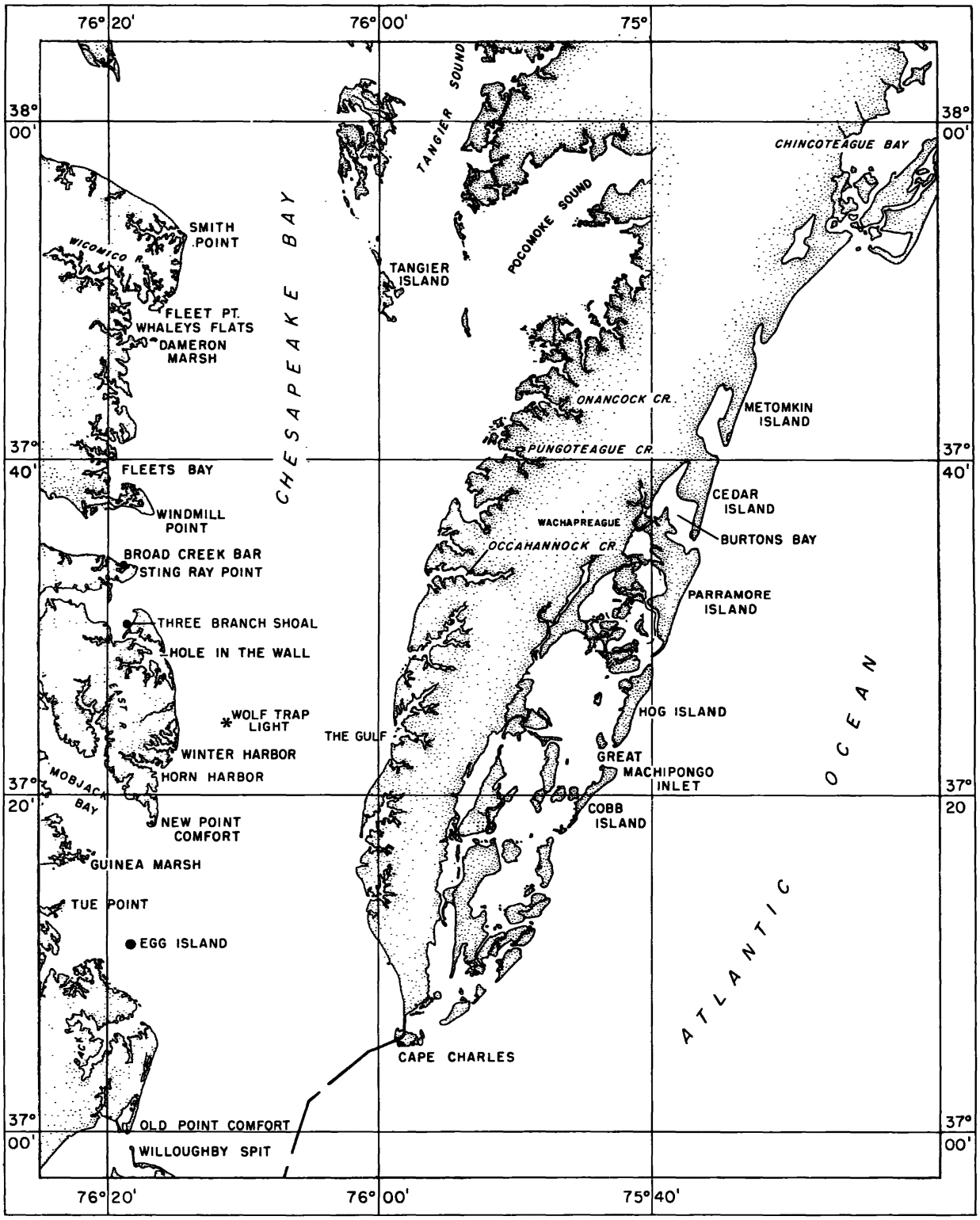

Figure 7

Names of oyster rocks, geographical points, towns and bodies of water on Eastern Shore of Virginia.

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). Emergency action is possible.

Oyster Harvesting Devices

Oysters are typically harvested from public rocks ("Baylor Grounds") by licensed watermen (usually called "tongers") using hand tongs, which are two elongated rake-like heads with sharp teeth attached to long wooden shafts (Figure 8). They are positioned in scissor-like opposition to each other to provide a "basket" when closed. Lengths of tong shafts sometimes reach 32 feet but most range from 14 to 24 feet. Hand tongs remain the only gear which may be legally used to harvest oysters from most of Virginia's public rocks. These rules mandating use of an inefficient, hand-operated harvesting gear such as hand tongs were established to prevent overharvesting and depletion of the oyster populations on the natural rocks. They have not accomplished these objectives! Rate of harvesting and depletion may have been slowed but most public beds have been over-harvested and some even obliterated by hand-tonging.[14] Though inefficient, the number of tongs in use and the combined time they have been applied have enabled tongers to take more oysters from public market oyster rocks than nature and VMRC could replace as overfishing of public bottoms persisted.

An early exception to the preceeding method of harvest was the limited use of patent tongs allowed in the deeper waters of the lower Rappahannock, in the Bay and on the Seaside of the Eastern Shore. Also, dredges were permitted during a sharply restricted season in several small areas in Tangier Sound. However, since the late 1970's, as production declined, areas where patent tongs may operate have been expanded to include many shallow and deep areas in the mid-Rappahannock and other locations where natural recruitment levels are low. As recently as 1986-87 patent tongers have sought access to grounds formerly closed to them. Also, since 1978, dredging has been permitted during a restricted season in most of the Pocomoke-Tangier Sound region and in several Bay areas during a regulated time in the winter months. Patent-tonging and dredging also have "obliterated" public oyster beds in certain areas.[15]

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[14] By "obliterated" we mean that existing oyster stocks have been reduced to such low levels that the beds in question no longer replenish themselves. Some beds have been so damaged that their topography and dimensions have been altered markedly as cultch was lifted during the harvesting process and dropped overboard elsewhere or even removed from the water entirely (Hargis, 1966).

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[15] Perhaps the best examples of this "obliteration" are some of the patent tong areas of the Rappahannock and Pocomoke which have been denuded of oysters, essentially.

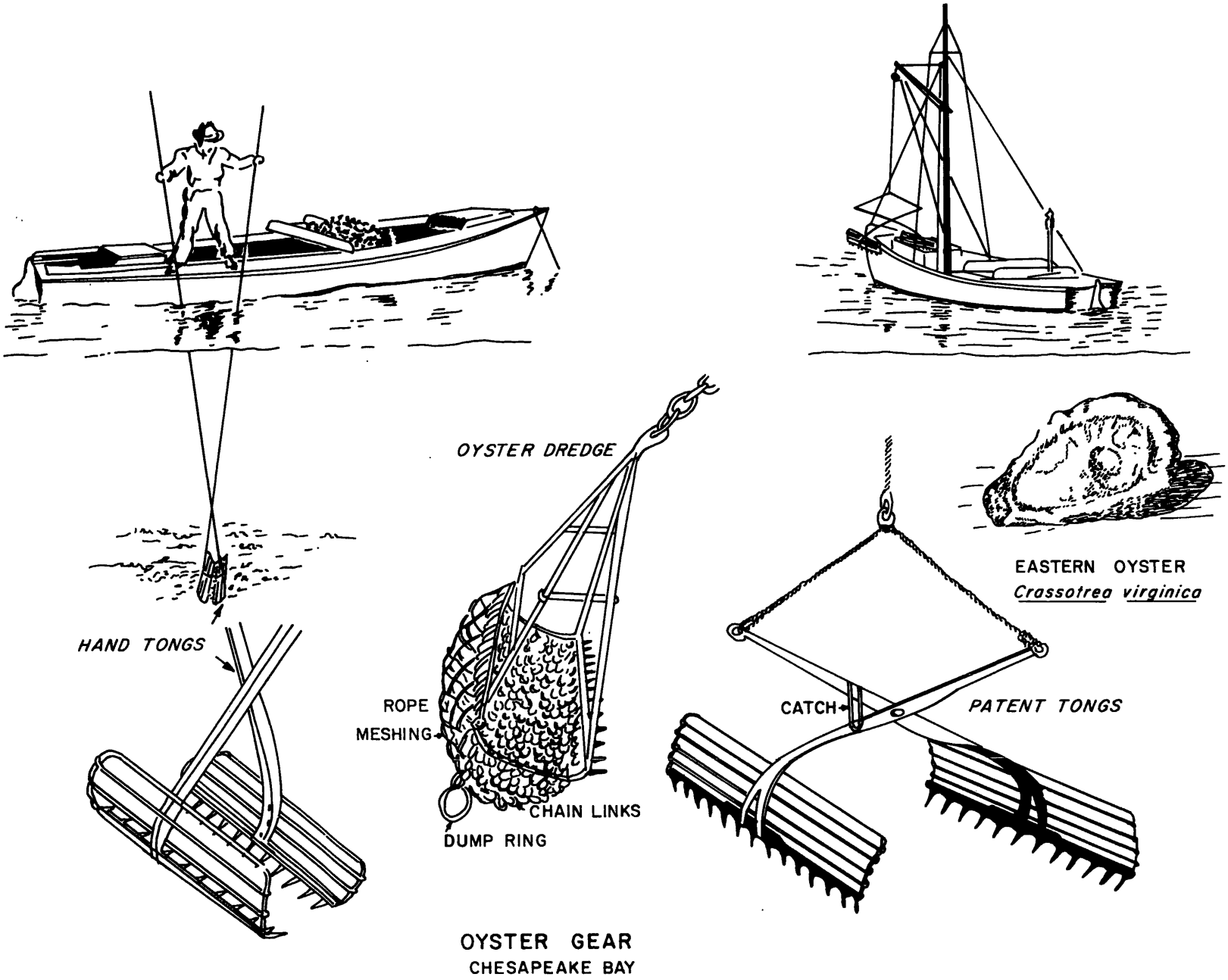

Figure 8
Illustrations of various oyster harvesting devices used in Virginia.

At times the Commission has allowed surface compressor-equipped, or SCUBA divers to harvest large single or clumped oysters or deep water oysters in selected places. Since overharvesting has been the rule on most public bottoms, additional incursions by patent tongers, dredgers and divers into areas not normally "hit" by hand-tongers have served to cause further depletion of already strained brood-stock populations. Pressures for this type of undesirable harvesting access are likely to increase as overharvesting by hand-tongers continues to deplete the more readily accessible shallow-water beds.

Hand-tongers operate from shallow draft boats 20 to 45 feet long, usually possessing a cabin or cuddy forward and a large open cockpit aft where the oysters harvested by the tonger are heaped. The boats have a wide washboard on which the oyster tongers may stand while harvesting. Freeboard is usually 2 to 4 feet. The crew generally consists of two or three persons. One member "culls" the catch at the culling-board, while one or two "tong." If market oysters are being harvested, culling consists of separating legal-sized oysters from smaller ones and returning to the water all oysters less than legal size as prescribed by law; shell must be returned also. When a waterman is working in a seed area the minimum size limit does not apply. However, by law and regulation all shell which does not bear visible small oysters must be culled from the catch and returned to the water. This process is called "clean-culling." This rule is intended to slow or eliminate the destruction of the rocks caused extensively in the past by removal of the shelly substrate so important to continued productivity. The same is true of the rule requiring return of shell to the bottom in market oyster areas. Had these regulations not been in place, seed and market oyster production would have diminished even more rapidly than they have. Undoubtedly they have been violated frequently. Despite them, many rocks have been seriously reduced or obliterated. Buried oyster shell reefs, once well above the bottom and quite productive, abound!

In general, catches of market oysters per boat range from 10 to 30 bushels daily. Daily catches of seed, usually higher, 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 shucking houses or their agents, or to shell-stock packers specializing in the sale of unshucked or "raw-bar" oysters. We term this first economic transaction, first-sale.

Seed oysters for planting on leased bottoms are handled somewhat differently. At the end of a harvesting period, usually a "working" day, the tonger may sell his catch to the operator of a "buy-boat." Buy-boats may be 60 to 80 feet long and 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 Virginia oyster bushel. Occasionally controversy develops between the buyer and seller as to whether the bushel measure is properly filled.

In recent years the sale of seed or market oysters to truckers instead of buy-boats has become the most common practice and the number of operating buy-boats has dwindled significantly. In this process the tonger transports

his oysters to a "dock"[16] where they are off-loaded onto a conveyor emptying into a truck. There is little effort to record the precise locations at which the seed was originally harvested; hence, records of production from specific oyster rocks are virtually non-existent! Thus, quantitative evaluation of the effects of repletion efforts in specific areas on individual rocks is impossible! This somewhat casual approach, which unfortunately pervades the entire data-gathering effort and seriously impairs research and management efforts, will be treated more extensively below.

Trucking probably increases the survival of seed oysters during transport since trucks are able to travel to many (or more distant) planting areas much faster than the buy-boats. However, at times many seed, especially the smaller sizes, are damaged or killed by poor handling or undue exposure during transfer, shipment and planting by either method. Oyster planters, truckers, buy-boat operators and State repletion officers alike would do well to investigate and reduce these operationally-induced seed oyster deaths as much as possible to allow increased yields from planted bottoms: "A penny (spat) saved is a penny (oyster) earned." When profits depend upon close margins, all losses and costs must be trimmed or eliminated.

For various reasons, transactions between the tonger and buyer have traditionally been in cash. Until 1976 this practice made it difficult to obtain valid statistics on price, volume or source of seed. However, by regulation the VMRC now requires an accounting of each sale and price and other economic details should be available to those with a need-to-know, if the system is working properly. Provided transactions are supervised and the rule is enforced, improvements in precision and accuracy of harvests and first-sale prices should have resulted.[17]

Recently part-time commercial and sport harvesters, who frequently use boats of lesser substance and sea-keeping qualities than those of full-time watermen, have increased. The catches of part-time, casual or subsistence and sport-catchers often are unrecorded and unknown to anyone save themselves. The amounts taken may be significant when considered in toto. This aspect should be investigated to determine its actual import, and, if necessary, to develop an appropriate coefficient to account for such normally unrecorded catches later.

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[16] The word "dock" is enclosed in quotation marks because it is widely misused, even by nautical persons who should know better. Actually the dock is the berthing space beside a pier, wharf or quay occupied by the vessel when alongside. It is, so to speak, the "hole in the water" into which the vessel fits when berthed.

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[17] Since October 1975 the tonger must sign a VMRC Buyer's Slip if cash is paid. It is not known how much production statistics have been improved by this arrangement. Probably much escapes reporting despite it. This aspect should be examined.

Season of Harvest

The season when oysters may be harvested from public rocks is regulated. In the James River oysters may be taken from sunrise to sunset from 1 October until 1 July, but this period may be modified by the VMRC. In all other regions of Virginia except Seaside, oysters may be harvested from 1 October until 1 June. The period encompassing the "open" months from fall to spring is considered the "biological year" (more properly "the harvesting year"), and landings data are often reported for the "split" year - as they are in this report (i.e. the 1984-85 or 1986-87 harvesting seasons or years). A harvest year, which would cover the catches of both public and private sectors, would extend from October 1 of one year through September 30 of the next to be complete since private producers may harvest at will. Hence, a harvest year would generally be cited as 1984-85 or 1986-87 in tabulations, figures and text as they are in this report. Occasionally landings are reported for the calendar year (i.e. 1984). In such instances the reporting period is from 1 January to 31 December of the same year. Calendar year data are used in this report (as stated in the accompanying text) only when complete "biological year" data are not available.

Private Grounds

Private leases used to produce oysters for business ventures or home consumption are scattered throughout Virginia, generally occupying marginal areas (in terms of natural production or unaided potential production of oysters), between the Baylor Survey Grounds and the shore (or between the Baylor Grounds and offshore channels in deeper waters). Most of them were not adjudged to be "natural" oyster bottoms when the original Baylor Survey was made. In most instances these areas do not receive significant natural sets but must be planted with seed to produce oysters. Usually leased bottoms are too soft for oyster culture without stabilization. In such cases, "shelling", is required. Shelling costs money and effort and adds to production expenses. From 1930 to 1960, and for some time before, private grounds usually produced 3 or 5 times as many oysters on a State-wide basis as did the public grounds, and on fewer acres. In the 1977-78 season public rocks yielded more for the first time in decades, and this situation has prevailed for most of the years since (Table II; Figure 1).

The private oyster industry in Virginia is almost wholly dependent upon the productive public "rocks" in the James River as sources for seed. Lesser public seed sources exist on public rocks in the Great Wicomico and Piankatank rivers but, as stated previously, the available acreage for oyster culture in these two systems is not sufficient for large-scale production. Consequently, without seed from the James River the private oyster growing industry of Virginia would never have developed. Without it neither the private nor the public sectors of industry can be revived in timely fashion.

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

Seed may be transported to growing areas by buy-boats for direct overboard planting; however, most are trucked and then loaded onto boats or barges (monitors). At the growing area 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 certain areas the monitors are equipped with a planting device consisting of a conveyer belt to move the seed to a revolving disc which scatters the seed more-or-less evenly over the bottom. Such modern seeding devices are not commonly used, however.

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, unacceptable losses of oysters due to predators and diseases usually occur. (Distribution and abundance of predators and diseases, and hence survival and production of both seed and market-sized oysters is often directly and positively related to salinity.)

While higher yields have been assumed by earlier writers and in some instances actually experienced, our studies show that the statewide average yield is a single bushel of market oysters from each bushel of seed planted. Were it possible to improve this 1:1 ratio the economics of private planting and of the public repletion program would be enhanced! Obviously, the degree of economic enhancement would depend upon the productivity improvements accomplished. We are convinced that productivity can be increased. Also, we are convinced that small economies and reductions of losses will be worthwhile economically, as, of course, will large ones.

Private growers often must plant shells in order to firm their market-growing (or "grow-out") bottoms prior to planting seed oysters or to provide cultch for spatfall. Such shell plantings may be at densities ranging from 5,000 to 10,000 bushels per acre. The small oysters attaching to these shells may be harvested and sold as seed. More frequently, they are allowed to remain and grow to market size in the area of setting.

Oysters from private leases may be harvested by tongs but, generally, towed dredges designed to catch oysters are used (Figure 9). Dredge boats may be 40 to 60 feet long although smaller ones are sometimes employed. In Virginia all are powered by internal combustion engines.[18] Oysters are transported to the shucking house or other place of first-sale by these dredge boats.

To reiterate, production of oysters from leased bottoms occurs, in most instances, only when they are planted with seed oysters or shell by the grower. The growers' expectation of an adequate economic return determines whether or not a leased bottom will be planted. Until recently, most (about 80%) of the oysters harvested in Virginia came from leased bottoms. In

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[18] Interestingly, in Maryland sailing vessels are still used as a conservation measure though restrictions of oyster dredgers to sail-power alone are weakening and powered pusher-boats are used more frequently to help move the sailing vessels over the dredging grounds.

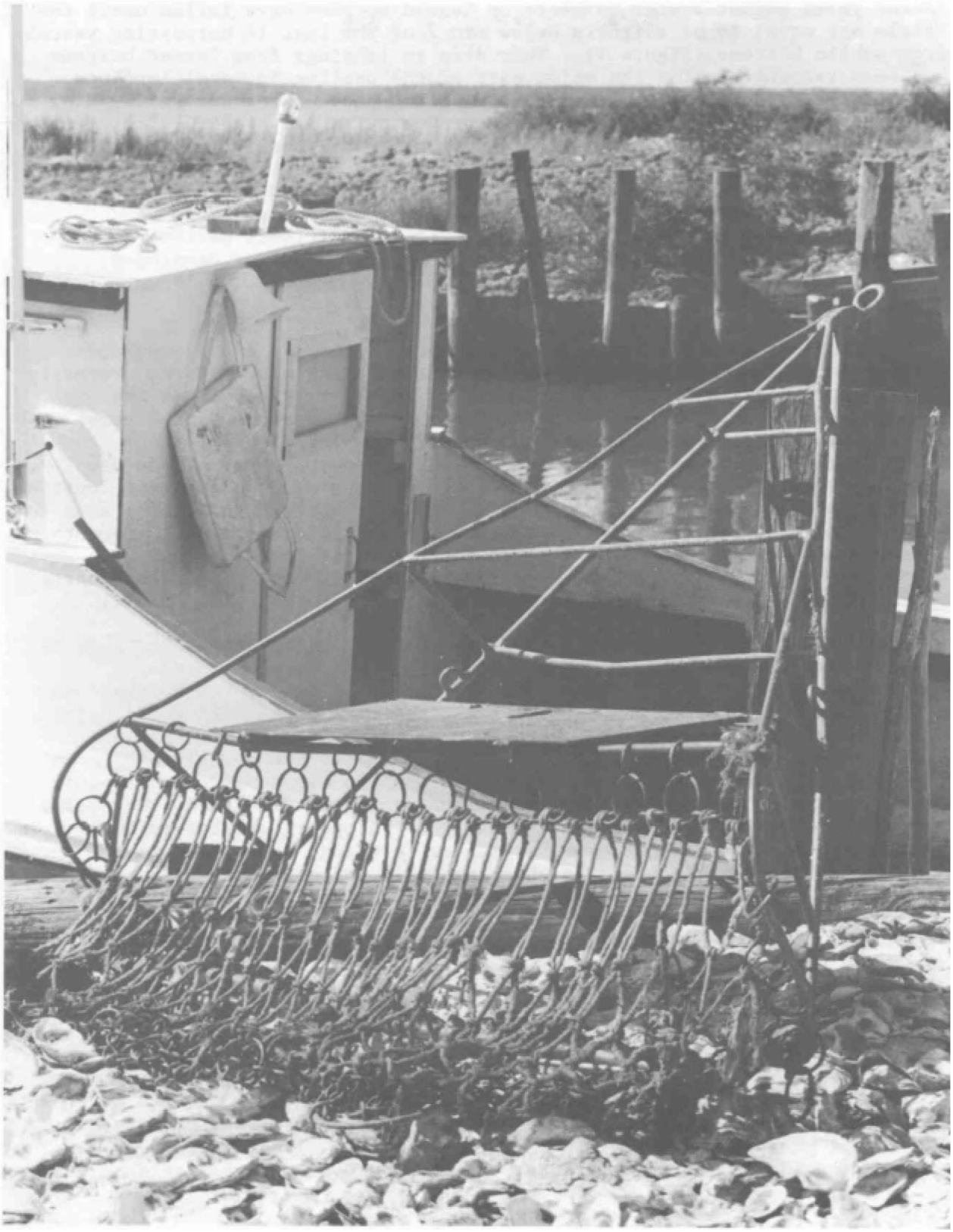

Figure 9

An example of an oyster tow dredge.

recent years market oyster harvests on leased bottoms have fallen until the totals are equal to or slightly below (in 7 of the last 10 harvesting years) from public bottoms (Figure 1). This drop in landings from leased bottoms has been responsible for the major part of the decline in total landings from the State since 1960. Even if our active public beds are restored by a major repletion effort to their former productivity and yields, Virginia's waters will not attain their full level of potential total yield, (i.e. realize their potential for oyster production), or even past levels of actual yield unless production on and harvests from leased areas increase. If market oyster production on leased (and public bottoms) is to be restored, seed yields must be increased. Also, additional markets for "soups", shucked and "raw-bar" oysters must be found and/or developed.

Shucking Houses

Oysters from public rocks as well as private leases are opened and processed in licensed shucking houses scattered along most rivers. Formerly many more such establishments existed but a number have closed as the industry declined. The current number is about 53, a reduction of some 36 percent since our 1978 estimate of 83 in 1975 (Table IV, p53). Many Virginia shucking houses are now shucking or repacking oysters from New Jersey or Maryland waters or the Gulf Coast waters, or even the West Coast, as local production continues to decline. Oyster growers on Seaside seem to be producing larger percentages of "barrel-stock" for the raw-bar trade than formerly and shucking has been reduced there. It is possible that competition by shucked stock from the South Atlantic, Gulf, and West Coasts has been partially responsible for this change (Castagna, pers. comm.)

Oysters to be shucked are transported from the dredge boat or truck to a small storage room adjacent to the shucking house by wheelbarrow, mechanical conveyor or front-end loader. There, on waist-high benches rest small elevated blocks on which the oysters are placed and held while being opened by hand. The method of shucking or opening oysters has changed little in the past century (Figure 9). Shuckers may use a small hammer to break off 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 first breaking the bill. Mechanized "chippers" similar to hole-punching machines may be used in nicking or "bitting" to facilitate shucking. Once the blade of the shucking knife is inside, the shucker deftly cuts one end of the adductor muscle loose from the shell with the oyster knife and the shells are forced apart with a quick twist of the wrist and blade. Then the other end of the adductor muscle is separated from its anchorage on the opposing valve and the entire body or meat is dropped into a gallon container half-full of fresh water. Efforts have been made to reduce labor costs by development and use of opening or "shucking" machines. Limited success has crowned these efforts however, and hand-shucking remains the primary method.

When the 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 the meats remain. This is called draining. Tax payment for shucked oysters is based on the volume of drained meats.

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 which may be held in this apparatus for no longer than 30 minutes (Figure 10). "Blowing" time (the time air jets are left on) has two effects. First, the longer the meats are blown the more thoroughly they are cleared of mucus, sand, mud and small bits of residual shell making them cleaner, more desirable and improving their shelf life. Secondly, the meats take up fresh water and their volume may be increased from 10 to 20 percent. Meat weights and monetary yields are enhanced. Unscrupulous operators may take advantage of the latter effects by "blowing" longer than necessary.

After blowing, oysters are cooled to 40-45^{o}F and packed into containers ranging in capacity from less than a pint to five gallons which are then placed in ice. In this form they may be shipped by truck to markets throughout the United States. Some are frozen for later use. In some instances the shucked oysters are processed as breaded oysters. Shucked and cleaned oysters are sold commercially in graded sizes. Ranges in numbers per gallon are: Standards - 300 and up; Selects - 210 to 300; Extra Selects - 160 to 210; Counts - 160 or less.

There are major differences in sizes and quality of oyster meats between areas of the Bay or rivers and even between regions or rocks in a river. Why such quality differences occur is not known exactly, but is undoubtedly due, in part, to the plankton and other sources of food and nutrients in the water, competition from other nearby oysters and other plankton and suspended-particle feeders, and at times, the presence or absence of micropredators, parasites, and oyster pathogens. Differential water quality, including quality of sediments and sediment loads may also be involved. As indicated in Section IV below, additional research on this important question is needed.

Not all oysters are opened or shucked by hand. For example, the small "soups", are steamed open without shucking. This latter practice usually precedes further processing into canned soups, stews, or chowders. Some are shipped in the shell (sometimes called barrel-stock) for opening and processing elsewhere or for the raw-bar trade. The "packing" required to get such shelled 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 harvester or grower for whole oysters are discussed in detail in our book (Haven, Hargis and Kendall, 1978a). In actual practice the price paid is usually based upon the numbers of pints of meats the oysters will "shuck" per bushel. This is determined by taking a small sample prior to shucking or by paying for the yield on the entire lot after the oysters are shucked or 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, a listing

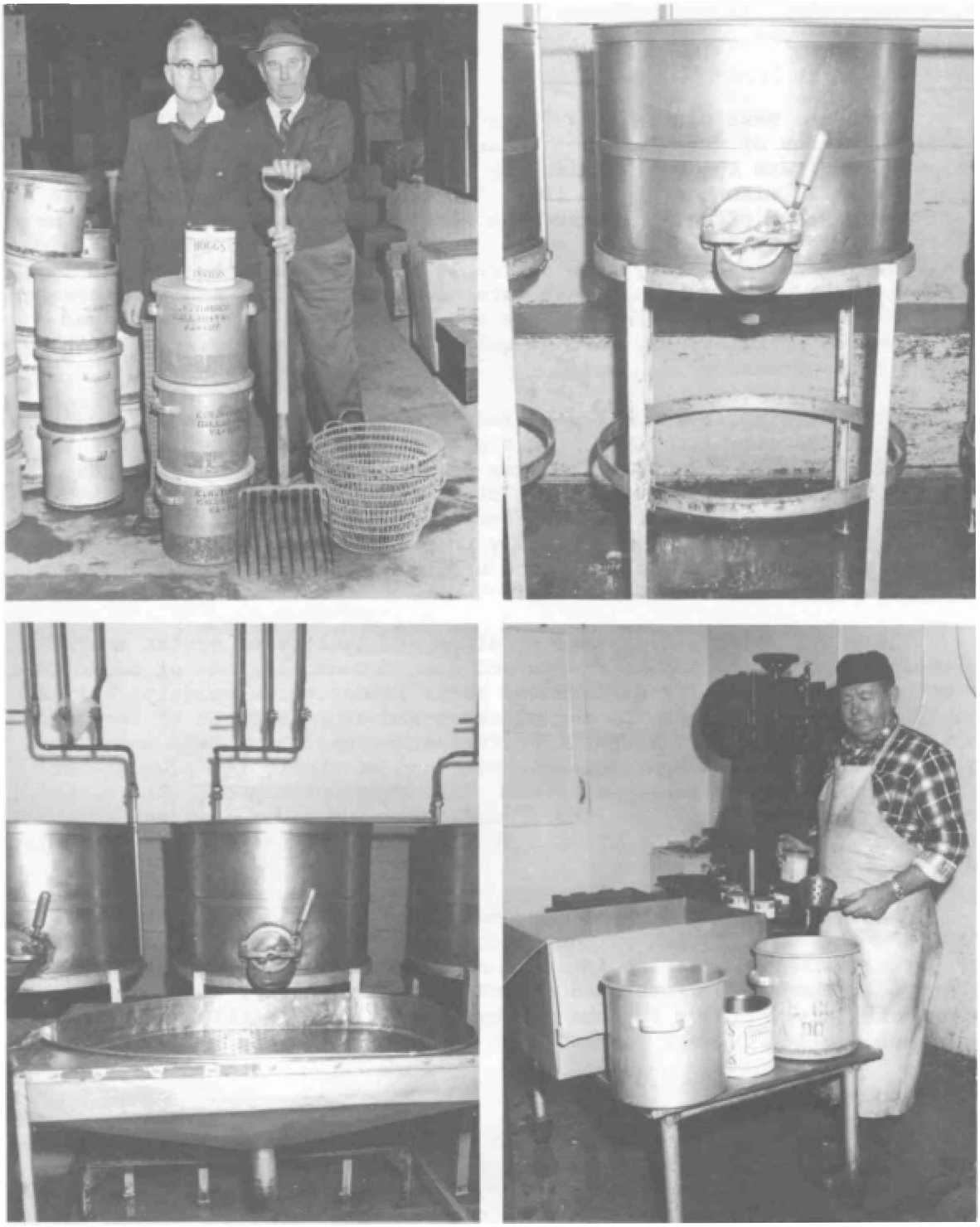

Figure 10

Methods of processing oysters.

a. Five gallon cans for shipment of shucked oysters, fork and baskets for handling and storing oysters.

b. Tank for washing and blowing oysters.

c. Blowing tanks and tables for washing and draining oyster meats.

d. Equipment used for cold-canning (i.e. without the meats being significantly heated as would be done for pasteurization and "heat-canning") oyster meats for shipment.

of certified companies is published monthly. Basically there are four types of businesses:

RS = Reshipper - Shippers who trans-ship shucked stock in original containers, or shellstock 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 shellstock 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 also.

Table IV

Number of authorized market oyster-handling and processing businesses by category.

	1975	1985	Change (%)
Shucker-Packer	83	53	-30 (36%)
Shell-stock Shipper	54	47	- 7 (13%)
Repacker	46	51	+ 5 (11%)
Reshipper	0	1	+ 1
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Totals	183	152	-31 (17%)

The numbers of businesses in each category in Virginia in 1975 and 1985 are shown in Table IV. The decline in numbers of business organizations involved in these phases of the oyster industry is obvious and amounts to an overall loss of about 31 businesses, or 17%, in ten years. Noteworthy is the fact that the shucker-packer segment has declined more drastically (36%)

than the others; a further indication of the decrease in production and shucking of locally-grown oysters.[19,20]

The manner in which the businesses listed above may interact to influence price is not clearly understood. (Usually retail prices are considerably higher than those at dockside causing the harvesters and others whose prices often are not reflected in increases at the retail level, to wonder where and why those increases occurred.) 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 and detailed understanding of practices, interactions and economics of the buyers, shuckers, packers, repackers, shippers and associated activities would require careful and comprehensive study of these phases of the industry. Such socioeconomic study is recommended very highly in the research-needs portion of Section IV below.

Meat Yields

Factors governing oyster quality or yields, extremely important economically, are only partly understood, as indicated above. Yields of meats may vary seasonally and regionally. A statewide average might be 6.0 to 6.5 pints per Virginia bushel! The range, however, is from 4.0 to about 8.0 pints. A yield of 7.5 pints or more per bushel of shucking stock is exceptional.

Natural Factors Affecting Oyster Production

Hydroclimatological factors

Tropical Storm Agnes struck Virginia on June 21, 22 and 23 of 1972 and dropped unprecedented quantities of water on the major watersheds emptying into the tributaries of the Chesapeake Bay. As a direct result of this storm many oysters were killed as waters of lowered salinity inundated public and private beds alike. Losses of oysters in terms of total populations were estimated as follows: James - 10%; York - 2%; Rappahannock

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[19] Availability and costs of maintaining competitive wages of productive shuckers and losses of such personnel to other employment undoubtedly played roles in the decline of shucking houses in Virginia as elsewhere in the mid-Atlantic and the northeast. However, in recent years the major factor in the lower Chesapeake area has been reduction of local market oyster production. All economic factors interact, of course, and discovery of their true importance would be one purpose of the socioeconomic research urged herein.

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[20] Even as one of the later drafts of this report was written in 1987, a large packer (J. W. Ferguson and Sons of Remlick) on the lower Rappahannock announced plans to close its shucking facility after almost a half-century of operation.

- 50%; Potomac Tributaries (Virginia) - 70%. No attempt is made to analyze the impact of Agnes on the economy of the State in this report since that information has been summarized elsewhere (Haven, Hargis, Loesch and Whitcomb, 1976). It is sufficient to note that it caused more than eight million dollars in damage to the oyster industry. Public beds were affected and private planters suffered losses which were often catastrophic. Despite this damage, Agnes only accelerated temporarily, but did not otherwise change, the downward trend established much earlier. Diminishment of production continued in the post-Agnes period even though low salinities due to the massive storm-related freshets also wiped out the sometimes major predators, the oyster drills, in many places where oysters were able to survive.

This account serves to illustrate the susceptibility of oyster production to natural calamities. Like agriculture, wild production and natural or "outdoor" mariculture (as opposed to controlled-condition, indoor mariculture) of oysters depends upon favorable short- and long-term meteorological events and on continued favorable hydroclimatology, water quality and bottom features. Certain beds are more susceptible than others to "natural" losses. Using less-susceptible beds reduces those risks. Increasing production in damage-free periods ("good years") improves the economic balance-sheet. Employment of high-yield beds increases normal productivity and reduces risks and economic losses. As in agriculture, such factors are normal concomittants of oyster production and must be considered.

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 holes through the shell, rasping the meats and ingesting the shredded flesh. When salinities average less than about 15 ^{o}/oo drills do not live; about and above this level they do and may be serious and destructive pests. Within Chesapeake Bay the two screwborers or oyster drills, Urosalpinx cinerea and Eupleura caudata, cause difficulties, with the former being the more prevalent and serious (Figure 11).

On the Seaside of the Eastern Shore the two drills are somewhat different. There the two, considered to be different subspecies, are named Urosalpinx cinerea follyensis and Eupleura caudata etteri to set them apart. These grow to be larger than their Chesapeake Bay "cousins" and occur in nearly all oyster-growing regions since there are few low salinity areas (below 15 ^{o}/oo) on Seaside. With appetites matching body sizes, their destructiveness is great. While they eat other shelled animals, and even may prefer barnacles, drills of all sizes prey readily on small oysters whose thin shells are easily penetrated. Where oysters set or are planted in areas of heavy drill abundance, few survive to market size.

As indicated above, in June of 1972 Tropical Storm Agnes killed drills in many areas of the lower Chesapeake where they had been a major problem. The principal areas affected were the lower parts of the James and Rappahannock rivers and Mobjack Bay. Reduction of their oyster prey by natural catastrophies and disease probably contributed to the reduction of

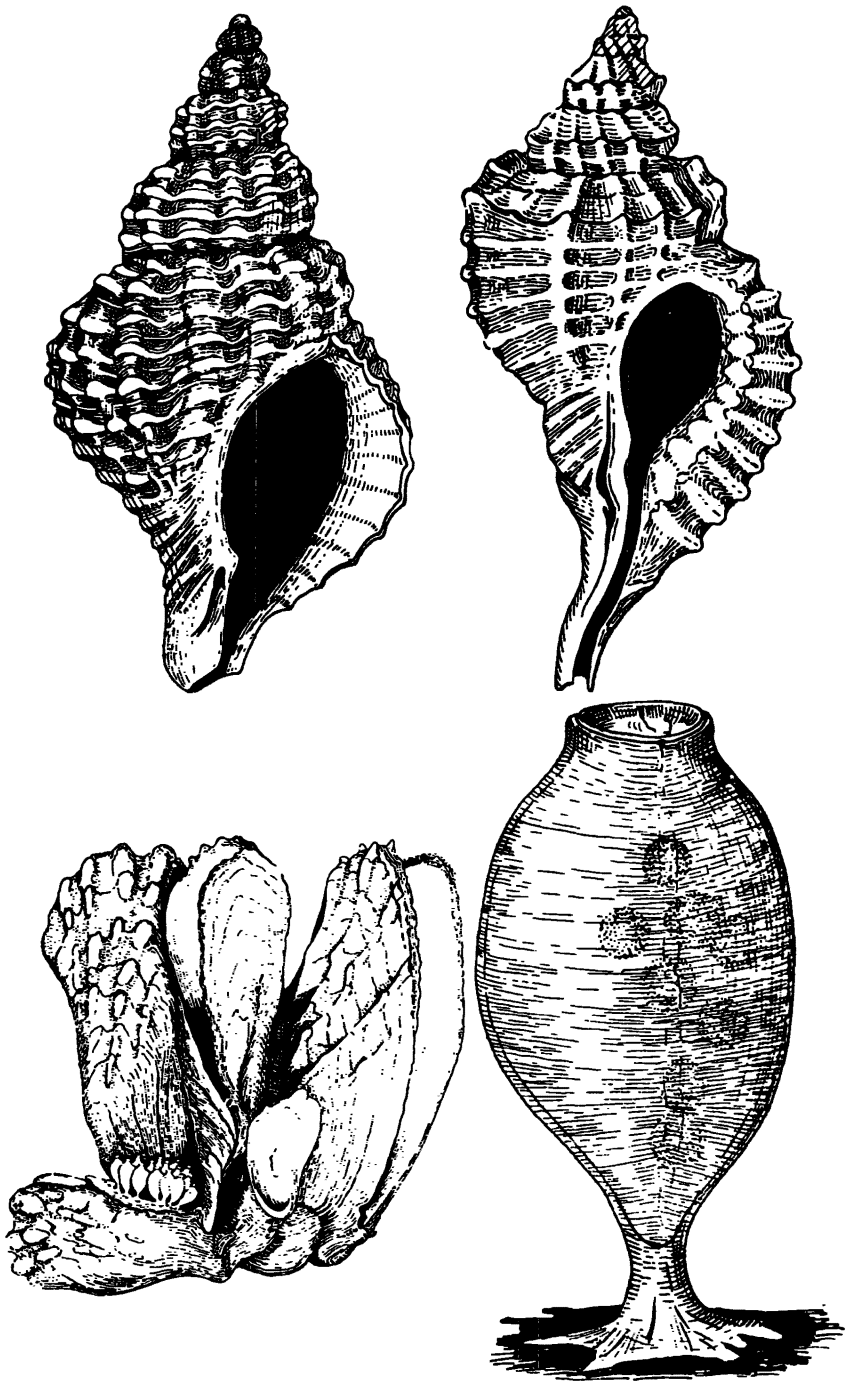

Figure 11

Species of oyster drills (screwborers) found in Virginia. Urosalpinx cinerea (left) and Eupleura caudata (right).

these predatory snails as well. Due to the recurrence of freshets and associated lowered salinities (and probably to continued scarcity of small oysters to feed upon), drills have not yet returned to these locations in sufficient numbers to cause problems, but if these areas experience long periods of high or even normal salinity they will again cause significant losses, especially as public and private oyster culture efforts are increased.

Other predators of small oysters are the oyster leech, Stylochopsis (=Stylochus, in part) ellipticus; mud crabs, Panopeus, spp. and Eurypanopeus sp.; and blue crabs, Callinectes sapidus. Oysters are also eaten by fish such as drum, Pogonias chromis, and cownosed rays, Rhinoptera bonasus. In recent years (1972-1985) cownosed rays have been especially destructive on leased bottoms in the Rappahannock River. Micropredators (or small ectoparasites) such as the snail, Boonea impressa, and relatives also feed upon oysters and other pests take their toll in reduction of numbers and meat quality.

Pathogens

Several oyster pathogens cause varying degrees of mortality in oyster populations in Virginia waters (Andrews, 1984 a, b and c and Hargis 1985). One which has evidently long affected oysters in high salinity areas of Chesapeake Bay is Perkinsus marinus, which causes the disease commonly called "Dermo." This fungus disease probably has been in the Bay since oyster culture started, perhaps before, and losses from it have always affected market-oyster production. Deaths from Perkinsus occur during warm-water periods of mid- to late summer. Its occurrence and severity are directly temperature dependent.[21] The death rate in two- and three-year old oysters may average as much as 25% annually, although a lesser rate is usual. The disease is active when mean salinities exceed 12-15 parts per thousand ($^{o}/oo$). Activity is related to temperature, also. With proper management, losses to oyster growers may be minimized during periods of normal salinity and temperature patterns. Timing of planting and of harvesting is important. Oysters should be planted sufficiently early in the year to allow maximum growth before harvest. If practical, they should be harvested before the heavy losses of mid-summer occur. Removal of old oysters prior to planting new crops may reduce losses since these old oysters serve as reservoirs for the disease. A planting density (less than 1,000 oysters per acre) is also recommended. For reasons as yet unknown,

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[21] MSX has normally caused more deaths than Dermo in affected portions of the lower Bay and its tributaries. However in 1986, and more especially in 1987, Dermo apparently produced more deaths and spread further into populations unaccustomed to its presence. Its effects reached into the Rappahannock, the Potomac and many areas of Maryland's upper Bay. This unusual spread and severity of Dermo-disease was apparently related to abnormally high salinities during 1986-87, the warmer than normal winter of 1986-87 and the unfortunate rapid transfer of the disease by movement of Dermo-infected seed into areas where it had not been (or had not been a significant factor) before.

"Dermo" causes only limited mortality on Seaside of the Eastern Shore even though it is the highest salinity area where oysters are grown in Virginia. Shore temperature regimes are similar to those elsewhere in coastal Virginia.

The major oyster disease of Seaside Virginia is caused by the "Seaside Organism" or SSO. The scientific name of the organism responsible is Haplosporidium costalis. It occurs 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 until recently. 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 seasonally. SSO may kill up to 36 to 44% of a crop during the second year. Losses usually range from 12 to 14% 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 protozoan pathogen, Haplosporidium nelsoni (or MSX), which entered or became active and 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. MSX, more than any single factor, has been directly or indirectly responsible for the major decline in total oyster production from Virginia since 1960. As discussed previously however, the major part of this decline was due to the cessation of production in the lease-holds located in high salinity areas after the severe mortalities caused by MSX. Prior to the MSX epizootic the higher salinity beds in Mobjack Bay and the lower Chesapeake held and yielded most privately cultured oysters. Production from the public beds located in the lower salinity waters declined, but not to the same extent (Table II, Figure 1). Because of the great impact of this Haplosporidium-caused disease on the industry, it will be briefly reviewed.

MSX was first observed in the lower Chesapeake Bay by scientists in Virginia in February 1959. In two years its effect was noted throughout the Bay in nearly all areas where average fall salinity exceeded about 15 $^{o}/_{oo}$ (Figure 12).[22] It did not cause appreciable losses in most areas on the Seaside of the Eastern Shore.

The areas heavily influenced by MSX include nearly all of Chesapeake Bay from the mouth of the Rappahannock south, and the downriver oyster-growing regions in the James, York and Rappahannock rivers (Andrews, 1968). Even now, 25 years after the onslaught, annual losses in susceptible seed

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[22] Oyster mortalities had occurred earlier in the Chesapeake. Actual causes are unknown but much consternation resulted when they did. It is, of course, possible that some of those early epizootics were caused by the same organisms now active in the Bay.

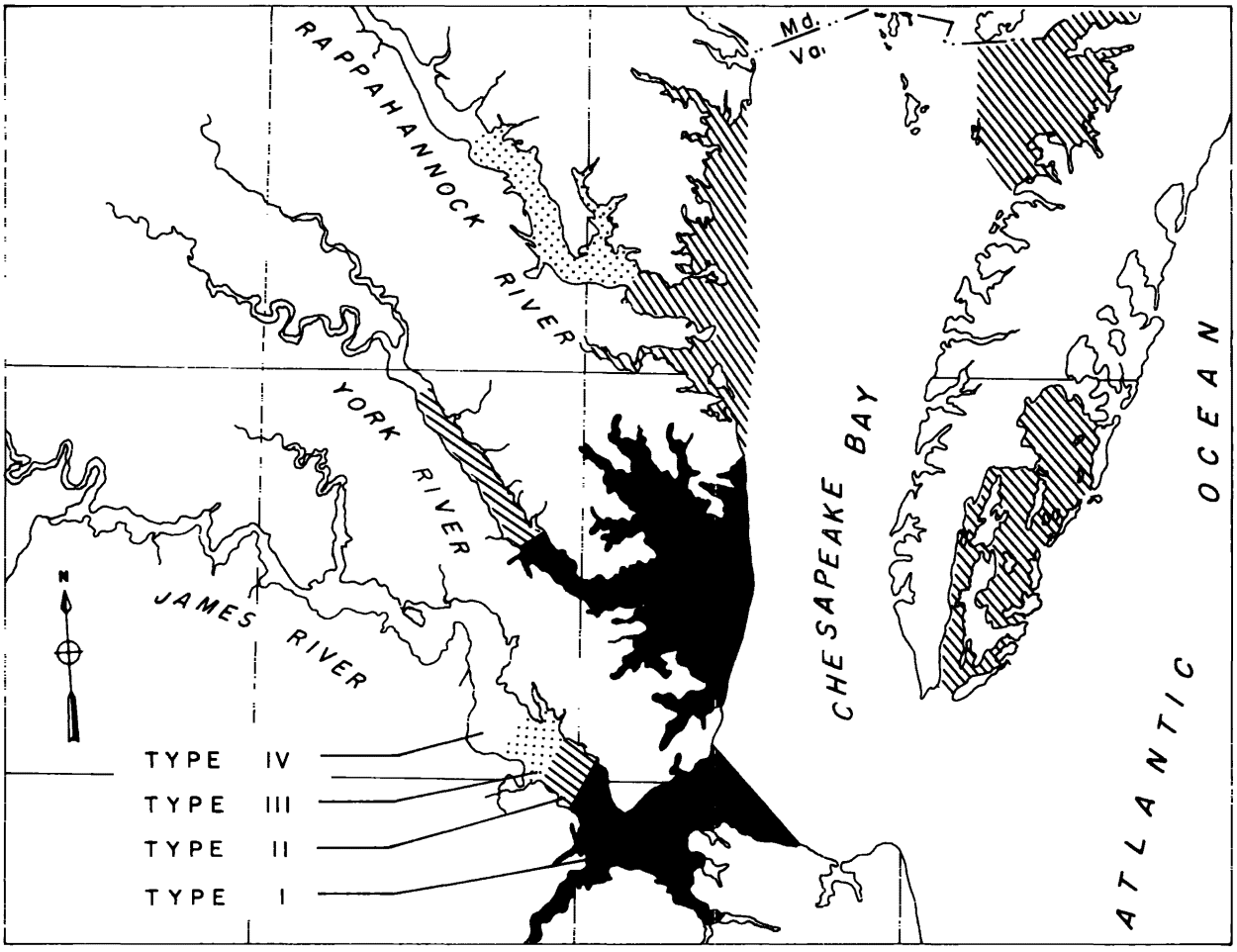

Figure 12

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.

Extent and location of these disease-affected areas are determined by prevailing salinity patterns, themselves established by rainfall in the upper drainage basins of the major tributaries. Though generally more-or-less stable under normal rainfall patterns and situated as shown here they can become dynamic if climatological conditions change and prolonged drought reduces freshwater inflow into the Bay for appreciable periods. Under such drought conditions waters of higher salinity move up-Bay and up-tributary and the MSX disease-type areas shown here move with them. Dermo may "move" also, as it did in 1986 and 1987. Combined effects of these two pathogens can be staggering.

stocks in high-salinity areas may approach 50% to 70% (Andrews 1968 and 1984a, b and c). The high mortalities associated with this disease made commercial oyster culture almost impossible in these regions during the 1960's, especially in the mid-60's when salinities were extremely high. Similar problems resulted from the drought of 1986-87.[23] The loss of these growing areas to private planters caused the major drop in production for the State. Public rocks in high salinity areas also suffered significant reductions.

The effects of MSX on oysters taper off in regions where mean salinity in the fall begins to drop below about 15 ppt, and the disease is virtually absent where autumn 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. Many public oyster grounds are located within this transition zone where productivity has declined in recent years (Figure 12). Few public oyster grounds are located in high salinity areas in the Bay. Private growers continue to hold many leases in the latter zone, adopting the policy of planting only areas above this transition zone where they feel they will not suffer significant losses.

A major effect associated with MSX is the decline in setting of small oysters (spat) on the important James River seed beds (Table V and Figure 13). The drastic drop in available brood stock due to high mortalities and elimination of formerly massive private plantings in the high-salinity beds downriver has played a significant role in the reduction of setting on those beds. However, there remains some argument among scientists as to the possible relative roles of pollutants versus the decimation of brood stock by MSX as the cause of the decline and/or its continuance. This complex question is discussed more fully in the main report (Haven, Hargis and Kendall, 1978a) and in several papers and reports which have appeared since its completion (see the Bibliography).

According to certain evidence, oysters setting in some high salinity regions of the Lower Rappahannock and the Lower Bay where heavier mortalities occurred earlier, showed only minor losses from MSX in recent years (i.e. from about 1972 to 1985--Haven, unpublished data). Additional data are required to allow determination of whether this is a permanent change in their resistance, or due to some other factor. Unfortunately, due to prolonged and severe drought, mortalities in 1986 and 1987 in these same areas were again very high and few adult oysters survived in the Lower Rappahannock, Mobjack Bay, and in the Bay. It is not clear, however, if this mortality was due largely to Dermo or MSX, or a combination of both, but it was probably the last. Nor is it clear whether unusually high levels of infective particles from MSX or Dermo, or both, were able to overcome

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[23] This intensive drought resulted in increased salinities conducive to its survival, spread and pathogenicity all over the lower Chesapeake region and far into Maryland's portion of the Bay. The lethal effects of MSX and Dermo combined or by themselves upon oyster populations unaccustomed to their onslaught were severe and Chesapeake Bay oyster production (as reflected by harvests), public and private, plummeted.

Table V

Average set and range of set of James River oyster spat on various seed rocks for pre- and post-MSX years (1947 to 1960 and 1961 to 1986-87). Data shows average numbers of spat per Va. bu. of dredged bottom cultch. (U = Upriver; D = Downriver; N = Northside; S = Southside)

Location		Station	Prior to 1960	Range		After 1960	Range		% change
				min.	max.		min.	max.	
U	S	Deep Water Shoals	1108	36	6024	269	0	1502	-76%
U	S	Horse Head Bar	1638	34	4312	236	0	952	-86%
U	N	Wreck Shoals	1593	227	3056	228	0	945	-86%
U	N	Gun Rock[a]	1060	220	2320	108	2	650	-90%
D	N	White Shoals	1087	176	2116	164	6	795	-85%
D	N	Brown Shoals[b]	761	184	1836	55	0	166	-93%
D	S	Nansemond Ridge[b]	119	17	258	78	0	338	-34%

[a] Data for 1985 and 1986 for Thomas Rock (1 km away).

[b] Prior to 1972 oyster drills reduced survival rates of oyster spat.

[c] Though classified into two upriver-downriver categories (U and D) in simplicity, there could have been three, including Intermediate (I), with Gun Rock, Thomas Rock, and White Shoals as intermediates. The results would be the same with the downriver rocks having least spat survival and the upriver rocks the greatest with the intermediate in between, both before and after MSX's onslaught in 1959-60.

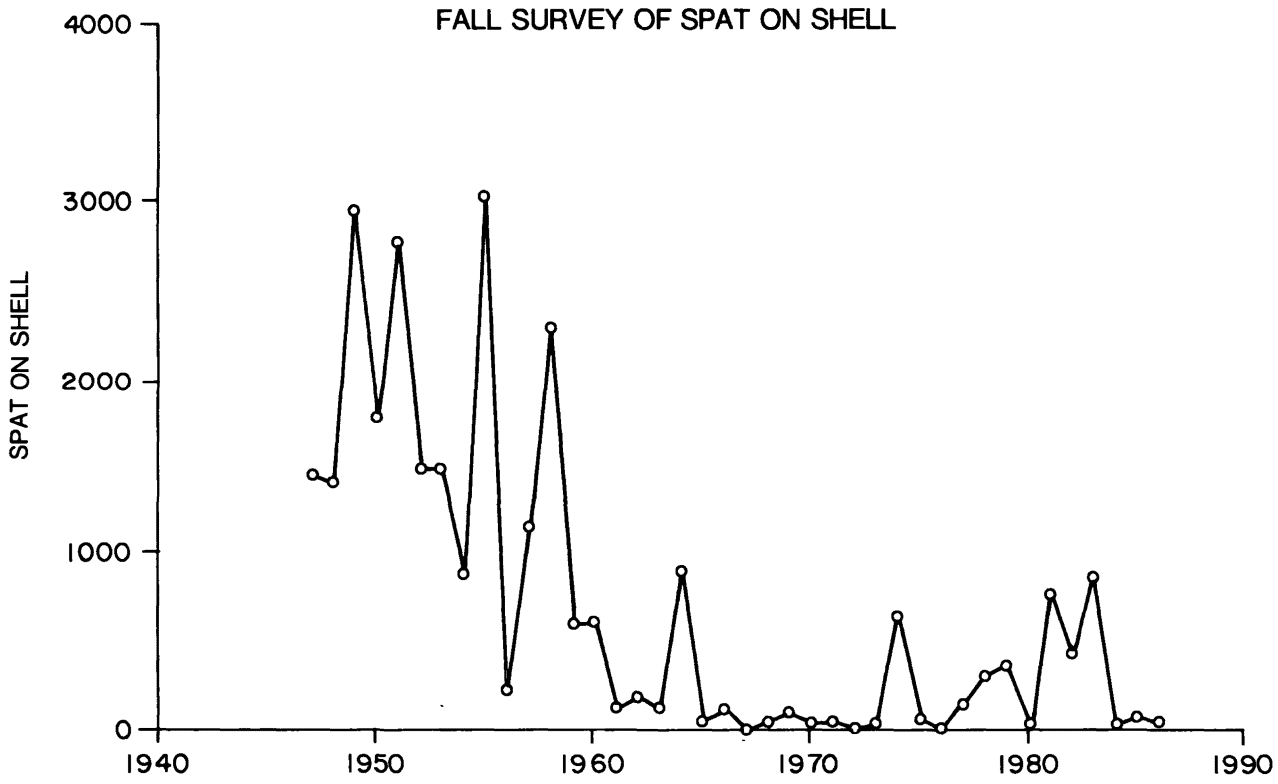

Figure 13

Numbers of spat per bushel of bottom cultch at Wreck Shoals in the James River Virginia from 1947 to 1986. This measure reflects those young oysters present on the cultch sample at the time of collection or, more specifically, at the time of examination and counting. Consequently it represents "recruitment" (i.e. number of spat set minus those dying during the period between setting and sampling - or survival) into the "fishable" population as it was at time of sampling. And it is the "seed" population which, excepting those eliminated in the interim regardless of cause, will be available at the time of final harvest.

defenses of oysters whose disease-resistant properties could not cope with an unaccustomed onslaught. "Swamping" of immune responses is a disease phenomenon known in higher animals.

Certainly both were involved where they co-occurred; however, in some areas Dermo appears to have been more prevalent and more deadly, which seems a departure from its significance as a death-causing agent in the past. This aspect, too, requires more study as recommended below. (This research should be pushed forward rapidly.)

Data Availability and Needs

Availability of Oysters to the Fishery

The number of spat or older oysters existing in an area at any given time is influenced by the sum total of a multitude of inter-related environmental and man-associated factors. This aspect is especially true in reference to oysters on public bottoms. Basically, it is determined by the numbers of individuals at initial set as reduced by "natural" mortality[24] and total fishing-related mortality, each of which has several components. In the discussion below various aspects associated with these three salient features will be considered.

It is pertinent to state here that fair-to-good information exists at VIMS concerning the basic characteristics of oyster-setting in Virginia waters based upon regular surveys of small oysters settling on bottom cultch at particular locations. Also available in varying degrees of completeness are quantitative data on natural mortalities associated with predators such as drills and diseases such as MSX, Dermo, and SSO. These data must continue to be obtained by VIMS, and should be improved.

For effective management, accurate data on fishing effort are required to allow careful calculations of catch-per-unit-effort and of total fishing mortality. To be complete, calculations of total fishing mortality would include both removals by the fishery, (or catch mortality), and fishing-associated mortality; These being, respectively, 1) the quantities of oysters actually removed from natural populations by harvesting activities and 2) those killed during catching and culling, i.e. by the harvesting and culling gear and associated activities, by handling and transportation. Data currently available include only catch mortality, and even that is none too good. We know little about fishing-associated mortality. Further, we know little of these factors as they affect private production from leased grounds.

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[24] "Natural" is enclosed in quotation marks because as used here it includes truly natural factors such as deaths caused by inherent weaknesses, starvation, "normal" smothering, predation and disease. It also includes factors induced or exacerbated by non-fishing related human activities such as introduction of contaminants and agricultural and construction-related siltation.

In general, total fishing mortality may be evaluated in three basic ways:

1. On the basis of catch-per-unit-of-effort data in which the daily, weekly, monthly or yearly catch is related to information on effort based on numbers of boats fishing, or man-hours spent harvesting (along with information on specific areas where harvest were made, gear employed and manner of use). To be accurate and most useful it should include only man-hours tonging or patent-tong hours or hours dredging (i.e. times when the gear was actually on the bottom and "fishing") or a more specific indicator of "actual", directed harvesting effort than now exists. Available effort data, usually in the form of numbers of boats observed in certain areas of the estuary do not approach this ideal. In fact, effort data now available to State managers are very poor!

2. By relating annual catch in bushels or in pounds of meats to the magnitude of that portion of the resource remaining on the bottom. To be most useful, these data should be specific as to location and magnitude of the catches from and estimates of stocks remaining on the beds fished. Unfortunately current information is neither specific nor complete!

3. By use of information from careful scientific surveys of the beds before and after harvest and at sufficient intervals in between to allow establishment of natural mortality with fishery-independent data.[25] Surveys should examine mortality and survival of the current year's spat and older stages, and determine probable causes of declines or increases where possible. (Compared with other marine invertebrates, hard-shelled bivalves such as oysters provide better "records" of their existence and passing and probable causes of death than most, and precise, or even accurate, "take" and available stock data should be collectible, Hargis, 1985). Coupled with the data from the fishery indicated in items 1 and 2 above, such survey data would provide an accurate picture of population levels and the forces acting upon them. They would also provide a check of fishery-dependent reporting. Unfortunately, adequate survey data are sparse and becoming even more rare.

Since effort data in relation to specific area fished are often incomplete, or lacking, catch-per-unit-of-effort calculations so important in determining the ability of the stock to support harvesting are correspondingly poor. Managers will be deprived of this important information as long as these weaknesses in the data persist. Effective management requires reliable, accurate and precise estimates of effort!

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[25] Fishery-independent data are those statistical data obtained by careful scientific or public management agency surveys and not through or from the fishery or fishery participants. Such data, properly gathered, are more likely to be free of bias than those provided by industry.

In comparison with those working with other fisheries whose resources are migratory, managers of the oyster fishery are fortunate in being able to secure reasonably good estimates of stocks "on the bottom" and of setting and recruitment should they care (or should they be permitted and enabled) to do so. Data on non-fishing deaths also can be obtained. There is no fundamental scientific reason why oyster stock and recruitment records cannot be accurate. Efforts to continue and improve quality and coverage of these vital data are necessary. Science and management must have accurate and precise population and fishing pressure data! This aspect cannot be stressed too strongly! Social, legal and regulatory barriers to acquisition of complete and reliable fishery data must be eliminated! Otherwise managers and scientists alike will be severely handicapped in their efforts to understand and properly manage the oyster resource and the industry based thereon. No business could operate effectively or profitably on data of the quality now available to VMRC!

The private grower would or should want information of comparable detail concerning planting, survival, growth, harvests and intervening mortalities and their most-probable causes. Scientists and state managers should also be able to secure these production statistics from private growers, under conditions of reasonable confidentiality, in order to understand and manage the overall oyster fishery. Effective management of public seed production, leasing and understanding of the factors affecting oysters under "wild" culture requires accurate, precise, complete and timely data.

SECTION III

REVIEW OF PROBLEMS AND NEEDS

Introduction

Historically the oyster industry of Virginia has passed through six phases. Phase I began over 350 years ago and was characterized by underutilization of a huge population of reef oysters existing throughout most sections of Tidewater. In pre-Colonial and early Colonial days many oyster "reefs" extended upward into the water column so far as to threaten navigation. Many were awash at low tide. These surfacing reefs have long since disappeared, as have many submerged ones. Many now exist only as "reef-shell" beds buried under inches or feet of sedimentary overburden. Harvesting activities for food, shell and lime; channel dredging; continuing high-rates of sedimentation; and, sea-level increases have all been involved, with the first most important. Beginning in the mid-1800's Phase II began. It was characterized by increasing demand caused by human population growth, especially along the Eastern seaboard. Production generated in response to this demand grew, eventually reaching a plateau during the third period, Phase III, lasting from 1894 to about 1912, with annual harvests ranging from about 5 to 7.5 million bushels.

A gradual reduction in landings in the fourth period, (Phase IV), from about 1913-1932 was associated with overharvesting (and a drop in certain markets probably due to economic recession) of the public beds. Reported production fell to a low in 1931 and 1932 when annual production from the State declined to 2,396,287 bushels (Figure 1 and Table II). Most likely, local human populations made greater use of oysters and other Bay products to provide food during lean economic times of the Great Depression years. Increased harvests by Tidewater avocational or subsistence oyster fishermen for home consumption and local distribution, which likely occurred during this period of general economic distress, probably were unreported and would not show up in the official statistics. Phase V began shortly after this as landings increased, reaching about 4.0 million bushels in the 1958-1959 season due largely to harvests from leased and private bottoms. Phase VI, which we are now experiencing, has been characterized by a catastrophic reduction in production (and harvests) from leased bottoms which began when MSX was detected in the Bay in 1959-60. Moreover, production from public bottoms has also trended slowly downward during the 1960-87 period.

The continuing reduction in landings occurred, not only in waters of higher salinity affected by the disease but also statewide in disease-free, low-salinity areas, and even on Seaside of the Eastern Shore in those high-salinity waters where MSX is not a problem ordinarily. The drop has taken place on Baylor Grounds and on leased bottoms. During the 1974-1975 period annual harvest from private and public bottoms totalled only 895,597 Va. bushels! In the 1984-85 season it was only 658,679 bushels (Table II). Non-James River market oyster harvests increased slightly to 715,003 Va. bu. in 1985-86, but declined in 1986-87 (539,506) the second lowest year of the

57 years of formal record. Harvests during both years were far below pre-1960 levels and even below those of 1980-81, and 1981-82.[26]

All information now available suggests that statewide landings from non-James River bottoms will drop even further in the near future. This statement is based on reports that many mature oysters died in the Lower Rappahannock, Mobjack Bay and in the Bay itself during the fall of 1986 and the spring and summer of 1987 and that oysters on the bottom in those places are at all-time lows.

Another adverse situation developing is a probable shortage or a high price for James River seed in the 1987-88 season due to excessive harvest of oysters for clean culls for "market" use during 1986-87 (which activity is continuing into the 1987-88 harvesting year - at higher selective levels than in 1986-87). Seed costs could be very high in 1987-88 and beyond. These conditions will tend to reduce levels of planting on existing leases; and result in lower levels of on-the-bottom production and lower harvests at a later date.

It is feared that the oncoming shortage of oysters from public bottoms will result in pressure from harvesters to request an increase in areas where patent tongs or dredges may operate. Such pressure should be resisted! There is a place for both types of gear in Virginia's future, but not on bottoms from which most of the oysters have already been removed, or where natural recruitment levels are low.

The 26-year trend of decline in market oyster production from Virginia waters described above as characterizing Phase VI has occurred and persisted not only because of MSX (and in 1986-87 Dermo as well) and continued overfishing of public oyster beds, biological and environmental problems (such as mortalities due to other diseases, predators, or fresh-water kill, lowered brood-stock levels, lowered setting and juvenile survival rates, and pollution), but also because of economic and social causes. Rising production costs, increasing costs of capital, availability of higher monetary returns at less risk in other forms of investment, stagnant dockside prices, consumer resistance, failure of 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. 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

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[26] Due to failure of natural production elsewhere in the lower Bay and its tributaries in 1986-87 brought about by disease-related mortalities, significant market oystering efforts shifted to the James River seed area for the first time. During harvest year 1986-87 202,239 Va. bu. or 42.5 percent of all publicly-produced market oysters came from the James. This trend worsened in the 1987-88 harvesting year.

needed. However, 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 (or whatever goal is selected) several of the pressing problems, biological and environmental, but especially managerial, economic and sociopolitical, must be resolved! To remedy or obviate the biological and environmental problems without correcting the essential elements of public and private management practices or reducing the political, economic or technological restrictions will do little to rectify the present deplorable state of the Commonwealth's oyster industry. Such efforts have consistently failed for over 100 years.

The Virginia oyster industry is in a condition of crisis; remedial measures should and must be taken along the lines outlined here if it is to continue as an effective element in Virginia's economy! Both sectors, the public and the private, must be assisted since they are dependent on one another.[27] If our management recommendations are not adopted effectively, production of oysters, seed and market, from Virginia's waters will continue to decline to some lower, less economical, sustainable level! The industry will suffer and the people of Virginia, who are the real owners of the public bottoms and resources, will be poorly served.

Despite the difficulties associated with this complex task, we are firmly convinced that marked improvement in production at all levels within a reasonable period is possible and that every effort should be bent toward revitalizing the public and private sectors of the industry![28] The Commonwealth will benefit.

We review here the major causes of the reduction in oyster production from Virginia waters in order that effective remedial measures can be developed and recommended in Section IV. In this review some of the material previously presented (in outline form to provide a preliminary

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[27] Here, we are assuming that the policy of the State to maintain and encourage production of market and seed oysters by both the public and private sectors of industry will continue. Should this policy change, our recommendations would be altered to suit the new production conditions. Whether one or both sectors is ultimately involved, the basic requirements and recommendations would be the same!

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[28] This assumes that the climatological picture of the montaigne and piedmont regions of the Chesapeake Bay watershed will resume its 100 or 200 year pattern and that prevailing regimes of regional rainfall and Bay-wide salinities will return to normal: There is no compelling reason to expect otherwise at this point. However, along with many other hydroscientists, we are concerned about possible long-term climatological and hydrographic effects related to earth-warming due to atmospheric contamination. Should a long-term drought and warming trend develop at our latitudes many phenomena would change, along with the natural oyster production of the Chesapeake.

overview of the whole problem) is given in greater detail. For clarity, it is necessary that definitions of certain words, phrases and concepts describing the oyster industry and the factors affecting it be clearly understood prior to indicating remedial measures. For example, one cannot use the phrase "oyster production in Virginia" to mean "oyster production (harvests) from Virginia waters" because many oysters processed by the Virginia oyster industry are grown in out-of-state waters and are merely shucked, processed and packaged here. Some are even grown and shucked and shipped into Virginia for reprocessing and/or repackaging.[29] The volume of oysters imported to Virginia after being shucked and processed elsewhere may be very large. Beginning in the late 1960s and early 1970s over half the oysters processed in Virginia were imports, mostly from Maryland with a lesser volume from the South Atlantic and Gulf coasts. Even as Maryland production fell, Virginia continued to import oysters and in 1985 imports (largely from Maryland, New Jersey, Texas, and Louisiana) accounted for over half of the oysters shucked in Virginia. Of the four states, Maryland contributed about 52%. We understand that oysters have been imported from as far away as Washington State for processing and/or repacking here in recent times. They are products of the Virginia oyster industry, but not of Virginia waters! Obviously, both processing and repacking of imported oysters bring money into the Virginia economy and create employment; though not as much as growing, harvesting and processing home-grown ones. For our purposes, we must separate actual production (harvests) from Virginia's bottoms from those oysters harvested elsewhere but processed or repacked here; also characterized as production. We must also separate production as indicated by landings, harvests or yields from natural production represented by the actual numbers of seed or market-sized oysters on any unit of oyster-setting or growing bottom.

The Decline in Production from Virginia Waters

The major factors involved in the decline in production of oysters from Virginia waters are discussed in detail in this section.

The Impact of Disease

As indicated previously, 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, with the exception of newly-set spat. During the 1986-87 drought period both MSX and Dermo increased their ranges up-Bay and up-tributary markedly. Extensive mortalities accompanied their spread, and Maryland oyster production tumbled significantly, as did that of Virginia.

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[29] Evidence indicates that some of these are even represented as having been grown in Virginia, a seemingly fraudulent practice which should be vigorously discouraged.

The Magnitude of the Decline in Market Oyster Production and Harvests on Baylor Bottoms and on Leased Grounds

A major point reiterated here is that it is the reduction in market oyster production and harvests from leased bottoms since 1960 (after appearance of MSX) which has been responsible largely 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 up to 5 times more oysters than the 243,404 acres of Baylor bottoms.[30] Average annual harvests from all leased acres from 1951 to 1960 was about 2.6 million bushels. The drop to only 316,922 bushels during the 1984-85 harvest season constituted a 91% decline. The 1986-87 private harvest of 265,695 Va. bu. was the lowest of the 57 years of record.

On the State's non-James River seed-beds Baylor Bottoms, landings fell from about 550,000 bushels to 341,757 during the 1984-85 season (a 38% decline). In that period, the public market oyster grounds yielded about 7% more oysters than those under lease! In fact, harvests from leased bottoms have been lower than those from public grounds in 7 of the last 10 years of record since 1976-77 according to data currently available. This major reversal of predominance of yields from leased-bottoms clearly indicates that oyster planters have reduced investments in planting and other efforts at production, and that this is a significant element of the problem associated with the continuing trend of reduction of total oyster yields from Virginia waters. Declining market oyster harvests from non-James River seed-bed bottoms continued in 1985-86 (328,338 Va. bu.) and 1986-87 (273,811 Va. bu.): Dismal!

Lowered Setting Levels

While MSX directly caused a major decline in numbers and volumes of market oysters harvested from the leases and public bottoms, and to a lesser extent on seed-producing areas in 1959-60 and later; it also had, we believe, an indirect impact on the setting rates and ensuing on-the-bottom production of oysters in several areas of the James. A summary of the information available on spat survival at 8 stations in the lower James is

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[30] We are mindful, as noted elsewhere herein, that many of the bottoms within the current "Baylor Survey" boundaries now are unsuitable for oyster culture. Many of them were not productive when they were nominated for inclusion as Lt. Baylor made his survey. However, the "survey" boundaries incorporated almost all of the bottoms with the best capability or potential of producing oysters as well. As a result of the State's decision to sequester the Baylor Grounds for public use alone only the non-Baylor bottoms, most also of poor quality and potential were available for lease. Despite this fact, until 1959-60 the bottoms leased to private planters produced and yielded many more oysters than the public bottoms. Had some of the Baylor bottoms of better quality and producing potential been made available to the private growers the yield disparity of 5X would have been even greater. This factor provides the basis of some of our most important recommendations.

provided in Table V. Data on spatfall as measured by spat-per-shell occurring on shellstrings installed and collected weekly at selected stations in the lower James are also available, i.e. Table 13 of Haven, Hargis and Kendall 1978a and VIMS spatfall printouts.

In 1960, the year following the onset of MSX in Chesapeake Bay, a major decline in numbers of spat attaching to shell substrate in the James River seed areas began. Since that time, in the lower James River seed area, numbers of spat-per-bushel of substrate (or cultch) have dropped about 80-90 percent from the pre-1960 level (Figure 13; Table V). In the upper seed areas, over the same period, the decline has been less severe. The most probable cause follows: In 1960, MSX killed most oysters in the very large stocks of privately planted, and public oysters in the lower James River, Hampton Roads and just outside around its mouth, which produced many of the larvae that set in the seed area. Subsequently, seed oyster production and harvests of seed in the James River dropped. This conclusion is based upon the principal that the fewer the brood stock oysters the fewer the larvae produced, and the fewer the larvae the lower the initial set, and the lower the initial set the fewer the seed oysters! This effect was especially severe since it resulted in a major reduction in the total numbers of seed oysters per-unit-volume of substrate on nearly all of the most productive bars in the James River, a situation which persists (Table V).

Table V (p47) compares the average count with ranges of spat-per-bushel of cultch for the pre-1960 years (before MSX) versus the post-1960 years at 7 stations in the James River seed area.[31] Three (3) of the stations regularly observed are on the "southern" side of the estuary and 4 are on the "northern." As the table clearly shows, spatfall in the lower James, as measured after setting has been completed in late fall or early winter, has dropped drastically since 1960. For example, on the major seed rocks on the "northern" side the declines in the average spat per bushel were as follows: Wreck Shoals, 86%; Gun Rock, 90%; White Shoals, 85%; and, Brown Shoals, 93%. On the "southern" side the declines were: Deepwater Shoals, 76%; Horsehead Bar, 86%; and, Nansemond Ridge, 34%. It is noted that on the downriver beds on both sides of the river where salinities are higher than upriver, the predatory oyster drills were abundant until 1972 when freshets from Hurricane Agnes "knocked them out." Had drills not been present in these locations in the pre-1972 and especially the pre-MSX years, the number of spat surviving on the bottom might have been much higher during that period. Hence, the comparative decline in survival of spat between the past-MSX period shown in Table V might have been much greater at the downriver stations (i.e. Nansemond Ridge, Brown Shoals, White Shoals). These three

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[31] After 1985 and 1986, respectively, collection of data was discontinued at Deep Water Shoals and Brown Shoals. This discontinuance was a mistake since Deep Water Shoals is a frontier or "bell-whether" seed area, as is Brown Shoal. Over the long-term, data from such sites are the most informative though they may be most difficult and costly to secure and have less long-term numerical impact to oyster production data from the rest of the James River seed area.

bars have been on the fringes of the area in Hampton Roads where disease occurred.[32] Similar reductions in setting and in numbers and density of seed and other young oysters were noted in other areas during the same period. In respect to the James River, seed harvests between about 1965 and 1986 were probably in equilibrium with the lowered recruitment rates. Should demand for seed increase it is highly probable that the James River seed area will not be able to meet that demand at current levels of recruitment. (The use of the James River seed beds for clean-cull, market oyster harvesting in 1986-87 and 1987-88 makes this probability even more likely!)

While very strong evidence points to MSX as the cause of reduction in brood-stocks in the approaches to the James River seed area (and hence of larvae which could set and develop into spat), which was the major factor responsible for lowered setting in that river, other factors may have contributed as well. For example, chlorine and chlorine 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. Concentrations exceeding these levels have been found in parts of the James seed area. The sources of chlorine contamination are sewage treatment plants, refineries and power plants, and other chlorine users and dischargers. Thus far, close relationships between concentrations of chlorine and its derivatives on setting success in the James River, itself, have not been demonstrated. While chlorine or related compounds eventually may be implicated as a cause for lowered setting and/or spat survival, other chemical substances as yet unidentified, also may be involved as exemplified by the finding of Kepone in the James River in the mid-1970's. Most recently, tributyltin chloride (TBT), an organotin compound employed increasingly in antifouling paints for pleasure, commercial and military vessels, has been shown to be extremely toxic to oyster larvae, juveniles

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[32] This is not to say that annual counts of spat-per-bushel of bottom cultch have been uniformly lower after 1960 than before. However, counts at Deep Water Shoal exceeded the pre-MSX average (1108 spat-per-bushel) in only two years, 1970 (1181) and 1977 (1502), out of the 24 years of record for the period 1961-1985. In no case did they exceed the pre-MSX maxima of 6024 which occurred in 1947 and 2126 in 1953. At Horsehead Bar, no annual post-MSX counts have equalled the pre-MSX average (1638); none have even come close to the 7 predisease maxima, which ranged from 1084 to 4312. At Wreck Shoals, the principle source of seed oysters in the mid-James River, post-MSX annual counts have never reached the pre-MSX average (1593). In most years (19 of 27) they have been lower, even, than the pre-MSX minimum of 227 spat-per-bushel. The picture is similar at other stations. Clearly, though there have been years of an occasional improvement in spat-per-bushel "counts" after 1960 (post-MSX), the annual set on bottom cultch at the end of each season remains drastically lower than those prior to onset of the epidemic. The inescapable conclusion is that natural spatfall on the James River seed beds has declined, appreciably since MSX became a major factor in mortality of oysters in the lower end of the Chesapeake and nearby tributaries.

and to oyster gametes (sperm and eggs). Roberts and DeLisle (personal communication) have found that several of the embryonic and larval stages are affected in different ways at different levels by exposure to tributyltin chloride. For example, larval growth is slowed at 0.3 parts per million, pediveliger metamorphosis is particularly inhibited at 0.1 parts per million and significant numbers of embryos, D-cell veligers and older veligers are killed in 48 hours by concentrations of from 1.0 to 5.0 parts per million. It is claimed that concentrations as low as 4 to 6 parts per trillion of TBT will immobilize oyster sperm (Castagna, personal communication). The significance of such findings to oyster setting, survival and production and for pollution management must be established, and quickly!

It is possible that contaminants such as these are synergistic amongst themselves or with other morbidity or mortality factors. They may cause chronic disability and encourage disease, or they may kill outright. Prevalence and intensity of infection by MSX and "Dermo" may be affected by increased pollution levels. However, setting has declined and mortalities have occurred in areas which, as far as we know, are not affected significantly by chlorine, tributlytin chemical or other known pollutants at current levels of detectability by commonly employed techniques of environmental chemical analysis. Decline in setting and/or seed levels as measured by VIMS monitoring efforts coincided so closely with the advent of severe MSX-caused mortalities in the lower Bay and James that decimation of brood stocks must be the primary candidate as the cause of reduced seed production. Whatever the cause or causes (and they may vary from place to place and time to time), the lowered level of setting is a major problem[33] requiring attention by both science and management because seed is vital.

The Importance of an Adequate Seed Supply

Without a reliable source of high-quality seed at reasonable cost the private oyster industry as it operated in the past and exists today, with its almost total dependence upon natural seed from the James River, will cease to exist. The public beds (those which derive their populations naturally and replenish themselves - natural recruitment) also require an adequate set for their continued production. Those with diminished levels of setting, such as the James River seed area, may continue to decline in productivity and yields and then stabilize at much lower levels (Table III and Figures 2 and 3), provided fishing pressure stabilizes. Stabilization of fishing pressure will occur only when seed or market oysters are effectively "fished-out," when market demand and economics dictate, or when necessary and appropriate management controls are instituted. The last is the most desirable, by far.

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[33] In 1983 a large-scale project termed "The James River Initiative Program" was begun at VIMS to determine more accurately how hydrographic conditions are related to setting patterns, and to determine certain possible causes of larval and spat mortality and setting failure more specifically. We hope that this program, which should be pursued vigorously, will be successful.

Leaseholders and Those Working or Managing Baylor Grounds Face Different Problems

While some problems are shared, all of the difficulties facing private growers, who operate using leased grounds, are not the same as those confronting public managers (VMRC) and the harvesters of the public (Baylor Survey) grounds. For example, leaseholders are bound directly to those grounds they hold or can gain access to. Public managers have access to the gamut of grounds within the entire Baylor Survey (or should have). However, private planters generally can choose which beds they will cultivate and harvest and when and how they will do so. Public managers are frequently pressured on all three points. Private managers, almost uniformly, must "firm" and seed their beds in order to secure production. On some public beds VMRC needs neither shell nor seed but must merely close the beds to allow setting and growth. On others they, too, must plant shell or seed. Unfortunately their ability to take either action effectively is frequently restricted by political pressure.

Those who harvest public rocks are dependent upon the natural forces affecting setting, survival and growth of available stocks or, increasingly, upon the availability of monies for and the success of state-managed repletion efforts. Private planters are affected by natural forces as well, but may have more freedom financially. Success of both public and private managers and harvesters is closely dependent upon such factors as suitable salinities, plankton levels and abundance of predators and diseases. All can be adversely affected by contamination as well. Essential factors affecting productivity are discussed further below.

Failure of Some Leaseholders to Relocate After MSX or Others to Increase Production in Non-MSX Areas

When MSX killed millions of bushels of oysters on leased beds in the higher-salinity, downriver beds and in the lower Chesapeake Bay, it 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 University and NMFS), 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 monetary losses. Some did nothing and suffered severe economic disruption. None of the four major companies then occupying large leases in the lower Bay area were able to resume former levels of oyster productivity. Two have since disappeared. The two remaining are involved in other fisheries or marine-related activities to sustain themselves.

Interestingly, not one of those four large companies (whose leases were mostly in high-salinity areas) relocated their planting operations after 1960 to non-MSX areas in order to continue production, despite timely suggestions by scientists that they consider doing so. We have wondered why. Perhaps suitable low-salinity beds were not available to them or, considering the massive losses they had suffered, perhaps economic factors prevented such action. After the initial negative impact of MSX, other factors began to operate in the private oyster-farming segment of industry.

Most of the remaining 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, even though advised to do so. (The few who did increase plantings immediately after the disaster seem to have prospered significantly, at least temporarily.) Instead, the needs of the oyster packers (that segment of the industry which packs and/or processes for distribution in the marketing network) in Virginia were increasingly satisfied by imported oysters produced on the public rocks in Maryland or, more recently, by oysters grown far outside the Chesapeake in the Gulf of Mexico and even from the West Coast.

Possible reasons why the majority of oyster growers of Virginia failed to increase oyster culture activities in regions less prone to MSX damage in the years following the MSX epizootic are many and complex and still only partially understood, but probably are based largely upon economic factors related to increased costs of money and production, transport, processing, marketing and other operational aspects of oyster culture, as well as the lure of other investment opportunities.[34] Discussion of the major economic factors involved follows.

Stable Wholesale Prices and Consumer Resistance to Higher Prices - Reduced Profits for the Growers

Since about 1964, consumer demand for Virginia oysters and those produced in other states seems to have reached a plateau. Apparently, the reason is associated with consumer resistance to high prices of the marketed products, or possibly a nationwide shift in food preference to shrimp or other seafood products. The effects of these stable demand levels have reverberated 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 and harvesters selling oysters at dockside. The net effect of this stable or declining wholesale price (adjusted for inflation, which probably should include devaluation) during the whole inflationary period has been especially severe on growers operating on leased bottoms.

For example, the private grower has been faced with major escalations in costs of labor, insurance, fuel, plant and marine equipment, vessels,

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[34] Since 1983 interest rates appear to have fallen as have the costs of fuel and lubricating oil. It will be interesting to see if these economic factors have any effect on the numbers of acres planted by private sector growers, especially if they continue or trend even lower. The recent slowing of inflation may also contribute to economic recovery of the private-growing industry. Unfortunately, reduced petroleum costs will not continue long and interest rates and inflation rates may increase within the next several years since oil supplies are being depleted and basic economic factors have not changed appreciably. Trends toward such increases seemed to appear this fall (1987).

supplies and money in a period during which dockside prices remain mostly static.[35] This circumstance reduced the margin of profit. Consequently, surviving growers found it economically advantageous to plant seed and culture oysters only on their best bottoms where they could expect the highest and most reliable yields. In quantitative terms, these were the beds on which a grower might hope to secure an average of two bushels of market oysters for every bushel planted. In other words, they were and are using those beds which offer highest yields at lowest risk of loss.

The beds on which the historically profitable average yield of one-to-one could still be easily realized are not being used to the same extent because such yields no longer warrant the effort, time, cost, and hazard.[36] These and many lower-yield beds remain under lease, however.

In relation to lease size, our study in the late '70's showed that 83 percent of all lease holders in the state leased 17 percent of the total bottom, and that the average size of leased bottom (total leased under one name) was only 4.7 acres (Haven, Hargis and Kendall 1978a). Clearly, such small acreages cannot provide enough yield to support even a small family, much less a significant business operation! Our study also showed 50 acres to be marginal as a sole source of a single family income, while some 300 acres or more were sufficient.[37] However, we learned that only about 17% of all lease holders held acreages in which combined sizes totalled 50 acres or larger. Unless our data and calculations are badly awry most leaseholders cannot expect to operate a successful business venture on holdings of such small size. Perhaps most are merely augmenting income and/or supplying their own tables. Or, perhaps, they work from "banner" year to "banner"

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[35] In 1985-86 and 1986-87 dockside prices began to escalate. What effect this will have on private planting is impossible to say at this stage. Whether the upward trend will continue is also unknown.

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[36] 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. As pointed out in footnote 34, certain economic factors have improved in recent years which should reduce the costs associated with production. With more helpful State leasing practices planters could be encouraged to increase their efforts and investments.

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[37] It seems likely that the amount of acreage required to support a single family would be much higher now (mid-winter 1987-88) due to ensuing inflation of business and personal costs and devaluation of the U.S. dollar. A business with larger overhead than a single-family operation would require commensurately more acreage. Obviously, the acreage-to-need ratio would vary directly according to actual yield-per-acre of planted bottoms. Calculations on this point would have to be carefully made, with ample allowance for uncertainty.

year without investing too much on a regular basis. Possibly they lose more than win and merely write the losses off. This aspect definitely requires additional examination by VIMS, or similar research institutions, and should be given special attention from the VMRC as it considers revamping the State oyster-ground leasing program.

Status of Knowledge and the Need for Research and Engineering Innovations

Research and engineering are essential components of effective management. Much scientific and engineering effort has been directed at the oyster fishery, especially since World War II. Despite the considerable research aimed at learning more about oysters and their requirements and about oyster-based economic and social activities, areas of ignorance remain about key topics! Disease specialists, for example, still cannot transmit MSX from one oyster to another even though they understand the epidemiological aspects fairly well, can identify and induce certain levels of disease-resistance in selected oyster populations and can recommend mortality-reducing measures. On the Seaside, SSO is a major deterrent 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. We have not investigated the possibilities of genetic engineering of Crassostrea virginica to solve production problems. Effective control of oyster predators remains elusive and we do not have any clear concept of mortality rates of spat during the early weeks of growth. We do not yet have a firm grasp of the normal and abnormal cytology, histology and immunology of oysters. Elements of the nutritional and environmental requirements of oysters continue to be mysterious. The comprehensive effects of toxic or damaging materials such as oil, biocides and heavy metals on oysters must be learned in order that Federal, State and local management of water quality and liquid and solid wastes can be fully conducive to oyster cultivation.

Of major importance is the continuing existence of considerable technological, engineering and operational inadequacies. Reliable growing systems must be planned and arranged, and more adequate mechanization installed to increase productivity and reduce costs for the industry. (In some situations negative factors such as losses and costs can be reduced simply by improved handling practices which will increase production or reduce costs, or both.) Additional discussion of needed research and the engineering developments and socioeconomic investigations which should be carried out in the interest of maintaining and increasing production, social benefit and economic profit over the long-term is presented in the Recommendations (Section IV) immediately following.

SECTION IV

RECOMMENDATIONS FOR IMPROVED MANAGEMENT, SCIENCE AND TECHNOLOGY

Detailed Recommendations for Increasing Statewide Oyster Production

We will now consider our findings and present remedial recommendations in detail. Statewide oyster production can be increased by appropriate action; but the approach must be to remedy several aspects simultaneously, or as nearly so as possible.

Leasing Currently Nonproductive Baylor Bottoms

Until recently, beds under management by private growers have out-produced those cultivated by the State for harvest by independent watermen by factors ranging from 2 to 5 (or about 10X per acre). This occurred despite private leases being limited normally to bottoms having little, if any, natural set, which were usually of much poorer quality (hence lower producing potential), and involving less acreage. In fact, most leased beds required physical "firming" before they could be used and most required seeding. The superior production on leased bottoms occurred despite these adverse factors! There is no 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 since private growers may control time and manner of shell and seed planting and harvesting. In contrast, the State often has been forced by political and financial pressures to plant shell where it could only receive marginal or no set, or at the wrong time. Further, even seed oysters often have been placed in less than optimal locations in terms of survival and growth. Also, the State is usually prevented by political pressures from keeping areas fully closed until maximum yields-per-bushel of seed could be attained, or from limiting harvests to reasonable levels. (These factors must change if productivity on public bottoms is to be restored!)

Since economic factors have driven growers to discontinue use of beds where productivity is marginal and risky if mortalities are high, the State could provide incentives for growers merely by making more high-quality bottoms available for private lease in areas normally little affected by disease so that more market oysters could be grown at lower cost per-acre or per-unit-time, or at less risk and at a greater profit - even at relatively stable dockside prices.

Most of Virginia's best growing areas are within the Baylor Survey boundaries. It is from this source of potentially productive bottoms that less risky growing grounds can be made available for lease. This can be done without harming public production because most public beds are either 1) not cultivated at all or 2) ineffectively cultivated and therefore not very productive. The number of acres receiving no effective cultivation is very high!

A recent survey showed that only 22% of the 243,404 acres of Baylor bottom surveyed was naturally productive. The remaining 78% was classed as nonproductive.[38] Furthermore, very few of the "naturally productive" Baylor beds are under effective management; most are overharvested and underproducing; few are utilized effectively. In fact very few are shelled or planted. So many acres of Baylor bottoms which require more effective management to be truly productive, are available that the State cannot possibly replenish them all without truly massive amounts of money to do so. State coffers possibly could provide such funds, at least on a one-time basis but it seems unlikely that the many millions of dollars necessary to increase state repletion programs to a level which would allow full, long-term usage of these grounds will be made available by the General Assembly. Unproductive Baylor bottoms should not be allowed to remain unused or underused. Those which cannot be effectively used by VMRC should be made available for leasing!

To reiterate this important point, careful study has clearly established that most of the Baylor grounds are unused or underused and that it would be difficult, probably impossible for the State to replenish many of them effectively on a long-term basis due to lack of funds! Thus, many could be made available to private enterprise for growing market oysters, and should be! Conditions for leasing and use of these unproductive public bottoms should be such that active efforts at culture must be pursued within a reasonable period of time or they automatically revert to the State. Fees should be sufficiently high to: 1) discourage "idle leasing"; 2) defray reasonable costs of policing and administrative management; and 3) compensate the People of Virginia for their use. Other lease arrangements should also be designed to ensure use while preventing abuses.

We are confident that suitable legal terms can be developed which will assure that the State's (i.e. the People's) goals in making such leases of better quality publicly-owned bottoms are met and, at the same time, made attractive to potential private oyster farmers. Furthermore, this will not limit the State's own repletion efforts, but will enhance them. For decades many competent study groups, including various State 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 since. It will be to the State's interest to enable and encourage this change of leasing policy! It will be against the State's and thus the People's interest not to do so!!

In the paragraphs following we elaborate on the important features of leasing arrangements that require correction or which must be considered as Baylor Survey grounds are made available for leasing. In proposing these

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[38] Much of this nonproductive bottom was in deep water or where the bottom was largely soft mud or sand unsuited to oyster culture without modification. Some of these mud or sand bottoms can be made productive if planted properly with shell or seed (Haven, Whitcomb and Kendall, 1981a and b).

corrections it is not our purpose to dictate details of present or future leasing arrangements, but to help define parameters for remedial activity.

If seed oysters continue to decline in numbers, or if demand for seed increases as production is restored, it will be necessary to enhance seed production. This can be done at little cost to the State by making some of the seed-producing acreage within Baylor Grounds or other publicly-controlled bottoms in seed-producing regions available for leasing! This would induce and enable private growers to produce seed. There will be resistance by public watermen (most notably the tongers), or by traditionalists and reactionaries in the industry or State government, to leasing of Baylor Grounds, but it should not be allowed to defeat or delay adoption of this most useful and essential management alternative.[39] No sound reasons exist to abstain from such a highly promising practice! All reasonable and significant objections can be met. Unreasonable, ill-founded and emotionally-based objections can never be met! To deny the "non-watering" public (the vast majority of Virginia citizens) the benefits of maximum production from their own common-property oyster grounds cannot be justified! To lease beds which the State is not now replenishing and cannot use effectively will not lower the productivity of those Baylor Grounds retained under State management for public watermen and will increase overall oyster production! It will not damage the few remaining independent oystermen. In fact, if oyster growers are successful, there will be additional opportunities for watermen in that there will be greater demand for seed and more work on the water. Additionally, increased brood stocks resulting from enlarged plantings probably will aid in improving productivity of nearby seed beds due to increased production of larvae. With proper incentives oystermen so inclined may be encouraged to become seed and market growers themselves, a factor which should reduce resistance. Jobs for tongers, boat operators, truckers, and others who work directly for the growers or processors, including shuckers, would be increased. Further, improvement in these sectors will encourage and benefit supporting businesses.[40] Clearly, it is in the Public's interest to encourage private (and public) oyster culture by all logical and legal means!

Accordingly, we strongly repeat the recommendation that appropriate legislative action be taken to allow the VMRC to make selected, currently

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[39] It would also be possible to develop a seed-ground leasing plan which would allow persons now tonging to grow seed for their own use, or for sale to growers. This move might make leasing of Baylor Grounds more palatable and practical for "tongers". Such a move, with preferential treatment for active public watermen (at least in the beginning until they are able to compete) might be made to encourage market-oyster leasing of Baylor Grounds, and reduce objections to doing so.

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[40] Considering the several economic multipliers associated with new jobs, or with increased income, the monetary benefits to fishing communities and the regions in which they are located would be markedly enhanced and the entire economy of Virginia would benefit.

unproductive or underproductive Baylor Survey grounds available for private leasing and use! (It could even be required to do so should forceful legislative prompting be necessary.) It is within the purview of the General Assembly to take such action. Before such leases are made, the Commission, working closely with VIMS, should first determine how much acreage it can effectively manage, which acreages could be leased, and which are to be retained for State use and recommend those to be leased to the General Assembly, which should then take the necessary legislative actions to allow VMRC to make them available.

It is important at this juncture to indicate that much of the quantitative information of the detail and accuracy that science and management must have concerning which of the public grounds are most productive or potentially productive is now available (Loesch, Haven and Whitcomb 1975 and Haven, Whitcomb and Kendall 1981a and b)! These VIMS publications detail the locations and extent of the State's Baylor Bottoms in a series of charts and texts. Also, acreages and bottom type are shown, and the best uses of each area are discussed.

As soon as the General Assembly makes leasing of pre-identified portions possible, the following should be done:

1. Specific tracts to be leased should be determined by the VMRC, with VIMS assistance. Those areas so identified should be subdivided into blocks, each with a minimum size which would allow economically viable activity - perhaps 100 acres. Larger plots would provide suitable economies of scale and possibilities of meaningful profit that are vital to the success of the effort. Further, larger lease areas would reduce conflicts and policing problems by allowing economically viable harvesting to proceed without encroachment on other nearby leaseholds or unleased public bottoms. The actual economically-viable minimum lease size, i.e. 100, 150, 200, 250, 300, required to allow atttainment of a specific economic-yield objective should be carefully determined by suitable economic research as recommended below. However, we would suggest that no lease-holder, individual or corporate, should be allowed to accumulate sufficient acreage as to achieve a monopoly in any area.

2. Rights to lease such acreages might best be established by public bidding, perhaps with some preference given to individual watermen presently employed as hand- or patent-tongers. There should be a minimum leasing fee set at a sufficient level to prevent "frivolous" bidding, and to help defray costs of public management measures; preferably even cover them fully. Current leasing fees are too low for either purpose. The public should not long subsidize private efforts after the program is effectively underway!

3. Leases should 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 purposes. Leases should be renewable, but all should be quickly recoverable by the State on a

reasonable and fair basis. Leasees' 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 and provisions enabling voiding of leases for non-use included.

To assist in establishing proof-of-use, we recommend a law, or better a regulation (since the Commission should be given more latitude in establishing and enforcing regulations by the General Assembly and specific legislative enactments governing details of fishery operations 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. Supporting data, required for continuation of leases, should involve estimates of oysters on the ground, amounts of shell or seed planted and yields. A mechanism for checking such statements should be provided. Failure to supply the required information should be established as prima facie evidence of lack of intent to use and cause the lease to automatically become void at the end of its third year. The Commission should be given the power to renew leases should legitimate mitigating circumstances be established by the leaseholder at his or her expense. Not infrequently, poor growing periods occur. It is also conceivable that adverse economic periods would mitigate against reasonable use. Misrepresentations of use when there has been none would be established as prima facie evidence of lack of good faith and cause the lease to become void at the end of the third or fifth year. No renewal of lease should be possible in such instances.

Using Leases for Purposes Other Than for On-the-Bottom Oyster Culture

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 by threatened or actual litigation. In fact, some shellfish beds have been more valuable for use in business deals or legal contests than in shellfish production. Often such actions, especially suits against local, state or Federal government agencies or public utility projects, have been contrary to public interests. Some have increased costs of public projects. At times, lease-holders have become enriched by business deals or legal contests using public bottoms for which they pay mere pittances in rental fees.

There also have been legitimate uses of state-leases for purposes other than oyster culture. Such uses should not be discouraged. Off-bottom culture of oysters and hard clams in floating or on fixed structures in certain areas is now economically feasible. Therefore, specific provisions should to be made for this use of leased bottoms or of the water above them.

Certainly, there are "legitimate" reasons or objectives for leasing public bottoms to private entities or nonstate public or semi-public bodies other than oyster production. Such reasons include other economic or social uses of resources or protection of amenities which are in the interests of the public; for example, marl or shell mining, fixed-location fishing, clam culture, diving, historical preservation, archaeological activities, etc.

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 inadequate conditions of the past, are no longer sufficient to encourage economic development and conservation (where necessary) of the valuable bottoms of Virginia. A new system of leasing is required; one geared to clearly identified purposes for such leasing and to realization of these purposes.

Recommendations for Improving the Public Repletion Program for Seed Oysters

The three most important seed areas in Virginia are the James, Piankatank, and Great Wicomico rivers. The James River is the most valuable because it now produces over 75-85% of the seed planted by lease holders.

In respect to the James River a danger now faces the Commonwealth and its oyster fisheries since there has been a general decline in setting during the last 28 years (Figure 13). As explained above, the productive 1974 setting season and the slightly higher sets observed from 1977-79 and from 1981-83 in which stations above and below the Wreck Shoal area showed isolated peaks in spat density must be regarded as isolated events - exceptions to the general trend of decline since 1960. As the data show, these were improved sets for the post-MSX period and more than met the demands of the time, but none approached average setting levels established during the pre-MSX period!

As indicated previously, the reduced demand for seed in the James River is being met by the lowered annual rate of natural production of seed even though the latter is lower than pre-1960 levels (Table V and Figure 13). In fact, harvesting rates and recruitment of seed may have reached equilibrium for the first time in decades. However, should demand increase or the supply of seed (through overharvesting or diminishing setting recruitment or survival due to natural forces) decline further, then natural seed supplies will clearly become inadequate! Therefore, we recommend that the main objectives of the Public Seed Repletion Program be to:[41]

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[41] As indicated earlier we are assuming that the policy of state encouragement of oyster production by both private and public oystermen, which is based upon almost 400 years of legislative and executive activity in Virginia, will be continued - at least for the foreseeable future. Consequently, our recommendations are based upon the assumption that both public watermen ("tongers" and others) and private oyster growers will be encouraged and supported. A different policy would necessitate different combinations of the remedies suggested herein. However, the essential biological attributes and socioeconomic characteristics of industry would prevail regardless of any possible basic policy alterations, as would the recommendations for renewal of oyster production in Virginia's waters.

1. Increase the production of low-cost seed in existing, productive public seed areas such as those in the James and to a lesser extent in the Great Wicomico and Piankatank rivers;

2. Encourage private planters to develop their own sources of seed to augment seed production from currently leased or public bottoms; and,

3. Encourage development and adoption by industry (and by the State) of new techniques for producing and cultivating hatchery-reared seed.

The objective of more seed at a lower cost cannot be achieved by the system of management presently employed by the State![42] Such a goal, however, can be attained (all other things being equal), by more efficient management of seed-producing areas as outlined immediately below.

1. Shell-planting practices for <u>seed</u> <u>production</u> should be modified as follows:

   Shell should be planted only in areas of recorded moderate-to-high setting. (The possibility of restoring rocks destroyed by earlier harvesting activities or even of building new ones in promising setting areas should not be overlooked.) 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 lower James River from Jail Island Shoals downriver, especially the seed beds now producing only marginally. Traditionally, much of this valuable area has not been shelled effectively due to the complaints of tongers and even some public management personnel who believe that planted shell "dilutes" the catch and makes culling more difficult or that it may kill the underlying oysters. Obviously both factors might have major impact if shell were heavily planted (say 10,000 bu/acre) on a very productive bottom. But, shelling need not be this dense on bottoms on which significant populations

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[42] During the 1986-87 and continuing into 1987-88 oystering year the practice of harvesting the seed beds for clean-cull or market oysters reached great proportions. In fact, the James River seed beds provided most Virginia-produced Chesapeake Bay market oysters. This practice has placed even greater strains upon these crucial seed rocks than existed before. Rapid depletion seems certain if it continues. Further, with James River clean culls bringing $13.00/bu. or more the prospects of inexpensive seed (<u>i.e.</u> at $3.00/bu.) seem to be dimming appreciably unless drastic steps are taken by the public management agency. This assumes that inexpensive seed will be important to restoration of public and private market oyster production.

already exist, as shown immediately below. Shelling at this same density would have major benefits in respect to seed production if done on suitable bottoms with little or no current commercial production. The few oysters killed would be more than compensated for by the major increase in harvest resulting in 2 to 3 years. We recommend such heavy shell plantings for those seed beds with little production.

The more productive seed areas should receive much lower volumes of shell (i.e. 500 to 1,000 bu./acre). These densities would only slightly inconvenience tongers since the original substrate would still be available, and by harvest time most of the newly planted shell would probably have a set of small spat. In either case "harvesters" should be required to cull carefully, returning shells to the same rock where harvesting has taken place!

An even better alternative for both types of seed rocks would be for the State to conduct its plantings so the shelled beds could be closed immediately after planting and not opened until the seed reached a suitable size on a plot-by-plot basis. An arrangement producing a continuous succession of replenished beds could provide both harvesters and buyers with a steady access to harvestable areas.

There is no way to plant shells on the more suitable setting bottoms without disturbing active harvesting unless harvesting is halted, at least temporarily! Under no circumstance should complaints of disturbance or of disaccommodation or temporary disruption be allowed to deter the State from its objectives of increasing production of seed from all of its public bottoms as they have in the past. Further, closures to allow setting and growth on shelled areas should be established where necessary. Such inconveniences to current users as might occur will be a small price to pay for restored productivity, increased yields and an improved economic basis for the industry and the State. Such inconvenience is as necessary as it is unavoidable and will be in the long-term interest of the overall public and the watermen as well! One cannot derive benefits from taking medicine without taking it despite its possibly unpleasant taste and side effects. The same is true of the temporary disruptions of effective repletion activities: They must be borne!

Later in this discussion we suggest that certain areas be set aside, planted with shell, allowed to grow to a usable seed size, and then harvested by careful dredging. Shell plantings on these bottoms should range from 5,000 to 10,000 bushels of shell per acre.

We further recommend that when seed oysters are so dredged from the shelled areas in the James River they be "culled" by a

mechanical device, a practice which has been widely used in the Delaware Bay seed area. This device is a rotating drum on the deck of the dredge boats which separates live oysters from shell and other discardables mechanically. Plantable oysters are retained on the vessel while shell and attached small oysters are returned immediately to the bottom. Breakage may be considerably less than separation by the culling hammer.

b. The Piankatank and Great Wicomico rivers are also important seed areas, but both systems lack the acreage required to replace the production of the James River unless, as has been suggested (Andrews, personal communication), they both be devoted to seed production primarily, or even solely. Of the two systems, the Piankatank probably can be considered, next to the James, as the best supplementary source of seed at this time and under present conditions. Seed oysters produced there in limited quantities could be transported at less cost to the Potomac River and to the Tangier-Pocomoke Sounds area than those from the James. Piankatank oysters would have to be harvested (thinned) regularly since "Dermo" and MSX both operate there. The same may be true of other disease-affected seed oyster rocks elsewhere.

The Great Wicomico River has produced large quantities of seed in the past, but its setting record has been erratic due to the low oxygen levels often occurring in the system caused by heavy loading of BOD and COD pollutants.[43] This situation seems to have abated, but this must be verified by suitable monitoring.

Should Great Wicomico seed production not be needed immediately, this system could be held in reserve and not be developed as a seed source until needed. As in the Piankatank, marketable oysters probably would have to be harvested (thinned) regularly to keep the disease "Dermo", and associated mortalities to lowest levels possible. Alternatively, should the low oxygen conditions in the Great Wicomico abate, it could be made the prime alternate seed-growing area to the James and the Piankatank used as a reserve. The Great Wicomico is even closer to the Potomac and to Tangier and Pocomoke Sounds than the Piankatank. As a further option, these two seed areas could be alternated if necessary.

c. Seed oysters may be grown in many areas on the Seaside of Virginia, but suitable cultch is now a significant limiting factor. The major difficulty is the high cost of transport and placement of shell in the shallow waters of this region. We

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[43] Recent research indicates that hypoxic water in the Chesapeake Bay occurs off of the Great Wicomico River. It should be determined if hypoxia in Bay waters is in any way related to or influences the environmental quality of the Great Wicomico.

recommend that these two problems receive study aimed at their solution. More shell is definitely needed on most Seaside seed beds for setting to reach its maximum potential. Improved predator control may be necessary for enhanced survival.

d. Other locations in the State occasionally receive sets of sufficient size to qualify sporadically as seed areas, but their production or potential is not as dependable or as great as that of the James, Piankatank, Great Wicomico rivers and on Seaside. However, their production can be improved.

e. During exceptional years, shell plantings made for the purpose of growing market oysters in place (without transplanting) occasionally receive high sets (i.e. 1500-6000 spat per bushel). When this occurs they should be thinned out. The oysters so removed should be marketed or transplanted early as seed. The beds involved should be closed if located where diseases and disease-caused mortalities are not problems. When the oysters reach market size the beds can be opened to controlled harvesting. They should not be "wiped-out" as is now so often the case. In years when mortalities due to disease are low, managers should set harvesting limits so as to leave brood stock on the bed. These limits should be based on prior sampling of the oysters on the bottom by VMRC and VIMS.

Such areas are the Lower Rappahannock and a large area of bottom in Chesapeake Bay just below and above the entrance to the Rappahannock River. Monitoring of the VMRC repletion program and other sources indicates that these locations are not dependable seed areas, but with judicious, controlled planting and harvesting they may be made productive for market oysters, during periods of normal salinity patterns.

2. It is recommended that seed oysters from the James River, when needed for VMRC repletion purposes, be obtained by careful "light" dredging in the manner currently (1987) practiced by the Potomac River Fisheries Commission (PRFC). Doing so should reduce the cost of harvesting and allow larger plantings for the same amount of money. The following specific recommendations are based partially upon practices employed and tested by PRFC modified to suit the James River seed area. Steps to be utilized are:

a. Set aside currently "unproductive" areas in the Lower James where oyster density is marginal and the bottom is moderately firm and shelly. Shell should be added as necessary.[44]

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[44] We have noted elsewhere that due to the higher salinities of 1986-87 and other recent periods MSX and Perkinsus (Dermo) have increased in some seed beds of the lower James. This fact must be considered as repletion efforts are planned and conducted. It seems safe to anticipate that normal rainfall and salinity patterns will return. As it does the role and importance of disease will be reduced.

b. After a set is obtained, these locations should be closed to oyster harvesting while seed grows.

c. After the seed reaches harvestable size, VMRC should seek competitive bids for its harvest by dredge ("careful light dredging") and for transport to and planting in good growing areas.[45]

d. After dredging the area should be reshelled in timely fashion.

e. Use of the technique of "hilling" (i.e. planting shells in lumps) to increase surface area interdicting larvae-bearing water masses more effectively and increasing setting area should be tested.

The somewhat more costly but possibly manageable and productive practice of shell-bag planting, probably even on long-lines, may be an even better alternative, especially in shallow areas. The ability of shell-bags to secure higher sets and provide better survival than "horizontal" or flat cultch is well-proven. It should be tested carefully in all known seed or potentially good setting areas to determine its possible utility or limitations.

f. All phases of these operations should be under strict and careful VMRC supervision. This may necessitate a larger VMRC repletion program with some significant infusions of funds to set the program in motion.

3. It is 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 oyster drills are active, it should be transplanted in October or November of the first growing season to a low salinity area (where drills cannot survive). All transplants should be "screened" to reduce numbers of drills moved with the seed.

Areas where drills are or may become a problem are: the lower Piankatank, the lower Rappahannock, the Bay between the Rappahannock and the York Rivers - including Mobjack Bay and the lower York, off the Poquoson River, off Plum Tree Island, the lower James River below Brown Shoals, and inside Willoughby Bay and Lynnhaven Inlet. Drill abundance varies with time and space. If surveys disclose that drills in these places are scarce or doing little damage and disease-related mortalities are low, then the

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[45] Great care should be taken in planning and conducting such transplantations in order to avoid carrying MSX and Perkinsus to planting areas where they could become temporarily or permanently established or otherwise cause significant problems in local oyster populations.

seed oysters should be allowed to remain where set, provided they are not too dense for proper growth. Should the latter condition exist, thinning and spreading should be practiced. Excess seed could be moved to bottoms requiring it. Care must be taken to avoid or reduce the possibilities of incurring disease-related losses by judicious preparation and harvesting. Such transplantations should be conducted so as not to spread diseases and predators.[46]

Increasing Seed Production by the Private Sector

1. To increase seed production by or for the private sector we strongly recommend that the moratorium against leasing additional non-Baylor Grounds in the James River be lifted. Doing so would enable lease-holders to grow seed in areas where recruitment is moderate to high. It is realized that this policy may create policing problems due to the proximity of the leases to public bottoms, but this possibility may be mitigated by suitably restrictive leasing arrangements, suitable pricing arrangements and strict enforcement. Additionally, suitable buffer zones could be established. Continuation of leases could be conditioned upon avoidance of encroachment upon Baylor Bottoms by neighboring leaseholders.

2. If legislation to allow leasing or use of Baylor Bottoms is enacted by the General Assembly we recommend that the Commission seriously consider leasing limited acreages in the James River Baylor-enclosed seed area to private industry for purposes of seed production. Should this recommendation be adopted as we urge, the leasing arrangements should be more stringent than those suggested above, for the currently non-productive market oyster producing grounds.

   Minimum annual fees might be as high as $100 to $200 per-acre-per-year or even more (or a percentage of the seed yield for State repletion activities, or a percentage of the profit, or some other arrangement more flexible than the current fixed-fee rental arrangement for leased bottoms that would allow for bad years as well as good ones). Proof of use should be required as a condition of lease retention. Shorter terms for leases and for the proof-of-use period for seed-producing grounds should be arranged than those applying to market oyster grounds. It should be easier for the State to recover these beds if the leaseholder does not use them for the purposes of the leasing arrangements. If deemed advisable, leases could be let by public auction to the highest bidder with

[46] All of the management activities discussed or recommended above and below must be accompanied by adequate monitoring of the beds to determine their status, survival and likely causes of low productivity or of mortality. Unless this is done proper management responses are not possible.

acreages to any single bidder limited in amount.[47] Preferential leasing arrangements could be extended to public oystermen for socioeconomic and political reasons.

The reasoning behind this last pair 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 have been widely used by seed tongers. The market oyster growing beds from the Baylor Survey Grounds mentioned above do not have these highly valuable characteristics. Increased revenues resulting from higher fees should be used to support efforts to enhance seed production on those Baylor Grounds retained for use "by the public," i.e., the individual, non-leaseholding "tongers".

3. In the event it is decided not to lease Baylor Bottoms in the seed-producing portion of James (though we strongly urge that such not be the case), seed could be grown by the State on selected Baylor Bottoms in the Lower James River seed oyster area and made available directly to private market-bed lease holders. A suggested plan facilitating such action is:

   a. After a survey, a certain area of 100 or more acres of suitable bottom should be set aside and shelled by VMRC. This area could be adjacent to the location just suggested on page 73 for seed dredging by VMRC.

   b. After shelling, the area should be closed to harvesting by the VMRC.

   c. When the seed reaches harvestable size, the area could be opened to qualified persons to harvest by dredging under a quota system or a limited-access arrangement.

   d. The harvester should pay the State the cost of planting this area with shell, plus an amount for the seed itself, (or some such suitable fee arrangement) and monies thus derived be used to reshell and manage the same area.

   e. An alternate plan would be to allow qualified persons to harvest the area only if the VMRC had no use for the seed. If

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[47] The potential profit for private industry from seed production on non-Baylor Grounds (not currently leased in the James River) and, especially, Baylor Bottoms in the James, Piankatank and Wicomico is such that commensurate leasing fees can and should be charged. A graded fee or bid arrangement with charges lower at first; then increasing as production increases, which would encourage leasing might be considered, also.

VMRC needed the shell it could take care of the harvesting, which probably should be by dredge for maximum efficiency.

4. A seed oyster hatchery now operating at VIMS is producing limited quantities of eyed-larvae for experimental use for research and the public and private sectors. In this process, mature eyed-oyster larvae are transported to small tanks of seawater operated by growers, where a set is obtained on plastic, gravel or shell. After a period of holding, the seed is moved to a growing area. Greater utilization of this seed source could well benefit private (and public) growers. At present, development of sufficient quantities of suitably disease-resistant seed seems possible only under hatchery conditions. This factor alone may be the principal justification for development and maintenance of commercial-scale hatchery operations. Continuation of the VIMS hatchery operation should be encouraged until its utility is fully explored and, if found feasible, exploited until full benefits and possibilities are realized.

Recommendations for Improving the Public Program for Growing Market-Sized Oysters From Planted Seed or Shell.

The second aspect of the State's repletion activities, directly related to the seed program, is the controlled growing of market-sized oysters on Baylor Bottoms. The principal regions today where market oysters are grown and harvested are: Seaside and Bayside of the Eastern Shore, Pocomoke and Tangier Sounds, Potomac River tributaries, the Great and Little Wicomico rivers, Rappahannock River (including the area in Chesapeake Bay above and below its entrance), and the York, Poquoson, and Back rivers.[48] Data for recent years show that the most productive market oyster locations of those areas, in order of their average landings (1974-1984) are: the Lower Rappahannock, Mobjack Bay, Mobjack Bay tributaries, Potomac River tributaries, the Poquoson River and Back River and the Little Wicomico. (Here we ignore the large quantities of market-oysters harvested from the James River seed area in 1986-87 and 1987-88. We devoutly hope and strongly recommend that this practice be discontinued!)

Market-oyster production on Baylor Bottoms is presently enhanced by the State in two ways: 1) Shell is planted to obtain a set in areas like the lower Rappahannock and allowed to grow to maturity without moving, and 2) seed oysters grown in a setting area (like the James, Great Wicomico or Piankatank rivers) are moved to one of the State's many suitable growing areas where recruitment (setting) is low or non-existent. (As indicated elsewhere, many potentially productive bottoms within the Baylor survey boundaries are not cultivated at all.)

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[48] Due to overfishing and disease, oyster populations in many of these areas are extremely low.

Detailed Guidelines for Decisions on Growing Market Oysters from Seed or as a Set on Shell

1. Decisions to move seed oysters from setting areas to growing areas elsewhere, or to allow them to remain and grow to maturity where they were set, should be based on the following considerations:

   a. It is economically feasible to move seed with counts as low as 350-400 spat-per-bushel, but higher counts are more desirable for transplantation efforts. If the seed is a mixture of spat and older oysters, minimum counts should range from 400-500 oysters-per-bushel.

   b. Seed oysters which total less than 350-400 per bushel should be left in place where they can grow to maturity, provided prospects of survival are reasonable.

   c. Moderate to high density seed (500-1000 spat-per-bushel) can be left in place to grow to maturity, especially in locations where natural mortalities due to predators and diseases may kill some of the growing oysters. If chances of survival on the setting area are poor, it should be moved to better growing bottoms.

   d. If seed oysters reach counts of 1000 spat-per-bushel and over and occur in a market-growing area where mortalities due to predators and disease are low, crowding will occur as the oysters mature, growth will be slow and the oyster may grow elongated or "snappy" if the majority survive. In such instances some of this seed should be transplanted to accomplish thinning and enhance production elsewhere.[49]

   e. It is suggested that the best areas to receive shell for the purpose of growing market oysters (without transplanting) in years of "normal" disease and mortality distribution are: the lower Rappahannock, that area in Chesapeake Bay above and below the mouth of the Rappahannock, Mobjack Bay and its tributaries, and many areas on the Seaside of Virginia.[50]

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[49] As indicated earlier, great care should be exercised in planning and conducting such seed transfers to assure that MSX and Dermo or other diseases as well as predators are not transplanted to areas in which they could create significant temporary or lasting problems.

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[50] Until salinity patterns return to normal and disease abates, care must be taken in transfer, and planting seed to avoid moving infected seed into areas of unsuitable salinity. Further, "clean" seed should not be moved into "diseased" areas. Disease and predators must be taken into account by public and private oyster culturists at all times!

f. Areas which would greatly benefit from seed planting are the mid- and upper Rappahannock (above Smokey Point), Tangier and Pocomoke Sounds, the Virginia tributaries of the Potomac River, and the estuaries on the Bayside of the Eastern Shore.

g. Seed, setting in Type I or Type II MSX areas (see Figure 12, p62 above) should be allowed to remain in place since it seems to be more resistant to MSX than seed originating from areas where MSX is not active. Where it might be useful, seed from these areas could be transplanted to other growing areas where MSX is also present since such seed may have acquired resistance to MSX. However, if drills are abundant in the prospective growing site within the 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.

2. As oyster culture is practiced today by the VMRC, 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 the area is one which will produce marketable oysters in reasonable time with minimum loss due to diseases and predators. In 1986 shell cost about 53¢ per bushel to plant in the James River, provided no further expense was incurred.

The exact yield from shell plantings varies with the area. However, if seed oysters are moved certain unavoidable mortalities due to mechanical damage and other stresses occurs. Further, relocation requires labor and money which increases production costs. Also, only about 75% of the oysters on the bottom can be harvested without excessive cost. A relatively recent estimate (1986), for example, indicates that if seed is dredged, transported and replanted, the cost will be about $1.60 to 1.70 per bushel.

The above comparison oversimplifies a most complex problem but serves to illustrate our point that as oyster culture is currently practiced by the VMRC it is less costly to plant shell than seed in areas where a moderate to good set occurs. However, in areas where (and when) recruitment is lacking or poor, seed must be planted if timely market production is desired.

3. We recommend that the Commission take all possible steps to optimize set on the shells it plants.

In the past, costs of planting, available funds, proximity of shell piles, availability of cheap labor and sociopolitical pressures to have shell planted "in our district" have often dictated where and when shells were to be placed into the water. As noted, these practices have been reduced in recent years and some improvement in the shell planting program has resulted.

If the objective is to secure maximum sets-per-bushel of shell planted, as it should be, the concept of timing shell plantings

primarily to keep costs down should be abandoned totally. Shell at 60 ¢/bu. (or even at higher costs), 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 shell at 43¢ to 53¢/bu. (1986) planted at the wrong place and time which receives little or no set. It is even less expensive if two or more poorly timed or located plantings are required to assure appropriate yields of seed. We recommend that the Commission adopt a policy of paying the price necessary, even adding a reasonable premium if required, to have the shells planted at the optimum times and places.

Certain historical practices will have to be altered or abandoned to achieve the goals outlined in the preceeding paragraphs. Moreover, there will be sociopolitical costs in changing some of the traditional practices. The tongmen, and other elements of industry and their supporters may object. Despite objections, the benefits to be gained should not be overlooked, denied, avoided or sacrificed merely because of political pressure from a few vociferous users! Tongboats and oystermen are, by and large, mobile, and can move their harvesting operations from area to area to match availability of suitable oysters.

Since production can be improved in many of the waterways (except the most highly polluted - and even there depuration might make increased production useful) of Virginia, the resultant increased oysters will be accessible to most watermen, no matter where they may live along the shores of the lower Chesapeake and its tributaries. Other members of the oyster industry will benefit from increased production. So also will consumers and the general Public (which actually owns the resources - ultimately)! Eventually all ("tongers", planters and processors alike) will realize the value, wisdom and necessity of more realistic and productive repletion practices of such management actions as they share in the benefits.

4. We recommend development and use of mechanical gear to renew old shell plantings which will efficiently prepare the areas to catch maximum spatfall.[51]

On many beds (especially in higher salinity areas), shells become quickly and heavily fouled with silt, bacteria, and fungi or by mats or colonies of bryozoans, tunicates, sponges, barnacles, etc. Even new shell plantings which are mistimed (and there will be some even under the most rigorously and objectively planned and

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[51]This recommendation and recommendations Nos. 6 and 7 below, if followed and successful, will also result in increased seed production in the designated seed areas, (i.e. James, Piankatank and Great Wicomico, and others should they be developed) as well as increased "market" production on other Baylor Bottoms.

pursued 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 as long as this "scurf" cover remains.

In some regions or during unusual years, fouling is reduced naturally due to changes in environmental conditions, usually by above-normal flows of fresh water which reduce salinity. In many localities and in most years, however, such conditions do not usually exist and fouling and silting is so heavy that setting is regularly or frequently interfered with or even prevented.

Commercial growers, the Institute, and the Commission have conducted occasional and casual experiments with cleaning the shell beds by "harrowing" them with a toothed (and bagless) dredge just prior to historical setting time(s) for the areas involved. The limited tests conducted by VIMS and VMRC of those "experimental" treatments indicated that it works if properly timed and conducted in moderate to heavy set areas, but that the process was costly. We believe, however, that costs may be reduced by using a modified dredge in more efficient fashion and that the process should be more widely used. Techniques to "harrow" shell plantings are discussed in more detail in a later section.

5. The Commission should investigate the advisability of resuming use of reef shells harvested from Virginia waters for cultch in public shell-planting operations 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, 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 retained (or sold) a portion of the shells as a raw product for cement production. Royalties to compensate the public for mining rights 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 program as originally conducted), the operation effectively demonstrated that shells suitable for cultch lie buried beneath the surface of the bottoms of our estuarine rivers in many locations.

Beginning in 1968 the Commission began importing reef shells annually from Maryland. Each year thereafter, as the supply of fresh shells declined in Virginia, the quantity of reef shells imported from that state by Virginia has increased and in 1985 over 1.5 million bushels were imported. Comparable reef shell available in Virginia might well cost less than from the upper Bay. We recommend that these possibilities be examined carefully by VMRC 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.

(Some information regarding these resources is available or is now being gathered by geologists at VIMS. This effort should be increased as indicated below.) At the same time, the cost and potential of securing reef shells or other suitable cultch materials elsewhere should be carefully investigated to enable an objective 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 recommended immediately above, mining should be done on a regular contractual basis for the Commission by an established and reliable dredging company. Possibly, a company might be hired to dredge shell for a month or two each year and the shell stored for use at some central location such as Craney Island (if permission can be obtained to do so), or elsewhere at strategic sites along the shore. Buried shell reefs are exhaustable and due consideration should be given to this aspect wherever and whenever shell mining is planned.[52] Additionally, consideration should be given to using surf clam, ocean quahog and scallop shells shucked from catches brought in by oceanic shellfishermen to several landing places or processing locations in Virginia, Maryland, and Delaware. The expense of "mining" or harvesting this type of shell has already been borne by the offshore mollusc harvesters.

6. We recommend that the Commission, working with VIMS acting in an advisory capacity, undertake development of a comprehensive and detailed program of monitoring the State's Oyster Repletion Program. Improvements in monitoring and data acquisition appear to have been made in recent years by the Commission. Any resulting progress is commendable but much more must be done to allow adequate feedback and control. Availability of reliable data which can be obtained in timely fashion remains a major need for efficiently managing the oyster fishery. The data which must be secured and entered into a suitable computer-based data file should be: a) quantities of shell or seed planted; b) area planted; c) nature of shell or seed planted, i.e., size, condition, mortalities; d) other management efforts applied; e) expenditures; f) spatfall and survival; g) final yields of seed or market oysters; and, h) economic results. The areas involved should be accurately and precisely established, as should effort and costs. Shells mined, rate of extraction, mining effort and exact location, extent and depth of mined reefs should be recorded also. This process may necessitate more funds and personnel than are presently allocated by the VMRC for this purpose, but increased and more reliable yields will result and should more than cover costs, eventually. Further, ultimate costs can be reduced by judicious use of appropriate computer-based data acquisition, handling and analyzing techniques.

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[52] Shell mining should not be conducted at sites which are likely candidates for repletion in the future. Long-range planning is necessary to avoid such possibilities.

7. We recommend that more effort be devoted by the State to evaluating, developing and utilizing hatchery-reproduced seed.

Spawning and rearing seed of known parentage and desirable characteristics, (i.e., features such as rapid growth, favorable shell shape and thickness, disease-resistance or other desirable characteristics) in large quantities under controlled conditions in a VIMS' hatchery and/or in industry-owned ones should be possible. As with agriculture and stock breeding, controlled and genetically-based stock improvements seem most promising. The full range of possible genetic arrangements should be investigated, including development and use of triploids and other polyploid animals.

While pilot-scale production of seed is now a technical reality or possibility, problems remain regarding assurance of the survival of such seed in large-scale, commercial-sized plantings so that it will reach market size. Efforts now underway at VIMS are directed toward this goal and a joint VIMS-Industry program, currently evaluating and testing technique to grow recently set hatchery-reared spat to maturity, should be continued and expanded[53].

Recommendations for Evaluating the Resource and Improving Utilization

A major recommendation in our 1978 report was that a survey be made of the extent, actual productivity and potential productivity of its Baylor Grounds. VIMS made such a survey. It required almost four years to complete, and resulted in the publication of two volumes (Haven, Whitcomb and Kendall 1981a and b), which show, in text and an extensive series of charts, the location and extent of suitable oyster growing regions in all of Virginia's major estuaries. The setting records of each area are discussed, and the presence or absence of predators and diseases is outlined. Though this document has been completed, management has used it little, despite the fact that it could be of major value in developing the long range management plans and for determining the best use of each area of State-owned bottoms. It should be put to use immediately and we so recommend strongly!

1. We further recommend that the Commonwealth take steps to determine the extent to which potentially productive bottoms leased to private persons and companies for purposes of culturing oysters are actually being used for that purpose. This suggestion is based upon our findings that many leases are not now employed to produce oysters. Some have never produced significant quantities of oysters due to lack of cultivation. Some have been actively

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[53] Specific details on the lines of research which should be urged and supported and the advantages to be gained therefrom are provided in the section on recommended research and development.

cultivated, but only rarely. Some have been used regularly.[54] Idle leases held by one person or company cannot be used by others who might wish to raise oysters. Since leases under the current scheme may be held for 10 years with an option for renewal at very little cost-per-acre ($1.50 per acre, or less) and little financial risk to the lease-holder, lack of cultivation of such lands is common. Potentially productive bottoms involved in unused leaseholds result in "lost" oyster production for the State.

The recommended cooperative review by VIMS and VMRC personnel should determine whether the bottoms are not being used because of being: a) actually unsuitable for oyster culture; b) only marginally productive; c) actually economically inadequate; d) affected by disease or predators; e) used in rotation, a reasonable practice which should be allowed; f) employed as a geographical margin, buffer zone or barrier, also a reasonable practice which should be allowed - within limits; and, g) held for purposes of law suits or to prevent use by others, or such similar unworthy purposes. These data should be used to: a) evaluate current leasing arrangements, b) determine the parameters for new ones, and c) allow recovery by the State for reassignment for re-use those lands now being held under false pretenses.

As noted previously, there are reasonable uses for bottoms other than growing oysters, such as clam culture, establishment and maintenance of fishing stands, off-bottom culture of hard clams and oysters, mineral production, etc. which are also in the interest of the people of the Commonwealth to encourage or facilitate. Such uses must be considered in any revision of leasing arrangements.

2. We must strongly reiterate the recommendation that the VMRC system of gathering, handling and storage of oyster-fishery statistics be further improved. Improvements over former practices have been made by the Commission staff, but they remain inadequate.

   In review, the improvements needed at VMRC to make biological, environmental, sociological and economic data relevant to oyster production available and fully useful to management and to science are:

   a. Adequate data storage arrangements for easy retrieval of information on current and historical landings of seed and market oysters by specific area;

   b. Detailed and accurate catch-per-unit-effort data for specific growing areas and for the various individual shell and seed

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[54] Some were never productive or even promising, having been unsuited for oyster culture for many years - or many since before the Baylor Survey was conducted.

planting areas (data must be site-specific);

c. Results of carefully designed and conducted on-the-grounds surveys of VMRC shell and seed plantings at suitable intervals after planting and;

d. Information on actual levels of spatfall and survival (obtainable from VIMS) for specific areas; and over long periods of time.

e. Data on production from private leases.

Such data would help answer questions such as: Are seed production and availability increasing or decreasing in the James River or elsewhere? Is market oyster production waxing or waning? Is fishing pressure at any one site, or at all of them, too heavy for the level of replenishment and the rate of growth of the resource? Is more seed needed, etc.?

Full use should be made of the knowledge, availability, observational capabilities, proximity and time of the inspectors or marine police to acquire these kinds of data or to spot-check those submitted. Aerial observations, even with photography as necessary for accurate enumeration and records, could also be utilized for counts or confirmation of effort, i.e. boat counts, activity by area, types of harvesting, etc. Verification of all written industry records and reports by fishery-independent means must be involved.[55] Only with accurate and precise data can the effects of repletion programs, and the health of the stocks be determined and the true extent of the status, problems and progress of the fishery be known. Efforts to improve reporting and data collecting will (as stated previously) require more personnel working on this aspect and more funds, but the final objective will be worth the added cost. Adequate information is vital for effective management!

3. We recommend that the system of fees and taxes currently applied by the State be re-examined with a view toward updating and making the income from oyster production match actual costs of maintaining an adequate public oyster management effort more nearly. The entire tax and fee system should be involved in this review. It is quite possible that a reasonable system could result in recovery of sufficient monies to pay for most or all of the oyster repletion and management program if it is kept current. Funds thus released

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[55] The term "fishery-independent data" means those data which are obtained by scientific survey, or by the management agency directly and not from any segment of "the fishery" itself, i.e. completely free of the possibility of bias from industry.

could be used to speed rehabilitation of on-the-bottom production, production technology, better data management systems, and additional research.

A special study commission, including a variety of capable and experienced representatives from the major oyster industry segments, could be convened by VMRC (or a legislative body) for this purpose. Consumer representatives and financially disinterested parties should also be involved. Persons with special interests in the oyster fishery should be present but should not dominate! It should be well, objectively and effectively led. Whatever mechanism is decided upon, 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 equitable. A regular objective review arrangement is necessary to properly track and evaluate the Commonwealth's Oyster Repletion Program.

4. As stated previously, our studies and analyses indicate that the supply of seed oysters from Virginia seed areas is generally adequate to meet present levels of demand from the growers.[56] Additionally, the demand for soup oysters (i.e. oysters which are smaller than either standard shucking oysters or half-shell oysters and are processed into oyster soups, stews or chowders) can be met from these same bottoms. However, should demand for seed or soup oysters increase or be renewed to past levels, respectively, the current natural productivity (recruitment) of the seed areas as we understand it from spatfall and seed-survival data currently available, especially the James River, will be insufficient. Production will have to be increased! Recommendations for increasing seed production have been outlined previously and are not repeated here.[57]

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[56] In the absence of more active seed-production efforts it is likely that due to the excessive harvest of "clean culls" from the James River during 1986-87 and 1987-88 for use as market oysters that this shortage will develop in the 1989-90, 1990-91, or 1991-92 seasons unless seed demand continues to be low due to persistence of disease in areas not normally infested.

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[57] Since about 1975 soup companies have not utilized James River oysters because of the Kepone incident, etc. Since Kepone is no barrier to use of small oysters as seed because they cleanse themselves quickly when moved to Kepone-free waters, 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. In reality Kepone levels in small oysters in the James are so low (well below action level) that resumption of the soup trade would be possible without endangering human health should this course of action be desirable. Obviously, raw oysters from the James River seed beds are already reaching the tables of consumers due to the current harvesting, sale and distribution of "market" oysters from the James River seed areas.

During the 1986-87 harvesting season the James River seed area was employed to supply market oysters to replace those killed by disease in the severe drought of 1985-87. This practice has been continued in the 1987-88 season. In fact, part way through the harvesting season the size limits being applied for clean-culls on the James were dropped from 3 inches to 2 inches under pressure from harvesters. In our opinion, depletion of the seed beds has increased as a result. This practice should be stopped. It should not be resumed except with careful study and well-justified reasons, if ever. The James River seed beds are the key to the future. Already damaged, they must not be injured further!

Enhancement of Consumer Demand

Demand on the part of the ultimate consumer may be enhanced by a reduction in retail price since several competent economists have expressed opinions that demand for oysters is "elastic." That is, if the retail price is lowered then demand at the consumer level for the oysters likely will increase. Increase in demand will help stimulate a higher level of production by processors, and perhaps by the oyster grower or 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 in detail the possibility of heightening 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 homemakers. Other institutions, including several partially or wholly supported by industry for its own development and enhancement, are already active in these fields.[58] We are convinced, however, that product and market development efforts will be important in rejuvenation of the Commonwealth's oyster industry, or even in its maintenance at current levels because of intense and increasing competition from oysters produced elsewhere.

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[58] In the Commonwealth the Virginia Marine Products Board and the Sea Grant Marine Advisory Services programs of VIMS and VPI-SU have been active. Regionally the Mid-Atlantic Fisheries Development Foundation, Inc. has been the prime mover. At national and international levels the National Marine Fisheries Service has helped promote U.S. (and local) seafood products. This work should be continued, preferably with increased financial commitment and involvement by industry.

Recommendations for Research, Engineering and Technological Developments to Benefit Both Public and Private Phases of the Oyster Industry of Virginia

Both public and private segments of the oyster industry are dependent upon ready and inexpensive access to sufficient quantities of oysters (which must be palatable and safe to eat), for shucking or for the half-shell trade, for the stew, chowder and soup market, or merely viable ones for seed. There is a direct relationship between the quantity and quality of oysters and the sediments under and around them and the water about them. Where active predators or diseases exist, oyster population levels are affected. Where waters or sediments are contaminated, oysters may be immunologically affected, genetically damaged or even killed; their life cycles may be interrupted, or they may become undesirable, unpalatable or unsafe to eat, among other possible effects. Virginia must give increased and constant attention to maintenance of water quality suitable to growing oysters which can be consumed without cooking!

Consideration also must be given to biological and physical factors related to maintenance of productive oyster stocks and to the economic and technological aspects of the oyster industry. For public and private management to be able to operate effectively, managers 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 at current levels of knowledge and technology. In other words, we can increase production with the scientific knowledge and technology now available! However, much remains to be learned and done before we will be able to manage the oyster industry with maximum assurance of success and profit and minimum risk. It is to these scientific, engineering, and technological requirements that the remainder of our report is addressed. We intend that this list of required research and technological study and development will be useful to those who must plan, develop and conduct relevant research and advisory projects.

Though some of the recommendations for research and engineering studies which follow have been mentioned above they are reiterated in this last section in order that all may be available together and arranged in order of perceived importance.[59] Specifically we urge the following research and

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[59] Two types of research are recommended, socioeconomic and ecophysiological. Sociological and economic aspects are accorded the highest priority because the major stumbling blocks to effective management of the oyster fisheries are economic, sociological and political. Because most research into the sociological aspects of the fishery has been anecdotal, poorly defined and ineffectively conducted this priority recommendation causes us some unease. Well-designed studies are needed which will examine the important issues in an objective and statistically sound manner. They should not be designed to justify continuation of cultural and sociological attitudes and practices certain to lead to extinction of the oyster industry as a viable economic activity, but to determine the facts objectively.

The ecological, physiological and technological research recommended is important and should proceed simultaneously with the socioeconomic studies.

engineering activities:

1. Research on the sociology of the oyster industry.

Understanding the important sociological aspects of the various elements of the oyster industry is necessary for establishment of realistic socioeconomic goals for its oyster production program. Consequently we recommend that tightly conceived and controlled sociological research be directed at key elements of the industry and its activities (as indicated in the box model presented in Figure 3 above).

Early objectives should be understanding those elements of the oyster fishery such as the professional full-time seed and market "tongers", part-time commercial and subsistence harvesters, casual or sport harvesters, their roles in the fishery and their expectations, dependence and other problems. Accurate and precise data on actual harvest efforts, costs, areas harvested, by whom and how and yields must be available. Objective and thoroughly-done research should enable the State to design and install oyster repletion and management programs with greatest economic (and social) benefit to the harvesters as well as to the general "public" (which actually owns the resources), and to the consuming public. Sociopolitical aspects of participants in the various segments of the oyster industry such as traditional attitudes, resistance to change, lack of true concern for the resource or its future, fear of the new or unknown, resistance to management, distrust of science and technology, disregard for resources, environment or for posterity, persistent ignorance, resistance to new information and resistance to management by government resource agencies as well as other attitudes affecting the industry should be carefully examined.[60]

As indicated several times above, overharvesting by fishermen, resistance to more effective and efficient management measures and the lack of will by public and private sectors to manage the oyster fishery and the resources on which it is based (and the environment on which they depend), and not lack of knowledge or technology, are

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[60] Long experience forcefully indicates that because of the common-property nature of these public beds, competition between the many harvesters, buyers and processors and the continuing financial obligations most face for that limited resource individual watermen and other industry members cannot be expected to take the long view and control their own harvesting efforts for the benefit of the future and posterity. Economic pressures of the moment prevent this. In fact, we have asked directly and been told by tongers "themselves" that management of the resources, self regulation and policing cannot be expected. Industry cannot be expected to look out after the public and posterity's long-term interest. Effective public management of public bottoms and resources is essential!

major factors responsible for the continuing decline of the resource and industry! Since these factors are so important, sociological (and economic as recommended above and below) research would seem paramount! Accordingly, we place a high priority on soundly-conceived and conducted sociological, sociopolitical and socioeconomic studies. Too often past sociological research has tended to be "folksy", anectodal, subjective, mystical and aimed at hallowing and/or preserving traditional ways; or focused on relatively small enclaves or restricted aspects of the "watering" public. Such research is not the type we urge here. There is no reason that preserving traditional cultures or group of workers could not be one of the possible goals of public management; but if it is, it should be understood clearly and established deliberately as a suitable public aim. The costs should be recognized and the resources necessary to its achievement allocated for that purpose.

2. Research on economics of the oyster industry

A major need to understand important details of the economics of the seafood industry exists. Data provided by suitable studies would be useful to the sociopolitical activities necessary to bring about restored production of oysters in Virginia. At this point, the major deterrents to introduction of needed changes and reforms in public management and industry are either economic, sociological, political or combinations thereof. Problems to be undertaken or questions to be answered include:

a. Development of detailed understanding of the economics of specific activities involved in the oyster industry of Virginia as constituted today, as it was, and as it could - or should be (See Figure 3 for the various elements involved.)

b. What economic factors must be considered and met as the State and private industry move forward with efforts to restore oyster production to former levels?

c. Why did the wholesale market prices (adjusted for inflation) of oysters remain nearly stable until just recently? What accounts for the rapid rise in 1985-86 and 1986-87? Was it the drop in the value of the dollar?

d. Have recent increases in retail prices altered demand significantly? To what extent would a drop in retail prices stimulate an increased demand for oysters?

e. How is total (gross and net) income from sales distributed among segments of industry?

f. How are retail and wholesale price increases established and distributed throughout the industry?

g. What is the consumer demand for oysters? How does it develop and change? Can consumer demand be increased significantly for Virginia oysters and for reasonable lengths of time?

h. Can Virginia capture a larger percentage of the national market for oysters and oyster products produced from Virginia waters?[61]

i. Would new and better handling and processing help increase demand and sales and/or reduce losses and production costs sufficient to create significant markets or increase economic profit?

j. Has promotion by advertising such as that now practiced by the Virginia Marine Products Board and similar organizations resulted in increasing sales? If the study shows sales to have been increased, this activity should be expanded. If it discloses problems, they should be corrected. If such promotions produce no significant long-term benefits and/or are not clearly in the public interest, Virginia's participation can be terminated. Also, if these activities have been successful, industry should be encouraged to assume a large share of the management and expenses of the program.

3. Understanding the diseases affecting oysters and developing means of dealing with them.

The oyster disease MSX continues to be the first non-socioeconomic problem requiring further study. All related signs indicate that it remains the primary reason why growers cannot raise oysters effectively on their down-Bay or down-river high-salinity beds. MSX also occurs on Seaside of the Eastern Shore [where Dr. Andrews (personal communication) contends that it is now equal to or even more important than SSO as a cause of oyster deaths]. We cannot corroborate Dr. Andrews' opinion but are convinced that MSX is a, probably the, major reason why Baylor Grounds in MSX Type I and MSX Type II areas are producing less (Figure 12). Further, during extended periods of low-rainfall in the Chesapeake drainage basin, especially the Susquehanna and Potomac, the disease MSX rapidly moves up-Bay and up-tributary and causes infections and mortalities in stocks not normally exposed to such pests. "Dermo" also appears to cause mortalities greater in the fringe or "frontier" areas of its distribution, especially during warm temperature periods. It also appears to "move", or be more successful in areas in which it normally causes few problems,

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[61] We seem to be doing reasonably well with oysters imported from elsewhere that are processed and packed in Virginia since Virginia processors and packers have "markets" for oysters in many states.

when these conditions occur. This happened during and following the extensive droughts of the mid-'60s, in 1981-82 and, especially, in 1986 and 1987.[62] Many questions, which if answered could lead to possible control measures, or improved accommodation techniques, remain. We, therefore, recommend:

a. Continuation of laboratory studies of the mechanism of transmission of MSX from one oyster to another. It must be determined if the disease is waterborne or whether there are vectors and/or alternate or reservoir hosts involved.[63]

   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 this aspect.

b. Field studies related to those in the laboratory are also important since applicability of laboratory findings to natural conditions are vital for confirmation. Further, studies of possible intermediate or reservoir hosts or vectors should be continued and expanded. Naturally, epidemiological data might be regularly obtained in controlled, standard and comparable fashion. It is important for scientists and managers to know the prevalence and levels of infection in all critical disease areas and strategic fringe locations, and to consider such information in time to take such action(s) as may be necessary or possible. Knowledge of the factors affecting one's stock is always important to effective management!

c. Research aimed at developing oysters resistant to MSX should be expanded. If this goal is reached and if sufficient quantities of resistant seed are available, the possibilities of restoring oyster production at suitable sites in Type I and II MSX areas in all Virginia rivers should be tested. Carefully planned and controlled trial plantings, at least one acre in extent, preferably more, should be made in several areas including the lower James.

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[62] Perkinsus marinus, the agent causing the disease "Dermo," is frequently introduced into a new area or augmented where it already occurs by transplantation of oysters infected elsewhere. Undoubtedly, however, it can move of its own accord as conditions favorable to natural transmittal develop as well but dispersal this way is much slower than by movement of infected oysters into Perkinsus-free areas.

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[63] Studies directed toward this objective are now in progress at VIMS, but they should be more actively supported and pursued.

The purpose of this research would be to determine 1) 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 (or to better it) and 2) how long it takes oysters to reach maximum biomass or the size of maximum economic yield. These would be long-term studies.

d. Efforts to determine the exact nature of MSX resistance should be pursued vigorously. Has resistance been developed or observed? (Evidence that it has is convincing!) Is it genetically determined or is it related to acquired resistance or are elements of both involved? Studies to determine antigenic activities and host resistance responses, including cellular and humoral antibody responses should be included. Such well-planned research as may be underway at this time should receive additional support and attention. Breakthroughs in our understanding of molluscan resistance to disease are needed before the possibilities of other types of disease controls would be known.

e. Studies should be done to determine the effects of low (and high) salinity on oysters infected with MSX. Do freshets caused by storms like Tropical Storm Agnes in June of 1972, or even less catastrophic freshwater inflows, eliminate MSX from oysters or reduce its incidence or virulence?

f. The oyster disease, traditionally called "Dermo", caused by the organism Perkinsus marinus, also affects oysters in Virginia waters, seriously. Many of the extensive mortalities which accompanied the acute drought of 1986-1987 have been attributed to "Dermo". Some even consider it to have been the primary killer, rather than MSX. In some populations this may have been so, but questions remain. We are convinced that it did kill oysters, along with MSX where they co-occurred and hydrographic and host-susceptibility conditions were conducive to disease - and death. Certainly, this event and this suspicion clearly justify continued, even increased research on P. marinus and its effects on oyster populations and, the factors affecting the disease and methods of reducing those effects. They also underscore the necessity for continued monitoring in core and fringe or "frontier" areas of infestation! Studies similar to those recommended above for MSX must be made of P. marinus and other disease-producing organisms.

It is especially interesting to note that a report, released just recently, implicates the micropredator (or ectoparasite), Boonea impressa, a small pyramidellid snail, as a transfer agent or vector of P. marinus in oyster populations (White, Powell, Ray

and Wilson, 1987). Such possibilities should be pursued for this and other oyster diseases.

4. Development of more thorough-going and useful understanding of the environmental and other factors responsible for low setting levels and high spat mortality and the converse - adequate or high setting and survival of seed and market oysters, is of paramount importance to science and management.

The James River has experienced only two periods of nearly adequate spatfall, in pre-1960 terms, in over 25 years (Table V and Figure 13). Even those two were numerically below the sets which occurred prior to 1960. Indications are that sets have failed with some regularity or declined in at least two other seed-producing river systems, the Great Wicomico and the Piankatank rivers, during the past 20-25 years as well. A continued trend of declining setting will seriously damage the Virginia oyster industry as it is now conducted and thwart efforts to restore production. Reduction of brood-stock, caused by natural mortalities and overfishing, is implicated strongly. However, other factors such as contamination from biocides, heavy metals, PAH's and other pollutants acting independently, oppositionally or synergistically and other causes of debilitation may also be involved. Also, low levels of dissolved oxygen which develop in certain tidal waters in late summer recently have gained added importance as possible causes where they occur. Only additional, carefully-done research can answer the numerous questions involved. It is recommended that studies of the lethal and sublethal effects of heavy metals, pesticides, detergents, nutrients, and other pollutants on all stages of the oyster's life history be more vigorously pursued. Recent oil spill, residual creosote, chlorine and Kepone and tributyltin chloride problems are excellent examples of why this work is essential.

Included in such research would be consideration of the phenomena related to routes and pathways for toxicants in nature, uptake, distribution and effects in the organisms, and depuration or self-cleansing by young and market oysters, public-health significance and possible role of contaminants in oyster diseases and mortalities. Also, 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 major reasons for the consistent set failures in the lower Rappahannock, the Great Wicomico and elsewhere in the Chesapeake Bay. Other aspects such as availability of brood-stock, larvae, disease etc. should be studied in the field.

Among the problems to be approached are:

a. Laboratory studies utilizing bioassay techniques to evaluate survival of laboratory-reared spat and the plankton or other materials 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. Careful chemical analyses should

be done regularly during each season at each important location, on each important component of the water column and associated sediments and over a period of years. Suitable field bioassays should be conducted also.

If toxic substances are demonstrated using applicable state-of-the-art analytical and bioassay techniques, an extensive effort by VIMS should be directed toward determining the substance or substances involved and their source(s) and possible prevention or remedial actions. Assays, toxicity studies and microchemical analyses can be expensive, some costing hundreds of dollars per individual sample. Therefore, additional financial support to do the extensive field and laboratory studies required will be needed by VIMS. Clearly, efforts to monitor critical environmental sites for presence, levels, increases or decreases of key biological, chemical, geological and physical factors are a vital adjunct of this work and important to any repletion effort. Toxicological research should utilize embryos as well as larvae and juveniles as subjects. Success of each stage is essential to the development of viable seed or market oysters.

b. Oyster set has often failed in recent years in the Great Wicomico River (as previously stated) and at times 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 have been the source of organic matter concentrated in the sediments (and those of the Bay nearby) which causes the O_2 depletion, but natural conditions related to circulation of the Bay water may also be responsible, partially or wholly.[64] This area should be studied carefully

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[64]The number of menhaden and pet food processing plants on the Great Wicomico has diminished in recent years. It is our understanding that only one major menhaden-reducer, Zapata-Haynie, operated there in 1986. Even if Standard Products resumes operations of its menhaden plants to earlier levels the number of industrial discharges has been reduced markedly. Further, control of plant wastes seems to have improved. These factors may reduce low O_2 problems and aid in restoration of oyster production there. Unfortunately, sediments in and near Cockrell Creek remain heavily contaminated. Nevertheless, if discharges of industrial wastes continue to be reduced, water quality in this part of the Great Wicomico should improve. Interestingly, setting near Fleeton in the Great Wicomico is reported to have improved markedly in recent years. This may indicate that conditions have already begun to improve.

to determine what the basic causes are and what steps may be taken, if any, to remedy the situation. Field studies should evaluate Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), dissolved oxygen (O_2) and hydrogen sulfide (H_2S) values and levels of other critical components in the sediments and waters of that system (and other anoxic locations) to see if levels are sufficiently high to kill oyster larvae or the plankton on which they feed. Careful examination of the physical and geological features pertaining should also be involved in this research.

c. Fouling of shells on the bottom may have increased over the past twenty-six years due to growing nutrient enrichment of the water. 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.

5. Use of Reef Shells or other types of cultch for the VMRC Shellplanting Program.

The importance of adequate and timely supplies of oyster shell or other suitable cultch material for the VMRC repletion program has been fully discussed on pages 81 and 82. It is mentioned here for added emphasis. A "preliminary" study by C. Hobbs of VIMS has located limited shell deposits. A full scale economic geology study should investigate the extent of Virginia's reef shell supply, and all aspects of its mining, storage and costs. Other kinds and sources of cultch should be investigated as well, as suggested in the management recommendations above.

6. Research to improve setting and survival of seed oysters in Virginia.

As explained in exhaustive detail above, an adequate supply of high quality and inexpensive seed oysters is vital if the Virginia oyster-producing industry is to survive and compete with imported oysters from Maryland and other oyster-producing regions in the Nation (or enable independence and economic survival of the Virginia oyster industry should outside sources fail). Therefore, every effort should be made to reduce the cost and to improve the quantity and supply of seed oysters. We recommend that:

a. Efforts to develop an efficient method of cleansing cultch in place should be vigorously pursued as urged under the management recommendations. One possibility is to test and develop efficient underwater gear designed to uncover near-surface deposits of buried shell and "turn" surface shell so it may be available to receive oyster larvae ready to set, thus enhancing seed production. A design for such a unit has been developed by VIMS scientists. It or other, possibly better, machine(s) should be built and tested in realistic fashion.

b. Some mollusc scientists contend that oysters may set best on those rocks where live oysters occur. In the 1950's, 90 per cent of setting is said to have been on other oysters (Andrews, personal communication). Others have reported similar findings. This suggests that a useful strategy to improve setting might be to build and maintain living populations on seed rocks. If this phenomenon is significant it would be unwise to harvest an area on which setting is desired to the point that absence of active oysters would reduce chances of larval settlement and attachment markedly. This possibility must be vigorously pursued in research and development. In doing so the possibility of active culling of beds to reduce disease, mortalities or stunting due to crowding must not be ignored.

c. Encapsulated quicklime has been said to control fouling on oyster shell so that oyster larvae may attach. Limed tiles are in widespread use in France as spat collectors. Studies should be conducted to establish its utility in Virginia waters.

d. The possible use of hard clam, ocean quahog and surf clam shells, as well as slate fragments, cobbles, and other such materials as cultch for spat attachment should be studied. Suitability, cost and availability are predominant features in the search for new supplies or kinds of cultch. Risks of significant environmental contamination from possible cultch materials must be considered. Materials carrying toxics should not be used.

7. Understanding, accommodating to and/or controlling predation in Chesapeake Bay and on Seaside.

A significant biological problem needing further research and development in Virginia is development of practical methods of controlling oyster drills (Urosalpinx cinerea and Eupleura caudata and their larger seaside "cousins") and other predators. While these predaceous snails have become less of a problem in the Chesapeake Bay during the last 16 years because of Tropical Storm Agnes, subsequent freshets, and reduction of prey populations by disease, reduced planting and overharvesting, they remain major deterrents to oyster production on the Seaside of Virginia. It seems highly likely that as salinity levels resume their long-term patterns and oyster cultivation is increased drills will again become significant in the higher salinity waters of the lower Chesapeake and its tributaries.[65] If MSX-resistant oysters

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[65] Especially in the lower Rappahannock River below Towles Point, which has been most productive during much of the last 15 years because of extensive repletion efforts by the VMRC and the absence of drills.

are planted in high-salinity areas, drills may pose threats to them as well.

Oysters often set in areas such as the lower York River or similar areas where drills are abundant, but in normal times the small oysters are usually killed by them before they grow large enough to be moved about as seed. If drills were controlled, or the seed moved to drill-free, low salinity areas, then the downriver and other intertidal areas could become suitable sources for inexpensive seed.

The large oyster drills, Urosalpinx cinerea folleyensis and Eupleura caudata etteri, are major biological problems which have always hampered oyster culture on Seaside. Development of controls or improved adaptation to their requirements is a major task of research and management. Obviously, much of the required research on these drills and their control would have to be done on Seaside where they occur.

To develop suitable methods to control drills we recommend the following possible lines of research:

a. Control of drills by sterilization of feral or cultured males and introducing them into the population to be controlled as outlined by Hargis, Arrighi, Ramsey and Williams (1957). This promising technique, which has been successfully applied to several insect pests, should be seriously pursued. Chemical sterilization should be tested as well as radiation.

b. Utilization of suction-dredging or other mechanical techniques to clear or reduce drills on areas under cultivation.

c. Employment of automated cleansing techniques for use on oysters, seed or shells to be relocated from drill-infested areas.

d. Development of non-toxic chemical repellents (or attractants in association with traps or sterilization) to selectively reduce or attract drills, should be attempted.

e. Perhaps a combination of control techniques will have to be employed. The time for their development and application is now, before stock-rebuilding programs begin in earnest and before drill populations resume their former destructive proportions.

f. Recent research indicates that crab predation, especially that caused by xanthids, is more important now than that from drills according to Castagna (personal communication). Evaluation of this source of predation, its importance and means of reducing it deserves significant effort. If it is found to be more

important as a cause of destruction of oysters its position in terms of necessity for and priority of research should be temporarily higher than that for drills. However, essential drill research should continue since their populations will increase as oyster production in Virginia waters is increased and the residual effects of Tropical Storm Agnes and oyster population reductions disappear and salinity patterns return to normal.

g. The importance and possible control of other pests, such as the pyramidellid snails, including Boonea impressa, recently implicated in the spread of "Dermo," should be investigated.

8. Controlling Haplosporidium costalis (the organism causing SSO disease) on the Seaside of Virginia.

The oyster pathogen H. costalis is normally a major biological problem facing oyster growers on the Seaside. Since the discovery of SSO-disease, its pattern of seasonal mortality and part of its life cycle have been described and, most recently, significant sporulation observed. However, very little is known about its transmission or the possible effects of temperature and salinity and other environmental factors 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 careful monitoring of the incidence of this disease on Seaside.

b. A series of laboratory studies to determine the complete life cycle of SSO and how it 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 or whether other factors are involved.

d. Efforts must be made to induce genetic or acquired resistance to SSO-disease in oysters. Improved methods of accommodation to reduce losses should be sought, but cultivating resistant oysters may be the only means of combatting this disease since it is so firmly entrenched and apparently well-adapted.

9. Controlled oyster-breeding research and development

Preliminary tests at VIMS from 1972 to 1976 showed up to 50 percent survival of laboratory-reared, cultchless (and uniform) spat in low salinity regions and where the bottom was "shelled" prior to planting the seed. This compares favorably with survival of naturally-produced seed. Unfortunately, the price-per-oyster of cultured seed in that study was about twice as high as that of

James River seed (prior to 1986) which was of much larger size and, probably, of better survivability. We believe, however, that the unit-price of hatchery-reared seed can be reduced through research on improvement of applicable 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 Program.[66]

There is a need to increase survival rates of hatchery seed through research. Even with this need, it is our opinion that hatchery-reared seed can be planted and grown successfully on many large areas of bottom where salinities are low and where predation is reduced. It is recommended that field trials be made using hatchery seed set on oyster-shell and other promising cultch materials. However, other studies might concentrate on holding spat until large enough to resist predators or setting and rearing them on the newer type predator-resistant collectors.

We strongly recommend 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 that which has a genetic basis;

b. To develop oysters resistant to SSO and Perkinsus (Dermo) as well as MSX;

c. To develop oysters which show fast growth and high-meat yields; and,

d. The results of a., b. and c above should be evaluated through well-designed, statistically-sound field testing programs.

e. To investigate the technical feasibility of developing adequate facilities for quarantine of oysters or other molluscs for export or import.

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[66] Or if costs of natural seed production increase and make hatchery-reared seed more competitive in price, or natural seed is no longer available in adequate quantities. As a result of the practice of harvesting market oysters from the James River seed beds, which took place during the 1986-87 oyster season and is continuing in 1987-88, it seems certain that prices of seed from "wild" sources will increase, perhaps by as much as 100 per cent. Attractiveness of hatchery seed will be affected by changes in costs of natural seed.

f. To provide stocks and facilities which can be employed in genetic engineering of oysters such as production of triploids or other polyploid individuals.

10. Research, development and advisory services to encourage private hatcheries for controlled production of oysters and other desirable molluscs.

Hatcheries seem to have a definite place in the future of both the public and private sectors. Certainly, they seem to be working well on the West Coast. 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.

11. Research to establish more exactly the nutritional requirements and preferences of larval, juvenile and adult oysters.

Much research activity has been devoted to mollusc feeding and production. Despite this and all of the research on estuarine energetics and on the biology of the oyster accomplished thus far, our understanding of specifics of oyster nutrition remains limited. Traditional concepts of productivity in marine and estuarine oysters recently have been upset somewhat by the discovery that the picoplankton (i.e. extremely small plankters <1 u in size) is extremely important in marine productivity. It is likely that oysters utilize picoplanktors in their diets in early or even adult stages and that these microscopic plants are important sources of food. Bacteria are also probably utilized. Had we better knowledge of food and nutritional requirements, answers to questions such as a) why one estuary or estuarine reach is more productive of oysters than another, and b) why some bottoms are good seed-growing areas while others produce better market oysters, etc., would be at hand, and both scientific understanding and our ability to manage would be enhanced. Further, with improved knowledge about oyster feeding, food requirements and nutrition, hatchery operations could be made more productive and efficient. Accordingly we recommend additional research in the laboratory and field on this important practical aspect of oyster biology.

12. Research efforts in engineering development and food technology

An evaluation of material presented in this report and of the work being done at VIMS and elsewhere shows a continuing paucity of research efforts in the fields of engineering development and in food technology. 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 production techniques, new ways of packing and selling their product, improved or new products, and new or improved handling, transporting and processing techniques. Also, oyster

growers as well as watermen working the public rocks will be helped if effective machines are constructed to harvest oysters, to turn buried shell and help increase spatfall, to open oysters, etc. Among a possible list of projects which may be of value would be:

a. Development of ways to keep cownosed rays and other predators away from oyster grounds. Such things as nets and fences and electrical fields should be considered and promising leads or variations examined.

b. Development of techniques and technology to control oyster drills, limit their recovery and spread and reduce their destructiveness and/or to accommodate to them.

c. Development of more suitable cultch or cultch preparation and handling equipment and operating techniques to increase seed production as mentioned above.

d. Development of improved gear to process oysters mechanically, which would include machines to plant, culture, harvest, open and process oysters.

e. Working with industry to determine its needs for new methods of raw product manipulations and transport, food processing, marketing, etc.

f. The validation of mechanical gear such as is now used in New Jersey and elsewhere to separate shell and shell fragments from live oysters after they are dredged.

g. The 50 to 60% of U.S. women who work full time seem keenly interested in quickly prepared meals. Every effort should be made by State and Federal officials and industry to encourage development of prepared meals using oysters and expansion of the oyster-canning industry. Doing so would help expand markets and demand for Virginia-grown and processed oysters. Should research support the possibility, relevant State and Federal laws could be modified to permit canning of oysters from some restricted areas. Different convenience-food preparations using oysters as a base should be developed.

In providing this brief catalog of recommended R&D efforts we have included all areas believed to be important over the short-, medium- and long-term. It would be best were it possible to undertake (or increase in the case of activities already underway) them all at once.[67] Because this may not be possible, we have

[67] Fortunately, many are in progress at VIMS and elsewhere. These efforts should be examined carefully and if they are found worthy and relevant, enhanced. Time is of the essence!

attempted a loose ranking or priority in the listing above to be considered. This loose ranking of research needs is based upon our best judgment of the urgency of acquiring the information (whether or not significant R&D activity is already underway) and the difficulty of the research (hence time necessary to secure results required). As has been indicated above we now consider it necessary to rank the sociological, sociopolitical and socioeconomic research higher than formerly because the principal barriers to restoration of oyster production from Virginia waters are resistance to: 1) installation of appropriate management arrangements and 2) involvement of more efficient technology, as described carefully above. Additional information from research in these areas probably should help reduce or remove the sociopolitical barriers and bring about improved management in more timely fashion. Accordingly, this research is essential and must be given very high priority; and we recommend its pursuit at once! It is hoped that reduction of those barriers will not take long to accomplish since they are the major stumbling-block to effective management and to restoration and economic recovery of the Virginia oyster industry - both public and private sectors.

The rapid spread of MSX and Perkinsus (Dermo) and associated mortalities into previously little affected or unaffected populations during recent drought periods underscores the importance of effective disease and disease-combatting studies, accordingly these are accorded the highest priority of the biological research areas, as is more effective monitoring of disease and mortality in "core" and "frontier" areas. Better monitoring of spatfall, survival and seed production as well as market oysters is also critical to more effective, scientific understanding and management of the resources.

In any case, as new or improved R&D projects and programs are planned, undertaken and pursued it would be advisable to review this list of research and development recommendations regularly to see if new problems and needs requiring different attacks have arisen or whether new scientific information and engineering developments call for altered priorities. We cannot afford to concentrate limited research and engineering resources on problems of little scientific importance or socioeconomic relevance.

V. SUMMARY AND CONCLUSIONS

The oyster industry of Virginia, continuing its long and sometimes precipitous (i.e. the abrupt 1936 and 1960 drops) descent, attained a new low in production (658,679 Va. bu. market oysters) in the 1984-85 harvesting season from a recorded high of 7,612,289 bu. in 1904 (our data, Table I, Table II and Figure 1). Seed oyster harvests, which reached a high of 3,184,851 Va. bu. from public and private seed bottoms in the 1954-55 harvesting season (Table III and Figure 2), have declined in similar fashion to a near low of 259,678 bu. in 1985-86, about an order-of-magnitude less. Though a slight increase to 715,003 bu. of market oysters occurred in the 1985-86 harvesting season (the harvest of seed oysters actually decreased), all information now available suggests that total statewide market- and seed-oyster landings will fall even lower in the next several years as, indeed, they did in 1986-87 to 539,506 Va. bu., the next lowest level on record.

This forecast is based upon 1) the continuing basic pattern of the long-term downward trend in production of market oysters; 2) failure of private oyster-growers to resume significant plantings on their leaseholds; 3) the fact that few of the features responsible for continuous overharvesting of the public market-oyster rocks have changed; 4) the continuing resistance to improved management practices; 5) increasing harvesting by patent tongs of formerly inaccessible deep-water populations and in areas of low recruitment adding to already high levels of overfishing; 6) the fact that the objections of relatively few public watermen[68] continue to block the leasing of potentially more productive but unused Baylor Grounds, a move which would allow private planters to resume planting at less economic exposure and with greater assurances of profitable yields of market (and seed) oysters; 7) continuing presence and sometimes spread of the disease-causing organisms, Haplosporidium nelsoni (MSX), H. costalis (SSO) and Perkinsus marinus (Dermo); 8) recent salinity-related, disease-driven deaths of many mature oysters in the lower Rappahannock, Mobjack Bay and the Bay, itself, during the fall of 1986; 9) recent harvesting of market oysters from the James River seed beds; 10) continuing contamination of important waters; and, 11) continuation of economic, sociological and political factors which interfere with rehabilitation of the prime and promising oyster-producing bottoms by public and private managers.

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[68] In comparison to the general populace of the State, the actual owners, the environment and the resource and their potential production and amenities, the number of working watermen is very small. They are important and their service and means of making a livelihood should be preserved in our opinion, but they should not be allowed to prevent utilization of effective management nor should they or anyone else be allowed to impinge on the rights of posterity. Continuation of harvest at levels which cannot be sustained is not wise use of resources or resource potential. Neither is continuing destruction of habitat and increasing contamination of public waters by others. All should be controlled!

We fear that the oncoming shortage of oysters from once naturally productive public bottoms will result in pressures on the VMRC (or on the General Assembly, or both) from public harvesters to 1) expand areas where patent-tonging, diver-picking or dredging may be used or 2) allow increasing harvest of (ever smaller) market-sized oysters from the James River seed area. It is possible also that pressure to allow use of dredges on low-yield or deep-water bottoms will develop. There is a place in a well-planned and operated public seed and market oyster production program for controlled harvesting by dredges and/or patent-tongs, but it is <u>not</u> on those beds whence most of the oysters have already been removed, or where populations are naturally low or on public bottoms important as brood-stock sanctuary. Pressures to increase harvesting in such areas must be resisted adamantly!

Despite the various negative factors operating we have found no long-standing natural or environmental reasons why state-wide production of market and seed production of market and seed oysters from Virginia waters cannot be restored to pre-1959 levels or perhaps even higher - to the yields of earlier times.

We have examined the factors responsible for the present condition of the industry very carefully. This examination has brought to light a number of remedial activities which can be undertaken quickly, provided negative sociological and political factors can be overcome. Knowledge and technological and management capabilities now at hand are sufficient to halt and reverse the decline of productivity from Virginia's over-harvested and under-managed public bottoms (Baylor Grounds)!

Private managers can also be encouraged by appropriate State actions to increase production on existing and newly-available leased bottoms using their own financial resources. Evidence is convincing that levels of 900 thousand to 1 million bushels of market oysters from public bottoms and 1.5 to 2 million bushels from private leases are possible within 5-10 years after the critical management steps recommended in Section IV, pp. 64 to 83 above are initiated.[69]

Also we have recommended certain scientific research and engineering development activities as well (Section IV, pp. 88 to 103). If these R&D activities are continued and reinforced, where already underway, or undertaken anew by the Commonwealth and by private elements, the long-term future of the industry undoubtedly will be enhanced.

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[69] As indicated several times earlier, this assumes resumption of normal rainfall patterns in the upper reaches of the major tributaries of the Chesapeake Bay and a return of normal salinity patterns to Bay waters. There is no sound reason not to make such an assumption at this point.

Should continued atmospheric pollution, or other factors, cause a major change in regional rainfall patterns, and salinity distribution in the Bay becomes altered as a result, a major re-evaluation of oyster production and the fishery will be necessary.

Briefly, the Virginia oyster industry is at a crossroad. Its continuance as a viable economic entity of the Commonwealth is imperilled! Remedial measures more drastic and extensive than ever before attempted are necessary to halt and reverse its decline. Half-way measures will not do! Public production must be revived at the same time that private growers are encouraged and enabled to resume production. Seed and market oyster production must be increased, processors encouraged and the competitive market position of Chesapeake-grown oysters enhanced, since all of these elements are dependent upon one another.

If the essential management recommendations made above are not adopted effectively, production of oysters, seed and market, from Virginia waters will continue to decline until it reaches some lower, less economic, sustainable level. Harvesting and dependent elements of the oyster industry of Virginia will be diminished further and the general public of Virginia will have been poorly served as its oyster resources decline and the natural productive potential of its public oyster grounds continues unrealized or diminishes further. Such an occurrence will be lamentable, especially since it need not happen!

Oysters, like other fishery resources, are renewable and, like the others, with proper management can produce economically and socially useful crops year-after-year ad infinitum with a minimum of effort in those places which are environmentally suitable. Should the management, scientific and engineering activities we recommend be pursued effectively we are confident that Virginia's portion of the Chesapeake and its tributaries can resume its place among the premier oyster-producing regions of the world. The results will be well worth the efforts required!

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