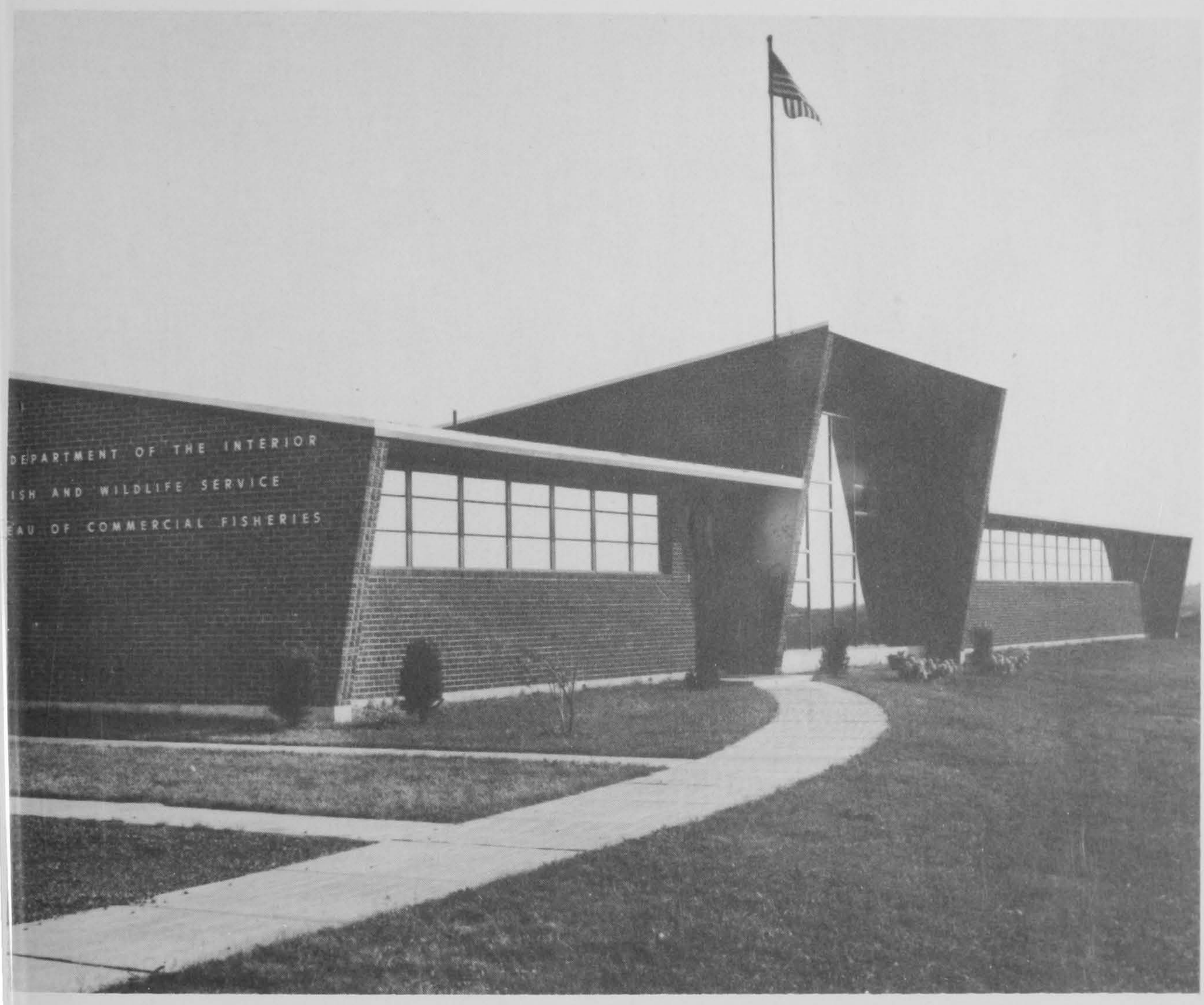
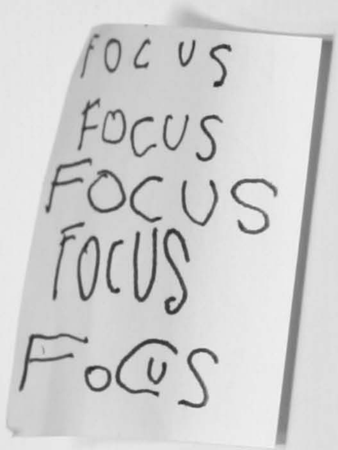
# THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY OXFORD, MARYLAND:

# PROGRAMS AND PERSPECTIVES





**UNITED STATES DEPARTMENT OF THE INTERIOR**
**FISH AND WILDLIFE SERVICE**
**BUREAU OF COMMERCIAL FISHERIES**
**Circular 200**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Circular 200

Washington, D.C.
October 1964

Cover Photo: The Bureau of Commercial Fisheries Biological Laboratory at Oxford, Maryland. The main building was completed in 1960, and supporting facilities in 1964, at a total cost of $350, 000.

# CONTENT

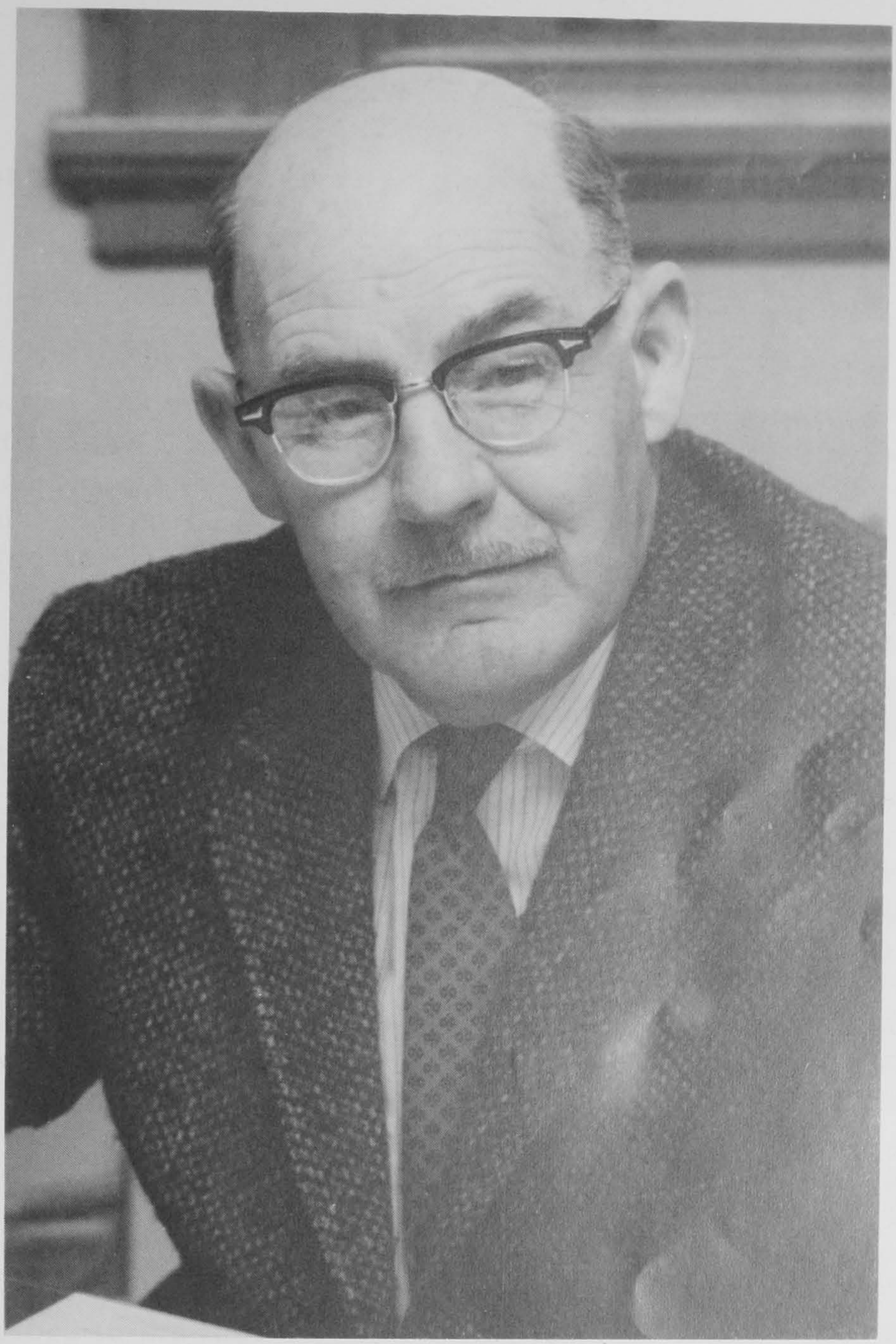
# FOREWORD

Shellfish research in the Middle Atlantic States was materially advanced in 1960 when the Bureau of Commercial Fisheries Biological Laboratory at Oxford, Md. was established on the eastern shore of Chesapeake Bay. Committed to increased understanding of shellfish biology, and with particular interest in factors influencing survival, growth, and reproduction of shellfish, the laboratory joined an impressive group of state and university research units involved with comparable problems. Federal shellfish investigations in this section of the Atlantic coast extended backward in time to the early part of the century and show promise of future expansion.

The series of papers contained in this volume has been prepared by biologists concerned with the laboratory's activities. Several articles represent summarizations of the past, present, and future of research programs of the Bureau in this region. Also included are several papers that illustrate the nature and scope of such programs, and some of their more significant accomplishments.

This volume is dedicated to James B. Engle, Senior Shellfish Scientist, former Director of the Bureau's Biological Laboratories at Annapolis and Oxford, and present Chief of the Bureau's Shellfish Advisory Service. He has been instrumental in developing the present laboratory and in shaping the course of shellfish research in Chesapeake Bay.

Carl J. Sindermann
Laboratory Director



James B. Engle

First Laboratory Director of the Bureau of Commercial Fisheries Biological Laboratory, Oxford, Md.

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# A Brief History

# of Federal Shellfish Investigations in Chesapeake Bay

James B. Engle

Chesapeake Bay with its tributaries has one of the richest estuarine environments in the United States, providing abundant and diverse marine products, and being outstanding as a center of commercial and recreational fishing. Among its utilized natural resources are shellfish, with the oyster having the greatest dollar value. Molluscan shellfish have inhabited Chesapeake Bay for many centuries; perhaps while the land surrounding the bay was still a submerged portion of the ancient coastal shelf. Numerous outcroppings of oyster, clam, and scallop shells appear in the steep cliffs exposed when the sea receded, and give evidence of former dense populations before the advent of man.

When the first colonists arrived on these shores in the 17th century they found shells which indicated shellfish had long been abundant and used by man. Shellfish were smoked and dried for barter with the inland Indians. This may have been the start of a more intense shellfish interstate trade. A great industry had its start in the 1830's in Maryland when Baltimore oyster dealers began packing and shipping oysters. In the ensuing years Baltimore became the oyster capitol of the nation, and retained this position for the rest of the century. The harvest steadily declined, however, from the 1900's until today. The problems brought about by this decline are many and reach beyond purely biological matters into the realm of the economic and social conditions that surround the national as well as the local industry. The per capita consumption of oysters in the United States dropped from 3.09 pounds in 1880, to 0.24 pounds in 1963. Some of this may be ascribed to the increase in population and the decline in oyster production. But this is not the whole story, because the average price of beef and oysters per pound is about the same today. Consumer choice has been affected. All the facilities of science, industry, and advertising need to be employed and coordinated to make this fine natural food resource a product of more general use on the tables of our nation.

James B. Engle has been a member of the Bureau since 1935, and presently is Chief of the Bureau's Shellfish Advisory Service. His research interests and publications are in the field of shellfish culture and ecology.

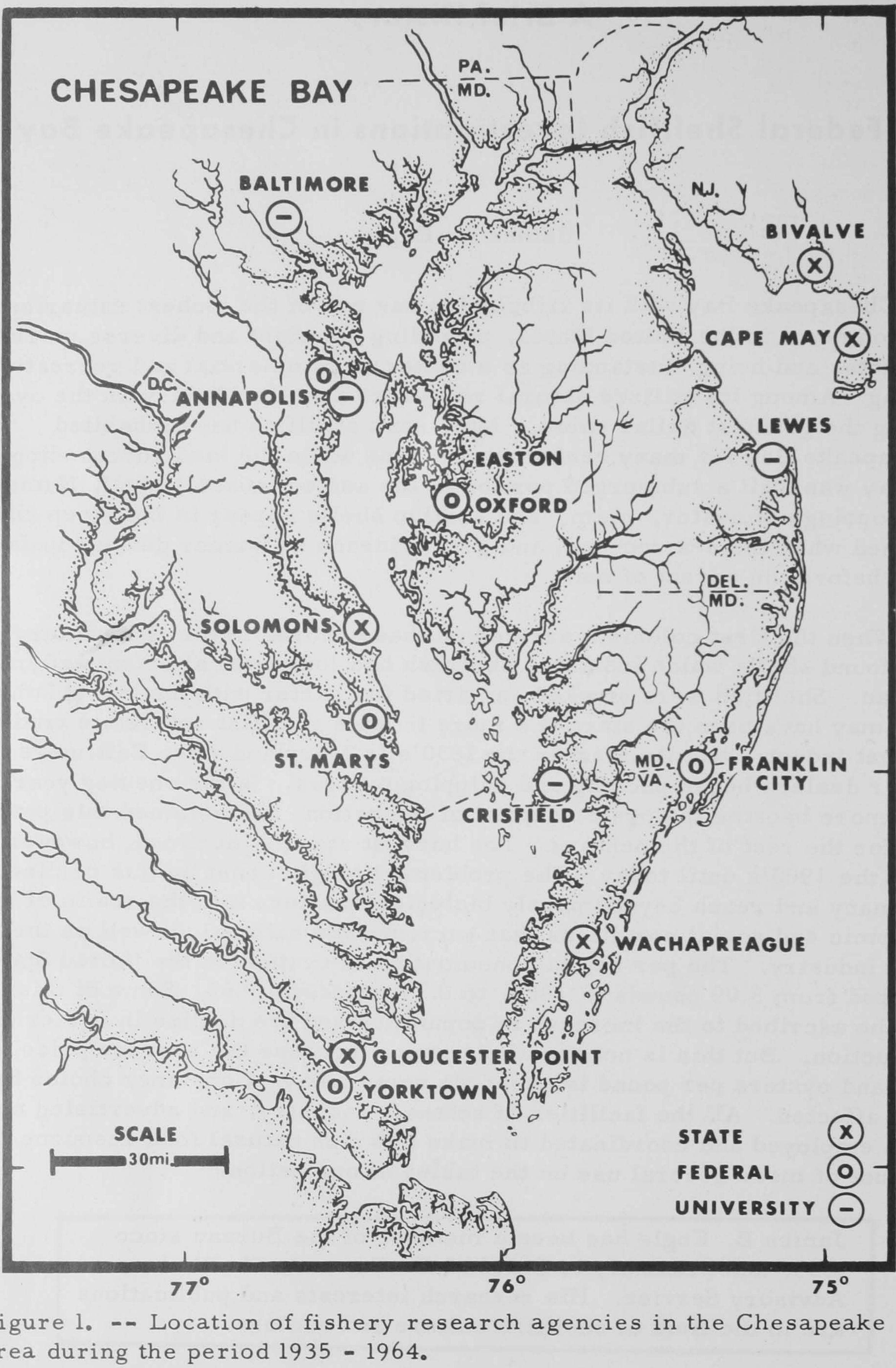


Figure 1. -- Location of fishery research agencies in the Chesapeake Bay area during the period 1935 - 1964.

Chesapeake Bay and the middle Atlantic area also have the distinction of supporting many research institutions. The States of Maryland, Virginia, New Jersey, and Delaware have marine laboratories searching out the secrets of life and productivity in the waters within their jurisdiction. State and private universities in the area apply their knowledgable efforts to similar tasks. The Federal Government, at the requests of the States and industry, has been part of this group of specialists searching out the mysteries of marine life and related environmental regimes (fig. 1). Chesapeake Bay is certainly a body of water attractive to the scientific community as a place to delve into the biological problems that affect aquatic populations.

Occupying many pages in the old, but valuable, publications of predecessor agencies of the Bureau of Commercial Fisheries and the States of Maryland and Virginia are the observations by many distinguished biologists which provide excellent background for present research. Brooks, Grave, Ryder, and Stevenson are among the scientists who have observed the shellfish life in Chesapeake Bay. W. K. Brooks in 1891 and C. H. Stevenson a short time later discussed the problems of management and harvesting, and pointed out the need for a change in methods and responsibility. They advocated a change from public to private culture as they forecast the future decline in production of oysters under the public system that was current then and now (fig. 2). Stevenson, reviewing the history of oystering since 1820 and reporting in 1894 on the oyster industry of Maryland made the following statement:

> "Maryland, however, has persistently refused to encourage an extensive development of private oyster fisheries, devoting instead all of its energies toward protecting the free fishery on the public domain."

Problems of exploitation, pollution, and management have arisen, however, since the latter part of the 19th century. The impact of modern man on this resource has produced conditions that have required thoughtful consideration and inspection by responsible authorities.

Federal efforts in shellfish research in Chesapeake Bay in the past have been somewhat sporadic and usually brought about by pressure from emergency situations. The blue crab distribution problem was studied by Pearson in the early 1940's and Churchill 35 years earlier; the location and population density of oysters in the Potomac River were determined

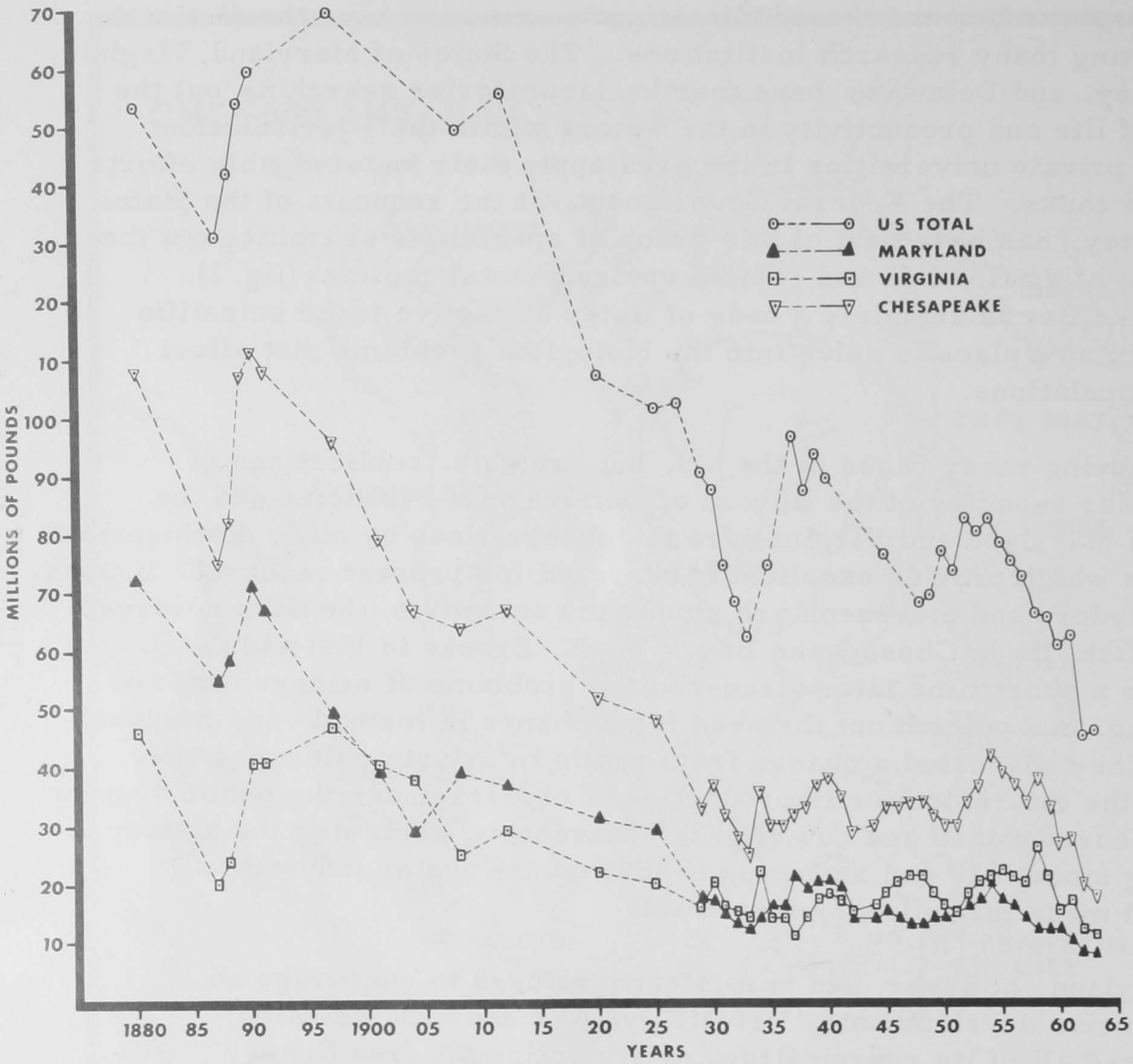


Figure 2. -- The total annual production of oysters for the eastern United States, for Chesapeake Bay, and for each of the two Chesapeake Bay States, Maryland and Virginia, during the period 1880-1963.

and charted by Frey, also in the early 1940's; pulp mill effluents and their relation to the oyster population decline in the York River were investigated in the late 1930's by Galtsoff, Chipman, Engle, and Calderwood with headquarters at Yorktown, Va.; oyster drill biology and predatory activity in Chincoteague and Chesapeake Bays, and oyster mortalities in Mobjack Bay were examined by Prytherch in the early and mid 1930's.

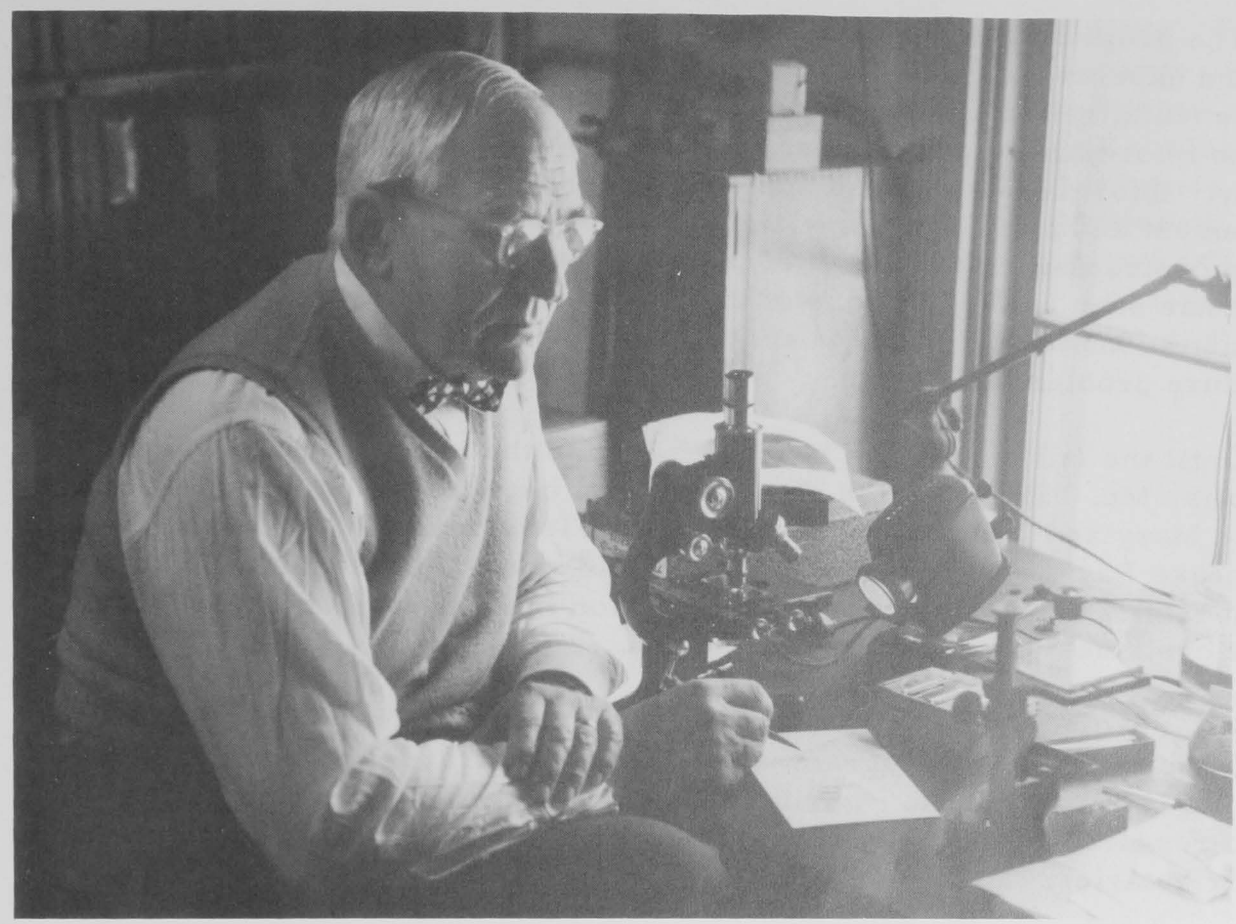

Figure 3. --Paul S. Galtsoff, Senior Research Biologist

The present Federal program began during the winter of 1943-44 when Paul S. Galtsoff (fig. 3) then in charge of Shellfish Investigations, U. S. Department of the Interior, Fish and Wildlife Service, prepared a plan of cooperative oyster research for Maryland waters. The plan of research was reviewed and approved by the Maryland Department of Research and Education (R. V. Truitt, Director) and the Maryland Board of Natural Resources (E. Warfield, Jr., Chairman).

The principal object of these studies was the development of a program of shellfish management adaptable to existing conditions, but incorporating the knowledge and principles of successful oyster culture developed here and elsewhere. In May 1944 James B. Engle and David G. Frey, Fishery Research Biologists of the Fish and Wildlife Service were assigned the task of carrying out this program. Within the year Frey was inducted into the Navy, and Engle supervised the field program in Chesapeake Bay.

The program for the next 15 years was devoted to ecological observations and experiments with the oyster. Reproduction, larval distribution, environmental relations, predator effects, growth and fattening rates, age and size information, and natural recruitment were among the specific items of study. Information on these subjects was made available to the fishery management authorities of Maryland and industry by publication, conference, and demonstration. Acquisition of facts on culture methods to increase production has been and still is one of the purposes of the program. With the accumulated knowledge of the years refined to present needs, the answer to the culture problem will come.

Until the fall of 1960 the headquarters for the investigations was in Annapolis, Md. This location was convenient because of the desirable liaison with the Maryland Department of Tidewater Fisheries (now the Department of Chesapeake Bay Affairs) in Annapolis. Field work often was conducted from patrol boats of this Department. Cooperation maintained in our research studies continues to be mutually beneficial.

After World War II a boat was acquired from the Navy and outfitted for the work of the Federal program. This boat (illustrated on page 11), a converted St. Augustine, Fla., shrimp trawler, is still in operation as the Bureau research vessel "Alosa" in Chesapeake Bay. Smaller boats are used in the tributaries.

In 1955, a substation on Chincoteague Bay was established to concentrate on studies of oyster predation by the drills, Urosalpinx cinerea and Eupleura caudata, long a scourge here and in many other oyster areas. The substation on the old railroad pier at Franklin City, Va., has served more recently as the seaside location for biological research on the surf clam (Spisula solidissima) and field studies in the oyster mortality program.

Realizing that problems in the biology and economy of shellfish production were increasing and recognizing the important place that Chesapeake Bay plays in the production of these resources, the Bureau of Commercial Fisheries proposed a more permanent establishment for shellfish research in the bay. In 1960, a new biological laboratory at Oxford, Md., was built on land given to the United States by A. J. Grimes (now deceased) of Easton, Md. The laborator[y] was opened September 1960 with J. B. Engle as the first director. It provided part of a research complex designed to study all phases of shellfish biology, with a main laboratory, auxiliary, and service buildings, and artificially constructed salt-water ponds for research and demonstrations of shellfish culture techniques. Total cost of the facility was $350,000.

The program now being directed by Carl J. Sindermann is one embracing the significant fundamental scientific and applied research on the shellfish of the area. It fits into a place coordinated in the Bureau's program of national responsibility for conservation of our marine resources. The laboratory is becoming a center of fishery knowledge and influence to restore the shellfish resources of Chesapeake Bay to their potentially important place in the nation's food supply. The present laboratory is the most recent phase of a Federal shellfish research program in Chesapeake Bay that had its inception over a quarter of a century ago, and that has contributed significantly to knowledge of shellfish biology.

# The Bureau of Commercial Fisheries

# Biological Laboratory at Oxford

# Present and Future

Carl J. Sindermann

Biological research in the marine waters off the Middle Atlantic States is being conducted by an expanding group of Federal, State, and University laboratories. The U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, is represented in this area by its Oxford, Md., laboratory (cover photograph) on the eastern shore of Chesapeake Bay. The laboratory, first occupied in 1960, is primarily oriented toward shellfish biological studies, with particular emphasis on oysters (Crassostrea virginica). Other shellfish of commercial significance in Chesapeake Bay include the soft-shell clam (Mya arenaria), the hard-shell clam (Mercenaria mercenaria), and the blue crab (Callinectes sapidus). The bay is also an excellent breeding, nursery, and feeding ground for many sport and commercial fishes.

The laboratory maintains a substation on seaside Chincoteague Bay, as well as sampling facilities on the New Jersey coast. Thus a wide range of environmental conditions is available for experimental and field studies.

The laboratory is located in the historic Eastern Shore town of Oxford, an area prominent in shipping activities since earliest colonial times. Pleasure boating today serves as the basis for a number of industries in this and neighboring communities. Ten miles away is the city of Easton, the county seat of Talbot County. This charming progressive city of 8,000 has scheduled airline and interstate bus connections with Baltimore and Washington, and excellent divided highways leading to these cities, as well as to coastal points north and south.

Carl J. Sindermann has been a member of the Bureau since 1956, and Laboratory Director at Oxford since November 1963. His research interests and publications are in the area of marine populations and diseases of marine organisms.

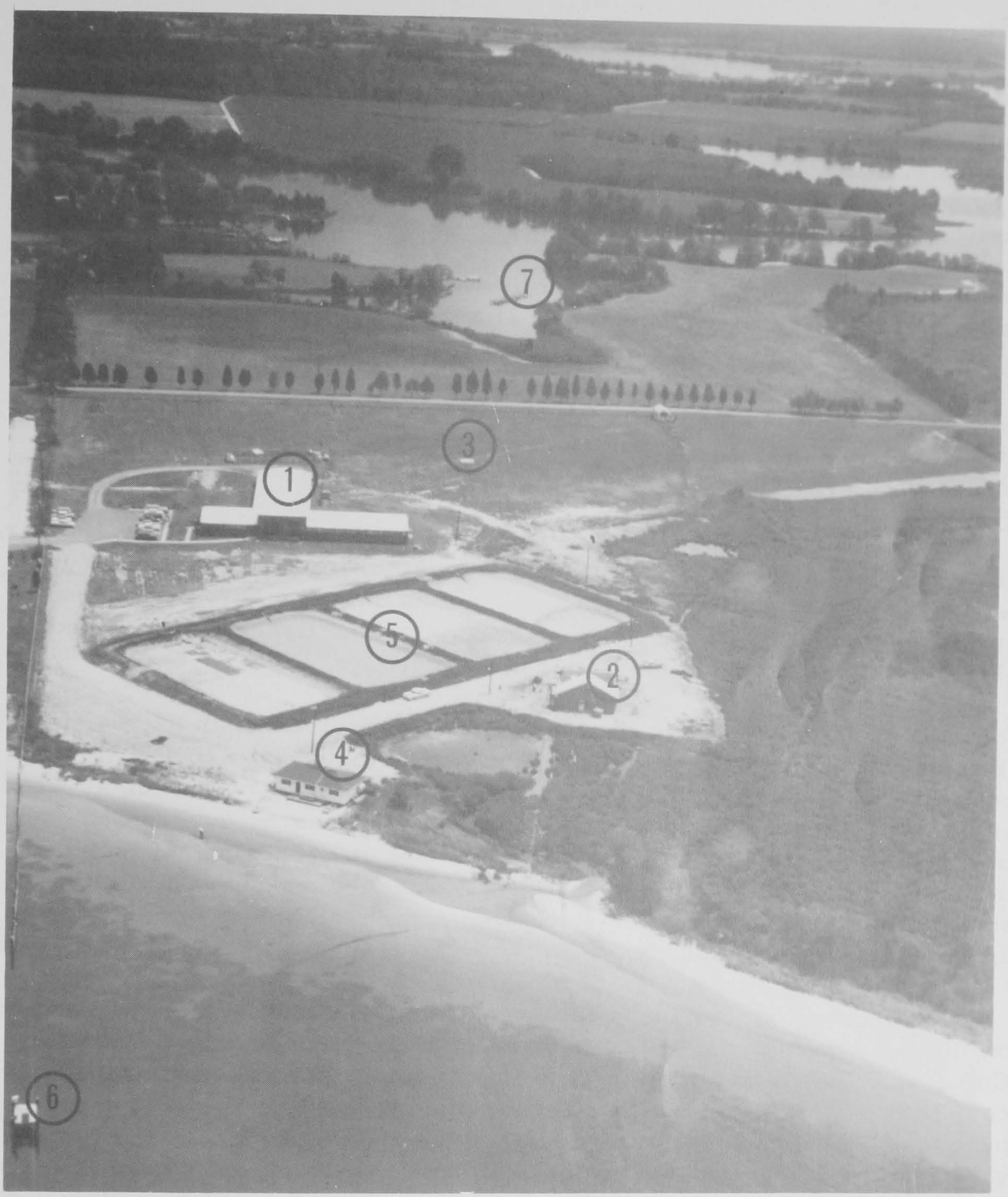


Figure 1. -- Aerial photograph of the laboratory (1) and its supporting facilities, which include shop-storage building (2), animal house (3), summer laboratory for visiting scientists (4), artificial ponds (5), salt-water intake and instrument platform (6), and oyster culture suspension rack system (7).

The physical facilities of the laboratory include 13,000 square feet of laboratory space for chemical, histological, microbiological, and physiological research. Running sea water, with a flexible series of indoor and outdoor experimental tanks, is available in the laboratory and its substation in Virginia. Other facilities include a separate shop-storage building, an animal house, and a small laboratory building for visiting investigators (fig. 1). Four quarter-acre experimental ponds for oyster culture are supplied by pumps with a capacity of 700 gallons per minute. These pumps also service a series of outdoor experimental tanks. The laboratory property has 11 acres, with a sand beach fronting on the Tred Avon River.

The laboratory has several small boats for inshore studies and the 50-foot "Alosa" (fig. 2) used in Chesapeake Bay. The laboratory also charters larger vessels in its offshore study of surf clam biology.

Apparatus and equipment of the laboratory include constant temperature rooms, photographic dark room, refrigerated centrifuges, low temperature deep freeze, lyophilizer, autotechnicons, cryostat, and spectrophotometer. Separate media preparation, tissue culture, and phytoplankton culture rooms are maintained.

An excellent working library, with the services of an experienced librarian, subscribes to and maintains back files of over 100 serials and periodicals, and has an extensive and growing reprint collection as well as the appropriate text books and monographs. Nearby government libraries in Washington can supply photostats of literature not included in the laboratory's holdings. Emphasis is placed on journals related to shellfish biology, parasitology, pathology, microbiology, ecology, biochemistry, and taxonomy.

At present, biological research at the Oxford laboratory is carried on in four programs: Shellfish Mortality, Surf Clam Biology, Shellfish Culture, and Shellfish Ecology and Physiology. The research staff is composed of 12 professional scientists and an equal number of supporting personnel. A limited amount of space is available for visiting investigators. The Laboratory Director is Carl J. Sindermann, whose research contributions have been in the areas of diseases and population studies of marine animals. Arthur S. Merrill, whose research interests and publications are in shellfish ecology and taxonomy, is Assistant Laboratory Director.


Figure 2. -- The "Alosa" -- a 50-foot converted shrimp boat used in Chesapeake Bay studies by the Bureau of Commercial Fisheries.

In addition to the research staff, representatives of two other Bureau of Commercial Fisheries units are based at the Oxford laboratory. The Bureau's newly created National Shellfish Advisory Service is headed by James B. Engle. The unit provides a bridge between Bureau research laboratories and the shellfish industry and is designed to translate research results into usable form for the industry. Jim Engle became leader of this unit after many years as Laboratory Director and Shellfish Research Scientist at Annapolis and Oxford. The Shellfish Advisory Service should also provide the nucleus for a future shellfish extension service similar to that carried on by the Department of Agriculture.

Another Bureau of Commercial Fisheries unit represented at the laboratory is Fishery Statistical Services, whose Fishery Reporting Specialist is responsible for collection and compilation of fish and shellfish landings in this section of the Central Atlantic States.

## SHELLFISH DISEASES AND MORTALITIES

Mass mortalities of oysters in Delaware Bay and lower Chesapeake Bay reached epidemic proportions in the late 1950's, almost wiping out the oyster industry in Delaware Bay and severely damaging the industry in Virginia. There is epidemiological evidence to indicate that an organism called MSX (multinucleate sphere of unknown taxonomic position) may be the pathogen responsible. This organism has certain life cycle stages suggesting affinities with the protozoan order Haplosporidia.

Prior to 1959, research programs of the laboratory were directed primarily toward studies of the ecology and management of oyster resources in the Chesapeake and Chincoteague Bay regions. As the problem of mortalities caused by disease became more severe, the research emphasis changed toward an expanded study of diseases as they affect shellfish in the waters of the Middle Atlantic States. Now the Shellfish Mortality Program, encompassing disease and predator studies, is the largest single program at Oxford.

Field and laboratory studies are designed to determine the patterns of disease-caused mortalities as they occur in Chincoteague Bay and Chesapeake Bay, as well as to compare the disease resistance of indigenous and imported stocks of oysters.

Past surveys of disease in Chesapeake Bay have pointed to Pocomoke Sound as the northernmost area of the bay where MSX occurs with some degree of regularity. Consequently, an intensive monitoring of the area is being carried on to determine, throughout the year, the levels of mortality, incidence of disease, and the spread of disease up the bay, as well as to provide experimental material for laboratory study. Laboratory studies are aimed toward discovering new or unidentified pathogens and developing staining and other diagnostic methods to detect or identify pathogens.

Of all the microorganisms implicated in shellfish mortalities only one, Dermocystidium marinum, has definitely been shown to kill oysters. The main block to experimental proof of an organism's pathogenicity is the lack of ability, thus far, to culture suspected disease organisms and to be able to infect oysters with culture material. For these reasons, tissue culture studies are being conducted to establish cell lines on which to grow fastidious organisms such as viruses, to carry out life cycle studies, and to determine the effects of pathogens in living cells. In addition, parasite culture studies are also being attempted, to relate serological, chemical, and infection studies.

The development of oyster stocks resistant to disease may prove essential to the rehabilitation of the industry in depleted areas. A project emphasizing serological, cytogenetic, and chemical techniques is being conducted to distinguish differences among stocks or populations of oysters resistant or susceptible to disease, and to learn more of the genetics and mechanisms of disease resistance. The methods employed in this study may also be used to diagnose the presence of pathogens in shellfish.

Other environmental factors that cause oyster mortalities are being examined. Limited studies of oyster drills, particularly oriented toward chemical and biological control measures, are being made at the Chincoteague Bay substation.

In addition to disease research carried on by the laboratory staff, a number of educational institutions have been given research contracts. Notable among these is a contract with Rutgers University, initiated in 1958, to study aspects of extensive oyster mortalities in Delaware Bay.

## SURF CLAM BIOLOGY

Surf clams (Spisula solidissima) are taken by dredging in waters from 20 to 120 feet deep. The center of the fishery is now off the central New Jersey coast, although the range of the species extends from Labrador to the Gulf of Mexico. The commercial fishery has grown remarkably since the early 1940's, but members of the industry are properly concerned about depletion. The Bureau's initial responsibility lies in defining the amount and location of the resource, and in determining the reproductive rates, growth rates, and death rates, so the industry will know the numbers of clams that can be taken without overfishing.

Investigation of surf clams became part of this laboratory's research effort in 1963. The biological program now under way is concerned with the clam populations between New York and Virginia. Two major projects are (1) life history and growth, and (2) population dynamics and distribution. Surf clam distribution and abundance are studied in cooperation with the Branch of Exploratory Fishing with attention to the entire size range of clams. Collections of clams are made periodically.

Analysis of data collected during a Bureau-Industry cooperative survey in the summer of 1963 indicated strongly that appreciable annual recruitment of surf clams is not assured. Our studies indicated that several successive years may pass with little clam recruitment.

Other projects within the program are concerned with (1) the clam reproductive cycle over several successive years, within the study range, but with samplings to the north and south; (2) the age of sexual maturity and the frequency of spawning; (3) the full size range of clams actually present on the grounds and their abundance; and (4) the relation of clam size to age. This knowledge is essential to estimate natural and fishing mortality, and to provide answers for such problems as the time required for replenishment of fished grounds.

An experimental jet dredge has been designed for abundance studies. The dredge can be adjusted to catch clams from those 1 or 2 years old on up to the largest and oldest. It also can be changed at sea to duplicate the size selectivity of commercial gear and to be fully comparable to the catching efficiency of commercial efforts. This dredge is a major tool in studies of surf clam populations.

## SHELLFISH CULTURE

In culturing shellfish, this country has tended to lag behind certain other countries, notably Holland, France, and Japan. Shellfish farming is a logical progression from the "hunting" methods of shellfish harvest still practiced today in many coastal areas. The problems of pollution and ever increasing pressures of human population on coastal habitats have made the development and use of aquatic farming methods even more critical.

The aim of this phase of the laboratory's research program is to develop techniques of shellfish culture in natural and artificial ponds and in adjacent natural waters, so that important commercial species can be better utilized. One project under this program is the measuring of potential oyster setting in local areas. Asbestos flexboard is used as a collector to measure weekly fluctuations in oyster setting. As spat collectors these boards save considerable labor over earlier methods using oyster shells and enable us to study a wide area of Chesapeake Bay. With methods developed at the Bureau of Commercial Fisheries Laboratory, Milford, Conn., we are testing the use of chemicals (particularly Polystream and Drillex) to increase oyster setting and to control predation. Tests have shown that, in most instances, treating shells with either Drillex or Polystream increases oyster setting. Tests in Chincoteague Bay have also shown that setting and survival are greater in areas where Drillex-treated sand is used.

Four quarter-acre artificial ponds have recently been completed for use in shellfish culture research. Initially these ponds will be used to test survival and growth of various strains of oysters. Seed oysters from several different Maryland localities will be suspended from fiberglas rafts moored in the ponds. The growth and survival of this seed will be measured and compared. Future plans are to use the ponds for seed production and fattening experiments.

A commercial-scale experiment in off bottom culture of oysters in a local natural salt pond is also in progress. Seed oysters have been suspended from a platform in a pond adjacent to the laboratory. We expect that the seed will be large enough to market in 2 years. Growth rates, mortalities, and costs will be evaluated to determine if such methods are commercially feasible.

The program also studies the growth, condition, and survival of oysters in Chincoteague Bay and in upper Chesapeake Bay. Particular attention is given to the seasonal fluctuation in the condition of oysters imported into Chincoteague Bay as compared to native stocks.

## SHELLFISH ENVIRONMENT AND PHYSIOLOGY

The object of this phase of the laboratory's research is to provide ecological information for oysters and soft-shell clams. Such information involves collecting data on physiological responses of commercial shellfish to the environment in low-salinity water of the Tred Avon River and high-salinity water of Chincoteague Bay, and data on the physical, chemical, and biological milieu of waters adjacent to the laboratory. These studies are specifically oriented toward future manipulation and management of commercial shellfish stocks in natural and artificial situations. The program is divided into two major projects: (1) physical and chemical factors in upper Chesapeake Bay and (2) ecology and distribution of oysters and clams.

Recent studies have emphasized observations on the physical and chemical characteristics of the Tred Avon River and Broad Creek, in an attempt to relate such findings with the great differences in oyster setting and growth in these areas. Records of temperature, salinity, and oxygen levels have been obtained for several years in both areas. Chlorophyll "a", an indicator of phytoplankton abundance, and dissolved phosphate, an important nutrient, have been measured throughout 1963. Weekly observations on abundance of oyster and clam larvae have been made during May to September for several years, and help to predict time and intensity of set. Current studies and qualitative faunal studies were recently begun in the Tred Avon River.

Future environmental studies will emphasize qualitative and quantitative studies of the phytoplankton and zooplankton in the Tred Avon and Broad Creek regions. Weekly samples, surface and bottom, will be taken at two stations (one downstream and one upstream) in each area, and organisms identified and counted. The physical-chemical studies of local waters will be expanded to obtain information on tidal volumes and water exchange rates, and sediment profiles of bottom substrate will be obtained. Parallel physical, chemical, and biological studies will also be carried on in the new artificial salt pond facility. These ponds will provide a unique opportunity to observe the establishment of animal populations, the stages and sequence of community formation, and the factors regulating the abundance and distribution of local fauna. To this end, long-range ecological studies are planned for one pond, held as a control, providing a basis for environmental manipulation and evaluation of experimental factors in other ponds. Laboratory studies on the physiological responses of larval, juvenile, and adult oysters and clams are planned for winter, when field activity is curtailed.

## SUMMARIZATION

The present research programs of the laboratory include long-range studies of diseases, ecology, culture, and populations of shellfish. Each research area can serve as a nucleus for broader investigations in the future.

Commitment to fundamental studies of shellfish biology is extremely critical, since most questions -- even those of purely practical nature -- usually require basic knowledge to provide adequate answers. With the existing commitment to studies of disease in the marine environment, a staff of specialists is being assembled that will be able to investigate mass mortalities of marine species on a comprehensive scale. Recently completed facilities for research on oyster culture methods make possible tests on a commercial scale of shellfish farming techniques. Surf clam studies have extended our shellfish investigations far out on the continental shelf, where problems inherent in research on oceanic species must be confronted, and where stocks of shellfish species not now exploited are known to exist. But wherever our shellfish research effort is concentrated -- whether in an estuary or in the open ocean, there are problems, some of long standing, for which adequate answers must be found through continued study.

# Environmental Features of the Laboratory Site; the Tred Avon River

Robert W. Hanks

The Oxford laboratory is situated near the mouth of the picturesque Tred Avon River (fig. 1). In some ways the Tred Avon is much like Chesapeake Bay in miniature, being long and shallow with several major tributaries and many minor creeks and streams. From Easton Point the river winds 9 miles to the southwest, where a broad, mile-wide, mouth discharges into the Choptank River. The greatest depth of the Tred Avon at midchannel is about 40 feet, and bottom sediments are sand and clay mud in the upper to middle region, with increasing amounts of sand near the mouth. Oyster bars and soft-shell clam beds are distributed the length of the river, and a commercial shellfish harvest is obtained each year. Tidal amplitudes are small (the mean tidal range is about 1 1/2 feet) but are strongly influenced by the direction and force of the wind. Tidal currents are not strong, but affect the direction of flow throughout the entire Tred Avon.

Annual fluctuations in important environmental factors have considerable influence on the kind and abundance of animals living within the areas. Extremes of temperature, salinity, or dissolved oxygen levels can be lethal to some animals, or can limit reproduction in others. Only through long-term studies of such factors can we understand interrelations and evaluate the impact on commercial shellfish. Continuous observations have been made for several years on some factors. Figure 2 summarizes the seasonal changes in temperature, salinity, dissolved oxygen, and concentration of chlorophyll "a" for 1963.

## TEMPERATURE

Water temperatures fluctuate from 0°C. in the winter to about 30°C. in midsummer. The rates of the increase and decrease of temperature vary from year to year, but generally give a symmetrical annual temperature distribution. Generally, the temperature is uniform from top to bottom, but a

Robert W. Hanks has been a member of the Bureau since 1955, and presently is Program Leader of the Shellfish Ecology and Physiology Program. His research interests and publications are in the field of marine ecology.

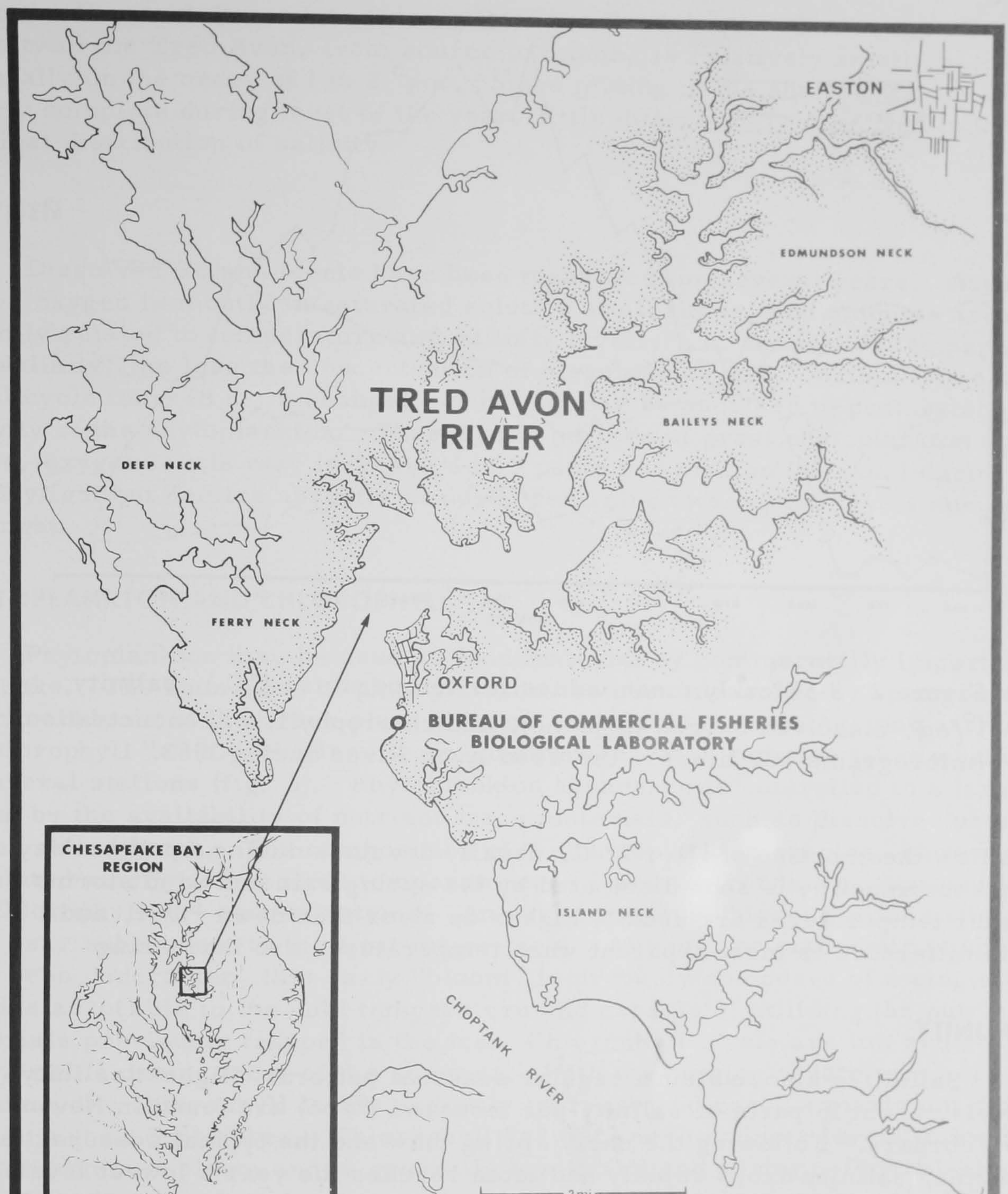


Figure 1. -- The Oxford laboratory site on the Tred Avon River, and (insert) its geographical relation to Chesapeake Bay.

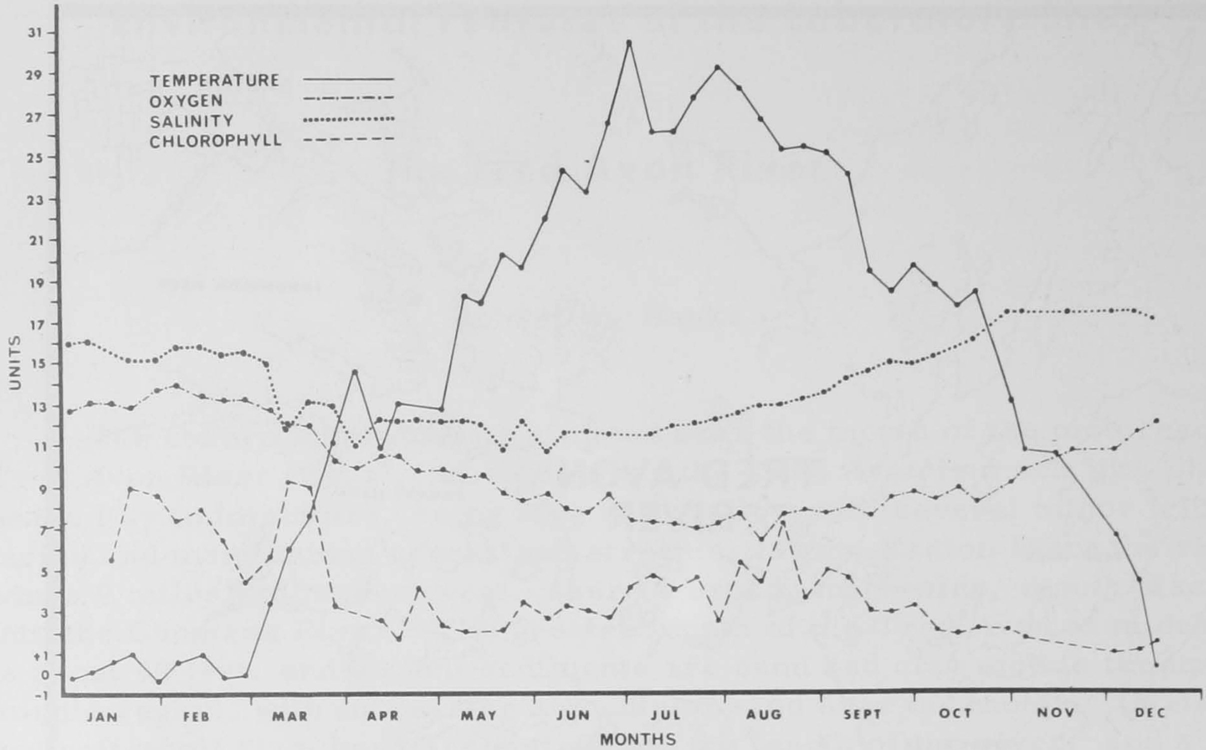


Figure 2. -- Weekly mean values for temperature (°C.), salinity (°/oo), dissolved oxygen (p. p. m.), and chlorophyll "a" concentrations (micrograms per liter) in the Tred Avon River during 1963.

shallow thermocline of 1° or 2° C. usually develops during April or May. This thermocline is soon dissipated by the spring rain and wind storms. Water temperatures are usually higher up river than down river, and this difference is most apparent when temperatures are increasing

## SALINITY

Salinities also exhibit a regular seasonal pattern. Highest salinity levels, about 16 parts of salinity per thousand (°/oo) are found in November to February. Following the early spring thaw and the typical seasonal rain storms, salinity drops rapidly and often reaches the year's lowest levels (8-9 °/oo) by March or April. Levels during the summer generally reflect the amount of rainfall and fluctuate between 10 and 13 °/oo. By midsummer, salinities begin to increase and continue to rise rapidly to the winter peak. Salinity is generally higher down river, except during March, April, or May when progressively lower salinities are found toward the river mouth. This salinity inversion possibly occurs when strong winds force fresh water from the Choptank River into the mouth of the Tred Avon. The range of salinity in the Tred Avon, from source to mouth, is relatively small, perhaps generally on the order of 1 to 2 $^{o}/oo$. Since mixing in the shallow waters is nearly complete during most of the year, little difference is observed in the vertical distribution of salinity.

## OXYGEN

Dissolved oxygen levels have been measured for several years. Apparently, oxygen is mostly in saturated solution at all times, and amounts are directly related to temperature and salinity levels, i.e. the higher temperature and salinity, the less the concentration of dissolved oxygen. Within this seasonal cycle marked daily changes occur and may be ascribed to photosynthetic activity of the phytoplankton. Thus during periods of great phytoplankton abundance, oxygen levels may increase 4 to 5 parts per million (p.p.m.) during the daylight but decline abruptly at dusk, returning to seasonal levels during the night.

## PHYTOPLANKTON AND CHLOROPHYLL "A"

Phytoplankton may be used as food material by commercially important mollusks. The abundance of phytoplankton has been measured by spectophotometric analysis of the green plant pigment, chlorophyll "a". Acetone extracts of chlorophyll "a" are obtained from quantitative water samples taken weekly at several stations (fig. 3). Phytoplankton abundance is controlled to a large extent by the availability of nutrient trace materials, such as dissolved phosphates and nitrates. The composition of the phytoplankton species, however, is related mostly to seasonal temperatures. Seasonal trends are apparent in the chlorophyll "a" concentrations. An early massive "bloom" is indicated each year subsequent to the first major thaw. Although no taxonomic studies have been undertaken, this early "bloom" is probably composed of a single species adaptable to the cold temperature and capable of utilizing the nutrient materials previously trapped in the ice. Chlorophyll levels are low and relatively stable during most of the summer. With the coming of late summer, however, the chlorophyll levels suddenly increase and reach a maximum during late August or September. Chlorophyll "a" declines to winter levels following the late summer bloom and is generally low in fall and winter. Phytoplankton distribution in the river is never uniform, and this patchiness complicates sampling procedures. The upper parts of the river usually have higher chlorophyll levels than the lower parts -- a possible indication that the source of plant nutrients stems from direct runoff from farm lands in the upper Tred Avon area.

Figure 3. -- Extensive water sampling procedures provide material for intensive laboratory analyses of physical, chemical, and biological processes.

## FAUNAL STUDIES

Studies of the invertebrate fauna are just beginning in this rich estuarine region. To understand the complex factors affecting the production of commercially important shellfish, we have undertaken to identify the kinds of animals in the area, their abundance, their life history and range in this region, and their relation to commercial species.

Two important aspects of the Tred Avon fauna have been studied for several years. One study dealt with the abundance and occurrence of bivalve larvae during the summer and fall with special emphasis on larvae of oysters and soft-shell clams. As a result, spawning periods for both species can be anticipated, and the success of spawning has been measured for the study years. In a second study special collectors ("Thorson bottles") to capture pelagic larvae of estuarin invertebrates have provided much information on the seasonal occurrence of the organisms, including their potential as competitors with newly metamorphosed oysters and clams.

The Tred Avon and surrounding waterways are particularly interesting areas for ecological studies for they present many diverse environmental types and provide a rich flora and fauna. Research in this area will provide basic biological knowledge about estuarine organisms and will support other studies on propagating and managing commercial shellfish.

# Natural and Artificial Pond Culture of Oysters

William N. Shaw

The production of the oyster industry on the U. S. east coast has declined continuously since the turn of the century. Chesapeake Bay production has dropped from over 115 million pounds of shucked meats in 1880 to an all-time low of slightly over 18 million pounds in 1963. The States of Virginia and Maryland are attempting to end this decline in oyster production. Each State is faced with certain specific problems that must be overcome before the industry can be restored.

In the Virginia part of Chesapeake Bay, oysters have had heavy mortalities that are believed to be caused by a disease known as MSX. Studies are now underway at the Virginia Institute of Marine Science to develop a strain of oysters resistant to this disease.

In Maryland many natural oyster bars are no longer productive. Hoping to revive many of these bars, the Maryland Department of Chesapeake Bay Affairs has expanded its program of seed production. Thousands of bushels of oyster shells are planted annually on the most productive seed producing bottoms in the State. After it sets, the seed is moved to depleted natural bars where it grows for 3 to 4 years before being harvested. Even though both Maryland and Virginia have greatly expanded their efforts to rehabilitate the oyster industry, the landings of the shellfish in the bay are still on the decline because of possible overfishing, pollution, disease, and predation.

Even before the turn of the century H. F. Moore of the U. S. Fish Commission foresaw many of the problems which now face the oyster industry. His suggestions on methods to increase oyster production, though at that time uneconomical, are slowly becoming more realistic. In the Report of the Commissioner for the year ending June 30, 1897, of the U. S. Commission of Fish and Fisheries, Part XXIII, Page 297, Moore stated, "There are indications, however, that in certain portions of our oyster belt it may be necessary to follow some method of pond culture, ...... Should the feasibility of this be demonstrated under conditions prevailing in the United States, a vast increase

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could be made to our oyster supply...." Moore further mentioned that, "By some modification of pond culture it may also be possible to raise seed oysters in regions in which few or none are now produced, thus adding another considerable item to the wealth-giving powers of our coasts."

Pond culture of oysters has been attempted with varying degrees of success. In Europe, such countries as Italy, France, and Norway have successfully cultured oysters in ponds. In the middle of the 19th century at Lago Fusaro, Italy, oysters were grown on pyramids of stones. Later, bundles of branches called facines were used to catch seed oysters. In France, oysters are placed in shallow ponds, "claires", to fatten. C. M. Yonge reported in 1960 that oysters may double their weight in 6 months and acquire a creamy consistency in these fattening ponds.

In Norway, ponds ("polls") are used for breeding, growth, or fattening. Norway has an unusual method of pond cultivation: oysters in wire cages are suspended in a middle layer of saline water because the surface layer is fresh water and the bottom layer is without oxygen and saturated with hydrogen sulfide. These oysters are able to spawn because a temperature of over 20° C. in this saline middle layer is maintained by the fresh surface layer.

In the United States the use of ponds for culturing oysters has been limited. In 1883, John A. Ryder excavated a small pond (50 square yards) in a salt marsh on the shore of Chincoteague Bay. The pond was connected with the bay by a trench or canal about 10 feet long, 2 feet wide, and 3 1/2 feet deep. Fertilized oyster eggs were poured into the pond, and 46 days later small oysters 1/4 to 3/4 inches long were observed to have set on shells. This was one of the first studies carried out in the United States to show the possibility of using ponds for seed production.

In 1944-49, C. Robert Lunz had some success in the pond culture of oysters at Wadmalaw Island, S. C. Unfortunately, a heavy oyster mortality thought to be caused by a fungus, Dermocystidium, developed in the pond in 1950 and the oyster studies ended. Other investigators have felt that the utilization of salt-water ponds for the culture of oysters was feasible but that there was a need for further extensive basic research.

In 1956, the Bureau of Commercial Fisheries at Woods Hole, Mass., began studying the commercial feasibility of oyster culture in natural ponds. These studies were made in Oyster Pond and Oyster Pond River, Chatham, Mass. Adopting methods similar to those used by the Japanese, Bureau scientists used wires to string shells with newly attached oysters and suspended

Figure 1. -- Taylors Pond, West Chatham, Mass. Site where comparative studies on the growth and survival of different strains of oysters were made.

them from a log raft so that they would be above the bottom. These oysters grew twice as fast and survival was six times greater than those placed on the bottom. The results of this small-scale operation indicated that raft culture appeared to be commercially feasible in these northern waters.

Further studies on the raft culture of oysters were carried out in Taylors Pond, West Chatham, Mass. (fig. 1). Seed oysters from Wareham River and Mill Creek, Mass., and Long Island Sound, Conn., were strung on nylon ropes suspended side by side from a fiberglas raft. The results of the experiments indicated that Wareham River oysters grow more slowly than oysters from Lon Island Sound and Mill Creek. This study showed the significance of selecting proper stocks for pond culture.

The results of these initial studies were so encouraging that an expanded program in oyster pond culture was started in 1960 at the Bureau's Biological Laboratory in Oxford to determine if oysters could be grown commercially in natural salt-water ponds in more southern waters. The early tests were so

Figure 2. --Wooden structure, 108 x 12 feet, capable of supporting 4,000 strings of seed oysters. This framework is located in Boone Creek, a natural salt-water pond adjacent to the laboratory in Oxford.

promising that more elaborate experiments have been started. In the spring of 1964 a rigid structure 108 x 12 feet capable of supporting 4,000 strings of seed oysters was placed in Boone Creek (fig. 2). To date 1,000 strings have been suspended, and we anticipate that about 300-500 bushels of oysters will be harvested from these strings in the fall of 1965. We also plan to suspend additional strings containing 1964 seed oysters.

To complement this program, studies will soon begin on the culture of oysters in the four 1/4-acre artificial salt ponds (fig. 3) recently constructed at the Oxford laboratory. In these ponds we will be able to control many environmental factors. We will first determine which type of bottom is most suitable to support oysters. Those bottoms to be tested include ones with oyster shells, sand, polyethlene film, and the natural clay bottom.

Figure 3. --View showing two of the four 1/4 acre artificial, salt ponds located in front of the laboratory in Oxford. The pond on the right is being prepared for ecological studies, while the pond on the left is being used to compare the growth rates of seven different strains of seed oysters.

Another pond will be used to study the growth and survival of seven different stocks of oysters collected from seed producing areas in Maryland. The purpose of this experiment is to compare the growth potential of the various strains under identical conditions. Faster growing stocks can be used in future selective breeding experiments.

One of the ponds will be used for seed production. Oyster larvae will be raised in the laboratory and released in the pond just prior to their setting time. Clean oyster shells will be evenly distributed on the bottom and suspended from rafts just prior to releasing the larvae, and after setting is completed the shells will be removed to growing areas. The procedure will then be repeated as often as possible during the summer or until the water temperature in the pond drops below that required for the larvae to undergo metamorphosis.

As stated by C. M. Yonge in his book entitled Oysters (1960, Collins, London, p. 194), "...the probability of a future for the oyster industry (will be) based largely on the results of intensive research at laboratories.." By controlling such environmental factors as temperature, salinity, amount and kinds of food organisms, predators, diseases, and pollution, oysters could be raised as successfully as many of the products now grown on land. The use of both artificial and natural salt ponds will make many of these controls possible.

# Studies of Oyster Microparasites

Aaron Rosenfield

Mass mortalities among shellfish populations have long been known to occur; recently, in 1957 and again in 1959 disease killed oysters in Delaware and Chesapeake Bays, and the mortalities continue. Important research aims of the Bureau's laboratory in Oxford are to determine what kills oysters and to devise and use methods to eradicate or control the causes of death. The primary program of research uses many disciplines of science, and organization of the laboratory work is not unlike that in most research hospitals or research foundation laboratories.

Populations or stocks of shellfish from local areas where shellfish diseases are present at low levels or at epidemic levels (primarily Chesapeake and Chincoteague Bays) are monitored at appropriate intervals, and samples brought into the laboratory. Shellfish from other cooperating laboratories and even foreign countries are accepted frequently for examination. "Biopsy" sections are taken and immediately examined both grossly and microscopically to ascertain pathologic conditions, if any, within the tissues. Data, such as the condition, presence, and incidence of microparasites (plant and animal), type of infection, timing of epidemic periods, and other epidemiological information are recorded and analyzed. Permanent sections of the specimens are also routinely made for our slide files, for staining experiments, for detailed life cycle and morphological studies, and for exchange with other researchers. Diseased or infected shellfish are turned over to specialists within the laboratory or to other authorities for parasite identification and culture, and for other experimental purposes.

A myriad of organisms are often encountered in oyster tissue. Several figures follow that illustrate a few of these micro-organisms, some of which are known to cause mortalities in oysters, others of which are strongly suspect and still others which do not cause apparent damage to oyster tissues. Some of the pictures are those taken from a demonstration exhibited at the 16th International Zoological Congress, Washington, D. C., in 1963.

Aaron Rosenfield has been a member of the Bureau since 1961, and is presently Program Leader of the Shellfish Mortality Program. His research interests and publications are primarily in the field of marine parasitology and microbiology.

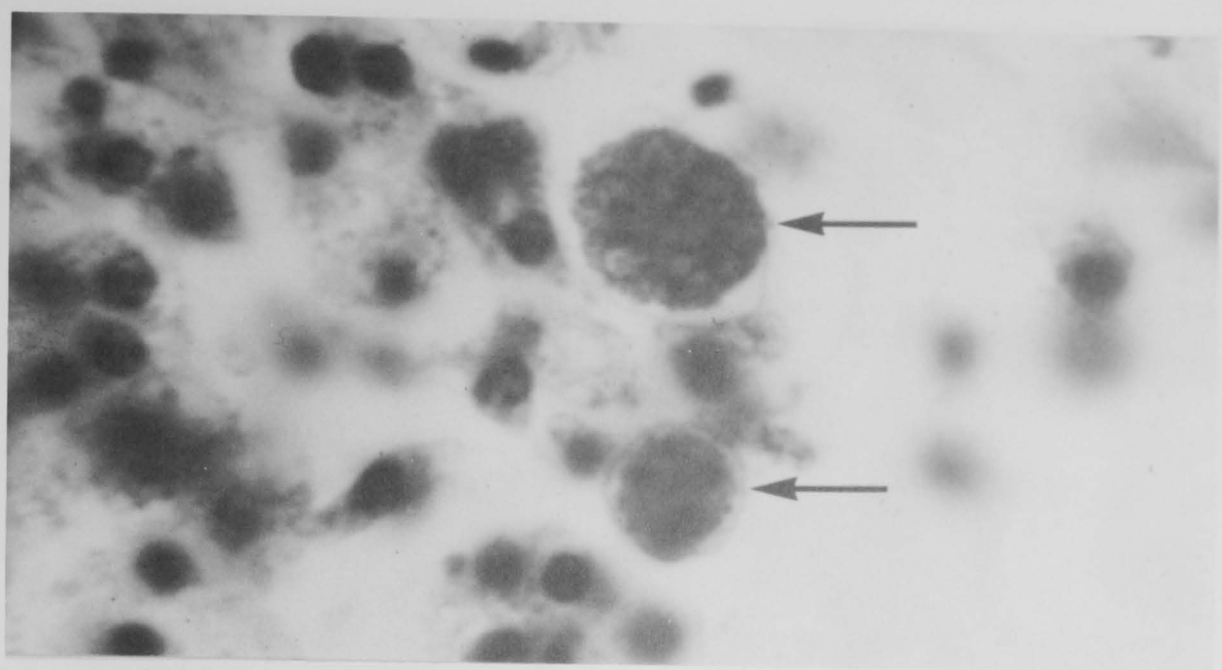

Figure 1. -- Plasmodial stage of MSX.

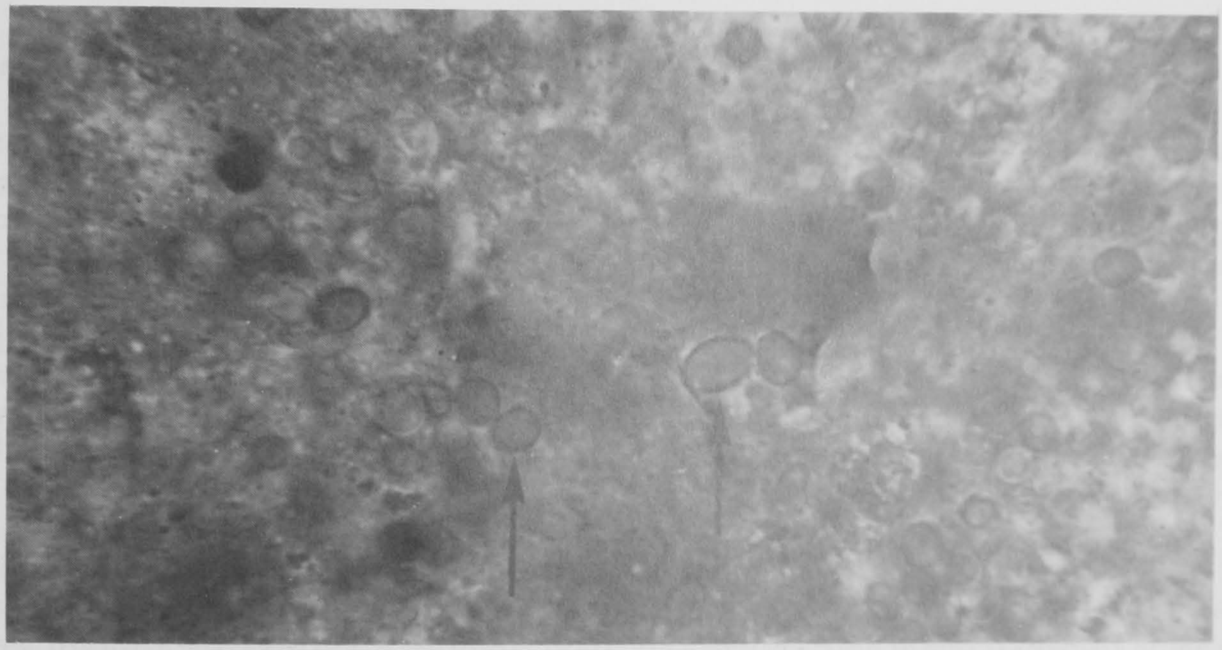

Figure 2. -- Spore stage of Minchinia costalis.

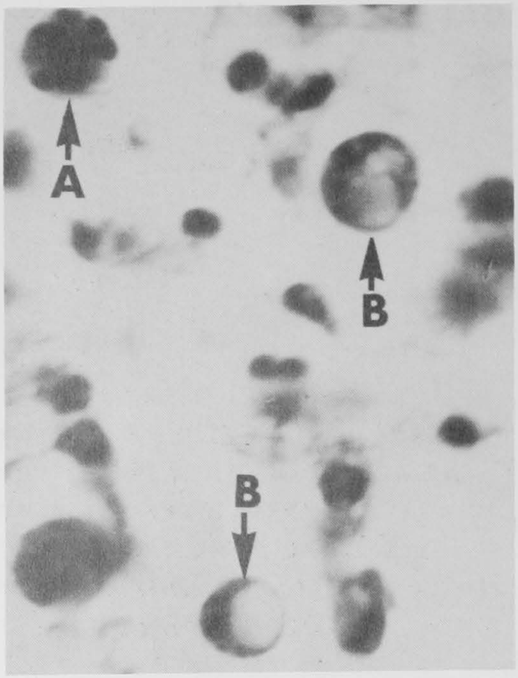


Figure 3. --Dermocystidium marinum, (A) rosette stage, (B) hypnospore stage.

Figure 4. --Hexamita sp. trophozoite.

Figure 1 shows a plasmodium of MSX (Multinucleate Sphere-Unknown), an organism believed to be responsible for mass oyster mortalities in Delaware and lower Chesapeake Bays. Although its life cycle has not been completely worked out, it is thought to be a protozoan parasite of the genus Haplosporidium. This organism was discovered in the late fifties by Harold Haskin and his colleagues at Rutgers University.

The spore stage of an identifiable haplosporidian, Minchinia costalis, is discernible in figure 2. First described by J. L. Wood and J. D. Andrews of the Virginia Institute of Marine Science in 1962, this organism is believed to cause oyster mortalities in the highly saline waters on the sea side of the Eastern Shore of Delaware, Maryland, and Virginia.

The rosette stage of a fungus parasite, Dermocystidium marinum, is seen in figure 3. This species is known to cause mass oyster mortalities in the Gulf of Mexico. It is particularly infectious in highly saline, warm water under crowded conditions and has also been reported in Chesapeake and Delaware Bays. The organism was described in 1950 by John Mackin and his colleagues of Texas Agricultural and Mechanical College.

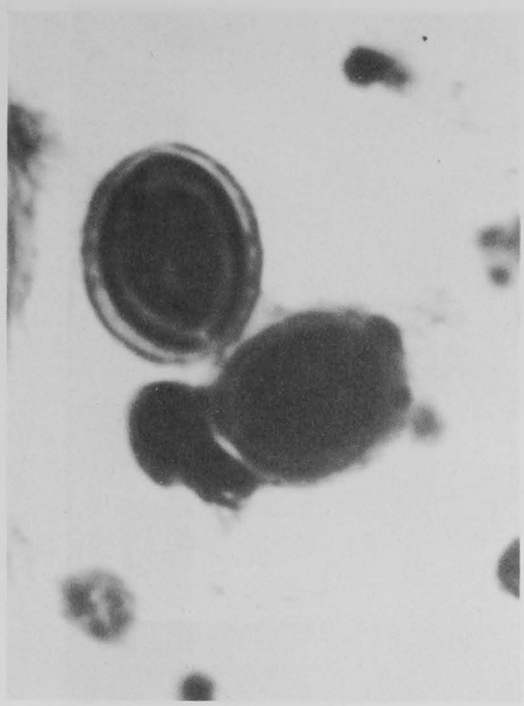

Figure 5. --Spores of Nematopsis ostrearum.

Figure 6. --Cercarial stage of Bucephalus cuculus.

In figure 4 the trophozoite stage of the flagellate protozoan Hexamita sp. is depicted. A similar organism is suspected of causing mortalities in oysters in Holland, Canada, and the northwestern and eastern coasts of the United States. It is found associated with oysters and other mollusks and is more abundant during the colder periods of the year.

The spore stage of Nematopsis ostrearum is shown in figure 5. The alternate host for this gregarine parasite is the mud crab. The spores are often found in oysters of the Atlantic and Gulf Coasts. Originally believed to cause oyster mortalities, later evidence indicated that the presence of spores in oyster tissues did little harm.

The cercarial stage of the worm, Bucephalus cuculus, is pictured in figure 6. The intermediate hosts of this trematode parasite are the oyster and other marine bivalves. The sporocysts develop in oyster gonads and cause functional castration. The cercariae are produced directly from sporocysts. Adults inhabit the digestive tract of carnivorous fish. The parasite is not responsible for mass oyster mortalities.

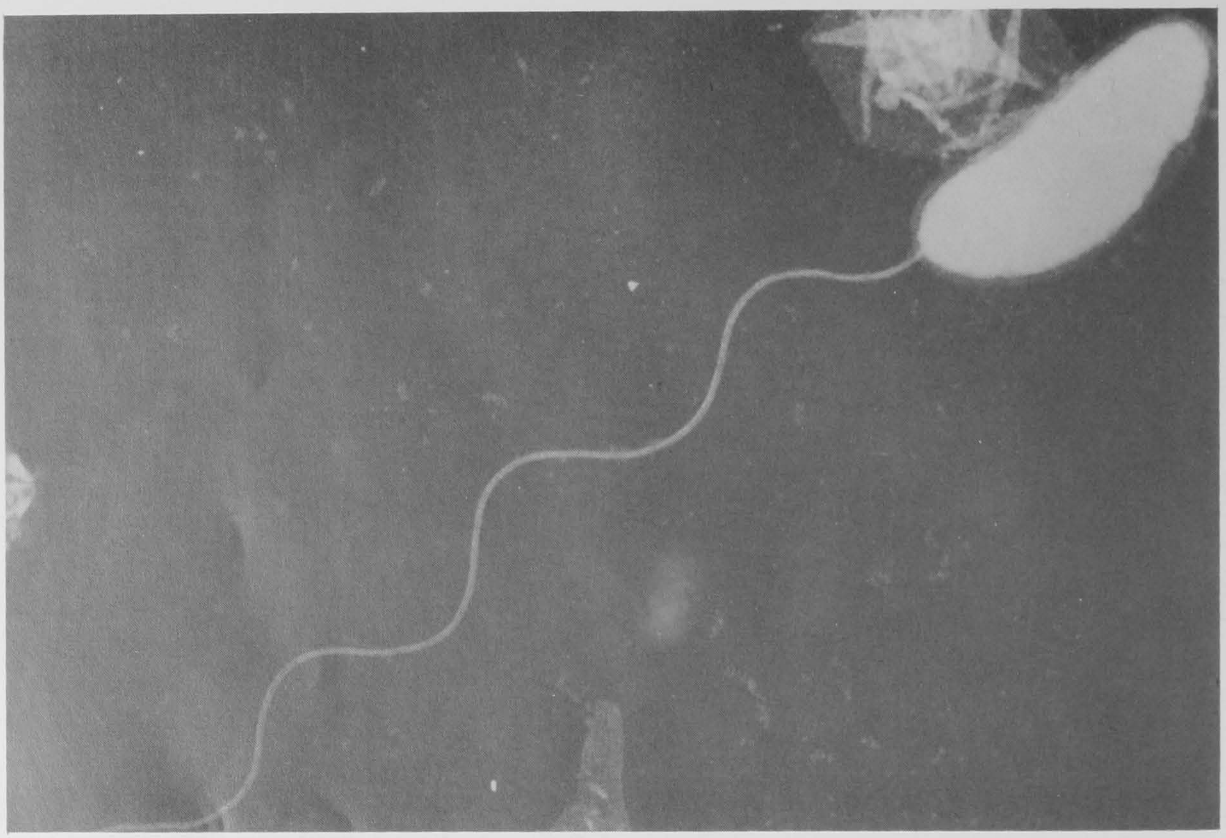

Figure 7. --Bacterial pathogen of bivalve larvae (greatly enlarged).

Figure 7 is a photomicrograph of a bacterium as seen under the high-power of an electron microscope. It is a bacillus, probably Aeromonas sp., which causes infection and heavy losses among artifically cultured larvae and juveniles of American and European oysters, quahogs, and other bivalve mollusks. Strains of these bacteria have been isolated from experimental hatcheries at the Bureau's Biological Laboratory at Milford, Conn., and elsewhere. They have been classified serologically into five types. This photomicrograph was prepared from a young broth culture by William Gaylord Yale University School of Medicine.

In addition to parasitological and bacteriological studies, which are the major efforts in the mortality program, other basic research projects are being undertaken.

An attempt is being made to develop cell cultures of shellfish tissues, either in suspension or in single layers, for screening of viruses and micro-parasites. A large number of diversified mammalian and insect tissue cultur media and artificial sea-water formulas are being tested for their ability to

Figure 8. --Oyster heart tissue explant.

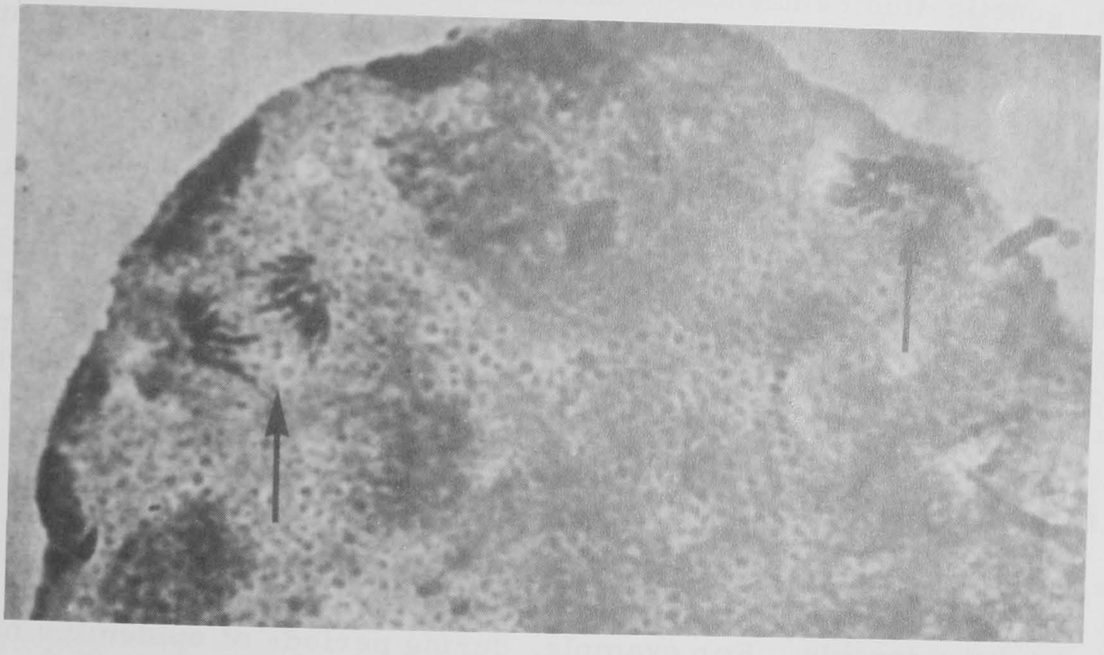

Figure 9. --Chromosomes in dividing cells of Crassostrea virginica.

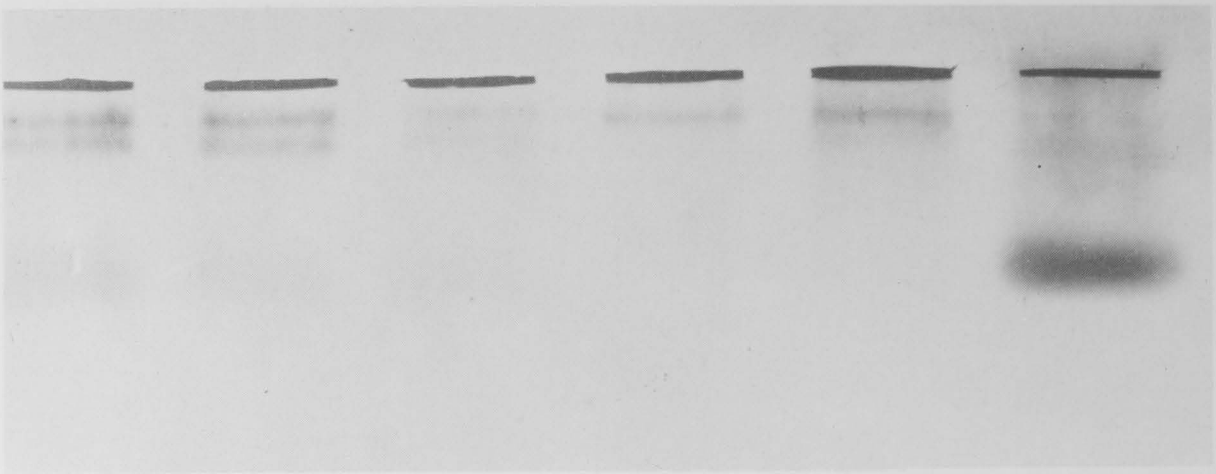

Figure 10. --Electrophoresis pattern of oyster serum proteins.

help maintain tissue and promote growth of tissues and cells. Figure 8 shows a segment of oyster heart tissue (possibly even outgrowth of cells) that has kept beating, within a test tube, for the past 9 months.

Studies leading to the development of disease resistant strains of oysters are receiving increased attention here. To understand and interpret breeding practices, genetic studies have been undertaken to determine chromosome numbers and chromosomal morphology. Dividing cells are needed to count and study chromosomes; figure 9 shows an example of this. In the figure, chromosomes can be clearly seen in dividing cells of an oyster.

Biochemical and serological techniques are being used to identify and distinguish differences among disease-resistant and disease-susceptible stocks of oysters used in laboratory breeding experiments. The same methods can be used to diagnose the diseased condition and to make population studies. Figure 10 shows the end result of an experiment where blood from various geographic populations of oysters were analyzed and compared. The dark bands in the photograph represent the proteins present in the serum.

## SUMMARY

Segments of a marine or estuarine resource that have been affected by disease or predation are completely unavailable to the fishing industry. These can often be considerable. For example, during periods of epidemics mass mortalities can often be observed or an entire industry may be eliminated because of lack of supply. Even during "normal" periods certain segments of any population are susceptible and others resistant to disease. Thus, a reservoir of disease can exist and with the proper environment can become epidemic. Not to be forgotten are introductions of foreign disease agents and predators into areas where they can increase and become manifest under the proper circumstances. Consequently, disease investigations must be long range in nature and both basic and imaginative in approach. The scientific community must, wherever possible, use any appropriate experimental method, tool, or technique that will assist them to understand better the causes of shellfish mortalities and make every effort to eradicate or control them.

# Progress in Surf Clam Biological Research

Arthur S. Merrill and John R. Webster

The Atlantic surf clam, Spisula solidissima, is one of the largest species of bivalve mollusks found along the east coast of the United States, attaining a size of about 7 inches. It has been found in fossil deposits estimated to be over ten million years old, and is known by a variety of common names depending upon the geographic area. In Maine it is referred to as the "hen clam," Canadians call it the "bar clam," around Massachusetts it is known as the "sea clam." In the area of its greatest abundance (North Middle Atlantic) it is called the "giant clam," "beach clam," "skimmer clam," or "surf clam." The Bureau of Commercial Fisheries recognizes and uses the common name "surf clam."

The range of the surf clam is from Labrador to the Gulf of Mexico but differences in maximum size occur between geographic regions throughout its range. Those south of Cape Hatteras are quite diminutive and known by the varietal or subspecific name, raveneli. To date we have found surf clams from the beach to depths of about 35 fathoms; however, museum records indicate they live in depths as great as 70 fathoms, the bathymetric range increasing southward along the middle Atlantic continental shelf. Abundance and distribution are not homogeneous throughout the range; many areas have few clams while other areas have heavy concentrations of clams commonly called "streaks" or "patches." It is these beds in which the industry is most interested.

Surf clams are harvested with heavy equipment -- jet dredges -- towed from 60- to 80-foot vessels (fig. 1), which now make 1-day trips. Several hundred bushels of clams are taken on each trip. Most of surf clams are now landed at Point Pleasant, N. J., and most of the fleet is now concentrated on the New Jersey coast, particularly near Barnegat Lightship, although there are stocks north and south that have been fished in earlier years. The center

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John R. Webster has been a member of the Bureau since 1930, and Program Leader of the Surf Clam Program and Chief of the Franklin City Substation since March 1963. His research interests are in the area of shellfish populations and ecology.


Figure 1. -- The vessel "Rebecca Snow" entering Manasquan Inlet, Point Pleasant, N. J., her decks loaded with surf clams.

of the fishery have shifted drastically, even in recent years.

During 1952-53, the principal fishing grounds extended from Atlantic City southward to Winter Quarter Lightship, in 8-15 fathoms of water. During 1954-57 areas of major fishing effort extended further offshore and somewhat further southward. During the past 5 years most of the production has been within 30 miles of Point Pleasant Inlet, concentrating near Barnegat Lightship in depths less than 20 fathoms. A small fleet out of Wildwood, N. J. has recently been operating on grounds around the Delaware Lightship.

This is a young growing industry but its members are properly concerned about eventual depletion -- and this is where the Bureau's responsibility lies -- in determining the dynamics of the fishery -- so that the amount and location of the resources available can be defined and the numbers of clams that can be taken without running the risk of depletion will be known.

It appears unlikely that the presently known stocks of clams are sufficient to sustain production at its current level, much less to support continuation of the growth that has been the history of this fishery. As with any industry, abundant supplies of raw materials are essential. This is a highly efficient fishery in many ways, dealing with what is apparently a slow-growing, high seas species, so that rational use is very critical.

The Bureau has undertaken programs both in exploratory fishing and gear research and in biological research to work out solutions to these current and impending problems.

Charged with developing the program of exploration and gear improvement are personnel of the Exploratory Fishing and Gear Research Base at Gloucester, Mass. The base, in cooperation with industry, started small-scale operations in the summer of 1963 in the area of the present fishery. The program has recently been greatly expanded; exploration of several areas, selected for investigation as a part of the overall survey of the resources of the continental shelf is well underway. The Bureau vessel,"Rorqual," is being used presently for survey operations. The vessel is equipped with commercial-type jet dredges and staffed by Bureau scientists and crew.

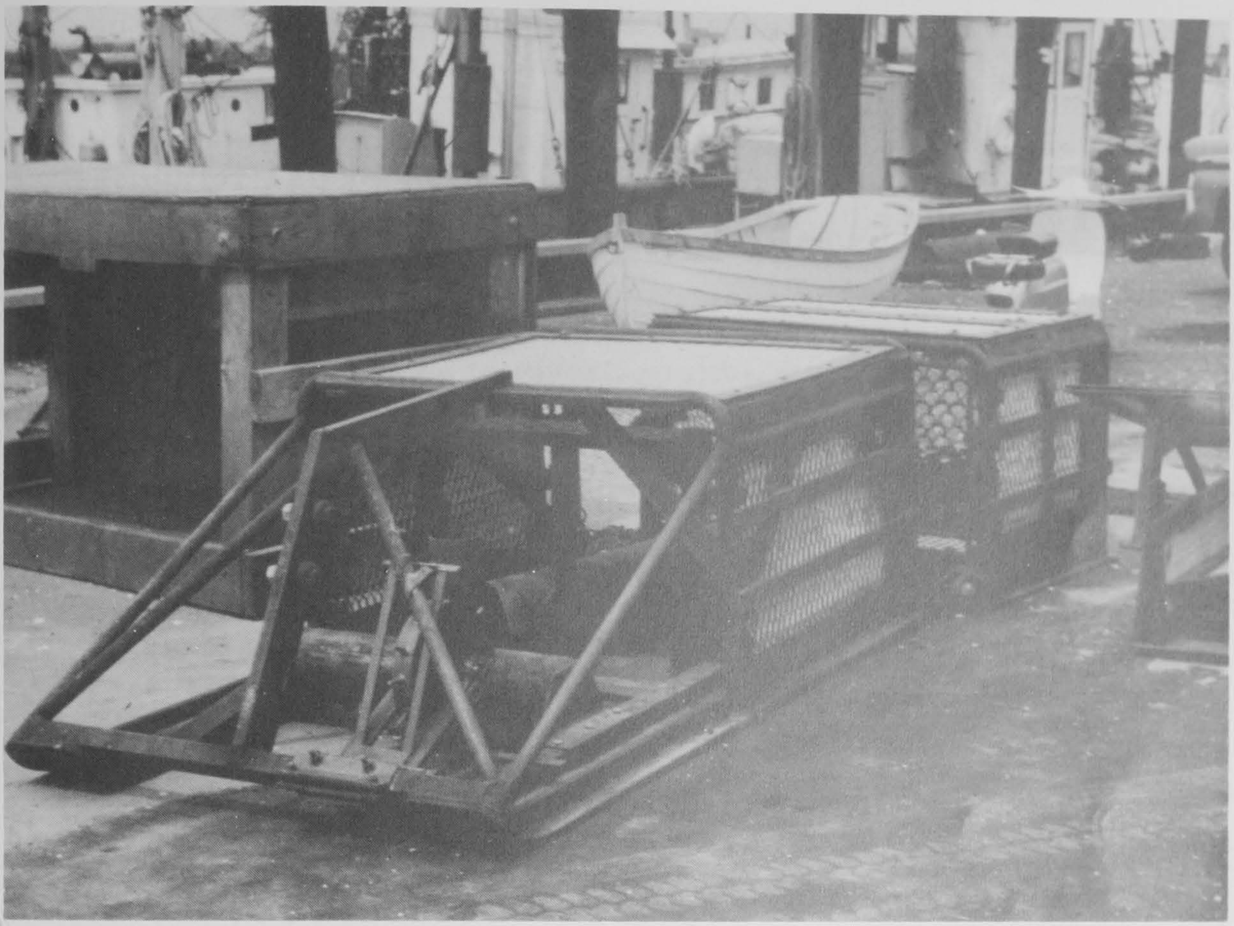
## BIOLOGICAL RESEARCH

Biological research on surf clams by the Bureau's laboratory at Oxford is a relatively recent activity -- beginning in 1963 with a small-scale program based at the Bureau's substation at Franklin City, Va.

Despite its recent origin, this research has disclosed a number of significant facts about the species.

To study size distributions, as a clue to rate of replacement of commercial sized clams, we have designed and tested an experimental jet dredge (fig. 2) patterned after commercial gear but equipped with removable wire mesh panels that will retain all sizes of clams. This gives us a much more accurate picture of what is actually on the beds than we could obtain from commercial sampling.

Size frequencies of clams from the commercial catches indicate that the industry is taking clams from 4 to 6 inches in length, (fig. 3) which is their maximum size. Commercial gear takes relatively few of the smaller sizes,



'igure 2. -- Experimental surf clam jet dredge similar to the commercial ;ear used presently in the fishery.

ut these sizes are represented in at least some of the fishing areas, as lemonstrated in experimental catches when the dredge is lined with fine-mesh iet to retain the smaller clams. The lower graph in figure 3 is an average of izes taken in a commercial dredge, while the upper graph is an average of lam catches taken in lined dredges on apparently virgin grounds off the Delaware ightship. The left-hand peak in the upper graph represents younger clams not aken in commercial catches. The relative absence of clams as shown in other arts of this curve indicates lack of recruitment in a particular area, since the ined dredge would have retained them if they were present. Such gaps in size istributions are not uncommon, and suggest failure of particular year classes n certain areas.

Another area where progress has been made concerns the reproductive abits of the surf clam. Samples have been collected from commercial catches

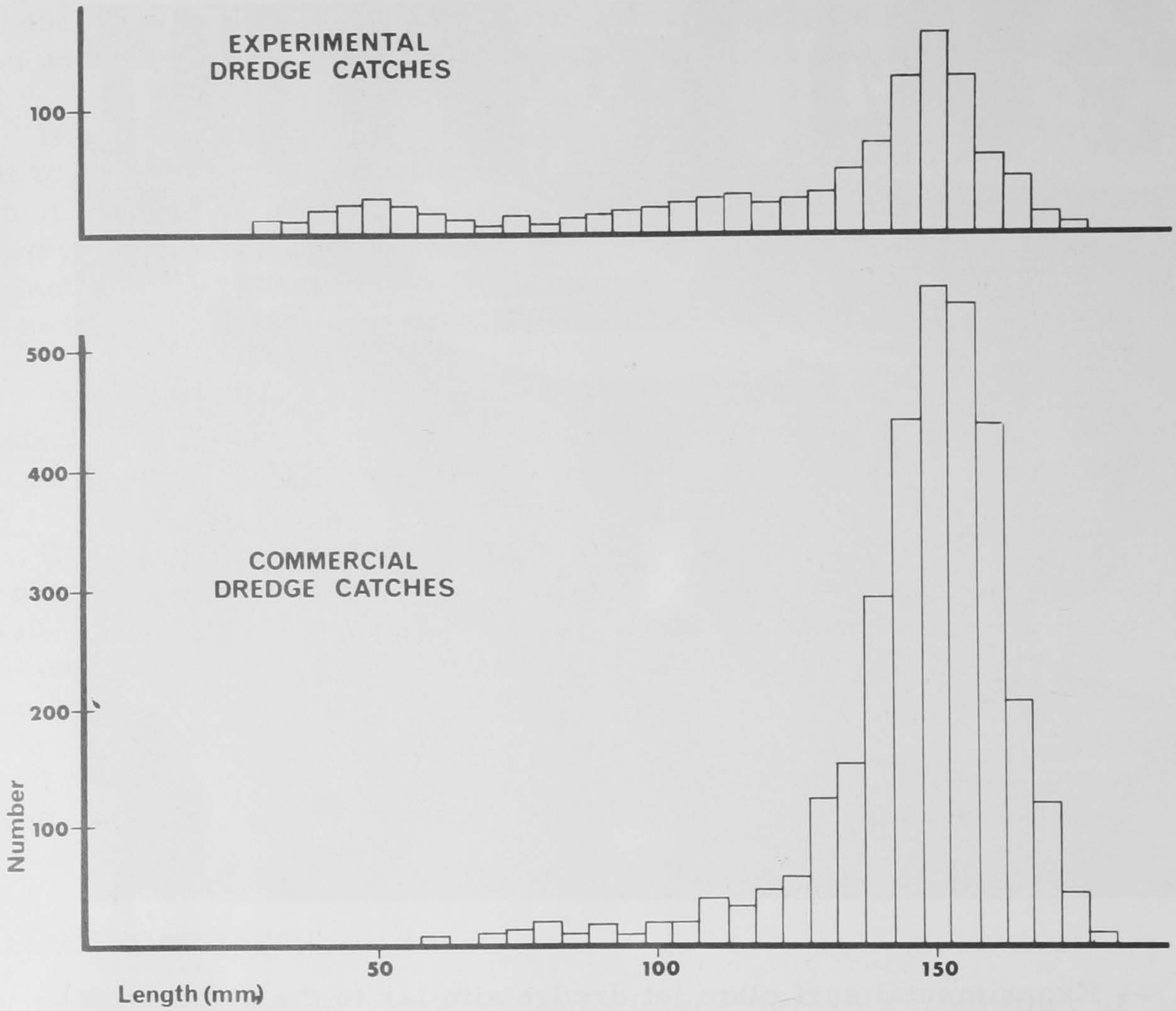



Figure 3. -- Examples of size composition of surf clam populations resulting from modification of the same gear. Experimental dredge retains small clams; commercial dredge retains only large clams.

for over 2 years, and the clams examined for spawning condition. New Jersey coast clams have two spawning periods - one in June-July, and another in September-October. There is some evidence that spawning is initiated by change in temperature, and mortalities of eggs increased above and below 14 to 20° C. Best larval growth occurred at 20°C., and at this temperature larva settled to the bottom in 18 to 30 days after fertilization. Eggs failed to develo in salinities below two-thirds normal sea water. Clam larvae have been rais successfully in the laboratory to setting stage by feeding unicellular algae.

Other information from surf clam research concerns the distribution of clam stocks in deeper waters further offshore; also the relationship of these stocks to type of bottom and to the mahogany or ocean quahog, Arctica islandi

Ocean quahogs are not common in shallow waters where surf clams are abundant, but it is not unusual for the commercial fishery to suddenly run into mixed concentrations of surf clams and ocean quahogs further offshore. Ocean quahogs are of minor commercial importance at this time, although the potential for a fishery is great. At present the ocean quahog is simply a nuisance to surf clam fishermen who are interested primarily in dredging up pure catches of surf clams.

A research cruise originating at the Bureau's Biological Laboratory in Woods Hole was designed to investigate the distribution of invertebrates in offshore water depths of 20 to 80 fathoms along the continental shelf from Block Island, R. I., to Cape Hatteras, N. C. Eight major transects were made, and additional stations were occupied between the transects (figs. 4 and 5).

Recently the Bureau, in cooperation with the Woods Hole Oceanographic Institution and the U. S. Geological Survey, has developed a preliminary sediment chart of the middle Atlantic area. Most of the entire shelf out to about 70 fathoms is made up of detrital sands ideal for settlement of bivalve larvae (figs. 4 and 5).

The distribution of ocean quahogs is widespread, and this species takes liberal advantage of the shelf in its distribution, even living in sandy silt (fig. 4). The depth distribution of the quahog is rather uniform, with a slight preference to the shallow 20 to 39-fathom water (graph insert, fig. 4). Notice particularly how the distribution pattern weakens in the area closer to Cape Hatteras (fig. 4).

The depth distribution of surf clams is rather shallow (fig. 5) compared to the ocean quahog (fig. 4). The greatest depth in which surf clams were taken in offshore middle Atlantic water was 35 fathoms. On the other hand, the species was taken at most shallow water stations. The graph insert shows this distribution clearly. It can be seen that the bathymetric distribution of surf clams is much more limited that that of the ocean quahog. The limiting factor is not the type sediment, for favorable sediment is available in deeper waters. Notice the concentration in the lower area near Cape Hatteras, the area where the ocean quahogs are less abundant. Perhaps this is an area further offshore that can be exploited for pure catches of surf clams in the future.

Development of tags and tagging methods, important in determining age, growth, and mortality rates, has progressed rapidly. We have devised a workable tag and have tested it on clams held alive in the laboratory. The tag consists of a nylon screw with a numbered colored plastic disc, inserted in a hole drilled in the shell. The clam quickly seals off the hole, and the tag is permanently incorporated in the shell. We also are using another tagging method to

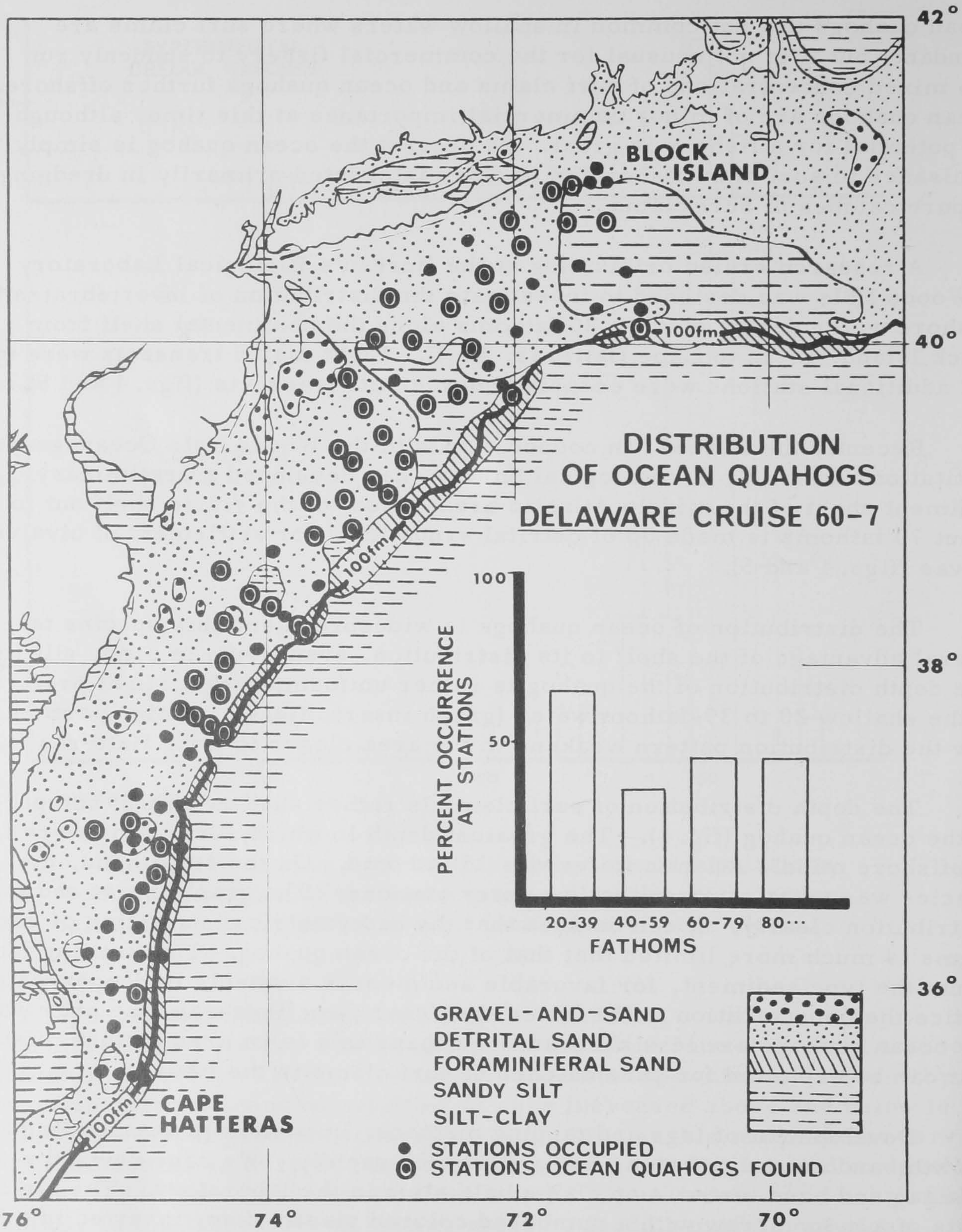



Figure 4. --Distribution of ocean quahogs at stations occupied during a research cruise, superimposed on a generalized bottom sediment chart of the middle Atlantic coast. Graph inset demonstrates a general pattern of distribution for the quahog at all depths sampled.

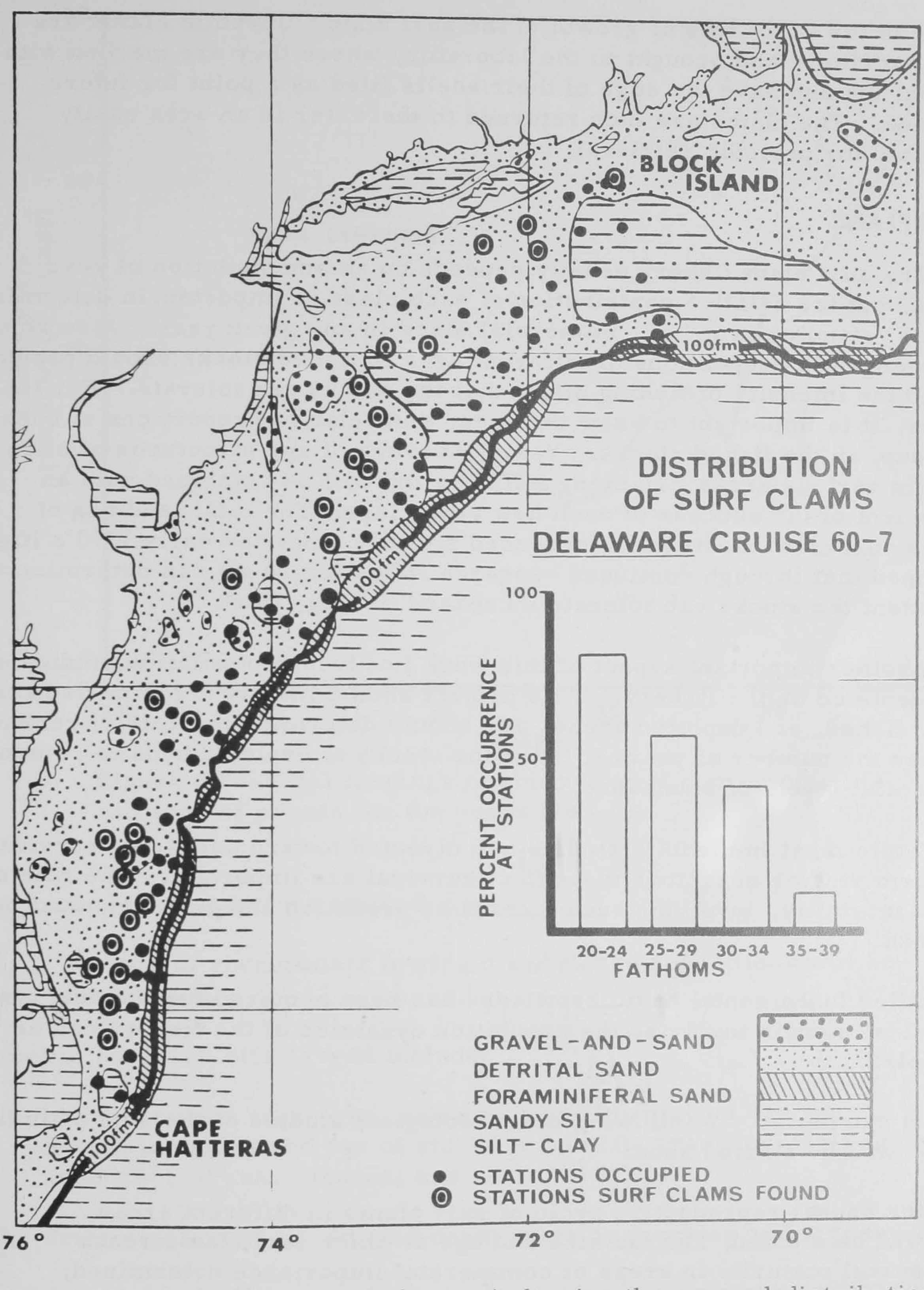



Figure 5. - -Same chart as in figure 4 showing the general distribution of surf clams to be different from that of the ocean quahog. Graph inset illustrates the shallow distribution of the species.

determine the early rate of growth of the surf clam. Juvenile clams are dredged offshore and brought to the laboratory where they are marked with a special ink and have the edge of their shells filed as a point for future reference. The clams are then returned to the water in an area easily accessible for periodic retrieval.

## FUTURE PLANS

The surf clam fishery usually depends on an accumulation of year classes, but the relative contribution of each class is important in determinin the total "standing crop" of commercial sizes in any given year. Also, long-term changes in proportions of different ages in fished stocks should provide clues to the intensity of fishing effort that the stocks can tolerate. For these reasons, it is important to know the ages, and relative proportions of each age group, in the fished stocks. Yearly surveys of age structures of clam stocks in various areas are being initiated and will be combined with an assessment of the success of each new year class. The total landings of shucked surf clam meats have increased steadily since the early 1950's (fig. 6 It is hoped that through continued research in the future we can determine to what extent the stocks can tolerate increased fishing effort.

Another important aspect of this work involves repopulation studies of areas depleted by the fishery. This project should involve a comparison of virgin, fished, and depleted areas, and should determine the rate of recruitment and the number of years it takes for stocks of depleted beds to return to commercial levels of abundance.

While most immediate studies are directed toward assessing survival, long-term studies of factors that affect survival are important. The role of natural mortality, involving such factors as predation and disease, must be examined.

After fundamental basic knowledge has been acquired for the surf clam theoretical models involving the population dynamics of the fishery can be assembled.

In summary, the following basic biological studies of the surf clam ha been or will be started soon:

1. the annual reproductive cycle of surf clams in different areas will be studied, and the size and age at which surf clams reach sexual maturity in areas of commercial importance determined;

2. surf clam growth rates will be determined, and the age structure

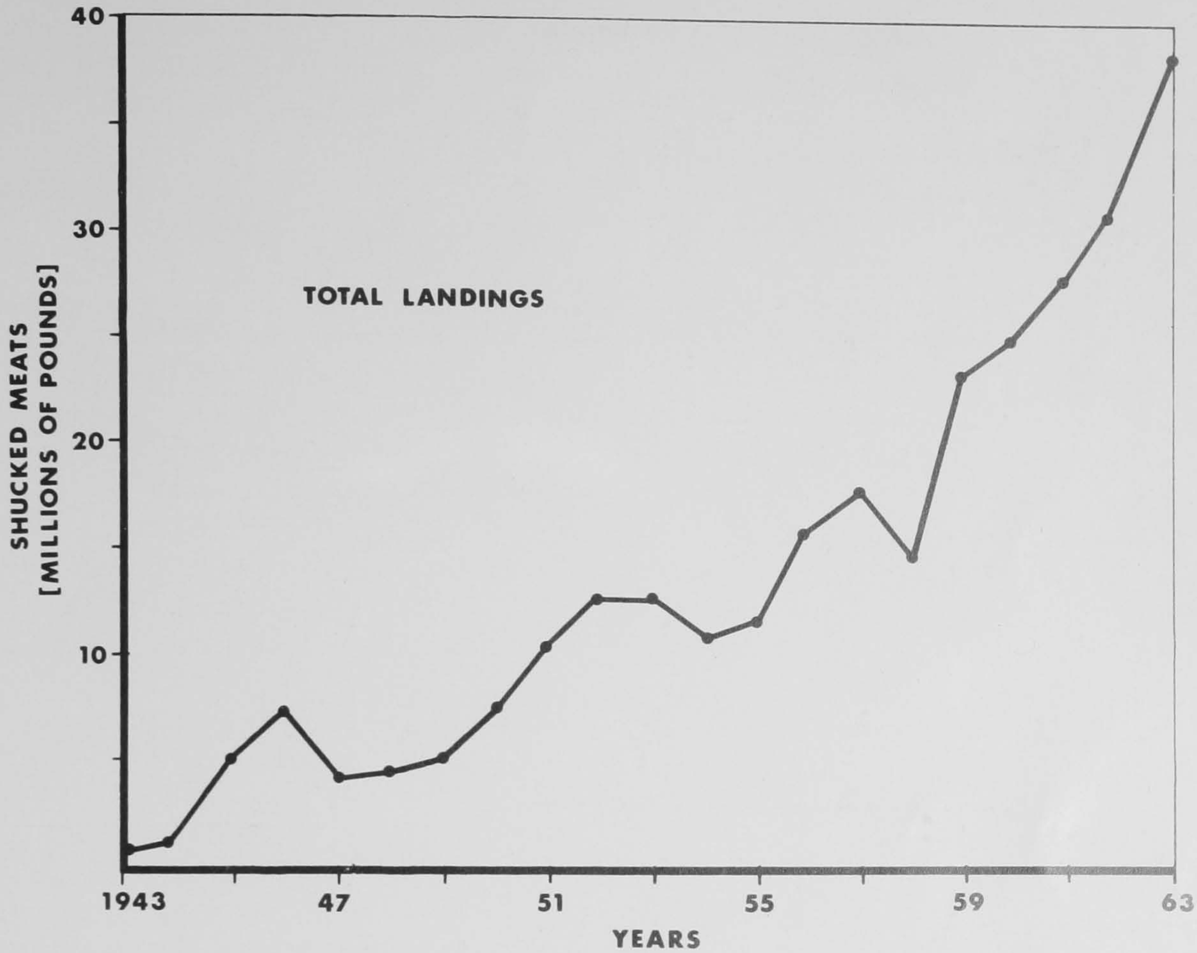



Figure 6. --Total landings of shucked surf clam meats in millions of pounds for the years 1943-63.

of clam populations studied; and

3. the rate of recruitment in virgin and fished populations will be determined.

Specific research efforts will include:

1. charter vessel transects, using an experimental jet dredge, to determine sizes and age of stocks in various areas and the relative abundance of year classes; and

2. determination of growth and death rates by marking and tagging.

Based on these findings and those from studies of virgin and depleted areas, theoretical models will be prepared indicating maximum exploitation rates that the clam population in any area can stand.