Progress in Oyster Mortality Studies

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INTRODUCTION

SEVERAL MASS MORTALITIES in oyster populations have occurred over the past 50 years and ineffectual attempts to control them have been made. A review of some of these is given.

Disease epidemics which virtually destroyed the entire oyster industry occurred in Malpeque Bay, Prince Edward Island, Canada, in 1915, and over a period of years spread to other areas within the Canadian Maritime Provinces (Needler and Logie, 1947). The cause of this disease is still unknown, though each of several authors, cited by Laird (1961) suggests a different causative organism. The oyster industry in the affected areas regained its former level of production by the 1930's, and it is hypothesized that the current populations there are resistant strains that have developed from the survivors. Evidence that the infective agent is still present is suggested by the fact that introduced oysters are susceptible to the disease and die within the first or second year after introduction (Needler and Logie, 1947). Research on several aspects of this disease is continuing under the direction of Mr. Roy Drinnan at the Fisheries Research Board Sub-Station in Ellerslie, Prince Edward Island, Canada (Drinnan, personal communication, 1962).

Korringa's (1952) review paper on the biology of the oyster included a summary of the European oyster epidemic. In 1919 mass mortalities of European oysters (*Ostrea edulis*) occurred in Italy. In 1920 and 1921, a disastrous oyster epidemic of a similar nature hit both the natural and artificial oyster beds in England, France, Germany, Denmark, and Holland. The theory has been advanced that the disease was spread by oysters setting on the hulls of ships in Italy and subsequently being transported with the disease agent to other European ports. Because there was no evidence of infection nor of parasites, the possibility of excessive rains and starvation were suggested as reasons for the mortalities. According to other investigators, however, this possibility is precluded on the basis that identical ecological factors could hardly exist simultaneously in such a diverse and vast area (Korringa, 1952).

In Holland during the 1930's and 1940's an outbreak of shell disease in *O. edulis* was recorded. The agent responsible was classified as a fungus, and presumably the infection was spread by spores carried in water currents. The fungus appeared to thrive on old decaying shells, particularly of *Cardium* and *Crepidula* used as spat collectors. Removal of old shells and chemical treatment (dipping) of planted oysters was suggested, and this treatment was used, up to 1951 at least, as a control measure for this disease (Korringa, 1951).

In the United States, an organism associated with oyster mortalities in the Gulf of Mexico has been described. The parasite is a fungus and has been named *Dermocystidium marinum* (Mackin, Owen, Collier, 1950). This micro-organism has been fully implicated as the cause of heavy mortalities in oysters (Ray, 1954), and can be positively diagnosed by culture techniques (Ray, 1952).

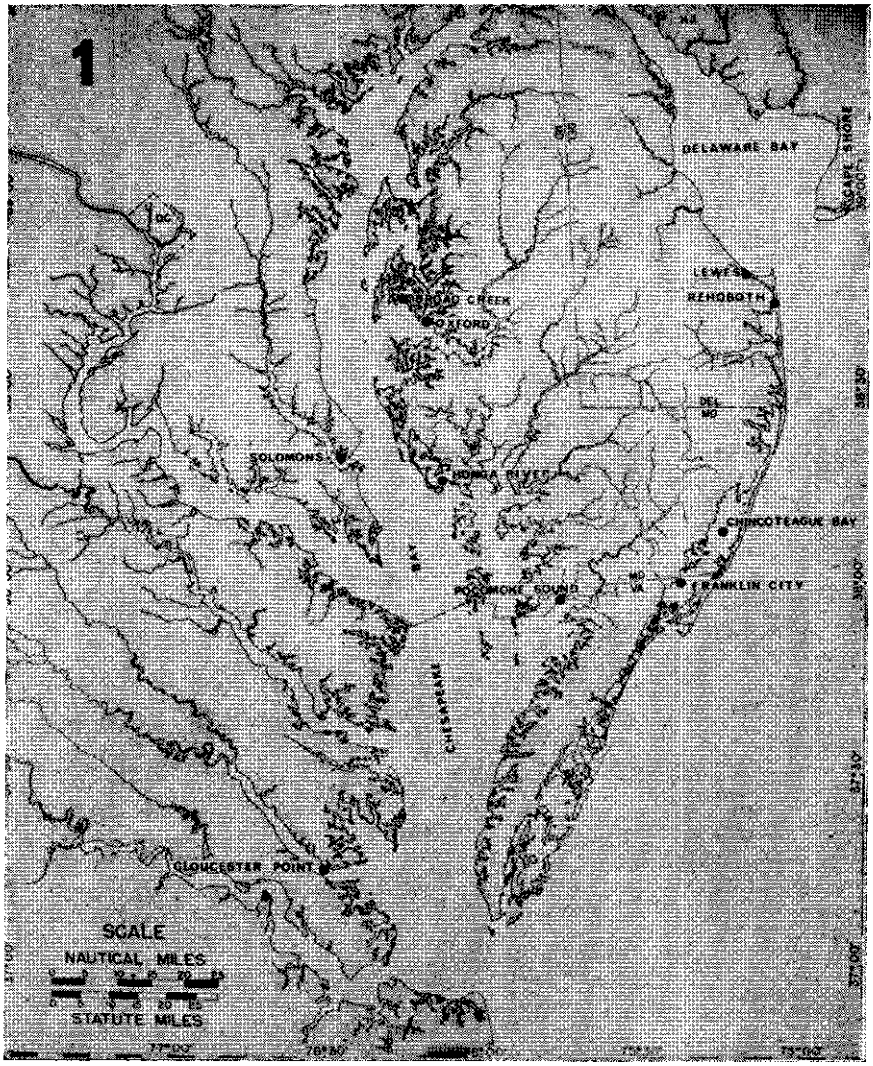


FIG. 1. Chart, showing locations mentioned in text.

Andrews and Hewatt (1957) clearly established that *Dermocystidium* is also endemic to several areas in the lower Chesapeake Bay, and have worked out the intensity of infection and seasonal pattern of mortality caused by the organism in these areas. Further observations have revealed the presence of this fungus in oysters in Delaware Bay, in South Carolina (Andrews and Hewatt, 1957), and in the middle portion of Chesapeake Bay (Dunnington, personal communication, 1962). Mortalities caused by *Dermocystidium*, although occurring in some areas of the Gulf throughout the year, occur primarily in the

summer in more northerly latitudes when the water temperature and salinity are relatively high.

The most devastating oyster mortality to have been reported in the United States is that which started in the spring of 1957 in Delaware Bay and continues to the present. The focal point of the disease was at first close to the New Jersey side of the Bay on the planted beds, but by the spring of 1958, oyster mortalities were reported along the Delaware shore (Fig. 1). By late summer of 1958, mortalities were reported in Rehoboth, Chincoteague, and Virginia seaside bays, though the heaviest mortalities were still reported from Delaware Bay. The first major mortality reported in Chesapeake Bay occurred in lower Virginia waters during the spring of 1959, and it was not until the summer of 1960 that mortalities due to this disease were confirmed in Maryland water in middle Chesapeake Bay (Fig. 1).

In 1957, under the guidance of Dr. Harold Haskin, biologists of Rutgers University conducting oyster research for the State of New Jersey began a study of the causes of mass oyster mortalities in Delaware Bay. Proximity and cross infection experiments under both natural and laboratory conditions, tray monitoring, and bacterial isolation were attempted to determine the extent and distribution of mortalities. A histological program was also begun in an attempt to discover if a histo-pathogenic agent was responsible for the mortalities. In 1958, a parasite thought to be the cause of oyster mortalities in Delaware Bay was discovered. This organism is a multinucleate sphere of unknown taxonomic position, hence it was tagged with the initials MSX (Haskin, personal communication, 1958. Fig. 7).

Since the time of its discovery in 1958, MSX has been observed in oysters in Chincoteague Bay, seaside Virginia, and in the lower part of the Chesapeake Bay in both Maryland and Virginia. Indeed, heavy mortalities believed to have resulted from infection by this parasite have prevented oyster plantings in some areas within the Virginia portion of the Chesapeake Bay (Andrews and Wood, 1961).

Another parasite, *Haplosporidium costale,* that possesses a definite spore stage, has been described in oysters from the Eastern Shore of Maryland and Virginia (Wood and Andrews, 1962). As this organism was found in oysters inhabiting the seaside regions, it has been called the seaside organism, or SSO, prior to its description in the literature.

Perspectives in the Study of Oyster Mortalities

The accomplishments in oyster mortality studies have come through the cooperative efforts of a great number of investigators currently involved in marine disease studies. Workshops and conferences among these researchers from state and federal agencies, universities, and industry are held at frequent intervals throughout each year. Ideas are exchanged, and progress, difficulties, and research plans are discussed in an uninhibited scientific atmosphere.

Despite these actions and accomplishments, progress in oyster mortality studies has been relatively slow principally because of the enormous complexities of the problems involved. A few examples of the problems that confront us are as follows:

1. *Mortalities caused by physical factors, predation, and competition.*

The continuing base levels of mortality that occur in the absence of specific disease must be determined and evaluated. Thus, during epidemic periods

mortalities due to factors other than disease can be distinguished from that due to disease.

2. *Absolute identification of the pathogenic organism suspected of causing disease.*

The fungus *Dermocystidium* previously mentioned has some stages within its life cycle that are remarkably similar to some stages of MSX. Distribution of *Haplosporidium costale* (SSO), like *Dermocystidium,* overlaps the distribution of MSX and to some extent produces overlapping peaks of mortality. *Haplosporidium* also has certain stages that appear identical to certain stages of MSX to the inexperienced observer (Fig. 6).

3. *The life cycles and characteristics of the microparasites and other organisms present in oyster tissues must be established.*

The life cycle of the MSX parasite has not been completely described, nor has its mode of transmission been established. Furthermore, the picture is made even more complex by our relative lack of knowledge and life cycle stages of such parasites as *Hexamita, Ancystrocoma, Bucephalus, Nematopsis,* bacteria, to name a few, that may cause mortalities when present in oyster tissues (Figs. 2-5).

4. *The question of resistance and susceptibility in oyster populations must be answered and strain differences in the host and parasite must be studied.*

It is possible empirically to develop resistant strains of oysters by breeding the survivors of mortalities experimentally, or by natural selection as occurred in Prince Edward Island (Needler and Logie, 1947) and to some extent in Delaware Bay (Haskin, Kunkle and Richards, 1961). However, in order to more fully understand the phenomena that occur, it is necessary to study not only the genetics and immune reactions of oysters themselves, but also that of the parasite responsible for mortality.

5. *The cytology, cytochemistry, and the metabolic processes of both the uninfected and parasitized oyster must be more fully understood.*

To devise specific and rapid diagnostic tests for diseased oysters and to interpret the results, it is essential to be able to recognize with certainty the various cell types before and after their exposure to various experimental staining procedures.

Furthermore, an understanding of the biochemistry of both healthy and infected oyster tissues and fluids would assist investigators to develop rapid diagnostic and clinical tests for diseased oysters.

6. *A thorough understanding of the epidemiology of the oyster mortality and disease pattern and an effective and efficient management program for the resource based on the accumulated information is essential.*

Regulatory and conservation practices to prevent the spread of shellfish disease and to institute control measures will be possible only through an understanding of disease patterns as they occur in a marine environment.

Research Activities by the Bureau of Commercial Fisheries in the Study of Shellfish Diseases

Research efforts prior to 1959 by the Bureau's Biological Laboratory, presently located in Oxford, Maryland, were directed toward studies of the ecological (which included effects of predation and climate), conservation, and management aspects of oyster production. As the problem of mortality from disease became more severe, the research emphasis changed toward an

expanded study of oyster mortalities as they occurred in the mid-central Atlantic states.

The Bureau's contributions in 1958 consisted of modest assistance through contracts to the biologists of Rutgers University who had already begun investigations of oyster mortalities in New Jersey. Later this support was increased and the contracts are continuing. The research being carried out at Rutgers includes the projects mentioned earlier plus an expanded effort, through detailed histological procedures, to discover the life cycle of MSX and to describe its various stages. In addition, they have begun a program of oyster larval culture designed to develop and test strains of oysters resistant to mortality.

In 1961 the State of New Jersey, with the cooperation of the oyster industry and the state shellfish research personnel, undertook a large scale experiment to test possible resistance of oyster seed to MSX. In the spring of this year, 160,000 bushels of seed oysters from the state seed beds were transplanted to parts of the private planted beds where MSX first struck five years before. These seed oysters were larger than normal but were the accumulated survivors of the sets of the previous five years. The larger of these oysters, harvested in the late fall of the same year, showed remarkable growth and survival.

The Congress of the United States recognized the need to assist oyster farmers in taking advantage of progress in the knowledge of disease resistance by passing HR 7336 which the President signed as Public Law 87-850. This law authorizes the purchase and transplanting of resistant oysters to aid in the rehabilitation of MSX damaged oyster areas.

The Bureau has also awarded contracts to marine biologists of the University of Delaware. The research at Delaware includes tray studies to aid in the determination of the extent and distribution of mortalities. They also include histochemical studies inaugurated to determine the significance of the presence of peculiar "brown bodies" in oysters and their role, if any, in combating disease.

The Bureau staff at Franklin City, Virginia, directed its attention to the mortality problem in 1959 and began tray studies for the purpose of determining the temporal distribution and intensity of mortalities.

In 1959 Bureau personnel, in cooperation with the Chesapeake Biological Laboratory and Maryland Department of Tidewater Fisheries, began a survey of the Maryland portion of Chesapeake Bay to determine the distribution and types of parasites in oysters. The results of this survey disclosed almost no pathogens in the oysters sampled. However, a few histological sections of oysters did reveal the presence of *Ancystrocoma* and *Nematopsis* (Burton, 1961).

The survey was expanded and continued in 1960, again with the cooperation of the Chesapeake Biological Laboratory and Maryland Department of Tidewater Fisheries. Results of this survey showed that although no mortalities were observed in the northern latitudes of Chesapeake Bay, they did occur and MSX was present in samples of oysters from Pocomoke Sound. Some *Dermocystidium, Hexamita, Bucephalus, Ancystrocoma,* and *Nematopsis* were also observed, primarily in oysters not infected with MSX (Burton, 1961).

A large number of specimens were collected and an almost overwhelming number of histological sections were prepared and examined during the surveys described above. Because of this, and because the information obtained from the surveys justified a change in sampling schedules, it was decided to limit our

program of sampling to three areas, but at frequent intervals, over the entire year of 1961. One of these (Pocomoke Sound) is located in an area where mortalities have been observed, another area (Honga River) is located at the edge of the mortality zone further up the Bay, and the third area is located well up the Bay in Broad Creek where no MSX has been observed. This program has been carried into 1962 also. Thus we have a sampling program which may disclose the spread of MSX, if it occurs, into the upper portions of Chesapeake Bay. We can also follow the distribution, intensity, seasonal pattern of mortality, and the degree of infection with MSX. Infected material can be used for our laboratory experiments. The results of our sampling program are as yet incomplete, but it is anticipated that we will complete this one phase of our data collection by the spring of 1963.

In addition to our survey, field sampling, and other field programs, we have been conducting laboratory experiments over the past two years. The nature and results of each are outlined below:

1. A method that permits the identification of known parasites in oyster tissue within a few minutes after live oysters are brought into the laboratory is of immense value. Such a method was developed for oyster tissue in our Oxford laboratory, and employs the cryostat technique. It was adapted from that used for the rapid histological analysis of mammalian biopsy material. The success of this technique has enabled us to begin other laboratory experiments with living parasites and with known infected oyster tissues (Carriker, 1962).

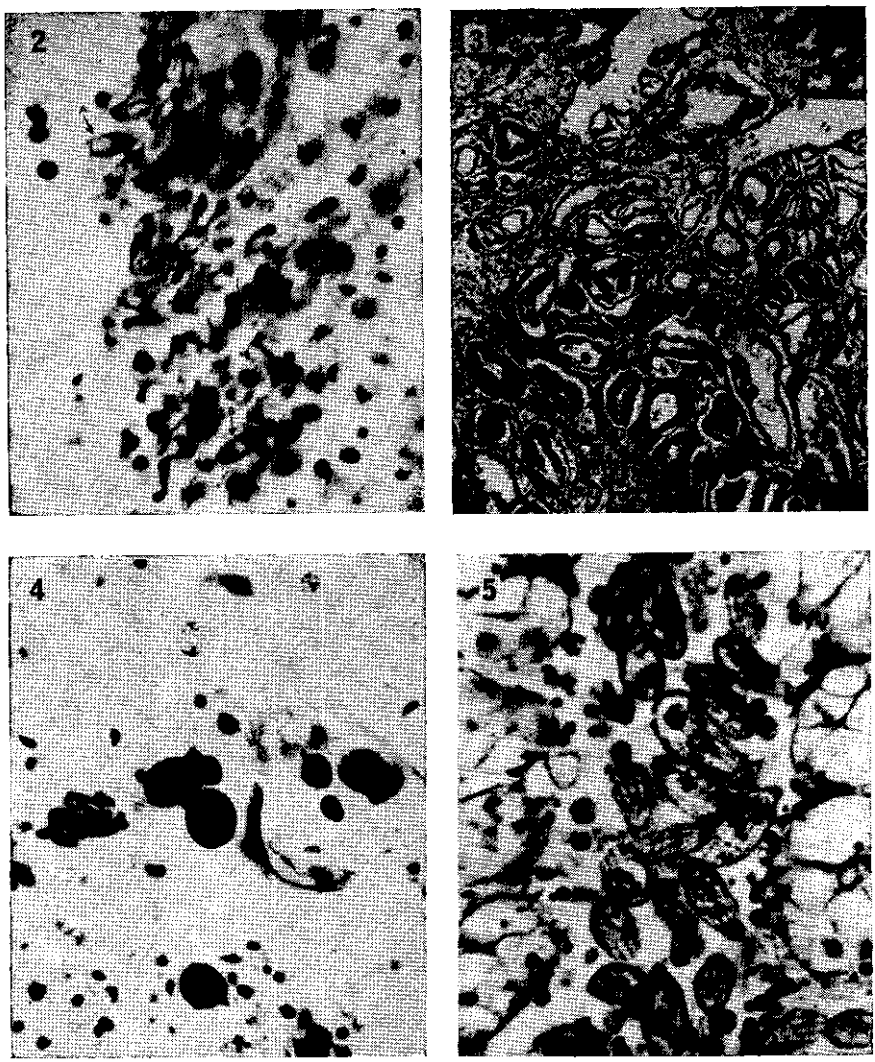
2. Cross infection experiments in attempts to determine the virulence of organisms suspected of causing mortalities in oysters have been completed. In these experiments, oysters from epidemic areas (Delaware and Malpeque Bays) and presumably therefore carrying an infective agent, and oysters from areas never having had a history of disease (Sheepscot River and Boothbay Harbor, Maine) were reciprocally crossed in recirculated seawater systems at various salinities. No mortalities due to disease were observed during the course of the experiments, and preliminary histological examination indicated that Delaware Bay oysters when brought into the laboratory "lose" their infection under the experimental conditions used. These results must still be regarded as preliminary. However, they appear to agree with the results obtained in other laboratories in Delaware and Chesapeake Bays where cross infection experiments were employed.

A three-phased study, with the ultimate goal of distinguishing populations or strain differences among oysters, was conducted in anticipation that resistant genera or populations would be developed or found. In addition, these studies would add some basic knowledge to the field of oyster biology.

Chromosomal analyses of various oyster genera and species were started. Thus far, we have learned the chromosome numbers for *Crassostrea gigas* and *O. edulis,* but further study of *C. virginica* material is needed (Rosenfield and Honey, unpublished data, 1962; Rosenfield and Lovejoy, unpublished data, 1962).

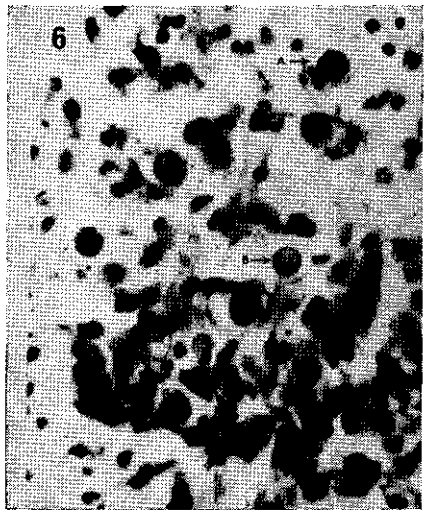
Starch gel electrophoresis studies of serum protein from various oyster populations have shown that this technique is a valuable tool to distinguish differences in oysters on the generic level, but further refinements are necessary before it can be used for lower taxonomic levels.

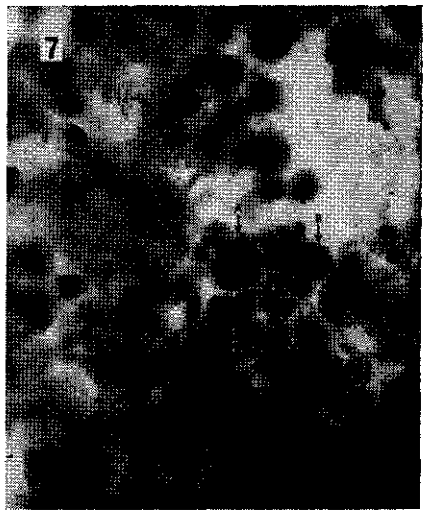
Rabbit antisera against sera from various groups of oysters have been developed, and serological differentiation tests are in progress.



Oyster Tissues: Sectioned at 6 microns; stained with iron haematoxylin and eosin. Various oyster parasites are shown. (Photographs taken by C. Austin Farley, U.S.B.C.F., Oxford, Md.)

FIG. 2. *Hexamita* trophozoites (970X)
FIG. 3. *Bucephalus* cercariae in tubules of male gonad (430X)
FIG. 4. Nematopsis spores (970X)
FIG. 5. *Ancystrocoma* (970X)





Oyster tissues: Sectioned at 6 microns; stained with iron haematoxylin and eosin. (Photographs taken by C. Austin Farley, U.S.B.C.F., Oxford, Md.

FIG. 6. *Dermocystidium* (970X) (a) Rosette stage (b) Hypnospore stage.
FIG. 7. MSX: Note Plasmodia at A and B.

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Observations on the Commercial Potential of Tuna in the Oceanic Northwest Atlantic

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Abstract

Explorations using tuna longline gear in the oceanic northwest Atlantic, from off Cape Hatteras to east of Bermuda and north to near the Grand Banks, indicate that bluefin tuna, *Thunnus thynnus*, and yellowfin tuna, *Thunnus albacares*, are to be found in potentially commercial quantities.

Exploratory catches by the research vessels DELAWARE, CRAWFORD, SILVER BAY, SHOYO MARU and CAP'N BILL III are projected to a theoretical catch rate of 100 ten-hook baskets of tuna longline gear.

Bluefin tuna appear very abundant in the general area of the Gulf Stream from late fall to late spring; yellowfin tuna were taken in commercial quantities in the

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