Recent Studies in the United States on Parasites and Pathogens of Marine Mollusks With Emphasis on Diseases of the American Oyster, Crassostrea virginica Gmelin

William J. Hargis Jr.

Follow this and additional works at: https://scholarworks.wm.edu/vimsbooks

Part of the Marine Biology Commons, and the Parasitology Commons
Parasitology and Pathology of Marine Organisms of the World Ocean

William J. Hargis, Jr. (Editor)

March 1985
Recent Studies in the United States on Parasites and Pathogens of Marine Mollusks With Emphasis on Diseases of the American Oyster, *Crassostrea virginica* Gmelin¹

WILLIAM J. HARGIS, Jr.²

ABSTRACT

Morphological, systematic, faunal, and life cycle studies predominated research on marine parasites and pathogens in the United States before World War II. Much was primarily basic or academic in nature. Since then it has grown and diversified under pressure of efforts to: 1) increase yields of invertebrate-based fisheries, in nature and under controlled conditions; and 2) understand, protect, and improve the resources, estuarine and marine environments, and human health and welfare. Over the last 30 yr pathobiological investigations of economically and ecologically important marine invertebrates have broadened into submicroscopical anatomy (TEM and SEM techniques), physiology, immunology, genetics, host-parasite ecology, interactions between environmental pollution and disease, and prophylaxis and treatment of their diseases.

Importation of foreign oysters (and other shellfish species) and their transfer and transplantation between the coastal regions, provinces, and states of North America have resulted in growing disease problems and a corresponding interest in the parasitology and pathology of the mollusks involved. It has also spawned efforts to control introductions and transfers.

Two major diseases have been found to interfere with production of native Atlantic oysters along the Gulf and/or Atlantic coasts of the United States. These are the “Dermo” or “Hemangium” disease, caused by the apicomplexan protistan *Perkinsus marinus* (both coasts) and “MSX” or Delaware Bay disease, caused by the sporozoan *Haplosporidium nelsoni* (the Atlantic coast—principally in Chesapeake and Delaware Bays). Knowledge of these important epizootic-producing diseases is reviewed and discussed, along with that of other parasites and pathogens of molluskan shellfish in North America, and an extensive References section of the results of recent research on molluskan parasites and diseases is presented.

INTRODUCTION

Most of the research on parasites and pathogens of marine invertebrates has taken place in this century. Faunal, morphological, systematic, and life cycle studies predominated the literature before World War II. Much early work on parasites of invertebrates was primarily basic or academic in nature or on animals used in experimentation, but even then the necessity to explain unusual or catastrophic events, such as fish kills, major declines in fishery catches, impacts of plankton blooms (such as red tides and mahogany waters), the impacts of pollution on fishery populations, and other practical questions predominated.

Since World War II, research has increased markedly. More scientists and institutions are involved in pathobiology of marine invertebrates and invertebrates than ever before. Academic interest continues to be a force but the need to produce more shellfish (Mollusca and Crustacea) on a sustained basis from coastal and ocean waters and to protect the environment and human health have been primary factors prompting government support for these studies. The growth of commercial display aquaria and of laboratory experimentation with marine fishes and invertebrates has also encouraged interest in parasites and diseases.

New knowledge, techniques, and equipment have enabled pathobiological investigations to broaden into submicroscopic anatomy (i.e., studies of ultrastructure using scanning and transmission electron microscopes), immunobiology, immunochemistry, genetics, host-parasite ecology, microecology, physiological ecology, and research on techniques for prophylaxis and treatment of disease.

The development of marine aquaculture has increased the need to understand the impacts of parasites and pathogens on the marine invertebrates being used. Mollusks, being among the easiest of marine invertebrates to “farm” or bring under culture are of special interest. Most research activity on parasites and pathogens of this group centers upon bivalves of the genera *Ostrea* and *Crassostrea* of the family Ostreidae because of their economic importance, but numerous other shellfish are involved also.

The increase in importation of mollusks from other countries such as *Crassostrea gigas* Thunberg 1793, the Pacific oyster, and *Ostrea edulis* Linnaeus 1758, the European flat oyster, has resulted in introduction of new parasites and diseases into the United States. Further, transfer of these and endemic species of mollusks around the coast of North America has caused the spread of their parasites (and predators as well). The problem of importation of foreign parasites and pathogens (from other countries or regions) has become of sufficient importance to cause development of specific control procedures such as the establishment of controlled or prohibited areas and species, examination and certification, and quarantine arrangements. Of concern to science, industry, and government are the oysters mentioned above as well as the mussels *Mytilus edulis*, Linnaeus, 1758; *Brachidontes recurvis* Rafinesque, 1820; and others. Interest in the parasites and diseases of other commercially important mollusks such as *Mercenaria*...
arenaria (Linnaeus, 1758), the soft clam; *Mercenaria* (Linnaeus, 1758), the hard clam or quahog; *Mya arenaria* (Linnaeus, 1758), the surf clam; *Spisula solidissima* (Dillwyn, 1817), the bay scallop; *Placopecten magellanicus* (Gmelin, 1791), the ocean scallop; *Aequipecten irradians* (Lamarck, 1819), the red abalone, has grown also in the last decade due to increased interest in improved management or culture of these organisms. Consequently, most of the research is concentrated in the mollusk-producing regions of the northwestern United States (Oregon and Washington) and adjacent British Columbia, the Gulf Coast (Texas, Louisiana, Mississippi, Alabama, and Florida), the Mid-Atlantic (Virginia, Maryland, Delaware, New Jersey, and New York), the northeast (Connecticut, Rhode Island, Massachusetts, and Maine), and the nearby maritime provinces of Canada (Fig. 1). Research activity related to abalone occurs mostly in California. (A number of relevant publications are provided in the References section.)

The literature mentions a large number of symbionts (employed here in the broad sense) which infect oysters (*Ostrea* spp. and *Crassostrea* spp.) and other bivalves and cause diseases or are suspected of doing so (Appendix I). In his very useful recent publication, Sindermann (1977) listed 10 diseases of cultured oysters (*Crassostrea virginica* Gmelin, *Crassostrea gigas* Thunberg, and *Ostrea edulis* Linnaeus) in the United States and Canada and mentioned at least 6 others and there are more. The 10 primary diseases cause significant mortalities. Some of those in the “mentioned” category are merely suspected of causing disease, having been found in host tissues during surveys, but some are known to cause deaths also.

Undisturbed or relatively undisturbed natural populations of most (if not all) animals and plants bear parasites and pathogens.

Undoubtedly, disease-related mortalities occur in such populations. When man intervenes, either by altering the environment, by moving animals and plants to new habitats or by bringing them under culture, losses due to disease increase—sometimes so drastically that epidemics or epizootics involving numerous deaths occur. At times the extensive mortalities result in severe diminishment of production and ensuing commercial losses. Animals under culture or in experimental or display aquaria, which usually are crowded, are particularly troublesome in this regard.

In North America, oysters have been widely transported and transplanted and under crude culture since the end of the last century. In recent years oyster culture techniques have become more sophisticated, though most commercial producers continue to utilize procedures developed and refined well before World War II, which involve transplantation of young oysters, called “seed-oysters” from good setting beds to “grow-out” or fattening beds whence they are harvested when they or the market are ready. As would be expected, “oyster-kills” (severe mortalities) have occurred with some frequency on all coasts of the United States and Canada where oysters are under such culture. Two such disease events are the subject of the remainder of this paper.

Mortalities of *Crassostrea virginica* Gmelin populations along the gulf and east coasts of the United States and in Canada (Fig. 1) in the late 1940’s and the 1950’s and later in the late 1950’s and early 1960’s caused interest in the parasites and pathogens of *C. virginica* and related oysters to intensify. Federal and state governments and industry became especially concerned. Since my institution, the Virginia Institute of Marine Science, was involved deeply in both efforts, they will be described as examples.

**“DERMO” DISEASE OR “FUNGUS” DISEASE OF CRASSOSTREA VIRGINICA**

When the oil industry of the Gulf of Mexico was accused by oystermen of causing deaths in natural and cultivated beds of oysters (*C. virginica*) along the U.S. coast of the Gulf of Mexico (the gulf coast) in the late 1940’s, research was begun to find the possible cause or causes.

Scientists found the apicomplexan protistan *Perkinsus marinus* [Phylum Apicomplexa, Class Perkinsia, Order Perkinsida: first named *Dermocystidium marinum* and then *Labrynthomyxa marina* (which was then considered to be a fungus—hence the confusion in the common name of the disease)] to be responsible (see Appendix II). Investigations made elsewhere for the same reasons showed the organism to be present in natural and cultivated populations of oysters (*C. virginica* Gmelin) along the entire east coast of North America from Florida to Massachusetts as well as on the gulf coast (Fig. 1). From Chesapeake Bay southward and into the Gulf of Mexico, it causes mortalities of epizootic proportions; elsewhere it is mostly enzootic [except in Delaware Bay (Figs. 1, 2) in the mid-1950’s when mass mortalities, apparently due to importation of infected oysters from Virginia, were reported].

The pathogen can be identified easily in prepared cultures or in squashes or sections of tissue taken from live or moribund hosts. Crude experimental infections can be brought about in the laboratory but the etiological agent has not been obtained in pure culture.

Infections can be reduced or mitigated chemically under laboratory conditions, but not eliminated. Chemical control in nature is not now possible and may never be feasible due to the dilutive and dispersive nature of the “universal” solvent and/or
carrier—water. Under farming conditions, losses can be reduced by avoiding planting seed oysters in infested high salinity areas. This salinity relationship has been demonstrated in the laboratory and in nature. As recently as 1982 the pest moved into waters from which it was previously excluded, when drought in 1980 and 1981 caused salinities in Chesapeake Bay to increase and “move” upstream. The parasite does not do well in salinities below 15 ppt. Losses can also be reduced by timing the planting and harvesting of the host. The parasite is also temperature-dependent and causes most mortalities in summer and early fall when water temperatures are between 25° and 33°C. Intensity of infection and mortalities can be reduced by controlling the density of planting, since it has been found to be density-dependent as well.

Because the pathogen, *P. marinus*, has not been isolated in pure culture, Koch’s postulates have not been satisfied. Additionally, the life cycle is not completely understood and it is not known whether reservoir or intermediate hosts are required or involved but it may not require them because of its mode of sporulation and the fact that in some observations infections seem to be spread to other hosts by material from disintegrating neighbors. It forms sporangia which release biflagellate zoospores. That some related organisms have direct life cycles adds strength to the arguments of J. D. Andrews of the Virginia Institute of Marine Science and others who contend that no alternate hosts are involved. It (or closely related species) has (have) been found in many other bivalves (Appendix I).

**“MSX” DISEASE OR “THE DELAWARE BAY” DISEASE OF CRASSOSTREA VIRGINICA**

In 1957, mortalities began to occur in cultivated populations of oysters (*C. virginica*) in Delaware Bay. Because of the proximity, even contiguity of Chesapeake Bay through the connecting Chesapeake and Delaware Canal and via the intervening Atlantic coastal lagoons and embayments and the associated intracoastal waterway, and because of frequent transfer of hosts between these bodies of water by fishermen, scientists anticipated infestation of the Chesapeake system (Fig. 2). Industry and government became concerned, and considerable scientific effort was mounted in the states of New Jersey (Rutgers University), Virginia (Virginia Institute of Marine Science—VIMS), and Maryland (Chesapeake Biological Laboratory at Solomons Island, Maryland—now a part of the University of Maryland Center for Environmental and Estuarine Studies).

The disease, called “MSX-disease” (for Multinucleated Spore X—a name coined before the causative agent was discovered and described), or “Delaware Bay disease,” was found by epidemiological techniques to be caused by a “sporozoan” (Phylum Balanosporida, Class Stellatosporea, Order Balanosporida) parasite *Haplosporidium nelsoni* (=*Minchinia nelsoni*). See Appendix II for taxonomic placement. The pathogen was found in populations of *C. virginica* from Massachusetts to North Carolina but was most concentrated in populations in Delaware Bay and Chesapeake Bay, where it caused mortalities of from 50 to 60% annually until the commercial plantings in infested areas were killed by the pathogen or harvested by industry. In Delaware Bay (Fig. 2), oyster production dropped from about 2 million bu to about 10,000 bu annually in about 2 yr. In Virginia’s Chesapeake Bay (Figs. 2, 3), it dropped from 4 million to 2 million bu/yr in a...
similar period (1 U.S. bushel = about 35.2 l). It is still present and a threat in formerly infested regions of appropriate salinity.

Epidemiological studies indicate MSX disease to be salinity-dependent, occurring in areas ranging from 15 to 35 ppt. Figure 3 depicts the areas of infestation of lower Chesapeake Bay and the coastal lagoons of Virginia's Eastern Shore. In this figure the oyster-growing areas are classified according to level of MSX infestation occurring in years of average rainfall and salinity. These zones are used in management by accommodation or avoidance techniques. During drought years, higher salinity water moves upstream in the Bay and its tributaries and invades areas where the water was previously fresh. Since MSX is salinity-dependent, it is able to invade formerly uninfeeted zones or intensify where it already is, depending upon the level of saltiness of the water. It is most lethal at 20 to 25 ppt. This salinity dependence was again demonstrated forcefully in 1982 when MSX infections and associated mortalities appeared in the normally disease-free and lower salinity waters of upper Chesapeake Bay due to the drought of 1980 and 1981.

Like P. marinus above, it is also temperature-dependent, but not as closely so (most deaths occur in summer but some occur in late winter as infected individuals succumb to the combined stresses of over-wintering plus disease and associated poor physiological condition). First year oysters normally are not killed but older ones are.

MSX, or Delaware Bay disease, cannot be treated in the laboratory or in nature but can be avoided by not planting susceptible seed or market oysters in areas of known high infestation and by timing the planting and harvesting of oysters to avoid periods of highest mortality in areas of moderate infestation. As with Dermo-disease, chemical control is not now possible and may never be feasible. Disease resistance apparently develops in populations endemic in areas infested with the pathogen, but introduction of new susceptible hosts usually results in numerous deaths. Some investigators and institutions claim to have developed disease-resistant strains by controlled breeding techniques. Their aim in these research efforts has been to develop resistant oysters to be used as "brood-stock" to replenish populations in MSX-decimated areas.

The pathogen has not been isolated and the requirements of Koch's postulates have, therefore, not been met. The life cycle is not fully elucidated and it is not known whether intermediate hosts or reservoir hosts other than oysters are involved. As the scientific name implies, encapsulated spores are formed. Some investigators contend that no intermediate or reservoir hosts are required. Others argue that they are. It is known that organisms very much like H. nelsoni occur in other bivalves and in some shipworms and other crustaceans.

A similar and related disease occurs in oysters (C. virginica) in the coastal regions and tributaries of the Eastern Shore of Maryland and Virginia and extends northward into the waters of Long Island (Figs. 1, 2, 3). SSO disease, called thus for "seaside organism," is caused by Haplosporidium costale (Appendices I and II), a relative of the MSX organism, H. nelsoni.

Research to answer the unanswered questions mentioned above continues on both "Dermo" and "MSX" diseases of Crassostrea virginica. Solution of some of the critical remaining questions, especially those relating to isolation and culturing of the pathogens, explanation of the life cycle, and development of methods of mitigation, prevention, or cure, is of importance in efforts to restore oyster production in both Delaware and Chesapeake Bays.

During the course of the research on the parasites and pathogens of Crassostrea and Ostrea, species of which have been imported from the Far East and Europe and moved around between the coastal waters of North America, science has learned that diseases endemic to Crassostrea virginica or to a single geographical location have been transferred to other areas as industry has moved the hosts around. Additionally, parasites and diseases have been brought to North America with imports of C. gigas from the Far East and O. edulis from Europe. They have been spread around North America. Many in the United States oppose direct importation or transfer of hosts from one area to another. As indicated above, some states have taken measures to restrict importation and intrastate transfer.

In summary, studies on both of these diseases typify the threat and status of marine invertebrate pathobiological research in the United States, which is largely devoted to examining: 1) The roles of parasites and pathogens in natural, cultivated, and captive populations of economic importance; 2) the interactions between parasites and pathogens and pollution; 3) human health aspects of invertebrate diseases; 4) the impacts on marketability of fishery products; and 5) mitigation, prevention, or treatment of diseases in experimental or economic-level culture activities. Lessons learned demonstrate forcefully that transfer of hosts and their parasites to new regions, or exposure of susceptible hosts to parasites of relatives in new regions, can be dangerous and that importation and exportation of oysters and other shellfish must be done with great care. They also emphasize the importance of an adequate knowledge of the host and its parasites and pathogens and the ability to assure good quality water in proper management of the fisheries and of aquaculture and in the maintenance of natural populations.

REFERENCES

ANDREWS, J. D.
ANDREWS, J. D., and M. FRIERMAN.
ANDREWS, J. D., and W. G. HEWATT.
ANDREWS, J. D., and J. L. WOOD.
ANDREWS, J. D., J. L. WOOD, and H. D. HOESE.
BECKERT, H., D. G. BLAND, and E. B. MAY.
BREISCH, L. L., and V. S. KENNEDY.
CHEW, K. K., A. K. SPARKS, and S. C. KATKANSKY.
1965. Preliminary results on the seasonal size distribution of Mytilicola oren-
GALTSOFF, P. S.

HELM, M. M., and F. M. SMITH.

DRINNAN, R. E., and L. A. ENGLAND.

FARLEY, C. A.

HASKIN, H. H., L. A. STAUBER, and J. B. MACKIN.

KERN, F. G., L. C. SULLIVAN, and M. TAKATA.

DAVIS, H. C., V. L. LOOSANOFF, W. H. WESTON, and C. MARTIN.


1952. Oyster disease caused by *Dermo­


1957. Oyster disease caused by *Dermo­

1979. Cell structure of the shellfish pathogens and hyperparasites in the *Dermo­

1947. Serious mortalities in Prince Edward Island oysters caused by a con­

1977. *Dermo­


1960. The taxonomic relationship of *Dermo­

1970. Oyster disease caused by *Dermo­


APPENDIX I

A PARTIAL LIST OF IDENTIFIED DISEASES OF BIVALVE MOLLUSKS IN NORTH AMERICAN MARINE WATERS

A. Viral

1. Herpes-type virus diseases
   a. Digestive gland virus disease—Crassostrea virginica, mortalities reported, Piscataqua River, Maine
   b. Genital tissue or ovacystis disease—C. virginica (Papova virus?)
   c. Digestive gland virus disease—C. virginica (C-type oncorna virus)
   d. Neoplasmic disease—Mya arenaria (uncharacterized filterable agent)
   e. Lukemic disease—Mya arenaria (probable virus infection)

B. Chlamydia

Chlamydial disease—Mercenaria mercenaria, the hard clam (digestive diverticulum—Chesapeake Bay)

C. Bacteria

1. Bacillary necrosis—C. virginica larvae (Vibrio anguillarum, V. alginolyticus, Vibrio spp., also possibly aero monads and pseudomonads, U.S. east coast)
2. Bacillary necrosis—Mercenaria mercenaria larvae (same etiological agents as above, U.S. east coast)
3. Focal necrosis—C. gigas (unidentified gram-positive bacterium—Willapa Bay, Wash.)

D. Fungi

1. Dermo-disease—C. virginica (Perkinsus marinus)—severe mortalities in waters of gulf coast and east coast, United States. Also found in Ostrea equestris, O. frans, Mercenaria mercenaria, Mya arenaria, Argopecten irradians, Brachidontias recurvis, Martesia spp., and others.

2. Larval mycosis of oysters—C. virginica (Sirolpidium zoophthorum—U.S. east coast)
3. Larval mycosis of clams—Mercenaria mercenaria (Sirolpidium zoophthorum—U.S. east coast)

E. Protozoan

1. MSX disease or Delaware Bay disease—C. virginica (Haplosporidium nelsoni—U.S. east coast)
2. Seaside disease—C. virginica (Haplosporidium costalis—high salinity coastal waters extending from Chesapeake Bay mouth to Long Island Sound)
3. Hexamitiasis—C. virginica [Hexamita inflata (a flagellate) —Prince Edward Island, Canada]
4. Nematopiasis—C. virginica [Nematopsis ostrearum (a gregarine)—Chesapeake Bay to Louisiana]

F. Metazoan

1. Mytilicola or red worm disease—C. gigas and Ostrea lurida—the Olympic oyster [Mytilicola orientalis (parasitic copepod)—U.S. west coast]. Also reported from mussels.
2. Trematodiasis—C. virginica [Bucephalus haimeanus (Digenea)—brackish waters U.S. east coast and elsewhere]

G. Diseases of unknown etiology

1. Malpeque Bay disease—C. virginica (causative agent unknown—Gulf of St. Lawrence, Canada)
2. Denman Island disease—C. gigas (agent unknown—British Columbia, Canada)
APPENDIX II

CURRENT TAXONOMIC ARRANGEMENTS OF THE PROTISTAN OYSTER PARASITES DISCUSSED

Subkingdom Protozoa

Phylum Apicomplexa Levine, 1970
  Class Perkinsea Levine, 1978
    Order Perkinsida Levine, 1978
      Genus Perkinsus (≡ Dermocystidium, partim)
        Perkinsus marinus (Mackin, Owen, and Collier, 1950)
          (≡ Dermocystidium marinum Mackin, Owen, and Collier, 1950)

Phylum Ascetospora Sprague, 1978
  Class Stellatospora Sprague, 1978
    Order Balanosporida Sprague, 1978
      Genus Haplosporidium (≡ Minchinia, partim)
        Haplosporidium nelsoni (Haskin, Stauber, and Mackin, 1966)
          (≡ Minchinia nelsoni Haskin, Stauber, and Mackin, 1966)
        Haplosporidium costalis (Wood and Andrews, 1962)
          (≡ Minchinia costalis Wood and Andrews, 1962)
    Order also includes the Genera Urosporidium and Minchinia