International Council for
The Exploration of the Sea

C.M.1977/E:15
Fisheries Improvement Committee

A SYNOPSIS OF DISEASES AND DISEASE CONTROL MEASURES IN UNITED STATES MARINE AQUACULTURE

by

Carl J. Sindermann
U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Sandy Hook Laboratory
Highlands, New Jersey 07732

SUMMARY

A number of diseases have been identified in culture populations of marine/estuarine fish and shellfish in United States. Larval diseases, principally of microbial etiology, have proved to be of significance. Many of the diseases in culture populations, at any life history stage, seem to result from activities of facultative pathogens, operating on stressed animals -- with water quality and nutrition as important determinants. Disease control measures emphasize reduction in environmental stresses, with additional prophylactic and chemotherapeutic steps as required.

CONTENTS

INTRODUCTION

Interest in marine aquaculture has increased in United States and elsewhere in the world -- as a source of high unit value commercial products and as a source of animal protein. The necessary technological base for successful commercial aquaculture includes such biological contributions as nutrition, genetic selection, and disease control. During the past decade much new information has been developed about the diseases of principal marine/estuarine aquaculture species -- and about measures to control such diseases.

The amount of information available at present seems to warrant attempts at summarization -- recognizing that in this or any other dynamic research and development area, the accumulation of new knowledge quickly renders the summarization obsolete. This paper provides a synopsis of present understanding of what seem to be the significant disease problems in United States marine aquaculture -- and of the control measures that have been tried.

Principal crustacean species considered are the penaeid shrimps, Malaysian prawn, lobster, and blue crab; principal molluscan species are oysters and clams; and principal fish species are salmon, pompano and striped bass. For each of these groups a list of significant diseases has been assembled, together with suggested control methods.

CRUSTACEAN DISEASES

Crustaceans which are receiving the most research and development attention in the United States at present are (in order of priority) penaeid shrimps (genus Penaeus), Malaysian prawns (Macrobrachium rosenbergii), lobsters (Homarus americanus), and blue crabs (Callinectes sapidus). Only the culture of penaeid shrimps has reached the large scale commercial production stage; Malaysian prawns are in limited production; and the others are still in the research and development stage.

Penaeid Shrimp Diseases

Principally because of the extensive research, development, and production activity in culture of shrimps of the genus Penaeus, much information about diseases and their control has become available. At present, nine diseases -- one viral, three bacterial, two fungal and three protozoal -- seem to constitute reasonable entities, with several others of unknown or uncertain etiology. An apparent problem is the proper recognition of what can be called generalized disease signs, such as black gills, which may result from a number of causes, infectious and non-infectious. Some of the diseases described seem clearly related to unsatisfactory water quality.

TABLE 1. PENAEID SHRIMP DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Penaeus duorarum, P. aztecus	Virus disease	Baculovirus penaei	Polyhedral intranuclear inclusion bodies in hepatopancreatic cells; mortality under stress	None reported
All Penaeus spp.	Vibrio disease	genus Vibrio -- principally V. parahemolyticus, V. alginolyticus, and V. anguillarum	Disorientation, muscle opacity, abdominal flexure, turbid hemolymph	Terramycin, Furacin, Furanace
All Penaeus spp.	Shell disease (Brown spot disease)	Chitinolytic bacteria (Benekea, Vibrio and Pseudomonas)	Brown eroded areas on exoskeleton, often beginning as discrete circular spots	Prevent injuries which act as portal of entry; treat with Terramycin, malachite green plus formalin
Penaeus aztecus, P. setiferus, P. vannamei, P. californiensis P. stylirostris	Filamentous bacterial disease	genus Leucothrix (and possibly other related genera	Filamentous growth on appendages and gills	Maintain water quality; treat with cutrine plus, copper chloride

TABLE 1 --continued

Host species	Disease	Cause	Disease signs	Control measures
All *Penaeus* spp.	Larval mycosis	*Lagenidium callinectes*	Extensive branched mycelium throughout body	Malachite green, Treflan
Penaeus duorarum *P. aztecus*, *P. californiensis*, *P. stylirostris*, *P. occidentalis*	*Fusarium* disease	*Fusarium solani*	Expanding lesions, usually blackened, on body surface, gills, appendages; extensive mycelium with characteristic boat-shaped conidia on surface of lesions	Nystatin, Azalomycin F
Penaeus duorarum, *P. setiferus*, *P. aztecus*, *P. braziliensis*	Cotton shrimp disease	Microsporida: *Nosema nelsoni*, *Thelohania duorara*, *Pleistophora* sp.	Opaque white areas in abdominal muscles; characteristic microsporidan spores in muscle squashes	Destroy infected stock, sterilize equipment
Penaeus setiferus	Microsporidiosis of reproductive organs	*Thelohania penaei*	Opaque white areas along dorsal midline of shrimp; characteristic microsporidan spores in squashes	Destroy infected stock; sterilize equipment
All *Penaeus* spp.	Ciliate disease	*Zoothamnium penaei*, *Epistylis* sp. (and possibly other ciliates	Fuzzy mat on gills and appendages; stalked ciliates easily seen in wet mounts	Maintain water quality; treat with formalin, quinacrine hydrochloride

Note: Diseases of uncertain or unknown etiology include: Black gill disease, "Black death" disease, Blisters on the carapace, cramped tails, and muscle necrosis.

Malaysian Prawn Diseases

Several species of fresh-water prawns, particularly the giant Malaysian prawn, Macrobrachium rosenbergii, have been subjects of intensive culture efforts in the United States and elsewhere during the past decade. Because spawning and larval development occur in saline waters, these animals logically become part of marine aquaculture.

Thus far, disease problems with Macrobrachium culture have been relatively minor, and seem to result largely from poor water quality or other stresses characteristic of artificial environments.

TABLE 2. MACROBRACHIUM DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Macrobrachium rosenbergii; M. vollenhovenii	Black spot disease	Chitinolytic bacteria (Benekea, Pseudomonas, Aeromonas)	Progressive erosion of exoskeleton, beginning as small brown spots	Reduce stocking density; handle carefully; treat with Furanace
M. rosenbergii	Filamentous bacterial disease	genus Leucothrix	Filamentous growth on body surfaces	Mass water exchange; reduce stocking density; treat with Furanace, Nitrofurazone
M. rosenbergii	Ciliate disease	Epistylis sp. Zoothamnium sp.	Fuzzy mat on body surfaces, composed of stalked ciliates	Sulfaquinine; acetic acid; malachite green, copper sulfate
M. rosenbergii	Muscle opacity and necrosis	Environmental or physiological stress	Body muscles become opaque, and, if stress is prolonged, necrotic	Maintain optimal culture conditions; reduce stress factor quickly when first signs appear

Note: Diseases of unknown or uncertain etiology include: Bacterial necrosis, Black nodules, various fungus infestations, and a protozoan disease -- possibly caused by a suctorian.

Lobster Diseases

Natural production of the American lobster, Homarus americanus, has been unable to meet market demand, despite continuously increasing prices. Several major multidisciplinary research and development projects exist in the United States and in Canada, and much information has accumulated about a number of lobster diseases. Seven have been recognized as being of significance in culture systems, three bacterial, three fungal, and one protozoal.

TABLE 3. LOBSTER DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Homarus americanus	Gaffkemia	Aerococcus viridans (var. homari)	Lethargy; hemolymph does not clot; gram positive tetrads in blood, some phagocytized	Strict sanitation in holding tanks; treat with Vancomycin
	Shell disease	Chitinolytic bacteria	Exoskeleton pitted and eroded; gills may be necrotic	Cull infected individuals; enforce strict sanitation in holding tanks; treat with malachite green
	Filamentous bacterial disease	Leucothrix sp.	Fuzzy coating on eggs and larvae in advanced cases	Maintain sterility of influent water; treat with malachite green
	Lagenidium disease	Lagenidium sp.	Larvae opaque, with fungus mycelium permeating entire body, often beginning in appendages	Strict cleanliness of larval rearing systems; treat with malachite green
	Haliphthoros disease	Haliphthoros milfordensis	Necrotic lesions accompanied by dark red-brown melanization; melanized tissues contain fungus mycelium	Strict cleanliness of culture systems; treat with malachite green; Furanace

TABLE 3 -- continued

Host species	Disease	Cause	Disease signs	Control measures
Homarus americanus	*Fusarium* disease	*Fusarium solani*	Black spots on exoskeleton and brown discoloration of gills	Strict water quality control; remove infected individuals
	Ciliate disease	*Anophrys* sp.	Hemolymph cloudy or milky due to presence of large numbers of ciliates	None reported

Blue Crab Diseases

Annual production of blue crabs, Callinectes sapidus, on the East and Gulf Coasts of the United States is high, but variable from year to year. Market demand makes it a desirable species for culture and some limited attempts are being made. The recognized diseases of blue crabs of significance to culture operations have increased in number rapidly. At present ten diseases -- two viral, two bacterial, one fungal, and five protozoal -- have been described.

TABLE 4. BLUE CRAB DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Callinectes sapidus	Herpes-like virus disease	Herpes-like virus	Hemolymph chalky white, hemocytes with enlarged nuclei and refractile cytoplasmic inclusions	Dispose of infected groups of crabs; clean and decontaminate tanks before reuse
	Reovirus-like virus disease	Reovirus-like virus	Failure to molt; lethargy; paralysis; brown-spotted exoskeleton; gills red-brown; viral inclusions in cytoplasm of hemopoietic cells	Dispose of infected groups of crabs; disinfect holding tanks before reuse
	Bacterial disease	Gram-negative bacteria, often Vibrio sp.	Lethargy; opaque white nodules in tissues and gills; massive hemolymph clotting	Maintain water quality; handle crabs carefully
	Shell disease	Chitinolytic bacteria	Necrotic lesions of exoskeleton, beginning as discrete brown spots	Remove infected individuals; handle crabs carefully

TABLE 4 -- continued

Host species	Disease	Cause	Disease signs	Control measure
Callinectes sapidus	Fungus disease of eggs and larvae	Lagenidium callinectes	Eggs become opaque, and entire egg mass assumes a grey to brown color. Infected larvae become quiescent and die	Destroy females with infected egg masses; commercial fungicides tested, but may affect egg hatching
	Microsporidiosis	Nosema michaelis	Muscles develop opaque chalky appearance; characteristic microsporidan spores in muscle squashes	Destroy infected crabs; Buquinolate prevents experimental infections
	Paramoebiasis	Paramoeba perniciosa	Lethargy; greyish discoloration of ventral surface of crab; amoebae with two nucleus-like bodies in hemolymph	None reported
	Haplosporidan disease	Minchinia sp.	Lethargy; hemolymph opaque and does not clot; spherical uninucleate or multinucleate bodies in hemolymph	None reported
	Ciliate disease	Lagenophrys sp.	Gills infested with ovoid tests formed by the ciliate	Avoid crowding; treat with formalin dips
	Hematodinium disease	Hematodinium perezi	Lethargy; opaque hemolymph, containing large numbers of the uninucleate non-motile dinoflagellate cells	None reported

MOLLUSCAN DISEASES

Most of the molluscan aquaculture in the United States concentrates on oysters, although there are limited research and development projects with bay scallops, abalone, and several species of clams. Disease problems can be categorized as (1) larval diseases in hatcheries, and (2) epizootic and enzootic diseases in extensive open-system culture. Some control measures have been developed for diseases in both categories -- with environmental and stock manipulation the method of choice in extensive culture.

Oyster Diseases

Aquaculture of oysters in the United States emphasizes two species -- the American oyster, *Crassostrea virginica*, and the Pacific oyster, *Crassostrea gigas*. There is some very limited culture of the Olympia oyster, *Ostrea lurida* and the European oyster, *Ostrea edulis*. Oyster hatcheries now exist on both coasts, but their contribution to commercial production -- when compared to natural set -- is small.

Hatchery diseases recognized so far are bacterial and fungal, and seem related to water quality. The most important diseases in grow-out areas are fungal and protozoal.

TABLE 5. OYSTER DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Crassostrea virginica	Virus disease	Herpes-type virus	Sporadic mortalities; pale digestive gland; intra-nuclear inclusion bodies	None reported, but environmental temperature may be a factor
C. virginica	Bacillary necrosis	*Vibrio* spp. (and possibly certain pseudomonads and aeromonads)	Decrease in larval motility; high sudden mortalities; bacterial swarming apparent microscopically	Maintain water quality; treat with antibiotics (combistrep, chloramphenicol, polymyxin[B], erythromycin, neomycin)
C. gigas	Focal necrosis	Unidentified gram-positive bacteria	Sporadic mortalities in seed and adult oysters; multiple abscesses in tissues	None reported

TABLE 5 -- continued

Host species	Disease	Cause	Disease signs	Control measures
C. virginica	Larval mycosis	Sirolpidium zoophthorum	Growth of larvae ceases; sporadic mortalities; fungus mycelium invades entire body	Filtration and ultraviolet sterilization of culture water helps to prevent outbreaks
C. virginica Ostrea frons, O. equestris	Fungus disease	Dermocystidium marinum (Labyrinthomyxa marina)	Late summer and early autumn mortalities in grow-out areas; emaciation in chronic infections; characteristic life history stages of the fungus in histological sections	Low density planting; avoid high salinity areas; follow seasonal grow-out schedule
C. virginica	Delaware Bay disease	Minchinia nelsoni	Poor condition of oysters; mantle and shell lesions; mass mortalities	Transfer infected stock to low-salinity areas; rear seed in epizootic areas if possible; limit length of culture
C. virginica	Seaside disease	Minchinia costalis	Growth ceases; sharp mortality peak in early June	Transplant stock to low salinities; early harvest at minimal size
C. gigas O. lurida	Mytilicola disease	Mytilicola orientalis	Poor growth and condition; sporadic mortalities; dissection discloses reddish worm-like copepods in digestive tract	None reported

Note: Diseases of unknown or uncertain etiology include: two additional viruses, Malpeque Bay disease, and Denman Island disease.

Clam Diseases

Hatching, rearing and limited production of hard-shell clams, Mercenaria mercenaria, exists on a small scale on the United States east coast. Other species, such as the east coast surf clam, Spisula solidissima, and several west coast clams have attracted some research attention, but at present almost all clam production is from natural beds. Only two diseases -- bacillary necrosis and larval mycosis -- have been clearly associated with larval mortalities, although a number of bacteria have been shown to have deleterious effects.

TABLE 6. CLAM DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Mercenaria mercenaria	Bacillary necrosis	Vibrio spp. (and probably pseudomonads and aeromonads)	Decrease in larval motility; high sudden mortalities; bacterial swarming apparent microscopically	Maintain water quality; treat with antibiotics (combistrep, chloramphenicol, polymyxin^{B}, erythromycin, neomycin)
M. mercenaria	Larval mycosis	Sirolpidium zoophthorum	Growth of larvae ceases; sporadic mortalities; fungus mycelium invades entire body	Filtration and ultraviolet sterilization of culture water helps to prevent outbreaks

Note: A number of other diseases of uncertain etiology have been described from clams, including shell deformities, and bacterial infections (principally Vibrio and Pseudomonas).

FISH DISEASES

A number of marine, estuarine, and anadromous fish species are in experimental or pilot plant stages of salt-water culture in the United States, but only the Pacific salmon is in the production stage. Other species receiving some research attention include pompano, striped bass, Atlantic salmon, and mullet.

Salt-water rearing of fish, using net enclosures or so-called "silo" techniques of intensive culture, has encountered sporadic disease problems -- with vibrio infections among the most serious.

Pacific Salmon Diseases

Commercial-scale rearing of Pacific salmon (Oncorhynchus spp.) in salt water has been undertaken on both coasts of the United States in the past several years. Salt-water rearing has had to contend with some of the classic diseases of fresh-water salmon hatcheries -- furunculosis and kidney disease -- but also with severe problems with halophilic vibrios, particularly Vibrio anguillarum. For several years the continued survival of salt-water rearing attempts with salmon seemed to hinge on solution to the vibrio problem. Some successful control methods have been developed, but the problem still exists. At present, three bacterial infections are of significance in salt-water culture of salmon -- vibriosis, furunculosis and kidney disease. Other disease problems exist, but they seem to be of lesser importance at present.

TABLE 7. PACIFIC SALMON DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Oncorhynchus tshawytscha, O. keta, O. nerka, O. gorbuscha, O. kisutch, O. masu; Salmo salar, S. gairdneri, S. clarki, S. trutta	Vibriosis	Vibrio anguillarum	Inactivity; cessation of feeding; necrotic lesions of abdominal musculature; exophthalmos, erythema at bases of fins; mortality	Avoid stresses of handling and overcrowding; prophylactic immunization with polyvalent vaccine; treat with oxytetracycline

TABLE 7 -- continued

Host species	Disease	Cause	Disease signs	Control measures
Oncorhynchus nerka O. keta, O. tshawytscha, O. gorbuscha, O. kisutch; Salmo salar, S. gairdneri	Furunculosis	Aeromonas salmonicida	Acute: rapid mortality with few external signs; Chronic: large furuncles in muscles; erythema at bases of fins; hemorrhages in skin and viscera	Avoid stresses of overcrowding and high temperatures; treat with oxytetracycline, sulfamerazine
Primarily Oncorhynchus kisutch; but also in O. tskawytscha, O. gorbuscha, O. keta, O. nerka, O. masu; Salmo salar	Kidney disease	Coryne-bacterium sp.	Cessation of feeding; lethargy; exophthalmos; edema; sudden mortality in second year in salt water	Select disease-free stock; avoid unpasteurized food; treat with sulfamerazine

Note: Other diseases, of lesser significance than the above, have been reported from salt-water reared salmon. They include: myxobacterial (Sporocytophaga) disease; protozoan (Trichodina) disease; and parasitic copepod infestations.

Pompano Diseases

Pompano, *Trachinotus carolinus*, has long been a delicacy in southeastern United States, but supplies from natural stocks have been limited. During the past decade a number of attempts at artificial spawning and rearing have been made. Culture methods include tanks, floating pens, and silos. Several disease problems have emerged -- but thus far those reported are mostly controllable.

TABLE 8. POMPANO DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Trachinotus carolinus	White spot disease	*Cryptocaryon irritans*	Pinhead size white cysts on gills and body surfaces	Clean and sterilize grow-out tanks; treat with tris, formalin, or cupric acetate
	Cardiac myxo-sporidiosis	*Henneguya* sp.	Sporadic mortalities; small white cysts on and in heart; cysts contain typical myxo-sporidan spores	Clean and sterilize grow-out tanks; remove and destroy abnormal individuals
	Dinoflagellate infestation	*Amyloodinium ocellatum*	Any abnormal or erratic swimming behavior; tiny white spots on fins and skin	Fresh-water and copper sulfate baths
	Monogenetic trematode infestation	*Benedenia* sp., *Bicotylophora trachinoti*	Small white worms on gills; pigmented worms (*Benedenia* sp.) on body surfaces	Avoid overcrowding; remove infested fish; treat with formalin baths
	Fatty liver degeneration	Dietary deficiency	Poor growth; emaciation; lethargy; cessation of feeding; edema; sporadic mortalities	Provide diets adequate in protein

Note: Other poorly defined diseases of pompano include bacterial infections, and infestations by *Trichodina* and *Scyphidium*.

Striped Bass Disease

The striped bass, Morone saxatilis, is an anadromous species which now occurs on both coasts of the United States, and is highly valued as a sport fish. Salt-water and brackish water rearing is being attempted on a limited scale, using ponds and floating pens in thermal effluents. Several diseases have been observed, but few control measures have been developed.

TABLE 9. STRIPED BASS DISEASES

Host species	Disease	Cause	Disease signs	Control measures
Morone saxatilis	Lympho-cystis	Irridovirus	Raised grayish-white nodules on fins and body surfaces, often becoming confluent	Destruction of infected individuals reduces the spread of the disease; fish usually recover spontaneously
	Epithelio-cystis	Microorganisms of the Bedsonia group	Raised white patches on gill lamellae	Not reported
	Fin erosion	Gram-negative bacteria -- Vibrio, Pseudomonas, Aeromonas	Variable erosion of fins, particularly caudal; may be accompanied by systemic bacterial infection	Avoid stresses of overcrowding, temperature extremes, and poor water quality; treat with oxytetracycline

TABLE 9 -- continued

Host species	Disease	Cause	Disease signs	Control measures
Morone saxatilis	*Pasteurella* disease	*Pasteurella piscicida*	No external signs; white nodules in viscera; mortalities	Minimize environmental stresses; treat with sulfonamides or nitrofurazone
	Myxosporidan disease	*Kudoa cerebralis*	No external signs; cysts apparent on dissection of cranial cavity	Complete sterilization of culture system

Note: Other diseases and abnormalities of striped bass include parasitic ciliates on gills, and skeletal anomalies such as spinal curvatures and pug-headedness.

DISCUSSION

Disease control in marine aquaculture depends on three significant factors: (1) correct diagnosis and understanding of the life cycle of the causative agent; (2) preventive measures, such as maintenance of water quality, provision of an adequate diet, prophylactic immunization, and reduction of environmental stress; and (3) treatment, usually in the form of chemotherapy. While this paper is concerned largely with infectious diseases, it is apparent that poor water quality and inadequate nutrition are often basic determinants of disease outbreaks in culture systems. There are of course frank pathogens such as Aerococcus viridans in lobsters, Microsporida in shrimps, and Myxosporida in fish, which must be excluded from culture systems, but the greatest damage seems to result from facultative microorganisms -- often part of the natural flora -- which affect stressed culture populations. Stresses may take the form of overcrowding, inadequate diets, oxygen deficiency, buildup of metabolic byproducts, toxic chemicals from external sources, temperature variations, and a number of other less obvious features of what is at best an abnormal environment for marine animals. Control measures, therefore, should emphasize reduction of stresses, and chemotherapy should be considered as a "last resort" method. However, this does not mean that chemotherapeutic methods should be ignored, since they must be available if other control measures fail. Excellent progress has been made in the elaboration of chemical treatments for fish and shellfish diseases, although there are some conditions -- particularly in larval culture -- where the method of choice is still to discard the entire population, sterilize the system, and start over again.

One serious handicap in disease control is the absence of approval from government regulatory agencies for legal use of certain chemicals. Adequate testing must be done before chemicals can be cleared for use on fish and shellfish destined for human consumption. The testing is slow and expensive. At present, for example, very few such chemicals have been cleared for use by the Food and Drug Administration of the United States. Thus, even if a substance has chemotherapeutic properties useful in marine aquaculture, it may not be used legally. This is true at present for the entire class of nitrofurans developed initially in Japan.

A more positive approach to disease control is that of prophylactic immunization. Vaccines have been developed to reduce the effects of vibriosis in saltwater reared salmon, and it seems quite likely that other microbial diseases of fishes would be susceptible to similar methods of control. Some of the larger crustaceans -- notably the lobster -- have been found to be immunologically responsive, and some protection has been demonstrated against at least one disease (gaffkemia) using live vaccine preceded by antibiotic injection. With newer methods of vaccine application, treatment of entire cultured populations becomes feasible.

In summary, much has been learned within the past decade about diseases affecting principal marine/estuarine aquaculture species, and control measures to reduce their effects. Some problems persist and much remains to be done, but it seems that the technology of disease control -- one of the bases for successful large-scale commercial aquaculture of marine/estuarine animals -- is progressing satisfactorily.