PART I

THE FISH HEALTH MANAGEMENT PROBLEM

1. THE NATURE OF FISH DISEASES
2. THE ROLE OF IMPROVED HUSBANDRY PRACTICES
3. PLANNING A FISH HEALTH PROGRAM FOR HATCHERY OPERATION

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THE NATURE OF FISH DISEASES

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Many bacteria and parasites that are capable of causing serious diseases of fish are normal inhabitants of the aquatic environment. In spite of their presence, disease may not occur. Are these potential pathogens and their fish hosts merely players in a larger environmental scenario that controls their interrelationship? Dr. S.F. Snieszko (1972), in addressing this question, concluded a review article entitled "Progress in fish pathology in this century" with a quote from George Bernard Shaw's "Doctor's Dilemma" which says:

> "The popular theory of disease is that every disease had its microbe duly created in the Garden of Eden, and has been steadily propagating itself and producing widening circles of malignant disease ever since. It was plain from the first that if this had been approximatly true, the whole human race would have been wiped out by the plague long ago, and that every epidemic, instead of fading out as mysteriously as it rushed in, would spread over the whole world. It was also evident that the characteristic microbe of a disease might be a symptom instead of a cause."

Snieszko ended his article with the rhetorical question: "Was he (Shaw) right?" It is the purpose of this paper to provide information that will give insight into this question.

Simply stated, disease is literally a lack of ease. It can be defined as a morbid process or condition in the body or its parts with characteristics which distinguish it from other morbid processes or conditions and from the normal state. Diseases can be infectious, that is, communicable from one host to another, or non-infectious. The course of a disease may range from short-term, lethal effects to chronic, inapparent conditions which are detectable only by necropsy or by specific tests conducted at appropriate times. Obviously these definitions are broad and encompass a wide variety of circumstances and results. Disease is a complex interaction between the fish, disease agents and the environment. Understanding the processes involved is vital when considering diagnosis, prevention and cure.

In fish populations, one of the earliest signs that disease may be present is a nonspecific increase in the mortality rate. Fish that die at this stage may be those that are unusually susceptible to the pathogen present or may be those that are most susceptible to the adverse environmental conditions that may trigger epizootics. In any event, a fish culturist or biologist who is attempting to cope with a disease problem must first assemble some basic information.

THE HOST, PATHOGEN, ENVIRONMENT RELATIONSHIP

Three factors must be considered in any fish disease investigation. These are the susceptible host, the virulent pathogen, and the environment in which they encounter one another. Even though all three may be present, a host and pathogen may interact without resultant disease. However, if a disturbance in any of the three factors disrupts the relationship, disease can appear and spread. One can think of this graphically as a weighted balance in which one of the pans represents the pathogen and the other pan represents the host. Environmental conditions would be represented as weights placed on either pan since these factors may affect the host in either positive or negative ways. If the pathogen and the host are in equilibrium, the balance remains at rest. If weights (environmental factors) are added to one side only, the balance will tilt. The causes of this imbalance must be determined if one is to develop an understanding of these three important factors and their interplay.

THE SUSCEPTIBLE HOST

If a plant or animal host is not susceptible to a disease, that disease cannot occur. This, of course, has been the basis for mass immunization programs in human medicine against poliomyelitis, measles, and other diseases. Susceptibility, however, is not governed only by immunity. Habits and customs affect the susceptibility of certain ethnic groups to food-borne infections. For example, those who do not eat pork cannot get trichinosis from that source. Similarly, the practices and techniques used by fish culturists also play an important role in the infectious agents to which their fish may be exposed. A high-quality diet and a clean water supply will eliminate a number of potential sources of disease just as would avoiding the introduction of new fish from another hatchery.

Within the fish itself, the defense mechanisms are varied and complex. Resistance to infection is arrayed like an army, in several echelons. The front line of defense is the skin, scales and mucous membranes which limit the entry of toxic, infectious, and parasitic agents. The next rank of defense is physiological. White blood cells that engulf pathogens, avoidance mechanisms, the ability of the liver to detoxify chemicals from the water or diet, storage of certain metals in the bones, local tissue reactions, and other reponses all help fish to keep noxious agents from overwhelming the body. The last line of defense is the immune system and its specific activity against biological agents such as viruses, bacteria and parasites.

Other, more general factors also join in defending the host against disease. Certain diseases affect fish of certain age groups or species more severely than others. A constitutional factor, or the will to live, may help fish resist the effects of disease or trauma. Evidence of this might be an adult salmon's instinct to complete its spawning migration.

THE VIRULENT PATHOGEN

A virulent pathogen is usually thought of as a microbe, capable of causing infectious disease. Obviously, if such a pathogen is absent, there can be no infection or disease. However, one must not forget those factors whose absence may cause non-infectious diseases. Vitamin deficiencies, a deficiency of oxygen, and mineral deficiency in the water can all cause survival problems. Pathogenic agents can therefore be classified as physical, chemical, and biological.

Physical agents may be mechanical, thermal, or radiant in origin. One of the most common examples of mechanical agents in cultured fish is the "boot fever" suffered when fish are stepped on, injured, or stressed during handling, sorting, or moving. Simple traumatic injuries share many pathogenic features with some of the more complex disease problems. Temperature extremes are physical factors that threaten both cultured and wild fish. Unlike warm-blooded animals, the environment controls the body temperature of fish. In the wild, free-ranging fish sometimes have a greater opportunity to seek more desirable temperatures, but occasionally oxygen levels are too low in cooler water near the bottom of a pond or lake where fish seek relief from higher temperatures. Radiant agents include ultraviolet rays from the sun which can cause sunburn or possibly cataracts in sensitive fish. Physical agents are sometimes responsible for sudden, explosive mortalities in both cultured and wild fish populations.

Chemical agents can cause illness in a variety of ways. Environmental contaminants, taken in by adults, may be concentrated in the oils that are deposited in their eggs. Such contaminants may later cause the death of sac fry during early development. Fish feeds contaminated by aflatoxins, produced by molds during storage, can cause hepatomas in rainbow trout. Nutritional disturbances ranging from excess body fat and hypervitaminoses to malnutrition and vitamin deficiencies are caused by the overabundance or lack of dietary elements. Drug and chemical overdosages that cause mortalities would be classified with chemical agents.

Biologic agents have played a major role in the initiation of disease and are the primary focus of attention when infectious diseases are encountered. They include multicellular organisms like flukes and worms; single-celled organisms such as *Ichthyophthirius, Trichodina* and a myriad of other forms including microscopic pathogens like bacteria; and finally, viruses that are too small to be seen under the ordinary microscope. All are important disease agents which can be responsible for serious epizootics.

A complete understanding of all of the agents of disease is usually not possible for every worker but fishery personnel should have a working knowledge of the nature of pathogens, their manner of spread, routes of entry into fish cultural facilities, and methods for their possible avoidance or eradication.

THE ENVIRONMENT

The causative agents of disease and their fish hosts do not carry on their struggle in a vacuum. The environment in which the encounter takes place may favor one or the other. Changes in the environment, whether natural or fish cultural, may shift the balance from one side to the other and will often determine whether the host will survive or succumb. Understanding and managing the environment is the key to successful fish culture, and a knowledge of the role of the environment in the nature and occurrence of disease is essential to fish disease control.

The physical environment provided for fish culture is affected by the location (geography) of the facility. Latitude governs the ambient temperature of ground water and temperature and altitude both determine oxygen saturation levels. Season and climate are also tied closely to geography. Climatic conditions have a great influence on the sources, quantity and quality of water available and consequently, in the determination of the species and numbers of fish that can be safely reared at a given facility. The physical conditions set by the environment also affect which fish pathogens might flourish and which ones might be of little significance. For example, columnaris disease is seldom a severe problem at water temperatures below 55” F (12.7°C)(Holt et al. 1975) so it is less of a problem in northern regions than in the south. Oxygen depletions due to snow-covered ponds are a problem in the winter in the north, while oxygen depletions due to decomposition following heavy algae blooms, are more common in southern pond culture during the summer.

Facility design and construction can have a profound bearing on the occurrence of disease. Earthern facilities provide environmental conditions that favor certain disease agents that need not be considered when concrete facilities are used. Sanitation, a clean water supply, proper collection and disposal of moribund and dead fish, and proper management of population densities are among the measures that contribute to the production of healthy fish (Wedemeyer et al. 1976).

Biological factors in the environment are of particular importance in the evaluation of fish cultural conditions and in the occurrence of infectious diseases. It is important to know whether fish reside in the water supply. If they do, the culturist must be alert to the possibility that such fish may be the reservoir for infections that occur in cultured fish. Infectious disease cannot occur in the absence of a virulent pathogen and fish in the water supply system are a common source. Hatcheries with springs and wells for water supplies have greater control over the entry of disease agents than facilities that are stream-fed.

Variations in water quality are a major source of environmental stress encountered by fish. Human beings maintain a nearly constant body temperature of 98.6°F (37°C) and breathe atmospheric air which, at sea level, normally contains 21% oxygen, 78 % nitrogen, 1% argon and 0.04 % carbon dioxide. On the other hand, in the aquatic environment, temperatures and concentrations of dissolved gases are highly variable. Supersaturation of water by air and other gasses can be a source of environmental stress. Although fish are well adapted to underwater life, they are at the mercy of the environment.

THE OCCURRENCE OF DISEASE

Wedemeyer, et al (1976) devoted an entire book to the role of environmental stress in fish diseases. In explaining the role of stress as a predisposing factor, they quote Dubos (1955):

> "There are many situations in which the microbe is a constant and ubiquitous component of the environment but causes disease only when some weakening of the patient by another factor allow infection to proceed unrestrained, at least for a while. Theories of disease must account for the surprising fact that, in any community, a large percentage of healthy and normal individuals continually harbor potentially pathogenic microbes without suffering any symptoms or lesions."

The pertinence of this quotation to the occurrence of disease in cultured or wild fish populations is obvious. Snieszko (1973) illustrates the situation with three overlapping circles to graphically represent the interrelationship between the susceptible host, the virulent pathogen and adverse environmental conditions (Fig. 1). As the significance of each of the contributing factors increases, the circles can be visualized to increasingly overlap, thus enlarging the common central area that represents circumstances under which coinciding elements will result in the occurrence of disease. By decreasing the impact of any of the three elements, there is a corresponding reduction in the magnitude of the disease threat (Fig. 2 and 3). This interrelationship is another way to express the example given earlier regarding the weighted balance concept.

When a disease outbreak is encountered, the pattern of losses, the species and sizes of fish involved, and the duration of the epizootic can provide a great deal of useful information (Wedemeyer et al. 1976). Sudden, explosive die-offs, involving all fish present (and sometimes tadpoles and other aquatic animals) usually indicate the occurrence of an acute environmental problem, such as a lack of oxygen, a lethal chemical toxicant, or lethal temperatures (Fig. 4). Mortalities that begin with the appearance of a few sick fish, unusual behavior, or a loss of appetite can signal the onset of infectious disease. These diseases have incubation periods ranging from a day or two for virulent pathogens like some outbreaks of columnaris (Becker and Fujihara 1978) to prolonged periods of several months in cases of bactarial kidney disease (Fryer and Sanders 1981). Infectious disease outbreaks in wild fish populations often affect only a single species (Wedemeyer et al. 1976; Unpublished case history records, U.S. F. W. S., Fish Disease Control Center, La Crosse, WI).

CONCLUSION

At the outset, a rhetorical question was asked regarding whether or not the presence of "the characteristic microbe of a disease might be a symptom instead of the cause." In many situations, cultured fish live healthy, normal lives in the continuous presence of pathogens. However, when environmental stresses occur and the balance tips in favor of disease, the characteristic microbes flourish. If the fish cannot adequately adjust or, if fish cultural corrections are not made, disease may occur. If losses mount in typical patterns, the fish culturist must act. By resolving environmental problems and applying effective therapeutants, a balance between the host and the pathogen can be restored. The

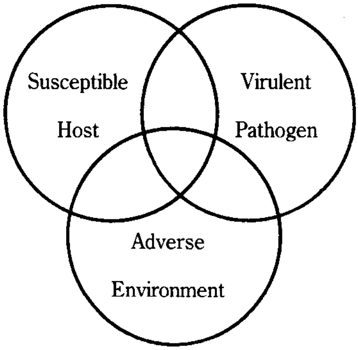

FIG. 1 Host-Pathogen-Environment interrelationship with disease

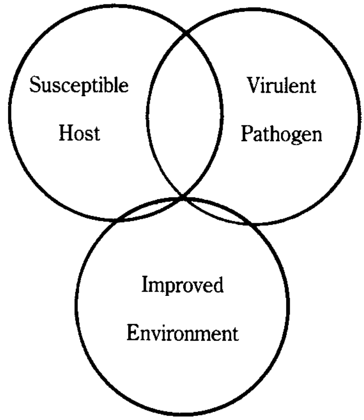

FIG. 2. Host-Pathogen-Environment interrelationship: No disease, improved environmental conditions

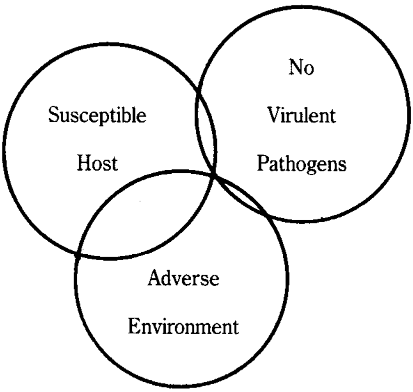

FIG. 3 Host-Pathogen-Environment interrelationship: No disease no virulent pathogens

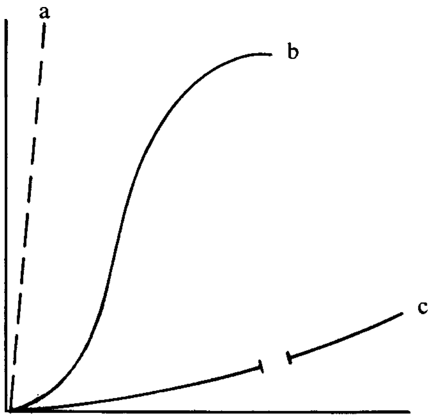

FIG. 4 Mortality curves: (a) acute environmental failure, (b) acute & (c) chronic infectious diseases

question still remains: Was the disease caused by the microbe or were the microbes and the fish merely players in a larger environmental scenario? A microbial infection can often be the symptom of environmental failure and an urgent signal that conditions must be changed. Successful fish culture often hinges on whether correction of adverse environmental conditions can be achieved in time to prevent losses (Snieszko and Bullock 1975). The skills related to fish culture which are required to maintain the balance between the host and the pathogen in the face of changing environmental conditions indicate that there is still a great deal of "art" in the "science" of fish culture.

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