PART IV

INTEGRATING FISH HEALTH MANAGEMENT OPTIONS

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SYNTHESIS OF A FISH HEALTH MANAGEMENT PROGRAM

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Fish health protection is an art and science that can be guided by both public and animal health programs and by agricultural pest control techniques. Fish suffer from the same types of diseases as other animals and plants. Some of these diseases infect only fish. These are caused by obligate fish pathogens that do not survive indefinitely in the aquatic environment unless diseased or carrier fish are present. Bacterial kidney disease (BKD) is a typical example. On the other hand, the majority of infectious diseases of fish are caused by facultative (opportunistic) fish pathogens usually present in the environment. Outbreaks of disease caused by facultative fish pathogens often occur when the fish have been rendered susceptible by stress. Examples include bacterial gill disease, columnaris, and infections caused by *Aeromonas hydrophila*

Strategies for preventing or controlling fish diseases must consider the nature of the disease in question and when and where it occurs. If a disease outbreak among cultured fish can be prevented, economic losses can be avoided and complex disease control and clean-up procedures need not be applied. The first portion of this discussion will be devoted to a brief review of measures that can be taken to prevent fish diseases. This will be followed by a discussion of how to control diseases caused by obligate fish pathogens along with material on the development of an integrated fish health management program.

FISH DISEASE PREVENTION

Prevention is the cornerstone of any health protection program and can be as challenging and complex as the actual control of existing diseases. Key elements of disease prevention include the reliable detection of disease carriers, knowledge of how pathogens are transmitted, development of effective methods to limit the entry of pathogens or carriers into clean fish cultural facilities, and the capability to provide environmental conditions conducive to good fish health. Herman (1970) discussed progress made in several areas of fish disease prevention and control. Since bis 1970 review, important advances have been made in mass immunization of fish, detection of fish pathogens in carriers, enhancement of environmental conditions, and fish nutrition.

REGULATORY AND COOPERATIVE MEASURES

Avoidance of disease is a fundamental part of programs developed to protect the health of man and domestic animals. Regulatory and cooperative measures can be effective in preventing exposure to physical, chemical and biological disease agents. Regulations are developed to provide organizational structure and to assure the execution of specific procedures designed to contain diseases and their pathogens and to guide the action to be taken when outbreaks occur. Cooperative efforts also have a role. In the poultry industry, programs have been organized to improve flocks, to control serious diseases, and to raise quality standards. Cooperative programs are only beginning in the fish cultural field, however.

Regulations for fish health protection are most useful in the control of those diseases clearly identified as being caused by obligate fish pathogens. It is essential to have the capability to accurately diagnose these diseases and to have both governmental and industry support behind any effort to develop regulations. Properly designed regulatory programs can help solve certain problems that cannot be effectively dealt with by other, less restrictive, methods but there are many other important elements of fish health management that should be considered before regulations are drafted.

FACILITIES, WATER SUPPLIES, AND ENVIRONMENTAL MANIPULATION

Successful fish culture is the result of effective environmental manipulation of circumstances dictated by the design of the facility and the natwe of its water supply. The occurrence of infectious disease is often related closely to environmental stress (Wedemeyer et al. 1976). Needham (1977) pointed out that "in salmonid culture far more fish are lost from systems failure than disease." Environmental conditions imposed on fish are determined by site selection, water supply characteristics, facility design, fish handling and transport systems, and the efficiency of waste removal. Disease prevention in fish culture is, to a large degree, a function of the nature of a facility and how it is managed.

NUTRITION AND FEEDING

Proper feeding of a nutritious diet is important, not only for growth and prevention of nutritional deficiencies, but also for the overall health and vigor needed to cope with a variety of disease agents. Fish under intensive culture rely entirely upon the nutritive quality of artificial feeds. Diet selection, feeding frequency, and quantities fed are controlled by the fish culturist. "Demand" feeders, triggered by the fish themselves, are being widely adopted for use in the culture of salmonids. These labor-saving devices permit the fish to feed when they desire and appear to be practical and useful in minimizing environmental stresses associated with feeding behavior and accumulated metabolic wastes.

Nutritional problems, arising from dietary imbalances, continue to cause problems in cultured fish even though great advances have been made in the knowledge of the nutrient needs of fish. Work by Paterson et al. (1981) shows that fish nutrition plays a significant role in determining the host's ability to resist infectious disease. Paterson's work demonstrated BKD to be least serious in Atlantic salmon fed high levels of trace minerals and low levels of calcium. BKD probably cannot be eliminated by simply adjusting the mineral composition of the diet, but dietary manipulation is an interesting concept that broadens the diversity of methods that can be integrated into a fish health management program to reduce the severity of complex disease problems.

GENETIC RESISTANCE TO DISEASE

The idea of genetically enhancing the resistance of fish to disease has tantalized workers for many years (Snieszko et al. 1959). Field and laboratory results periodically raise new optimism for selection of stocks with increased resistance to disease in cultured salmonids (McIntyre 1977). Fish are known to adapt to disease in nature, and these traits of resistance can be measured experimentally

There are several problems involved in the process that make it clear that the development of disease-resistant strains of salmonids may be a difficult obiective to attain. Ehlnger (1977) fcund that some brook trout strains that were selected for their resistance to furunculosis, had acquired a greater susceptibility to bacterial gill disease during the selection progress. According to Winter et al. (1980), some strains of West coast steelhead trout, that were resistant to BKD, were those that were also most susceptible to Vibrio anguillarum infections encountered on migration to the sea. The loss of genetic diversity in a selection process makes it difficult to develop strains of fish that are resistant to several diseases at once. Generally, by maintaining a high level of genetic diversity in a stock and by developing hybrid vigor, there should be potential for breeding fish strains with an enhanced ability to withstand stress and infectious disease agents (F! Ihssen, Ontario Min. Nat. Res., Maple, Ontario, personal communication, 1982).

The process of selecting strains of fish that are resistant to a specific disease can create another problem. Disease-carrying populations of fish have been maintained at some installations to allow for "natural selection" in survivors and as a practical method of challenging selected stocks to measure any increases in resistance. Fish strains to be tested were held in water that already had passed through an infected population. Survivors of ensuing epizootics were retained for breeding purposes. Unfortunately, this process requires the perpetuation of virulent fish pathogens and long-term maintenance of infected carriers. The risk is not severe if the pathogen involved is not transmissible from the parent stock to their progeny via eggs produced by carriers. However, vertically transmissible diseases, such as infectious pancreatic necrosis and BKD, could be spread to any location to which the eggs of the disease-resistant stock are shipped. Until better procedures are available. other methods should be used to solve fish disease problems which have fewer complications than the process of selecting survivors of disease outbreaks.

IMMUNIZATION

Rapid progress has been made in research on the immune responses of fish and in the development of immunization procedures. As a result, licensed vaccines are now available against vibriosis, enteric redmouth, and funmculosis diseases. These vaccines do not provide absolute protection from infection but do help fish combat infections sufficiently to make immunization cost-effective in many situations where these specific diseases cause repeated problems. The significant points are that salmonids have a sensitive immune response system that can be stimulated by immunization and that vaccine delivery systems have now been developed to efficiently immunize large numbers of fish with a minimum of labor and stress.

Vaccines are still needed to reduce the impact and spread of bacterial kidney disease, infectious pancreatic necrosis, and infectious hematopoietic necrosis. These diseases are caused by obligate fish pathogens that are difficult to control by therapeutants and may be transmitted from place to place with eggs taken from infected adults. Immunization has been a highly successful tool for controlliig viral diseases in humans and domestic animals. Fryer et al. (1976a) successfully vaccinated sockeye salmon against infectious hematopoietic necrosis virus. On the other hand, early work on the development of a vaccine for the control of BKD was not highly promising (Fryer et al. 1976b).

FACILITY SANITATION AND DISINFECTION

Little information has been published regarding fish cultural facility sanitation methods, disinfection procedures, or tests determining which measures are most effective in meeting the needs of different types of facilities. Herman's 1970 review cited only the work of O'Donnell (1947) as a source of written information.

The goal of a sanitation program is to prevent the transfer of fish pathogens from one point to another. Egg disinfection strives to prevent the vertical transmission of pathogens from the parent stock to the progeny and to prevent horizontal transmission from the egg facility to the rearing facility (Bullock et al. 1978). During the rearing of fish, sanitation measures can be helpful in maintaining different stocks of fish in isolation from one another. In the event that infectious disease or parasites are detected in one group of fish, sanitary procedures can confine pathogens to a single group of fish or to a single rearing unit. To be effective, measures of this kind require proper equipment, appropptiate chemicals, and discipline.

The methodical and thorough use of disinfectants can remove fish pathogens from an entire facility provided that re-entry through the water supply or other source has been blocked. Disinfection can be carried out in phases or in a single, facility-wide operation. Phased disinfections (McDaniel 1971) can be performed whenever a facility cannot be de-populated and disinfected in a single operation. Total facility disinfection disrupts fish production but it is easier to carry out. There is also a better chance of success in a total facility disinfection than in a phased operation because recontamination is less of a problem in a total disinfection operation. Many fish cultural facilities incorporate a routine program for the phased disinfection of rearing units to prevent transmission of pathogens from older year-classes to younger fish. Even if these methods of fish disease prevention are faithfully applied, there is no absolute guarantee that the facility will be free of fish health problems. Some methods may be more useful than others and each fish cultural operation must develop its own sanitation policies and practices. When disease outbreaks occur, however, prompt technical assistance is needed for an accurate diagnosis and prompt corrective action. The containment measures to be taken depend upon the kind of causative agent and the circumstances involved. If an obligate fish pathogen is responsible, steps may be taken that could eliminate the problem entirely. On the other hand, if a common facultative disease agent is found, long-term management of the host-pathogen relationship may be the only feasible approach.

THE CONTROL OF FISH DISEASES CAUSED BY OBLIGATE FISH PATHOGENS

Infectious disease occurs when a virulent pathogen, whether obligate or facultative, is able to overwhelm the defense mechanisms of a susceptible host under environmental conditions that are conducive to the disease process. The assignment of fish pathogens to obligate or facultative categories implies an understanding. albeit imperfect, of the pathogens involved and the epizootiology of the diseases they cause. As this understanding increases, so do the pos-slbdltles for development of control strategies.

There are three kinds of control measures for coping with infectious diseases: (1) those that reduce or eliminate the source of infection; (2) those that break the connection between the source of infection and susceptible fish populations; and, (3) those that reduce the susceptibility of fish that are exposed to disease. These procedures are most pertintent to the control of diseases caused by obligate pathogens but they also have application in the control of other diseases. In the control of disease in higher animals, the measures are applied in programs that define the distribution of the disease, restrict its known range, and work within that range to eliminate the disease or minimize its impact.

To reduce or eliminate sources of infection, accurate disease diagnostic techniques and sensitive pathogen detection methods are basic requirements. How diseases are spread from fish to fish and from place to place must be determined. As more is learned, steps may be taken to prevent the spread of disease by controlling the transfer of infected fish or eggs in areas believed free of disease. Quarantine measures have been useful in containing outbreaks of disease in new areas after a disease control program has been put into operation. The elimination of infected carriers from a facility’s water supply and specific therapy programs can reduce disease problems to the point where eventually they can be eradicated from a facility, a watershed, or an entire river basin system.

Breaking the connection between the source of infection and susceptible fish populations is the second measure that may be applied. This step can be initiated as soon as research findings show which methods might be effective even though significant sources of infection still exist. Broodstock populations which carry disease agents can be treated or eliminated. Stream water supplies may harbor infected carriers but the connection between the sources of infection and the cultured fish can be broken through the use of water sterilization equipment. When "wet" diets that included raw fish products were fed to Pacific salmon fingerlings, the diet exposed them to fish tuberculosis and other diseases. After the development of the Oregon moist pellet, fish were fed only pasteurized fish products instead of raw salmon viscera and carcasses. Pasteurization broke the lii between the source of infection and susceptible fish. Fish tuberculosis is now seldom detected (Wood 1974). Disinfection of rearing facilities between uses by different year-classes of fish can also break the connection between an infected stock and the next group of fish to be reared.

If it is assumed that the ability of a pathogen to cause disease (virulence) is an intrinsic characteristic of a given microbe, then procedures that help tilt the balance in favor of the host fish will be those that reduce their susceptibility. Susceptibility to disease is governed, not only by factors from within the fish, such as species and strain of fish, immunity, and age, hut also by the fish's ability to adjust physiologically to changes in the external environment. Fish cultmists often can help by adjusting environmental conditions to reduce adverse affects. Ingenious methods have been found to regulate water temperatures, alter oxygen and other dissolved gas levels, reduce ammonia and nitrite levels, reduce population densities, and to improve handling methods to protect the integrity of the skin, scales and mucous membranes of fish. These measures also help in the control of diseases caused by facultative fish pathogens. However, these agents often are widespread in the environment and all available techniques may have to be integrated into a broad fish health protection program before long-term fish disease control is attained.

INTEGRATED FISH HEALTH MANAGEMENT

Many diseases caused by facultative, opportunistic disease agents are often closely related to fish cultural stresses or to adverse environmental conditions. These deficiencies must be corrected before chemotherapy will he successful for any length of time. At most facilities, there is a familiar variety of diseases that must be managed on a regular basis and "lived with." This is not unlike the situation faced by agriculturists who must control crop pests. To cope with crop pests, a system of integrated pest management (IPM) has evolved in agriculture that may have value in the culture of fish. In fish culture, as in the raising of crops, there is little potential for totally eliminating ubiquitous disease agents and a program to manage them must be established.

Sawyer (1979) reviewed the history, principles, and application of integrated pest management when he described how IPM techniques might be used in control of the sea lamprey in the Great Lakes Basin. In his article he stated that:

> "The approach is essentially one of applied systems ecology. It should be useful in almost any situation in which a complex natural or semi-natural system (hatchery) is to be managed by manipulating biological and abiotic factors that are controllable and monitoring those that are not... There are occasional claims that IPM is what economic entomologists have been practicing for decades. While many of its cotnpo-

nent tactics have, indeed, been used throughout the 20th century, it is only in recent years that IPM has emerged as a structured discipline with a coherent phiiosophical basis."

The parallels in fish culture are obvious. A form of integrated fish health management has been practiced since fish culture began.

According to Sawyer (1979), great progress has been made in developing sophisticated agricultural programs for integrated pest management that incorporate a "transdisciplimxy viewpoint in which all classes of pests and their interrelationships are jointly considered, and in which crop protection is seen as contributing to the overall management of an agroecosystem. Second, it extends the early concept of integrated control as the combination of chemical and biological control to the integration of all available management techniques. This does not merely imply simultaneous, but independent, application of two or more control methods, but rather their coordination into a unified program which seeks optimal control." These same principles are directly applicable to controlling fish diseases, especially those caused by facultative fish pathogens.

In practice, IPM techniques are used in crop protection programs to keep pests below a population density that will cause an unacceptable economic loss. In fish culture, fish species and strain selection, immunization, environmental manipulation, nutrition, and chemotherapy work toward this end. There comes a point, however, when the economic threshold of fish disease control has been reached and further efforts to control or eliminate pathogens will become more costly than the benefits derived. An obvious exception would be those circumstances in which certain dangerous diseases caused by obligate pathogens cannot be tolerated at any level and eradication is the goal of the control program. The economic threshhold for diseases caused by facultative pathogens, on the other hand, may be more difficult to determine. Through experience with varying environmental conditions and changing fish populations. the fish culturist learns to recognize early warning signals and to make timely corrections. Through experience, the economic impact of a disease can be more clearly identified and a better understanding of the merits of additional control measures then can be developed.

SUMMARY

The control of obligate fish pathogens is based on identifying sources of infection, breaking the connection between such sources and susceptible fish populations, and on reducing the susceptibility of exposed fish. A broader strategy that integrates all available management techniques is required for the control of diseases caused by facultative fish pathogens. A folly integrated fish health management program is an orchestration of all available preventive and control tactics rather than a reliance upon a few specific techniques such as chemotherapy, immunization, or developing genetic resistance. The collective strength of the various elements in an integrated program, each working in synchrony with the others, can potentially achieve better results than would be obtained by use of any single method. Continued progress in integrated fish health management is dependent upon the continuous develoment of new tools and techniques through research to replace those lost through changes in needs

and changes in the kinds of problems to be solved. Progress is dependent also upon the willingness of fish culturists, fish pathologists, and conservation agency administrators to take aninterdisciplinary viewpoint. This requires close cooperation between public and private sectors of fish culture and between the various operational levels in fish culture, research, and extension programs.

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